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THE ASBESTIFORM-FIBER CONTAMINATION OF LAKE SUPERIOR AND THE RESULTING POTENTIAL HEALTH HAZARD: AN INTERPRETATION OF INTERLOCKING PHYSICAL AND HUMAN GEOGRAPHICAL SYSTEMS

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A DISSERTATION

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TECHNICAL NOTES

Throughout the text, the method utilized for the citing of references is an internal scientific citation system employing the author's last name and date of publication. Page numbers are cited only in cases where direct quotes are used. Any personal comments of mine included within the body of a direct quote are explanatory in nature and are set off by brackets []. Footnotes are used for explanatory purposes, rather than for reference citation.

ABSTRACT

In recent years the United States has witnessed a rising concern over the degradation of the physical environment caused by industrial pollution--especially when, among the ramifications of such pollution, there are potential hazards to human health. Such is the case with the asbestiform-fiber contamination of Lake Superior waters resulting from the operation of Reserve Mining Company's taconite beneficiation plant at Silver Bay, Minnesota. The waste products--taconite tailings--from the mining and processing systems are discharged into the Lake Superior ecosystem at the rate of 67,000 tons per day. Circulatory processes distribute the fiber-bearing tailings throughout the western arm of Lake Superior, thus facilitating the entry of the asbestiform fibers--potential carcinogenic agents--into the municipal water systems of shoreline communities.

As a result, consumers are exposed to a potential carcinogen via the drinking of contaminated Lake Superior water. Furthermore, there exists the "hidden" hazard of ingesting food and beverage products manufactured using asbestiform-fiber contaminated water and made available to the public via the marketing/distribution system. To illustrate the geographic patterns of exposure to a "hidden" health hazard, the dissertation focuses on the spatial distribution of food and beverage products manufactured in Duluth, Minnesota.

The Duluth Problem is illustrative of the majority of

environmental pollution cases in that it is characterized by multi-variate components and complex interactions among interlocking physical and human geographical systems. At the interfaces of the interlocking systems are "channels of ignorance" which allow the passage of pollutants from one system to the next. Only through the recognition and elimination of channels of ignorance can pollution systems be regulated.

The regulation of a pollution system lies not within the system itself, but within the higher-order systems constituting the environment within which the pollution system operates. Thus, it is with these higher-order systems--the engineering, environmental, and medical sciences; and the social, economic, and political systems--that those persons charged with environmental policy-making must contend.

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CHAPTER I

THE SCOPE OF THE PROBLEM

Introduction and Problem Statement

In recent years the United States has witnessed a rising concern over the degradation of the physical environment caused by industrial pollution--especially when, among the ramifications of such pollution, there are potential hazards to human health. The purpose of this dissertation is to demonstrate the use of systems analysis in determining the spatial distributions of health hazards resulting from industrial pollution. Systems concepts and methodology are applicable to the majority of environmental pollution-health problems in that they provide a flexible tool with which to explain the geographic patterns associated with the multi-variate aspects of industrial pollution.

To illustrate the manner in which systems concepts may be used to analyze the health-hazard ramifications of environmental modification incurred by resource development, I have chosen the case of the pollution of Lake Superior waters by Reserve Mining Company of Silver Bay, Minnesota. In this case, the pollution has arisen from the discharge of potential carcinogenic agents, in the form of taconite tailings bearing asbestiform fibers, into Lake Superior from Reserve Mining Company's beneficiation plant. Asbestiform fibers from Reserve's plant have been found in municipal water supplies, notably that of Duluth, drawn from Lake Superior. Thus, consumers of this water, or of products containing it, risk exposure to a potential health hazard.

Using the "Duluth Problem" as an illustrative example, the dissertation seeks (1) to illustrate the use of systems analysis in determining the spatial distributions of pollution-related health hazards; (2) to analyze the "chain reaction" which occurs as waste outputs from an industrial system are allowed to become inputs into other systems. This often occurs because of initial ignorance, on the part of man, as to the true nature of the industrial wastes being dumped into environmental systems. This lack of knowledge provides "channels of ignorance" at the interfaces of interlocking systems which allow the passage of potentially harmful substances from one system to the next. If unchecked, this passage of pollutants may cause dysfunctioning in the systems themselves, as well as posing health hazards to thc human populations occupying the space within which the systems operate. In the Duluth case, the drinking of asbestiform fiber-contaminated water is the "obvious" hazard. Therefore, in those sections of the dissertation dealing directly with the health hazards of the Duluth Problem, the emphasis is on the "hidden" hazard associated with the consumption of food and beverage products manufactured using contaminated Duluth municipal water; and (3) to explore the reasons for the existence of, and the means of eliminating, channels of ignorance--more specifically, how to prevent Duluth-type problems from occurring elsewhere.

The Geographic Significance of Industrial Pollution/ Health Hazard Research

Studies of health hazards resulting from industrial pollution share three basic characteristics with those problems generally included within the realm of geographic research, namely, (1) such problems are multi-variate; (2) industrial pollutants are distributed in geographic space; and (3) there exists an underlying man-land relationship.

Investigations of industrially-produced health hazards can be justified by relating them to at least two of the "Four Traditions of Geography" (Pattison, 1963). First, such problems can be placed within the spatial tradition since the multivariate components of pollution-related health hazard problems are characterized by "the true essentials of the spatial tradition--<u>geometry</u> and <u>movement</u>" (Pattison, 1963, in Durrenberger, 1971, p. 87). Secondly, studies involving "resource use and conservation" (Pattison, 1963, in Durrenberger, 1971, p. 92) are firmly couched within geography's man-land tradition.

It may be said, perhaps, that the approach to pollution-related health problems, as attempted herein, constitutes a research frontier in geography. It is true that such a study, by necessity, transcends the traditional sub-disciplines, or research clusters, of the geographic discipline. Investigations of pollution-related health hazards are relevant to a number of geographic research clusters. Among these clusters are political, resource management, manufacturing, marketing, urban, medical, and physical (geomorphology, hydrogeography, etc.) geography (Durrenberger, 1971). An approach such as this is essential, however, if geographers are to participate in contemporary, applied pollution problem-solving.

To fully understand the ramifications of industrial pollution, it is convenient to view the problem systematically and macroscopically. At a time when geography, as a discipline, seems to be moving toward the adoption of a new system-based paradigm (Harvey, 1970), research on the systems through which potentially harmful industrial pollutants flow appears to have geographic significance. Systematically tracing the flows and quantities of industrial pollutants from their sources to their consumption by the human populations occupying the geographic space within which the systems operate serves to strengthen systems analysis both as a conceptual tool and as a methodology in geographic research.

Furthermore, the type of approach used in this dissertation provides a macroscopic view of health hazards arising from resource-development activities. The macroscopic viewpoint aids in the identification and explanation of the spatial distribution patterns of industrially-produced health hazards. In addition, such a viewpoint facilitates the recognition of the location of channels of ignorance, the knowledge of which is vital to the processes of pollution control and abatement.

In the past, most pollution-related research has been conducted by individuals trained in non-geographic disciplines. Consequently, there has been a tendency for data and research related to environmental pollution cases to be microscopic in nature. Great difficulties arise when trying to piece together fragmented data on the multiple aspects of a particular pollution problem when an overall guiding, integrating concept is lacking. It is in such instances that the spatial viewpoint characteristic of the geographic discipline may prove to be invaluable, especially when that viewpoint is couched within a systems framework.

The lack of geographic research on the problem of the pollution of Lake Superior, for example, has fostered a failure to recognize the full range of areas and populations exposed to the asbestiform fibers from Reserve's operations. Since the Lake Superior problem heretofore has not been studied from the standpoint of spatially-interlocking systems, the aspect of exposure to asbestiform fibers via contaminated foods and beverages has been overlooked completely. The bulk of the published studies on the pollution of Lake Superior and on asbestos as a health hazard, as well as the District Court testimonies (U.S.A., et al., v. Reserve Mining Company, et al., U.S. District Court, District of Minnesota, Fifth Division, St. Paul, August, 1973 - April, 1974), have been by biologists, geologists, economists, chemists, limnologists, oceanographers, and medical personnel. A broader view of the spatial aspects of this environmental pollution problem which would facilitate the identification of those local and non-local populations exposed to asbestiform fibers from Reserve's taconite processing is needed. Hopefully, this broader view, as attempted herein, could provide the basis for future geographic research into the dispersion of environmental pollution agents. More importantly, it could supply a critical parameter for future medical geography studies dealing with the incidence of cancer--especially malignancies of the gastrointestinal tract.

Several recent works on the geographic patterns of cancer incidence have indicated strong relationships between cancer and environmental factors. For example, Clark and Lord (1975, p. 42) comment on this relationship as follows:

> ...the National Cancer Institute has just published an atlas that illustrates trends in death rates from various types of cancer across the U.S. The study reveals sharp geographic differences in cancer mortality that may provide important clues to the cause and prevention of malignant disease. It also lends strong support to the notion that most cancers result from environmental exposure to carcinogens.

Barry Commoner, in a paper entitled "Chemical Carcinogens in the Environment" (1975), discusses environment-cancer relationships and a possible method of carcinogen identification known as the Salmonella technique, mutagenic screening, or the Commoner Cancer Screen. As Commoner states (pp. 4-5):

> Environmental cancer confronts us with a serious problem...that of detecting, identifying and tracing the origins of the ...compounds that account for the environmentally-induced incidence [as much as 75-80%] of cancer in the U.S. ...if we can succeed in this aim,...we can then act to limit human exposure to these agents.

Using a technique devised by Dr. Bruce Ames of the University of California at Berkeley, Commoner, et al., tested 100 organic (mostly synthetic) compounds (50 noncarcinogens and 50 presumptive carcinogens) for their effect on the mutation rates of the bacteria, Salmonella typhimurium. As noted by Commoner (p. 13):

> All but one of the 50 noncarcinogens...do not affect the mutation of the bacteria. [The one exception is a close chemical relative of a known carcinogen.] ...Of the 50 presumptive carcinogens all but 9 exhibit significant enhancement of the Salmonella mutation rate. [The metabolites of several of the 9 exceptions also produce increased mutation rates.]

Commoner concludes (p. 38):

> ...it would appear that the opportunity now exists to develop a new strategy for controlling the growing problem of environmental cancer. It would begin with detecting presumptive carcinogens in environmental samples, identifying them and tracing their movements in the environment by means of screening based on bacterial mutagenesis. Then by determining the mutagenicity of human urine samples it may be possible to determine which of these presumptive carcinogens represent carcinogenic risks to people. With such information in hand it would be possible to reduce this

> risk by tracing environmental carcinogens back to their origins, and then taking the final, and most difficult step--regulating environmental emissions--that will, at last, prevent the disease.

Thus, modern research seems to be stressing the importance of environmental factors in cancer studies. Through systems-oriented environmental/geographic research and through innovative biological research techniques such as mutagenic screening it may be possible, in the future, to institute before-the-fact regulation of those environmental pollutants which have carcinogenic potential. In this way, it may be possible to eliminate the negative aspects of industrial operations, such as are evident in the case of Reserve's operations.

The use of the Lake Superior ecosystem as a dumping ground for Reserve's taconite waste has, indeed, produced an undesirable environmental side effect (a negative externality) that poses a potential threat to human life. Reserve's activities provide disutilities for those who consume contaminated Lake Superior water, whether the ingestion of the asbestiform fibers is facilitated via drinking water or via indulging in foods and beverages manufactured using such water.

Typically, externalities, such as the pollution of Lake Superior with asbestiform fibers, are not randomly distributed. Rather, they display recognizable geographic or spatial characteristics. In the opinion of Kevin Cox (1973, p. 3):

> For the geographer considerable interest stems from the fact that externality effects are not spatially random. Rather their intensity is often a

> function of relative location: this is indicated by the term 'neighborhood effects' which is occasionally applied to externalities. As Harvey [David W. Harvey, "Social Processes, Spatial Form and the Redistribution of Real Income in an Urban System" in M. Chisholm, A. Frey and P. Haggett, eds., Regional Forecasting, London: Butterworth, 1971, pp. 273-4] has shown, factors determining accessibility (nearness, channels, barriers) are all related to the intensity of indirect costs and indirect benefits.

In the case under investigation, accessibility to Reserve's discharge is provided by the Lake Superior circulatory system, the water distribution systems of shoreline communities, and the market system responsible for the sale of food and beverage products containing asbestiform fibers. Thus far, the emphasis of government abatement procedures has focused on the first two systems, since the heretofore identified "areas-at-risk" are more or less contiguous to the source of pollution. Along these lines Tullock (1970, p. 64) states:

> Most cases in which governmental action is called for...are cases of contiguity because a certain designated group of people must be dealt with who live, own property, or work next to each other. The typical externality is 'geographic.'

In any case dealing with environmental pollution, governmental agencies or other regulatory bodies cannot act wisely if they do not possess a comprehensive knowledge of the functioning of the interlocking systems involved in the problem. Once a pollutant and its source have been identified, a key principle of pollution control is that of tracing the movement and concentration of the pollutant as it moves through the interlocking systems which lie between the source and the ultimate consumers of the pollutant. In the case of Lake Superior, irreversible harm may already have been inflicted on the populations exposed to the asbestiform fibers carried not only in the municipal water supplies of shoreline communities but in food products manufactured using contaminated Lake Superior water. It is in the identification of the location, size, and degree of exposure of populations to asbestiform fibers carried in Duluth-manufactured foods and beverages that this dissertation has geographic significance.

Systems Analysis as a Method in Geographic Research

The use of systems analysis as a methodology aimed at explaining variations in spatial distributions has been gaining popularity in modern geographic research. Fostering this increasing use of systems analysis has been the shift of emphasis in geographic studies from relatively simple problems with few variables to multi-variate problems with complex interactions.

In discussing the role of systems analysis as the key to explanation in geography, Harvey (1970, pp. 448-450) states:

> The general relationship between the concept of an explanation. . .and the concept of a system provides a strong justification for examining the nature of systems.
>
> . . . .
>
> A further justification for regarding the system as the key to explanation arises from major applications of the concept in all areas of empirical investigation during the twentieth century. From both a methodological and an empirical point of view, therefore, the concept of a system appears absolutely central for our understanding of explanation in geography.
>
> . . . .
>
> The intimate connection between systems analysis and the analysis of complex structures makes this approach very attractive to those disciplines dealing with phenomina that are highly interconnected. Given the multivariate nature of most geographical problems, it is

hardly surprising that systems analysis provides an appealing framework for discussing these problems.

Although geographers have only recently begun to utilize formal systems concepts in their research, elements of systems thinking have long been evident in the discipline. For example, in the early nineteenth century the Erdkunde (earth science) approach of Carl Ritter brought a number of systems-related concepts to geographical writing. Among these concepts were the ideas of (1) unity in diversity, i.e., the interlinkages between geographic elements which produce a functional whole; and (2) an empirical base for geographic research that would lead to the "new scientific geography" (James, 1972, p. 167).

In the early years of this century, Vidal de la Blache's support of the Humboldt/Hettner concept of chorology as the study of the associations of elements in geographic space served to strengthen "systems thinking" among geographers. Many of Vidal's ideas were elaborated upon and popularized in Europe by Jean Brunhes. In the United States, the chorological concept of the nature of geography was strongly supported in the works and teachings of Carl O. Sauer.

The concept of functional regions, incorporating systems thinking, was first elaborated by C.B. Fawcett (1919), who mapped the service areas of major English cities. More recently, the nested hierarchy of urban places in Walter Christaller's Central Place Theory, Brian J.L. Berry's studies of "cities as systems within systems of cities" (Berry, 1964), and Walter B. Stöhr's work (1974) on interurban systems and regional economic development have helped solidify the role of systems thinking in the fields of urban and economic geography.

Systems thinking also has been incorporated in the writings of physical geographers. Many of William Morris Davis's ideas on landscape development, for example, carried overtones of "closed system" thinking, although his concept of grade was closely related to the "steady state" concept embodied in open-system thermodynamics. The use of open-system thermodynamics has been gaining popularity among contemporary geomorphologists, especially among such fluvial geomorphologists as Chorley (1962; 1969) and Leopold (with Langbein, 1962; with Wolman and Miller, 1964).

Other geographic researchers who have utilized systems analysis include those specializing in spatial organization, for example, Abler, Adams, and Gould (1971) and Haggett (1965), and those who seek to establish the ecosystem as a fundamental organizing concept in geographic research. The ecosystem approach has been especially favored by environmentalists who view the ecosphere as a composite of innumerable open systems, so interrelated that changes in one system may effect changes in other systems.

In reference to the concept of systems analysis as applied in environmental studies, Watts (1974, p. 24) has stated that:

> ...the environment should be seen to function, both as a whole and in the interlinkages of its discrete parts, under the control of the laws of thermo-

> dynamics. Interactions between the organic and inorganic components of an environmental system, involving the input, transfer, storage and output of energy and essential materials through the system, are in the final analysis energy dependent. Under natural conditions, or when largely undisturbed by man, environmental systems tend to be self-regulatory.

There are two key ideas in Watts's statement: that of the control of ecosystems by the laws of thermodynamics and that of system self-regulation. Ecosystems are cybernetic, ie., they adapt themselves in response to information feedback.

Among the more prominent works on the ecosystem as a geographic principle and method is that of D.R. Stoddart (1965), who believes that the fundamental contribution of ecosystem concepts to geographic research is in providing a methodology. According to Stoddart, there are four main properties of the ecosystem concept which render it valuable in geographic research:

> First, it is monistic: it brings together environment, man, and the plant and animal worlds within a single framework, within which the interaction between the components can be analysed. Secondly, ecosystems are structured in a more or less orderly, rational and comprehensible way. The essential fact here, for geography, is that once structures are recognized they may be investigated and studied. ... Thirdly, ecosystems function; they involve continuous throughput of matter and energy. In geographic terms, the system involves not only the framework of the communication net, but also the goods and people flowing through it. Once the framework has been defined, it may be possible to quantify the interactions and interchanges between component parts. ... Fourthly, ecosystems are a type of general system and the ecosystem possesses the attributes of the general system. In general system terms, the ecosystem is an open system tending towards a steady state and obeying the laws of open-system thermodynamics. [Stoddart, 1965, in English, 1972, pp. 157-160.]

As mentioned earlier, the use of systems concepts in geography is not new. As a result of geography's "man-land tradition" (Pattison, 1963) and an increasing familiarity with the concepts utilized in the biological sciences, geographers have, for some time, been applying ecosystems analysis to geographic problems. Those who claim that ecosystems analysis is "not geography" overlook two important points. First, in the study of environmental relationships (ecology), humans are not separate from nature but are integral components of ecosystems. Secondly, if the study of space relationships (geography) is to proceed beyond the "mere nominal-scale classification of areas" (Stoddart, 1965, in English, 1972, p. 163), systems concepts must be employed. Furthermore, the boundary between "environmental relationships" and "space relationships" appears to be undefinable (Davies, 1961, p. 415). Ecology and geography are not, therefore, totally separate entities.

A further recommendation for the use of systems analysis by geographers is the flexibility of the approach in regard to scale. Systems analysis may be employed at any "level of resolution" the researcher wishes, since inherent in the concept is the idea of systems within systems *ad infinitum*.

Applying systems analysis to geographic problems facilitates not only the recognition of structures and functions, but also the quantification of flows or links between system elements or components. Furthermore, the utilization of systems analysis in geographic research aids in integrating geography with the natural sciences, from which the geographic discipline can learn valuable research techniques.

Finally, Harvey (1970, p. 479) contends that:

> ...methodologically, the concept of the system is absolutely vital to the development of a satisfactory explanation. If we abandon the concept of the system we abandon one of the most powerful devices yet invented for deriving satisfactory answers to questions that we pose regarding the complex world that surrounds us. The question is not, therefore, whether or not we should use systems analysis or systems concepts in geography, but rather one of examining how we can use such concepts and such modes of analysis to our maximum advantage.

It is the intent of this dissertation to employ systems analysis in explaining the spatial distributions of an industrial pollutant (asbestiform fibers). By using systems analysis, it is possible, given sufficient data, to determine the locations of the affected populations as well as the quantities of the pollutant to which they have been exposed.

The Applicability of Systems Analysis to the Duluth Problem

Before using systems analysis as a means of explanation, it must be determined if the problem at hand possesses those characteristics necessary to place it within a systems framework. Inherent in systems analysis are the concepts of system structure, comprised of elements and links; boundaries; parameters; state; environment; and behavior. Each of these concepts can be applied to problems of industrial pollution.

In order to view the overall system involved in a case of industrial pollution, it is necessary to identify the systems's elements, or basic units, at a low level of resolution.

Consequently, the elements of the overall system tend to be sizeable, complex systems in themselves. Once the elements are identified, the researcher must discover the links between the elements so as to determine the type of relationship which characterizes the pollution system. These relationships may be classified as being series, parallel, feedback, or compound (Harvey, 1970).

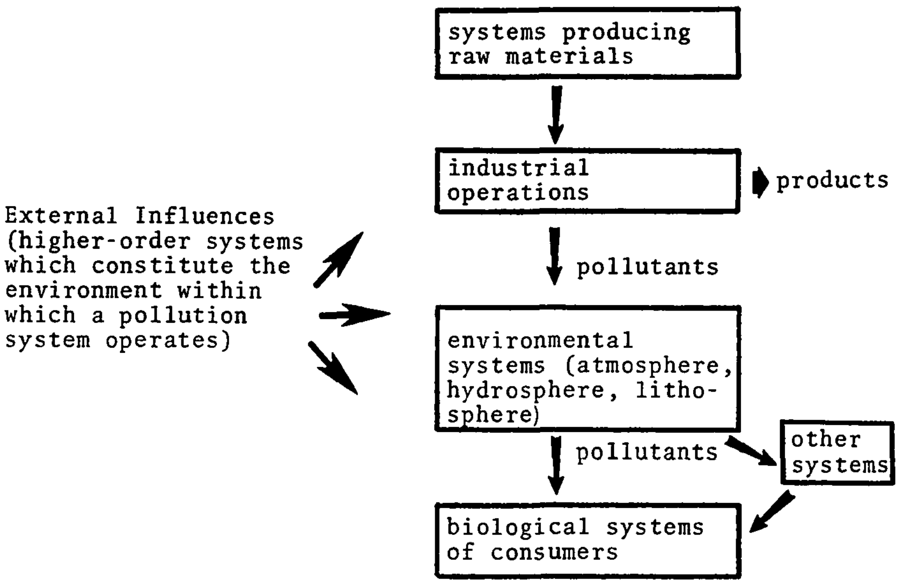
Structurally, a system is composed of elements or subsystems and links, links not only between the elements themselves but also between the elements and the larger environment within which the system operates. Armed with a knowledge of its structure, it is possible to set the boundaries of the overall system. In light of the nature of the research problem, the researcher must decide which elements are relevant and basic to solving the problem and which are irrelevant or outside the boundaries of the system under consideration.

Those higher-order systems of which the system under investigation is a part constitute the system's environment (Harvey, 1970). This environment influences the system being examined in that changes in higher-order systems may affect the elements in lower-order systems. Figure 1.1, a generalized diagram showing the basic elements and links involved in an industrial pollution system characterized by a series relationship, is an illustration of the foregoing concepts.

A further step in systems analysis is to identify the parameters, or basic inputs, of the system in order to deter-

Figure 1.1

GENERALIZED DIAGRAM OF THE BASIC ELEMENTS (SUBSYSTEMS) AND LINKS IN AN INDUSTRIAL POLLUTION SYSTEM



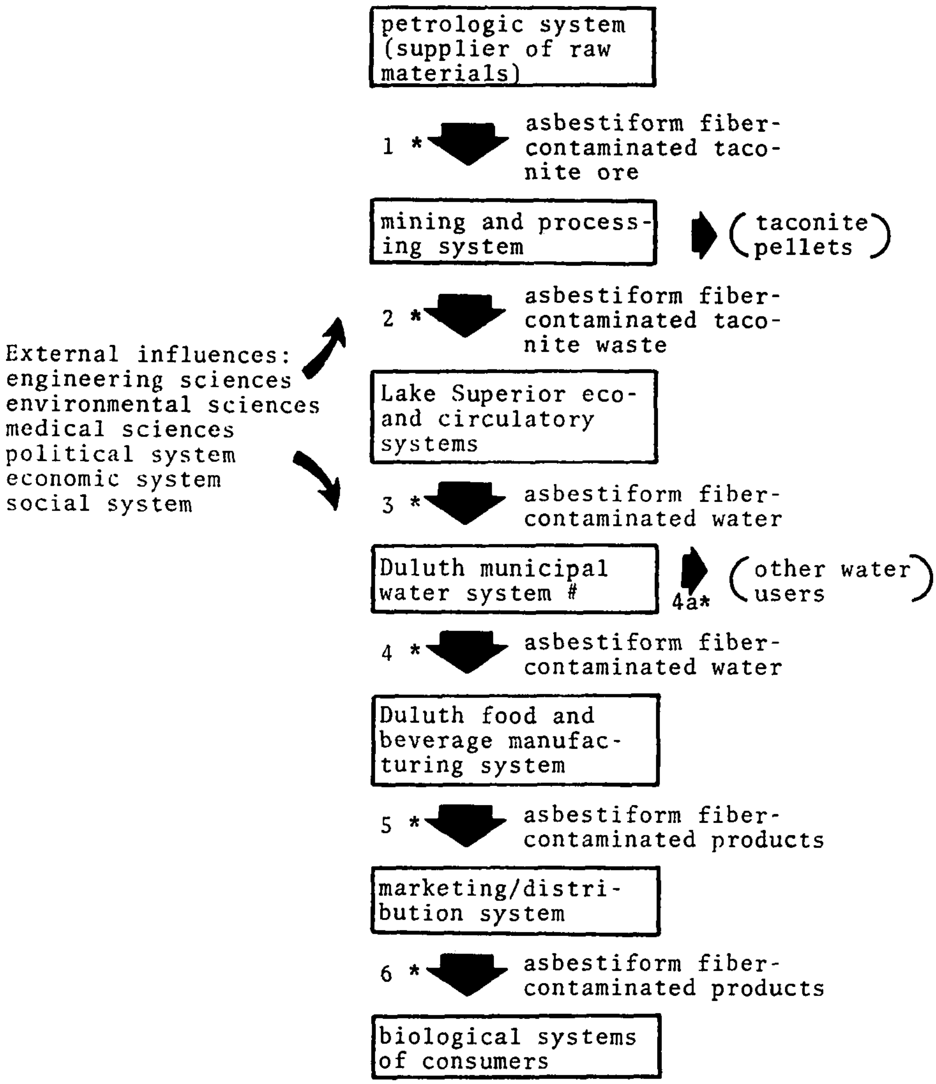
mine the state of the system (the values of the system's variables) at any given time. Model building provides clues to the overall behavior of pollution systems, even though the relationship between a pollution system model and reality is homomorphic (Klir and Valach, 1967). Granted, precise information on variables and/or functions within the elements or subsystems of a pollution system may be lacking. Even if the researcher must treat certain elements or subsystems as "black boxes," the important thing is to understand the responses (outputs) of the elements or subsystems to given stimuli (inputs) so as to gain insight into pollution-system behavior.

As applied to the Duluth Problem, systems analysis provides a methodology with which to explain the spatial distribution of the health hazard posed by asbestiform fibers. As the asbestiform fibers move from their source in northeastern Minnesota to the consumers of food and beverage products manufactured using contaminated Duluth municipal water, they pass through a series of interconnected systems (see Figure 1.2).

The first of the systems shown in Figure 1.2 is the natural petrologic system responsible for the formation of the asbestiform fiber-bearing taconite ores of the eastern Mesabi Iron Range. The output (taconite ore) from the petrologic system comprises the input for a second system, that of ore mining at Babbitt, Minnesota, and taconite processing at Silver Bay, Minnesota. As part of the waste output (taconite tailings)

Figure 1.2

THE INTERLOCKING SYSTEMS INVOLVED IN THE DULUTH PROBLEM



* denotes the location of a channel of ignorance

\# denotes the site of the first detection of asbestiform fibers in Lake Superior waters, 1973 from the mining-processing system, the asbestiform fibers enter a third system: the natural ecosystem of Lake Superior. Circulation processes within the Lake Superior system transport the asbestiform fibers southwestward from the discharge site at Silver Bay. The nature of the circulation within the lake's ecosystem enables the asbestiform fibers to become an input into a fourth system: the Duluth municipal water distribution system. As a component of the output from the Duluth water system, asbestiform fibers reach the consumer directly via the drinking of Duluth municipal water. This is the "obvious hazard." The "hidden hazard" lies in the movement of asbestiform fibers through two additional systems, the Duluth food and beverage manufacturing system and the marketing/distribution system, before the fibers enter the biological systems of the consumers. The obvious hazard is quite localized; the hidden hazard affects both local and non-local populations.

As noted in Figure 1.2, at the interface between each set of subsystems, there exists a channel of ignorance. If unchecked, industrial pollution systems tend to develop a series relationship between their elements or subsystems because, at every location of a channel of ignorance, there is, at least initially, the lack of a feedback loop from further along the chain that would serve to eliminate the channel. In the case of the Duluth Problem there are controlled man-made systems interlinked with the natural, dynamic system of Lake

Superior. The trouble is, the lack of knowledge regarding the presence of asbestiform fibers in Lake Superior waters caused a time lag in the negative feedback mechanisms of the overall system.

Once a channel of ignorance is recognized to exist, however, there usually are steps that can be taken to eliminate the channel. Suggested remedies for the elimination of each channel of ignorance in the case study are given in Table 1.1. To avoid exposing humans to further industrial pollutants it is necessary to eliminate the channels of ignorance that lie closest to the pollutants' sources. In the case of Lake Superior, although the elimination of ignorance channel number two is a prime consideration, the extent of the asbestiform-fiber contamination has necessitated the construction of a new filtration plant to cleanse the entire Duluth municipal water supply. The use of the filtration plant, which began full operations in February of 1977, serves to eliminate channels of ignorance 4, 4a, 5, and 6.

Although pollution systems involve a variety of inputs, of major concern is the pollutant itself. Thus, the focal parameter in the Duluth Problem is asbestiform fibers and the investigations into the state of the pollution system are geared to locating and quantifying asbestiform fiber concentrations.

In summary, systems analysis can serve as a method of explaining the behavior and structural characteristics of

Table 1.1

SUGGESTED REMEDIES FOR THE ELIMINATION OF THE CHANNELS OF IGNORANCE IN THE DULUTH PROBLEM

Channel of Ignorance	Remedy
1	do not mine
2	remove asbestiform fibers or cease dumping into Lake Superior
3	remove asbestiform fibers before pumping water through system
4	remove asbestiform fibers before using water for manufacturing
4a	filter water before use
5	government or company action to prevent asbestiform fiber-contaminated products from entering marketing/distribution system
6	government or company action to ban shelf sales of contaminated products -or- refusal of informed consumers to buy contaminated products

complex interrelated industrial pollution phenomena. Consequently, systems concepts can provide a valuable conceptual framework in the investigation of substantive geographical problems such as the identification and quantification of the spatial distributions of health hazards associated with industrial pollution.

The Rationale for Selecting the Duluth Problem As the Illustrative Case Study

The Duluth Problem was selected as the illustrative case study for the dissertation since it has certain aspects in common with the majority of environmental pollution problems. As stated in the previous section, the Duluth Problem involves a number of complex, interconnected systems characteristic of industrial pollution cases. Systems analysis, therefore, is applicable to the case study. Of special importance is the identification of channels of ignorance, for the presence and spatial distribution of health hazards associated with industrial pollution would not exist if there were no channels of ignorance.

Although the discharge of asbestiform fibers from Reserve Mining Company's beneficiation plant has contaminated the water supplies of a number of western Lake Superior communities, the total populations involved are small in comparison with Duluth. Since Duluth is the largest of the western Lake Superior ports and since the most continuous and extensive water analyses of asbestiform fiber content have been conducted on the Duluth municipal water supply, this research focuses on the Duluth Problem.

Of the numerous environmental pollution cases that have reached the higher courts, few have resulted in such a monumental Federal case as that involving the pollution of Lake Superior by Reserve Mining Company (U.S.A., et al., v. Reserve Mining Company, et al., 1973-1974). In this case the official list of defendants, plaintiffs, and intervenors entails twenty-six parties, including the States of Minnesota, Wisconsin, and Michigan, a number of counties and municipalities, and various environmental agencies and interest groups.[1]

The major catalyst responsible for the nine-month Federal trial, which culminated with the April 20, 1974, ruling by Judge Miles W. Lord of the U.S. District Court to close Reserve's Silver Bay facilities, was the June 15, 1973, public announcement issued by the Environmental Protection Agency. This announcement stated that asbestiform amphibole fibers (allegedly from Reserve's discharge of taconite tailings into Lake Superior) posed a potential health hazard in the municipal water supply of Duluth, Minnesota. The EPA charge shifted the focus of the case from one of water pollution abatement to one of public health impact related to Reserve's discharge of

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[1]See APPENDIX A for the trial background and a complete list of the parties involved in the case. The appropriate sections of the statutes allegedly violated by Reserve Mining Company are contained in APPENDIX B, while APPENDIX C contains copies of the discharge permits issued to Reserve Mining Company by the State of Minnesota.

asbestiform fibers into Lake Superior and into the ambient air of Silver Bay and its environs.

The EPA announcement which served as the major catalyst for the Federal trial resulted from the analysis of a series of incidents which had occurred over a period of about ten years. By the mid-1960's, Duluth residents were beginning to notice highly visible taconite tailings issuing from their home water taps and settling in the bottoms of toilet tanks and bowls.[1] As a result, some area residents became concerned over the possible implications of the appearance of taconite tailings in the Duluth water supply.

Following a conversation with Joseph Mengel, a University of Wisconsin-Superior geologist who suggested that Reserve's taconite tailings contain asbestos-like fibers and mentioned that, in other instances, asbestos fibers had been related to the incidence of cancer, Mrs. Arlene Lehto, a local businesswoman and founder of the Save Lake Superior Association, brought the potential "asbestos problem" to the attention of local officials.[2] Thus began the EPA National Water Quality Laboratory's investigations, via X-ray diffraction and electron microscopy, which resulted in the June 15, 1973, announcement that the waters of Lake Superior, including the Duluth supply, contain asbestiform amphibole fibers that pose a potential health hazard to area residents.

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[1]Statement based in part on author's personal experience.

[2]Personal interview, Arlene Lehto, July 9, 1974.

In addition to (1) the court proceedings dealing with the pollution of Lake Superior and (2) the potential health hazard related to the exposure to asbestiform fibers, there is a final reason for choosing this particular research problem: the aspect of non-local populations being exposed to asbestiform fibers via the ingestion of food and beverage products made in Duluth has, for all practical purposes, been overlooked.[1] To date, emphasis has been placed on the North Shore residents who have been drinking contaminated municipal water as the population-at-risk.

Furthermore, the thrust of the economic studies related to this case has been aimed at the industrial costs and benefits of the abatement of Reserve's pollution of Lake Superior. A study of the distribution of food and beverage products that have been contaminated with asbestiform fibers from the Duluth water supply provides a more complete picture of those areas and populations exposed to the industrial pollutant produced by Reserve Mining Company.

Although local news media[2] have made Lake Superior area

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[1]A few persons (Nader and Harris, 1973; Glass, personal interview, November, 1974) have mentioned that such a problem exists but, thus far, nothing concrete seems to have been done to further knowledge in this area.

[2]The Duluth Herald-News Tribune, the Superior Evening Telegram, the St. Paul Dispatch and other Twin Cities papers, and local television and radio affiliates of ABC, CBS, and NBC are among the news media which have given substantial coverage to the Reserve case and its associated asbestiform fiber health hazard.

residents aware of the fact that they have been ingesting asbestiform fibers for years, this news has remained remarkably localized. Despite the publicity brought about by the District Court trial, little mention of the problem has appeared in the national media.

In light of recent government efforts aimed at consumer protection, a study designed to identify those populations exposed to the potential hazard of asbestiform fibers from Reserve's operations appears to have merit. It may never be possible to determine the identity of every individual so exposed, but the identification of those areas actually serviced by the Duluth food and beverage industries whose products have been manufactured using contaminated municipal water provides another step toward increased protection of the consumer. Thus, by using the Duluth Problem as an example, it is the purpose of the dissertation to identify the systems and interconnections which are responsible for the spatial distribution of a potential carcinogenic agent.

Organization and Data Sources

In the dissertation, Chapters II, III, and IV are organized chronologically, based on the order in which asbestiform fibers move through the interlinked systems involved in the overall pollution problem. Chapter II elucidates the background of the problem by tracing the movement of the asbestiform fibers from their source in the Eastern Mesabi Iron Range through the mining and processing system, the Lake Superior circulatory system, and the Duluth municipal water distribution system. In gathering information on these three systems, I relied heavily upon state and federal court records and personal interviews, especially with personnel at the National Water Quality Laboratory-Duluth (now the EPA Research Laboratory) and the Lake Superior Basin Studies Center, as primary data sources. These were supplemented with data from secondary (published) sources.

The manufacturing and marketing/distribution systems involved in the Duluth Problem are discussed in Chapter III. Chapter III deals not only with the establishment of the service areas of Duluth's food and beverage manufacturers, but also with the extent of the exposure of consumers to asbestiform fibers carried in Duluth-manufactured products. With the exception of the data pertaining to population numbers, all information imparted in Chapter III was derived from primary sources, that is, from personal interviews and correspondence.

The gathering of data pertinent to the production and distribution of food and beverage products manufactured using Duluth municipal water had to take the form of interviewing, since no applicable previous study of Duluth's food industries existed. Market information was provided by Duluth Area Chamber of Commerce personnel and also directly by the companies.

The interview plan called for an initial contact with each firm, via mail and/or telephone, followed by a detailed interview in person. The major reliance upon personal contact, as opposed to mail or telephone interviewing, as a means of data procurement follows the reasoning of Brown and Beik in their work entitled Marketing Research and Analysis (1969). In their discussion of market research techniques, Brown and Beik (pp. 146-7) list the advantages of personal interviewing as follows:

(1) the ability to probe for complete information
(2) the greater flexibility in the number and kinds of questions possible
(3) the control of the response situation
(4) the flexibility in the length of the interview time
(5) the control over the speed of the interview, and
(6) the ability to use illustrative materials in support of discussion.

Once the production figures and market areas were obtained from each of the companies, the data were converted to written and cartographic form (Chapter III). Of the mapping techniques originally thought to be applicable to this problem, the "star-shaped" origin-destination technique used by Brush and Bracey (1955) was found to be too cumbersome and, given the nature of the data, the application of graduated circles proved difficult. Therefore, the decision was made to utilize market-area-boundary representations similar to the service-area technique employed by Harris (1940) and Ullman (1943).

For those portions of Chapter III which deal with the extent of exposure to asbestiform fibers carried in Duluth food and beverage products, density maps depicting estimated fiber ingestion per capita per year seemed most appropriate. First, density maps showing each company's contribution to the problem are presented, then these maps are combined to depict the total estimated annual per capita exposure to asbestiform fibers carried in Duluth-manufactured food and beverage products.

Consultation with Drs. Don Parker and Willis Owen, Department of Biostatistics, University of Oklahoma Health Sciences Center, Oklahoma City (July 14, 1976), confirmed that the method used in the dissertation is a reasonable and acceptable way to approach getting an estimate of fiber consumption. The only manner in which to calculate per-consumer exposure would entail having subjects in the affected areas keep detailed dietary records over a period of at least six months. Both Dr. Parker and Dr. Owen agreed that such an approach would be unfeasible in light of the extent of the geographic areas served by Duluth's food and beverage manufacturers. Thus, the use of per-capita estimates of exposure to asbestiform fibers is sound. Again, without detailed dietary records, Parker and Owen felt that the use of total population figures, in this case, probably gives a better estimate of exposure than if I had attempted to use population subgroups.

Dr. Parker commented that a confidential proposed study before the EPA, then in his possession, used similar techniques in estimating the exposure of populations, by county, to pesticides. Therefore, the procedures I have used to estimate "exposure," that is, the quantity of a pollutant entering various geographic areas, are not without precedent.

Chapter IV analyzes the final system directly involved in the Duluth Problem in that the chapter deals with the effect of asbestiform fibers on the biological systems of the human consumers. Thus, Chapter IV basically is a "medical" chapter entailing discussions of asbestiform fibers as potential carcinogenic agents and the possible effect of the ingestion of the fibers from Reserve Mining Company's activities on future cancer incidences. Data for Chapter IV was derived both from published sources and from a variety of primary sources, including federal trial transcripts, personal interviews, written and telephone communication, and the asbestos-related medical files of Dr. Robert Carter, Dean of the University of Minnesota-Duluth Medical School.

Chapter V serves as a forum for discussing the influence, on a pollution system, of external, higher-order systems (see Figure 1.2). Generally, it is the recourse to these higher-order systems that eventually effects the removal (or fosters the perpetuation) of channels of ignorance. Concluding comments and recommendations are contained in Chapter VI.

Summary

In summary, the dissertation employs systems analysis for the purposes of (1) explaining the spatial distribution of an industrially-produced health hazard and (2) identifying the channels of ignorance which serve to perpetuate the problem. In focusing on the Duluth Problem, the dissertation deals with a complex, multi-faceted environmental pollution problem. One of these facets, the medical aspect, is the ultimate concern of this research. Although humans may be exposed to asbestiform fibers from a variety of sources, including the "obvious" hazard of drinking contaminated water, the dissertation emphasizes the "hidden" hazard of exposure to asbestiform fibers carried in Duluth-manufactured food and beverage products.

Of necessity, this dissertation is of an exploratory nature and can be considered the first stage of an on-going study. In light of the relatively long (20 to 40 years) incubation period associated with asbestos-related diseases, it is not possible, at this time, to provide conclusive evidence that the ingestion of asbestiform fibers carried in Duluth water, or in products manufactured using such water, increases the consumer's risk of developing malignancies. That asbestiform fibers are known to be potential carcinogenic agents is, however, sufficient justification to merit the study of asbestos-related industrial pollution problems.

By no means does this dissertation provide all the answers. It does, nevertheless, represent a considerable amount of groundwork on the use of systems analysis in explaining the spatial ramifications of industrial pollution problems.

CHAPTER II

THE SYSTEMS COMPRISING THE BACKGROUND TO THE PROBLEM

In studies involving industrially-produced health hazards, an analysis of those interlocking systems through which the pollutant passes prior to reaching the consumer (human or otherwise) can be considered the "background" to the problem. The background, therefore, usually is comprised of tracing the movement of a hazard from its source through a common property resource,[1] such as the atmosphere, hydrosphere, or lithosphere, which renders the pollutant available for consumption. In most cases, industrial pollutants are "manufactured" during the processing of raw materials and are discharged into common property resources as by-products of industrial operations.

The asbestiform fibers which have created the Duluth Problem are discharged, as in the majority of industrial pollution cases, as a by-product of industrial operations. In the Duluth case, however, the health hazard posed by the asbestiform fibers exists in the raw materials themselves; the asbestiform fibers are not "manufactured" by Reserve Mining Company, but Reserve acts as a dispersing agent by dumping asbestiform-fiber-bearing taconite wastes into the common property resource known as Lake Superior. Consequently, the consumption of Lake

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[1]Throughout the dissertation, the term "common property resource" is used in the same manner as Garrett Hardin (1973) uses the term "the commons."

Superior water poses a potential health risk to the consumer.

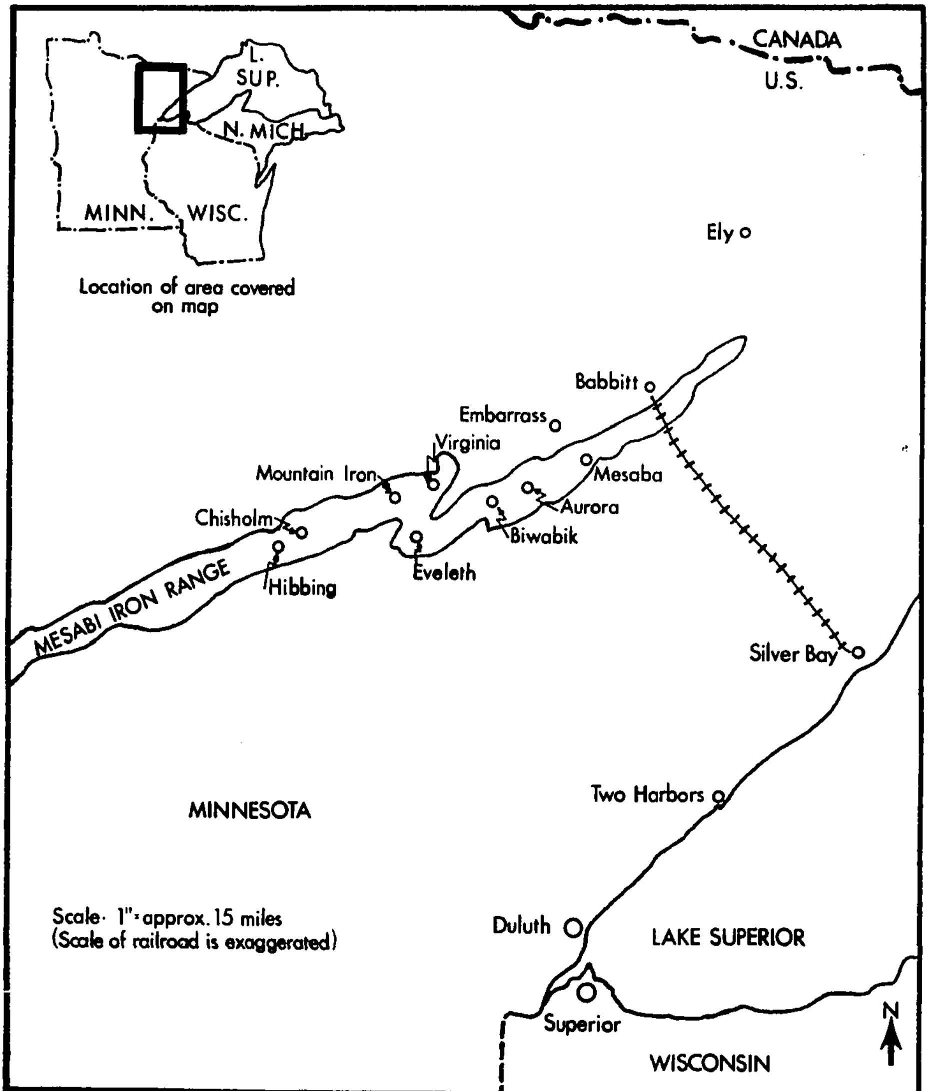
The purpose of this chapter is to trace the movement of the asbestiform amphibole cummingtonite-grunerite through the first four interlocking systems shown in Figure 1.2, that is, from the mineral's source in the Eastern District of the Mesabi Iron Range to its presence in the Duluth municipal water supply. This descriptive study is composed of three major sections: (1) the movement of asbestiform minerals from the petrologic system of the eastern Mesabi Iron Range through the taconite mining and processing system; (2) the discharge of asbestiform fiber-contaminated taconite tailings into, and their circulation within, the Lake Superior ecosystem; and (3) the presence of asbestiform fibers in the Duluth municipal water distribution system.

The Movement of Asbestiform Minerals from the Petrologic System of the Eastern Mesabi Iron Range Through The Taconite Mining and Processing System

Reserve Mining Company, whose parent companies are the Armco and the Republic Steel Corporations, was incorporated in 1939 and began mining and processing taconite in northeastern Minnesota in October, 1955. Reserve's Peter Mitchell Mine at Babbitt, Minnesota, is an open pit operation excavating taconite, a low-grade iron ore of approximately 20-25% magnetite (Furness, 1969) embedded in the eastern end of the Mesabi Iron Range (see Figure 2.1 for area locations). The taconite ore, a member of the Biwabik Iron Formation that was contact-metamorphosed by the intrusion of the Duluth Gabbro Complex,

Figure 2.1

LOCATIONS RELATIVE TO THE MESABI IRON RANGE



Source: adapted from: Reserve Mining Company, Your Visit to Reserve, Sixth Printing, Fourth Revision, August 1973.

is composed largely of magnetite, quartz, and the cummingtonite-grunerite series of asbestiform amphibole minerals. The deposits in Reserve's Peter Mitchell pit are approximately 26% amphibole (U.S.A., et al., v. Reserve Mining Company, et al., U.S. District Court, District of Minnesota, Fifth Division, St. Paul, Minnesota, No. 5-72 Civil 19, 1973-1974, Supplemental Memorandum to the Findings of Fact, Conclusions of Law and Memorandum issued on April 20, 1974, by the District Court -- hereafter designated simply as S.M., 1974).

Following the blasting operations designed to break up the ore body in the pit, the taconite is reduced to fragments less than four inches in diameter by mine-site crushers. This crudely-crushed ore is transported from Babbitt to the Silver Bay beneficiation plant via Reserve's 47-mile double-track railroad (see Figure 2.1). At Silver Bay the taconite ore passes through various machinery prior to shipment as taconite pellets (see Figure 2.2). As illustrated in Figure 2.2, two-thirds of the ore brought to Silver Bay becomes waste material known as taconite tailings.

The Discharge of Asbestiform Fiber-contaminated Taconite Tailings into, and their Circulation within, The Lake Superior Ecosystem

The Disposal Process

Reserve produces approximately 30,000 tons of finished pellets per day. The resulting daily by-product of the bene-

Figure 2.2

STEPS IN THE BENEFICIATION PROCESS

MACHINE	FUNCTION	PRODUCT
Crusher[1] ↓	taconite rock from mine is crushed into pebbles smaller than 3/4 inch	3.14 tons; 23.5% iron
Rod mill[1] ↓	taconite is ground in water to a muddy sand (particles 1/16 inch or less)	3.14 tons; 23.5% iron
Magnetic separator[1] ↓	pieces of rock with little or no magnetic iron are discarded	2 tons; 40% iron plus 1.14 ton of waste
Cone-type classifiers[1] (ball mill) ↓	pieces smaller than .004" pass by; all larger ones ground in ball mill	2 tons; 40% iron
Magnetic and hydro-separators[2] ↓	magnetite grains extracted from waste materials by magnets and via settling in water-filled basin	1 ton; 64.9% iron plus 1.02 ton of waste
Filter[3] ↓	water is drained by vacuum forming magnetite into a thick, black mud	.98 ton; 64.9% iron
Balling drum[3] ↓	thickened mud (magnetite) is rolled into small, round pellets	.98 ton; 64.9% iron
Pellet hardening furnace[3]	pellets are baked to a hard finish, converting magnetite to hematite	1 ton; 62.5% iron; final product ready for shipment delivered to storage bins; plant discharges total of 2 tons waste

[1] In these steps magnetite grains are freed from unwanted minerals.

[2] In this step the magnetite is sorted.

[3] In these steps dust-sized grains are combined into pellets.

Source: adapted from: Reserve Mining Company, Your Visit to Reserve. Sixth Printing, Fourth Revision, August 1973.

ficiation process is about 67,000 short tons of tailings as a slurry in 500,000,000 $\pm$ gallons of water (Weston, 1971).

The taconite tailings from the three stages of grinding and five stages of separation at the beneficiation plant are combined to form a slurry of about 2.7% solids (S.M., 1974); this slurry is transported to the shore of Lake Superior via gravity troughs known as launders. About 45% of the discharge is made up of fast-settling coarse tailings (Furness, 1969) which have formed a subaerial delta-shaped deposit along the lakeshore. The remaining 55% of the tailings is composed of finer materials (Furness, 1969) in a slurry of about 1.5% solids (S.M., 1974) which flows across the delta and down its toe into Lake Superior.[1] The location of the delta is shown on Figure 2.3.

The Discharged Taconite Tailings: Their Characteristics And Their Movement Within the Lake Superior Ecosystem

Once the magnetite has been removed from the taconite ore, what remains is composed largely of quartz, cummingtonite-grunerite, non-crystalline iron oxides, and small amounts of the

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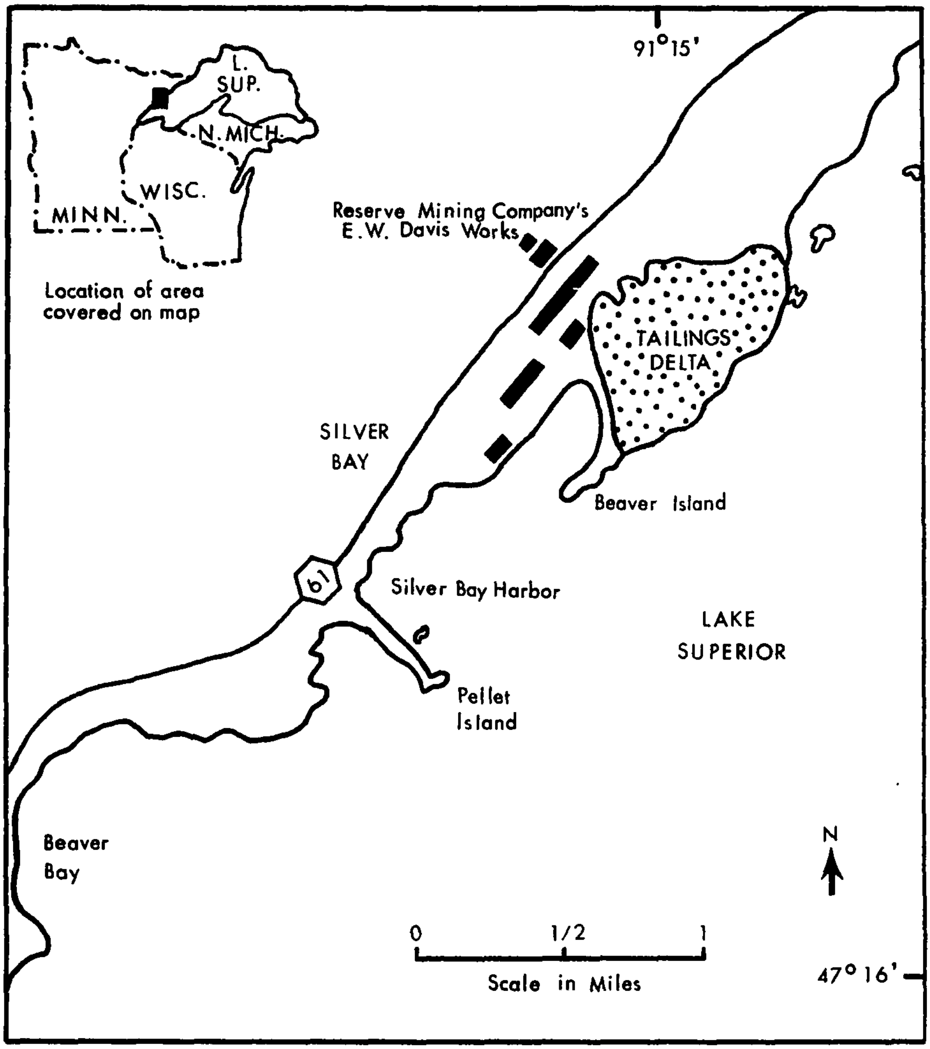
[1]Reserve's original permit to withdraw water from, and to discharge water and taconite tailings into, Lake Superior was issued in 1947. There have been subsequent amended permits issued to allow Reserve to increase its withdrawal and discharge. (See APPENDIX C.) The permits state that the quality of Lake Superior's water cannot be impaired by the discharge; therefore, the plaintiffs in U.S.A. v. Reserve alleged that the company was in violation of its permits in light of the evidence which indicated that the quality of Lake Superior water was being impaired by the discharge of Reserve's taconite waste into the lake.

Figure 2.3

THE NORTH SHORE OF LAKE SUPERIOR IN THE VICINITY OF RESERVE'S BENEFICIATION PLANT



Source: composite drawn from Stoddard Report, 1968, Fig. 11, p. 61, and from Gerard, Costin, and Assaf, 1972, Fig. 6-8.

clay minerals chlorite, montmorillonite, and vermiculite (Mount, 1969). Reserve's discharge of this waste adds considerable amounts of suspended solids to the waters of Lake Superior. According to District Court findings (S.M., 1974, p. 29):

> ...Reserve's discharge is the singularly most significant input of suspended solids into Lake Superior [at least five to six times larger than the approximate 12,000 tons-per-day contribution of streams and shore erosion (S.M., 1974)]. ...of the natural sources of solids entering Lake Superior [daily] only 640 to 1,300 tons...are finer than five microns whereas some 3,500 to 5,800 tons of Reserve's discharge contain particles that are finer than five microns.

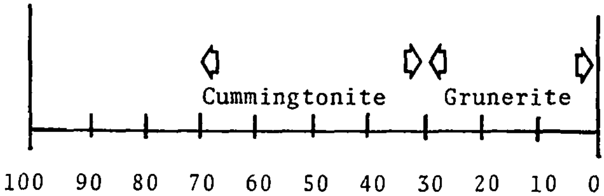
Reserve's launders discharge 67,000 tons of tailings waste onto the delta and into Lake Superior each day. Within this discharge 30-40% of the particles are smaller than 45 microns; 5-8% are less than five microns; and about 2% are smaller than two microns (S.M., 1974).

The District Court stated that "approximately 44% of the total tailings discharged into Lake Superior are [sic] made up of amphibole material of which 50 to 70% is in the cummingtonite-grunerite series" (S.M., 1974, p. 29). Cummingtonite-grunerite is a silicate amphibole series that varies in its iron to iron-and-magnesium ratio. Although the entire series commonly is referred to as "cummingtonite," the term "grunerite" specifically denotes the iron-rich members of the series. Figure 2.4 offers a graphic explanation of the composition of these minerals.

The importance placed on the cummingtonite-grunerite amphiboles in Reserve's discharge stems from the fact that within this series are asbestiform minerals similar to amosite asbestos,

Figure 2.4

COMPOSITION OF THE CUMMINGTONITE-GRUNERITE AMPHIBOLE MINERALS



$Mg_7Si_8O_{22}(OH)_2$ $Fe_7^{+2}\ Si_8O_{22}(OH)_2$

100 Mg: $(Mg+Fe^{+2}+Fe^{+3}+Mn)$

Source: extracted from Deer, Howie, and Zussman, 1963, Fig. 63, p. 242.

a known human carcinogen. It was the opinion of the District Court (S.M., 1974, p. 26) that:

> ...scientists for both sides [U.S. Exhibits 6, 28, and 171; testimonies of David Pytynia (Reserve) and Dr. Arthur M. Langer (U.S.)] have found that cummingtonite-grunerite and amosite have in most instances similar morphology, crystallography and chemistry and are, therefore, indistinguishable.

The presence of cummingtonite-grunerite in Reserve's taconite tailings has been detected by various District Court witnesses (Cook, Johnson, Krause, Langer). Although actual fiber counts are done via electron microscopy, the presence of detectable cummingtonite-grunerite is determined by X-ray diffraction. A sample X-ray diffraction pattern from sediments less than two microns in size is shown in Figure 2.5. Angle two theta (2θ) is the angle at which the X-ray transmitter was set -- that is, the angle from which the X-ray was "shot" at the sediment lying on a flat surface. The Y axis represents intensity,[1] while the X axis represents the angle in degrees at which the receiver of the diffracted X-rays was raised from the horizontal. Peaks four and seventeen show detectable quantities of amphibole minerals. This method has been used to detect the presence of cummingtonite-grunerite in the waters of Lake Superior, including the municipal water supply of Duluth, Minnesota.

Before describing the movement, in western Lake Superior,

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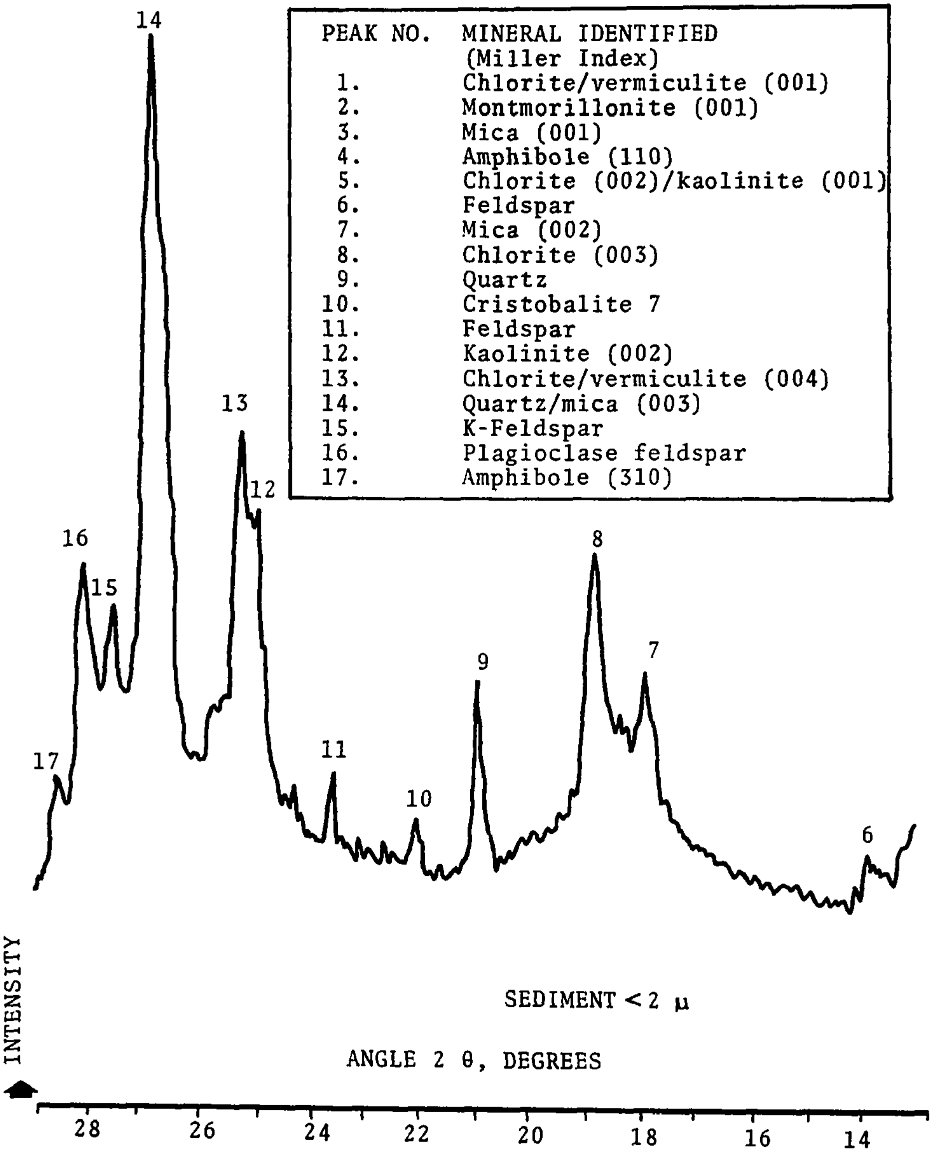
[1]In a personal interview in August, 1974, Glass stated that the intensity, or the height of the peaks, usually is measured in millimeters.

Figure 2.5

SAMPLE X-RAY DIFFRACTION PATTERNS



(to be continued)

Figure 2.5 (continued)

Source: extracted from Andrew, 1973, Figure 1.

of taconite tailings containing asbestiform amphibole fibers, a few words should be said in regard to possible sources of cummingtonite-grunerite other than Reserve's discharge. Green (personal interview, August 1, 1974) has stated that the rocks and glacial drift of northeastern Minnesota are essentially barren of cummingtonite-grunerite except in the Eastern Mesabi District, where the iron formation has been metamorphosed by the Duluth Gabbro Complex. It is possible to find traces of cummingtonite in the glacial drift southwest of Ely-Babbitt since the glacial movement in this area was from the northeast to the southwest across the Biwabik Formation. Also, the lava flows along the North Shore of Lake Superior may contain a small amount of cummingtonite, but it would not be more than a trace.

In addition to the lack of cummingtonite-grunerite-bearing rocks exposed to erosion within the Lake Superior watershed, the confinement of cummingtonite-grunerite to the upper layers of Lake Superior bottom sediment would indicate that the quantities of cummingtonite-grunerite currently found in the lake could not have been derived from the natural processes of erosion and sedimentation. Green testified to these facts in District Court and Carson (1969), Mount (1969), and Phinney (1969) basically concur with these views.

The Findings of Fact (U.S.A. v. Reserve Mining Company) issued in April of 1974 support the allegation that Reserve's discharge is, for all practical purposes, the only major source of the cummingtonite-grunerite found in Lake Superior. The

District Court found that:

> The assumption that cummingtonite in identifiable quantities does not enter the lake from natural sources is consistent with the geological make-up of the area. Substantially all of the natural cummingtonite in this area is found in areas of highly metamorphosized rock. There are only four iron formations in the area in which cummingtonite-grunerite might be found. They include the Mesabi, Gogebic, Gunflint and Marquette ranges. These areas in the Gunflint Range and in the Marquette Range do not drain into Lake Superior. The drainage areas from the Mesabi and Gogebic Ranges do lead to Lake Superior but it is unlikely that significant quantities of cummingtonite-grunerite from these areas ever reach the lake, in that the particles would have to travel significant distances through terrain characterized by flat, swampy land, ponds and dams (S.M., 1974, p. 30).
>
> . . . .
>
> It would be highly unlikely that substantial quantities of cummingtonite were carried into Lake Superior by the rivers and streams that drain into it.
>
> The plaintiffs have collected suspended sediment from over fifty Lake Superior tributaries, including all of the streams between Duluth and Silver Bay. Many of the streams were sampled twice and all were sampled at high flow when there would be a larger amount of suspended sediment present in the stream. The samples were analysized [sic] by x-ray diffraction and only one, the Montreal River, contained cummingtonite-grunerite in detectable quantities. Furthermore, Mr. Stewart, a witness for the United States, examined samples from the Beaver, Stewart, Baptism, and St. Louis Rivers which lie between Silver Bay and Duluth by electron microscope and found no amphibole fibers of any kind present (S.M., 1974, p. 31).
>
> . . . .
>
> Reserve also did a study in which they analyzed by x-ray diffraction many samples from the tributaries entering into Lake Superior. It was the conclusion of Reserve's expert witness that the studies revealed the presence of cummingtonite-grunerite in 60 tributaries emptying into the lake. However, when exposed to extensive cross-examination during which the original graphs were re-examined in Court, it became clear that the criteria used for identifying cummingtonite-grunerite in this study was highly subjective with bias entering into the determination. Therefore, the Court, as trier of fact, cannot give these particular results much weight.
>
> Even if the Court were to accept the results of

> Reserve's study, it would prove only that cummingtonite-grunerite enters into the lake from the rivers and streams in barely detectable quantities. Once in the lake, these small quantities of cummingtonite-grunerite would become even more diluted so as to become undetectable in the lake itself (S.M., 1974, p. 32).
>
> . . . .
>
> The conclusion is clear that cummingtonite-grunerite in detectable quantities is generally not deposited into Lake Superior from natural sources. The Court finds that where cummingtonite-grunerite is found in the Western Arm of Lake Superior in detectable quantities, it can be traced to Reserve's discharge (S.M., 1974, p. 33).[1]

The cummingtonite-grunerite series has been used by a number of researchers in tracing taconite tailings in Lake Superior waters (Baumgartner, et al., 1971; Dybdahl and Rouse, 1972; Andrew, 1973; Lempke, 1973; Cook, April and July, 1973; Glass, 1973; and Mount, 1973). The following evidence in support of the movement of taconite tailings from Silver Bay to Duluth is based on the presence of cummingtonite-grunerite in Lake Superior sediment and water samples.

As mentioned in the previous section on Reserve's operations, the finer waste products from the beneficiation process (55% of the total discharge) flow down the face of the tailings

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[1]As is true when dealing with any phase of a court case, the question of whom to believe arises. Reserve's officials have denied that the company is responsible for the pollution of Lake Superior. The company's Public Relations Department and Reserve's Findings of Fact both claimed that no asbestiform minerals were contained in the company's discharge (telephone interview with Edward Schmidt, Public Relations, Reserve Mining Company, July 30, 1974; testimony of Donald Wright, Assistant Director of Public Relations, Reserve Mining Company, in Reserve Mining Company v. Minnesota PCA, 1970; Findings of Fact Proposed by Defendant Reserve Mining Company (Second Set), U.S.A. v. Reserve Mining Company, April 18, 1974). Nevertheless, EPA publications and the District Court transcripts have produced seemingly overwhelming evidence against Reserve Mining Company.

delta into Lake Superior. As the slurry enters the lake it forms a gravity-driven density current which flows downward in the general direction of the Great Trough, a 700 to 950-foot-deep trench lying parallel to the northern shoreline in the western embayment of Lake Superior. The Great Trough extends from the vicinity of Two Harbors, Minnesota, for approximately 51 miles northeastward and lies from 1.5 to 8.2 miles offshore (Baumgartner, et al., 1971).

Evidence suggests that the density current is not completely effective and not all the taconite tailings settle in the Great Trough. Among others, U.S.A. v. Reserve Mining Company transcripts (1973-1974), The U.S. Department of the Interior Federal Water Pollution Control Administration (1969), and Baumgartner (1969) have noted the instability of this density current. Baumgartner (1969, p. 186) concludes that:

1. Reserve's discharge does not exist under conditions likely to result in a stable density flow.
2. Instability and turbulent conditions will cause clouds of turbid water to shear off from the density flow, which can then be transported with the currents in the lake.
3. The main portion of the density current will probably descend to the lake bottom, except that when a strong thermocline exists, a significantly large portion of the stream may be carried off into the lake near the thermocline.
4. The solids in the portion of the density stream which reach [sic] the bottom are not completely removed by sedimentation within the immediate vicinity of the plant, say 50 square miles. The fine particles remaining in suspension are subject to transport over large distances by weak currents near the bottom and subject to widespread vertical and horizontal distribution during periods of storm and/or customary spring and fall periods of vertical mixing.

5. The currents and topography of the lake are such that suspended solids concentrations would increase more rapidly in the Duluth Embayment than in the lake generally, and would always be somewhat higher than in the rest of the lake.

And, according to the Federal Water Pollution Control Administration (1969, p. 27):

> As the tailings meet Lake Superior water, 'billowy gray clouds' of waste were visible leaving the density current, both at and under the water surface near the shore line. Extending off shore as far as 300 feet, these clouds were observed and photographed at a depth of 35 feet. It appeared that 'green water' was formed as gray tailings clouds diffused (became less concentrated) and more daylight penetrated among the particles.

Figure 2.6 illustrates the mechanism by which "green water" is created.

In his discussion of the North Shore surface waters of Lake Superior, Lempke (1973, p. 1335-16) attributed much of the "green water phenomenon" to Reserve Mining Company's discharge when he stated:

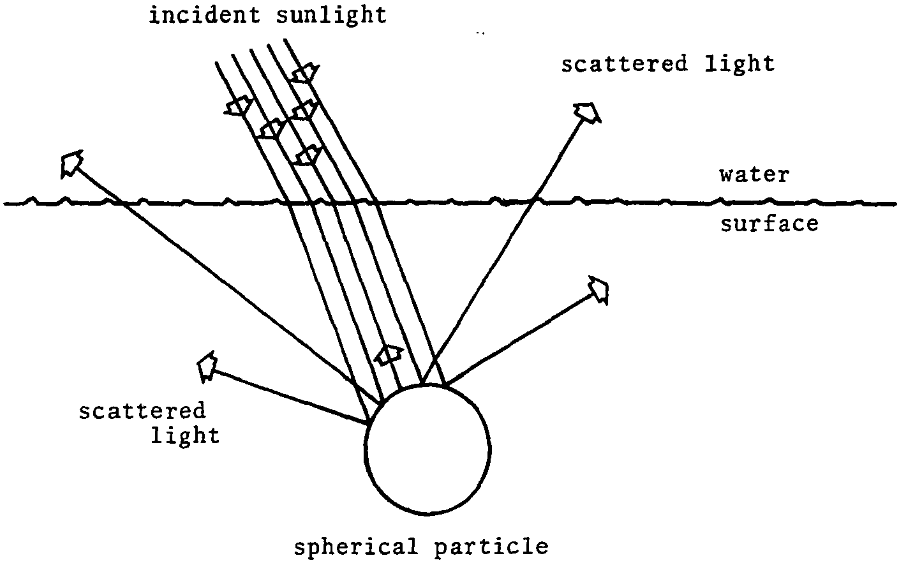
> The green water (large discontinuous masses sometimes 7 miles wide) seen along the North Shore is being caused in a significant part of the episodes by particulate matter from the tailings operations.... The taconite processing operations at Silver Bay...are contributing to an increase in turbidity in Lake Superior, particularly in the area S.W. of Silver Bay, but to a lesser extent in other nearby areas. Suspended solids in the same area have been increased as the result of the ore-processing operations. Material from the tailings discharge is being transported to all parts of the study area, and current data indicates [sic] that this being the case the tailings fines (fine particulates) are at least being distributed throughout the Duluth arm of Lake Superior.

Furthermore, evidence related to the inefficiency of Reserve's density current caused the District Court to conclude (S.M., 1974, pp. 34-35):

Figure 2.6

SCATTERING OF SUNLIGHT BY SPHERICAL TACONITE PARTICLE IN WATER:

THE "GREEN WATER" PHENOMENON *



*Green water can occur naturally, but the presence of taconite tailings greatly increases the frequency of its occurrence.

Source: adapted from Dybdahl and Rouse, 1972, Figure 96.

> It is the finding of this Court that although the existence of the heavy density current is a fact, there are a number of physical phenomena working both on the density current and the tailings after they escape the force of the current that precludes it from being effective. The following is a list of those phenomena: prevailing currents, the presence of thermoclines, deep currents, wind action, internal wave action, upwelling, wave action, slumping, and vertical mixing. [These will be discussed in the following pages.]
>
> It is agreed by both sides that the prevailing currents in the western arm of Lake Superior are from the northeast to the southwest, from Silver Bay toward Duluth, and then around to the northeast along the Wisconsin side. These are of sufficient intensity to affect any particles in suspension in the area in which they operate.

In accordance with the above views is the Federal Water Pollution Control Administration's statement (1969, p. 27) that:

> ...current measurements in the vicinity of Silver Bay show that the prevailing current is to the southwest and of sufficient velocity to transport particles of 4 microns or less more than nine miles per day.

The foregoing materials relative to the movement of taconite tailings within the western arm of Lake Superior testify to the basic cyclonic circulation pattern of the lake's prevailing currents documented as early as 1895 (Harrington). In 1958 Ruschmeyer and Olson discovered cyclonic eddies in the Silver Bay area and within the triangle formed by Duluth, Beaver Bay, and the Apostle Islands. That the easterly drift along the South Shore of Lake Superior turns north and then westward at the eastern end of the lake was demonstrated by Hughes, Farrell, and Monahan (1970). On a more theoretical basis, Murthy and Rao (1970) predicted, via a linear mathematical model of wind-driven circulation, that Lake Superior should have a general counter-clockwise circulation pattern.

It is wise to note, however, that not all researchers agree with the above findings. Adams (1970) showed that upwelling caused by westerly winds along the North Shore could effectively reverse the general counter-clockwise circulation pattern. Nevertheless, this seems to have been a temporary phenomenon which could be destroyed by a few days of easterly winds. Sydor (personal interview, July 31, 1974) claims that the dominant theories on the counter-clockwise circulation pattern of Lake Superior are only "rough guesses" and that "no matter what you say about the circulation of Lake Superior, you could be proven right or wrong at some time or other."

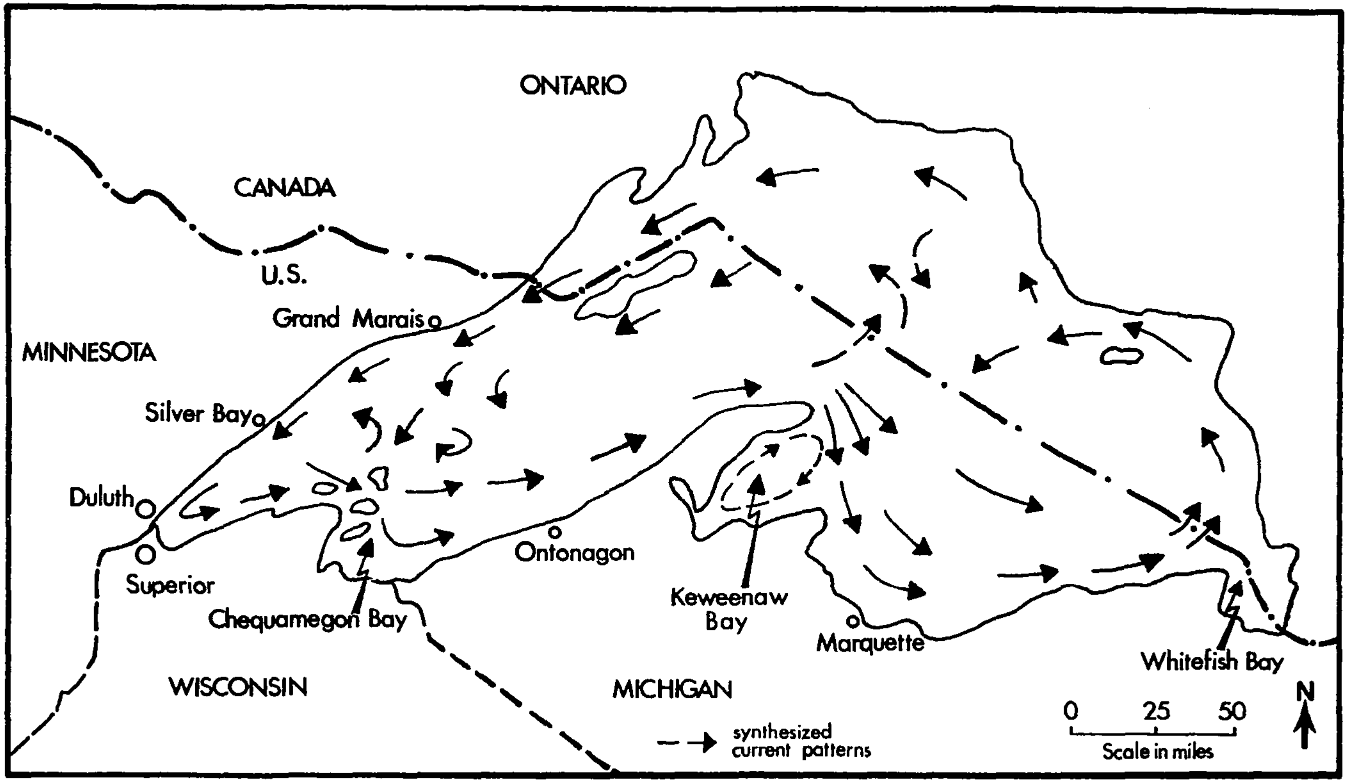
Regardless, at this stage in man's knowledge of Lake Superior's circulation, the acceptance of the counter-clockwise pattern seems to prevail. As asserted by the Michigan Water Resources Commission (1969, p. 884-27):

> Since Lake Superior has no flow-through, current patterns result primarily from wind action. The wind-driven current is modified by the rotation of the earth, density differences (temperatures in Lake Superior) and the shape of the basin. In Lake Superior the forces create a cyclonic or counter-clockwise movement -- generally an eastward flow along the southern shore and westward flow along the north shore.... [While some studies have indicated] some modification, this interpretation [of a cyclonic circulation pattern] is considered valid in its general concept.

In accordance with the foregoing materials, the general net surface circulation of Lake Superior is illustrated on Figure 2.7, while Figure 2.8 is a more detailed representation of the current pattern in the western half of the lake. These

Figure 2.7

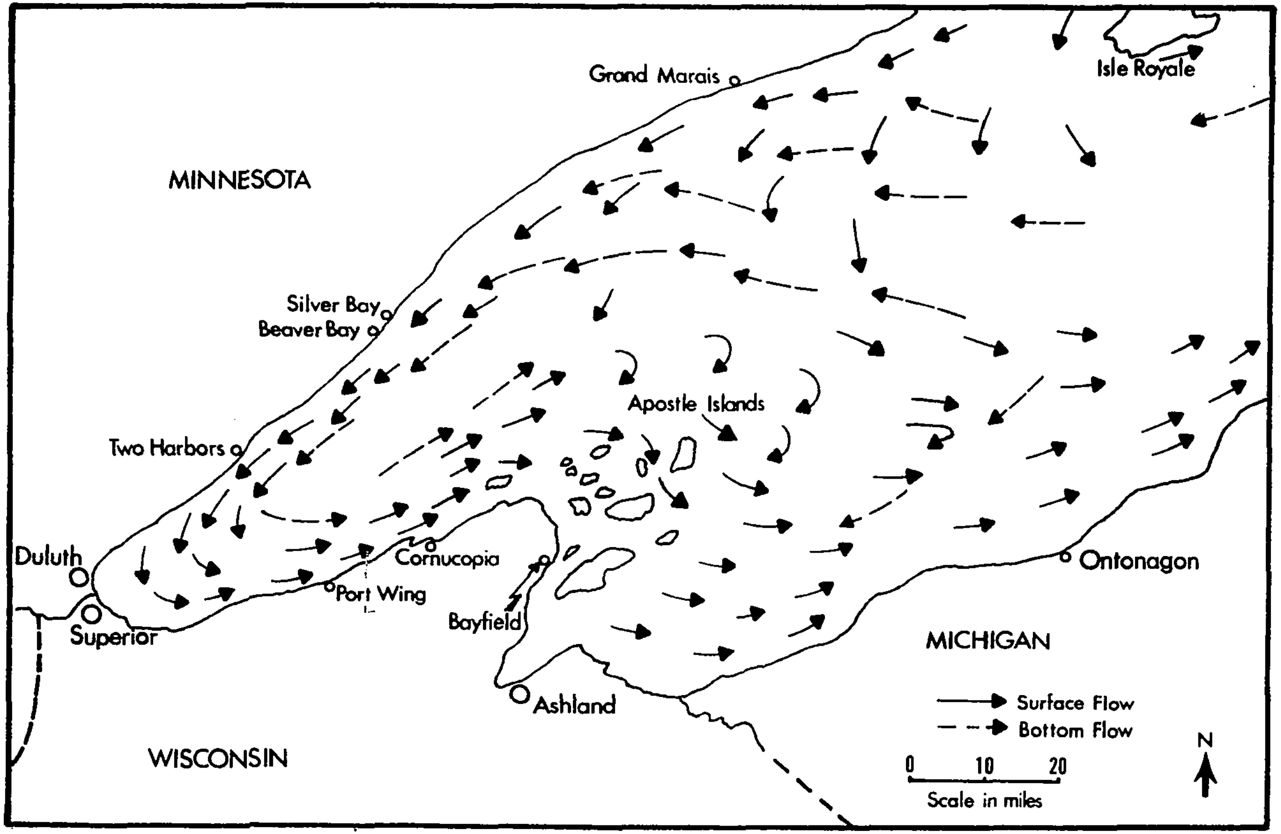
NET SURFACE CIRCULATION OF LAKE SUPERIOR



Source: adapted from U.S. Department of the Interior, April 1969, Figure 5, p. 14.

Figure 2.8

CURRENT PATTERNS (NET FLOW) IN WESTERN LAKE SUPERIOR



Source: adapted from U.S. Department of the Interior in: Stoddard Report, 1968, Figure 3, p. 53.

prevailing currents tend to disrupt Reserve's density current and to move suspended taconite tailings southwestward away from the discharge site.

In addition to the prevailing surface currents, thermoclines act to decrease the efficiency of Reserve's density current. In reference to the presence of thermoclines in the western arm of Lake Superior, the District Court (S.M., 1974, p. 35) concluded:

> It was proven to the Court by plaintiff's witness Mr. Gerard that...thermoclines exist in this area of Lake Superior and effectively peels [sic] off a portion of the density current as it goes down the delta slope and through the thermocline. This phenomenon is more pronounced during the winter thermocline period since the thermocline is then deeper in the lake and the density current has less force to overcome it. The effect of this is to free a portion of the tailings entrained in the density current and suspend that portion above the thermocline layer. Materials in the area directly above the thermocline are more likely to be affected by the air-sea interface forces and to be moved by the horizontal prevailing currents because of the less dense nature of the water and because the currents are strongest in the first one hundred feet depth of the lake.

On the subject of thermoclines, Ragotzkie (1969, p. 1378) has asserted:

> Once the tailings are transported below the thermocline, both winter and summer, the stability of the water stratification will tend to isolate the material from further recirculation into the surface waters. This isolation certainly exists during the summer and winter stratification and may also prevail during the brief periods when the lake is isothermal.

Although he does not state so explicitly, in actuality Ragotzkie is referring to the taconite tailings that are able to pass <u>through</u> the thermocline. As noted previously, a portion of the sediments entrained in the density current is sheared off prior to passage through the thermocline. In addition, the Findings of Fact of the District Court (S.M., 1974) question the stability of the taconite tailings "isolated" below the thermocline.

As the density current loses some of its force via velocity shear,[1] prevailing currents, and thermoclines, taconite tailings tend to disperse and form a nepheloid layer.[2] This nepheloid layer has been noted to be as long as 3 miles with accompanying width and thickness of 37 miles and 100-300 feet, respectively (S.M., 1974). Although its force is diminished, the density current, deflected clockwise from the point of discharge, due to the earth's rotation, travels southwestward from Silver Bay. Descending diagonally into the Great Trough, the density current entrains other waters so that the combined strength of these deep currents is sufficient to enable a marked flow to climb up and out of the western end of the Trough. These deep currents, carrying suspended taconite tailings, travel toward Duluth and proceed counter-clockwise along the South Shore of Lake Superior (S.M., 1974).

Further evidence of the movement of taconite tailings southwestward from Silver Bay can be found in the results of

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[1]a decrease in velocity from the "core" of the current to the outer edge (Ragotzkie, 1973).

[2]a localized area of turbid water within another body of water (S.M., 1974). In this case the phenomenon is known as "green water."

the limnological studies of Lake Superior conducted jointly by the Lamont-Doherty Geological Observatory and the EPA during the period July-September, 1971 (Gerard, Costin, and Assaf, 1972). As stated in the report (p. 4-4):

> The bottom flow density current may be expected to deposit most of its suspended load into the deepest part of the trough boardering [sic] the northern shore of the lake. However, ...turbid bottom water...[has been] observed at the 600 foot depth contour south of the deepest portion of the trough and nearly 8 miles from the taconite tailings discharge.

Figure 2.9 is an isopach chart of the distribution of tailings bottom sediment in western Lake Superior, based on data from core samples taken by Reserve Mining Company. On this chart, adapted from Gerard, Costin, and Assaf, tailings distributions have been superimposed on known topographic contours of the lake basin. Gerard, Costin, and Assaf (p. 4-4) explain the tailings distribution pattern in the following manner:

> If the tailings sediment distribution were entirely the result of a bottom flow density current, one would expect the isopachs and topographic contours to coincide. The observed distribution, however, shows a considerable disconformity between the two, with the sediment distribution strongly favoring the southern direction. For example, the farthest extent of the tailings sediment (the 0 inch isopach) to the northeast just reaches the 900 foot contour of the trough in this direction, yet the same isopach line coincides with the 400 foot contour at the southwestern end.

From the above statement it is obvious that the distribution of taconite tailings in Lake Superior results not only from the density current but from other physical phenomena

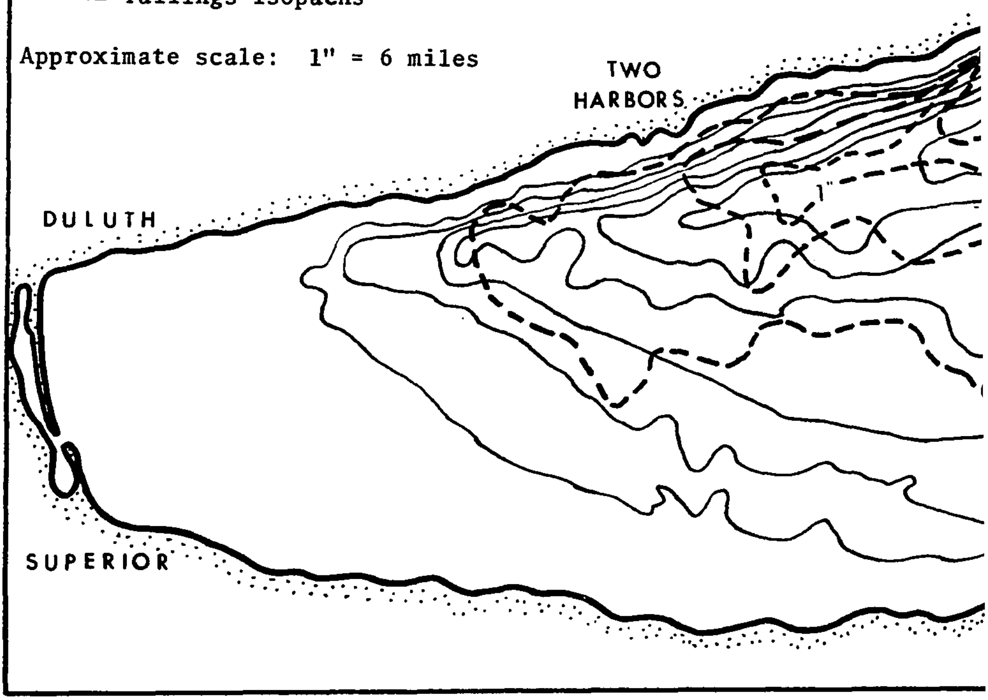
Figure 2.9

THE DISTRIBUTION OF TAILINGS BOTTOM SEDIMENT IN WESTERN LAKE SUPERI

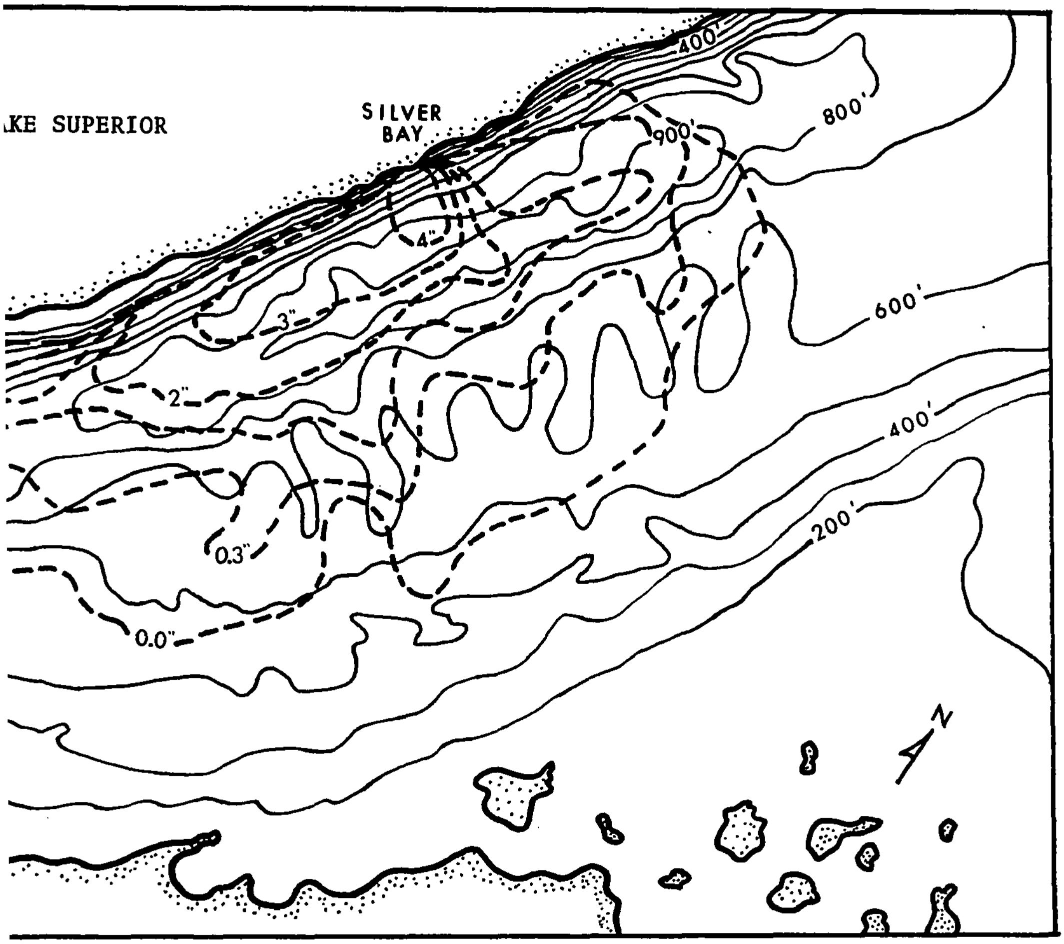
——— Topographic contours

— — — Tailings isopachs

Approximate scale: 1" = 6 miles



Source: adapted from Gerard, Costin, and Assaf, 1972, Figure 4-11.



ıre 4-11.

(notably prevailing surface currents) as well. Perhaps a word of caution should be added in reference to the distribution shown on Figure 2.9: the isopachs are drawn according to Reserve's data which were judged by the District Court (U.S.A. v. Reserve Mining Company, 1973-1974) to be too conservative. Furthermore, the distribution is of bottom sediments and does not include suspended sediments, which are finer particles largely made up of asbestiform amphibole minerals (cummingtonite-grunerite).

In addition to prevailing currents and the presence of thermoclines, another factor contributing to the "skewed" tailings distribution and to the inefficiency of the density current in keeping taconite tailings deposits localized near the plant site is the breakup of the winter and summer thermoclines in the spring and fall, respectively. The conditions of a relatively well-mixed warmer layer of water overlying a colder, basically isothermal, layer are destroyed at least twice a year. This allows for widescale vertical mixing within the lake in response to wind and wave action. Consequently, deep sediments formerly "trapped" below the thermocline are subject to resuspension and to transport via prevailing currents.

Furthermore, the combination of wave action and slumping on the slope of the delta act to resuspend previously-deposited taconite tailings. These resuspended sediments, like the deep sediments mentioned above, also can enter the stream of the prevailing currents.

In reference to the role of Lake Superior's physical processes (prevailing currents, deep currents, thermoclines, wave action, delta slumping, upwelling, and vertical mixing) the District Court (S.M., 1974, pp. 37-39) concluded:

> When all these phenomena are considered, especially in light of the fact that the particles that are of critical importance are those in the less than five micron size range and tending therefore to remain in suspension, the allegation of Reserve that the density current is effective is erroneous. Large numbers of particles are not caught up by the density current, are sheared off of it and remain in suspension, or are deposited and resuspended. The currents in the lake at or around Reserve are not only of sufficient intensity to move suspended particles many miles but also are of sufficient intensity to resuspend sediment on the delta slope.
>
> ...Using cummingtonite as a tracer, a practice heretofore adopted, one plaintiff's witness confirmed the presence of tailings in an area in excess of 600 square miles near the bottom of the western arm of Lake Superior; in the public water supplies of Beaver Bay, Two Harbors, Silver Bay, Duluth, and Superior, Wisconsin, all of which are to the southwest of the Reserve discharge; and in the water and sediment of Wisconsin and Michigan.
>
> . . . .
>
> [Based on this and other testimonies] it is reasonable to assume that the actual area of Lake Superior despoiled by the waste from Reserve is over 2,000 square miles, or an area approximately the size of the State of Delaware.

To summarize the preceding sections, asbestiform fibers, as components of the cummingtonite-grunerite fraction of the metamorphosed Eastern Mesabi iron ores, are shipped from Reserve's Peter Mitchell Pit at Babbitt to the E.W. Davis beneficiation plant at Silver Bay, Minnesota. From the plant these fibers are discharged, as part of the taconite tailings, into Lake Superior. Lake Superior's circulatory system then transports the fibers counterclockwise throughout the western arm of the lake.

The Presence of Asbestiform Fibers in the Duluth Municipal Water Distribution System

Since water drawn directly from Lake Superior serves the majority of the western Lake Superior shoreline communities (Silver Bay, Beaver Bay, Two Harbors, Duluth, and Superior), municipal water supplies have become subject to contamination by asbestiform fibers. This is the case with western Lake Superior's largest port city, Duluth, Minnesota, which draws its water from Lake Superior via the Lakewood Pumping Station at the eastern end of the city. As Cook (April, 1973, p. 2) explains:

> The Duluth water intake is located at a depth of about 60 feet, one-fourth of a mile offshore of the Lakewood Pumping Station which is situated on the North Shore about eight miles from the Duluth Harbor entrance.... The distance from the water intake to Silver Bay is approximately 45 miles.

Until February of 1977 Duluth municipal water was not filtered. Lake Superior water simply was treated with ammonia, chloride, and fluoride prior to a 1 - hour delay in the Lakewood detention basin, after which the water entered the Duluth distribution system of seventeen reservoirs, 325 miles of mains, and numerous tanks and auxiliary pumping stations.

Researchers have found taconite tailings, identified via cummingtonite-grunerite X-ray diffraction patterns, both in the detention basin sediments and in the Duluth municipal water supply. Table 2.1 shows the amount of tailings present in the detention basin sediments during the periods May 1960 - May 1962 and May 1962 - April 1969. It is evident that the

Table 2.1

LAKEWOOD PUMPING STATION DETENTION BASIN SEDIMENT SAMPLES

Period of Sedimentation	Size Fraction	Amount of Tailings[1]
May 1960 - May 1962	< 2 microns	16%
	2-5 microns	++
	> 5 microns	not detectable
May 1962 - April 1969	< 2 microns	31%
	2-5 microns	++
	> 5 microns	++

[1]++ = major amount. [That is, with the possible exception of quartz, the tailings were the dominant constituent of the sediment being analyzed. Cook calculated percentages only for the <2 microns size fraction.]

Source: Cook, July 1973, Table 3, p. 1521.

amount of taconite tailings present in the <2 microns and >5 microns size fractions increased during the 1960's. Since the tailings in the 2 to 5 microns range are registered simply as "major amounts" in both time periods, one cannot compare these two figures. It should be noted that the smaller the size fraction the greater the percentage of asbestiform minerals present in the sediment.

As evidenced by the water sediment analyses conducted by the EPA National Water Quality Laboratory (NWQL) at Duluth, the presence of cummingtonite-grunerite in Duluth's municipal water supply is a post-1950 phenomenon. The 1973 analysis (Cook, July 1973) of historical raw water samples collected at the Lakewood Pumping Station during 1939-1940, 1949-1950, and 1964-65 showed no detectable taconite tailings in the 1939-1940 and 1949-1950 samples, but all eight of the 1964-1965 samples contained tailings. For the 1964-1965 samples a conservative estimate of 0.1 mg/l taconite tailings concentration was made in regard to the <2 microns fraction of the suspended sediment.

Another historical sample of Duluth's water, collected for Civil Defense purposes at the County Jail on June 5, 1963, showed a tailings concentration of 0.08 mg/l. Again, this probably is a conservative figure, since some particles undoubtedly adhered to the sides of the plastic container during the 10 years that elapsed between collection and analysis (Cook, July 1973).

In summarizing the results of the analyses of these historical samples Cook (July 1973, p. 1524) states:

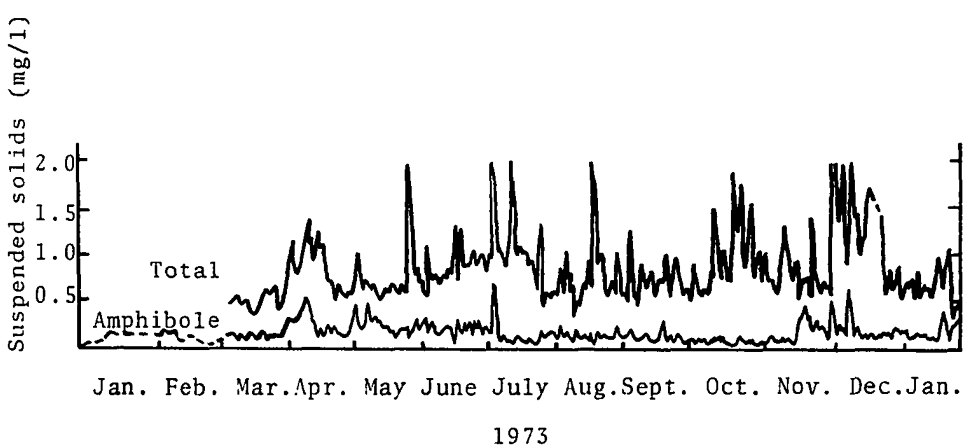
> Analyses of these preserved Duluth water supply samples clearly indicate that the cummingtonite-grunerite minerals characteristic of Reserve Mining Company's discharge were absent from Lake Superior water entering the Duluth Water Supply prior to the 1950's. Taconite tailings were present in the Lakewood detention basin in 1960-1962 and have been measured in the suspended solid present in the distribution system in 1963. Concentrations in the water during the mid-1960's probably averaged more than 0.1 mg/l tailings.

In March of 1973 the NWQL began daily analyses of the suspended solids in Duluth's water; to date, the presence of cummingtonite-grunerite has been found in every sample of unfiltered water. Figure 2.10 represents the daily amphibole and suspended solids concentrations for Duluth water during 1973. It can be seen that cummingtonite-grunerite concentrations in the Duluth water supply are not constant, but rather fluctuate in response to a number of parameters. The pattern shown in Figure 2.10 becomes more meaningful in light of the explanation given by Cook, Glass, and Tucker (1974, p. 854):

> The Duluth water intake, located at a depth of 20 m, may receive water with increased amphibole concentration when the surface water circulation from the northeast is promoted by extended periods of easterly and northeasterly winds, as during the periods of 29 March to 9 April, 29 April to 1 May, and 1 to 7 May. These same winds may also cause the resuspension of recently settled amphibole-rich sediment by wave action in the shallow water around the water intake. A period characterized by very high concentrations of suspended solids (approximately 20 percent amphibole) occurred in December 1973 when strong easterly winds resuspended surface sediments and the river sediment input was low. Ice cover, which normally begins in January, prevents such wind-generated resuspension of lake sediment.

Figure 2.10

DAILY AMPHIBOLE AND SUSPENDED SOLIDS CONCENTRATIONS FOR DULUTH WATER



Source: Cook, 1974, extracted from Figure 5.

> Amphibole concentrations in Duluth water diminish during the period of increasing summer stratification of western Lake Superior water until fall overturn [late November]...probably because of the decreased circulation of deeper lake water from the northeast. During times of isothermal conditions without ice cover this circulation is more pronounced, and thus the peak amphibole concentrations occur in spring and late fall.

In a paper entitled "Semi-Quantitative Determination of Asbestiform Amphibole Mineral Concentrations In Western Lake Superior Water Samples" given at the Twenty-third Annual Conference on Applications of X-Ray Analysis held in Denver on 9 August 1974, Cook summarized the 1973 findings of the NWQL in the following manner:

> Maximum amphibole concentrations (up to 0.8 mg/l) occur in the late fall and spring [during the break-ups of the summer and winter thermoclines]. Minimum amphibole concentrations (0.04 mg/l) occur during the late summer and early fall when a thermocline [the relatively shallow summer thermocline that may lie within 100 feet of the surface and which retards deep vertical mixing] is present in Western Lake Superior. The average amphibole concentration measured was 0.19 milligrams per liter with 0.83 milligrams per liter total suspended solids.

These figures refer to tap water drawn at the NWQL, which receives water soon after it leaves the Lakewood detention basin. Sediment and cummingtonite-grunerite concentrations tend to experience a slight "distance decay" as water moves through the Duluth water distribution system. Concentrations of tailings in water from Duluth home taps roughly average 0.09 to 0.13 mg/l (my calculations based on Cook's 1973 data). However, as noted by Cook (July 1973, p. 1533):

> ...hydrant drainage or water line repair resulted in

tailings concentrations of 18 and 26 mg/l [in two home tap samples taken in 1973], roughly 200 times the usual home tap concentrations measured.

In addition to suspended sediment and cummingtonite-grunerite concentrations measurements, various persons have conducted asbestiform fiber counts[1] on Duluth municipal water samples. Electron microscope examination of Duluth water samples taken in the spring of 1973 showed the presence of fiber bundles, in addition to diatom fragments, organic detritus, and quartz particles (Cook, July 1973). Figures 2.11, 2.12, and 2.13 are illustrations of electron micrographs of asbestiform fibers found in taconite tailings (Figure 2.11) and in Duluth tap water (Figures 2.12 and 2.13).

In reference to the fiber concentrations in Duluth water in 1973 Cook, Glass, and Tucker (1974, p. 854) concluded:

> We estimate a range of (1 to 30) x 10^6 SAED-[selected-area electron diffraction] identified amphibole fibers per liter of water with a mass concentration of 1 to 30 μg/liter. The concentration of fibers in the drinking water varies with lake conditions and tends to decrease with the increasing residence time of the water in the distribution system. Occasional peak concentrations (up to 10^9 fibers per liter) can result from the resuspension of settled sediment in the water lines.

In a personal letter dated 14 August 1975, Glass stated that the 1973 average fiber count for Duluth municipal water, based on NWQL fiber counts and X-ray diffraction, was 90 million amphibole fibers/liter (positively identified). In addition, the

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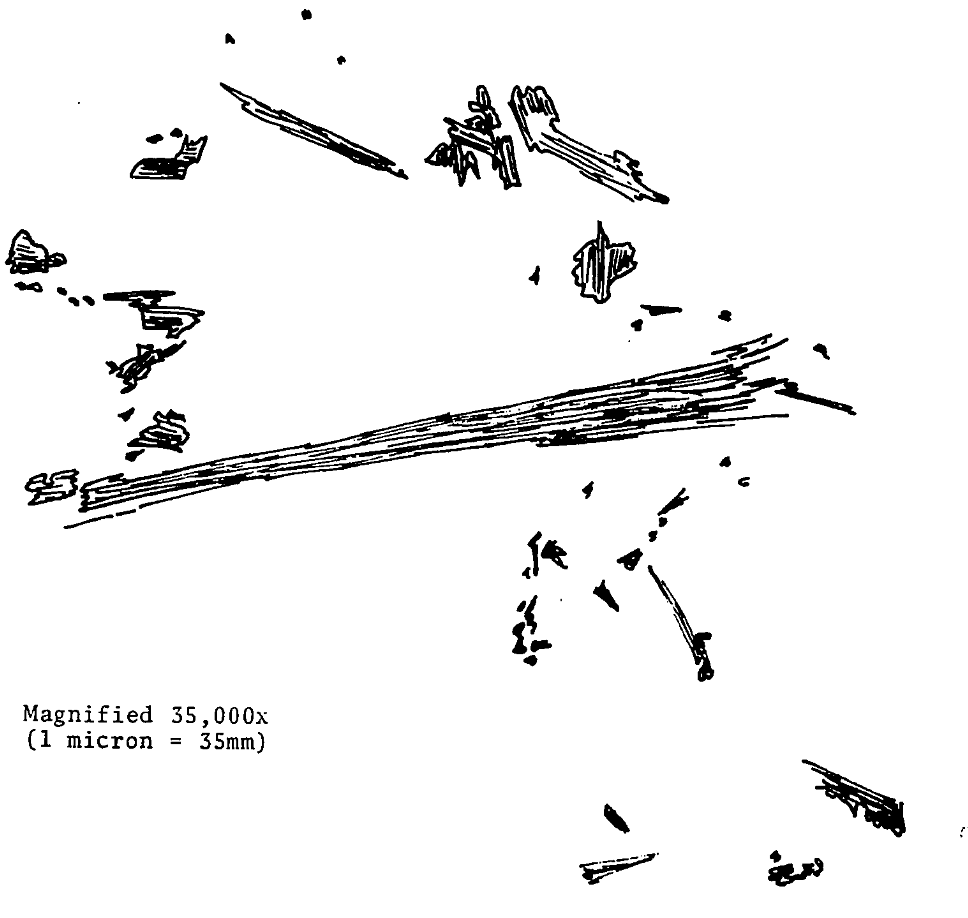
[1]Particulate matter is considered fibrous if it has at least a 3:1 aspect ratio (length-to-width ratio), appears rigid, and has relatively smooth and parallel sides (Fairless, 1973; Lemire, 1974).

Figure 2.11

FIBER BUNDLE IN TAILINGS OF LESS THAN TWO MICRONS



Magnified 35,000x
(1 micron = 35mm)

Source: drawing based on Cook, July, 1973, Figure 2.

Figure 2.12

ASBESTIFORM FIBER IN DULUTH TAP WATER

Magnified 25,000x
(1 micron = 25mm)

Source: drawing based on Cook, July, 1973, Figure 8.

Figure 2.13

FIBER BUNDLE IN DULUTH TAP WATER

Magnified 75,000x
(1 micron = 75mm)

Source: drawing based on Cook, July, 1973, Figure 12.

EPA NWQL found an average of 130 million ambiguous fibers/liter. These ambiguous fibers include amphibole fibers not positively identified.

Similar results were found by the Water Supply Research Laboratory, National Environmental Research Center, when it conducted its Duluth Asbestos Study in June and July of 1973. The Laboratory personnel, who drew water samples from various areas along the shore of western Lake Superior, found (p. 5):

> All of the waters drawn from Lake Superior have high optical fiber counts, even when only fibers of greater than 5 microns length are included in the count. At 1000x magnification the counts are about 10^7 f/l.

Although the majority of the foregoing materials were drawn from reports compiled by EPA personnel and others called as witnesses for the plaintiffs in U.S.A. v. Reserve Mining Company, the Defendant's Research and Development Division also reported high fiber counts in the Duluth municipal water supply, as well as in other area waters. The data in Table 2.2 are extracted from R.S. Lemire's 25 February 1974 report to Reserve Mining Company entitled "Optical Microscope Examination of Particulates of 3 to 1 Aspect Ratio or Greater in Waters of the Lake Superior Region." It is not surprising that, in every sample, the number of fibers in the < 5 microns size fraction is much greater than the number of larger fibers. Characteristically, the majority of cummingtonite-grunerite asbestiform fibers fall in the < 5 microns size range.

In its Supplemental Memorandum (1974, pp. 60-61) the

Table 2.2

OPTICAL COUNTS OF FIBER PARTICLES IN MUNICIPAL WATER SUPPLIES: SAMPLES FROM DULUTH, MINNESOTA

Sample Type*	Collection Date	Fibers number/l >5μ	Fibers number/l <5μ	Total Fibers (millions/l)
RI	8-02-73	30,500	1,577,600	1.9
RI	6-26-73	49,254	3,178,448	3.2
RI	8-06-73	113,570	3,747,952	3.9
RI	8-09-73	38,480	1,408,368	1.4
RI	8-08-73	57,720	2,129,227	2.7
RI	8-10-73	111,164	2,462,720	2.6
RI	8-13-73	123,991	2,462,720	2.6
RI	8-14-73	29,929	1,975,307	2.0
RI	8-15-73	17,102	590,027	0.7
RI	8-16-73	55,582	666,987	0.7
RI	8-17-73	64,133	2,565,333	2.6
RI	8-18-73	192,400	2,437,067	2.6
TI	8-18-73	106,888	3,078,400	3.2
TI	8-09-73	98,338	3,178,448	3.3
TI	8-13-73	119,715	3,232,320	3.3
TI	8-10-73	38,480	4,104,533	4.1
TI	8-14-73	42,756	2,308,800	2.4
TI	8-08-73	213,778	3,463,200	3.7
TI	8-15-73	72,684	1,282,667	1.4
TI	8-16-73	106,889	1,975,307	2.1
TI	8-19-73	141,093	3,437,547	3.6

(to be continued)

Table 2.2 (continued)

Sample Type*	Collection Date	Fibers number/1 >5μ	Fibers number/1 <5μ	Total Fibers (millions/1)
TW	8-02-73	129,000	2,565,000	2.7
TW	8-08-73	43,098	2,462,720	2.5
TW	8-09-73	123,991	1,828,952	2.0
TW	8-06-73	94,062	1,527,656	1.6
TW	8-10-73	42,756	2,360,107	2.4
TW	8-14-73	81,236	2,924,480	3.0
TW	8-17-73	47,031	769,000	0.8
TW	8-18-73	17,102	230,880	0.2
TW	8-16-73	102,613	846,560	0.9
TW	8-06-73	94,062	1,410,933	1.5

*RI = raw intake; TI = treated intake; TW = tap water

Source: extracted from Lemire, 1974, Table 2, p. 9.

District Court summarizes its findings in regard to the asbestiform fiber contamination of municipal water supplies by Reserve Mining Company's discharge:

> The Court finds, consistent with the Court's study of amphibole fiber concentrations in the water supplies of Beaver Bay, Two Harbors and Duluth, that on the 28th of August, 1973, in the samples analyzed by seven laboratories that the mean fiber concentrations[1] were: 12.5 million fibers per liter in the public water system at Duluth, 21.1 million fibers per liter in the water at Two Harbors, 63 million fibers per liter in the water at Beaver Bay, and 450,000 fibers per liter at Silver Bay. The Court further finds, consistent with Dr. Nicholson's analysis, that Superior, Wisconsin's drinking water has an amphibole fiber level of four million fibers per liter. These fiber counts are consistent with the plaintiff's view of the case that by a process of entrainment the density current from Reserve's discharge takes most of the solid material in the discharge to or near the bottom of the lake only to surface several miles downstream from the discharge. From there the effect of the discharge diminishes slightly as it moves down the shore to Duluth and Superior. [This explains the higher fiber counts at Two Harbors and Beaver Bay, both of which lie between Duluth and Silver Bay.] The other evidence in the case indicates that the time in which the samples were taken, late summer, is a time of the year when Reserve's discharge has its least effect on the water downstream from Silver Bay [indicating that winter, spring, and fall fiber counts would be much higher]. This is largely due to the summer thermocline which in combination with the heavy density current tends to keep more of the discharge on the bottom of the lake than in the other seasons when the lake is isothermal and there is no thermocline [spring and fall] or when the thermocline is located deeper in the water [during the winter] and actually retards the settling of the discharge on the bottom of the lake. In any

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[1]Mean fiber counts probably have more significance, since fiber-count methodology may vary from laboratory to laboratory. As the Court states (S.M., 1974, p. 59): "...one should be very cautious in accepting as definitive the results of any single investigator who is attempting to define through electron microscopy the levels of fibers in a given air or water sample."

> event, it can only be concluded that at all times Reserve adds millions of asbestos fibers to every quart of water drunk by every citizen of Duluth, Two Harbors, Beaver Bay, and Superior, Wisconsin at every time of year. These concentrations may exceed one hundred million fibers per liter at certain times of year, notably the spring and fall.

The District Court leaves little doubt that asbestiform fibers have been present in Duluth's municipal water supply for years. However, high concentrations of fibers probably do not pre-date the early 1960's, at which time Reserve Mining Company expanded its E.W. Davis Works and greatly increased its tailings discharge into Lake Superior (see APPENDIX C, which deals with Reserve's permits). None-the-less, the citizenry in the western Lake Superior area, and in the areas serviced by Duluth's food and beverage industries, have undergone years of exposure to a substance, asbestiform amphibole fibers, virtually identical to amosite asbestos, a known human carcinogen.

Summary

To briefly summarize the foregoing background materials, the asbestiform amphibole fibers originating in the petrologic system of the Eastern Mesabi Iron Range pass through Reserve's mining and processing system, the Lake Superior circulatory system, and the Duluth municipal water distribution system prior to (1) consumption by humans via the drinking of Lake Superior water or (2) use in Duluth food and beverage manufacturing.

At the interface between each set of interlocking systems involved in the pollution system there exists a channel of ignorance (see channels of ignorance numbers 1, 2, 3, 4, and 4a in Figure 1.2) which has permitted the passage of a potentially carcinogenic substance, asbestiform fibers, from one system to the next. It is when asbestiform fiber-contaminated water is allowed to enter the biological systems of human consumers that the potential health hazard truly has an impact. Because of the existence of channels of ignorance, asbestiform fibers from the Duluth municipal water system have not only reached the consumer via the drinking of such water, but via the consumption of contaminated foods and beverages manufactured in Duluth.

The next two chapters deal specifically with the human-consumption aspect of this research. The delivery of the pollutant to the consumer via the manufacturing and marketing/distribution system is the subject of Chapter III, while the adverse effects of asbestiform fibers on the biological system of the consumer is discussed in Chapter IV.

CHAPTER III

DELIVERING THE POLLUTANT TO THE CONSUMER: THE MANUFACTURING AND MARKETING/ DISTRIBUTION SYSTEMS

Introduction

It is commonly recognized that humans who consume industrially-polluted common property resources, such as air or water, may be exposed to potentially harmful contaminants. For example, the inhalation of coal dust-laden air or the drinking of water contaminated with chemical wastes may adversely affect the biological functioning of the consumer. These are the "obvious" health hazards, of which the consumers are often aware, associated with the development and utilization of natural resources. There exist, however, "hidden" hazards when polluted common property resources are used in the manufacturing of food, beverage, or drug products. In such cases potentially harmful contaminants reach the consumer via the marketing/distribution system. "Hidden" hazards exist since the consumer often is unaware that he is ingesting potentially harmful substances, a situation fostered by the presence of a channel of ignorance at the interface between the marketing/

distribution system and the biological system of the consumer.

It is at this point that the chaos between and among the interlocking elements and external influences of an overall industrial pollution system becomes critically evident. If it were not for the presence of channels of ignorance fostered by a lack of knowledge, evaluation, and/or communication, in some cases stemming from a conflict of goals, there would be no potential health hazards with which society must contend.

Using the Duluth Problem as the illustrative case, this chapter is devoted to an analysis of a pollution system's manufacturing and marketing/distribution subsystems which deliver the "hidden" pollutant to the consumer. Succeeding chapters deal with (1) the effects of industrial pollutants, notably asbestiform fibers, on the biological system of the consumer and (2) the ways in which the external influences constituting the environment within which a pollution system operates affect the functioning of the pollution system.

The Duluth Problem

The main purpose of this chapter is twofold: (1) to present the 1963 and 1973[1] production figures and market areas

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[1]These two years were chosen to provide some idea of the changes in the service areas and production during the period of Reserve's greatest discharge of taconite tailings into Lake Superior. 1973 was chosen in preference to later years since 1973 is the most recent year which pre-dates the Findings of Fact of the District Court (April, 1974). Because of these Findings and the water analyses conducted by the EPA NWQL, some firms have since installed filters capable of removing most of the asbestifibers from the water. In addition, the City of Duluth's filtration plant became operable in February of 1977.

for those food and beverage firms manufacturing products containing contaminated Duluth municipal water as an ingredient, and (2) to depict the estimated 1973 per capita exposure to asbestiform fibers resulting from the ingestion of food and beverage products manufactured using Duluth municipal water.

Following a discussion of Duluth food/beverage manufacturers in general, coordinated sets of tables and maps are employed to portray the production of goods, the location of market areas, and the degree of exposure of populations to asbestiform fibers attributable to each company. Then, composites of the individual tables and maps are used to show the estimated annual per capita exposures resulting from the ingestion of asbestiform fibers carried in the products of all eight Duluth food and beverage manufacturers. In this way it is possible to discern the geographic areas and populations exposed, via the marketing of foods and beverages, to the asbestiform fibers from Reserve Mining Company's Silver Bay operations.

The Duluth Food and Beverage Manufacturers

In 1973 there were 11 food and beverage manufacturers operating in Duluth and serving market areas extending beyond the city's corporate limits. Table 3.1 lists these companies, the types of products they manufactured, and their generalized areas of distribution.

In this study the selection of a sample was not necessary, since the entire population of food and beverage manufacturers serving areas larger than Duluth could be contacted. As Adler

Table 3.1

DULUTH FOOD/BEVERAGE MANUFACTURERS, 1973

Name of Firm	Types of Products	Market Area*
American Bakeries Co.	bakery products	2
Andresen-Ryan Coffee Co.	coffee	2
Neal Bort Co.	catering, school and industrial foods	2
Bridgeman Creameries	ice cream, cottage cheese, milk, fruit drinks	2
City Bottling Co.	soft drinks (Pepsi, Hires, Mountain Dew, Nesbitts)	2
Coca-Cola Bottling Midwest, Inc.	soft drinks (Coca-cola, Tab, Fresca, Bubble Up, Tom Moore flavors and mixes)	1 (1963) 2 (1973)
Elliott Packing Co.	beef, pork, portion control meats and poultry, ham, bacon, sausage, lard, vegetable shortening	2
Franklin Creamery, Inc.	dairy products, fruit drinks	2
Jeno's, Inc.	Wilderness dessert products, Jeno's snacks and convenience foods	3
Zinsmaster Baking Co.	bakery products	2
Zinsmaster Hol-Ry Co.	rye wafers	3

*Explanation of code: 1 = state (markets in Minnesota only)
2 = regional (more than one state)
3 = international

Data sources: Duluth: Profile of: Manufacturers, Wholesalers, compiled by the Duluth Area Chamber of Commerce, 1974; plus information personally gathered from the companies.

(1967, p. 92) contends: "If the universe consists of a few firms, the decision will usually be made to conduct a complete census." Figure 3.1 is a sample questionnaire of the type used during data gathering at each firm.

Although all 11 companies listed in Table 3.1 were contacted, one was omitted from this study because of its non-applicability to the research problem. Andresen-Ryan Coffee Company produces only one product, coffee, which does not contain water as an official ingredient, although water may be used during the processing of the product.

Dealing with an entire population is not without its problems, for as Adler (1967, p. 92) continues: "Especially in this case [complete census], but also in other circumstances, the problem of refusals to be interviewed arises. The smaller the universe the more serious it becomes and there is no clear-cut solution to it...." Of the 10 companies whose product lines are applicable to this research problem, one company refused any form of interview. The owner of City Bottling Company, Theodore Maki, refused personal interviews in July, August, and again in September of 1975. Furthermore, he failed to respond to two separate written questionnaires sent to him in October and November, 1975.

The refusal of firms to supply the necessary data was indeed a problem, especially in the cases of City Bottling Company and of the Neal Bort Company. Other than catering, the Neal Bort Company produces only frozen dinners sold by contract

Figure 3.1

SAMPLE QUESTIONNAIRE

1. Name of firm: ______________________________

2. Address of firm: ______________________________

3. Date firm began operations in Duluth: ______________

4. If firm has changed name or hands, give names and dates of establishment of firm's predecessors:

5. Are any of your firm's products manufactured using water as an ingredient? (If answer is no, omit remainder of questionnaire.)

6. What is your firm's source of water?

Water source	Inclusive dates during which firm used each type of water supply
City water	______________
Filtered city water	______________
Well water	______________
Other (specify)	______________

7. List all products manufactured by your firm using water as an ingredient:

(to be continued)

Figure 3.1 (continued)

8. What is the geographic distribution of each of the products listed in Question #7? Please include the following information for the year 1973 and the year 1963 (or the company's first year of operation, should the establishment of the firm post-date 1963):

   a. Product name

   b. Size of unit (ex.: 12 oz. can)

   c. Trace the movement of the product from the manufacturing plant to the final retail outlet and state the number of units shipped to each distribution point.

   This information may be supplied in the form of tables, flow diagrams, or any other form commonly used by your firm to record market areas and production figures.

to institutions, schools, and mining companies in northeastern Minnesota, northern Wisconsin, and the Upper Peninsula of Michigan. None of the firm's products are sold in retail outlets. The contract nature of the business makes production figures and exact market information confidential and therefore unavailable.

Because of the confidentiality of contract sales, it was necessary to limit this study primarily to those products sold on the retail market. Thus, with the exclusion of the Andresen-Ryan Coffee Company (non-applicability to the research problem), the City Bottling Company (refusal to be interviewed), and the Neal Bort Company (non-retail sales), this chapter focuses on the products of the remaining eight Duluth food and beverage manufacturers.

Five of the eight companies -- American Bakeries Company; Bridgeman Creameries, Division of Land O' Lakes Creameries, Inc.; Coca-Cola Bottling Midwest, Inc.; Elliott Packing Company; and Franklin Creamery, Inc. -- supplied complete production figures. Zinsmaster Baking Company supplied production figures for 1973, but its 1963 records were not available. The least detailed information was provided by the two international companies, Jeno's, Inc., and Zinsmaster Hol-Ry Company. Jeno's provided estimates of the firm's production; Zinsmaster Hol-Ry released sales figures, but not actual production figures. In the case of both these international companies, market area data is much more generalized than that obtained from the other six companies, which have smaller market areas and less complicated marketing systems.

The complexity of distribution systems often leads to a lack of knowledge on the part of the original manufacturer as to the complete distribution of its products. This was true especially in the case of the two international companies. The sale of goods through jobbers or under brand names of companies other than the original manufacturer may effectively camouflage the channels of distribution and the final destination of the product. Where possible, both 1963 and 1973 production figures and market areas are included in the following sections so that any major changes over this 10-year period can be discerned.

In estimating the exposure of populations to asbestiform fibers carried in Duluth-manufactured products, the production figures were converted to water-content figures based on the amount of water called for in the products' recipes. The decision to use the "recipe approach" in favor of water-content analyses of the final products stems from the fact that water can be lost during the processes of cooking, baking, and drying foods, although initial fiber content varies only slightly. Although a small number of fibers may become airborne during cooking processes, the loss is minimal in comparison with the amount of water that is vaporized.

Once water contents were determined for the products of each company, all figures were converted to liters to standardize measurements and facilitate comparisons. The water contents of the products sold in each market area were divided by the area's population and then multiplied by the average number of asbestiform fibers per liter found in Duluth municipal water in 1973. For Duluth municipal water the 1973 average fiber counts were as follows: 90 million asbestiform amphibole fibers per liter (positively identified); 130 million ambiguous fibers per liter (including amphibole fibers not positively identified); and an estimated 280 million total fibers per liter (Glass, personal letter dated 14 August 1975).[1]

For the purposes of this research, the average 1973 fiber count utilized to compute the per capita exposure figures was 90 million fibers per liter, which represents the number of positively-identified asbestiform amphibole fibers. Since actual fiber counts were not taken in 1963, the results discussed in the sections of this chapter dealing with estimated per capita exposures to asbestiform fibers are based on 1973 production and fiber statistics. Although the EPA NWQL gives a rough estimate of 50 to 200 million fibers per liter, excluding storm action, for 1963 (Glass, personal letter dated 22 January 1976), retrospective estimates of fiber content for 1963 have little scientific meaning because of the paucity of

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[1]Data are based on Environmental Protection Agency National Water Quality Laboratory, Duluth, fiber counts and X-ray diffraction procedures conducted in 1973.

precise measurements taken at that time.

In arriving at the exposure figures (estimated per capita ingestion of asbestiform fibers) for 1973, the total population residing in each market area was calculated. Since all of the products included in this study are total-population products -- that is, they are consumed by all age, race, sex, income, etc., subgroups -- the decision was made to utilize total population figures. Population figures for 1973 were based on (1) 1973 U.S. Census of Population estimates and (2) 1971 Canadian demographic statistics, adjusted according to rates of population growth or decline established between 1961 and 1971.

The Individual Manufacturers

American Bakeries Company is a privately-owned corporation which began operations in Duluth in 1921. The company bakes 22 main varieties of bread products sold under name brands such as Taystee, IGA, Red Owl, Super America, Shoppers City, Covered Wagon, and Oven Gold. With the exception of Bessemer, Michigan, and Grand Marais, International Falls, and Benidji, Minnesota, which are served via jobber routes, the company's market areas are served by American Bakeries routes tied directly or indirectly to either the Duluth or St. Paul plants (a certain amount of Duluth's production is shipped to St. Paul for distribution in southern Minnesota and west-central Wisconsin).

American Bakeries' 1963 and 1973 production figures by market area are given in Table 3.2. As can be seen on Table 3.2, by 1973 the Iron Range percentage had increased, the Wisconsin-Michigan share of the market remained unchanged, and the Duluth-Superior area lost part of its share of the market to the area served via the St. Paul plant. The data used to determine the 1973 exposure figures for the company's market areas are shown in Table 3.3. The market area numbers on the tables are keyed to those on Figure 3.2. Whenever possible, on this and future maps, the market areas are ranked from highest (number 1) to lowest amounts. Thus, the first market area number gives the area's rank in relation to the other areas served by the company, according to th[illegible] of total production sold in the area in 1973; th[illegible] number ranks the area according to per[illegible]r exposure, as estimated for 1973.

<u>Bridgeman Cr[illegible]d O' Lakes Creameries, Inc.</u>, began as [illegible]uluth prior to 1900. Bridgeman Creameries, as [illegible]ed in 1936 and subsequently purchased by Land O' Lakes Creameries, Inc., in 1952. The Duluth plant manufactures ice cream, milk, cottage cheese, and fruit drinks, but only the fruit drinks contain municipal water as an ingredient. The fruit drinks are mixed in the Duluth plant using a concentrate shipped in from Land O' Lakes. Bridgeman products are sold on the retail market in northern Minnesota and northern Wisconsin at Bridgeman-owned and franchised stores.

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Bridgeman Creameries, Division of Land O' Lakes Creameries, Inc., began as a small operation in Duluth prior to 1900. Bridgeman Creameries, as such, was founded in 1936 and subsequently purchased by Land O' Lakes Creameries, Inc., in 1952. The Duluth plant manufactures ice cream, milk, cottage cheese, and fruit drinks, but only the fruit drinks contain municipal water as an ingredient. The fruit drinks are mixed in the Duluth plant using a concentrate shipped in from Land O' Lakes. Bridgeman products are sold on the retail market in northern Minnesota and northern Wisconsin at Bridgeman-owned and franchised stores.

Table 3.2

AMERICAN BAKERIES COMPANY: BREAD SALES BY MARKET AREA, 1963 AND 1973

Total production, 1963: 9,400,000 lbs.

Market Area	Portion of Total Sales
Duluth-Superior area: area bounded by Silver Bay on the northeast; Carlton, Barnum, Mahtowa, Kettle River, and Moose Lake on the west and southwest; Sandstone, Willow River, Findlayson, and Dairyland Township and Solon Springs, Wisconsin, on the south; and Pike Lake on the north	69% (6,486,000 lbs.)
Iron Range area: area bounded by Bemidji on the west; Ely and Grand Marais on the east; International Falls on the north; and a line twenty miles south of Grand Rapids on the south	30% (2,820,000 lbs.)
Wisconsin-Michigan area: area including Bayfield, Washburn, Ashland, and Hurley, Wisconsin, and Bessemer, Ironwood, and Wakefield, Michigan	1% (94,000 lbs.)

Total production, 1973: 9,000,000 lbs.

Market Area (keyed to first number on Figure 3.2)	Portion of Total Sales
1. Iron Range area	45% (4,050,000 lbs.)
2. Duluth-Superior area	42% (3,780,000 lbs.)
3. Area served via St. Paul plant	12% (1,080,000 lbs.)
4. Wisconsin-Michigan area	1% (90,000 lbs.)

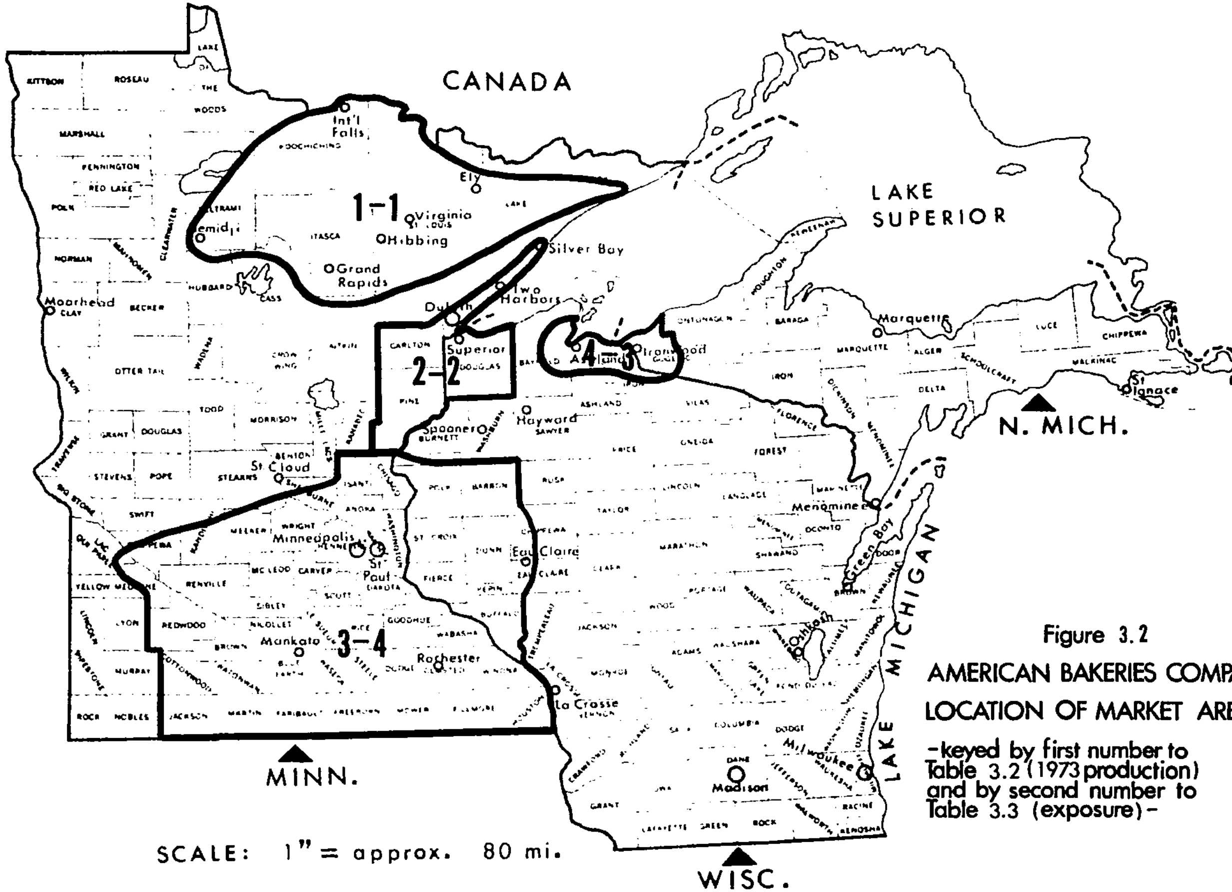

Figure 3.2
AMERICAN BAKERIES COMPANY:
LOCATION OF MARKET AREAS
-keyed by first number to Table 3.2 (1973 production) and by second number to Table 3.3 (exposure)-

Table 3.3

DATA USED TO DETERMINE THE 1973 EXPOSURE FIGURES (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREAS SERVED BY AMERICAN BAKERIES COMPANY

Product: bread

Estimated water content: .3557 lb. water/1 lb. bread

Market Area (keyed to second number on Fig. 3.2)	Total Amount of Water Consumed (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
1. Iron Range area	653,223.17	197,148	3.313	298.17
2. Duluth-Superior area	609,674.96	201,955	3.018	271.62
3. Wisconsin-Michigan area	14,516.08	28,603	.508	45.72
4. Area served via St. Paul plant	174,192.85	3,039,516	.057	5.13

Bridgeman's did not produce fruit drinks in 1963, but Table 3.4 gives the market areas and production figures for Bridgeman's fruit drinks sold in 1973. The exposure data for Bridgeman's market areas are presented in Table 3.5. Both tables are keyed to the market area locations shown on Figure 3.3.

Coca-Cola Bottling Midwest, Inc., is the only Duluth food-beverage manufacturer not privately owned or founded by Duluth families. The company, which began operations in 1925, manufactures Coke, Sprite, Tab, Fresca, Gatorade, and Tom Moore mixes. In addition, bulk shipments of Pre-Mix and syrup are sold to restaurants, and the company supplies area vending machines.

For total sales, Coca-Cola produced 305,500 standardized units of soft drinks in 1963 (one unit = 1 case = 24 8-ounce bottles = 192 ounces) and 1,243,630 units in 1973. This large increase was the result of the company's move into a new plant in 1970 and enlargements of Coca-Cola's marketing area in 1965, 1966, and again in the early 1970's. Home sales (retail) account for 67% of the company's sales, while cold bottle sales (restaurants and vending) account for the remaining 33%.

In 1963 Coca-Cola's market area was confined to the area within a 50-mile radius from Duluth, in Minnesota only. Thus, 100% of the company's sales in 1963 was quite localized. In 1965 the Superior-Douglas County, Wisconsin, area was added and in 1966 Grand Rapids-Itasca County, Minnesota, joined Coca-Cola's

Table 3.4

BRIDGEMAN CREAMERIES: FRUIT DRINK SALES BY MARKET AREA, 1973

Total production: 15,591.5 gallons, sold in half-gallon containers

Market Area (keyed to first number on Figure 3.3)		Portion of Total Sales
1. 20-mile radius of Duluth		68.55% (10,688.5 gal.)
subdivisions:	6 Duluth stores	45.79% (7,139 gal.)
	Superior, Wisconsin	9.46% (1,474.5 gal.)
	Proctor, Minnesota	7.16% (1,117 gal.)
	Cloquet, Minnesota	6.14% (958 gal.)
2. Bemidji-Western Iron Range area		21.85% (3,406.5 gal.)
subdivisions:	Virginia	6.18% (963 gal.)
	Hibbing	5.55% (865.5 gal.)
	Eveleth	5.43% (846 gal.)
	Grand Rapids	3.99% (622.5 gal.)
	Bemidji	0.70% (109.5 gal.)
3. International Falls, Minnesota		5.25% (818.5 gal.)
4. Ashland, Wisconsin		1.92% (300 gal.)
5. Ely, Minnesota		1.56% (243 gal.)
6. Floodwood, Minnesota		0.87% (135 gal.)

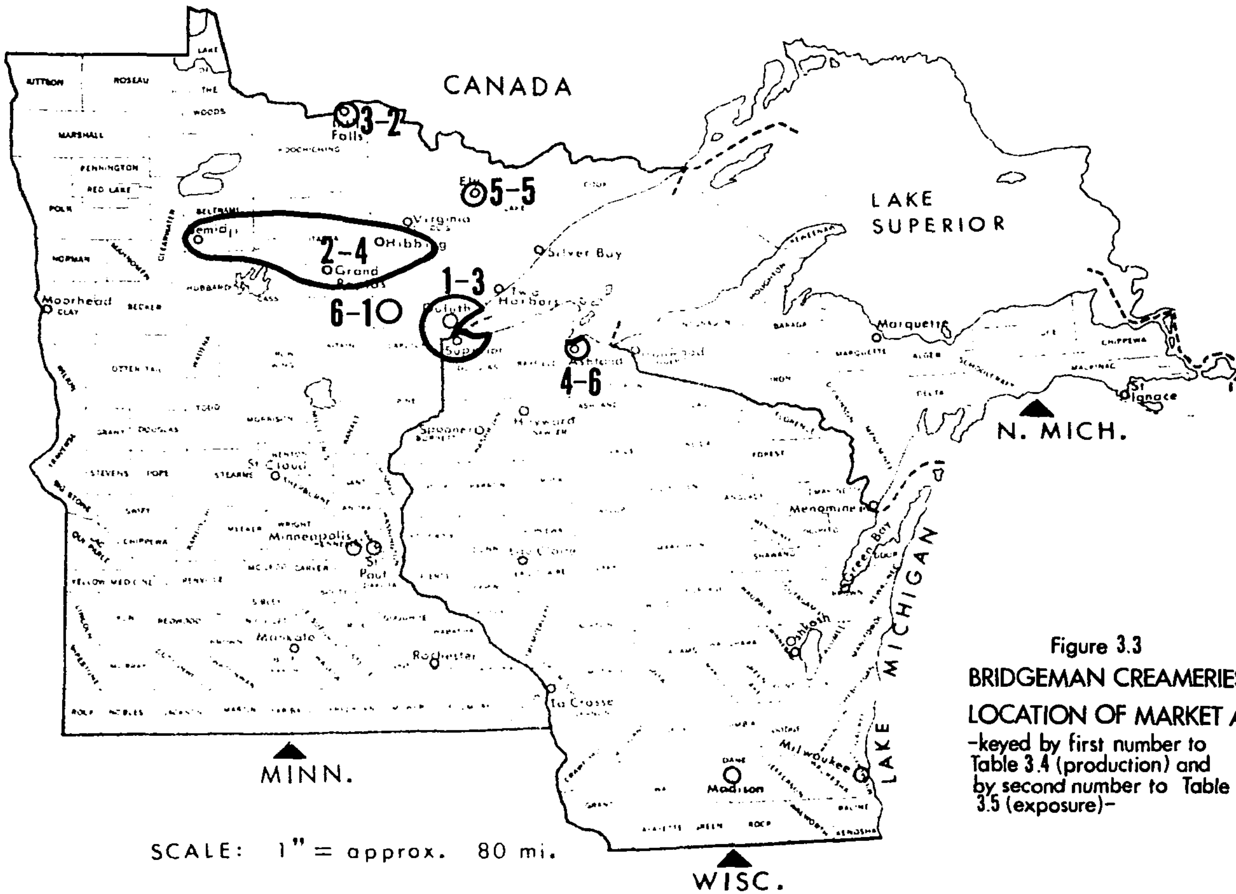

Figure 3.3
BRIDGEMAN CREAMERIES:
LOCATION OF MARKET AREAS
-keyed by first number to Table 3.4 (production) and by second number to Table 3.5 (exposure)-

Table 3.5

DATA USED TO DETERMINE THE 1973 EXPOSURE FIGURES (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREAS SERVED BY BRIDGEMAN CREAMERIES

Product: fruit drinks

Minimum water content: 90%

Market Area (keyed to second number on Fig. 3.3)	Total Amount of Water Consumed (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
1. Floodwood	459.882	650	0.7075	63.675
2. International Falls	2,788.218	6,337	0.439	39.51
3. Duluth-Superior	36,410.373	143,332	0.254	22.86
4. Bemidji-western Iron Range area	11,604.241	51,203	0.227	20.43
5. Ely	827.784	4,744	0.174	15.66
6. Ashland	1,021.95	9,460	0.108	9.72

market area. Between 1966 and 1973 five other cities and their immediate environs were added to the areas served by the company.

Coca-Cola Bottling Midwest's soft drink production figures by market area are given in Table 3.6, while the data used to determine the exposure figures for the company are contained in Table 3.7. For the sake of convenience, the unit figures used by the company have been converted to gallons in Table 3.6. Both tables are keyed to the market areas shown on Figure 3.4.

Elliott Packing Company was founded in Duluth in 1897 by Hiram R. Elliott. Following Elliott's death in 1938, his widow ran the company until 1952, at which time it was sold to C. Elmer Hammer, Dudley Smith, and Hiram Elliott (a nephew). After Mr. Hammer's death and Mr. Elliott's retirement, Dudley Smith became sole owner in 1969.

Elliott's began as a slaughter and packing house which grew to be the largest horse slaughter plant (for human consumption) in the world by the 1950's. The logging industry in Minnesota was switching from horses to motorized equipment, and there was a substantial market for horse meat in post-war Belgium.

In later years, Elliott's product line was expanded to include fresh beef, pork, mutton, and poultry; sausage; bacon; lard and shortening; smoked meats (mainly hams); and portion control meats (steaks). Water contents of these products vary

Table 3.6

COCA-COLA BOTTLING MIDWEST: SOFT DRINK SALES BY MARKET AREA, 1963 AND 1973

Total production, 1963: 458,250 gallons

Market Area	Portion of Total Sales
1. Area within 50-mile radius from Duluth, in Minnesota only	100% (458,250 gal.)

Total production, 1973: 1,865,445 gallons

Market Area (keyed to first number on Figure 3.4	Portion of Total Sales
1. Area within 50-mile radius from Duluth, in Minnesota only	44.43% (828,900 gal.)
2. Minneapolis-St. Paul	21.48% (400,711.5 gal.)
3. Superior-Douglas Co., Wisconsin	17.44% (325,350 gal.)
4. Grand Rapids-Itasca Co.	7.44% (138,750 gal.)
5. Bemidji	1.84% (34,346.7 gal.)
6. International Falls	1.84% (34,346.7 gal.)
7. Virginia	1.84% (34,346.7 gal.)
8. Mankato	1.84% (34,346.7 gal.)
9. Marquette, Michigan	1.84% (34,346.7 gal.)

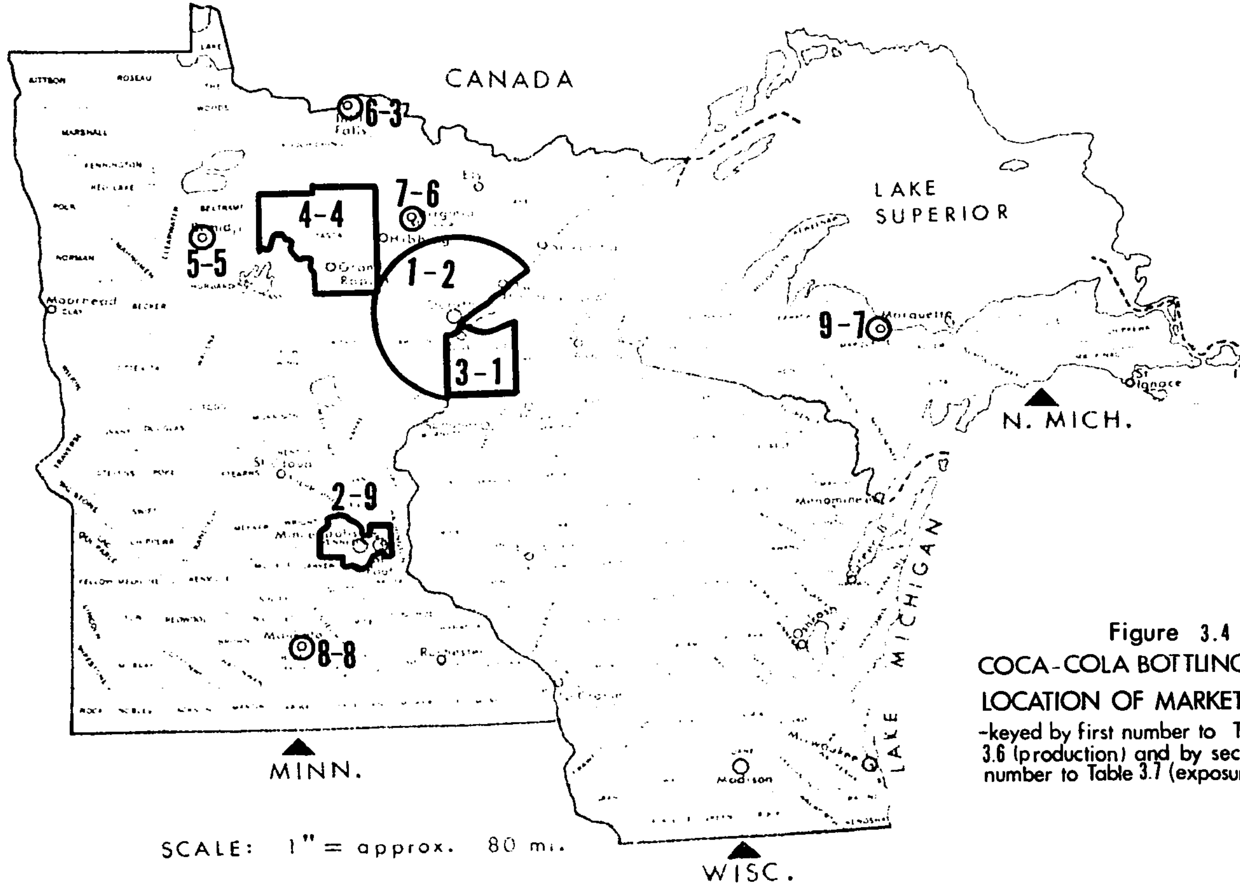

Figure 3.4
COCA-COLA BOTTLING MIDWEST:
LOCATION OF MARKET AREAS
-keyed by first number to Table 3.6 (production) and by second number to Table 3.7 (exposure) -

Table 3.7

DATA USED TO DETERMINE THE 1973 EXPOSURE FIGURES (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREAS SERVED BY COCA-COLA BOTTLING MIDWEST

Product: soft drinks

Average water content: 90%

Market Area (keyed to second number on Fig. 3.4)	Total Amount of Water Consumed* (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
1. Superior-Douglas Co., Wisconsin	739,239.28	45,800	16.141	1,452.69
2. Area within 50-mile radius from Duluth in Minn.	1,883,373.00	140,137	13.440	1,209.60
3. International Falls	78,040.352	6,337	12.315	1,108.35
4. Grand Rapids-Itasca Co.	315,258.79	37,200	8.475	762.75
5. Bemidji	78,040.352	11,950	6.531	587.79
6. Virginia	78,040.352	11,975	6.517	586.53
7. Marquette, Mich.	78,040.352	22,610	3.452	310.68
8. Mankato	78,040.352	33,024	2.363	212.67
9. Minneapolis-St. Paul	910,470.78	1,399,700	0.650	58.50

*Figures represent consumption from January-August 1973, after which time effective filtering devices were operable at the Coca-Cola plant.

considerably.[1] No water is added to lard, fresh pork, beef, or mutton with the exception of beef patties made with meat extenders. There is no Federal regulation limiting the amount of water that can be added to the patties, provided the product retains the characteristics of beef.

In regard to bacon and smoked meats, Federal regulations allow any amount of water to be added during the curing process so long as the net weight of the final product does not exceed that of the initial green (non-cured) meat. Consequently, although it is certain that water contaminated with asbestiform fibers has entered Elliott's meats during processing, there is no way to quantify this addition. The only meat product whose added water is quantifiable is the fresh pork sausage. Federal regulations allow added water to comprise 3% of the final net weight of the sausage.

Elliott's records are kept by their fiscal year, November to October. Since 1963 records were not available, the company supplied data for the fiscal year November 1963-October 1964 and for November 1973-October 1974. In the 1963 fiscal year the company produced 5,452,615 pounds of sausage; virtually all of this was sold in retail outlets. In 1970 Elliott's began restaurant, hospital, and institutional processing which, by 1973, accounted for 25% of the company's sales. Accordingly,

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[1]Information on the following Federal meat regulations was derived from a telephone interview with Mr. Marvin Siders, Meat Processing Program Supervisor, Oklahoma Department of Agriculture, on 11 December 1975.

of the 3,611,156 pounds of sausage produced during the 1973 fiscal year, 75% or 2,708,367 pounds reached the retail market.

Since Elliott's products are fairly evenly distributed throughout the company's market area by warehouse distributors and trucks out of the Duluth plant, the company was not able to supply a breakdown, by percentage, within its market area. The company's market area includes all of Minnesota and North Dakota, the northern half of Wisconsin, Northern Michigan, the extreme eastern counties of South Dakota, and the northern fringe of counties in Iowa (see Figure 3.5). The exposure data for Elliott's market area are given in Table 3.8

Franklin Creamery, Inc., Arrowhead Dairy Division, manufacturers of milk products and fruit drinks, was founded in Duluth circa 1925. In 1962 the company merged with three other Duluth creameries: Duluth Milk, Foremost Dairies, and the Arrowhead Co-op Milk Producers Association.

Franklin's fruit drinks are mixed at the Duluth plant using a concentrate (not manufactured in Duluth), sugar, and Duluth municipal water. The company sells its fruit drinks via home delivery, retail stores, and under private label for individuals and other companies.

Market areas and the portion of the total production sold in each remained essentially the same during the period 1963-1973, although total production dropped slightly during this period. Franklin's production figures and market area locations

Figure 3.5

ELLIOTT PACKING COMPANY: LOCATION OF MARKET AREA

-keyed by number to Table 3.8 (exposure)-

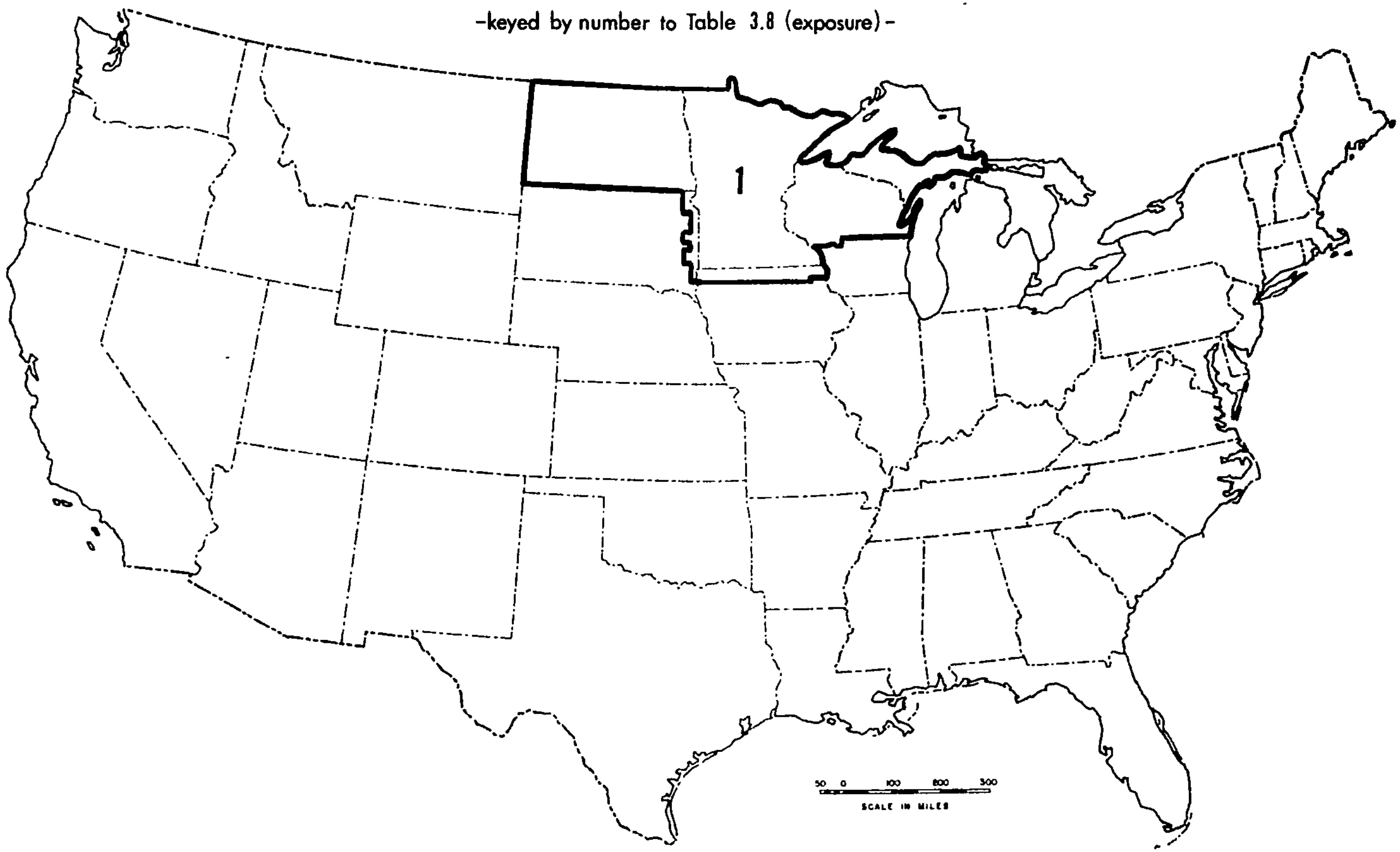

Table 3.8

DATA USED TO DETERMINE THE 1973* EXPOSURE FIGURE (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREA SERVED BY ELLIOTT PACKING COMPANY

Product: sausage

Water content: 3% of final net weight

Market Area (keyed to number on Figure 3.5)	Total Amount of Water Consumed (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
1. Minnesota, N.D., N. Wisconsin, N. Michigan, eastern S.D., N. Iowa	36,842.7	6,667,460	0.0055	0.495

*Fiscal 1973

are given in Table 3.9 and on Figure 3.6, respectively. Also keyed to Figure 3.6 are the exposure figures by market area shown in Table 3.10.

Jeno's, Inc., began operations in Duluth as Northland Foods, Inc., on 1 May 1950. The name of this privately-owned corporation was changed to Jeno's, Inc., in November of 1967 after its owner and Chairman of the Board, Jeno F. Paulucci, sold the Chun King branch of his business to the R.J. Reynolds Company. Reynolds closed the Duluth Chun King operations but the facilities were repurchased for use by Jeno's, Inc., which now has three plants operating in Duluth.

In 1963 the company's primary products were Jeno's pizza mix and canned fruit fillings sold under the Wilderness label. By 1973 new products included frozen pizzas, snack foods, and frozen and canned food service products (desserts, pizzas, pizza rolls, egg rolls, microwave products, pizza sauce, and Wilderness fruit fillings), including those for school lunch programs. The food service products are sold on a private contract basis, often under other brand names, and therefore these figures are considered confidential and were not released by the company.

Jeno's serves an international market comprised of the 50 United States and all U.S. military bases worldwide. The company distributes its products throughout the central U.S. via trucks out of Duluth; the remainder of the market area is serviced through 87 food brokers nationwide. An esti-

Table 3.9

FRANKLIN CREAMERY: FRUIT DRINK SALES BY MARKET AREA, 1963 AND 1973

Total production: 52,000 gallons in 1963; 42,000 gallons in 1973

Market Area (keyed to first number on Figure 3.6)	1963	Portion of Total Sales	1973
1. Area within 50-mile radius of Duluth in Minn. and Wisc.	(40,560 gal.)	78%	(32,760 gal.)
2. Tower-Ely, Minn.	(3,640 gal.)	7%	(2,940 gal.)
3. Virginia-Hoyt Lakes, Minn.	(3,640 gal.)	7%	(2,940 gal.)
4. International Falls, Minn.	(2,080 gal.)	4%	(1,680 gal.)
5. Ashland, Wisc.	(2,080 gal.)	4%	(1,680 gal.)

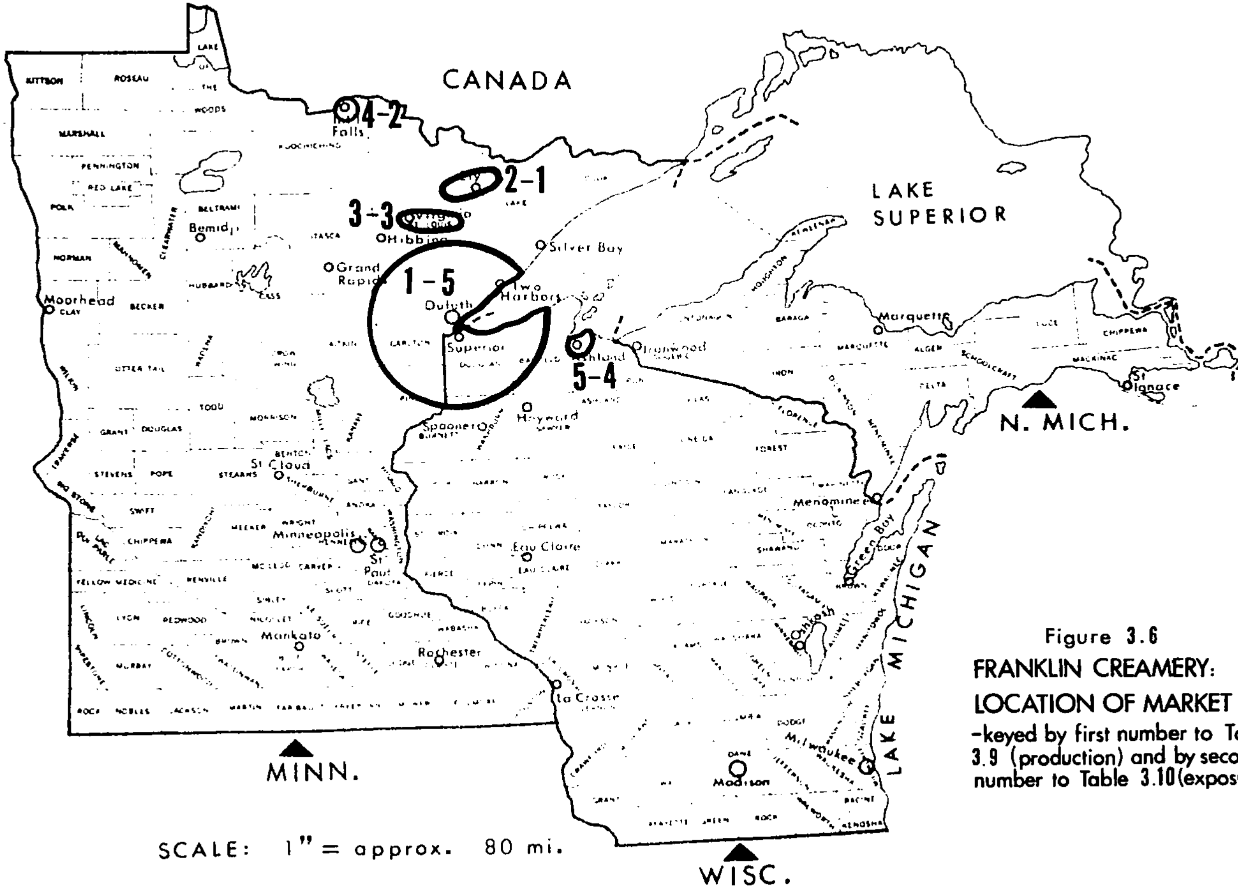

Figure 3.6
FRANKLIN CREAMERY:
LOCATION OF MARKET AREAS
-keyed by first number to Table 3.9 (production) and by second number to Table 3.10 (exposure)-

Market Area (keyed to first number on Figure 3.6)	Portion of Total Sales 1963		1973
1. Area within 50-mile radius of Duluth in Minn. and Wisc.	(40,560 gal.)	78%	(32,760 gal.)
2. Tower-Ely, Minn.	(3,640 gal.)	7%	(2,940 gal.)
3. Virginia-Hoyt Lakes, Minn.	(3,640 gal.)	7%	(2,940 gal.)
4. International Falls, Minn.	(2,080 gal.)	4%	(1,680 gal.)
5. Ashland, Wisc.	(2,080 gal.)	4%	(1,680 gal.)

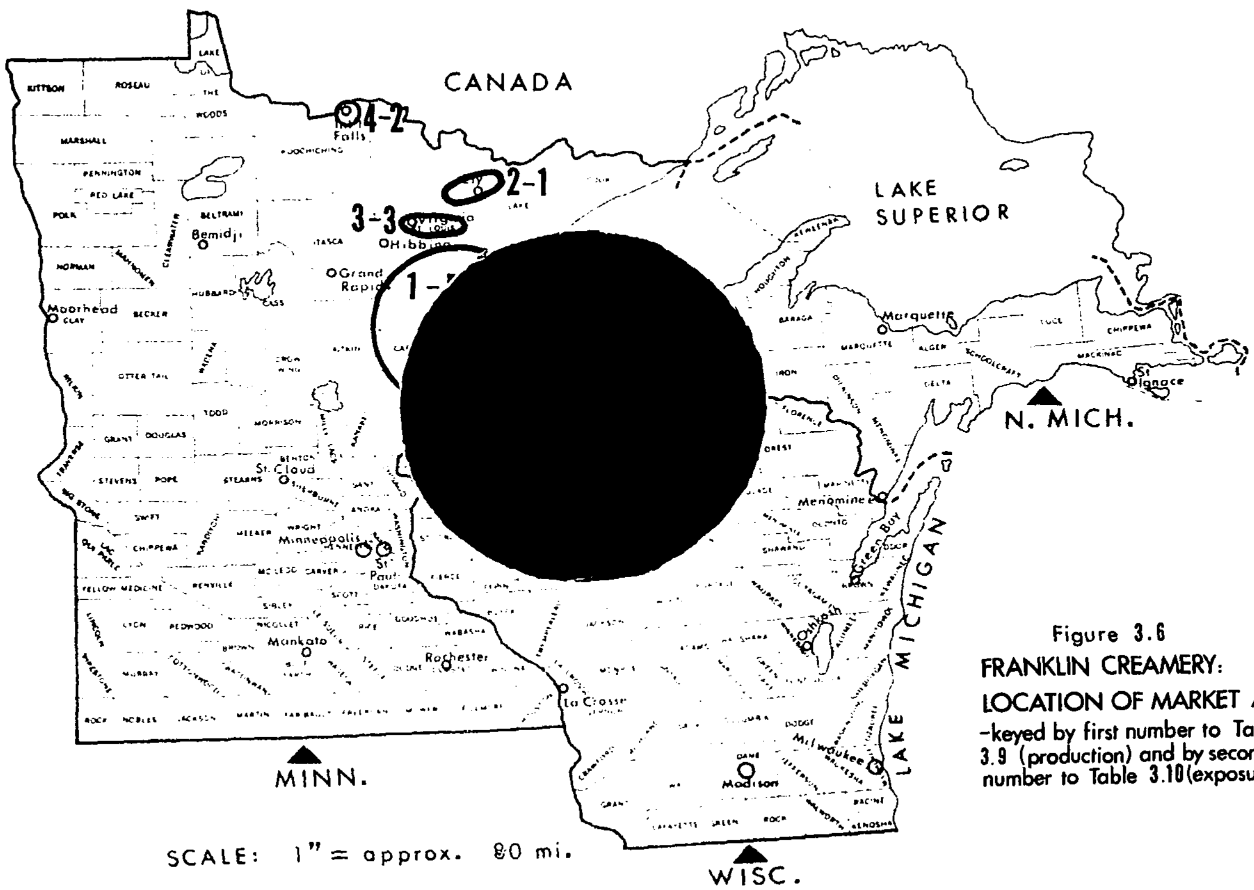

Figure 3.6
FRANKLIN CREAMERY:
LOCATION OF MARKET AREAS
-keyed by first number to Table 3.9 (production) and by second number to Table 3.10 (exposure)-

Table 3.10

DATA USED TO DETERMINE THE 1973 EXPOSURE FIGURES (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREAS SERVED BY FRANKLIN CREAMERY

Product: fruit drinks

Minimum water content: 90%

Market Area (keyed to second number on Fig. 3.6)	Total Amount of Water Consumed (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
1. Tower-Ely	10,015.11	5,443	1.84	165.60
2. International Falls	5,722.92	6,337	0.903	81.27
3. Virginia-Hoyt Lakes	10,015.11	15,743	0.636	57.24
4. Ashland	5,722.92	9,460	0.605	54.45
5. Area within 50-mile radius of Duluth in Minn. and Wisc.	111,596.94	187,322	0.591	53.64

mated 80% of Jeno's products is sold through retail outlets; the remaining 20% is fairly evenly divided between Food Service and military sales.

Other than stating that the Wilderness fruit fillings sell somewhat better west of the longitude of the western Great Lakes (due to strong competition along the East Coast) and that the metropolitan areas of Minneapolis-St. Paul and Detroit account for about 6% of retail sales each, the company was unable to further divide its sales among its remaining market areas. Consequently, it has been necessary to assume an even distribution of 88% of Jeno's retail sales throughout the bulk of the U.S.

The total production of Jeno's products for 1963 and 1973 is shown in Table 3.11, while Jeno's estimated retail sales of these products by market area are presented in Table 3.12. It must be kept in mind that the distributions shown in Table 3.12 are highly generalized. This problem again arises in the discussion of Duluth's other international company, Zinsmaster Hol-Ry. Table 3.13 contains the exposure figures for Jeno's market areas; both Table 3.12 and Table 3.13 are keyed to Figure 3.7.

Zinsmaster Baking Company is a private, family-owned corporation that was founded in Duluth in 1913. Zinsmaster produces 27 varieties of bread (under such labels as Master, Oven Glow, St. Johns, Roman Meal, State Fair and Woolworth), as well as six varieties of donuts.

Table 3.11

JENO'S, INC.: TOTAL PRODUCTION[1] 1963 AND 1973

Product	Production 1963	Production 1973
Wilderness canned fruit filling	3 million cases (12 #2 cans/case; ave. net wt. = 21 oz./can or 252 oz./case)	same as 1963
Jeno's frozen pizzas	0	6 million[2] cases (12 boxes/case; ave. net wt. = 19 oz./box or 228 oz./case; packaged as single, twin pack and milti-pack pizzas)
Jeno's snack foods (pizza snacks, pizza rolls, egg rolls)	0	3 million cases (12 boxes/case; ave. net wt. = 6.5 oz./box or 78 oz./case)

[1] only for those Jeno's products which contain Duluth municipal water as an ingredient

[2] conservative estimate

Table 3.12

JENO'S, INC.: ESTIMATED RETAIL SALES OF PRODUCTS CONTAINING WATER, BY MARKET AREA, 1963 AND 1973

Market Area (keyed to Figure 3.7)	Portion of Total Retail Sales, 1963 and 1973	
1. Minneapolis-St. Paul	6%	Number of Cases of Fruit Filling 1963: 144,000; 1973: 144,000 Number of Cases of Frozen Pizza 1963: 0 1973: 288,000 Number of Cases of Snack Foods 1963: 0 1973: 144,000
2. Detroit	6%	Number of Cases of Fruit Filling, Frozen Pizza, and Snack Foods: same as Minneapolis-St. Paul for both 1963 and 1973
3. Remainder of U.S.	88%	Number of Cases of Fruit Filling 1963: 2,112,000; 1973: 2,112,000 Number of Cases of Frozen Pizza 1963: 0; 1973: 4,224,000 Number of Cases of Snack Foods 1963: 0; 1973: 2,112,000

Table 3.13

DATA USED TO DETERMINE THE 1973 EXPOSURE FIGURES (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREAS SERVED BY JENO'S, INC.

Product	Estimated Water Content
Wilderness fruit filling	4 fl. oz./21 oz. net wt.
frozen pizza	4 fl. oz./16 oz. net wt.
snack foods	4 fl. oz./16 oz. net wt.

Market Area (keyed to Figure 3.7)	Total Amount of Water Consumed* (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
1. Minneapolis-St. Paul	515,517.98	1,399,700	0.3683	33.147
2. Detroit	515,517.98	4,100,211	0.1257	11.313
3. Remainder of U.S.	7,560,530.30	204,351,089	0.0369	3.321

*Figures represent consumption from January-August 1973, after which time effective filtering devices were operable at Jeno's Duluth plants.

Although 1963 production figures were not available, the company provided the following figures for 1973: donuts: 1,780,000 units (1 unit = 1 box = ave. net wt. of 1 lb.) or 1,780,000 pounds; bread: 6,645,000 pounds (1,223,000 pounds of dark bread and 5,422,000 pounds of white bread). Approximately 85% of the company's 1973 production (1,513,000 pounds of donuts; 5,648,250 pounds of bread) was sold through retail outlets, 12% went to institutions and restaurants, and the remaining 3% was sold to the government. Zinsmaster products are delivered to retail outlets by company representatives, as well as by private jobbers.

The distribution of Zinsmaster's retail products is detailed in Table 3.14 and the company's market areas are mapped on Figure 3.8. Table 3.15, also keyed to Figure 3.8, gives the exposure data for Zinsmaster Baking Company's market areas.

<u>Zinsmaster Hol-Ry Company</u>, manufacturers of only one product, rye wafers, was founded in Duluth in 1929. Although a separate corporation, it is owned by the same family that founded the Zinsmaster Baking Company.

The estimated 1973 production of Zinsmaster's rye wafers is 1,639,344 seven-ounce packages. Based on the company's statement that production increased 20% from 1963 to 1973, the 1963 production is estimated at 1,366,120 seven-ounce packages.[1]

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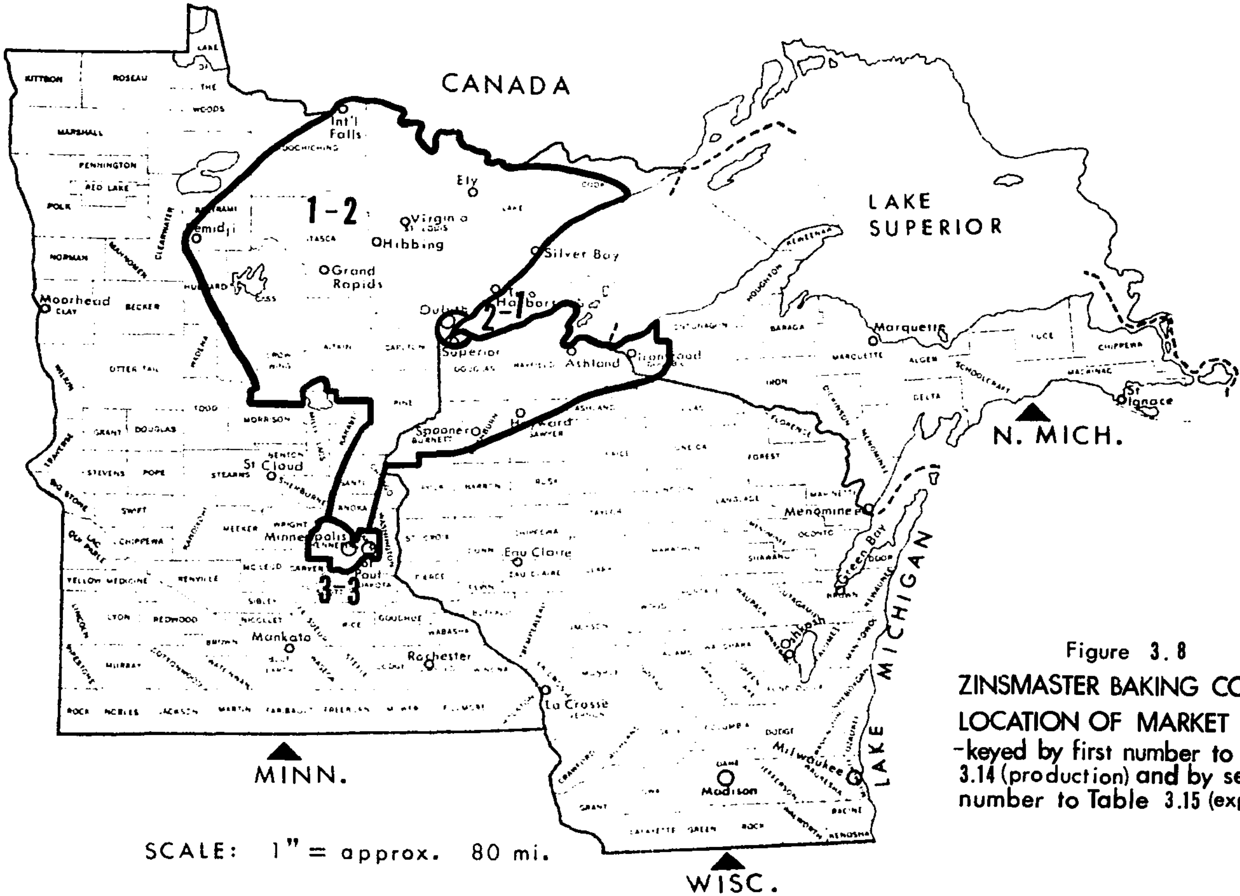
[1]Both the 1963 and the 1973 production figures are my personal estimates based on company sales figures for 1973 and the growth rate between 1963 and 1973.

Table 3.14

ZINSMASTER BAKING COMPANY: RETAIL SALES OF BREAD AND DONUTS BY MARKET AREA, 1973

Total production for retail sales: 5,648,250 lbs. bread; 1,513,000 lbs. donuts

Market Area (keyed to first number on Figure 3.8)	Portion of Total Retail Sales
1. N.E. Minnesota: area bounded on the south by the Minneapolis-St. Paul metropolitan area, on the west by Bemidji and Brainerd, on the north by International Falls, and on the N.E. by Grand Marais; plus N.W. Wisconsin and the Ironwood-Bessemer-Wakefield area of N. Michigan	40% (2,259,300 lbs. bread; 605,200 lbs. donuts)
2. Duluth-Superior	30% (1,694,475 lbs. bread; 453,00 lbs. donuts)
3. Minneapolis-St. Paul	30% (1,694,475 lbs. bread; 453,900 lbs. donuts)



SCALE: 1" = approx. 80 mi.

Figure 3.8

ZINSMASTER BAKING COMPANY: LOCATION OF MARKET AREAS
-keyed by first number to Table 3.14 (production) and by second number to Table 3.15 (exposure)-

Table 3.15

DATA USED TO DETERMINE THE 1973 EXPOSURE FIGURES (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREAS SERVED BY ZINSMASTER BAKING COMPANY

Product	Estimated water content
bread	.3557 lb. water/1 lb. bread
donuts	.22 lb. water/1 lb. donuts

Market Area (keyed to second number on Fig. 3.8)	Total Amount of Water Consumed (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
1. Duluth-Superior	318,581.21	136,429	2.335	210.15
2. N.E. Minnesota	424,774.97	581,193	0.731	65.79
3. Minneapolis-St. Paul	318,581.21	1,399,700	0.2276	20.484

Retail sales, which comprised 70% (956,284 seven-ounce packages) of the company's total production in 1963, accounted for only 54% of sales (885,246 packages) in 1973. The remainder was sold to private institutions on a contract basis.

With an international distribution system covering the contiguous United States plus the Canadian provinces of Manitoba and Ontario, only about 10% of the company's retail products remain in the Duluth-Superior metropolitan area. Thus, retail sales in Duluth-Superior were approximately 95,628 seven-ounce packages in 1963 and 88,525 packages in 1973. The remaining 90% of retail sales (860,656 packages in 1963; 796,721 packages in 1973), sold only in selected areas, was fairly evenly distributed, on a per capita basis, among the metropolitan areas listed in Table 3.16. These areas are keyed, by number, to the locations mapped on Figure 3.9. The exposure figures associated with Zinsmaster Hol-Ry's product sales on the retail market are given in Table 3.17. As in the case of Jeno's, Inc., the distribution for Hol-Ry wafers is highly generalized due to the sheer size and complexity of the company's operations.

General Comments on the Preceding Tables and Maps

In reference to the foregoing tables of exposure figures associated with the ingestion of asbestiform fibers (Tables 3.3, 3.5, 3.7, 3.8, 3.10, 3.13, 3.15, and 3.17) and market-area maps (Figures 3.2 - 3.9), the estimated fibers/capita in each market area vary directly with the sales volume and water content of

Table 3.16

ZINSMASTER HOL-RY COMPANY: MARKET AREAS (OUTSIDE THE DULUTH-SUPERIOR METROPOLITAN AREA), 1963 AND 1973

State or Region	Metropolitan Area (keyed by number to locations on Figure 3.9)
Arizona	1. Phoenix
California	2. Los Angeles
	3. Oakland-San Francisco
Colorado	4. Denver
Connecticut	5. Waterbury south to Stratford-Bridgeport
Florida	6. Miami
	7. Tampa-St. Petersburg
Illinois	8. Chicago-Elgin-Rockford
Indiana	9. Hammond-Gary
	10. Indianapolis
	11. Fort Wayne-New Haven
Iowa	12. Des Moines
	13. Davenport
Kentucky	14. Lexington
Kansas-Missouri	15. Kansas City-Kansas City-Independence
Massachusetts	16. Boston (via Beatrice Foods in Woburn
Minnesota-Wisconsin-Michigan	17. Area bounded by Minneapolis-St. Paul on the south (in Minn.); Bemidji on the west; International Falls (including Ft. Francis, Ont.) on the north; Ely on the N.E.; Eau Claire and Wausau on the south (in Wisconsin); and Ironwood-Bessemer-Wakefield south to Menominee, Mich., and Marinette, Wisc., on the east

(to be continued)

Table 3.16 (continued)

State or Region	Metropolitan Area (keyed by number to locations on Figure 3.9)
Michigan	18. Grand Rapids
	19. Kalamazoo
	20. Dearborn-Detroit
Wisconsin	21. Milwaukee
	22. Sheboygan
Nebraska	23. Omaha
New York-New Jersey	24. New York City metropolitan area
	25. Albany-Schenectady
	26. Buffalo
	27. Jamestown
Ohio	28. Euclid-Cleveland
	29. Akron
	30. Westerville-Columbus
	31. Cincinnati (Keebler label, 1973 only)
Oklahoma	32. Tulsa
Oregon	33. Portland
Pennsylvania	34. Sharon
	35. Pittsburgh
	36. Philadelphia (Keebler label, 1973 only)
Texas	37. El Paso
Utah	38. Salt Lake City
Washington	39. Seattle
Canada: Manitoba	40. Winnipeg
Ontario	41. Thunder Bay

Figure 3.9

ZINSMASTER HOL-RY COMPANY : LOCATION OF MARKET AREAS

-keyed by number to Table 3.16-

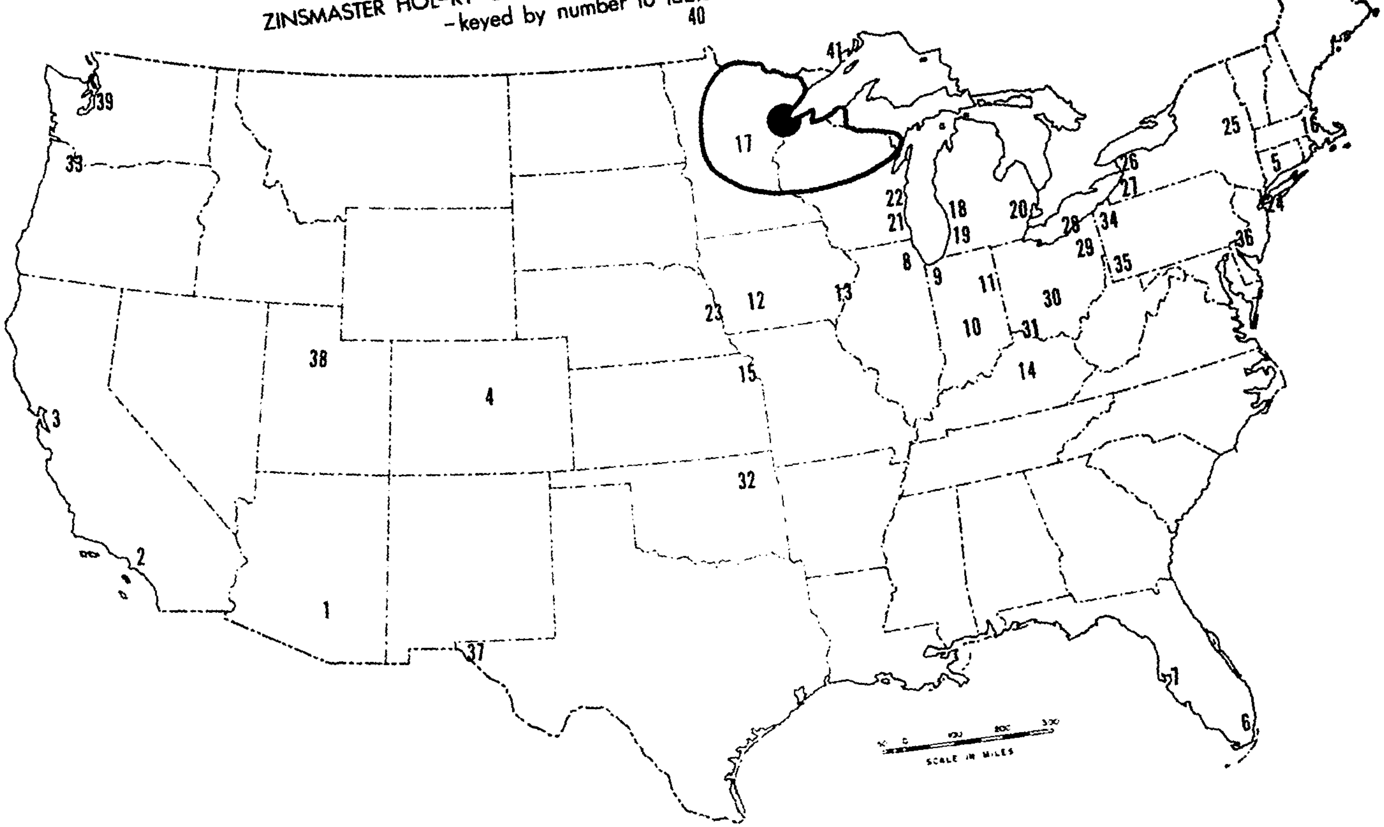


Table 3.17

DATA USED TO DETERMINE THE 1973 EXPOSURE FIGURES (ESTIMATED PER CAPITA ASBESTIFORM FIBER INGESTION) FOR THE MARKET AREAS SERVED BY ZINSMASTER HOL-RY COMPANY

Product: rye wafers

Estimated water content: 4% of final net wt.

Market Area*	Total Amount of Water Consumed (in liters)	Estimated 1973 Population	Liters/ Capita	Millions of Fibers Per Capita
● (Duluth-Superior)	702.4682	136,429	0.00514	0.4626
○ (all other areas)	6,322.1820	99,442,899	0.00006	0.0054

*Market area symbols correspond to those on Figure 3.9. The solid symbol denotes the Duluth-Superior area; the open symbol denotes all other market areas shown on the map.

each product, but vary inversely with the population of the market area.

Only three maps (Figure 3.4: Coca-Cola; Figure 3.8: Zinsmaster Baking Company; and Figure 3.9: Zinsmaster Hol-Ry Company) show a recognizable "distance decay" pattern outward from the Duluth-Superior metropolitan area. The variations found on the other five maps result from a number of factors, notably (1) variations in sales volumes; (2) population differences; and (3) competition from rival companies. As would have been expected, the companies contributing most to the estimated number of fibers per capita are those companies whose market areas are most localized and/or whose products have high water contents (American Bakeries, Bridgeman Creameries, Coca-Cola, Franklin Creamery, and Zinsmaster Baking Company).

The Composite Picture

For the purpose of gaining insight into the entire extent of the geographic area and populations exposed to a particular pollutant carried in food/beverage products, it is necessary to combine the statistics and market areas of the relevant food and beverage manufacturers. Such a composite picture for the asbestiform fibers carried in Duluth-manufactured foods and beverages is illustrated in Table 3.18 and on Figure 3.10. To facilitate interpretation, the 34 areas given in Table 3.18 and mapped on Figure 3.10 were grouped into seven categories based on natural breaks in the data; these seven classes are represented on Figure 3.11. The data were grouped

Table 3.18

ESTIMATED PER CAPITA INGESTION OF ASBESTIFORM FIBERS CARRIED IN FOOD AND BEVERAGE PRODUCTS MANUFACTURED USING DULUTH MUNICIPAL WATER, BY AREA, 1973

Area (as numbered on Figure 3.10)	Estimated Total Fibers/Capita (fiber figures are in millions)
1	2015.2386
2	1870.4214
3	1847.5614
4	1772.1486
5	1631.0214
6 (two sections)	1627.3314
7 (two sections)	1604.4714
8	1596.9114
9	1396.5264
10	1355.7114
11	1332.8514
12	1150.9614
13 (two sections)	1130.5314
14	1011.5514
15	976.0014
16	549.0414
17	533.3814
18	425.0214
19	367.7814
20	341.2314

(to be continued)

Table 3.18 (continued)

Area (as numbered on Figure 3.10)	Estimated Total Fibers/Capita (fiber figures are in millions)
21	314.4960
22	221.6160
23	179.5014
24 (two sections)	123.2514
25	117.7614
26	115.3314
27	74.7414
28 (six sections)	69.6114
29	11.3184
30 (Detroit metropolitan area--not shown on map)	8.9514
31	8.9460
32 (two sections)	3.8214
33 (four sections; westernmost section includes W. Minn. [shown on map] and all of N.D., the easternmost counties of S.D., and the northern one-fifth of Iowa [not shown on map])	3.8160
34 (remainder of U.S.)	3.3264 - 3.2210

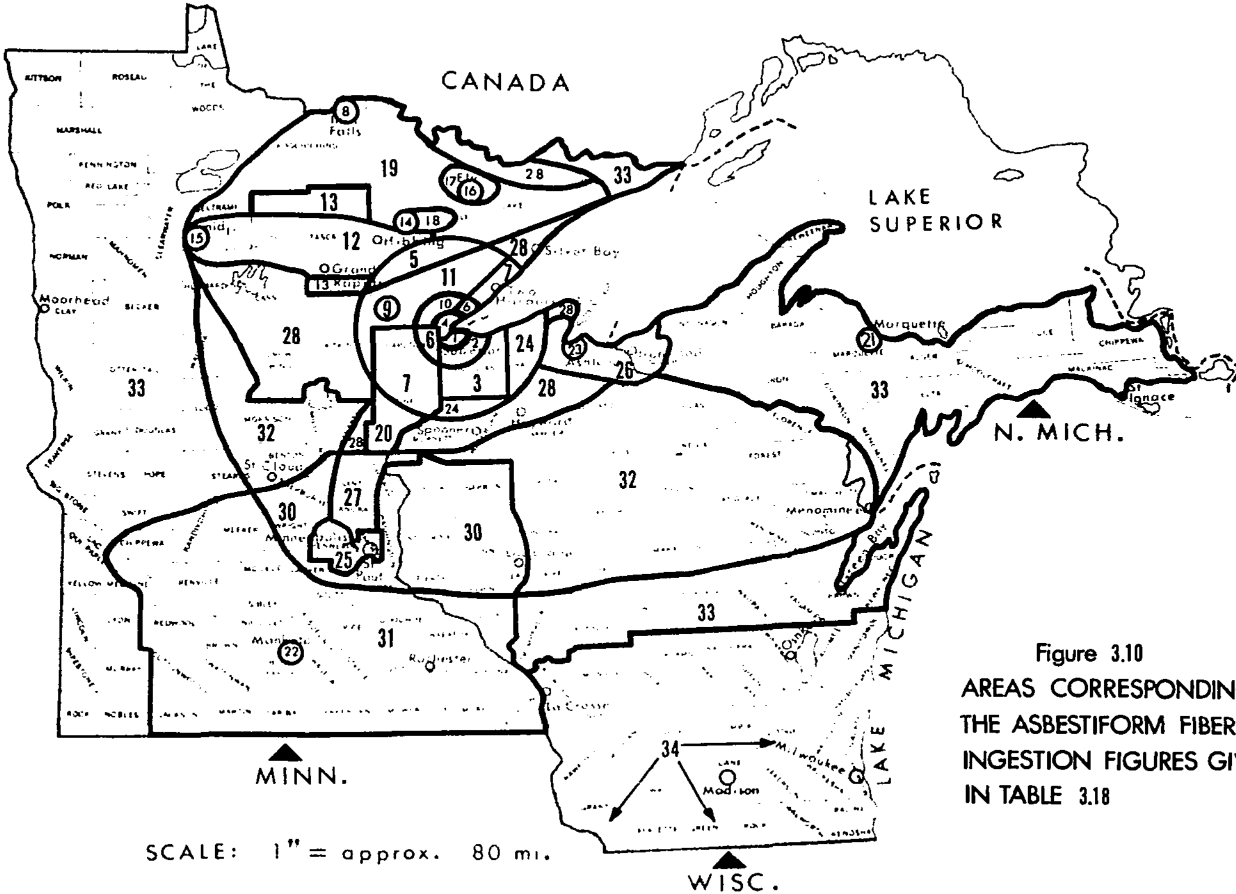
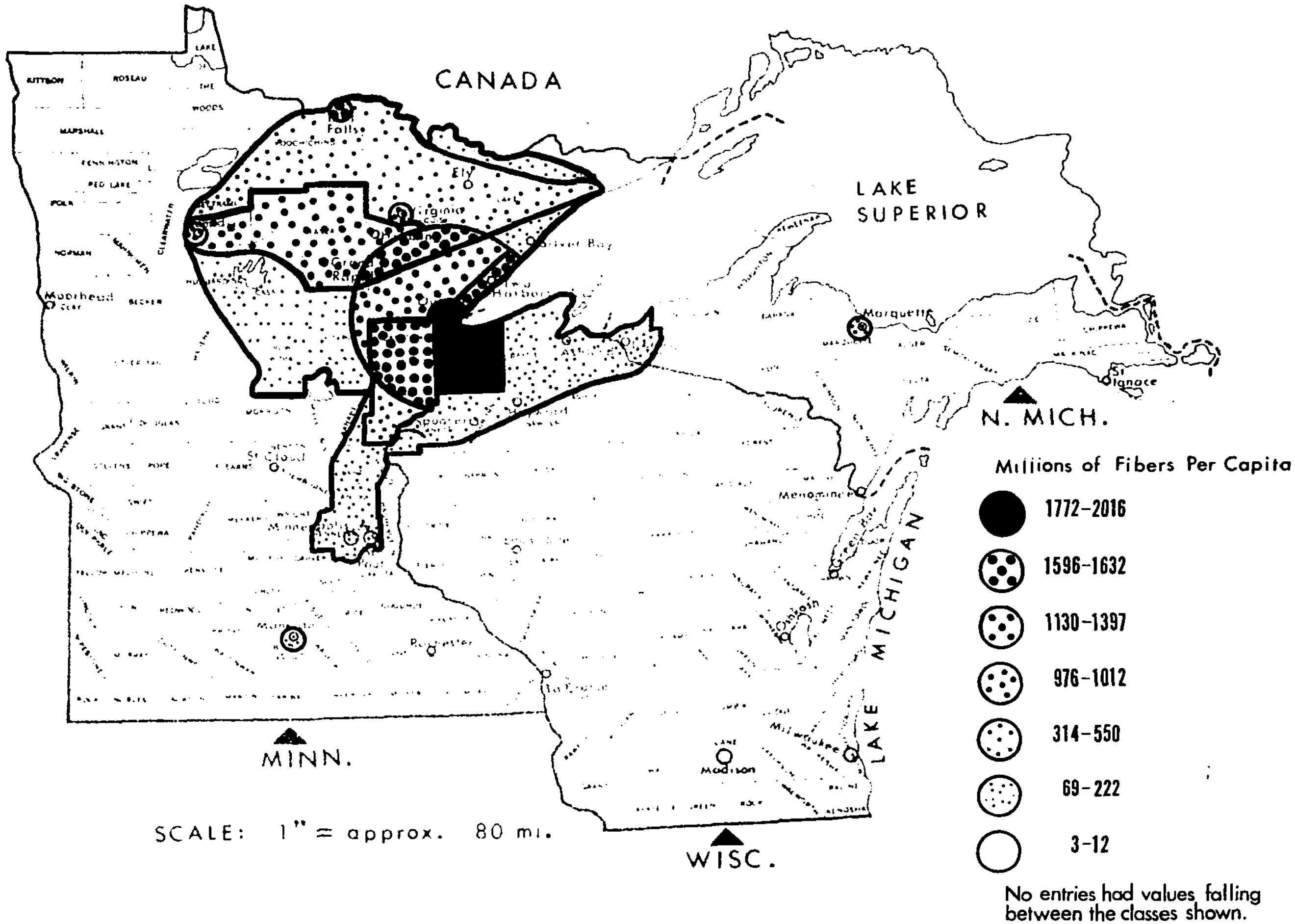


Figure 3.10
AREAS CORRESPONDING TO THE ASBESTIFORM FIBER INGESTION FIGURES GIVEN IN TABLE 3.18

Figure 3.11

ESTIMATED 1973 PER CAPITA INGESTION OF ASBESTIFORM FIBERS CARRIED IN DULUTH-MANUFACTURED FOODS AND BEVERAGES



according to natural breaks in preference to standard deviations since the standard deviation for this data set is so large (one standard deviation = 693.997958 million).

On Figure 3.11 a "distance decay" in the estimated number of asbestiform fibers ingested per capita is somewhat more evident than on many of the preceding individual company maps, since the data from all eight companies have been combined on Figure 3.11. With the exception of International Falls, the highest estimated fiber-per-capita figures are confined to two main areas: (1) the area within a 50-mile radius of Duluth and (2) the Mesabi Iron Range area. Also evident on Figure 3.11 is Duluth's influence on the I-35 corridor leading to the Twin Cities. The lower fiber-per-capita figures outside northeastern Minnesota and northwestern Wisconsin reflect not only the regional orientation of most of the Duluth food/beverage industries, but competition from other urban manufacturing centers (Fargo, N.D., to the west; Minneapolis-St. Paul to the south; and various Wisconsin cities -- Eau Claire, Madison, Green Bay, etc. -- to the southeast and east).

In summary, although the 1973 estimated asbestiform fiber ingestion figures shown on Figure 3.11 vary considerably, the number of fibers/capita in the areas represented by the first six categories is substantial. The lowest actual ingestion figure in category six is 69,611,400 fibers/capita/year; the highest figure in category one is 2,015,238,600 fibers/capita/year. It should be remembered that it was necessary to use total population figures; consequently, the number of fibers ingested by the actual purchasers of these products is certainly much higher. At a time when there is no known safe level of asbestiform fiber ingestion, the ingestion of millions, indeed even billions, of these fibers per year must be suspect as a possible environmental cause of malignancies. The possible adverse effects of an industrial pollutant, namely asbestiform fibers, on the biological system of the human consumer is the subject of the next chapter.

CHAPTER IV

THE EFFECTS OF AN INDUSTRIAL POLLUTANT, NAMELY ASBESTIFORM FIBERS, ON THE BIOLOGICAL SYSTEM OF THE CONSUMER

A great deal of the concern over the regulation of industrial pollution systems stems from apprehension related to the real or potential dangers of many industrial contaminants. These dangers, specifically those that threaten human health, often act as the catalysts for governmental and/or judicial actions to abate industrial pollution. Although this dissertation approaches a pollution system's elements or subsystems chronologically -- based on the passage of the contaminant through the various subsystems -- in this case, as in most other instances of industrial pollution, the problem is studied in retrospect following the identification of a potential health threat already in existence.

A determination of the degree of threat posed by a particular pollutant often dictates the intensity of the efforts aimed at eliminating the hazard. Some by-products of resource-development activities receive little attention because they pose only minimal threats to human health. For example, heated water released from industrial cooling systems or the increased sulfurization of waters in coal strip-mining areas have little effect on human populations, although they may adversely affect aquatic ecosystems.

Many industrial pollutants are, however, of concern to human populations, especial[illegible]minants are known to be potential pathogeni[illegible]inants as heavy metals (for example: le[illegible]coal dust, pesticides, nuclear wastes [illegible] to name a few, have been known to cause [illegible]uman biological system. Prior to causing [illegible]industrial pollutants enter the biological sy[illegible]nsumer via epidermal exposure, the inhalation of polluted air, the drinking of polluted water, or the ingestion of contaminated food, beverage, or drug products.

The catalyst that has spurred the long and continuous legal battle to halt Reserve Mining Company's discharge of taconite tailings into Lake Superior has been the potential adverse health effects associated with the ingestion of asbestiform fibers. At this stage in the development of medical science, the word "potential" must be used, since the majority of studies on asbestos-related diseases have dealt with the inhalation of fibers. Relatively little research has been done on the effects of direct ingestion of asbestiform fibers.[1] It would appear,

---

[1]The Reserve case, however, has prompted a number of asbestos-related ingestion studies including a twenty-year study by the Minnesota Department of Health, funded by the EPA; a three-year, $1 million federal study underway since 1974; a $2.7 million (continued on next page)

sulfurization of waters in coal strip-mining areas have little effect on human populations, although they may adversely affect aquatic ecosystems.

Many industrial pollutants are, however, of concern to human populations, especially when the contaminants are known to be potential pathogenic agents. Such contaminants as heavy metals (for example: lead, zinc, and mercury), coal dust, pesticides, nuclear wastes, and asbestiform fibers, to name a few, have been known to cause malfunctioning of the human biological system. Prior to causing the malfunctioning, industrial pollutants enter the biological system of the consumer via epidermal exposure, the inhalation of polluted air, the drinking of polluted water, or the ingestion of contaminated food, beverage, or drug products.

The catalyst that has spurred the long and continuous legal battle to halt Reserve Mining Company's discharge of taconite tailings into Lake Superior has been the potential adverse health effects associated with the ingestion of asbestiform fibers. At this stage in the development of medical science, the word "potential" must be used, since the majority of studies on asbestos-related diseases have dealt with the inhalation of fibers. Relatively little research has been done on the effects of direct ingestion of asbestiform fibers.[1] It would appear,

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[1]The Reserve case, however, has prompted a number of asbestos-related ingestion studies including a twenty-year study by the Minnesota Department of Health, funded by the EPA; a three-year, $1 million federal study underway since 1974; a $2.7 million (continued on next page)

however, that the similarity of the cummingtonite-grunerite asbestiform fibers in Lake Superior's water to amosite asbestos,[1] a known human carcinogen (Selikoff, Hammond, and Churg, 1972), is sufficient cause for concern.

Research dealing with asbestos-related diseases did not appear until the 1920's, when Dr. W.E. Cooke discovered asbestosis, a disease associated with diffuse fibrosis or scarring of the lung (Cooke, 1927).[2] Since Cooke's discovery of asbestosis, the list of asbestos-related diseases has grown to include cancer of the larynx (S.M., 1974), lung cancer, mesothelioma, and gastrointestinal (esophagus, stomach, intestines, colon, and rectum) cancers (Mount Sinai School of Medicine, 1973).

Although medical knowledge concerning asbestos-cancer relationships is far from complete, certain facts have become evident. From the testimonies of Drs. Selikoff, Wagner, Rankin, Brown, Davis, and Wright, the District Court (S.M., 1974, pp. 45-55) concluded:

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study by the National Institute of Environmental Health Sciences; and research conducted by (1) the Medical Advisory Committee on Health Problems Related to Asbestiform Fibers in the Drinking Water of Communities Using Lake Superior Water; (2) the Canadian Health Protection Branch; (3) the Duluth Mayor's Medical Advisory Committee; (4) the National Cancer Institute; (5) Dr. Irving Selikoff of the Mount Sinai School of Medicine; and (6) the American Medical Association.

[1]Cummingtonite-grunerite asbestiform fibers are similar to amosite asbestos in morphology, crystallography, and chemistry (S.M., 1974).

[2]Cooke actually discovered the disease in 1924, but his findings were not widely accepted until 1927.

> Exposure to asbestos fibers can and does produce significant and detrimental changes in the human body.
>
> . . . .
>
> There is no known safe limit of exposure,[1] below which it can be said that no detriment to the body will result.
>
> . . . .
>
> Carcinogens such as asbestos are stored by the body; their effects are often cumulative and irreversible. Hence even if it were possible to establish a threshold level, exposure below the threshold may increase the risk of cancer when acting with a co-carcinogen....
>
> . . . .
>
> The detrimental changes produced by exposure to asbestos will not be manifested in a detectable way until 20 to 30 years after the initial exposure.

In reference to asbestos-related gastrointestinal cancers, Carter and Knabe (1969, p. 20) point out that:

> ...the occurrence of increased gastrointestinal cancer in asbestos workers [Mancusco and Coulter, 1963; Selikoff, Bader, _et al_., 1967] suggests that inhaled asbestos reaching the gastrointestinal tract via the muco-ciliary escalator [of the lung] may be tumorigenic. In addition, a direct correlation between an increased incidence of gastrointestinal cancer and the amount of talc-polished (asbestos-contaminated) rice ingested has been observed in the Japanese population [Merliss, 1971].

As a further indication of the potential risk to persons ingesting asbestiform fibers, Henderson, _et al_., (1975) found conclusive evidence of the presence of asbestiform fibers in stomach tumors removed from Japanese males who had ingested asbestos-contaminated rice.

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[1] Although there is an industrial standard of five fibers greater than five microns in length per cubic centimeter of air (S.M., 1974, p. 54), fibers shorter than five microns actually may be more carcinogenic than the longer fibers (S.M., 1974, p. 49).

On the basis of the development of abdominal tumors following exposure to asbestos dust, Lee (1974, p. 113) states that it is only reasonable "to suppose that the ingestion of asbestos fibers in water or food would increase the risk of developing similar abdominal tumors." It is well known that asbestiform fibers are biologically active (Lee; Selikoff), but it is not known whether it is the size, shape, or surface contaminants associated with asbestiform fibers that is of most importance in cancer causation. It may well be that the presence of asbestiform fibers causes increased cell multiplication that may render tissues more susceptible to mutation by other carcinogens (Lee, 1974).

There is little doubt that asbestos fibers are more-or-less ubiquitous in the environment and can enter the body via numerous routes (Cunningham and Pontefract, 1973). Humans may be exposed to asbestos fibers via such things as industrial operations, automobile brake linings, construction materials and, until recently banned by the government, asbestos filters used in alcohol and drug manufacture. However, with the exception of direct occupational exposure to asbestiform fibers, these "background levels" of asbestos rarely reach concentrations anywhere in the vicinity of the concentrations found in the Duluth municipal water supply (Selikoff, 1974). The District Court's Findings of Fact (S.M., 1974, pp. 70-74) state that:

> ...the levels of fibers in the Duluth water and that of other cities is such as to give rise to the conclusion that...the residents of these communities may ingest as many fibers as do asbestos workers.

> ...Dr. Nicholson, using figures from the epidemiological studies of Dr. Selikoff, concludes that the levels of amphibole fibers in the drinking water in Duluth were comparable to exposures found to cause gastrointestinal cancer in asbestos workers.
>
> . . . .
>
> It should be pointed out that Duluth residents do not...enjoy a fortunate position with respect to the cancer experience for the entire state of Minnesota. There is [in Duluth] a statistically significant excess of rectal cancer with an increasing trend [from the testimony of Dr. Thomas J. Mason].... Therefore, we cannot say that the increase seen, although small in number at this time, is not due to ingestion by these persons of asbestos from Reserve's taconite waste. We also cannot exclude the possibility that this increase will, at a later date, parallel Dr. Selikoff's findings [Selikoff, Hammond, and Seidman, 1972] with respect to the three-fold increase in cancer of the gastrointestinal tract. Consistent with past experience of populations exposed to asbestos, the actual health effects of Reserve's discharge on the people of Duluth [and on those exposed via ingestion of foods and beverages manufactured using Duluth municipal water] will not be known for many years.

Despite the considerable incubation period associated with asbestos-related cancers, there are indications that the ingestion of asbestiform fibers may already have affected the health of Duluth residents. In his "First Annual Report to the National Institute of Environmental Health Sciences" (1974), Selikoff states that tissue contamination can occur among persons ingesting asbestiform fibers. From the autopsies performed on several long-time Duluth residents, Selikoff found amphibole asbestos levels in the tissues of the Duluth residents to be ten times greater than those of New York City residents or those of residents living near an asbestos factory.

As in the Japanese case cited earlier, asbestiform fibers ingested by persons drinking contaminated Lake Superior water by-pass the respiratory system and enter directly into the gastrointestinal tract.[1] On this topic Levy, Sigurdson, and Mandel (1974, p. 2) have expressed the opinion that:

> ...the possible link between exposure to asbestos fibers in the air and certain gastrointestinal (GI) cancers, presumed to result from swallowing initially-inhaled fibers, raises the possibility that drinking water with high concentrations of asbestos or asbestos-like fibers for sufficiently-long periods of time may lead to an increased incidence of GI cancers among those who drink it.

Furthermore, asbestiform fibers have the capability of penetrating the intestinal wall, entering the bloodstream, and being carried to any part of the body.

When asked his opinion as to whether or not the populace drinking Duluth municipal water is exposed to a health hazard, Selikoff (testimony before the District Court, U.S.A., v. Reserve Mining Company, St. Paul, September 21, 1973, p. 4858) replied:

> I think that this is a distinct public health hazard to the population in Duluth and to other populations which will be drinking that water and using it in one way or another that allows for its ingestion.
>
> I believe that it is not prudent in any way to allow or to require...these people to ingest particles which in other circumstances have been shown to cause cancer. We will not know whether or not these particular circumstances will cause cancer until another 25 to 35, maybe 40 years have passed.... This is in my opinion a form of Russian roulette, and I don't know where the bullet is located. ...the consequences are particularly bad because while we play the game others

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[1]Asbestiform fibers become airborne, however, and therefore available for inhalation, when contaminated water is used for showering or rug shampooing or in humidifiers, vaporizers, etc. (Carter, personal interview, 2 July 1974; Glass, personal interviews, summer, 1974).

will have to pay the penalty.

Throughout the trial Reserve contended that, although the medical evidence supporting asbestos as a carcinogen was substantial, this evidence referred to asbestos "similar" to that found in Reserve's discharge but not specifically of the cummingtonite-grunerite variety. However, a recent study of miners exposed to airborne cummingtonite-grunerite asbestos indicates that this type of asbestos also poses a serious health threat. As reported in the Duluth News Tribune (12 October 1975, p. 1):

> A recently completed government study has produced what appears to be the first conclusive evidence that submicroscopic asbestos particles like those found in the air near the Reserve Mining Co. taconite plant at Silver Bay increase the risk of lung cancer and other serious respiratory diseases to plant workers.
>
> ...one of the federal researchers who helped conduct the study for the National Institute for Occupational Safety and Health (NIOSH) has suggested that exposure to airborne asbestos particles from the Reserve plant may present similar health hazards for area residents.
>
> The study also raises serious questions about the adequacy of...federal standards to protect workers exposed to asbestiform particles.
>
> The two-part study of mortality rates and environmental conditions among 439 workers at the Homestake Gold Mine in Lead, S.D., found a significant increase over a 12-year period in the number of cases of lung cancer and non-malignant respiratory diseases.
>
> The study concludes that the primary cause of the increased rates of respiratory diseases was the workers' exposure to ores of the cummingtonite-grunerite amphibole mineral series which are nearly identical to those found in Reserve's taconite tailings.
>
> The Homestake study...has important implicatons for the still-unresolved Reserve Mining pollution case.

Furthermore, the NIOSH study showed the Homestake mine to have excellent air pollution controls. The mean concentration in 200 air samples collected from the mine in 1974 was 4.8 fibers per cubic centimeter. Only 6% of the fibers were longer than 5 microns, which is well below the industrial safety standard. The medical report would seem to indicate that the safety standard is still not sufficiently low and that even low-level exposure to asbestiform fibers must be suspect as a health hazard. The Homestake study also indicates that shorter fibers (such as those characteristic of Reserve's discharge) may be as dangerous to human health as the longer fibers (longer than 5 microns).

The potential health threat posed by the asbestiform fibers from Reserve's discharge is by no means over. Following the Eighth Circuit Court of Appeals' reversal of District Court Judge Lord's April 1974 closure order, and pending the outcome of District Court Judge Devitt's July 1976 ruling that Reserve must either switch to on-land disposal or close its Silver Bay operations on 7 July 1977, the discharge from Reserve Mining Company continues to circulate throughout the western arm of Lake Superior and to contaminate municipal water supplies with asbestiform fibers. Private water-filtering devices, in limited use, remove, at best, about 95% of the fibers. A filtration plant designed to cleanse the entire Duluth municipal water supply began filtering operations, which are approximately 98% effective, early in 1977.

Obviously, during the 21 years that Reserve's

Silver Bay beneficiation plant has been in operation, residents of Duluth and other Lake Superior ports have been ingesting asbestiform fibers.[1] Furthermore, persons, both locally and throughout the country, who have indulged in foods and beverages manufactured using unfiltered Duluth municipal water have been ingesting a potential carcinogenic agent, albeit without their knowledge.

As in the Reserve Mining Company case, once it has been established that a particular industrial pollutant has pathogenic potential, studies should be undertaken to determine if any relationship between pollution levels and disease incidence exists in the populations exposed to the contaminant. There often are, however, temporal problems. Cause-and-effect relationships between a pollutant and a particular malfunctioning of the human

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[1]Although Reserve began mining and processing taconite in October, 1955, it was not until the summer of 1973 that the EPA disclosed that Reserve's taconite tailings contained asbestiform fibers. This discovery was facilitated by the use of X-ray diffraction and the electron microscope, which are able to detect minute particles such as these, many of which are contained in the less-than-two-microns size fraction of the tailings. Even prior to the discovery of the asbestiform fibers, the presence of taconite tailings in Lake Superior water had been documented for a number of years (see CHAPTER II). Since Reserve Mining Company has been working the same body of ore and processing it in the same manner over the years, the continued presence of asbestiform amphibole fibers both in Reserve's discharge and in the waters of Lake Superior is assumed. The concentration of asbestiform fibers in Lake Superior water has increased with each year of tailings discharge. According to Dr. Gary Glass of the EPA National Water Quality Laboratory in Duluth, "resuspension appears to be a major mechanism [responsible] for the high fiber content of drinking water and the more material which is present in the lake and available for resuspension, the higher the fiber counts." (personal letter from Dr. Glass, dated 14 August 1975)

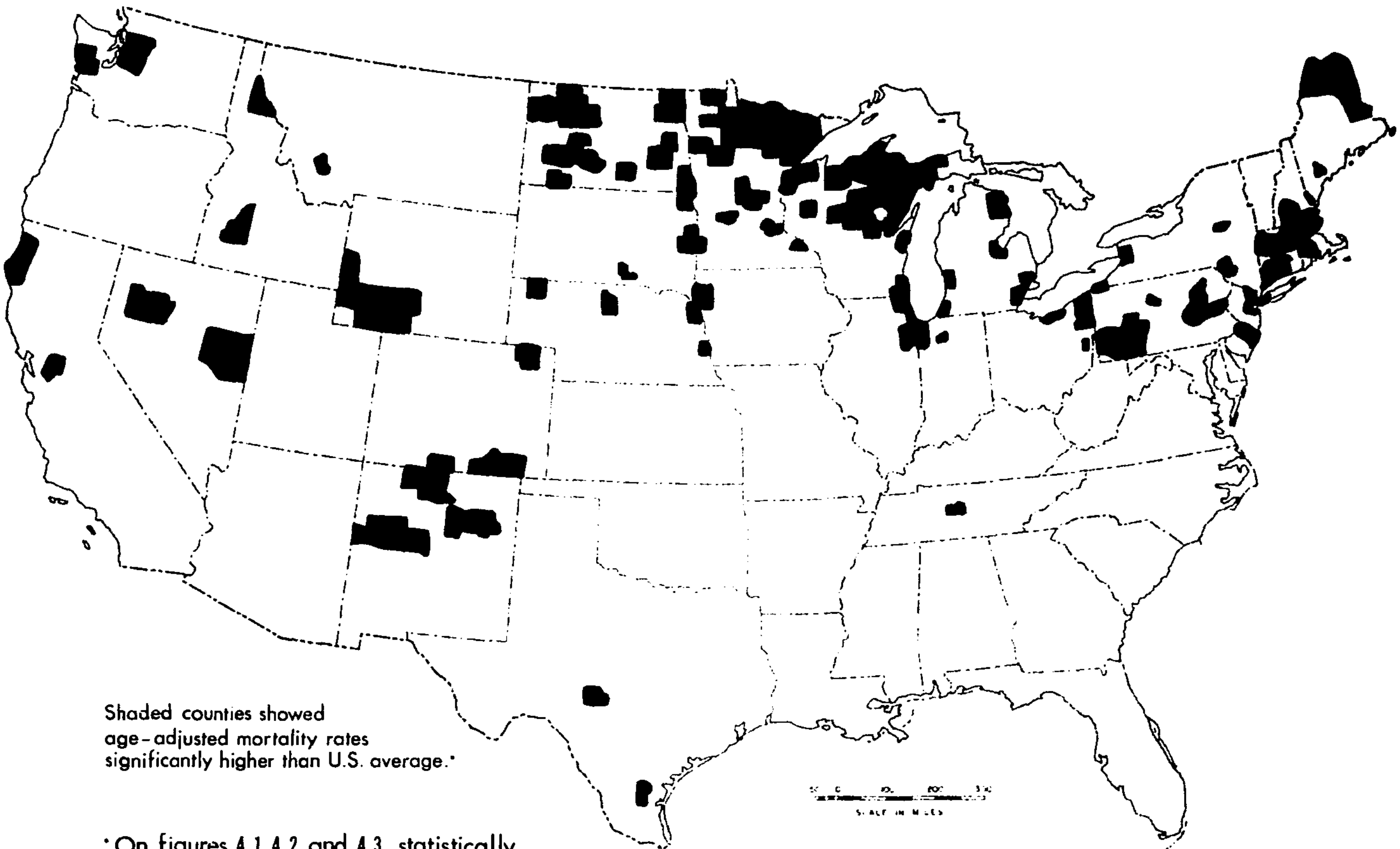
biological system may be obscurred by lengthy time lags, or incubation periods, between the initial exposure to a pathogenic agent and the development of disease. Such a problem is especially apparent in cases dealing with pollutants, such as asbestiform fibers, that are potentially carcinogenic.

Asbestos-related malignancies display an incubation period of approximately 20 to 40 years. That is, cancerous growths may not be detected for two or more decades following initial exposure. This renders it impossible to state, with any degree of credibility at this time, that evidence indicates a caus -effect relationship between exposure to asbestiform fibers from Reserve Mining Company's operations and malignancies in Lake Superior area residents. That is not to say that the ingestion of asbestiform fibers will not contribute to the development of cancers. The potential most certainly is there, especially since the upper Great Lakes region is one of this nation's stomach cancer "hot spots" (see Figures 4.1, 4.2, and 4.3).

To determine if any correlation between asbestiform fiber exposure and gastrointestinal cancer rates was discernable in the upper Great Lakes area, a number of scatter diagrams, plotting GI cancer rates per 100,000 white males against asbestifiber exposure, were drawn for those Minnesota, Wisconsin, and northern Michigan counties lying wholly or partially within the patterned areas shown on Figure 3.11. Clearly, no correlations, positive or negative, were discernable for malignancies of the

Figure 4.1

STOMACH CANCER MORTALITY BY COUNTY, 1950-69, WHITE MALES

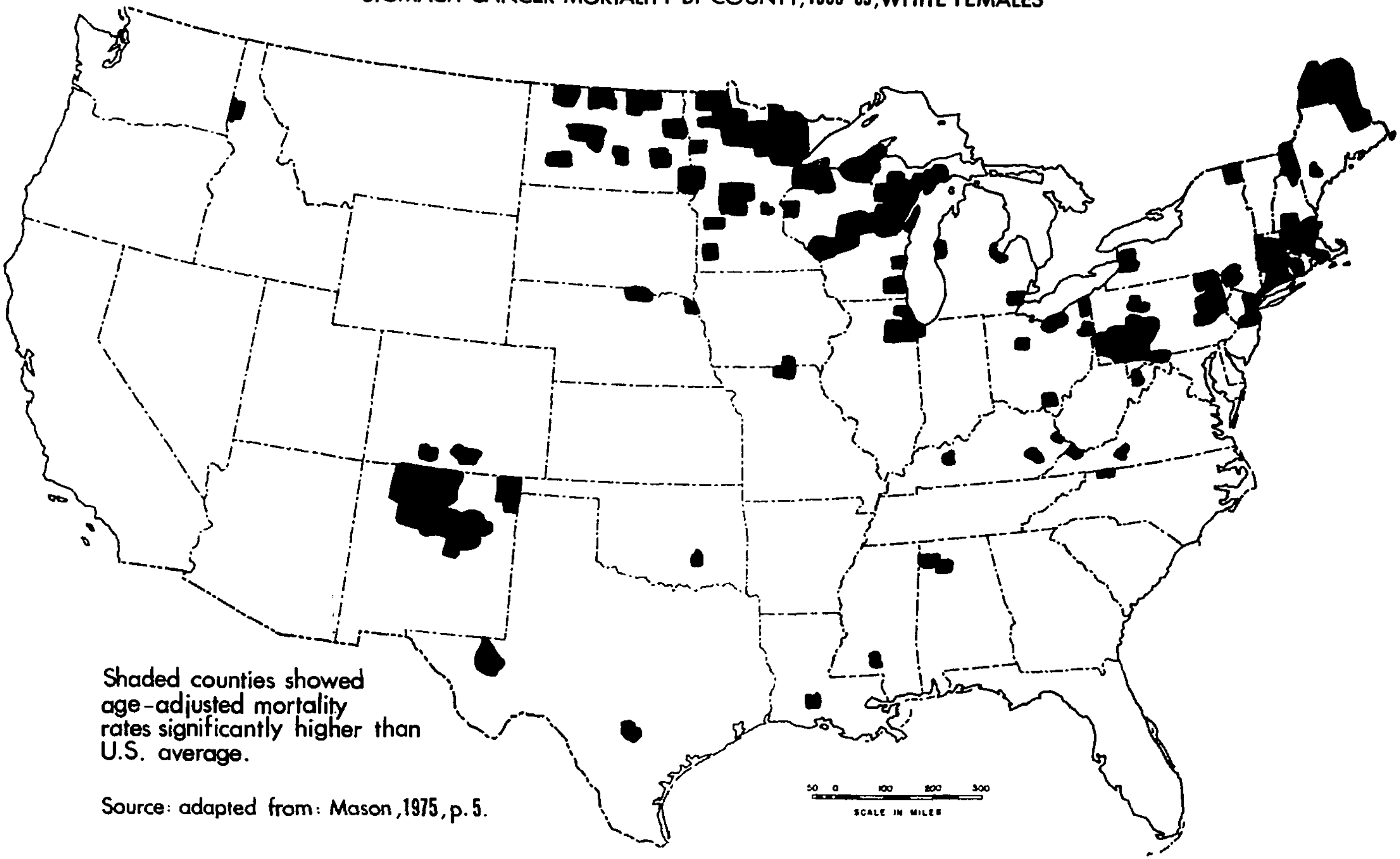


*On figures 4.1, 4.2, and 4.3, statistically significant differences resulted when the 95% confidence intervals for the local and national rates did not overlap.

Source: adapted from: Mason, 1975, p. 4.

Figure 4.2

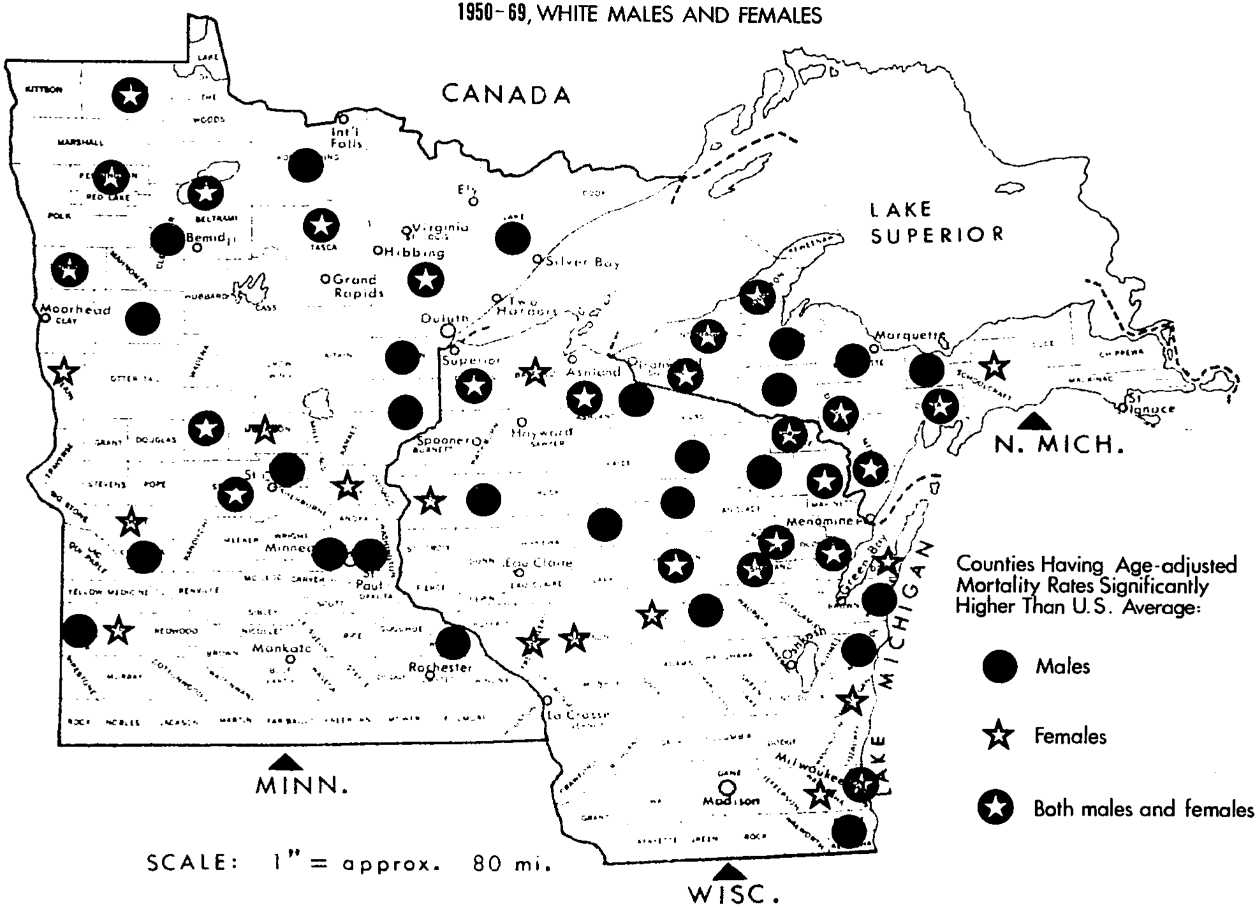
STOMACH CANCER MORTALITY BY COUNTY, 1950-69, WHITE FEMALES



Shaded counties showed age-adjusted mortality rates significantly higher than U.S. average.

Source: adapted from: Mason, 1975, p. 5.

Figure 4.3
UPPER GREAT LAKES REGION: STOMACH CANCER MORTALITY BY COUNTY
1950-69, WHITE MALES AND FEMALES



Source: adapted from Mason, 1975, pp. 4-5.

esophagus, large intestine, or rectum. These results are not surprising, since Reserve has only been operating for a period about equal to the minimum incubation period for asbestos-related malignancies.

There was, however, a slight positive correlation discernable on the stomach cancer scatter plot. In an attempt to quantify the "slight" correlation, Kendall's Tau correlation technique was used on the data set. First, the 27 counties relevant to the problem were ranked twice: once according to the stomach cancer rate established between 1950 and 1969 and once according to the estimated annual per capita asbestiform fiber exposure. If a county contained more than one exposure category, the category corresponding to the most populous portion of the county was chosen to represent the county. Based on 124 inversions and 351 possible pairs for the data set, the Kendall's Tau value for the correlation between stomach cancer rates and asbestiform fiber exposure was +.293. This correlation is not too impressive, but at least it is positive.

The decision to use a non-parametric correlation technique like Kendall's Tau in favor of a parametric correlation technique such as Pearson's Product-Moment Correlation Coefficient was based on the facts that (1) the data set could not meet the assumptions required for the use of the parametric technique (normal distribution, strict linearity, homoscedasticity) and (2) Kendall's Tau is less susceptible to the influence of extreme values than Pearson's technique. Kendall's Tau was chosen in favor of Spearman's Rho since there were some ties in the rankings of the data set and Kendall's Tau is less sensitive to ties than Spearman's Rho.

Concluding Comments

So, where does medical science stand in regard to asbestos-cancer relationships in the upper Great Lakes region? Until we are well past the minimum incubation period for asbestos-related malignancies, the asbestiform fibers from Reserve's operations must continue to be regarded as a "potential" hazard to human health. Indeed, in view of the rising emphasis upon a multiple-factor etiology for cancer (Selikoff, 1974), asbestiform fibers must share their carcinogenic potential with other suspects such as ethnic susceptibility, diet, and environmental exposure to other carcinogens.

The foregoing statements are not meant to minimize the potential carcinogenic risk posed by the ingestion of asbestiform fibers. Rather, they are included to emphasize the fact that in seeking explanations for the geographic distributions of malignant diseases the possibility of a multiple-factor etiology for cancer, or of synergistic effects among carcinogens, must not be eliminated.

The fact remains, however, that asbestiform fibers -- by themselves or in conjunction with other carcinogenic agents -- do constitute a potential health hazard. In light of the inability or reluctance on the part of medical researchers to issue precise statements on cancer cause-and-effect relationships, perhaps a "potential" warning is all that can be expected at this time.

So, armed with the knowledge of the presence of a potential health risk associated with a particular industrial pollution system, the decision must be made whether to ignore, perpetuate, regulate, or eliminate the problem. In most cases, the decision-making process does not take place within the pollution system itself but as a result of the actions of those working within the larger-order systems that constitute the pollution system's environment. The ways in which these external influences (see Figure 1.2) can affect the functioning of a pollution system, with special reference to the Duluth Problem, are the subject of Chapter V.

CHAPTER V

THE HIGHER-ORDER SYSTEMS, OR EXTERNAL INFLUENCES, WHICH AFFECT THE FUNCTIONING OF AN INDUSTRIAL POLLUTION SYSTEM

As a man-induced phenomenon, an industrial pollution system does not function in isolation from the higher-order systems which characterize modern human society. Rather, an industrial pollution system's creation, perpetuation, control, or termination is dependent upon the state of knowledge of, and the decisions made within, a number of external systems having direct or indirect bearing on the pollution system. The key external influences which may affect the functioning of an industrial pollution system are the engineering sciences, the medical sciences, the environmental sciences, and the economic, social, and political systems which create the environment within which pollution systems operate.

The Engineering and Environmental Sciences

When dealing with resource development activities, the engineering sciences dictate what actions or processes are technically feasible, while the environmental sciences are concerned with the maintenance of ecological balance. Ideally, resource development activities should be both technically feasible and environmentally safe, thus preventing the development of pollution systems. Unfortunately, since we lack omnipotent technological and ecological knowledge, not to mention the lack of unlimited funds, the engineering and environmental sciences often find themselves at loggerheads with one another, pollution systems do exist, and a certain amount of compromise is necessary.

For example, man has not yet devised a means of open-pit iron-ore mining and processing that does not, in some way, disturb the environment and its ecological systems. But, in the Reserve case, there is a means of waste disposal (namely, carefully-controlled on-land dumping) which is both technically feasible and environmentally safer than sluicing 67,000 tons of taconite tailings per day into Lake Superior.

Although on-land disposal, air pollution abatement proposals, and water-cleansing procedures may pose certain mechanical difficulties, the solutions to most of these problems lie within the reach of our technological capabilities. In the case of Reserve Mining Company there have been (1) questions as to the engineering design safety of tailings disposal basins, such as the possibility of dam failures, subsurface leakage, and contamination of surface waters; (2) concern over the control of potential airborne wastes emanating from on-land disposal sites; (3) technical problems with the new Duluth water-filtration plant; (4) design problems with the wet-wall precipitators designed to reduce Reserve's smokestack emissions, which amount to 8,000 pounds of fiber-laden waste daily; and (5) apprehensions as to the fate of the taconite tailings that have been dumped into Lake Superior over the past two decades.

Given sufficient time and money for experimentation and adjustments, the technological expertise of modern engineering sciences, aided by advice from environmental experts, can find solutions to all the aforementioned problems, with the possible exception of the cleansing of Lake Superior itself. In the case of Lake Superior, the long, slow processes of natural flushing and sedimentation--a minimum of 500-1000 years for an enclosed basin such as Lake Superior's (Sydor, personal interview, 31 July 1974)--must be relied upon to disperse and/or permanently remove from suspension those taconite tailings already in the lake. In all probability, Lake Superior will never again be completely free of asbestiform fibers.

The Medical Sciences

The influence of the medical sciences on pollution systems lies in the role of medical research in determining the effect of industrial pollutants on the biological system of the consumer. By assessing the presence and degree of malfunctioning of the body (if any) associated with exposure to various industrial pollutants, medical scientists can provide essential information concerning the magnitude of risk associated with a particular industrial pollution system. The greater the risk, the greater the influence of medical findings on the actions of those working within the political system to seek to regulate the emission of the pollutant.

In reference to the Duluth Problem, the present state of knowledge of the medical sciences in regard to the effect of exposure to asbestiform fibers on the biological system of the consumer has been expounded in Chapter IV. Medical science is continuing its research on asbestos-related diseases, especially in relation to the direct ingestion of asbestiform fibers. To increase medical knowledge in this area, more precise methods of detecting and quantifying asbestiform fibers in food and water are needed, as well as systematic determinations of fiber distributions. Throughout these studies, medical researchers will be faced with synergism among carcinogens and, therefore, must develop ways of dealing with multiple-factor cancer causation.

As researchers discover the causes of cancer and other diseases, they may be able to pinpoint high risk groups exposed to such causes, thus facilitating early detection and treatment. In the conduct of epidemiological and surveillance studies, the coordination of biological effects with environmental data is of utmost importance, since the majority of cancers, as well as certain "occupation-related" diseases, are thought to be environmentally-induced.

In addition to the risk of developing diseases from exposure to industrial contaminants, there is another side to pollution-related health problems: the adverse effect on the well-being of those employed by the polluting industry. The threat posed by the possible closing of a polluting industry's facilities can foster psychological stress and insecurity among those whose economic livelihoods are tied directly or indirectly to the industry. In Silver Bay, Minnesota, for example, Donald Haase, M.D. (Time, 10 January 1977), has noted an increase in stress-related symptoms, such as gastrointestinal upsets and acute and chronic depression, among Silver Bay residents since the prospect of Reserve closing its Silver Bay plant first came to light in 1974. Consequently, medical science can influence the operation of an industrial pollution system not only by determining the risk to consumers posed by the pollutant, but also by assessing the effect of economic insecurity on the health of those employed by the polluting industry.

The Economic System

Of all the external influences which affect a pollution system, the economic system traditionally has occupied the strongest position in favor of non-regulation of industrial pollution. Pollution control and/or abatement procedures generally require additional capital investment on the part of a business concern. The greater the cost of production, the smaller the profit and/or the higher the price of goods on the wholesale and retail markets. The higher the price of a company's goods, the greater is its competitive disadvantage on the open market.

Thus, the cheapest way for an industry to operate is to cut its costs of production, which usually entails minimum treatment of waste discharges and results in the pollution of common property resources. Of course, pollution has its hidden costs in the impairment of non-renewable resources and the possible costs related to the health of those who consume industrial contaminants. Western man's "frontier" or "cowboy" environmental ethic (discussed in greater detail in Chapter VI), however, has tended to weight the odds in favor of short-term, direct costs and benefits rather than those which are long-term and indirect.

Using the case of Reserve Mining Company as an illustration, the remainder of this discussion of the influence of the economic system on a pollution system concentrates on the short-term, direct costs and benefits of pollution control, or the lack thereof. The following discussion is divided into three sections: (1) the costs and benefits of the status quo situation characteristic of Reserve Mining Company's operations; (2) the costs and benefits of Reserve remaining in operation, but utilizing pollution-abatement procedures; and (3) the costs and benefits of the closing of Reserve's Silver Bay operations.

Maintaining the Status Quo

Reserve Mining Company's E.W. Davis Works at Silver Bay is the world's first and largest taconite plant. Accounting for the shipment of one-third of Minnesota's total production of taconite pellets, Reserve's plant produces 15% of the U.S. iron ore used in this nation's blast furnaces.

When Reserve Mining Company began taconite operations in northeastern Minnesota in the 1950's, the company built two plannedcommunity company towns to house its employees: Babbitt, with a population slightly greater than 3000, near the mine site; and Silver Bay, with a population of about 3500, at the beneficiation plant site. Reserve employs approximately 3200 workers, with an equal number of persons indirectly linked to the company through industrial interaction.

The income impact, direct and indirect, of Reserve Mining Company accounts for 95% of the total employment in the mining industry, 38% of basic industry employment, and 24% of the total employment in Cook and Lake Counties, Minnesota. Reserve's economic impact on the Arrowhead Region (the eight counties of northeastern Minnesota) plus Douglas County, Wisconsin, amounts to approximately 5% -- in excess of $50 million annually -- of the total regional income. (Foregoing data from Jesswein and Lichty, 1974)

In 1973 Reserve's payroll was $40,800,000 and its state and local taxes amounted to $6,600,000 (Reserve Mining Company, 1972; statistics updated by Schmidt, 1974). Reserve pays approximately 25% of the taconite production taxes, levied at the rate of $.75 per ton, collected by the State of Minnesota and distributed to local governments in lieu of property taxes (Labor World, 14 October 1976). As can be seen, Reserve Mining Company is one of the economic mainstays in a one-industry (iron mining and processing) region.

The operation of Reserve Mining Company "as is" has created a number of costs, in addition to those related to health risks, to those not directly connected with the company. Lake Superior's water quality has been impaired by suspended taconite tailings containing asbestiform fibers to such an extent that the City of Duluth was forced to construct, with the aid of a $4 million federal grant from the EPA, a $6.9 million water filtration plant to cleanse its municipal water supply. Similar problems are faced by smaller western Lake Superior communities. Also, there have been the costs of interim clean water programs, such as the installation of temporary tap filters and a free-bottled-water program in Duluth, part of which have been defrayed via court fines levied against Reserve Mining Company. In light of the lengthy legal battles surrounding Reserve Mining Company, the maintenance of the status quo is no longer a suitable alternative.

Remaining in Operation but Utilizing Pollution-abatement Procedures

There is no question that if Reserve is to remain in operation the company must utilize pollution-abatement procedures in its beneficiation plant and switch to on-land disposal of its taconite tailings. Should the State of Minnesota and Reserve Mining Company come to an agreement as to a mutually-acceptable disposal site (see APPENDIX A for additional information), the cost of Reserve's taconite production would, naturally, increase. The estimated cost of constructing tailings basins at Mile Post 7, favored by Reserve, is approximately $300 million, while the construction of basins at Mile Post 20, favored by the State of Minnesota as an environmentally-safer site, would cost about $440 million as estimated by Reserve; $386 million as estimated by the State of Minnesota (Labor World, 14 October 1976). Reserve also faces additonal production costs related to its installation of airborne-emission-reducing precipitators at the Silver Bay plant. In all probability, Reserve could receive grants and/or tax concessions from the State of Minnesota and/or the Federal Government to help defray these expenses.

A number of benefits would accrue as a result of Reserve remaining in operation. Its position as a major employer, economic benefactor, and taxpayer would not be altered. In fact, the company's conversion to on-land disposal calls for substantial construction and equipment modification that would necessitate augmenting the company's work force, thus increasing employment in the area.

Closing Reserve's Silver Bay Plant

Should Reserve Mining Company and the State of Minnesota not reach an agreement on a land-disposal site prior to the court-decreed 7 July 1977 deadline, the company, barring any unforeseen judicial decisions, would be forced to close its Silver Bay operations -- an action with few benefits and extensive costs. The benefits, if any, of the plant's closing would be realized by Reserve Mining Company, since the company would not have to increase its capital outlay by switching to on-land disposal. The physical plant probably would have to be written off, however, since it is unlikely that any other taconite producer would purchase the facility, and the use of the E.W. Davis Works for other purposes would be minimal. The cessation of the dumping of taconite tailings into Lake Superior could provide no substantial short-term benefit either, since the amount of tailings now present in the lake is sufficient to maintain high fiber counts in lakeshore municipal water sources for years to come.

In regard to the economic impact associated with the closing of Reserve Mining Company:

(1) 6000^{+} workers whose jobs are tied directly or indirectly to Reserve Mining Company would be unemployed, with little chance of switching to other industries because of the specialized and almost unique skills required of taconite workers;

(2) The families dependent upon the income of Reserve's employees would suffer economic instability;

(3) The town of Silver Bay, created by Reserve Mining Company, may become a North Shore ghost town. There is a chance that the Peter Mitchell pit at Babbitt would be useful to other Mesabi Iron Range taconite producers so the mining town's future is not as bleak as that of Silver Bay;

(4) Higher taconite production taxes would have to be borne by other Minnesota taconite producers if Reserve were not paying its traditional 25% share;

(5) The State of Minnesota would lose over $25 million and the Federal Government over $13 million annually in reduced tax revenues and increased welfare payments

and unemployment compensation;

(6) The Minnesota economy would suffer an annual loss in payrolls and purchases of approximately $120 million. This amounts to $4.8 billion over the estimated 40-year remaining life span of the Reserve mining operation in Minnesota;

(7) At least $17 million in lost equity in their homes would have to be absorbed by Reserve employees, not to mention the decline in real estate values throughout Silver Bay. (Preceding statistics are from Brissett, 1976, and from Labor World, 14 October 1976.)

On the strength of the foregoing statistics relative to the operation of Reserve Mining Company, the magnitude of the influence of the economic system on the functioning of pollution systems is readily discernable.

The Social System

It is difficult to separate the impact of the social system on pollution systems from that of other external influences, since the social system is so greatly influenced by the economic system and since social dictates generally are expressed via the political system. Of course, society has its mores by which it lives and its "sense of what is right," morally, ethically, and aesthetically. But the fact remains that it is difficult for many twentieth-century capitalistic Americans to concern themselves over the loss of the sparkle in the jewel that was Gitche Gumee, or over the threat of developing cancer 20 to 40 years hence, when they are fighting for economic survival <u>now</u>.

It is well known that economic instability can foster psychological stress and even contribute to anti-social behavior. In Silver Bay, for example, uncertainties related to Reserve's operations have temporally coincided with (1) an increase in cigarette, alcohol, and drug use, as well as vandalism, among the town's school children and (2) a six-fold increase in the number of divorces filed in Silver Bay (*Time*, 10 January 1977).

Whenever society becomes embroiled in an issue, various opposing factions tend to emerge. In cases of industrial pollution, the environmentalists and medical scientists generally find themselves in opposition to those struggling for economic survival. Unable to find mutually-acceptable solutions to the problems at hand, these two factions (bilaterally or, more often, unilaterally) seek arbitration via the political system.

The Political System

Ultimately, the degree of control imposed upon industrial pollution systems rests with the administrative, judicial, and/or legislative subdivisions of the political system. Often, all three subdivisions become involved in industrial pollution cases.

Working within the framework of statutory and common law, as well as under any pertinent judicial dictates, the administrative branch of the political system, whether at the local, state, or federal level, is responsible for implementing and enforcing policy. In the case of resource development activities, this entails reviewing and ruling upon the merits of industrial development, the issuing or denial of permits for construction, waste disposal, and use of common property resources, and the monitoring of environmental quality.

Should a government agency feel an industry is operating in an unethical or unlawful manner, or should a company feel it deserves exemption from certain dictates of agency administrators, recourse to the judicial branch of the political system may be sought. In the case of Reserve Mining Company, for example, Reserve won a civil suit against the Minnesota Pollution Control Agency in 1970 by claiming the company should be exempt from the provisions of Water Pollution Control Regulation 15 (see APPENDIX A and APPENDIX B). In 1973 the United States, the State of Minnesota, <u>et al</u>., filed a suit against Reserve alleging the company was in violation of its discharge permits, among other regulations. As in the Reserve case, the final decision regarding the regulation of any pollution system, should the situation be brought before the courts, rests with the procedures of decision and appeal inherent in the judicial system.

The legislative subdivision of the political system is responsible for instituting the statutes under which the administrative and judicial branches function. When dealing with environmental and/or pollution-control legislation, Congress, of necessity, must draft bills designed to be as all-encompassing as possible. As an illustration, the strength of the National Environmental Policy Act of 1969, a landmark piece of legislation, lies in the breadth of its applicability. Since environmentally-oriented legislation cannot hope to itemize <u>every</u> instance in which a specific statute may apply, broadness is essential for effectiveness. This necessary breadth is not, however, without its problems. In broadness may be found sufficient latitude for government administrators to vary in their interpretation of a statute, thus raising the question of "who watches the watchdogs?" Furthermore, polluting industries may claim that a certain act lacks preciseness, thus causing the judicial system to render decisions whenever courses of action are unclear.

Another problem facing those involved in pollution-abatement procedures lies in outdated or controversial legislation that remains on the legal books. As an example, several decades ago, at the height of Mesabi Iron Range mining, Minnesota passed a law that gave taconite companies the right to condemn land for purposes such as tailings disposal (Cohen, 1976). A number of private landowners in northeastern Minnesota have since threatened to challenge the constitutionality of that law. This is true of landowners in the Mile Post 7 area. Mile Post 20 also poses land-acquisition problems in that the disposal basins would have to be built wholly or partially on State-owned lands. State-owned lands cannot be sold to private individuals or industries; therefore, some arrangement would have to be made whereby the State of Minnesota and Reserve Mining Company traded land parcels.

Summary

Industrial pollution systems do not operate autonomously.

They are instituted, encouraged, regulated, perpetuated, or terminated in response to attitudes, decisions, and the degree of knowledge characteristic of the higher-order systems which constitute a pollution system's environment. Some of these higher-order systems tend to encourage the perpetuation of channels of ignorance at the interfaces of the interlocking elements or subsystems that comprise an overall pollution system, while some of the external influences tend to work toward the removal of channels of ignorance and the ultimate disassembling of the pollution system. Research within the engineering, environmental, and medical sciences generally strives in directions that favor channel removal. In instances where channel removal increases production costs, the economic system tends to favor channel preservation. The influence of the social and political systems on the presence of channels of ignorance tends to be so very complicated that it is difficult to generalize. Attitudes and decisions within these two higher-order systems may vary temporally as well as spatially.

Without a doubt, if channels of ignorance are to be recognized, and if pollution systems are to be abated or prevented from developing, the solutions lie _not_ within the pollution system itself. Rather, the solutions lie within the higher-order systems to which this chapter has been devoted. And it is with these higher-order systems that society must content if Duluth-type problems are to be prevented from occurring elsewhere. This topic is discussed at greater length in the concluding chapter.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Among the crucial problems facing the contemporary world is the regulation of the use of the environment--specifically, to reduce the threat of environmental pollution emanating from natural resource development activities. This is a difficult and complex undertaking, especially when common property resource systems are involved and/or when the onset of the pollution is gradual. The temporal lag between causes and effects in complex cybernetic systems may effectively camouflage the severity of a pollution problem until such time as pollution control becomes a "post-mortem" phenomenon. Once the full impact of an environmental pollution problem is realized, society often overreacts, thus initiating a crisis-panic-reaction-regret cycle.[1]

Modern society in general, and environmental scientists (including geographers) in particular, have at their disposal, however, a powerful and effective tool that can aid in eliminating the panic...regret cycle when faced with environmental pollution problems. This tool is systems analysis. Often, the failure to deal adequately with complex environmental problems

[1]For example: crisis and panic: alarm over atmospheric degradation resulting from CO emissions of motor vehicles; reaction: legislative action calling for installation of catalytic converters on new vehicles; regret: insufficient time allowed to perfect converters resulted in wide-scale recall of defective vehicles--economically a very costly operation.

results from the failure to recognize the unifying elements which characterize the complexity.

For example, by viewing an industrial pollution situation as a series of interconnected subsystems influenced by the higher-order systems that constitute the environment within which the pollution system operates, means of determining (1) the extent of the pollution, (2) the severity of the problem, and (3) feasible methods of pollution abatement become more readily discernible. Of utmost importance is the identification of any channels of ignorance that may exist at the interfaces of the interconnected systems, for, if channels of ignorance did not exist, there would be no pollution-related health risks.

For the purpose of illustrating the manner in which systems analysis can be employed to ascertain the extent and degree of exposure of populations to a pollution-related health risk, this dissertation has focused on the "Duluth Problem" related to the contamination of Lake Superior waters with asbestiform fibers from Reserve Mining Company's taconite beneficiation plant located at Silver Bay, Minnesota. By approaching this particular problem from the spatial and man-land viewpoints of a geographer, and by utilizing systems analysis, I was able to incorporate a heretofore-neglected aspect of the overall industrial pollution system created by Reserve Mining Company: the manufacturing and market/distribution systems associated with the Duluth food and beverage industry. Thus, systems analysis facilitated the recognition of a "hidden" potential health hazard associated with the industrial pollution of a common property resource.

The use of systems analysis also made it possible to arrive at an estimated index of the degree of exposure of populations to the asbestiform fibers carried in Duluth-manufactured foods and beverages. Although the health risk posed by the ingestion of asbestiform fibers is still "potential" due to (1) the lack of conclusive scientific/medical knowledge on the subject and (2) the long incubation period characteristic of asbestos-related diseases, studies such as that undertaken in this dissertation not only contribute to the foundation of knowledge concerning the geographic distributions of industrial pollutants, but may provide valuable parameters for future disease-distribution research. In addition, studies such as this demonstrate the value of systems analysis in providing the factual information necessary for sound environmental policy-making.

The Political System and Environmental Policy-making

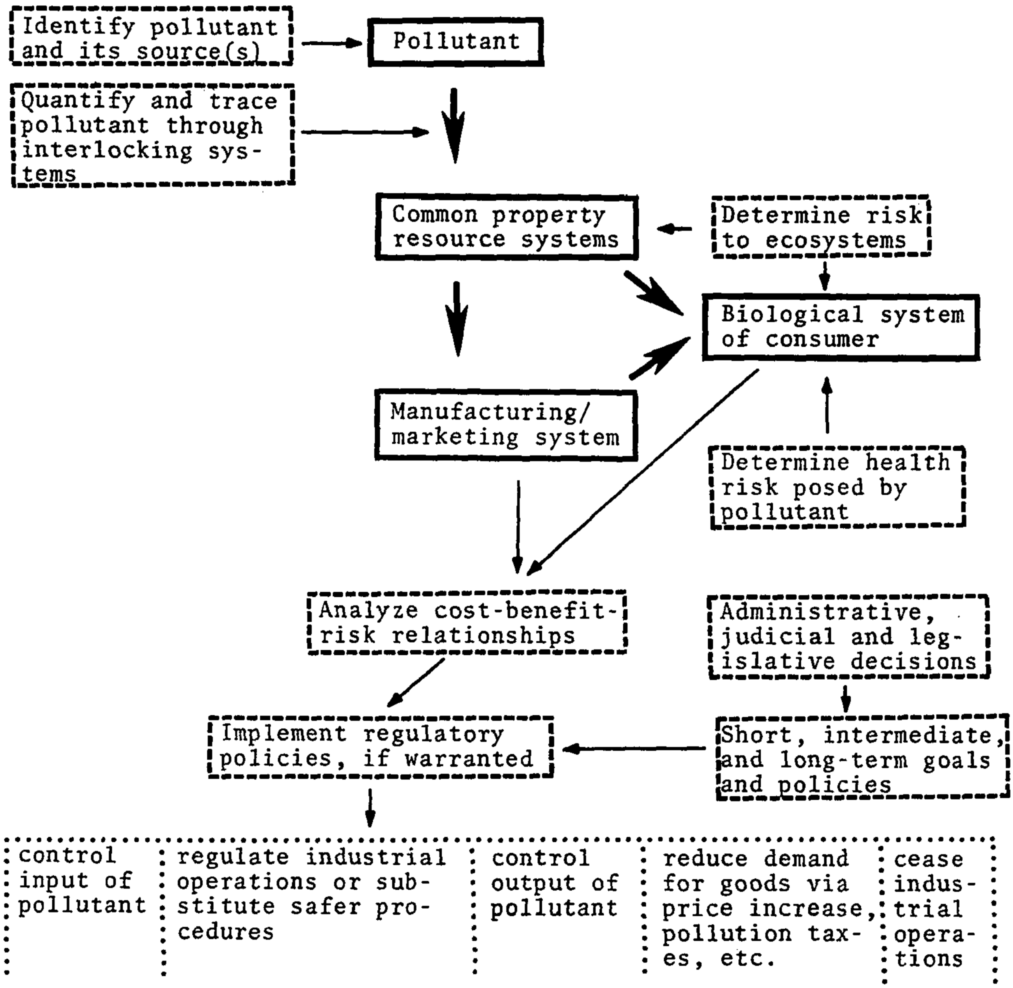
In our effort to establish fair and viable environmental policy-making decisions, it is necessary to "play with a full deck." That is, all aspects of an environmental situation must be considered. Although the advent of environmental impact assessments has practically revolutionized environmental policy-making in recent years, too often these assessments deal only with the "obvious" environmental questions related to a proposed government or industrial project. Because of time limitations and/or inadequate research, hidden ramifications--especially those which may not appear for a number of years--often are overlooked. In this way, permits to utilize common property resources may be issued and a company may have been in operation for years (as in the case of Reserve Mining Company) prior to the discovery that its operations are potentially deleterious to human health and/or ecological systems.

It is of utmost importance that hidden or secondary factors, such as the contamination of food products, be incorporated into future environmental impact assessments as well as into future hearings on permits related to industrial usage of common property resources. This is especially important when there exists a potential or actual risk to human health. Perhaps, via the greater foresight made feasible through the use of systems analysis, it will be possible (1) to avoid "hindsight" environmental policy-making; (2) to break the crisis-panic-reaction-regret cycle; (3) to control or eliminate channels of ignorance; and (4) to prevent Duluth-type problems from occurring elsewhere.

As an example of the use of systems thinking in pollution control and environmental policy-making, Figure 6.1 illustrates a sample sequence of systems-based pollution control procedures. Although the various components shown in Figure 6.1 are by no means exhaustive of all possibilities, they do represent the major elements with which pollution-regulation activities must deal. By utilizing procedures such as those suggested

Figure 6.1

POLLUTION-CONTROL PROCEDURES



in Figure 6.1, society will be better equipped to determine priorities, multiple usage, costs, benefits, and risks associated with economic development. In this way, desired levels of environmental quality could be more readily ascertained--provided there exist adequate techniques for monitoring the environment--since systems-based procedures tend to be comprehensive rather than atomistic.

Even with a vast infusion of systems thinking, however, our policies and goals concerning environmental quality and social priorities may face problems of implementation. The conceptual stage of environmental policy-making is the easiest; the organizational and operational phases are much more difficult. In light of the enormity of such an undertaking, a greater cooperative effort on the part of all levels of government and a greater awareness on the part of society in general are called for. Society must realize that environmental pollution is a symptom of population growth, increases in per capita income and shifts toward increasingly "more extravagant, and more polluting, technologies"(Hardin, 1973, p. 83). The stresses on the environment resulting from these three factors have rendered the traditional solutions to pollution--displacement, dilution, and natural recycling of toxic wastes--inadequate.

In addition to a greater environmental awareness, it would behoove us to develop a more satisfactory and expeditious method of settling environmental disputes than to clog our already-overcrowded courts of law with pollution-abatement cases. One method of reducing the burden presently placed on our judicial system would be to create an "environmental advisory court"--or perhaps a hierarchy of such courts at various levels of authority--that would hear and mediate cases involving conflicting goals in environmental use (see Figure 6.2). I would suggest that the environmental advisory court be composed of persons with recognized expertise in such fields as the environmental sciences, medical sciences, economics, political science, etc. Only in instances where mediation failed would cases be appealed to courts of law. Besides relieving the burden now placed on our courts of law, a further advantage of instituting an environmental advisory court would be that judicial courts could request counsel from the advisory court regarding interpretations of fact calling for scientific/ economic expertise.

Whether within or outside the courts, any form of environmental policy-making must take into account the higher-order systems which influence a pollution system and which are cyclically linked both to one another and to environmental ethics (see Figure 6.3). I believe that ethical considerations, or a "sense of right," must guide our environmental attitudes and actions. Nevertheless, it is often difficult to determine what "ought" to be done. For example, the complex issue concerning the pollution of Lake Superior has a multitude of facets, only one of which, the medical aspect, has been the major focus of this dissertation. Throughout the Lake Superior pollution proceedings, however, it has become obvious that eth-

Figure 6.2

PROCEDURES FOR THE USE OF AN ENVIRONMENTAL ADVISORY COURT

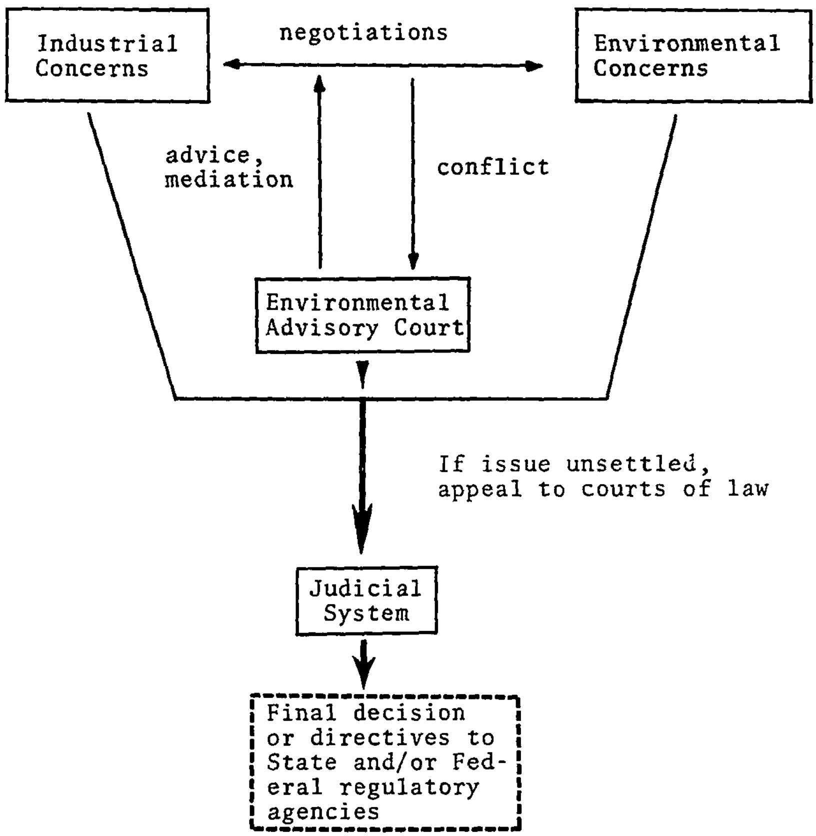
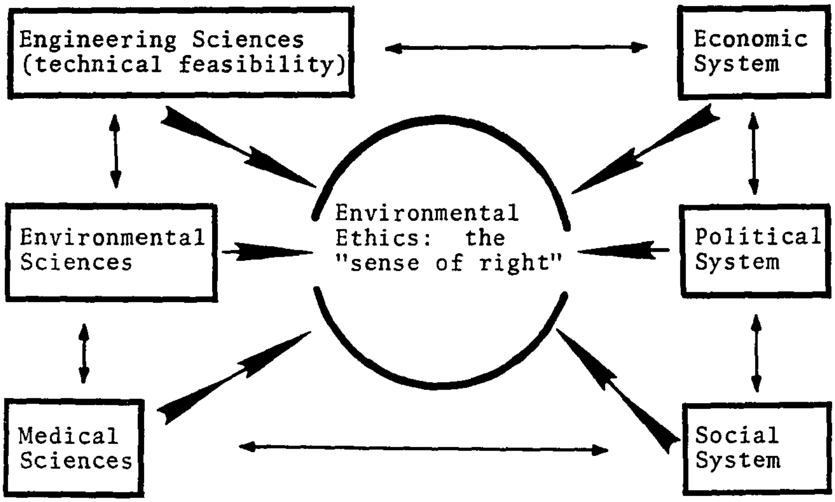


Figure 6.3
THE INTERRELATIONSHIPS OF THE HIGHER ORDER SYSTEMS
INVOLVED IN INDUSTRIAL POLLUTION
WITH ENVIRONMENTAL ETHICS



ical considerations have surfaced sufficiently to influence the outcome of this and perhaps future pollution questions. It is vital that the ethical component of environmental policy-making not only be maintained but encouraged, for only through a careful weighing of the relative importance and influence of each higher-order system can the viability of each component be preserved.

The Underlying Assumption

Regardless of the level of resolution at which one views pollution problems and/or environmental policy-making, there exists an underlying motive predicated upon the assumptions that (1) pollution and its negative effects on environmental quality are not desirable and (2) the preservation and quality of human life are desirable. On humanitarian grounds, few could argue this point.

As seen from a systems viewpoint, however, our medical ethic has both negative and positive aspects. As for the negative aspects, modern medical ethics hinder "survival of the fittest" and evolutionary progress by retaining "genetic errors" and by encouraging the perpetuation of disease-prone elements, thus eliminating the selection processes and feedback loops characteristic of natural systems. Based on these observations, some critics may voice opinions such as:

(1) Why should we concern ourselves with the burden of protecting the lives of vegetative masses no longer capable of proper physical functioning

within modern society?

(2) Why not let disease kill off its victims? and

(3) Why not allow industrial pollutants to aid in controlling the population explosion?

All moral and religious "right to live" beliefs aside--and speaking purely from a systems viewpoint--there is a very positive side to medical science and environmental protection: the human brain, as an information storage and retrieval system, represents vast inputs of time, energy, and educational training. The sheer magnitude of the investment in human knowledge perhaps justifies sustaining the not-so-perfect anatomical structure within which the human storage and retrieval system (the brain) is housed.

To preserve life, as well as to enhance its quality, it is necessary to institute controls on the use of the environment. Use of the environment is perhaps best regulated via policies adopted by government, that is, via the political system. As political systems (at least democratic ones) are sustained through the consent of the governed, environmental regulatory policies could prove to be virtually unenforceable if they did not reflect prevalent economic and social priorities and attitudes. Consequently, the goal of environmental quality preservation can only be accomplished in an atmosphere conducive to environmental regulation--and this calls for some revisions in our traditional economic and social attitudes.

Economic Attitudes

Traditionally, we have allowed economic goals and the quantity of goods to monopolize our lives, often at the expense or exclusion of perhaps a more long-term and more valuable concern: the quality of life. This monopoly of our lives is quite understandable in light of the vast powers of persuasion inherent in the capitalistic system. I agree with Galbraith (1971) that, in a market economy such as ours, the idea of the total sovereignty of the consumer is no longer valid. Nor is it even possible when the necessity for large investments of capital, time, and industrial planning is fully realized. Society has little choice but to purchase the goods supplied by the economic system at the prices the system establishes. American industry, through the extremely effective tools known as advertising and price regulation, has within its power the ability to dictate "wants" to the consumer (prime examples: clothing fashions, hula hoops, newer-faster-bigger- automobiles -- even newer-economical-compact automobiles, pet rocks, etc.). Because of the tremendous investments involved, it is only natural that modern American industrial enterprises seek to protect their autonomy and their profits by opposing governmental intrusion and pollution-abatement regulations.

Influencing industry's decision to continue polluting or to abate pollution are economic, environmental, social, and political pressures or encouragements--namely, the presence or lack of pollution control regulations, or incentives such as subsidies and public good will. In the case of Reserve Mining Company, as in many environmental pollution cases, the economic and environmental factions found themselves on opposite sides of the question. Thus developed the typical "tradeoff" situation: human health (as well as ecological and aesthetic consideration) versus status quo industrial operation. This conflict led to the question of the political feasibility of regulating the pollution of Lake Superior in order to reduce the potential risk to human health, while maintaining the economic viability of the Reserve operation.

To maintain its economic viability, American industry is geared to the concept of a substantial margin of profit. Consequently, it is not surprising that services not contributing to profit-making, such as health, education, welfare, and recreation, generally are excluded from the concerns of the industrial system. These services must, therefore, be rendered by the State. As a result, "public" services are placed at a competitive disadvantage when it comes to the expenditure of funds.

Furthermore, aesthetic considerations generally are in conflict with the goals of the industrial system, since pollution-control provisions tend to increase production costs, thereby decreasing the margin of profit and/or increasing the prices of goods. Yet, wholesale degradation of the environment cannot be tolerated. As the champion of environmental protection, the State must oppose environmental degradation as a matter of policy--not, as it has in the past, do so sporadically and only in response to monumental threats to environmental quality and/or human health. Throughout any environmental proceedings, nevertheless, it should be remembered that preservation of environmental quality cannot be achieved without some cost to economic expansion--nor can necessary economic development be accomplished without some degree of compromise in environmental quality. Somehow, a form of balance must be reached which reflects the general attitudes and goals of society.

Social Attitudes

Western man's "pioneer" or "cowboy" ethic regarding the use of the environment is no longer (if it ever was) a valid viewpoint in light of the limited supply of the earth's natural resources. Barring the colonization of other planets, earth men must manage this planet's resources wisely--or life as we know it will perish long before the demise of the earth as a potential life-supporting planet (4-6 billion(?) years hence).

We can no longer regard nature as a free good capable of self-renewal regardless of man's activities. Somehow, human society must come to appreciate the value of protecting environmental quality. But, how can this be achieved in a monetary-minded society that has not been able to place a dollar value on aesthetic concerns? One means of creating public awareness of the cost of pollution is to convert aesthetic values into monetary terms via the concept of energy input. As Odum (1971) contends, a viewpoint with which I strongly agree, it is possible to assign dollar values to ecosystem energies by utilizing the dollar/calorie equivalent characteristic of the industrial economy as a whole (about 10,000 Kcal/dollar for organic fuel-driven work). Thus, the loss of a forest or impairment of water purity can be related to the energy/monetary value of the resource in a non-degraded state.

By placing a monetary value on the cost of environmental degradation, it would then be possible for both direct and indirect costs of production to be reflected in the price of goods. The greater the amount of pollution created by an industrial concern, the greater would be the indirect costs that would have to be added to the direct costs of the firm's goods. The higher the total cost of production, the greater the competitive disadvantage of the firm's products on the open market. Borrowing a term from Hardin (1973), industry must "internalize" the costs of pollution of the "commons"--both in terms of pollution cleanup and prevention of environmental degradation. In using this method, which undoubtedly would have to be implemented via government legislation, it would make it unprofitable for a company to pollute common property resources. This would comprise a 180° reversal of the present situation in which it is actually more profitable to pollute than to adopt pollution-abatement procedures. For, as Hardin points out, the positive utilities derived from the use of the commons traditionally have accrued to the individual, while the costs of environmental degradation, or disutilities, are shared by all who use the commons. Thus, an individual industrial concern can derive maximum benefits from discharging pollutants into the commons, while at the same time shouldering practically none of the costs of pollution. What is needed is some form of feedback mechanism that would force polluting industries to assume responsibility for the pollution created by their activities.

Historical trends aimed at reducing or "enclosing" the commons have testified to the fact that a commons system cannot work in a finite world. Free use of a common property resource by individuals only leads to ruin, since man is ego-centered and therefore tends to overtax the carrying capacity of the commons--this inevitable outcome is the "tragedy of the commons." Unilateral withdrawal on the part of one commons user is ineffective, since his "conscienceless" competitors will proceed to ruin the commons anyhow. To avoid this type of double dilemma, all users of a common property resource must realize that the commons belongs to no single individual. They must view the preservation of the commons as a shared responsibility--that is, as a trusteeship rather than an ownership. But, how can this be accomplished? As Hardin advocates, preservation of the commons can be achieved only through "mutual coercion mutually agreed upon." In other words, it must be done via regulatory laws, despite some loss of individual freedom or national sovereignty.

All of the preceding recommendations hinge upon society's ability to re-evaluate its environmental ethic. A useful concept to employ in achieving this end is that of stressing Darwinian rather than Newtonian philosophy. We must program ourselves to treat processes (the systems approach) rather than states. That is, we must concern ourselves with the treatment of the disease (the "misdirected" societal decisions and outdated environmental ethics currently embodied in the higher-order systems) rather than the treatment of the symptoms (pollution).

Presently, there exist two extremely powerful institutions that can function as means to this end: our educational and religious institutions. To overcome such concepts as "man subduing nature" and "man AND nature," it will be necessary to inject substantial doses of systems-based environmental science into the training of students of religion and education. It is in this area, by the way, that geographers can make a vital contribution. By stressing man's partnership with nature, rather than the "man versus nature" concept, perhaps we can alter our societal values sufficiently to re-instate a basic constitutional right: the right of every individual to a safe life-support system.

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Jeno's, Inc.
Zinsmaster Baking Company
Zinsmaster Hol-Ry Company

APPENDIX A

PLAINTIFFS AND DEFENDANTS IN U.S.A., *ET AL.* v.
RESERVE MINING COMPANY, *ET AL.*

PLAINTIFFS: United States of America
State of Minnesota

PLAINTIFFS-INTERVENORS: State of Michigan
State of Wisconsin
Minnesota Environmental Law Institute
Northern Environmental Council
Save Lake Superior Association
Michigan Student Environmental Confederation
Environmental Defense Fund
The City of Duluth, Minnesota
The City of Superior, Wisconsin

DEFENDANTS: Reserve Mining Company
Reserve's parent companies:
Armco Steel Corporation
Republic Steel Corporation

DEFENDANTS-INTERVENORS: Northeastern Minnesota Development Association
Duluth Area Chamber of Commerce
Village of Babbitt, Minnesota
Village of Beaver Bay, Minnesota
Range League of Municipalities and Civic Associations
St. Louis County, Minnesota
Silver Bay Chamber of Commerce
Village of Silver Bay, Minnesota
Town of Beaver Bay, Minnesota
Lake County, Minnesota
Lax Lake Property Owners Association

TRIAL BACKGROUND (U.S.A. v. RESERVE MINING COMPANY)

The original complaint against Reserve Mining Company, based primarily on ecological issues,[1] was filed by the U.S. on 2 February 1972. The U.S., later joined by the States of Minnesota, Wisconsin, and Michigan, and a number of environmental groups, alleged that Reserve's discharge of taconite tailings into Lake Superior was in violation of Section 13 of the 1899 Refuse Act (33 U.S.C., Sec. 407); Section 10 of the Federal Water Pollution Control Act (33 U.S.C., Sec. 1160); Sections (a)(4), (c)(2), and (c)(6) of Minnesota Regulation WPC 15; and the Federal Common Law of Public Nuisance (as recognized in Illinois v. City of Milwaukee, 406 U.S. 91, 1972). (See APPENDIX B for pertinent provisions of the foregoing acts.) In addition, the States of Minnesota, Wisconsin, and Michigan claimed Reserve was in violation of numerous state statutes, as well as the Company's own discharge permits. (See APPENDIX C for information concerning the permits issued to Reserve Mining Company.)

Following a pre-trial order issued on 12 December 1972, hearings pertinent to the complaint were held in April of 1973.

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[1]Ecological issues had been the basis for an earlier trial (Reserve Mining Co. v. Minnesota Pollution Control Agency, 200 N.W. 2d. 142, Minn., 1972) held in the Lake County District Court from June 22, to August 5, 1970. The Minnesota Pollution Control Agency held that Reserve was in violation of Water Pollution Control Regulation 15 which, in 1969, set forth the water quality standards of the State of Minnesota. Since this standard was unpopular with Reserve, the company took the MPCA to court. Judge Luther Eckman ruled in favor of Reserve, stating that the company was exempt from the WPC-15 regulations.

The case came to trial in the U.S. District Court, District of Minnesota, Fifth Division, St. Paul, on 1 August 1973 and concluded on 20 April 1974, with the ruling by Judge Miles Lord to close Reserve's Silver Bay operations. Pending appeal (Reserve Mining Company, et al., v. U.S.A., et al., 1974-1975), the U.S. Court of Appeals for the Eighth Circuit, St. Louis, stayed Judge Lord's injunction closing Reserve's beneficiation plant. During 1974 this case was referred twice to the U.S. Supreme Court, which returned the case to the Court of Appeals on 9 July and again on 11 October.

On 5 March 1975 the States of Minnesota, Wisconsin, and Michigan once again requested that the United States Supreme Court reinstate the District Court's 20 April 1974 order closing Reserve's Silver Bay plant, since the Appeals Court had not yet made an official ruling. On 14 March 1975 the Eighth Circuit Court of Appeals ruled to allow Reserve to continue discharging its taconite tailings into Lake Superior for a "reasonable time period" during which Reserve was to switch to on-land disposal.

On 6 January 1976 the Appeals Court removed Judge Miles Lord from the Reserve case, charging Lord with "advocacy" and "bias" against Reserve Mining Company. Since that time, the legal aspects of the case have been presided over by U.S. District Court Judge Edward J. Devitt. Soon after assuming his duties, Devitt ordered Reserve to aid in defraying the costs of interim water filtration programs in North Shore communities and, on 4 May, 1976, Devitt fined Reserve Mining Company in excess of $1,000,000 for violating a state water discharge permit and for "bad faith" conduct in court hearings.

Currently, the major issue before the courts, the State of Minnesota, Reserve Mining Company, and various environmental groups and agencies concerns the location of the on-land disposal of Reserve's taconite tailings. Reserve Mining Company favors disposal at what is known as Mile Post 7, located along Reserve's company railroad approximately four miles inland from Silver Bay. Following a permit hearing conducted in May, 1976, Wayne Olson, State of Minnesota Hearing Officer, recommended that Reserve be denied permits for Mile Post 7, contending that Mile Post 20, located along Reserve's railroad about half way between Silver Bay and Babbitt, was an environmentally safer disposal site. On 6 June 1976 the controlling board of the Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources voted, 5-4, to issue Reserve permits for Mile Post 7. The board reversed its decision by a 6-3 vote on 1 July 1976, contending that Mile Post 20 appeared to be a compromise site which appropriately balanced health, safety, social, economic, environmental, and land-use considerations.

On 7 July 1976 Judge Devitt decreed that Reserve Mining Company would have to shut down its Silver Bay operations on 7 July 1977 if the Company and the State of Minnesota had not agreed on a land disposal site by that time. The 7 July 1977 closing date was upheld by the Eighth U.S. Circuit Court of

Appeals.

Reserve appealed the Minnesota Pollution Control Agency-Department of Natural Resources denial of Mile Post 7 dumping permits to the Lake County (Minnesota) District Court. Early in December, 1976, a three-judge panel (including Luther Eckman) ordered the state agencies to issue permits to Reserve for construction of an on-land taconite tailings disposal complex at Mile Post 7. The Minnesota Pollution Control Agency (PCA) and the Department of Natural Resources (DNR) appealed the Lake County District Court decision to the Minnesota Supreme Court. On April 8, 1977, the Minnesota Supreme Court upheld the Lake County District Court ruling that the PCA and the DNR grant to Reserve Mining Company the permits necessary for the construction of tailings basins at Mile Post 7. It appears unlikely that the PCA and the DNR will appeal the Minnesota Supreme Court decision. It is highly probably, therefore, that the July 7, 1977, closing date for Reserve Mining Company will be rescinded to allow the company time to switch to on-land disposal at Mile Post 7 -- a process which will take approximately 2 years.

APPENDIX B

PERTINENT PROVISIONS OF ACTS ALLEGEDLY VIOLATED BY RESERVE MINING COMPANY

1899 REFUSE ACT (33 U.S.C., Sec. 407)

It shall not be lawful to throw, discharge, or deposit, or cause, suffer or procure to be thrown, discharged, or deposited either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water of the United States...and provided further, that the Secretary of the Army whenever in the judgment of the Chief of Engineers anchorage and navigation will not be injured thereby, may permit the deposit of any material above-mentioned in navigable waters, within limits to be defined and under conditions to be prescribed by him provided application is made to him prior to depositing such material.

FEDERAL WATER POLLUTION CONTROL ACT, AS AMENDED IN 1970 (33 U.S.C., Sec. 1151, *et seq*.)

Section 10(c)(5): The discharge of matter into such interstate waters or portions thereof, which reduces the quality of such waters below the water quality standards established under this subsection (whether the matter causing or contributing to such reduction is discharged directly into such waters or reaches such waters after discharge into tributaries of such waters), is subject to abatement in accordance with the provisions of paragraph (1) or (2) subsection g of this section .... (33 U.S.C., Sec. 1160 (c)(5).)

Subsection 10 (g)(2): ...in the case of pollution of waters which is endangering the health and welfare of persons only in the State in which the discharge or discharges (causing or contributing to such pollution) originate, [the Secretary (now Administrator)] may, with the written consent of the Governor of such State request the Attorney General to bring a suit to secure abatement of the pollution. (33 U.S.C., Sec. 1160 (g)(2).)

MINNESOTA REGULATION WPC 15 (1969)

Section (a)(4): Natural Interstate Water Quality. The interstate waters may, in a state of nature, have some characteristics or properties approaching or exceeding the limits specified in the standards. The standards shall be construed as limiting the addition of pollutants of human origin to those of natural origin, where such be present, so that in total the specified limiting concentrations will not be exceeded in the interstate waters by reason of such controllable additions; except that where the background level of the natural origin is reasonably definable and normally higher than the specified standard the natural level may be used as the standard for controlling pollutants of human origin which are comparable in nature and significance with those of natural origin but where the natural background level is lower than the specified standard and where reasonable justification exists for preserving the quality of the interstate waters as nearly as possible to that found in a state of nature, the natural level may be used instead of the specified standard as the maximum limit on the addition of pollutants. In the adoption of standards for individual interstate waters, the Agency will be guided by the standards set forth herein but may make reasonable modifications of the same on the basis of evidence brought forth at a public hearing if it is shown to be desirable and in the public interest to do so in order to encourage the best use of the interstate waters or the lands bordering such interstate waters.

Waters which are of quality better than the established standards will be maintained at high quality unless a determination is made by the State that a change is justifiable as a result of necessary economic or social development and will not preclude appropriate beneficial present and future use of the waters. Any project or development which would constitute a source of pollution to high quality waters will be required to provide the highest and best practicable treatment to maintain high water quality and keep water pollution at a minimum. In implementing this policy, the Secretary of the Interior will be provided with such information as he requires to discharge his responsibilities under the Federal Water Quality Act, as amended.

Section (c)(2): No raw or treated sewage, industrial waste or other wastes shall be discharged into any interstate waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, oil slicks, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, or other offensive or harmful effects.

Section (c)(6): It is herein established that the Agency will require secondary treatment or the equivalent as a minimum for all municipal sewage and biodegradable, industrial or other wastes to meet the adopted water quality standards and a comparable high degree of treatment or its equivalent also will be required of all non-biodegradable industrial or other wastes unless the discharger can demonstrate to the Agency that a lesser degree of treatment or control will provide for water quality enhancement commensurate with present and proposed future water uses and a variance is granted under the provisions of the variance clause. Secondary treatment facilities are defined as works which will provide effective sedimentation, biochemical oxidation, and disinfection, or the equivalent including effluents conforming to the following:

SUBSTANCE OR CHARACTERISTIC	LIMITING CONCENTRATION OR RANGE
5-day biochemical oxygen demand	25 milligrams per liter
Total coliform group organisms	1,000 MPN/100 ml
Total suspended solids	30 milligrams per liter
Oil	Essentially free of visible oil
Turbidity	25
pH range	6.5-8.5

[Minnesota Administrative Rules and Regulations; Rules, Regulations, Classifications and Water Standards, 1969 Supplement, filed with the Secretary of State and Department of Administration June 30, 1969, pp. 4-7.]

APPENDIX C

PERMITS ISSUED TO RESERVE MINING COMPANY BY THE MINNESOTA WATER POLLUTION CONTROL COMMISSION[1]

DATE ISSUED	PROVISIONS
December 16, 1947	original permit; allowed discharge of 130,000 gallons per minute of water used in power production and in beneficiation of taconite (see complete provisions of original permit reproduced below)
Following public hearing on September 25, 1956	permit No. 2; original permit amended to allow for an increase in the waste waters discharged from 130,000 gpm to 260,000 gpm
September 8, 1960	permit No. 3; amended permit allowing for a further increase (up to 502,000 gpm) in the discharge of waste-product waters

PROVISIONS OF THE ORIGINAL PERMIT

Resolution Authorizing Issuance of Permit to Reserve Mining Co.

> Resolved by the Minnesota Water Pollution Control Commission, assembled in special meeting at St. Paul, Minnesota, December 16, 1947, all members being present, as follows:
>
> That the report submitted by the chairman of the commission in the matter of the application of Re-

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[1]From statement and exhibits provided by John P. Badalich, Executive Director, Minnesota Pollution Control Agency, in: Proceedings, Conference in the Matter of Pollution of Lake Superior and its Tributary Basin -Minnesota-Wisconsin-Michigan, EPA, held in Duluth, Minnesota, May 1969, Vol. 4, pp. 1200-1200d.

serve Mining Company, a Minnesota corporation, for a permit to discharge industrial waste be approved and filed, that the findings and recommendations of said report be and hereby are adopted as the findings and conclusions of the commission, and that in accordance therewith the secretary be and he hereby is authorized and directed to issue to said applicant a permit in the following form:

STATE OF MINNESOTA
WATER POLLUTION CONTROL COMMISSION
PERMIT TO DISCHARGE INDUSTRIAL WASTE

Pursuant to resolution adopted by the Minnesota Water Pollution Control Commission December 16, 1947, after due hearing and consideration as provided by law, there is hereby granted to Reserve Mining Company, a Minnesota corporation, in connection with the operation of a proposed taconite iron ore beneficiation plant and power plant located on the shore of Lake Superior N.E. of Beaver Bay in Sec. 6, Twn. 55 N., Range 7 W., and adjacent portions of Sections 5 and 7 in said township and range, and Sections 31 and 32, Twn. 56 N., Range 7 W., in Lake County, Minnesota,[1] for which operation water will be taken from Lake Superior at the rate of approximately 130,000 gallons per minute when operating continuously, a permit to return and discharge into Lake Superior the waters taken therefrom and used in the production of power and in beneficiating taconite in said plants, with tailings from such beneficiation plant in suspension, all upon the following conditions:

(a) The materials processed in said taconite beneficiation plant shall consist only of taconite of the magnetic type from deposits lying in Twn.'s 59 and 60 N., Range 13 W., and

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[1]This is the location of the present Reserve "company town" of Silver Bay, Minnesota.

Twn. 60 N., Range 12 W., in St. Louis County, Minnesota,[1] and shall not include any material quantity of hematite or red oxide of iron.

(b) The tailings discharged from said taconite beneficiation plant shall consist only of the crushed or ground residue of taconite as hereinbefore described after extraction of iron ore therefrom, with the water in which such residue is suspended, and neither such tailings nor the water returned from the power plant shall include any material quantities of matter soluble in water, organic matter, oil, sewage, or other waste except such taconite residue.

(c) For the purposes hereinafter set forth, the following described area is designated as the zone of discharge:

For the purpose of describing said zone of discharge a point called Point "A" is located on the shore of Lake Superior one and one-half miles southwesterly in a straight line from the intersection of said lake shore with the south line of Sec. 32, Twn. 56 N., Range 7 W., in Lake Co., Minnesota, said intersection being the approximate location of the point of discharge; a point called Point "B" is located on said lake shore one and one-half miles northeasterly in a straight line from said intersection; a straight line joining said Points "A" and "B" is designated as the base line; said zone is bounded on the northwesterly side by that portion of said lake shore between said Points "A" and "B", on the southwesterly side by a line running southwesterly from said Point "A" at right angles with said base line, on the northeasterly side by a line running southeasterly from said Point "B" at right angles with said base line, and on the southeasterly side by a line running parallel with said base line and three miles distant therefrom.[2]

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[1]This is the location of Reserve's Babbitt, Minnesota, operations.

[2]This section refers to an area of 9 square miles.

(d) Such tailings shall not be discharged so as to result in any material clouding or discoloration of the water at the surface outside of said zone except during such time as turbidity from natural conditions in the adjacent portions of the lake outside of said zone may be caused by storms, nor shall such tailings be discharged so as to result in any material adverse effects on fish life or public water supplies or in any other material unlawful pollution of the waters of the lake or in any material interference with navigation or in any public nuisance outside of said zone.

(e) The permittee shall acquire all land riparian to the lake shore within the lateral limits of said zone of discharge, or such licenses, releases, or easements as may be necessary to evidence the consent of the owners of such riparian land to the operations of the permittee hereunder.

(f) The granting of this permit shall not impose any liability upon the State of Minnesota, its officers or agents, for any damage to any persons or property resulting from the operations of the permittee hereunder. This permit shall be permissive only, and shall not be construed as estopping or limiting any legal claims against the permittee, its agents or contractors, for any damage or injury to any person or property or to any public water supply resulting from such operations.

(g) The permittee shall comply with all regulations concerning navigation of any federal authority having jurisdiction over navigation, and shall obtain any and all permits from federal authorities that may be requisite for the construction and operation of the facilities covered hereby.

(h) The permittee shall commence substantial construction work upon said taconite beneficiation plant or upon the dock and harbor facilities connected therewith within five years from the date of the permit, and shall continue such construction work with reasonable dispatch thereafter, and shall have at least one unit of said beneficiation plant in operation within ten years after the date of this permit, unless such time or times shall be extended by the WPCC or its successor in authority for good cause shown.

(i) This permit shall be for a term extending without limitation until the permittee shall surrender the same, or until revocation as hereinafter provided.

(j) This permit shall be subject to assignment, but no assignment shall be effective until notice thereof is filed in the office of the secretary of the commission or his successor in authority; provided, that the authorization of the permit so far as it related to water taken from and returned to Lake Superior in connection with said power plant shall be separately transferable by assignment or license so long as the major purpose of said power plant is the production of power for said taconite beneficiation plant and facilities connected therewith.

(k) The permittee shall allow the WPCC or its agents or successors in authority access to and inspection of the permittee's plants, premises, and operations under the permit at all reasonable times for the purposes of investigations and studies of the effects thereof on the interests of the public, and shall cooperate in such investigations and studies.

(l) The permit shall be subject to revocation only for violation of the conditions hereinbefore set forth. Before any such revocation, the WPCC or its successor in authority shall hold a public hearing upon charges specifying the alleged violation, of which at least thirty days notice in writing shall be given to the permittee and if such violation can be corrected the permittee shall be given a reasonable opportunity to correct the same.

Dated at St. Paul, Minnesota, this 16th day of December, 1947.

Minnesota Water Pollution Control Commission

By______________________________

A.J. Chesley, M.D., Secretary