URANIUM IN MICHIGAN
REPORT TO THE GOVERNOR

Prepared by the
Michigan Department of Natural Resources
and
Department of Public Health
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SUMMARY

This report has been prepared at the request of the Governor. It's preparation was stimulated by mining industry interest in leasing approximately 400,000 acres of state-owned lands in the Upper Peninsula for base metal exploration and potential mining development. Uranium was one of the metals of interest. Uranium, with its property of radioactivity, has been a socially controversial element or, more accurately, the use of uranium in the nuclear power industry and in the military have controversial. Thus, when the DNR held public hearings in July of 1980 to receive comments on a proposed metallic lease, two issues were identified. One dealt with the adequacy of the proposed lease and the second with the propriety of leasing state land for uranium exploration and development.

Citizens were concerned with the environmental and health hazards associated with uranium exploration, mining and milling. Uranium mining had never occurred in Michigan, but they had read or of the environmental and public health problems with existing uranium projects in Canada and the western United States. They were worried about the potential development of uranium mining in the Upper Peninsula. Specifically, they questioned the adequacy of existing public health and environmental statutes with respect to uranium exploration and mining and the ability of federal and state agencies to adequately monitor specific mining activities, obtain compliance with permit conditions and pursue enforcement and corrective action, when necessary, in a timely manner.

These concerns expressed to the Governor and in August of 1980 the Governor directed the departments of Natural Resources and Public Health to study the potential environmental and human health risks associated with uranium exploration and mining as well as review the existing regulatory framework under which uranium mining would be out carried out in Michigan. A hold was also placed on the leasing of any state land for uranium exploration and development pending the completion of the report.

In addition to public health and environment associated with uranium exploration and development, there were positions of complete opposition to uranium exploration, mining and milling un the Upper Peninsula on moral, philosophical and religious grounds. It was submitted that the development of uranium mining would aid in the proliferation of nuclear weapons and in the development of nuclear power. These were opined as immoral activities and the state, by entering into leases for uranium, would be acting immorally. This report does not address the social and ethical question to the uranium controversy.

This report does address two issues. 1) A review of the potential environmental and human health impacts relating to uranium exploration, mining and milling. 2) A review of the existing federal and state law in place to regulate uranium exploration, mining and milling.

It is necessary to point out that this report is prospective in nature. Uranium exploration activities currently underway in Michigan are at an early stage of mineral exploration. There are no uranium mines in the state. No state-owned lands are under lease. We view this report as a guide to aid in framing the issues and identifying the existing regulatory controls on uranium mining.

MAJOR OBSERVATIONS

A. Health Effects

1. The health effects of ionizing radiation are divided into acute radiation effects which occur at whole body exposure of 50 rems or more and subacute effects which occur at less than 50 rems. There are also delayed somatic effects which are not expressed for several months or years after the initial exposure and are observed as leukemogenic, carcinogenic or mulagenic changes.

2. Acute radiation effects have been documented from studies of laboratory animals and epidemilogical studies of humans. Human exposure data has been obtained by studying the survivors of nuclear explosions and nuclear weapon testing as well as individuals receiving medical radiation therapy.

3. The health effects of humans exposed to low levels of ionizing radiation (less than 1 rem) is not as completely understood as the health effects of humans exposed to high levels (greater than 50 rems).

4. The health effects of ionizing radiation are known to be dose dependent, but at low levels of exposure (dose) there is scientific debate on the exact cause-effect (dose-response) relationship and at which point exposure has no further biological effect.

5. For purposes of setting radiation standards to protect the general public and occupational workers, international, national and state scientific advisory boards and regulatory agencies take a conservative approach and assume for the purposes of risk assessment there is no threshold limit for low levels of ionizing radiation and that fraction of individuals affected would be proportional to the dose down to zero.

6. Radiation standards are developed to cover occupational workers and the general public and the basic goal of the standards is to set the maximum permissible dose as the highest dose of ionizing radiation that is not expected to cause appreciable bodily injury to a person at any time during his or her lifetime.

7. Naturally occurring or background levels of ionizing radiation in the United Stats and in Michigan is approximately 100 mrems/year (0.10 rems).

8. The recommended average annual exposure standard for the general public established by the National Council on Radiation Protection and Measurement is 170 mrems/year.

9. The federal government has established a radiation exposure limit on uranium fuel cycle facilities including uranium mining, milling, fuel fabrication, power plants and waste disposal. Under this radiation standard, the general public is not to receive more than 25 mrems/year exposure.

10. In the United States there are approximately 311,000 naturally occurring cancer deaths year. The lifetime risk of cancer death for a population exposed to 100 mrem (average U. S. background radiation level) is 0.9 to 4.8 deaths per 100,000 deaths in the population.

11. Epidemiological studies of uranium miners indicate the incidence of lung cancer is greater than expected for the general population and is estimated to be 13 cases per one million per year.

12. There is an occupational exposure risk associated with working in a uranium mine and mill. Under present standards with 5,000 rem/year maximum worker exposure limit, 4.5 to 24 in 10,000 deaths would be expected to occur as a result of occupational exposure to radiation.

B. Uranium Exploration

1. Uranium exploration in the Upper Peninsula over the 30 years has centered in eight counties (Baraga, Chippewa, Dickinson, Gogebic, Iron, Marquette, Menominee and Ontonagon). To date, surface and subsurface drill hole exploration has not resulted in a commercial uranium deposit and results indicate the uranium occurrences are small localized with uranium concentrations of than 1.0 percent.

2. The majority of the world's known uranium reserves are in Precambrian rocks. The Precambrian age rocks of the Upper Peninsula presents a similar geologic environment and it is assumed that the potential for economic uranium deposits exist in Michigan. However, in most places the Precambrian

rock is under a deep cover of glacial drift material which increases the difficulty for exploration and mine development.

3. Uranium exploration drilling on public and private land is subject to regulatory control of local units of government (county, township, municipal) through the power of zoning established by the County Rural Zoning Enabling Act (P.A. 183 of 1943).

4. Uranium exploration drilling on public and private land is subject to regulatory control in Michigan through the Mineral Wells Act (P. A. 315 of 1969).

5. There is a provision in the Michigan Wells Act which exempts a test well driller from the necessity of obtaining a permit prior to drilling test wells in areas with Precambrian rock directly underlying unconsolidated surface deposits. Since the areas of interest to uranium companies in the Upper Peninsula primarily include Precambrian rock with unconsolidated surface formations, a permit is not required.

C. Uranium Mining, Milling and Reclamation

1. Even if an uranium ore body is discovered in 1982, whether on private or public land, a uranium mine will not start up immediately in the Upper Peninsula. The decision to initiate a uranium mining operation is dependent on economic as well as geologic factors. The Federal Trade Commission studied the economic structure of uranium industry and concluded it takes 8 to 12 years from initial exploration to commencement of mining as representative of the average time period.

2. At the local level, uranium mining and milling is subject to local zoning authority the County Rural Zoning Enabling Act (P.A. 183 of 1943).

3. At the state level, uranium mining and milling is subject to state control under Part 135 of the Public Health aide (P.A. 368 of 1978), but this is limited to the mine wastes and uranium ores and does not include the uranium product (yellowcake) or the uranium mill tailings which are regulated by the federal government.

4. At the state level, radioactive air and water pollutants from uranium mines and mills are subject to regulation under the Public Health Code (P.A. 368 of 1978) to insure that the off-site concentrations do not exceed state exposure limits.

5. At the state level, non-radioactive air and water pollutants released into the atmosphere, surface or groundwaters of the state from a uranium mine and mill is subject to the state Air Pollution Act (P.A. 348 of 1965) and Water Resources Commission Act (P.A. 245 of 1929).

6. At the state level, radioactive mill tailings are specifically excluded from regulation under the Hazardous Waste Management Act (P.A. 64 of 1979), but non-radioactive solvents and certain chemicals may fall under regulation of this Act.

7. At the state level, mine reclamation is subject to the Mine Reclamation Act (P.A. 92 of 1970, as amended) for only open pit mines. Shaft mines are exempt from regulation under this Act.

8. At the federal level, uranium mining and milling is subject to the Atomic Energy Act of 1954, the Resource Conservation and Recovery Act of 1976 and the Uranium Mill Tailings Radiation Control Act of 1978. Uranium mines and mills must receive a federal license prior to mining and milling.

9. At the federal level, exposure of miners to radioactive contaminants from uranium mining and milling is subject to the federal Mine Safety and Health Act of 1977.

10. At the federal level, mine reclamation is subject primarily to the Uranium Mill Tailings Radiation Control Act of 1978.

CONCLUSIONS

A. Uranium Exploration

1. The Mineral Wells Act provides a sufficient basis to regulate uranium exploration drilling and promulgation of additional legislation is not necessary.

2. If uranium exploration permits are written to insure proper site preparation, mud and drilling pit construction, casing of the drill hole, cementing of the hole upon completion of data collection and sufficient soil coverage of mud pits and site restoration, the radiological and environmental impacts will not pose a health risk to the general public.

3. The exemption for obtaining a permit in areas of Precambrian rock with unconsolidated surface formations should be reviewed in light of uranium exploration. It does not provide for the prior review of a specific drilling plan nor allow for the inclusion of specific safeguards in a permit. The driller is under no obligation to identify the proposed well location or disclose his drilling, cementing or abandonment procedures for up to two years after drilling the hole. Thus, it is difficult for the regulatory agency to know the location, inspect the well site and operations carried out to determine if they are sufficient to prevent surface or underground waste.

In light of the public concern over uranium exploration, it would be proper for the health and welfare of the general public to require submission of permit applications for uranium exploration in the Precambrian rocks. It would appear that the statute gives the supervisor the power to set aside the existing permit exemption through the execution of a special order to control pollution or eliminate a hazardous condition. It appears a public hearing before the supervisor and the mineral well advisory board is required to take evidence on the need for the exemption.

4. Notwithstanding the conclusion that uranium exploration does not pose a significant health hazard to the general public, it is recognized that individual members of the public will remain unconvinced or skeptical. If uranium exploration is going to continue to be permitted and not prohibited by legislative action, it is recommended that the uranium mining companies improve their public relations with local government officials, landowners and public. It is our opinion that attempts by companies to conduct their activities in a secretive manner will only contribute to the fear and suspicions of the public. An open and public of questions and answers will aid in seeking a resolution.

5. The moratorium on leasing of state owned mineral rights for uranium exploration in the Upper Peninsula should be lifted.

6. Local units of government should review existing zoning ordinances and develop appropriate land use plans and ordinances for uranium as well as other metallic mineral exploration.

B. Uranium, Mining, Milling and Reclamation:

1. The ability to eliminate or minimize adverse public health and environmental impacts of uranium mining is keyed to three factors: the existence of <u>sufficiently</u> stringent regulatory laws, the ability of local state and federal agencies to <u>effectively</u> administer those laws and <u>conscientious</u> self-monitoring by the uranium Industry.

2. Presently, there is a regulatory framework in existence and uranium mining in Michigan would be subject to the requirements contained in these statutes. There are at least four federal, six state and one local statute which apply to one or more aspects of uranium exploration, mining, milling and reclamation.

3. There is not within the existing regulatory framework in Michigan a statute that addresses uranium mining in a comprehensive manner or any other metallic mineral mining.

4. In the case of uranium, the federal government has enacted the Uranium Mill Tailings Radiation Control Act of 1978 that incorporates a comprehensive review of uranium mining, milling and reclamation.

5. With respect to uranium mining, the Governor and Legislature have four options available either individually or in combination to regulate it.

a. Maintain the status quo and use existing federal and state statutory framework to regulate uranium mining,

b. Obtain federal delegation from the Nuclear Regulatory Commission for administration of Uranium Mill Tailings Radiation Control Act of 1978 as an agreement state.

c. Legislatively enact a comprehensive mining statute for Michigan to cover uranium mining as well as other metallic mineral mining.

d. Establish a formal Board of Inquiry to review site-specific uranium mining proposals and make findings and recommendations to the Governor on approving or restraining specific uranium mining projects. (This should be designed along the lines of inquiries conducted in Australia and Canada).

6. The implementation of agreement for state delegation for the administration of the Uranium Mill Tailings Radiation Control Act of 1978 from the Nuclear Regulatory Commission or the enactment of a state metallic mineral mining statute will require several years effort.

7. Until there is an indication of a commercially feasible uranium discovery and project proposal, the state need not initiate extension manpower or financial appropriations to implement the options identified in B-5. In light of the observation that a long lead time is necessary (4-6 years) in developing a uranium mining operation once an ore body is discovered, there would be sufficient time to provide for an orderly and open public review and legislative action relative to uranium mining, milling and reclamation.

8. The state need not become a federal agreement state now. There is an existing state and federal regulatory framework in place. A final determination on agreement status should be undertaken if uranium exploration indicates the development of an uranium mine is highly likely rather than a remote possibility.

9. Local units of governments could review existing zoning ordinances and consider appropriate zoning regulations for uranium mining and reclamation.

10. This report does not address the social and ethical question to the uranium controversy. While the matters of a factual nature in this dispute can be elucidated and resolved through scientific and engineering studies, the social and ethical values in dispute do not reside solely with the scientific and engineering community and administrative bodies. These are matters whose resolution lies within the political forum.

I. INTRODUCTION - PROPOSED METALLIC MINERAL LEASE

In 1980, the Department of Natural Resources (DNR) held two public hearings in Marquette and Lansing, Michigan, on July 17 and 24, respectively to receive public and industry comment on a proposed metallic mineral lease. The public hearings attracted approximately 300 people at Marquette and approximately 30 people at Lansing. The majority of those in attendance and providing public comments at Marquette were residents of the local communities, property owners, county and state elected officials. Out of the 64 speakers, there were only four industry representatives. The hearing in Lansing was attended primarily by industry representatives with 10 of 12 speakers representing industry's viewpoints. The public hearings very clearly identified two issues:

1. A significant difference of opinion existed between the mining industry and general public on the need for and the hazards associated with uranium exploration, mining and milling in the Upper Peninsula. Consequently, the mining industry favored the leasing of state land for uranium exploration and development and the public generally opposed it on state and private lands.

2. The mining industry and majority of the general public did not find the proposed lease instrument acceptable for adoption.

The stimulus for drafting the proposed lease was an unprecedented number of mining industry requests to lease state owned mineral rights for metallic mineral exploration and development in the Upper Peninsula. The applications were received by the department from 1975 through 1980. However, they did not come in at a uniform rate. The first applications, received in 1975, totalled only 17,361 acres. Then, in a six month period (January-June 1976) additional applications brought the total number of acres to 268,000. By the end of 1976 that total reached 460,000 acres. Since January of 1977, however, some applications have been withdrawn. As of June, 1980, pending applications total 390,599 acres. The DNR had never received such a large number of requests nor had as many acres nominated for metallic mineral leases.

In fact, mining industry interest in state lands in the Upper Peninsula in the last 40 years has been relatively low. Although the state owns approximately two million (19%) of the 10.5 million acres in the Upper Peninsula, the DNR, as administrator of state owned mineral rights, had leased only 87,659 acres for metallic mineral exploration and development, including leases for iron, copper and uranium. At the time most of these inquiries were submitted (1975 to 1977), about 3,900 acres were under lease for copper, iron and other metallic minerals.

Most of the 141 mineral leases entered into by the state between 1943 and 1976 granted the right to explore and develop only a single mineral. Industry was usually interested in a single target mineral, such as copper or iron. The present industry interest in a spectrum of metallic minerals within a single lease is a new development.

These industry applications were also significant not only for the acreage requested, but also because of the mineral of interest. A number of applications identified uranium as the target mineral. Historically, there had been very little interest in uranium in Michigan. Of the 141 mineral leases granted, only 11 were for uranium exploration and development (Table 1).

Type of Lease	*Lease Activity*	*Leases Granted*	*Leases Active*	*Acres Leased*	*Acres Under Lease (12-31-79)*
Iron	*1944-1967*	*73*	*3*	*33,682*	*200*
Uranium	*1948-1962*	*11*	*0*	*1,115*	*0*
Copper	*1953-1972*	*26*	*9*	*11,306*	*3,263*
Metallics	*1965-1973*	*31*	*3*	*41,556*	*440*

Table 1. A summary of mineral leases issued by the Department of Natural Resources from 1944 to 1976, the acres leased and under lease as of December 31, 1979.

County	*Number of Townships*	*Fee Ownership*	*Mineral Only Ownership*	*Total*
Marquette	*23*	*91,007*	*39,532*	*130,539*
Dickinson	*8*	*91,190*	*14,741*	*105,931*
Iron	*19*	*38,937*	*38,346*	*77,283*
Baraga	*17*	*40,305*	*17,883*	*58,188*
Menominee	*5*	*11,003*	*2,038*	*13,041*
Chippewa	*3*	*2,405*	*0*	*2,405*
Gogebic	*5*	*0*	*2,632*	*2,632*
Ontonagon	*2*	*0*	*540*	*540*
	82	*274,847*	*115,712*	*390,559*

Table 2. State mineral ownership (acres) requested by mining industry for leasing in the Upper Peninsula as of June, 1980.

These were issued between 1948 and 1962. Uranium discoveries were limited, no mining development occured and all the leases expired. Apparently, the uranium mining industry shifted its efforts in the United States to the western states, where uranium exploration in the 1950's and 1960's led to commercial mining development.

Presently, there are mining industry applicants interested in leasing state land for uranium-thorium. Other applicants are also interested in acquiring state leases to explore for minerals other than uranium, including nickel, lead, zinc, manganese, gold, copper, iron and molybdenum. Their interest centers on state mineral ownership in Marquette, Iron, Baraga, Dickinson and Menominee counties. Out of the 390,559 acres of interest for leasing, 384,982 acres (98.6%) are located in these five counties with the remainder (5,577 acres) located in Chippewa, Gogebic and Ontonagon counties (Table 2 and Figure 1).

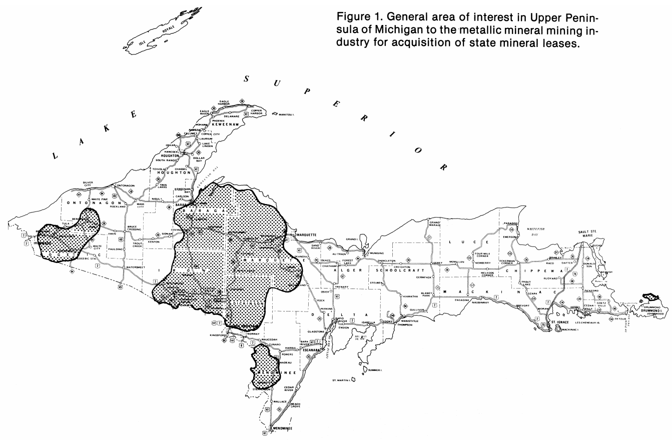

Figure 1. General area of interest in Upper Peninsula of Michigan to the metallic mineral mining industry for acquisition of state mineral leases.

A. PUBLIC RESPONSE TO PROPOSED LEASE

A central question surfaced as a result of industrial and environmental organizations comments at the public hearings: Is a lease solely an economic instrument or can it include environmental provisions as well? Industry averred that the lease should be solely an economic document between the parties. It should not include environmental protection provisions whose inclusion is redundant, since federal and state environmental and public health legislation exists to provide environmental protection and assure worker safety. They pointed out that any metallic mineral exploration and mining, whether conducted under state, federal or private mineral leases, must be done in compliance with all applicable federal, state and local statutes and rules. Additionally, they noted that a number of environmental permits will be required in any mining development, and that each has a specific permit review process with provision for public input and review prior to a federal or state agency decision to approve or deny the permit. They also point out that often an environmental impact assessment (EIA) or environmental impact statement (EIS) is by required by law.

For example, at the federal level, the National Environmental Policy act of 1970 places a duty on federal agencies, including the Environmental Protection Agency (EPA) and the Nuclear Regulatory Agency (NRC) to consider the overall environmental impact of a project requiring a construction and/or operating permit under specific federal statutes administered by these agencies. Correspondingly, at the state level, under the provisions of the Michigan Environmental Protection Act of 1970 (MEPA) regulatory agencies have a duty, in weighing the merits of issuing or denying a permit under specific legislation, to consider the environmental and health impacts beyond the narrower limits of each permit application. That is, an agency must read the specific statute in concert with the MEPA in arriving at a decision.

Further, since 1974, under the direction of the Governors Executive Order 1974-4 creating the Michigan Environmental Review Board, the state agencies in carrying out their own projects or granting approval to projects proposed by the private sector must consider the overall environmental impact. They can, at their discretion, declare a project to be a major state action and require the preparation of an environmental impact statement by the project's sponsors as part of the permit review. And, as a check against an agency acting arbitrarily in its decision to declare a project a major or minor state action, the Michigan Environmental Review Board can, in the presence of substantial public controversy, petition the Governor to direct the agency to declare the project a major state action and prepare a environmental impact statement. And, to ensure a public review all major actions must be submitted to the MERB for its review prior to the issuance of any state permits associated with the project. Thus, industry believes there is a sufficient regulatory framework in place to address site specific environmental issues and to provide for public input.

While the public and environmental representatives did not comment directly on the relationship between the proposed lease and the existing environmental-public health regulatory framework in place at the federal and state level, they did share with industry representatives a fear of uncertainty over future mining activities for the life of any metallic mineral leases entered into by the state. While there is no factual dispute over the existence of environmental and public health statutes in place, there is disagreement between industry and environmentalists over the degree of protection provided. The environmental comments express concern in two areas; first, in the adequacy of standards contained in the statues and second, in the ability of the federal and state agencies to adequately monitor specific mining activities, obtain compliance with permit conditions and pursue enforcement in a timely manner.

Since environmental legislation, like all legislation, is forged in the political arena, it is subject to future amendatory action. Concern was expressed that environmental controls incorporated to date in regard to mining are not lost at some time in the future. Thus, the commenting environmentalists view it desirable to include certain environmental provisions as part of the state metallic mineral leases. Thus, one of the two major concerns expressed at the public hearings focuses on the inclusion or exclusion of environmental protection clauses in the proposed state leases.

B. Public Response to Inclusion of Uranium In Proposed Lease

However, equally predominant, if not the main concern of general citizen and environmental speakers, was the propriety of allowing uranium exploration, mining and milling in the upper peninsula under any conditions. Speakers in favor of and in opposition to the granting of state mineral leases for uranium stated their position with emotion. It was clear to the DNR representatives conducting the hearing that polarization was evident and achieving a mutually acceptable solution to all parties would be, to say the least, difficult. As the proposed lease was drafted, it granted the right to the Lessee to explore and develop any uranium or thorium discovered in or upon the leased land. Those opposed to uranium exploration and mining expressed the view that the state should not include radioactive elements in any state metallic mineral leases. Specifically, they expressed the following concerns:

1. It was submitted that development of uranium mining in the Upper Peninsula would aid in the proliferation of nuclear weapons. It was further stated that Michigan by consenting to uranium exploration and mining would be, if not directly, at least tacitly approving the expansion of the global nuclear arms race. It was also opined that warfare is immoral and the state, by allowing uranium exploration and mining, would be acting immorally.

2. It was submitted that the development of uranium mining would aid in the development of the nuclear power industry. A belief was stated that nuclear power generation involves substantial public risk due to the possibility of accidental releases of radioactivity and the generation of high level radioactive wastes. It was also feared that expansion of the nuclear power industry involves increased risk of nuclear war as a result of the availability of plutonium produced in reactors for use in the production of atomioc explosives. It was expressed that the risk of nuclear sabotage and theft by terrorists and criminal groups would be enhanced through uranium mining development.

3. It was submitted that the exploration for uranium would release radon gas to the atmosphere in the process of coring and drilling when an uranium ore bearing formation was encountered. The concern was expressed that “interrupting the integrity” of the earth’s crust would increase the possibility or uranium and randon contamination of groundwater and drinking supplies. Thus, the exploration activity would pose a health risk to workers, visitors to areas of exploration drilling and residents on adjoining property.

4. It was submitted that past monitoring of exploration core holes by the state on private and state land had been inadequate to protect public health.

5. It was submitted that the past disposal of low and high level uranium tailings by industry had created public health hazards and environmental contamination in the western United States and Canada. It was also expressed that containment of uranium tailings required isolation for decades and even centuries due to the long half life of the radioactive waste. There was concern that the funding and regulatory monitoring of the tailings containment structures would be inadequate to ensure integrity of the containment site and prevent air, surface and groundwater contamination.

6. It was submitted that the intrusion of uranium mining (industrial development) in the Upper Peninsula was incompatible with the recreational, wildlife and forestry values of the area.

7. It was submitted that the economic benefits in direct employment, secondary employment, taxes and royalty revenue generated by uranium mining would not outweigh the social and environmental losses.

8. It was submitted that radon poses the principal radiation hazard in uranium mining and, in the past, workers have experienced health problems and death as a result of exposure to radon in the process of mining and milling the ore.

9. In light of recent discoveries of contamination of soil, ground and surface water in Michigan (Hooker Chemical Company, Muskegon County) and elsewhere in the United States (Love Canal, New York), it was submitted that little trust existed in the mind of the public that governmental regulatory bodies can or will effectively monitor uranium mining projects to protect the public health and environment from radiation hazards.

10. It was also submitted that the public wanted absolute assurance that an accident would not occur during or after the completion of uranium mining that would lead to exposure of public and environment to a radiation hazard.

In addition to the positions expressed against leasing of public land for uranium mining, a review of the hearing tapes reveals six distinct positions relative to uranium exploration and mining on either public or private land in the Upper Peninsula:

1. There were positions of absolute opposition to uranium exploration, mining and milling the Upper Peninsula under any condition on moral, philosophical and religious grounds.

2. There was a position of conditional opposition to uranium exploration, mining and milling due to past industrial and governmental errors that led to radiation exposure of workers, general public and environmental contamination.

3. There was position of for uranium exploration, mining and milling in the Upper Peninsula based on the improved governmental safety and environmental regulations and improved industrial awareness, which should greatly reduce or eliminate the likelihood of repeating the uranium mining errors noted in the 1950's and 1960's.

4. There was a position neither in opposition nor in support of uranium exploration and mining at this time, but in light of the past and present environmental and public health impacts, these individuals were interested in reviewing more data before taking a position. They favored a careful, thoughtful public review prior to any decision.

5. There was a position in opposition to uranium exploration and mining, but not opposition to the state entering leases for nonradioactive metallic minerals.

6. There was a position in opposition to the state entering any leases for any type of mining.

As a result of the DNR public hearings and the corresponding news coverage, knowledge of the potential for uranium exploration and developement in the Upper Peninsula became more widely known. More citizens became concerned with possible public health and environmental impacts associated with uranium mining. They spoke and wrote to their elected officials at the local, state and federal level in late July and August, 1980. They commented that they were unaware of the potential prior to the hearings. Uranium mining had never occurred In Michigan, but they had read or heard of environmental and public health problems with existing uranium projects in Canada and the western United States. There were confused and worried about the development of uranium mining in the Upper Peninsula.

Further, four local units of government in the Upper Peninsula adopted resolutions opposing the leasing of state land for uranium exploration and mining (Table 3). They requested immediate suspension of all negotiations on the lease until open public hearings are held in each county and also sought the cessation of uranium exploration on private and public land by all companies and individuals. They received support from the Charlevoix county Board of Commissioners in the Lower Peninsula.

Local unit of government	*Date of Resolution*
Delta County Board of Commissioners	*August 12, 1980*
Township of Bates - Iron County	*August 13, 1980*
Charlevoix County Board of Commissioners	*August 13, 1980*
Township of Portage - Houghton County	*August 14, 1980*
Baraga County Board of Commissioners	*October 14, 1980*

Table 3. Local units of government that adopted resolutions indicating opposition to the leasing of state land for uranium exploration and mining.

Not all local units of government voiced formal opposition to uranium leasing. Marquette, Dickinson, Iron and Menominee counties (four of the five counties with state land of interest to mining companies) did not, to the state's knowledge, take a formal position. Also, the state is not aware of any formal position taken by other township boards within the eight counties of interest (Table 2).

In addition to units of government, the Marquette Area Chamber of Commerce (July 15, 1980) and the Ishpeming Chamber of Commerce went on record in support of mineral leasing by the state and expressed concern over the lease as drafted. It is their position that the lease as written was a disincentive to mineral development rather than an incentive. They encouraged resumption of negotiations to develop an acceptable lease. Also, the Michigan State Chamber of Commerce, by resolution of its Board of Directors (October 28, 1980), supported the leasing of state owned minerals in 1981 immediately following the release of the report to the Governor. The Chamber also supported the inclusion of uranium in the lease while the Upper Peninsula Environmental Coalition (UPEC) adopted a resolution in November of 1980 to oppose exploration and mining for radioactive materials in the Upper Peninsula. This resolution contains the following nine reasons for their opposition.

1. It is an established fact that ionizing radiation is harmful to living tissues.

2. While dangers associated with exploration appear to be minimal, little systematically collected data on radiation levels at drilling sites have been gathered to confirm this theoretical assumption.

3. Likewise, no systematically gathered background radiation data exist for present conditions in the Upper Peninsula with which to make comparisons.

4. Without a defined policy, particularly on private lands, there appears to be little citizen control over whether radioactive materials, if discovered in commercial quantities, are mined and processed.

5. With regard to mining, the record of corporations and government regulatory agencies in controlling radioactive tailings in Ontario and New Mexico has been poor, resulting in environmental damage and human illness.

6. There has been practically no experience with uranium mining under the soil and moisture conditions existing in the Upper Peninsula.

7. The economic benefit for residents of the Upper Peninsula do not appear to offset the potential health and environmental risks involved.

8. The use of uranium for electrical generation represents a continued philosophy of dependence upon non-renewable sources and detracts from necessary efforts to develop renewable energy sources.

9. Mining and concentrating radioactive materials contribute to a growing unresolved global problem of radioactive waste disposal.

C. Governor's Response To Public Concern

On August 14, 1980, Governor Milliken, in a news release, directed the departments of Public Health and Natural Resources to study the potential environmental and human health risks associated with uranium exploration and mining. Although each department had some expertise and knowledge of the properties and effects of radioactive elements, neither had direct administrative experience with uranium mining. Due to the absence of uranium mining in Michigan, it had not been necessary to establish a regulatory program. However, it was recognized that the questions raised at the public hearings required an answer. In order to assure citizens in the Upper Peninsula that state lands would not be leased prior to completion of the study, the Governor directed that state lands not be leased for uranium mineral rights.

In addition, the Natural Resources Commission in August of 1980, in responding to objections over the language in the proposed metallic mineral lease, directed staff to enter once more into negotiations with the mining industry to seek a mutually acceptable metallic mineral lease instrument. The meetings should include representatives from environmental interests who had expressed concern over the proposed lease as well. These negotiations were to be conducted while this study was being prepared.

D. Scope Of The Report

It is within this controversial framework that this report enters. The likelihood of this report resolving the issues at hand is remote. The resolution of the uranium controversy is clearly in the political arena. The ultimate decision or decisions involve the weighing of factual, social and ethical issues. Perhaps this is best expressed by the Australian Commission of Inquiry in 1977 in its Ranger Uranium Environmental Inquiry Report (1). The three-member Commission, appointed by the Prime Minister, noted that:

> "ultimately, when the matters of fact are resolved, many of the questions which arise are social and ethical ones. We agree strongly with the view, repeatedly put to us by opponents of nuclear development, that, given a sufficient understanding of the science and technology involved, the final decisions should rest with the ordinary man and not be regarded as the preserve of any group of scientists or experts, however distinguished."

This report will address two issues.

1. A review of the potential environmental and human health impacts relating to uranium exploration, mining and milling.

2. A review of the existing federal and state law in place to regulate uranium exploration, mining and milling.

In doing so, it is necessary to point out that this report is prospective in nature. Uranium exploration activities currently underway in Michigan are at the early stages of mineral exploration. There are no uranium mines in the state. No state-owned lands are under lease. Thus, this report is generic in scope and not site specific. We view this report as a guide to aid in framing the issues and identifying the existing regulatory controls on uranium mining. It is our hope that it will educate and thereby aid in the timely resolution of the uranium controversy through the political process.

II. URANIUM MINING CONTROVERSY

A. Eastern States

Social controversy over the question of uranium exploration and mining in the Upper Peninsula should not be considered a phenomenon limited to Michigan. In the late 1970's, the uranium mining industry had become interested in the eastern United States and was actively seeking leases and conducting exploration programs in several states, including Virginia, New Jersey and Vermont. However, local opposition resulted in industry interest falling off on exploration along the eastern seaboard. Towns in New Jersey and Vermont passed restrictive ordinances and Vermont requires legislative approval prior to the operation of any uranium mine (2).

Closer to home, this controversy was voiced not only in Michigan in 1980, but in Wisconsin and Minnesota as well. As in Michigan, the controversy surfaced in response to ongoing or proposed uranium exploration on private and state lands. And, as for Michigan, neither Minnesota nor Wisconsin presently lease state land for uranium exploration. The Minnesota legislature in 1980 passed a statute which placed a moratorium on the leasing of state owned mineral rights for uranium until July 1, 1981. It also directed the Minnesota Environmental Quality Board to prepare a report describing what regulatory controls are necessary for uranium exploration and uranium mining by the same date (3). In a separate, but related action, the Legislative Commission on Minnesota Resources provided $25,000 to the Minnesota Department of Natural Resources in 1979 to prepare a report on the possible environmental impacts of uranium mining and milling in Minnesota. This report was completed in June, 1980. It was not site specific and drew no conclusions on whether uranium mining or milling should or should note be conducted in Minnesota (4).

Wisconsin, after much legislative debate, did not adopt a resolution in opposition to uranium exploration and mining. But, as in Minnesota, the legislature did adopt a statue to regulate the drilling of core holes for uranium exploration (5). Both states are also conducting monitoring programs to measure the randon release from uranium exploration drilling activity (4, 5).

B. Western States

This shift in public attitude on uranium mining, whether well founded or ill perceived, has also occurred in the western states. Public objection to uranium mining surfaced in Montana and South Dakota in 1980. Opponents of uranium mining called for a legislative ban. The issue was put before the voters in the fall of 1980. Montana adopted a citizen referendum banning the disposal of radioactive waste material in Montanna from uranium mining and nuclear power facilities. It did not ban uranium mining, only the disposal of by-products (tailings) in Montana (6). A citizen initiative in South Dakota placed on the ballot a proposal to require a statewide vote prior to the issuance of any state permits for each proposed uranium mining project. This proposal was defeated (7).

Not all the opposition to uranium mining is related to radiation hazards. For example, in the South Dakota Black Hills, an arid region with limited water resources, farmers, ranchers and local communities also view the development of uranium mines as another demand on the water resources of the region (2).

Historically, the greatest production of uranium in the United States has occurred in the western states of New Mexico, Colorado, Texas, Utah and Wyoming. The production from the 280 openpit and underground mines accounted for 90 percent of the U.S. production. The United States, as of 1975, was the leading producer of uranium. It accounted for 45 percent of world production. Throughout the early 1970’s uranium exploration and development was expanding. This was stimulated, to a large extent, by forecasts on the expansion of nuclear power plant programs. For example, in 1977 the U.S. had 69 operating nuclear power plants and federal government forecasts estimated an additional 100 reactors would be operating in the late 1980’s. Since virtually all uranium mined in the U.S. is sold to government and public utilities, the expansion of uranium mining looked promising (2,8).

New Mexico was the center of U.S. uranium production. In 1977, it supplied approximately half of the nation's processed uranium and 18 percent of the world output. But, as of August, 1980, one-fifth of New Mexico's uranium miners were laid off. According to a wall street Journal article of August 26, 1980, the uranium boom is collapsing in New Mexico due to "falling prices and uncertainty over the future of nuclear power since the Three Mile Island accident last year" (8).

C. Australia and Canada: Two Examples

The worldwide governmental response to the uranium mining controversy is varied. The examples covered here should not be considered selected or slanted to represent or favor a particular viewpoint or outcome. They are not meant to be inclusive of all governmental worldwide. They are merely illustrative. An exhaustive study was not conducted.

Australia

In 1970, Peko Mines Ltd. and Electrolytic Zinc Company of Austral Ltd. conducted a joint aerial survey over the Ranger area in the Northern Territory of Australia approximately 220 kilometers east of Darwin. This survey detected radiation anomalies and follow-up investigations confirmed the presence of rich uranium deposits. In 1975, the Commonwealth Government through the Australian Atomic Energy Commission entered into a joint venture with these companies to mine the ore and export the yellowcake (composed of 90% $U_3 O_8$) to other nations.

In July of 1975, the Prime Minister and Minister of State for the Environment, under the authority of Environment Protection (Impact of proposals) Act of 1974 directed that an inquiry be conducted on the proposed Ranger Uranium Mine. Under the regulations of the Act, a three member commission was appointed to carry out the inquiry. The commissioners were provided with nine advisors with expertise in various aspects of mining, ecology, public health, economics and law. (1) The inquiry was called, under the Act, to receive comments and make findings and recommendations to the Prime Minister and Minister of State for the Environment on approving or restraining uranium mining at the Ranger project site. All evidence was submitted by witnesses under oath at public hearings with each witness subject to cross-examination by any other witness upon approval of the commission. The commission could also receive written verified statements and could receive evidence in private when satisfied it was desirable to do so in the public interest.

The Commission of Inquiry was required to work within the following framework:

"The Commission Is required to inquire:
in respect of all the environmental aspects of:
(a) the formulation of proposals;
(b) the carrying out of works and other projects;
(c) the negotiation, operation and enforcement of agreements and arrangements;
(d) the making of, or the participation in the making of, decisions and recommendations; and
(e) the incurring of expenditure, by or on behalf of, the Australian Government and the Australian Atomic Energy Commission and other authorities of Australia for and in relation to the development by the Australian Atomic Energy Commission in association with Ranger Uranium Mines Pty Ltd of uranium deposits in the Northern Territory of Australia.”

The Environmental Protection (Impact of Proposals) Act of 1974 provided the Minister of State for Environment with the discretionary authority to require the preparation of an environmental impact statement by the proponents of a project and make the document available for public comment. An environmental impact statement was prepared, notices placed in newspapers and public hearings held in seven cities.

The Ranger Uranium Environmental Inquiry is divided into two reports. The first dealt with generic issues not covered in the site specific EIS. The first report considered whether "the use of uranium in the nuclear power industry carried with it risks and danger of such a nature and magnitude that Australia should not export it, or mine it at all." The hearing for the first report began on September 9, 1975, and concluded in August of 1976. A total of 281 persons gave evidence and 354 exhibits were submitted. The transcript of evidence covered 12,575.

The second report dealt with the array of issues intimately associated with the site specific mining proposal as identified in the EIS. With respect to the second report, 303 witnesses presented evidence and 419 exhibits were received. The total transcript covers 13,525 pages. The cost as of April of 1977 was over $800,000.

The first report was submitted to the government in October, 1976, and the second in May, 1977. The inquiry and preparation of the report covered 22 months. The two reports are 206 and 415 pages, respectively. The transcript record exceeds 26,000 pages.

Whatever the merit of this inquiry, its scope was wide and encompassed virtually all aspects of the uranium controversy. For example, the first report addressed the following items:

- The Basics of Nuclear Power
- The Present Status of Nuclear Power
- World Energy Consumption
- Energy Resources
- The Contribution of Nuclear Power to World Energy Requirements
- Uranium: Supply and Demand
- Benefits and Costs of Exporting and No Exporting
- Hazards of the Nuclear Fuel Cycle
- Environmental Hazards of Non-Nuclear Energy Sources
- Safeguards Against Diversion to Weapons-making
- Nuclear Theft and Sabotage
- Weaknesses of the Nonproliferation Treaty (NPT) and of the Safeguards System

The Commission developed 15 findings and recommendations with respect to the generic issue. They, like the issues raised, are broad in scope. Throughout the recommendations, there is the clear recognition of the need for continual diligence and precaution in the development of Australian uranium mining policy. The recommendations were advisory only. While approving the continuation of uranium mining development in Australia, it also called for the development of a national energy policy with the development of energy conservation and full research and development on energy resources other than fossil fuels and nuclear fission.

In its second report, the Board of Inquiry ruled on the adequacy of the EIS and potential site-specific impacts of the projects.

> "The Ranger project as proposed, and in the land use setting which was assumed, should not in our view be allowed to proceed. On the other hand, if the plan we propose is accepted, and the various matters we recommended in relation to it, and to the mining operations themselves, are carried out, the adverse environmental consequences of the proposal can be kept with acceptable limits. Every step in our recommendations is designed to ensure that a reasonable accomodation is reached between the proposed mining venture and the conflicting environmental values and interests."

The Ranger uranium project was authorized, but a number of limitations were placed on it to minimize adverse environmental and public health impacts.

Canada: Saskatchewan

In Saskatchewan, Canada, at about the same time (1976-1977) as the Australian Ranger Uranium Site Board of Inquiry was in process, the Minister of Environment asked the Saskatchewan Cabinet for a public inquiry on an uranium mine proposal submitted to the Department of the Environment by Amok Ltd. Amok Ltd. proposed to develop a mine in northern Saskatchewan near Cluff Lake. Saskatchewan already had two existing uranium mines at Uranium City and Rabbit Lake, but public opposition was raised over development of Cluff Lake project (9).

On February 1, 1977 the Cluff Lake Board of Inquiry was appointed. The Inquiry conducted formal and local hearings. The formal hearings were conducted in 5 months (April-September 1977) in Regina and Saskatchewan. The actual hearings required 67 days of direct testimony from 138 witnesses. The hearing record produced 10,786 pages of testimony plus 556 pages of summations.

After the formal hearings were held, local hearings were held at 23 locations throughout Saskatchewan to receive citizen input in contrast to the technical and scientific evidence presented by scientific experts at the formal hearings. These hearings were held between October 3 and 27, 1977 and attended by about 1,268 persons with 30 organizations and 260 individuals presenting comments.

Prior to the local hearings a public information and education program was developed. It included 25 town hall meetings where a speaker in favor and in opposition to nuclear power presented their respective viewpoints and the audience could ask questions of each. It also included radio and television presentations similar to the town hall format. Other efforts were made to stimulate public interest in the nuclear issue and make readily accessible to the public any information obtained during the course of the inquiry.

As part of the Inquiry and to allow public interest groups to participate in the Inquiry's formal hearings, 100,000 dollars was provided as grants to those groups lacking funding. A Financial Review Panel was established to review proposals from public interest groups and recommend which groups should be funded.

The Cluff Lake Board of Inquiry were to conduct the inquiry under the following obligations:

1. review all available information on the probable environmental, health, safety, social and economic effects of the proposed uranium mine and mill at Cluff Lake;

2. facilitate the provision of information to the public;

3. receive public comment on any matter related to the proposed development, including the social, economic and other implications of expansion of the uranium industry in Saskatchewan;

4. determine if the measures proposed by Amok Limited to protect environmental quality meet the requirements of Canadian and Saskatchewan law, regulations and policies and to report on the adequacy of such laws, regulations and policies;

5. determine if the measures proposed by Amok Limited to safeguard health and safety meet the requirements of Canadian and Saskatchewan law, regulations and policies and to report on the adequacy of such laws, regulations and policies; and

6. recommend to the Minister of the Environment whether the project should proceed, should not proceed, or proceed subject to specified conditions.

In the conducting of the Cluff Lake Inquiry, the Board:

1. will receive briefs, both written and oral, from individuals and organizations;

2. will organize and conduct public hearings in such places as the Board believes necessary to allow the public a reasonable opportunity to present their views;

3. will arrange for the proceedings of the hearings to be recorded and transcribed, and no later than November 1, 1977, the Board will:

(a) prepare a report of its findings and recommendations; and

(b) forward its report and a transcript of the proceedings of the public hearings to the Minister of the Environment."

As a result of the formal and local hearings which included 13,524 pages of transcript and 377 exhibits, a report entitled "Final Report: Cluff Lake Board of Inquiry" was completed (May 1978) and submitted to Minister of Environment with a recommendation to proceed in developing the uranium mine provided specific environmental and public health standards were followed.

A significant conclusion centered on the adequacy of laws and policies and the ability of the regulatory agencies to effectively enforce the laws as stated in the following findings of the report.

> "Adequate standards, adequate proposed methods to meet the standards, and adequate laws to enforce the standards will not be sufficient to protect the workers at the proposed Cluff Lake mine and mill unless:
>
> (a) Amok strictly compiles with its undertaking to implement those proposed methods, and
> (b) those laws are rigorously enforced by the appropriate regulatory agencies, namely The Atomic Anergy Control Board and the Occupational Health and Safety Division of the Department of Labour of Saskatchewan.
>
> Whether the laws are rigorously complied with, and whether sufficient inspections will be carried out to ascertain If (and to ensure that) Amok strictly complies with its undertaking as to methods, will depend in large measure upon the number of competent personnel the Government of Saskatchewan makes available to the Occupational Health and Safety Division to properly and fully carry out the duties cast upon that Division by the law."

Both the Ranger Inquiry in Australia and the Cluff Lake inquiry in Saskatchewan, Canada are well documented examples of extensive public review on the uranium issue and worth reviewing directly for those who wish to go beyond the scope of this report.

Canada: British Columbia

In addition to the previous studies, the government of British Columbia initiated a similar type of inquiry on the question of uranium mining and its related environmental, health and social issues. The inquiry was established in January, 1979, but it did not complete the review. In February, 1980, the British Columbia Cabinet voted to terminate the inquiry and by statute placed in effect a seven year moratorium on uranium development in the province. As of this date, the moratorium is still in effect and no legal challenges have been made on It (10).

D. Nuclear Power Controversy and Uranium Mining

The uranium mining industry's future in New Mexico and elsewhere in the U.S. is closely linked to the future of the nuclear power industry. In fact, many in the uranium mining industry believe it is too closely linked in the eyes of the public. For example, the disposal of high level radioactive nuclear power plant waste, an issue of substantial controversy for the past two decades, affects the uranium mining industry. They believe that if the nuclear waste disposal issue is not resolved, uranium mining will continue to shrink rather than expand in the United States (8). They also see the environmental issues surrounding nuclear power production spilling-over onto uranium mining. They find that a burden is placed upon them to not only explain their actions, but those that relate to the nuclear power fuel cycle in general.

In addition to the market place uncertanties facing uranium mining and the social controversy over nuclear power generation, a shift in public opinion is occurring or has occurred in the western states with active uranium mines (8). For example, environmental, public health and worker safety issues in New Mexico have emerged. The rupture of United Nuclear's tailings dam near Gallup, New Mexico in 1979 spilled tons of radioactive material into the Rio Puerco River and on a nearby Navajo reservation (11). In a review of this accident, the Nuclear Regulatory Commission found that the contamination of ground water presented a long-term problem. In light of this incident, and other published reports of problems with containment of uranium tailings, the New Mexico government has tightened waste regulations and raised the taxes on the Industry (8).

While uranium mining is still occurring in the western states and most residents do not oppose it, the complex socioeconomic-legal issues are far from resolution. In recent years law-suits have been filed in New Mexico to halt or limit uranium mining (8). Opponents of nuclear power generation view the blocking of uranium mining (on the front end of the nuclear fuel cycle) and blocking of nuclear waste disposal (on the tail end of the nuclear fuel cycle) as a means to slow down or stop nuclear energy development.

Proponents of uranium mining see this criticism from segments of the public as an overreaction. They contend that uranium mining, when measured against other types of mining, industrial and commercial activities carried out in the United States, is no more or less of an environmental or public health risk. While conceding there are potential adverse environmental and public health impacts, there are technological and engineering solutions through properly designed and operated facilities. While the uranium mining industry questions the magnitude and impact of past accidents associated with uranium mining used by environmental organizations to illustrate their opposition, they generally do not deny them, but point out the increased federal and state regulatory programs now in place in response to those incidents. From a long-term public health aspect, it is postulated by supporters of uranium mining and nuclear power generation that nuclear power should be viewed as a means of cleansing the earth of radioactivity.

This reasoning is described by Bernard L. Cohen in a June, 1977 Scientific American article (12).

"If one is to consider the public health effects of radioactivity over such long periods, one should also take into account the fact that nuclear power burns up uranium, the principal source of radiation exposure for human beings today. For example, the uranium in the ground under the U.S. is the source of the radium that causes 12 fatal cancers in the U.S. per year. If it is assumed that the original uranium was buried as securely as the waste would presumably be, its eventual health effects would be greater than those of the buried wastes. In other words, after a million years or so more lives would be saved by uranium consumption per year than would be lost to radioactive waste per year.

The fact is, however, that the uranium now being mined comes not from an average depth of 600 meters but from quite near the surf ace. There it is a source of radon, a highly radioactive gaseous product of the decay of radium that can escape into the atmosphere. Radon gas is the most serious source of radiation in the envionment, claiming thousands of lives in th U.S. per year according to the methods of calculation used here. When this additional factor is taken into account, burning up uranium in reactors turns out to save about 50 lives per million years for each year of all-nuclear electric power in the U.S., more than 100 times more than the life that might be lost to buried radioactive wastes.

Thus on any long time scale nuclear power must be viewed as a means of cleansing the earth of radioactivity. This fact becomes intuitively clear when one considers that every atom of uranium is desitined eventually to decay with the emission of eight alpha particles (helium nuclei), four of them rapidly following the formation of radon gas.

Through the breathing process nature has provided an easy pathway for radon to gain entry into the human body. In nuclear reactors the uranium atom is converted into two fission-product atoms, which decay only by the emission of a beta ray (an electron) and in some cases a gamma ray. Roughly 87 percent of these emission processes take place before the material even leaves the reactor; moreover, beta rays and gamma rays are typically 100 times less damaging than alpha-particle emissions, because their energies are lower (typically by a factor of 10) and they deposit their energy in tissue in less concentrated form, making their biological effectiveness 10 times lower. The long-term effect of burning uranium in reactors is hence a reduction in the health hazards attributable to radioactivity."

However, opponents to nuclear power production disagree with this position. They content that the health impact calculations of uranium mining and tailing disposal by nuclear industry proponents do not take into account future deaths from nuclear-generated electricity. This line of reasoning is described by David Dinsmore Comey in a September 1975 Bulletin of the <u>Atomic Scientists</u> article (13).

> "Last year an article in the Bulletin by Bernard L. Cohen opened with the above provocative statements. The health impact of 50 deaths per gigawatt-year from coal-fired plants was almost entirely due to sulfur oxides released from the plant

stack. The health impact of 0.01 deaths per gigawatt-year from a nuclear plant came from radioactive effluents released during normal plant operation, and assumed there would be no deaths from nuclear plant accidents. Other compairsons by nuclear proponents have reached similar conclusions…

…How could such enormous health effects have been overlooked? Probably because almost everyone has focused on emissions from the nuclear power plants and virtually ignored the other end of the uranium fuel cycle…"

The other end of the uranium fuel cycle is the mining, milling and tailings disposal. It is his position that uranium mine tailings will be responsible for at least 394 deaths per gigawatt-year instead of 0.01 deaths per gigawatt-year. He also states another position on the long-term impact.

"Based on the foregoing, it would seem to be a myth that the lethal health effects from coal-generated electricity are 5,000 times greater than the lethal health effects of nuclear-generated electricity as estimated by Cohen and others. The deaths induced by the decay of thorium-230 in uranium mill tailings alone seem to swing the statistics in the reverse direction, and further analysis of other parts of the nuclear fuel cycle may identify additional health effects that have been overlooked.

The Atomic Industrial Forum, the American Nuclear Society and others may argue that very few of the thorium-induced deaths will occur during our lifetimes, and that it is unfair to make such a comparison of current deaths from coal-generated electricity with future deaths from nuclear-generated electricity. But that makes the disparity a moral issue: Do we have the right to consume electricity from nuclear fission plants for the next few decades forcing thousands of future generations to suffer the lethal consequences?"

E. Commonality of Uranium Controversy

One can observe from the formal inquiries conducted in Australia and Canada and the debate in the United States over nuclear power a commonality in the issues and viewpoints held by proponents and opponents to uranium mining. It makes no difference whether the proposed uranium mining was in Australia, Canada or the United States, the generic issues are relatively constant. For example, the following excerpt from the Australian Commission of Inquiry on the Ranger Uranium Environmental Inquiry states the issues rather well (1).

"It was submitted that there dangers associated with the various operations of the fuel cycle, from the mining of uranium to the production of power in reactors, that there were serious and unresolved problems concerning the disposal of radioactive wastes, that there were risks of terrorist theft and use of plutonium, and that there were increased risks of nuclear war flowing from nuclear proliferation. It was contended that the continuing development of the nuclear power industry would produce greater inequality between the developed and undeveloped countries, and that this, as well as being undesirable in itself, was likely to lead to increased international tension. It was submitted that, taken alone, some of those matters constituted sufficient ground for not mining, and that taken together they certainly did so. The central proposition was that, if Australia supplied its uranium to the industry, it would be contributing in some measure to each of those hazards and problems and that therefore it should not do so. To some extent, the argument rests simply on ethical values. In some important aspects, such as the dangers of high-level wastes, of terrorism and of proliferation, practical considerations affecting Australia arise. The submission was that mining should not take place at all, or should at least be postponed until it was clear that major problems, such as the disposal of wastes, had been overcome.

"In further support of the submission, it was put that on economic grounds nuclear energy was not a satisfactory source of power, that it could only in any event offer a temporary way out of the energy problems of the countries wanting to use it, and that other sources of energy were preferable and could be developed. It was also submitted that nuclear power programs were less securely established than had been made to appear, and that there might well be a revulsion against them overseas. It was put that, for these and other reasons, the use of nuclear power would not develop as projected, with the consequence that there would be less demand for uranium and the profits would be less than predicted by the proponents and by others who support mining.

"The submissions and arguments mentioned were encountered by the proponents and by other witnesses. It was submitted that often the hazards were exaggerated by opponents of nuclear power, in some respects greatly so; that the economic social suffering which would occur if nuclear energy were not developed would be greater than the hazards inherent in nuclear power; that the nuclear industry in all its aspects had to date a very good safety record, not least in relation to harm from radioactivity; that the hazards concerned had been exhaustively investigated by various authorities, were well understood and were under control; that the nuclear industries in countries likely to purchase our uranium were closely regulated and supervised; that the problem of high-level wastes had been virtually overcome by the proposal for vitrification and geological disposal; that the risk of terrorist activities was recognized and guarded against; that the safeguards systems provided sufficient protection against diversion and proliferation; that the operation of nuclear power stations was cleaner and involved less risk to people and the physical environment generally than fossil fuel stations; that a number of countries needed nuclear power, and a number had become dependent on it, at least in the short term; that the governments of many countries had accepted nuclear power, and it was not to the point, even if it were correct, to say that there was a large body of opposition to nuclear power development in their countries; that there was a considerable assured market for uranium; that (according to some witnesses) there was a risk that if permission to mine was not given soon, the market might shrink and prices drop because of the projected introduction of fast breeder reactors; and that the profits to be made were very good. It was submitted that, if Australia did not supply uranium, others would, and its abstention would make no difference in kind or degree to the presence of such hazards, difficulties and problems as there were,

"An argument of a different kind relied upon by the parties opposed to mining was that if Australia were to decline to mine and sell its uranium specifically because of the hazards and problems involved, and were to announce its policy to the world, this would be likely to have an important effect in restricting further nuclear development, if not in actually causing a cut-back. The answer of the proponents, and others, was that such a course would be most unlikely to have the effect sought, but that, if it were desired to improve further the position in relation to the hazards and problems referred to, this could best be done if Australia were a supplier to the industry.

"The proponents, and witnesses supporting their viewpoint, took the view in relation to some matters (not including, for example, proliferation) that such risks and problems as now exist are relatively minor, are of the order ordinarily accepted in everyday living, and will in all probability be overcome before they become at all or serious. It would be time enough to adopt a more draconian attitude if and when it was found that they getting serious, and appeared intractable. Their opponents took more into account the long term future, as they saw it. They of the view that humanity should not have to suffer added risks, even if they may not be great, and that the nuclear industry should be to required to demonstrate that risks, particularly from radioactivity, were virtually negligible, before being allowed to develop any further. Associated with this viewpoint was the fear that if nuclear development was not stopped very soon, the industry would develop a momentum of its own, and be beyond effective control.

Some of the opponents placed reliance on a view that people in the developed countries should simplify their life styles appreciably, so as to decrease the demand on non-renewable energy resources such as coal, oil and nuclear fuel. The scope for energy conservation even with existing life styles, was emphasized."

Another common thread noted is the often lack of objectivity among proponents and opponents. Although each individual believes in his/her objectivity, the zeal to persuade can often cloud personal objectivity. Again, the Australian Commission of Inquiry reflects on this factor as obsesrved in their hearings (1).

"In considering the evidence, we have found that many wildly exaggerated statements are made about the risks and dangers of nuclear energy production by those opposed to it. What has surprised us more is a lack of objectivity in not a few of those in favour of it, including distinguished scientists. It seems that the subject is one very apt to arouse strong emotions both in opponents and proponents. There is abundant evidence before us to show that scientists, engineers and administrators involved in the business of producing nuclear energy have at times painted excessively optimistic pictures of the safety and performance, projected or past, of various aspects of nuclear production. There are not a few scientists, including distinguished nuclear scientists, who are flatly opposed to the further development of nuclear energy, and who present facts and views opposed to those of others of equal eminence."

"A few of the publicists for nuclear development characterize their opponents as lobbyists or dissidents, or worse. We would wish to make it quite plain that before us the opposition has come from a wide cross-section of the general community, and we would not be prepared to conclude that their motives and methods are any less worthy or proper, or intelligently conceived, than, in general, are those of the supporters of nuclear development."

Another common factor noted in the governmental responses described here is the fact that a study, whether elaborate or simple, does not produce a clear-cut conclusion. The studies merely lay out the viewpoints and supporting data for them. The ultimate decision is still a value judgment. In these democratic nations, the decision is reached by an elected political body. Thus, faced with the relatively similar array of issues, the Saskatchewan legislative elected to pursue the development of uranium mining in that Province while the British Columbia Legislature chose to place a moratorium on uranium exploration and mining. In the United States, some states have had and continue to have uranium mining (I.e., Colorado, New Mexico) while other states have enacted partial moratoriums on uranium mining (i.e., Vermont, Montana).

Thus we see that the public controversy over uranium mining has not been limited to the United States. Uranium mining development in Australia and Canada has stirred citizen objections. The central issue elsewhere and here in Michigan is: Should the government permit uranium mining and if so, under what conditions?

III. URANIUM IN PENINSULA OF MICHIGAN

A. Uranium

Uranium is a silver white metal that consists of the three semistable radioactive isotopes; uranium-238, uranium-235 and uranium-234. It is an important energy source because fission of uranium-235 releases large amounts of energy. This readily fissionable nuclide constitutes only about 0.7 percent of natural uranium. Uranium-238 makes up most of the remaining 99.3 percent and the uranium-234 only about 0.005 percent. Uranium-238 is not readily fissionable, but under neutron bombardment it converts to plutonium-239 which is fissionable.

Uranium was discovered in 1789 by Marten Klaproth in pitchblende from a mine in Germany. The element was first isolated in 1842. Radioactivity was first discovered in 1896 and radium, a daughter of uranium decay, was discovered by the Curies and Bemont in 1898 in pitchblende from Joachinsthal, Czechoslovakia, where the mineral had been known since 1727.

In the early 1900's radium became important in medical therapy. This led to a search for the ore as a source for radium. The first Important sources of radium besides Czechoslovakia were the uranium-vanadium sandstone deposits in western Colorado and eastern Utah and from 1898-1923 about 275,000 tons of ore were produced. This ore yielded about 200 grams of radium, 2,000 tons of vanadium and a small but indeterminate amount of uranium. Most of the uranium went into the tailings basins.

In 1913, the U.S. deposits supplanted as the source of radium by the large and rich Shinkolobew vein deposit in the Belgium Congo. In 1933 production began from another vein deposit, the Eldorado at Port Radium, Northwest Territories, Canada. Thereafter, the market was shared by Canada and the Belgium Congo. Only minor amounts of uranium-vandium sandstone ore were mined from 1924-1935.

In 1936, mining of uranium-vandium ores markedly owing to increased demand for vandium. In anticipation of the development of controlled nuclear fission, the United States in 1940 to recover uranium from tailings discarded during the radium and vandium operations and by the end of 1947, a total of 1,440 tons of uranium oxide (U_3O_8) had been produced. In addition, the U.S procured about 10,150 tons of U_3O_8 from outside sources, mainly Canada and the Belgium Congo (14).

Uranium has a number of commercial and research uses. However, the predominant commercial use is as a nuclear fuel for civilian power reactors. It is also used in U.S. government nuclear programs including weapons, propulsion, underground tests, research and development and space applications.

Relatively small quantities of depleted uranium are used in specialized non-energy applications of the unique properties of elemental uranium. This form, depleted in the fissionable isotope and therefore not suitable for nuclear use, is one of the most dense metals. It readily alloys with other metals to form stable compounds and is easily fabricated. Only about 10 percent of the annual industrial demand for uranium involves these nonenergy applications.

Because of its higher density, depleted uranium is better suited than lead and other dense metals for gamma-ray and x-ray shielding. Containers made of depleted uranium for radioactive materials require less weight and provide better protection. They vary in size from a few pounds to many tons.

Density and ease of fabrication make depleted uranium particularly suitable for missle ballast, for control surface balancing and counterweights in aircraft and space vehicles, and for payload simulation in test space vehicles. Castings are made in a variety of shapes and sizes, weighing up to several hundred pounds.

Depleted uranium also has a number of other nonenergy uses. Research and development on structural and mechanical properties of depleted uranium by the U.S. Army Materials Command resulted in demand for ordinance use. Uranium alloys, particularly with molybdenum and titanium, are useful for a wide range of military applications, including equipment parts, ammunition and special purpose artillery shells.

Early uses of uranium were in the chemical, ceramic and glass industries. A uranium-antimony oxide catalyst is used in the plastics industry for the production of acrylonitrile. Uranium is also used as a colorant in glass and ceramics and in steel and nonferrous metallurgy. In the electrical industry it is used for targets in x-ray tubes, electrodes in ultraviolet light sources and resistors in incandescent lamps (15).

There have been several surveys for radioactive minerals in the Northern Peninsula and analytical results have been reported in various ways. For example, the amount of uranium may be reported as percent uranium (U), percent uranium oxide (U_3O_8), percent uranium oxide equivalent (eU_3O_8), or as parts per million (U_3O_8) ppm.). Equivalent refers to measurement on a mechanical device that measures total radioactivity which could include uranium plus thorium plus radioactive potassium. The radioactivity of groundwater is normally reported in parts per billion (ppb.).

B. Geologic Occurrence

Uranium in Michigan has only been found in the western part of the Northern Peninsula. The bedrock geology of this area consists of a thick series of diverse and complex rocks combined under the general name of Precambrian. These rocks are characterized by their extreme age. Radiometric dating indicates they were formed between 3.5 and 1.0 billion years ago. Michigan's Precambrian rocks have been and remain an important source for iron ore and copper. These rock formations are exposed throughout eight counties in the western Northern Peninsula, an area of approximately 8,900 square miles. These Precambrian rocks are divided into the Lower, Middle and Upper Precambrian based on specific events which occurred over geologic time.

LOWER PRECAMBRIAN

The oldest rocks (Figure 2) are principally submarine lavas and pyroclastics with minor sediments. Pyroclastics are made up of varying sizes of volcanic debris consisting of rock fragments and ash. The Lower Precambrian volcanic rocks have a low radioactive background. A few sample analyses have been reported and these indicate a content of less than 2 parts per million (p. p.m.). A prominent sedimentary series of rocks in central Dickinson County contains layers of lenses of quartz-pebble conglomerate. It has been postulated that the conglomerate may have some potential for uranium, but no data is available.

The Lower Precambrian volcanic rocks are intruded by granitic rocks (Figure 2) of various compositions. Where the granitic rocks have assimilated pre-existing volcanics and sediments they are called gneisses. The granitic rocks were emplaced in two stages approximately 3.5 and 2.7 billion years ago.

A number of anomalous radioactive prospects have been located in the granitic rocks. For the most part they are thin fracture fillings and local in extent. Selected samples are as high as 0.11 percent uranium. In a recent regional study, 58 widely scattered samples indicate a range of 2--35 ppm uranium (16).

MIDDLE PRECAMBRIAN

Middle Precambrian rocks in Michigan (Figure 3) are a thick succession of sediments and volcanics, principally conglomerate, quartzite, dolomite, slate, iron-formation, volcanic lavas and associated pyroclastics. The Middle Precambrian has been subdivided into four groups which, from oldest to youngest have been named the Chocolay, Menominee, Baraga and Paint River Groups and are illustrated on Figure 4. The Chocolay and Menominee Groups now occur in widely separated ranges or districts. The Baraga Group covers the largest area and is more contiguous. The Paint River Group is contained in a completely isolated basin. Middle Precambrian deposition began some 2.1 billion years ago and ended some 1.9 billion years ago.

Chocolay Group

Figure 3 depicts the distribution of rocks and Table 4 shows the rock type and maximum thickness of individual rock layers of the Chocolay Group. No anomalous uranium of significance has been reported in Chocolay Group rocks. One sample of the quartzite was analyzed and contained 10.7 ppm. eU_3O_8.

The volcanic rocks have not exhibited radioactivity above background which is less than 2 ppm.

Menominee Group

Figure 3 shows the distribution of Menominee Group rocks and Table 5 the layered rock succession, rock type and maximum thickness.

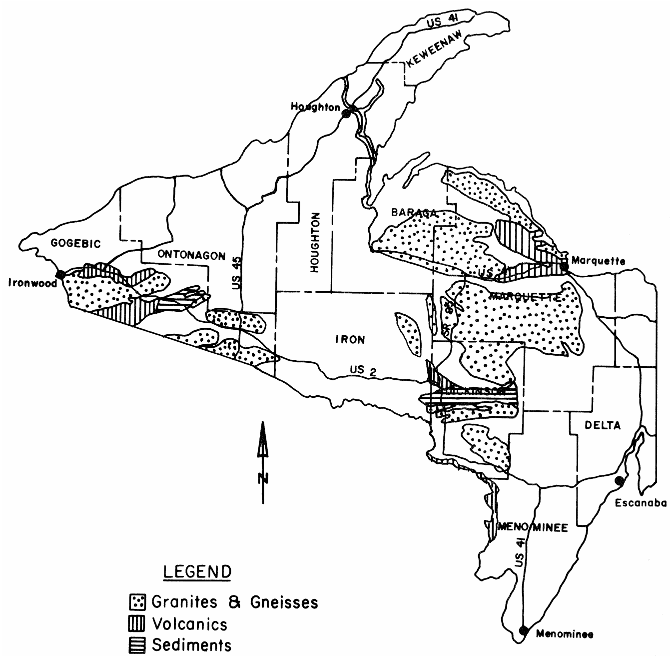

Figure 2. Distribution of lower precambrian sediments, volcanics, granites and gneisses.

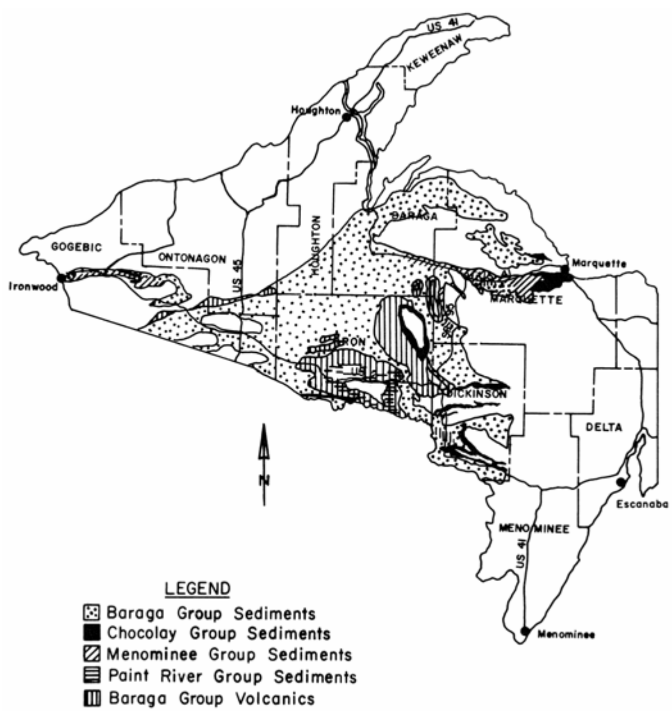

Figure 3. Distribution of middle precambrian chocolay, menominee, baraga sediments and volcanics and paint river group sediments.

Radiometric measurement of Menominee Group rocks have not indicated exceptional radioactivity. The average is on the order of 2 to 3 ppm. The quartzite and slate have been measured at 12.4 ppm. and 6.6 ppm.

eU_3O_8 in anomalous areas. The rocks indicated in black on Figure 4 represent most of the major productive iron formations in Michigan. Radioactivity of the iron formations is about that of background or less than 2 ppm.

	Rock Type	Maximum Thickness (feet)
UPPER PRECAMBRIAN (Keweenawan)		
Upper Keweenawan	*Sandstone*	*12,000*
	Shale	*700*
	Conglomerate	*6,000*
Middle Keweenawan		
	Volcanics	*8,000*
	Volcanics	*13,000*
Lower Keweenawan		
	Volcanics	*15,000*
	Volcanics	*4,400*
	Quartzite	*300*
MIDDLE PRECAMBRIAN		
Paint River Group		
	Slate	*4,000*
	Magnetic Slate	*200*
	Graywacke	*500*
	Iron Formation	*800*
	Slate	*1,500*
Baraga Group		
	Volcanics and Sediments	*15,000*
	Slate	*20,000*
	Ferruginous Slate & Iron Formation	*1,800*
	Volcanics & Sediments	*23,000*
	Quartzite & Conglomerate	*1,400*
Monominee Group		
	Iron Formation	*3,500*
	Slate	*3,100*
	Quartzite	*1,000*
Chocolay Group		
	Slate	*1,500*
	Dolomite	*2,500*
	Quartzite	*2,000*
	Slate & Conglomerate	*3,500*
LOWER PRECAMBRIAN		
	Granitic Intrusive Volcanics	*24,500*

Table 4. Stratigraphic Succession of Precambrian Rock Formations in the Northern Peninsula of Michigan.

Baraga Group

Figure 3 illustrates the distribution of Baraga Group sedimentary rocks and Baraga Group volcanic rocks. Table 5 indicates the rock type succession and maximum thickness of rock units.

In the sedimentary rock sequence of the Baraga Group, the lower quartzite conglomerate layers contain relatively large amounts of monazite near Palmer, Marquette County. Monazite is a complex mineral consisting of rare earth oxides, thorium and some uranium. Analysis of whole rock samples show thorium (Th) ranging from 500 to 2,300 ppm. and uranium from 20 to 62 ppm. U. This deposit may be a potential future source of thorium. It is the largest resource of radioactive material now known in the Northern Peninsula.

The slate formation covers a very large area of the Baraga Group. The formation includes other rock types including graphitic carbonaceous slate and minor iron formations. Locally, in several areas, anomalous samples containing uranium have been located and analyzed. Along the Huron River in northern Baraga County an iron formation sample ran 215 ppm. U_3O_8. Selected drill core samples ran .009 to .0016 percent U_3O_8 and averaged .001 to .002 percent. In central Baraga County samples from an old graphite quarry contained .005 to .037 percent U_3O_8 and iron formation from the same general area contained .003 to .068 percent U_3O_8. Iron formation west of Ishpeming in Marquette County showed .001 to .034 percent eU_3O_8. Selected samples of iron formation and graphite slate from abandoned mine dumps near Gwinn in Marquette County, show up to 0.1 percent e U_3O_8. Along Green's Creek in Marquette County, northwest of Gwinn, channel samples of ferruginous slate ran 0.004-0.036 percent U. Selected samples ran up to 0.1 percent U_3O_8.

Paint River Group

Figure 3 shows the distribution of Paint River Group rocks as contained within a triangular shaped basin. Table 5 indicates the rock type and maximum thickness of the rock succession.

Anomalous radioactivity in the Paint River Group is confined to the iron formation and the underlying slate. The upper 20-50 feet. of the basal slate immediately beneath the iron formation is a pyritic graphitic carbonaceous slate that contains 30 to 45 percent pyrite and 5 to 15 percent carbon. A scintillometer survey of the mines and mine waste dumps in this district revealed numerous anomalous samples of iron formation and black slate. The normal radioactive content of the unoxidized iron formation is about 0.001 percent eU_3O_8; that of the graphitic slate is higher, on the order of 0.003 to 0.004 percent eU_3O_8. The highest value analyzed was 0.513 percent eU_3O_8 from an iron mine 1,000 feet below the surface. Many other anomalous samples in this district were analyzed and contain 0.02 to 0.041 percent eU_3O_8. It must be emphasized that anomalous areas are local in extent and as far as it is now known these do not represent a minable resource.

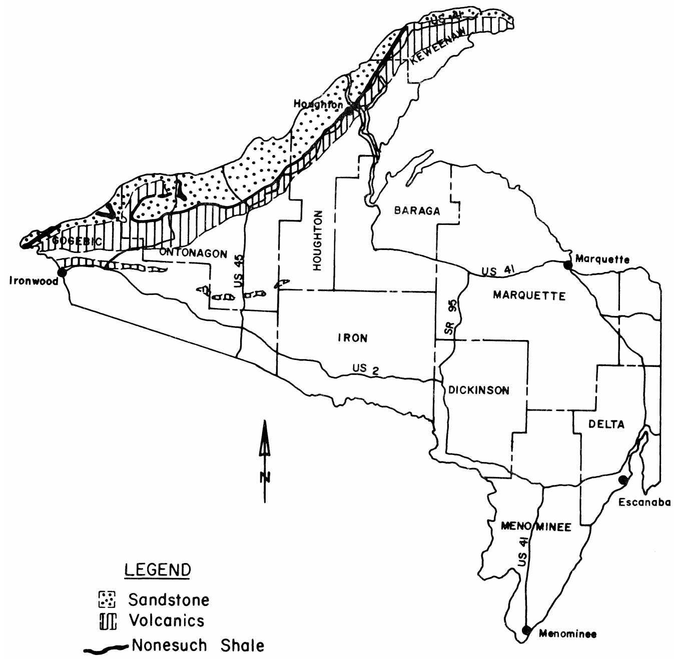

Figure 4. Distribution of upper precambrian (Keweenawan) sandstone, volcanics and nonesuch shale.

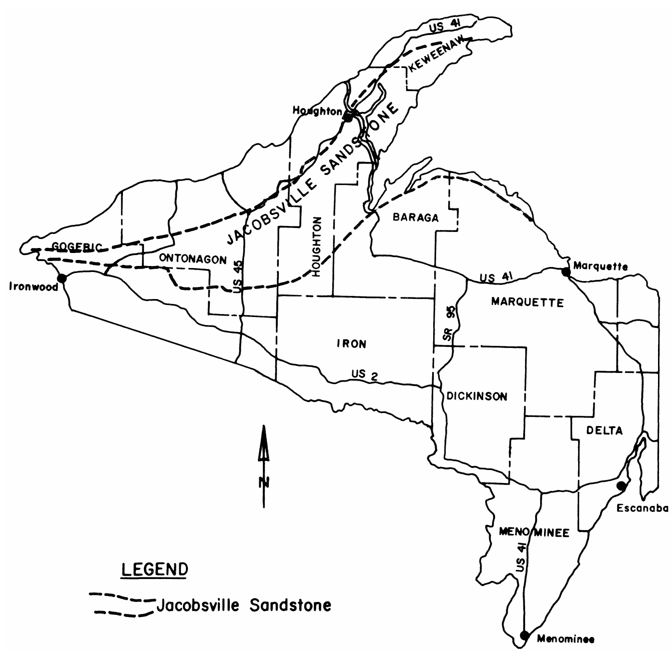

Figure 5. Distribution of upper precambrian (Keweenawan) Jacobsville sandstone.

UPPER PRECAMBRIAN

The Upper Precambrian rocks of northern Michigan (Figure 4) are collectively called Keweenawan and are subdivided into Lower, Middle and Upper Keweenawan units. Keweenawan rocks are formed some 1.4 to 1.0 billion years ago and consist of four formations of volcanics and four formations of sediments with a total maximum thickness of more than 60,000 feet. Table 5 show the rock succession, rock type and maximum formation thickness.

The Upper Precambrian rocks of Michigan are a small portion of a major geologic feature which extends from eastern Lake Superior to the west and southwest into northern Kansas. This is a rift zone of volcanics and sediments named the Midcontinent Gravity High.

Lower Keweenawan quartzite and volcanics have been measured to contain less than 2 ppm. eU. Middle Keweenawan volcanics contain 3 to 8 ppm. eU in general. However, one occurrence northeast of Lake Gogebic was measured at 0.02 and .003 percent eU. One sample is reported to contain 500 ppm. eU. Upper Keweenawan shale has 0.001 to 0.003 percent eU.

Jacobsville Sandstone

The age of the Jacobsville Sandstone (Figure 5) has been a controversial subject for over 150 years. Most maps refer to this formation as Precambrian or Cambrian in age. In 1976, the U.S. Geological Survey officially designated the Jacobsville as Upper Precambrian. The Jacobsville Sandstone covers an area of approximately 1,500 square miles shown on Figure 5 and an unknown area to the east.

Scintillometer surveys and analysis have indicated that the exposed Jacobsville rocks have a very low radioactive content, less than 2 ppm. eU. However, it has been hypothesized that where the Jacobsville overlies Lower and Middle Precambrian rocks, as in parts of Baraga and Houghton counties, the geologic environment is similar to that where Proterozoic-Unconformity type of uranium ore deposits have been found in northern Australia and in northern Saskatchewan, Canada.

the Geological Survey Division, Department radioactive occurrences located by private located on state-owned mineral lands. The determine if such locations were valid to systematic surveys were conducted by the

C. Uranium Surveys & Exploration in the Upper Peninsula

During the 1950's and 1960's, the Geological Survey Division, Department of Natural Resources field checked radioactive occurrences located by private prospectors. The occurrences were located on state-owned mineral lands. The purpose of the evaluation was to determine if such locations were valid to issue a state uranium lease. No systematic surveys were conducted by the Geological Survey.

In 1950, the U.S. Geological Survey (17) published a map of an airborne radioactivity survey for parts of Marquette, Dickinson and Baraga counties. The general conclusion drawn was that the radioactive anomalies were due to the radioactivity emanating from granitic rocks.

On April 30, 1951, (18) the Jones and Laughlin Ore Company, a wholly owned subsidiary of Jones & Laughlin Steel Corporation, contracted with the United States Atomic Energy Commission to sample and make radiometric analyses of the Precambrian sediments in the States of Michigan, Minnesota and Wisconsin. The initial purpose of the contract was to sample dark graphitic and pyrite bearing slates. Earlier exploration by the Jones and Laughlin Ore Company in Baraga County, Michigan had indicated these materials contained a small quantity of uranium.

In the early summer of 1951 uranium mineralization was found in the iron formation. The scope of the investigation was then broadened to include not only the iron formation, but also other Precambrian rocks. Field parties equipped with Halross scintillometers visited outcrop localities, open pit iron mines and active and abandoned mine dumps and made underground tests of mine workings. Where scintillometer readings exceed two or three times background level, samples for radiometric analysis collected. Over 2,000 radio-metric determinations for U_3O_8 equivalent were made. In addition, many chemical analyses for other elements by the iron ore research laboratory of the Jones & Laughlin Steel Corporation.

All data from the sampling program indicated that uranium concentrations of 0.1 percent or better are limited to (a) veins of quartz and calcite cutting black slate and (b) concentrations in iron formation associated with black slate. Veins or shear zones cutting through other types of rocks are still possibilities, but none are known and none were found by the scintillometer and sampling survey.

The chance of such a discovery is in the oxidized of the Upper Huronian iron formation of the Marquette and Menominee Ranges. Outcrops of oxidized iron formation and black slate extremely rare. Both formations are known to be widely distributed on the Marquette and Menominee Ranges, but the distribution is determined almost entirely from mine workings, drill exploration and magnetic surveys. Oxidized iron formation black slate are not resistant rocks and their outcrop is almost entirely buried beneath glacial overburden too thick to permit instrumental detection of radioactivity. Less than one-half of percent of the known iron formation is exposed for sampling or radiation tests. While no commercial urnaium deposits were found, the number of showings of plus 0.1 percent U_3O_8 in the limited area of favorable host rock available for testing was encouraging.

A study to evaluate geochemical methods of exploration for uranium was made in 1957 and reported in 1962 by the Atomic Energy Commission (19). About 600 water samples were collected from streams and subsurface sources in a reconnaissance survey of an area approximately 7,000 square miles comprising parts of northeastern Wisconsin and the northern peninsula of Michigan. The background value of U_3O_8 in waters ranged from less than 0.1 to 0.5 parts per billion (ppb). Anomalous samples were found in waters of a cutting through a sandstone outlier in Sections 32 and 33, T40N, R29W in Southern Dickinson County. Anomalous values of 3.2, 9.7 and 10.2 ppb. were obtained. The sandstone is probably a correlative of the Jabobsville Sandstone. Anomalous samples from wells in the Jacobsville were located in Section 2, T49N, R26W, Marquette County and the values ranged between 1.4 and 6.9 ppb. The highest sample came from a water well penetrating Lower Precambrian granite gneiss in Section 36, T41N, R29W, Dickinson County. The uranium concentration of this sample was 14.8 ppb.

Considering the scope of the problems encountered and the limitations imposed by the data acquired in this reconnaissance investigation, the following conclusions were offered:

1. Low Order of Uranium in Waters

In comparison with other areas investigated for uranium by hydrogeochemical methods in the Western regions of the United States, the uranium content and the dissolved solid content of waters in Michigan and northeastern Wisconsin is quite low. The low uranium background values suggest that geochemical anomalies in waters will likewise be of a low order due to the following conditions inherent to the area studied: (a) limited bedrock permeability in metamorphic terrane; (b) dilution effect of surface water runoff; and (c) rapid "fadeout" or inability of many streams to carry trace amounts of uranium over extensive distances.

2. Uranium in Bedrock and Surficial Cover

Metasedimentary rocks generally contain from 1 to 20 ppm. U_3O_8, but isolated pods of the upper iron member and a few mineralized zones of the Michigamme slate may contain as much as a few hundred ppm. Granitic rocks consistently carry uranium values ranging from 3 to 40 ppm. Surficial cover, with the exception of certain bogs, contains from 0.3 to 6.0 ppm. uranium. The U_3O_8 content of bog soils may range up to 300 ppm. The mean uranium content of sandy glacial till based on a limited number of samples in Michigan and Wisconsin is about 1.0 ppm., although individual samples may contain as much as 10 ppm.

In 1969 the Atomic Energy Commission (20) published the results of an examination of previously located uranium occurrences in the Great Lakes Region of Michigan, Wisconsin and Minnesota. The report noted large areas inadequately explored due to the sparsity of rock outcrops as a result of the extensive cover of glacial drift.

The Department of Geology and Geological Engineering, Michigan Technological University conducted studies of uranium and thorium occurrences in Precambrian rocks of Michigan and Wisconsin in 1976 and 1977 (16, 21, 22). The purpose was to evaluate uranium and thorium potential of the area. Uranium and thorium occurrences were reexamined. Attempts were made to relate the geologic setting of occurrences to major uranium deposits of the world. The study was sponsored by the Energy Research and Development Administration (ERDA).

In early 1977, the DNR's Geological Survey Division submitted an unsolicited proposal to the U.S. Energy Research and Development Administration (ERDA) entitled "Drilling for Geologic Information in Middle Precambrian Basins in the Western Portion of Northern Michigan". In September 1977, $588,000 was awarded for the project. Drilling commenced shortly thereafter and continued into the spring of 1978. Target areas selected for drilling were basins where geologic information was lacking. Five holes were drilled in northern Marquette County and one hole in north-central Iron County.

The six diamond core holes totaled 9,896 feet. Five feet of core from every 30 feet was subjected to mineralogical and chemical analysis. In addition, each hole was logged by five down-hole geophysical methods. A total of 338 samples were subjected to analysis for nine major oxides and 27 trace elements with a total of 9,126 analyses. Uranium content ranged from 0.2 to 130 ppm. and averaged 2.5 ppm. Open-file reports of this exploration project are available from the Geological Survey Division (23-30).

In 1978, the Department of Geology and Geological Engineering, Michigan Technological University, published a study (31) sponsored by the Department of Energy (DOE). This included a detailed account of the geology and uranium resources of the Proterozoic-Unconformity type uranium deposits of Saskatchewan and Australia. The Precambrian geology of various states including Michigan critically to determine the geological potential of this type deposit.

The U.S. Department of Energy (DOE), under their National Uranium Resource Evaluation (NURE) program conducted a high sensitivity airborne radiometric and magnetic survey of the entire Northern Peninsula. The objectives of the DOE/NURE, may be summarized as follows:

> "To develop and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States…"

As an integral part of the DOE/NURE Program, the National Airborne Radiometric Program was designed to provide cost-effective, semiquantitative reconnaissance radioelement distribution information to aid in the assessment of regional distribution of uraniferous materials within the United States.

Project areas are those covered by 1 degree latitude and 2 degree longitude topographic quadrangle maps. The quadrangles are those published as 1:250,000 scale topographic maps and cover an area approximately 96 miles in an east-west direction and 52 miles in a north-south direction. The surveys were conducted under contract by Geometrics, Inc. Traverse lines were flown at a spacing of 3 to 6 miles in an east-west direction with north-south tie lines 18 to 24 miles apart. Survey altitude was approximately 400 feet above ground level.

Numerous maps show computer plotted readings of radioactive uranium, thorium and potassium measurements and their various ratios plus radioactive anomaly interpretation maps. In addition, the reports show histograms for the frequency of counts per second for the various soil groups. The reports cover the Hancock (32, 33) and Marquette (34) quadrangles in Michigan, the Iron River (35) quadrangle, Michigan and Wisconsin, the Sault Ste. Marie/Blind River (36, 37) and Cheboygan/Alpena (38) quadrangles, Michigan and the Escanaba quadrangle, Michigan and Wisconsin (39).

As a part of the NURE program, a project of hydrogeochemical and stream sediment reconnaissance basic data is being conducted by Union Carbide Corporation under contract to the DOE. Stream sediment and groundwater samples are collected and reported on a quadrangle basis as above. Values for uranium specific conductance, boron, barium, potassium, sodium, strontium, alkalinity and pH are listed and plotted on maps for groundwater samples. Results for stream sediment samples are listed and plotted for uranium, thorium, cerium, nobium, titanium, vanadium, yttrium, zirconium.

For the Iron River quadrangle, (40) uranium in groundwater ranges from 0.02 to 220 ppb. Uranium in stream sediments ranges from 0.42 to 47 ppm. In the Marquette quadrangle, (41) uranium in groundwater ranges from 0.02 to 150 ppb. Uranium in stream sediments ranges from 0.049 to 11.38 ppm. The Ashland and Escanaba reports have been released, however, they include only a small portion of Michigan. The Escanaba quadrangle report (42) indicates uranium in groundwater ranges from 0.12 to 75.0 ppb and in stream sediments from 0.27 to 5.6 ppm.

D. Uranium Occurrence Conclusion

Various surface surveys and subsurface drill hole exploration programs in Michigan over the past 30 years have not been successful in locating a commercial uranium deposit. Numerous surface and aerial radioactivity surveys have been made and exploration drilling has been conducted in Baraga, Chippewa, Dickinson, Gogebic, Iron, Marquette, Menominee and Ontonagon counties. A total of 134 holes have been drilled. Samples from uranium occurrences have indicated uranium contents up to a few tenths of one percent. However, such occurrences have been very small and localized concentrations.

A major portion of the world's known uranium reserves are in Precambrian rocks. These include the type deposits generally classified as quartz-pebble conglomerate; Proterozoic unconformity related; disseminated magmatic, pegmatitic and contact; and vein. The Precambrian age rocks of northern Michigan are lithologically diverse and structurally complex. They display geological environments and features common to the above named types of deposits. It is therefore concluded that it is realistic to assume that the geologic potential for uranium deposits of economic volume and grade exist in Michigan Precambrian rocks. However, a limiting factor in the search for uranium in northern Michigan is the lack of surface bedrock exposure due to a deep cover of glacial deposits.

IV. ENVIRONMENTAL IMPACTS AND REGULATORY FRAMEWORK ASSOCIATED WITH URANIUM EXPLORATION

Exploration Impacts

It is known that the level of radioactivity at the drill sites may increase above the local background level in the process of drilling and sampling the hole (43). A question has been raised as to the human health significance of this radiation exposure. Individuals wonder if the increase is a radiation hazard to the workers and general public. It has been stated at the public hearings that it is and, therefore, exploration drilling for uranium should not be allowed In the upper peninsula.

Part of the opposition to the state leasing mineral rights for uranium is the fact that this will lead to more exploration drilling. This, in turn, would increase the chance of the inadvertent release of radioactive solids and gases into the groundwater supplies and atmosphere. This concern is addressed here.

Historically, the uranium industry has used drilling as an important tool in the exploration and development of uranium projects. Drilling activity has varied over the years. In 1948 surface drilling in the U.S. totaled 210,000 feet. One-hundred-thousand (100,000) uranium exploration holes were drilled in 1978 in the United States and this amounted to the all-time exploration and development drilling yearly maximum of 41 million feet. In 1979 exploration drilling totalled 26.8 million feet and represented 66 percent of total drilling (exploration and development) conducted (44).

While it is not possible to predicate the extent of future exploration drilling in the upper peninsula, it appears the use of drilling will be less than previously experienced in the western states for the sandstone formations. In a paper presented at the Uranium Resource/Technology seminar in Golden, Colorado (March, 1980), James F. Davis made the following observations (45).

> "For all of its history, uranium exploration in the United States has been dominated by the search in the sandstone environment. Recently, however, spurred by the fantastically high grade discoveries in Australia and Canada, U.S. explorationists have been reexamining their exploration philosophies and strategies and devoting an increasing amount of time and money to the search in the so-called "hardrock" environment. The transition is slow and sometimes painful for the explorationist, as the techniques can substantially differ from exploration in the sandstone environment--the drill replaced by geologic mapping as the primary data base source; the geologist is suddenly called upon to become a surface rather than a subsurface specialist. Instead of depositional environments, he must understand structural complexities and metamorphic gradients. Drilling is much more costly and every hole must be planned carefully. Gone is the luxury of drilling several hundred (or even several thousand) holes per year. Drill footage is no longer a measure of exploration. More money is spent on geophysics and geochemistry, as well as geologic mapping, in an attempt to best determine where the costly drill holes will be placed."

The upper peninsula of Michigan is one of those "hardrock" geologic environments.

Prior to any decision to mine uranium, an ore body of sufficient size and quality (percent of uranium oxide) must be located. Although uranium is widely disseminated throughout the earth's crust, it usually is present in relatively small quantities. However, certain geographic have higher concentrations of uranium. These are relatively rare. The purpose of uranium exploration is to locate these rare uranium deposits and evaluate their commercial viability.

1. Aerial Surveys

Field uranium exploration procedures include aerial and ground surveys. Aerial surveys consist of systematic flights over a defined geographic area with radiometric equipment to measure the relative gamma ray emissions from the earth. In 1969, 130,000 miles were flown with the majority of the flights In the western United States (44). Such flights measure the background gamma radiation in the earth's crust. They do not involve mechanical disturbance of the earth's crust. Consequently, there is no environmental Impact associated with it other than consummation of aviation fuel and combustion thereof.

2. Ground Surface Surveys

Ground surveys involve the systematic mapping of a given area to identify the pattern of background radiation. In this manner areas with higher potential for uranium deposits are separated from areas of lower potential. This type of survey involves the measurement of gamma ray emmissions by driving or walking over the area of interest with radiometric equipment and with electromagnetic equipment to measure the magnetic characteristics of the underlying formations. Again, as in aerial surveys, the earth's crust is not substantially disturbed. There is no increase in radiation hazard to the environment or human health. There is no disturbance of the earth's crust to alter the naturally occurring radiation fluxes emanating from it.

A ground survey will also involve the collection of water, soil and rock samples for further laboratory analysis. The collection of samples is as simple as wading into a stream to remove small quantities of stream sediment or removing small soil and rock specimens from existing geologic outcropings or abandoned mining sites. This involves a minimal disturbance of the earth's crust and poses no radiation hazard. Similar types of samples are taken routinely by foresters, aquatic biologists and geologists in carrying out their research and management programs unrelated to uranium exploration.

3. Ground Subsurface Surveys

In addition to surface sample collection, subsurface samples are often taken from the bedrock. To obtain a subsurface sample, an exploration hole is drilled. The holes are often three to six inches in diameter and can range in depth from just below the surface down to 1,200 feet (46). The specific depth can vary with each hole. Depending on the kind of samples desired, either a core or a rotary hole is drilled. Generally, the holes are vertically drilled, but the orientation can vary up to 40 degrees from the vertical position. This type of drilling is not unique to uranium exploration. It is essentially the same process as drilling water wells and similar to exploration drill holes used in the search for nonradioactive base metals.

The exploration operation is carried out in three steps; site preparation, drilling activity and site restoration. Generally, an area of 2,000 square feet is cleared to allow for operation of the drilling equipment, mixing of the drilling mud and containment of drill cuttings. Where possible, existing roads can be used to bring the equipment into and out of the drilling site. However, in some cases, off the road equipment may be used to reach a remote site or a temporary road may be constructed. If drilling is done in the winter over frozen ground, often the heavy equipment can be moved on skids without the need to construct temporary roads.

The actual drilling involves the cutting of the hole, removal of core and/or cutting samples for laboratory analysis and electrical log analysis of the hole. The drill cuttings removed from the earth in the process of drilling can be stored in small pits adjacent to the hole. Upon completion of the hole and data collection, the cuttings can be buried in the pits by covering with the topsoil removed in the process of site preparation. The site can be graded and leveled and seeded. The temporary roads removed and reclaimed to original state or are left open at the discretion of land owner. Usually, each exploration hole can be drilled in two to four days (46) including sealing of the hole.

In any drilling activity, the driller is faced with the possibility of contaminating a potable groundwater aquifer by intermixing with contaminated groundwater (naturally or man-induced) through the connection established by the drill hole. In the process of drilling the vertical integrity of the geological formations is altered. This is an inevitable consequence of drilling. It occurs with all drilling, but the degree of disruption varies with the type of geological formations encountered.

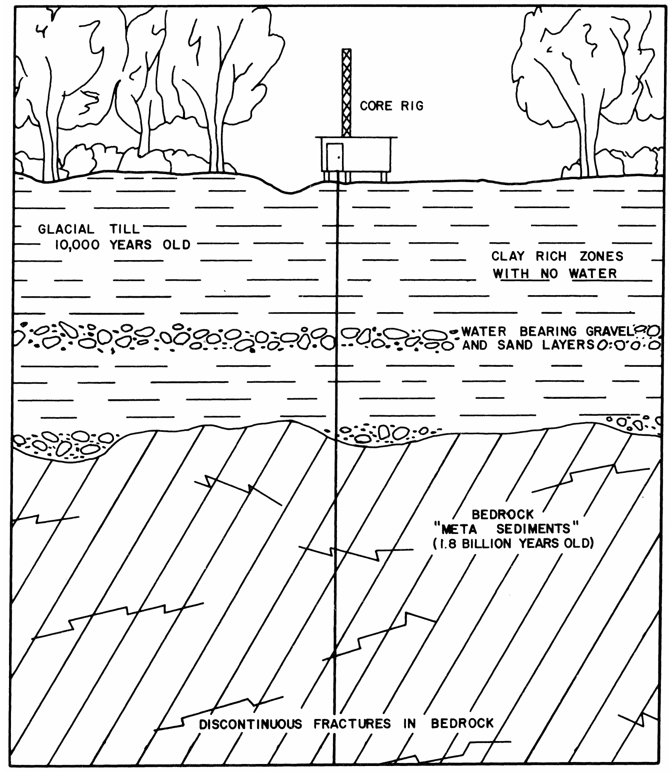

Figure 6. A side view of test well drilled into precambrian rock underlying unconsolidated surface deposit.

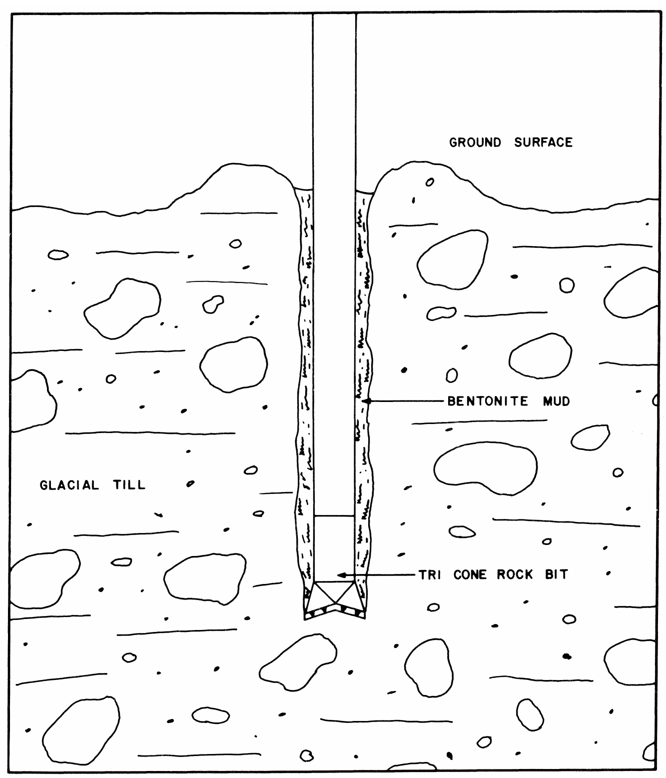

Figure 7. Example of exploration drilling method in unconsolidated glacial till.

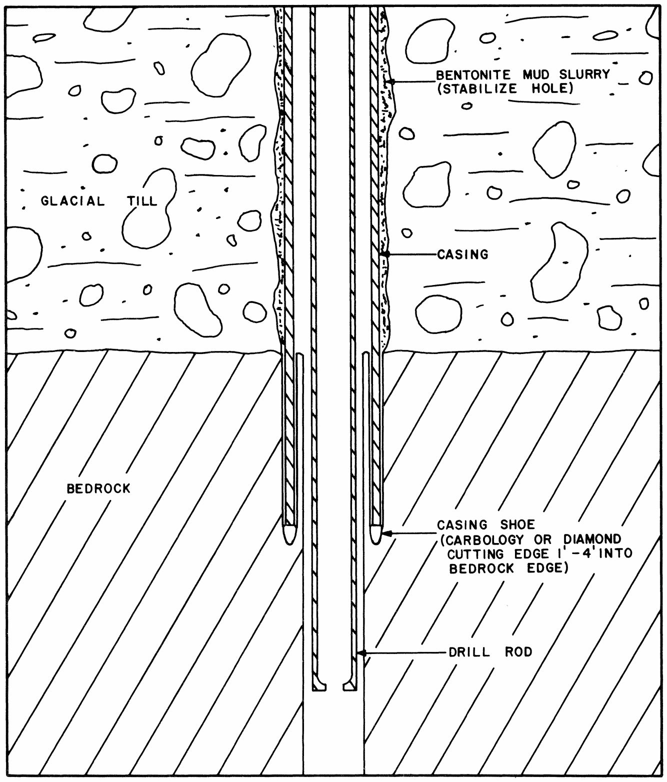

Figure 8. An illustration of a method to seat casing at the glacial till-precambrian bedrock interface.

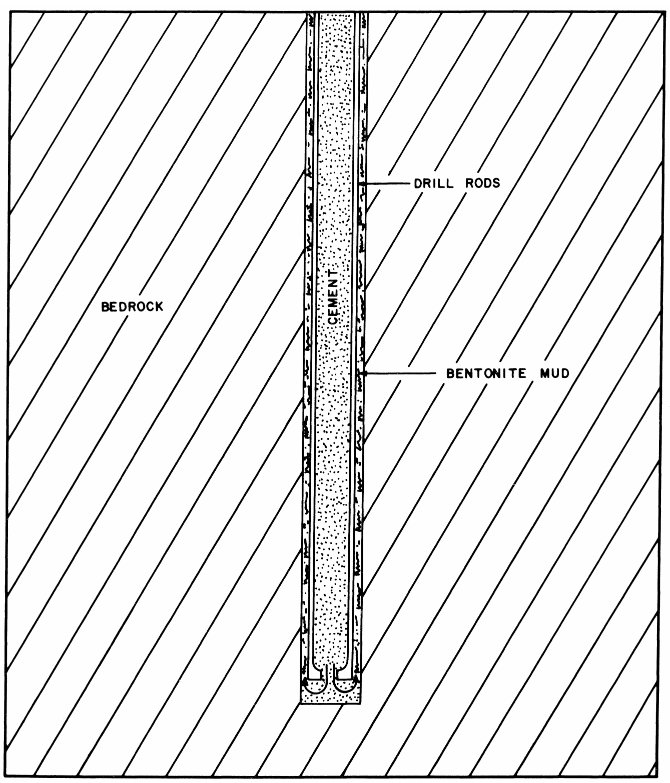

Figure 9. An illustration of the method used to cement the hole to seal it for abandonment.

In order to minimize the probability of vertical contamination as drilling is in process, the driller can place pipe in the hole to line (case) it. Then, upon completion and abandonment of the hole, it can be sealed with cement to prevent escape of gases, liquids and solids to the surface.

Figures 6 through 9 illustrate a typical method to drill and cement an uranium exploration test hole. Rocky Mountain Energy Company has developed and followed this procedure in Minnesota under state supervision.

Figure 7 indicates the initial drilling in the glacial till. A tri-cone rock bit is used to cut through the till and a bentonite mud slurry is injected around the drill to stabilize the hole. This system will be used until the underlying precambrian bedrock is encountered. Once the driller has encountered the precambrian bedrock, a casing of pipe will be set in the hole. This will provide a good seal between the bedrock-glacial till interface. It also will prevent sand and gravel from the glacial till entering the drill hole and producing bending and excessive wear on the drill rods (Figure 8).

Upon completion of hole and collection of in hole data as well as sampling of the cuttings, the hole will be abandoned. In order to seal the hole and restore the vertical and lateral integrity, cement will be pumped into the hole until it is filled to the bedrock-glacial till interface. The drill rods are then removed from the hole and the casing is freed from the bedrock. Cement is then pumped in again until it is sealed at the surface (Figure 9). The cementing and sealing process may take 8 to 20 hours.

4. Health Impacts of Uranium Exploration

There are two populations of concern when considering the health effects of uranium exploration; occupational workers and the general public. In relation to uranium exploration, the potential and actual release of radon gas from an open drill hole and its health impact is the major public concern. In the summer of 1980, the University of Wisconsin - extension service, through the Ecological and Natural History Survey, prepared a report on the safety issues associated with uranium exploration for the Wisconsin Legislative Mining Committee and Sub-committee on uranium exploration safety (47).

The report identified three ares of potential radiological exposure to the general public; groundwater contamination, mud pit contamination and radon release into the atmosphere. The conclusions reached were based on the development of a “worst case exposure” model for exploration drilling. That is, in calculating the potential exposures to drilling personnel, exploration geologists and the general public, it was assumed that the exploratory hole would encounter a “high-grade” uranium deposit (the richest uranium ore zone currently mined). In addition to this “worst case” assumption, a range of potential exposures was estimated on the basis of a typical uranium deposit likely to be encountered in geologic settings similar to northern Wisconsin.

The uranium concentration for the “worst case” and “typical deposits” are 7.7% and 0.3% U_3O_8, respectively. The high value is based on known values identified in the Cluff lake orebodies in Saskatchewan, Canada, while the typical values are based on orebodies in Washington and Colorado. The report also calculated the potential for radiation hazard from the three principal methods of uranium drilling; diamond-core, rotary-mud and rotary-air drilling. The report compared the exposures calculated for uranium exploration with human exposure from other radiation sources including natural background radiation levels. It also compared the exposure from uranium exploration to existing federal exposure standards.

a. Exploration Worker

Presently, the annual natural background general population radiological exposure is about 105 mrem. The standard for general public exposure is presently 500 mrem/year excluding the background exposure. Potential radiation impact of exploration workers per drill hole is significantly below the 500 mrem per year occupational standard based on the data in table 5.

If a driller used the diamond-coring drill method, he/she would have to work at about 1,111 individual drill per year to reach the permitted annual exposure of 500 mrems. Each hole would have to encounter a uranium ore body equal to seven percent U_3O_8 as used in the exposure. If "typical deposits" of 0.3 percent uranium content was encountered, a driller would have to work on about 50,000 exploration holes per year.

The rotary-air drilling method, under the model posed here, would result in the greatest radiological exposure to the driller. A driller could only work at about 37 individual drill holes for "high-grade" deposits and about 1,388 individual exploration holes for "typical" deposits before approaching the annual radiological exposure limit.

The driller would have higher radiological exposure than the geologist with the rotary-air driller method while diamond-coring and rotary-mud drilling methods would result in greater radiological exposure to the geologist on site. This is primarily due to the subsequent storage and analysis of the uranium-bearing material by the geologist. For example, a geologist would have to work on about 80 individual drill holes with the diamond-core drill method to reach the annual radiological exposure of 500 mrems for the "high-grade" deposit and work at about 4,166 individual holes with a "typical" deposit. Thus, with the proper monitoring by exposure badges and rotation of personnel, the risk of potential radiation hazard to the uranium exploration drilling crews and geologists is minimized and should not pose a significant health risk. The following except from the Wisconsin report explains this conclusion (47).

"Radon emanation from boreholes produced by rotary-mud and diamond-core drilling is considered insignificant because of the slow rate of radon emanation and the typical coating of the borehole with mud. Radon gas is heavier than air and this further indicates radon release from a borehole is not significant. In addition, boreholes are not left open for any significant period of time in Wisconsin as per the Department of Natural Resources' requirements for temporary and permanent abandonment of drillholes."

Radon impact to the driller assumes dispersion of the air in and about the drill site as a result of normal air movement. Thus, the total radon impact results from radon brought to the surface over the length of time it takes the drill bit to move through the uranium-bearing material. The air in the worker's breathing zone is assumed to have any particular minute the radon that has been released by the drill bit in the previous minute's drilling. Thus, the compressed air continuously replenishes the radon supply in the breathing zone, but the concentration remains constant as the previously released radon moves out of the breathing zone, is diluted by the atmosphere, and is dispersed away from the drill site and driller personnel.

Drilling Method	*Worker*	*"High-grade" Deposit*	*"Typical" Deposit*
Diamond-coring	*Driller*	*0.45*	*0.01*
	Geologist	*6.2*	*0.12*
Rotary-mud	*Driller*	*nil*	*nil*
	Geologist	*2.3*	*0.04*
Rotary-air	*Driller*	*13.4*	*0.36*
	Geologist	*2.3*	*0.04*
	Radon[2] (driller only)	*3.0*	*0.08*

Table 5. Potential Radiologic Exposure[1] of Exploration Workers Resulting from Uranium Exploration Drilling.

[1]Units are mrem per drillhole
[2]Units are working level-hours

"The radon is assumed to be in equilibrium with its daughter products for the purpose of calculating working levels (WL) of exposure of driller personnel. This assumption is plainly inaccurate and over-estimates the individual's exposure. However, the assumption greatly simplifies the calculation and is in keeping with the spirit of this memo to assume the "worst cause" situation where there is any questions of the amount of exposure."

"Radon exposure to the exploration geologist handling core and cuttings in the open air is insignificant, but radon levels in a storage/study facility may pose a potential hazard. this hazard is not significant if the facility is well-venelated. Measurements of radon in a core shack in British Columbia at an exploration site showed 0.005 WL, which is four times less than the Canadian federal limit of 0.02 WL for a member of the general public (British Columbia and Yukon Chamber of Mines, 1980). Ore grades associated with this exploration site are lower than those modeled for this memorandum, however. No further attempt is made here to evaluate the potential exposure to radon in a storage/study facility, but adequately ventilated facilities probably pose no hazard to workers."

b. General Public

Since the general public will normally not be present during the actual drilling operations and are not normally involved in the handling and analysis of uranium bearing samples, the potential for radiological exposure is associated with the mud pit, radon in the atmosphere and potential groundwater contamination. The exposure to the general public from the mud pits is not considered significant. For examples in the "worst case" situation, radiological exposure from the mud pit is 0.3 mrem/hour. This means an individual would have to be within 1 meter (about 3 feet) of the mud pit for over 1,500 hours (about 9 weeks) to absorb a radiological dose approaching the permitted 500 mrems/year annual limit.

Radon release from the drill hole is a source of atmospheric exposure to the general public, but it is not a significant increase above background radon levels as it mixes with the atmosphere and moves away from the drilling site (47).

"Since the borehole is not left open for any significant period of time, the general public's exposure potential to randon results from the drilling process itself. Radon would appear to be a problem of concern only for rotary-air holes, since the opportunity for radon release into the atmosphere is significant in any way only for this type of drillhole. Certainly, some aeration of radon entrapped in mud and water associated with coring or rotary-mud drilling would occur at the point of slurry release into the mudpit; however, this aeration would not be 100 percent and modeling the assumed 100 percent effective release of radon from rotary-air drilling appears to be "worst case". Based on the preceding, the general public's exposure to radon would be equal to the total release of radon, diluted by the compressed air, and further diluted and dispersed in the open air about the drill site."

"Extreme diurnal, seasonal, and other temperature variations associated with climatic and meteorologic conditions greatly complicate any straight-forward calculation of radon exposure downwind from a drilling area. Several studies of radon dispersion demonstrate that radon concentrations and working level measurements with increasing distance from this source (as well as being a function of climatic meteorologic factors). For example, data on radon concentration in the vicinity of an uranium mill in New Mexico shows a ten-fold in air cocentration at distances of 500 to 3,000 meters from a tailings pile. Because radon released from a drillhole is much less to begin with, the phenomenon of dilution and dispersion with distance indicates that general public exposure to radon as a consequence of uranium exploration drilling in remote areas is not a significant problem."

C. Groundwater Contamination

The potential for ground water contamination was also assessed in the Wisconsin report (47).

"Concern with the contamination of groundwater aquifers centers around the introduction of natural uranium into aquifers as a result of drilling into uranium-bearing material and subsequently "losing" drilling fluid into an aquifer. Other concerns that have been expressed, specifically interaquifer communication along the borehole, does not appear to be a significant concern because (1) State of Wisconsin abandonment procedures are designed to eliminate this possibility, and (2) if the abandoned hole does lose its integrity (cement deteriorates permitting movement of water along the borehole), the amount of uranium introduced from one aquifer to another is within acceptable health standards (see calculations below).

Potential contamination of ground water via introduction of drilling fluid into an aquifer is unlikely, particularly in systems using a mud slurry to cool the drill bit and bring cuttings to the surface. The mud tends to seal the borehole and if fluid loss does nonetheless occur, the driller can detect this loss and drilling stops to permit additional steps, such as cementing the borehole and allowing cement to move a short distance into the porous rock or open fissure that was causing the drilling fluid loss. Besides the sealing of boreholes with mud or cement, exploration boreholes are generally cased (lined with metal pipe that just fits inside the hole) as the hole is drilled. Casing alone eliminates any significant possibility of drilling fluid loss, especially if the casing is adequately cemented into the bedrock below the overburden.

Assuming, however, that drilling fluid loss does occur, the following calculation estimates the impact on groundwater. Given a nominal three inch diameter hole 300 meters in length and the mudpit dimensions noted previously, the volume of drilling fluid involved is approximately 30 cubic meters. Following the assumption that 3 ppm natural uranium is dissolvable into groundwater and 10 percent of the drilling fluid is lost (see Wells 1979; note that the solubility of uranium and percent-loss of drilling fluid are very high, "worst case" estimates), the following relationship derives:

1 g natural uranium = 6.77×10^5 pCi (Hersloff, 1980),
2×10^6 cm^3 of drilling fluid loss contains 6 g U-nat,

$$\frac{6 \text{ g U-nat}}{2 \times 10^6 \text{ cm}^3} \times 6.77 \times 10^5 \frac{\text{pCi}}{\text{g U-nat}} = \frac{2 \text{ pCi}}{\text{cm}^3/}$$

The maximum permissible concentration of natural uranium (MCP_W) dissolved in water is 2×10^{-5} microcuries per cubic centimeter of 20 pCicm^3. This MPC_W also considers the chemical toxicity of the long-lived uranium nuclides (see Table 1, p. 86 of NCRP Report No. 22 (1959), occupational exposures allowed are divided by 10 to derive permissible non-occupational exposures).

The natural uranium introduced into an aquifer is <u>less</u> by a factor of at least 10 of the maximum permissible concentration. Therefore, the potential for groundwater contamination as a result of uranium exploration is not considered a significant problem, especially in view of the liberal assumptions made for uranium solubility and drilling fluid loss.

The respective radon concentration released by drilling into high-grade and typical deposits both exceed the maximum permissible concentrations of Rn-222 in air, according to NCRP Report No. 22 (1959, table 1). However, this table of MPC_a is for 40 hours per work-week or 168 hours per week of continuous exposure. The MPC's listed insure that maximum permissible body burdens for a particular radionuclide are not exceeded over a 50-year span of continuous exposure. The relatively instantaneous exposure of personnel on a drillrig cannot be compared to recommended levels of continuous exposure over 50-year time spans.

The use of MPC_W is reasonable, however, for natural uranium dissolved in groundwater as a result of drilling fluid loss into an aquifer. The MPC_W for soluble natural uranium used for comparative purposes in this memo is for continuous exposure over a normal 168 hour week for 50 years. The slow movement of groundwater suggests the dilution of uranium released into an aquifer may be so low as to permit the assumption that the uranium concentration in the "contaminated" aquifer remains reasonably constant for a period of time that is commensurate with the assumptions in the MPC_W for soluble natural uranium."

B. Regulatory Framework In Wisconsin And Minnesota For Uranium Exploration

Based on this Wisconsin report, where the "worst case" conditions were employed to estimate worker and general public radiation exposure during uranium exploration drilling, the radiation hazard is shown to pose no significant health risk. However, this study is based on timely sealing of the drill hole after completion of collection.

In order to insure adequate and timely sealing of the drill holes the State of Wisconsin regulates uranium along with other drilling activities. Their regulations require a driller to have a license to drill for metallic minerals and obtain a $5,000 bond for faithful performance and reclamation of drill sites. The driller must permanently seal the hole, usually with cement and the site is inspected by state personnel to insure compliance with license conditions (5).

In response to the public concern over uranium exploration in Minnesota, the Minnesota legislature passed a mineral exploration statute in 1980. It requires the licensing of mineral explorers, establishment of drill hole sealing and abandonment procedures and state inspection of drill sites. The major provisions provide for the following activities (3).

-Require that a mineral explorer secure a license from the Minnesota Health Department in accordance with existing regulations (anyone supervising drilling must first pass an examination on water well construction, unless the supervisor is a registered professional engineer in Minnesota or a certified professional geologist.)

-Require that 30 days prior to the start of drilling an explore register with the Minnesota Department of Natural Resources.

-Require that 10 days prior to the start of drilling an exploration firm submit to the Minnesota Department of Natural Resources a county road map showing the location of each boring.

-Provide state and county officers and employees rights of access to drill sites for inspection and sampling of air and water.

-Require that the firm submit an abandonment report to the Minnesota Health Department and the Minnesota Department of Natural Resources within 30 days of temporary or permanent abandonment.

C. REGULATORY FRAMEWORK IN MICHIGAN FOR URANIUM EXPLORATION

1. Local Government

County, township and municipal governments can regulate mineral exploration and mining through the power of zoning established by the County Rural Zoning Enabling Act (P.A. 183 of 1943). Local governments can impose standards or criteria upon proposed exploration. Since the mineral owner has a strong property right to the recovery of minerals, local zoning ordinances cannot totally prohibit such activity.

The purpose of local zoning is to prevent creation of nuisance situations resulting from the presence of incompatible land uses. A zoning ordinance cannot, in general, prohibit any specific land use within a county or municipality unless it is shown that there is no location within the county where the use may be appropriately located.

The county zoning ordinances on mining currently in effect in Michigan typically set standards on noise, dust control, visual screening, operation and reclamation plans and protective fencing.

The fact that exploration could take place on state land would probably not eliminate local zoning control. The Michigan Supreme Court ruled that state lands are immune from the provisions of local zoning ordinances only when there is clear legislative intent that a state agency is to have "exclusive jurisdiction" over such an activity (Dearden v City of Detroit, Michigan Supreme Court, August 1978). This not appear to be the case with uranium mining on state land.

It is possible that a zoning ordinance could be written to drastically restrict or forbid uranium mining. In order to uphold the legality of such an ordinance, it must be shown that the ordinance is not unreasonable in its regulation of an activity and it is consistent with the protection of the public health, safety, or welfare of the citizens in its jurisdiction. Presently, most counties in Michigan do not zoning ordinances for metallic mineral mining. The public reaction to proposed uranium mining may cause such ordinances to be promulgated.

2. State Government

Uranium exploration drilling on public and private land is subject to regulatory control in Michigan. Any drilling must be carred out in compliance with the Minearl Wells Act (P.A. 315 of 1969) which is administered by the Department of Natural Resources, Geological Survey Division.

Under the provisions of this statute a mineral well includes four types of wells; disposal, storage, brine and test wells. Uranium exploration would be considered either a general test well or a geophysical test well since it is drilled to determine the physical presence of uranium bearing orebodies. Although all four types of mineral wells must meet specific requirements and a permit issued before the actual drilling and use of the well, only the statutory standards and rules applicable to uranium exploration drilling will be discussed here.

The supervisor of mineral wells (state geologist) must approve and issue a permit before an operator can drill a test well. The operator is required to submit the following information In a written application.

1. A description of the exact location of the proposed test well on a map or plat.

2. The map or plat of the well area should indicate the relationship of the proposed well to lakes, streams, swamps, drainageways, other wells, buildings, streets, highways, pipelines, power and other utility lines, railroads and other features within 300 feet of it.

3. A detailed description of the proposed well construction.

4. A detailed description of the proposed drilling procedure.

5. A detailed description of the proposed plugging and abandonment procedure.

6. A description of the approximate depth of the hole.

7. Proof of acquisition of a surety or security bond.

8. A stake or marker is set at the proposed well site to mark the exact location in the field.

9. An organization report is provided if required.

This information must be provided for each proposed well site. However, the statute allows for the granting of blanket permits in a limited geographic area. A blanket permit may be issued for test well drilling and geophysical test holes. If it is issued for test well drilling, the operator is limited to drilling no more than 200 test wells in an not to exceed nine square miles (1/4 of a township) as part of a geological test program. Under a geophysical test blanket permit an operator is also limited to no more than 200 holes except as authorized by the supervisor and the maximum area covered by each permit can be no larger than one county. The permit can restrict the area covered to less than one county for geologic reasons.

In order to obtain a blanket permit for a test well the driller must submit the following information in a written application.

1. A description of approximate number and locations of the proposed test wells on a map or plat.

2. A description of the proposed depth of the proposed wells.

3. A detailed description of the proposed well construction.

4. A detailed description of the proposed drilling procedure.

5. A detailed description of the proposed plugging and abandonment procedures.

6. Proof of acquisition of a surety or security bond.

Since a blanket permit for geophysical testing can cover a large geographic area (one county) than a blanket permit for test wells (1/4 of a township), the driller must provide, in addition to the information required for a blanket test permit, the following information in the written application.

1. The drilling plan must proposed alternative methods of plugging to cope with various soil and water conditions within the area to be covered by the permit.

2. The drilling plan shall specify criteria to be used In determining which plugging method is applicable.

3. The proposed drlling pattern of the wells.

Both types of blanket permits are valid for not more than one year and expire on December 31 of the year issued in.

Since a test well is defined in the statute to mean a well, core hole, core test, observation well or other well drilled from the surface to determine the presence of a mineral, mineral resource, ore or rock unit, an uranium exploration drilling program could be conducted under either an individual test well permit or under either of the blanket permits. In either case the supervisor, in reviewing the permit application, can deny a permit if the location and drilling of the well cannot be accomplished in a manner to prevent surface or underground waste.

The purpose of the act is to prevent surface or underground waste. The former is defined as damage to, injury to, or destruction of surface waters, soils, annual fish and aquatic life or surface property from unnecessary seepage or loss incidental to or resulting from the drilling and operating of brine, storage, disposal and test wells. Underground waste is defined as damage or injury to potable water, mineralized water or other subsurface resources. Thus, the statute allows the supervisor to include drilling and operating conditions in a permit to prevent surface and underground waste.

Based on a field review of the test well locations and a review of the information in the written application, any or all of the following conditions can be made part of the permit and the driller must conduct the drilling program in compliance with the specified conditions.

1. In preparation of the well site a pit or pits must be costructed in close proximity to the well to collect and confine drill cuttings and confine drilling muds or fluids.

2. Dikes may be constructed to prevent the escape of fluids from th well site.

3. Steel tanks, cribs or other approved containers may be required in an area where pits are not feasible or if the cuttings and fluids are to be removed from the well site.

4. Drilling shall not commence until the driller has complied with the specified conditions to prevent pollution.

5. Fencing, gates, warning signs may be required to protect life and property in a congested area.

6. The well site shall be maintained in an orderly manner and kept free and clear of debris and unnecessary or abandoned equipment.

7. In the drilling of th well the driller may be required to case and seal the well to provide protection to th ground and surface waters and to prevent migration of fluids between layers of earth material.

8. The removal of casing from a well upon completion of drilling and proposed abandonment can only be done with approval of the supervisor.

9. The operator, as a condition of the permit, shall keep and file a log of the drilling program with the supervisor. The log for a test well shall include the owner's name, permit number, site location, elevation, drilling contractor, drilling method, casing record, description and thickness of geologic materials penetrated, static water levels, flowing water zones, total depth, beginning and completion dates, occurrences of oil, gas or salt water and description of procedures and materials used in plugging.

10. A test well must be plugged promptly after abandonment or termination of the project in accordance to procedures specified by the supervisor in the drilling permit. The plugging may require the use of mud-laden fluid, cement, other suitable material or a combination of two or more of these items. Fluids and gases shall be sealed off, and confined to the strata in which they occur. A suitable plug may be required at the surface.

11. The well site, upon abandonment, shall be cleaned up. All pits and excavations shall be filled, leveled off at the surface, debris removed and all conditions which may create a nuisance or fire or pollution hazard shall be eliminated. The surface of the abandoned well site shall be returned as nearly as possible to its original condition.

12. A report shall be filed with the supervisor after plugging of a test well within time specified by the supervisor in the permit.

The statute, then, provides a sufficient basis to regulate uranium exploration drilling. If individual permits are written to insure proper site preparation, mud and drilling pit construction, casing of the drill hole, cementing of the hole upon completion of collection and sufficient soil coverage of mud pits and site restoration, the radiological and environmental impacts will not pose a health risk to the general public.

However, there is a provision in the statute which exempts a test well driller from the necessity of obtaining a permit prior to drilling test wells in areas with Precambrian rock directly underlying unconsolidated surface deposits. Since the areas of interest to uranium companies in the upper peninsula primarily include Precambrian rock with unconsolidated surface formations, a permit is not required.

This exemption should be reviewed in light of uranium exploration. It does not provide for the prior review of a specific drilling plan nor allow for the inclusion of specific safeguards in a permit. The driller is under no obligation to identify the proposed well location or disclose his drilling, cementing or abandonment procedures for up to two years after drilling the hole. Thus, it is difficult for the regulatory agency to know the location, inspect the well site and operations carried out to determine if they are sufficient to prevent surface or underground waste.

In light of the public concern over uranium exploration, it would be proper for the health and welfare of the general public to require submission of permit applications for uranium exploration in the Precambrian rocks. It would appear that the statute gives the supervisor the power to set aside the exemption through the execution of a special order to control pollution or eliminate a hazardous condition. It appears a public hearing before the supervisor and the mineral well advisory board is required to take evidence on the need for the exemption.

C. Federal Government

Exploration for uranium is regulated by federal agencies only when the exploration is done on federally owned land. The federal agency that has administrative control of the land and its use requires exploration permits.

D. Exploration Impact Conclusions

1. There are two types of environmental impacts associated with uranium exploration; (a) impacts due to the radioactivity of uranium and (b) other nonradioactive impacts including access roads, site preparation, noise and air emissions from mechanical equipment. The latter impacts are similar to those for other types of metallic mineral exploration and water well drilling. They are generally short term and can be minimized if site

reclamation is carried out. For example, brush may be cut for laying survey lines for reconnaissance exploration or a road may have to be built to bring a rig into the site. Drilling can often be done during the winter when equipment can be moved on skids over the frozen ground, and road building is not necessary. Vegetation that is damaged can be replanted or allowed to revegetate naturally. Roads are either reclaimed to their original state or are left open at the discretion of the landowner.

2. The radiation associated with uranium exploration does not pose a health risk to general public. If proper drilling procedures are employed, the chance of groundwater contamination is very remote. The release of radon gas from the drill hole to the atmosphere does not pose a hazard to the general public. If drill holes are sealed properly, radon gas will not escape into the atmosphere upon the termination of testing. The radon gas release while the hole is open, based on the worst case analysis referred to previously, will be small and will be dispersed and diluted through atmospheric mixing as the gas moves away from the well site. Reclamation of the mud pits with the drill cuttings by covering with top soil will reduce and contain any radiological emissions within background levels.

3. Notwithstanding the conclusion that uranium exploration does not pose a significant health hazard to the general public, it is recognized that individual members of the public will remain unconvinced or skeptical. If uranium exploration is going to continue to be permitted and not prohibited by legislative action, it is recommended that the uranium mining companies improve their public relations with local government officials, landowners and general public.

In Minnesota, Rocky Mountain Energy Company has developed a policy of inviting landowners and interested citizens to visit the sites and exploration surveys to observe and learn how data is collected. This company has developed a newsletter to its activities and has met with local units of government to describe its drilling program and safety procedures. Where applicable, it has with local county and township zoning boards to arrive at an exploration program consistent with zoning requirements. Further, it established a monitoring program to minimize drilling impacts and measure radiological exposure. It has also held an open house for citizens to visit its facilities.

These types of activities do not insure general public acceptance, but it provides for an exchange of viewpoints and allows the public to learn more about uranium exploration from the people who do it. Similar programs by companies in Michigan would help in sharing information and help to answer the myraid of questions associated with uranium exploration. It Is recognized this is a controversial issue. It is our opinion that attempts by companies to conduct these activities in a secretive manner will only contribute to the fear and suspicions of the public. An open and public exchange of questions and answers will aid in seeking a resolution.

V. ENVIRONMENTAL IMPACTS AND REGULATORY FRAMEWORK ASSOCIATED WITH URANIUM MINING AND MILLING

A. Land Use Impacts

Uranium mining and milling pose land use and land quality problems. Areas of land are taken away from their original use for extended periods of time. The amount of land required for a uranium mining and milling operation is dependent on the type of mining technique employed, the size, shape and depth of the ore body and the proximity of the mill to the mine. Open-pit mines impact more surface area than underground mines.

An open-pit uranium mine removing 500,000 of crude ore over a period of 20 years and consisting of one or pits, ore, lean ore, waste rock storage area, and associated buildings would occupy approximately 50 to 290 acres. The mill would require from 5 to 10 for facilities and from 20 to 80 acres for the tailings pond. These figures vary depending on the extent and depth of the ore, the location of the mill and the of tailings pond construction.

An underground uranium mine would disturb about one tenth of the surface area disturbed by an open-pit mine since overburden material is not removed and less land area is needed for waste storage. Surface area would be required for service buildings, a head frame and track-loading facility, a mine waste pile and a flow of water from underground sumps pumped to the surface for use in the mill and concentrator. The area occupied by the hoisting and loading facilities, shops, warehouse, changehouse and office may be only a few acres, but the reach of underground openings may be a mile or more. Most uranium ore deposits are long, but not thick and therefore require special adaptions of routine mining methods including highly mobile blasting and mining techniques to permit inexpensive and rapid digging (49).

The buffer zone of a one-half to one mile radius around uranium mining and milling facilities would be prudent to minimize the potential of radionuclides and other contaminants reaching the general public and to avoid obtrusive aesthetic impacts. With the inclusion of a buffer zone, the area required for an open-pit mine and mill during the operational phase would range from 1,300 to 3,300 acres or from two to five square miles.

Uranium mining usually restricts concurrent on-site land uses such as agriculture, although some land uses in the buffer area may be compatible with it. For example, timber production in the buffer region should be unaffected by mining. Some tree species are more susceptable to radiation than others. However, the expected radiation associated with a properly operated uranium mine mill Is usually not at the level known to cause damage.

However, the effect of a properly operated mine on terresterial vegetation adjacent to the mine facilities would require monitoring of the plants and wildlife to assess the degree, if any, of bioaccumulation of radioactive molecules into the food chain.

In many cases mined can be reclaimed to their original or to some other productive use at the cessation of mining. However, portions of a uranium mine and mill site may be permanently closed from future productive land use. Under current federal law the ownership of land used for uranium tailings disposal must be transferred to the federal or government.

B. Milling And Tailings Impact

Mined uranium ore typically contains a few pounds of uranium oxide (U_3O_8) per ton of material. To extract the usable uranium oxide the ore must be milled in a process similar to concentrating processes used in other types of hard-rock milling. Because of economic factors, such as haulage costs, uranium mills are located near the sources of the ore.

A typical uranium processing mill is a complex of small buildings. They contain crushing machinery, receiving bins, screening operations, conveyors and a chemical-treatment facility. The uranium ore is crushed, ground and leached by chemicals to dissolve the uranium minerals from rock. The leached uranium-bearing solution is separated from the undissolved material and uranium is recovered as a precipitated concentrate. This concentrate is roasted, pulverized, and drummed for shipment as a powdery material called "yellowcake". The wastes, known as mill tailings, are a slurry of finely ground solids in waste solutions. This slurry is transferred to a tailings pond.

The radioactive content of the tailings is about 85 percent of the radioactivity of the original uranium ore. A small percent of the uranium initially present in the ore remains in the tailings, as do most of the uranium decay products which were in the ore. Radium-226 is the most hazardous nuclide in the tailings. The quantity of radium and radon in the tailings will diminish by only one-half in roughly 1,600 years.

Many studies have concluded that uranium mill tailings must be as carefully managed as the more highly radioactive wastes from other portions of the nuclear reactor fuel cycle. Congress has recognized that the past record of control at mill sites has been poor and that little attention has been given to the problem of proper disposal of tailings. In 1978 Congress passed an amendment to the Atomic Energy Act, the Uranium Mill Tailings Radiation Control Act. This act, and action by the Nuclear Regulatory Commission and the Environmental Protection Agency, are leading to a complete review and revision of the various steps involved in the management of tailings, which are now formally recognized as radioactive wastes. The ultimate objective is to dispose of the tailings in a manner that reduces emissions of radioactive materials, primarily radium and radon, to as low a level as can reasonably be achieved, to isolate the tailings and to eliminate the need for continuous maintenance.

The Nuclear Regulatory Commission completed in September of 1980 a Generic Environmental Impact Statement (GEIS) on uranium milling. Alternative methods for treating and disposing of mill tailings were evaluated. These include various degrees of treatment to remove the radium, thorium and uranium as well as ways to stabilize tailings piles and methods to place the tailings underground (49).

The radium and radon problems of uranium mill tailings illustrate the underlying difficulties of managing radioactive wastes. The hazard is a long-term one and extends over thousands of years. Exposure to radiation is known to cause cancer and genetic damage. The impact per human generation may be relatively small, but the potential cumulative impact is large. Expenditures to manage the tailings (for example, chemical treatment to remove the radium, thorium, and residual uranium, developing methods to dispose of those elements safely, and placing tailings underground in a way that ensures they do not contaminate the circulating ground water) must be incurred at the time of milling, while the benefits of fewer cancers or genetic mutations would not be realized for a long time. These "value judgment" decisions emphasized by the NRC must be made prior to mining and milling.

Present NRC regulations require tailings to be disposed of in a natural basin sealed with an inactive clay or bentonite seal. These basins must be located and sited to avoid flooding from a 100-year flood cycle. The adequacy of these current regulations is now being examined.

Present measures are regarded as being adequate for the short term, but because the hazards persist for up to thousands of years, accepting these measures only postpones implementation of long-term safe management. Pending completion of the current NRC reevaluation, the requirements for new mines and mills cannot be stated (50).

C. Air Quality Impact

Uranium mining and milling may also diminish air quality both on and away from the mine site due to emissions of particulates and gases.

1. Mining operations

Radon gas has been the cause of a number of lung cancer deaths among uranium miners. To reduce radon exposure the mines must be well ventilated. Fresh air is usually directed downward through the production shaft, ducted to mining face, and returned through ore haulage ways where it is discharged through vent holes or shafts. The discharged mine air may contain significant quantities of rock dust and radioactive gases. Radon gas from mine shafts may infiltrate any accessible aquifers or contaminate the surface environment as it is released.

2. Fugitive dust

Particulate matter includes dust from tailings ponds (if less than 4% moisture content), mines, ore hauling, road construction, and piles of overburden and/or rock material. This dust would have a composition similar to that produced by mining or farming with one important difference; the presence of toxic ore particles that may be contained in the ore. These particles may include both radioactive and nonradioactive minerals.

The release of dust containing toxic ore particles can cause adverse health effects if ingested or inhaled. Large quantities of dust may reduce the photosynthetic activity of plants that become coated and may also have a negative aesthetic impact around the site. Fugitive dust may also contaminate nearby surface waters.

Most of the problems associated with fugitive dust can be mitigated by applying dust control measures. Tailings should be kept wet and stockpiles of waste and ore should be stabilized with vegetation or kept moist with water or chemical sprays. If these measures are not followed dust may be carried off-site and be deposited on the surrounding area. Transport of crude or crushed ore between the mine and the mill may also cause air pollution off-site if th ore is note covered and if unpaged transport roads are not sprayed regularly.

3. Gaseous emissions

Another potential impact to air quality is the release of gases including radioactive radon gas, gases form process chemicals, and hydrocarbon gases from mining and milling equipment that burn fossil fuels.

Radon gas can emanate from the walls of open-pit mines and form uranium mill tailings. Lesser amounts of radon may escape from the exhaust vents of underground mines, from ore storage piles and from mine waters that contain radium or radon.

The vent shafts, which flush the mine air for the miners, can pose a problem for nearby residents. Estimates of the magnitude of critical radon emission from the vented air vary greatly. Earlier studies, noting the remote location of most uranium mines, generally concluded that population exposures were negligible. Recent studies conclude differently. Radon gas decomposes rapidly but several of the resulting radioactive daughter isotopes appear to enter the food chain. The problem is critical where nearby homes are occupied by workers who are exposed to the same radon byproducts during working hours.

Impacts on air quality can also result if process chemicals escape from mills or other extraction facilities. Chemicals used in large amounts and having a high degree of volatility include sulfuric acid, anhydrous ammonia and organic solvents. Primary release of these substances would be from spills or evaporation from treatment ponds.

Combustion gases are produced by mining equipment, ore trucks and power generators that burn fossil fuel. These sources may not significantly degrade the air quality at the site but will Incrementally add air pollutants such as oxides of carbon and nitrogen and particulates to the atmosphere.

D. Water Quality Impacts

1. Mining operations

A significant environmental impact associated with uranium mining results from the dewatering of underground or open-pit mines. Mining significantly modifies the normal ground water flow cycle below the water table. Dewatering is accomplished either by a ring of dewatering wells, the use of sumps within the mine or a combination of these two methods. The lower water table can result in exposing mineralized rocks to a new environment which can affect the geochemical structure of those rocks and lead to increased oxidation and the dissolving of radiochemical and toxic materials. Radium-226 with other minerals and decay particles is leached from the mine water as it flows through the mine to the sumps. Ammonia is also present in the mine water due to the use of ammonia blasting agents. In open-pit mines, precipitation falling on the exposed ore and waste rock can leach radiochemical and toxic pollutants.

Ground water that enters underground uranium mines contains a variety of dissolved materials including radium, radon and uranium. It is important to establish the level of natural contamination prior to the commencement of mining. As the water travels through the mine to the collecting sumps it is likely to release radon gas into the mine atmosphere and the water may also become contaminated with uranium. This effluent can contain radioactive elements such as uranium and radium and concentrations of potentially toxic organic compounds such as amines, nitrated, and kerosene as well. The concentrations are dependent on the mining technique and the mineralogy of the deposit. In some operations it is economically feasible to recover uranium from this waste water. Effluent treatment is necessary prior to disposal.

2. Tailings ponds operations

Fluids containing toxic heavy metals may seep from tailings ponds and other ponds used for water treatment. The seepage from a tailings pond can contain a variety of radioactive and nonradioactive toxic heavy metals such as uranium, thorium, radium, selenium, molybdenum, arsenic, vanadium and others. The ponds are usually constructed so that the soil which underlies the pond can trap dissolved ions and prevent their movement. It has been observed that some ions can still migrate from the pond through groundwater movement. Selenium migrated one half mile during a thirty year period from an unlined tailings pond in Canon City, Colorado and is now polluting wells in the area.

Seepage from unlined tailings or water treatment ponds may reach streams or lakes directly. Under arid conditions, evaporation of contaminated ground water may result in the deposition of salts at the surface where they are transported by runoff. The seepage is usually diluted during these processes, but the concentration of the contaminants can be increased by natural mechanisms. The trapping of radionuclides and heavy metals has been observed in soils and stream sediments. Sediments that contain radionuclides can be transported downstream causing a concentration of radioactive material to move to other areas, such as lake sediments.

3. Waste rock storage areas

Piles of waste rock and overburden dumps can also be sources of contaminated seepage. Water from rain and snowfall can dissolve and transport minerals such as copper, nickel, mercury and zinc. The composition of seepage will depend on the mineralogy of the ore and other factors including the pH of the precipitation.

The prevention of may not be difficult. Lining mill and mine water treatment ponds with impermeable clay or synthetic materials reduces seepage significantly. The use of impervious ponds and covers for piles will help control both seepage and the removal of particles by wind action.

Waste rock containing uranium minerals of low grade ore can also present a potential for long-term radon emissions and dissolved toxics in surface runoff. Control practices range from no cover or stabilization to covering the waste with a gravel, clay or synthetic pad, and using a water treatment system for runoff from the pile. This problem, like that of management of the uranium tailings, is not yet resolved. Because of the long life of the radioactive materials the hazards persist for thousands of years. The long term effectiveness of radon emission control for various cover materials (or combinations of cover materials) is difficult to estimate due to variability of atmospheric influences, mechanicals stresses, and dislocations.

E. Postoperational Impacts

Postoperatlonal impacts from a mining and milling operation will depend on the siting of the facilities and the type of reclamation procedures that are followed. There are essentially three parts of the mining and milling operation that need to be reclaimed: the mine site, the mill site and the tailings pond.

1. Underground mines

Reclamation of an underground uranium mine usually includes removal of all above ground equipment, decontamination of the soil, sealing of all mine openings, grading and reseeding of the site. Roads that were constructed may or may not be removed. In some cases structures may also be left on the site after being decontaminated.

Problems may develop in the future if subsidence takes place after the mine is closed. Subsidence could adversely affect land use, water quality and air quality. Backfilling of underground mines should help prevent this problem. In many cases, an underground mine site can be restored to its original use after reclamation.

2. Open-pit mines

In the case of open-pit uranium mines reclamation is usually not complete. In the past most open-pits were not reclaimed. This practice severely limits subsequent land use and may necessitate the permanent closing of the area from public use. Current reclamation practices involve backfilling the pit with waste rock and overburden, and then grading and reseeding the site. Open-pit uranium mines reclaimed in this manner may be suitable for some future uses such as timber production. Agricultural uses may be discouraged because of the possible bioaccumulation of residual metals.

Both open-pit or underground uranium mines can seriously affect the long-term water quality of a region if uranium mines are unreclaimed or reclaimed in such a way that waters from separate aquifers intermingle. Surface waters may also be contaminated from windblown dust or runoff from improperly reclaimed mining sites.

Further, the air quality of the surrounding area can be impacted by fugitive dust and radon gas releases from lean ore in the walls of unreclaimed open pit mines and waste rock stockpiles.

3. Mill site

The uranium mill site would be subject to reclamation. Structures and soil would be decontaminated or demolished, and the mill site could probably be restored to its preoperational settings.

4. Tailings basin

Since over 85 percent of the radioactive materials in the crude ore are retained in the tailings, special consideration must be given to the design, construction and reclamation of uranium tailings basins. Past mining practices have led to environmentally unsound disposal methods, including dumping tailings directly into streams and siting tailings basins near populated areas or within the floodplain of a river.

Since tailings will remain radioactive for hundreds of thousands of years the disposal system will need to isolate the tailings for an extrodinary period of time. Basic precautions would include siting the tailings pond away from populated areas and in a topographic area that is geologically stable and not subject to severe erosion.

The basin should be lined with clay. At the completion of the project, the pond should be covered with several feet of overburden and soil to reduce radiation and radon emanations. Long-term maintenance and monitoring of inactive tailings would be necessary to insure that the tailings are not removed or eroded. Since the effectiveness of tailings disposal methods is uncertain, future land uses of the tailings site are limited. The title to uncertain, future land uses of the tailings site are limited. The title to the land should carry a restriction noting the presence of tailings basin. Ownership and future uses should be limited by legal constraints to avoid undue future environmental and public exposure as well as future costs.

F. HEALTH IMPACTS

1. Radioactivity

Radioactivity is the property of atoms with unstable nuclear configurations (radionuclides) to spontaneously transform. Such transformations are accompanied by the emission of particles and/or electromagnetic energy. These transformations will continue until a stable configuration is reached. For example, uranium-238 undergoes a specific decay path from radioactive, unstable uranium-238 to stable, non-radioactive lead-206. It involves 14 separate intermediate decay steps with the release of energy (radiation) through alpha and beta emissions (particulate) and gamma emissions (electomagnetic). Each of these 14 elements is termed a daughter in the uranium-238 decay series (Figure 10). Similar decay schemes exist for other naturally occurring radionuclides, such as thorium-232 and uranium-235.

All unstable nuclides undergo radioactive decay at characteristic rates. The time required for half of the atoms of a given radionuclide to decay is called the radioactive half-life. Measured half-lifes range from less than a second to billions of years. For example, the half-life of polonium-214, is 0.00016 seconds and the half-life of uranium-238 is 4.47 billion years (55).

There are many naturally occurring radioactive elements in the earth's crust. Among these are uranium-238, thorium-232, and unanium-235 and their daughters. These radionuclides are continually undergoing decay to stable, non-radioactive elements. However, based on the known half-lives, the time involved is measured in billions of years. It will take 4.5 billion years for 1/2 of the uranium-238 now present in the earth's crust to decay to thonum-234. It will take another 4.5 billion years for 1/2 of the remaining uranium-238 to decay. So, in terms of human existence on earth, uranium-238, thorium-232, and uranium-235 have always been, and will continue to be present in the earth's crust.

2. Sources of Radioactivity

All living organisms are constantly exposed to radiation from radioactive elements in the earth's crust and from extra-terrestrial or cosmic radiation from the sun. Life on earth has evolved amid the constant exposure to these sources. These types of sources are referred to as natural or background sources. In the last 100 years, exposure to radioactivity has occurred with the use of radioactive material by man. Often naturally occurring radioactive elements are mined and concentrated for medical or research purposes. Also, radioactivity is induced by high-energy particle bombardment in particle accelerators and by neutron activation in nuclear reactors. The testing of nuclear weapons has also contributed. These sources of radioactivity are often termed manmade or technology-enhanced.

Humans receive radiation doses from these natural and manmade sources by external exposure and through internal exposure by inhalation or ingestion of radioactive material. Each individual normally carries within his body small amounts of radioactive material derived from food, water or air. Some tissues and organs serve as depositories for certain radioactive materials. For example, radioactive iodine-131 tends to accumulate in the thyroid gland and radioactive radium-226 tends to accumulate in the bones. So, even in the absence of manmade sources of radiation, humans normally contain small amounts of radioactive material.

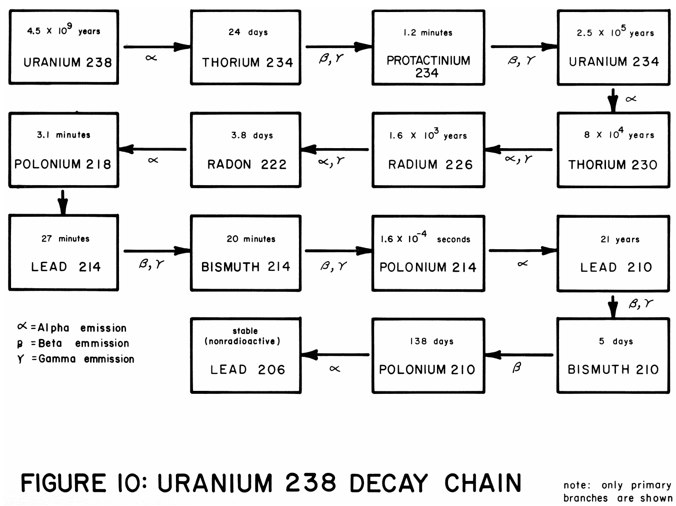

Figure 10. Uranium 238 decay chain.

The radiation levels measured from the earth's crust vary throughout the world. This is due primarily to the nonuniform distribution of radioactive elements in the earth's crust. Radioactive ore bodies are concentrated in relatively few locations and vary in percent of radioactive elements present. Also, an ore body can be near the surface or as much as several hundred feet below the land surface. These factors account for the fluctuations in radiation measurements at ground level.

In addition to variations in radiation levels from the earth, there are variations in the levels of cosmic radiation. These variations are primarily related to altitude, with increasing levels associated with an increase in elevation. For example, Aiken, South Carolina and Dallas, Texas have cosmic radiation levels of 3.7 and 3.6 uR/hr, respectively. This Is about 60% of those recorded for Fort Collins, Colorado and Elko, (5.8 uR/hr). South Carolina and Texas have mean elevations of 350 and 1,700 feet, while Colorado and Nevada have mean elevations of 6,800 and 5,500 feet. (Table 6) (51).

A comparison of terrestrial radiation levels for these cities also shows a marked difference. The two western cities measured levels in the 8.3-9.2 uR/hr. range while Dallas, Texas and Aiken, South Carolina record 2.9 and 2.7 uR/hr (Table 6). A review of this table further illustrates geographic differences in gamma radiation levels in 22 U.S. cities in 1965.

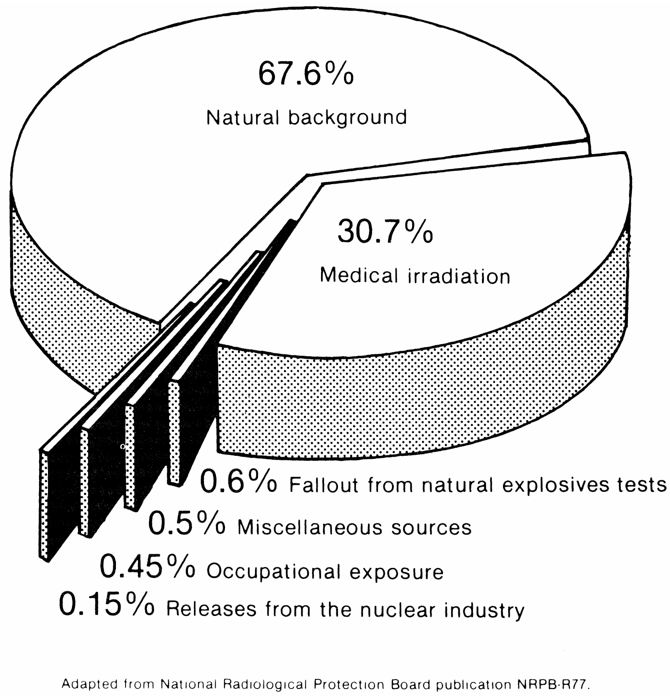

Figure 11. Radiation exposure from different sources.

In comparing the exposure of humans from different sources of radiation, including natural background, the International Atomic Energy Agency in Vienna, Austria, used the pie chart reproduced in Figure 11. This figure was constructed for the United Kingdom, but it is generally applicable to other developed countries. It shows that industrial commercial sources contribute 0.6% of the total radiation to human populations while natural background and medical sources account for 98.3%. Uranium exploration and mining are included in the 0.45% occupational exposure contribution.

Individuals living in different parts of the United States are exposed to different levels of natural radioactivity. Radiation doses to humans are expressed in rems (roentgen equivalent man). The rem is used to account for the fact that some types of radiation cause more biological damage than others. The following table illustrates different radiation does units (Table 7). In Table 8, we see that the average annual external gamma whole body dose from terrestrial radioactivity is about 60 mrem/person (52). Measurements were made in 36 states and territories of the United States. Measurements of Michigan levels were not made but were assumed to be equal to the U.S. average.

The total annual dose rate to the average U.S. citizen from radioactive material in the earth and from cosmic radiation is about 100 mrem per year (51). In Table 9, which is taken from the publication Radiation in Medicine and Industry-Nuclear Radiation Facts and Figures (53), the average radiation does in Michigan due to natural background is given as 80 mrem/person/year.

Location	*^{40}K*	*^{238}U + Dtrs[2]*	*^{232}Th + Dtrs[2]*	*Total Terres-trail*	*Cosmic*	*Total*
Aiken, S.C.	*0.1*	*1.2*	*1.4*	*2.7*	*3.7*	*6.4*
Dallas, Tex.	*0.6*	*0.9*	*1.4*	*2.9*	*3.6*	*6.5*
Reno, Nev.	*1.3*	*1.0*	*1.8*	*4.1*	*5.5*	*9.6*
Rapid City, S.D.	*1.1*	*1.5*	*1.7*	*4.3*	*4.7*	*9.0*
Spring Valley, Minn.						
Salt Lake City, Utah	*1.8*	*1.1*	*2.1*	*5.0*	*5.7*	*10.7*
New Orleans, La.	*1.9*	*1.2*	*2.6*	*5.7*	*3.5*	*9.2*
Goleta Beach, Calif.	*2.6*	*1.5*	*1.7*	*5.8*	*3.6*	*9.4*
Largo, Md.	*1.8*	*1.5*	*2.9*	*6.2*	*3.6*	*9.8*
Pelham, N.Y.	*2.2*	*1.3*	*3.0*	*6.5*	*3.6*	*10.1*
Sundance, Wyo.	*2.2*	*1.9*	*2.4*	*6.5*	*5.6*	*12.1*
Argonne, Ill.	*2.0*	*2.2*	*2.4*	*6.6*	*3.8*	*10.4*
Sioux Falls, S.D.	*2.1*	*1.8*	*3.0*	*6.9*	*4.1*	*11.0*
Carlisle, Pa.	*2.4*	*1.5*	*3.0*	*6.9*	*3.0*	*10.6*
Chadron, Neb.	*2.3*	*1.7*	*3.3*	*7.3*	*4.8*	*12.1*
New York, N.Y.	*2.2*	*1.4*	*4.2*	*7.8*	*3.6*	*11.4*
Alamagordo, N.M.	*2.8*	*2.1*	*3.3*	*8.2*	*5.0*	*13.2*
Fort Collins, Colo.	*2.5*	*1.8*	*4.0*	*8.3*	*5.8*	*14.1*
Elko, Nev.	*2.7*	*3.0*	*3.5*	*9.2*	*5.8*	*15.0*
Bonny Doon, Calif.	*7.8*	*1.4*	*1.8*	*11.0*	*4.1*	*15.1*
Denver, Colo. (various locations)	*(2.3-3.9)*	*(1.3-2.4)*	*(3.4-7.4)*	*(7.1-13.2)*	*(5.9-6.0)*	*(13.0-19.2)*
Rolesville, N.C.	*5.2*	*2.3*	*10.2*	*17.7*	*3.7*	*21.4*

1 uR/hr = 8.8 mR/year.
2 Dtrs. - Daughters.

Table 6. Terrestrial and Cosmic Gamma Radiation Levels Measured in the United States, 1965 (uR/hr)[1] (51).

3. Biological Effects of Radiation

Absorption of physical energy from ionizing radiation can damage or kill a cell. The absorbed energy causes ionization or excitation of molecules within the cell. For example, the excitation of water will produce extremely reactive free radicals (electrically neutral molecules containing an unpaired electron) which may then interact with biologically important macromolecules such as proteins and nucleic acids. These indirect reactions of the direct irradiation of these biologically important molecules may cause a variety of cellular and biochemical effects. The result is either cell death which, depending on the extent, could lead to malfunctioning or death of an organ, or a nonlethal change that may be expressed after a period of time, such as mutagenesis and carcinogenesis.

Unit	*Abbreviation*	*Definition*	*Comment*
roentgen milliroentgen microroentgen**	*R (mR) (uR)*	*represents the absorption of energy in air*	*for X-rays and gamma rays only*
radiation absorbed dose, or millirad	*rad (mrad)*	*represents the absorption of 100 ergs of energy per gram of material*	*important unit because it represents how much energy is absorbed in the material of concern*
roentgen equivalent man (or dose equivalent), or millirem	*rem (mrem)*	*this unit is the product of the amount of energy absorbed (rad) times the efficiency of radiation in producing damage (QF)** rem = rad x QF*	*this unit accounts for the different degrees of damage produced by equal doses of different radiations, for example: X-rays, gamma rays, and beta particles QF=1 neutrons QF=2 to 10 alpha particles QF=10 to 20*

** A milliroentgen is one thousandth of a roentgen*
A microroentgen is one millionth of a roentgen

*** QF = Quality Factor. Since the QF for beta, gamma and X-radiation is 1, the rem and the rad are equivalent in this instance and are frequently used interchangeably.*

Table 7. Radiation Dose Units.

Cells vary in their sensitivity to radiation. The cells most sensitive to ionizing radiation are generally those that divide rapidly, while slowly dividing cells, completely differentiated cells, and other cells no longer undergoing mitosis are the most radioresistant. This principle was first recognized in 1906 by Bergonie and Tribondeau who stated that, “the radiosensitivity of cells is related directly to their reproductive capacity and indirectly to their degree of differentiation.”

Based on this observation, five classes of radiosensitivity were developed. Cells having the highest sensitivity to radiation constitute the first class and include rapidly dividing types such as hematopoietic stem cells, cells of the intestinal lining, type A spermatogonia, germinal cells of the skin and granulose cells of ovarian follicles. The second class contains cell types that are less sensitive to radiation. These include cells of the hematopoietic system, spermatogonia and oocytes that are undergoing some degree of differentiation. The third class contains cells that divide irregularly and are therefore intermediate in radiosensitivity. Included in this class are endothelial cells and fibroblasts. The fourth and fifth classes consist, respectively, of cells that only slowly divide or cells that have completely lost the ability to divide and are well differentiated. The fourth class are relatively radioresistant cells which include: ephithilial cells; duct cells of the salivary glands, liver, kidney, and pancreas; and cells of the adrenal, thyroid, parathyroid, and pituitary glands. Fifth class cells that are the most radioresistant are neurons, some muscle cells, erythrocytes, spermatozoa, and epithelial cells of the sebaceous glands.

Political Unit	*Average Annual Doses*	*Political Unit*	*Average Annual Doses*
Alabama	*70*	*New Jersey*	*60*
Alaska	*60**	*New Mexico*	*70*
Arizona	*60**	*New York*	*65*
Arkansas	*75*	*North Carolina*	*75*
California	*50*	*North Dakota*	*60**
Colorado	*105*	*Ohio*	*65*
Connecticut	*60*	*Oklahoma*	*60*
Delaware	*60**	*Oregon*	*60**
Florida	*60**	*Pennsylvania*	*55*
Georgia	*60**	*Rhode Island*	*65*
Hawaii	*60**	*South Carolina*	*70*
Idaho	*60**	*South Dakota*	*115*
Illinois	*65*	*Tennessee*	*70*
Indiana	*55*	*Texas*	*30*
Iowa	*60*	*Utah*	*40*
Kansas	*60**	*Vermont*	*45*
Kentucky	*60**	*Virginia*	*55*
Louisiana	*40*	*Washington*	*60**
Maine	*75*	*West Virginia*	*60**
Maryland	*55*	*Wisconsin*	*55*
Massachusetts	*75*	*Wyoming*	*90*
Michigan	*60**	*Canal Zone*	*60**
Minnesota	*70*	*Guam*	*60**
Mississippi	*65*	*Puerto Rico*	*60**
Missouri	*60**	*Samoa*	*60*
Montana	*60**	*Virgin Islands*	*60**
Nebraska	*55*	*District of Columbia*	*55*
Nevada	*40*	*Others*	*60**
New Hampshire	*65*	*Total United States*	*60*

**Assumed to be equal to the United States average*

Table 8. Estimated Annual External Gamma Whole-body Doses from Natural Terrestrial Radioactivity in Millirems Per Person (52, 53).

There are several repair mechanisms available to the cell and organ that can offset some or all of the damage inflicted by radiation. However, the success of such repair is dependent on the extent of damage and the type of cell composing the tissue. For example, tissues containing rapidly dividing cells such as bone marrow, intestinal lining, and the developing embryo may undergo cell division before the repair process has time to correct the damage.

Source	**Amount of Radiation*
Natural Background	
Florida	*60 mrem/yr*
Michigan	*80 mrem/yr*
Colorado	*145 mrem/yr*
U.S. average	*100 mrem/yr*
Medical Diagnosis	
Average (US)	*75 mrem/yr*
Chest film	*10 mrem/film*
Dental X-ray	*300 mrem/film*
Nuclear Power	
Maximum dose to a member of the public who remains continuously for one year at the site boundary of a typical 1,000 megawatt, electric boiling water reactor (Ref.2)	*4.6 mrem/yr*
Maximum dose to a member of the public who remains continuously for one year at the site boundary of a typical 1,000 megawatt electric pressurized water reactor (Ref.2)	*1.8 mrem/yr*
Code of Federal regulations, Title 10, Part 50, Appendix 1 specifies the upper limit allowable dose to a member of the public remaining continuously for one year at the site boundary of a typical 1,000 megawatt, electric boiling water reactor or pressurized water reactor	*5.0 mrem/yr*
Three Mile Island accident (50-mile radius, average total dose per person)	*1.4 mrem*
Consumer Products	
High voltage color television sets (dependent on age and type of set, distance of viewer, etc.); wrist watches; smoke detectors	*0.03 mrem/yr*
Air Flight	
Los Angeles - London, round trip	*4 mrem/trip*
Global Fallout	*4 mrem/yr*
**These numbers will vary slightly in different publications.*	

Table 9. Average Doses and Dose Rates From Various Radiation Sources (52)

4. Health Consequences of Radiation

a. Dose relationship

The adverse health effects associated with high doses of ionizing radiation have been elicited from studies of laboratory animals and epidemiological studies of exposed humans. Studies have been conducted on the survivors of the nuclear explosion in Japan, Japanese fisherman, Marshall Island residents exposed to nuclear weapon test fallout, and persons treated with radiation in medical therapy (52).

Based on these studies, it is known that deposition of sufficient energy in a particular organ will cause cell death, which, if sufficiently extensive, will lead to a malfunctioning of the organ or eventually its death. Symptoms associated with acute radiation damage include nausea, vomiting, diarrhea, skin lesions and cataracts. Death from high levels of exposure may be due to destruction of the gastrointestinal tract (gastroenteric syndrome), cardiovascular degeneration or damage to bone marrow cells. The onset of these effects is rapid and their severity and incidence are dose-dependent. Adverse health effects of this nature are generally referred to as acute radiation damage and can occur following a whole-body exposure of 50 rem and greater (Table 10). However, exposure levels of this magnitude are only likely to occur under extreme situations such as nuclear accidents or nuclear warfare.

Generally, the higher the dose, the more drastic are the effects and the sooner they appear. A thousand rem of acute whole-body exposure will kill any human within one or two weeks from blistering of the lining of the small intestine. If a number of humans are exposed to 350 rem (350,000 millirem) of acute, whole-body X-rays, approximately one-half the number will die of blood and bone marrow damage within the first 60 days.

Very large doses of radiation exposure also seem to accelerate the normal aging process. That is, persons exposed to very large doses of radiation may age more rapidly than those who are unexposed. Doses of between 50 rem (50,000 millirem) to 350 rem (350,000 millirem) and upward can produce a variety of subtle effects, including various degrees of nausea, vomiting, diarrhea, reddening of skin, loss of hair, blisters, a depression of the number of blood and bone-marrow cells and a decreased efficiency of immune response to infections.

Doses of between 25 and 50 rem (25,000 and 50,000 millirem) can produce measurable clinical (disease-related) effects in adult humans. In the human fetus, especially in the first trimester, injuries can be sustained from doses of from 1 to 10 rem (1,000 to 10,000 millirem). At later growth stages, the fetus is not as radiosensitive, but is still quite vulnerable.

At 4,000 to 12,000 mrem, following cardiac catheterization procedures, an increase in chromosome aberrations sometimes is observed within 30 minutes after human exposure. At 2,000 to 5,000 mrem, a reduction of as much as 35 percent in lymphocyte count can be observed in humans. At 1,000 to 3,000 mrem, the sensation of light can be produced in human subjects and is probably an effect on peripheral rod cells of the eye.

In addition to acute damage from radiation exposure there is also strong evidence that the induction of delayed somatic effects may occur. Animal studies and epidemiological studies of humans have clearly shown that ionizing radiation is leukemogenic, carcinogenic and mutagenic at high dosages. For example, laboratory animals exposed to sublethal doses of radiation have significantly shortened life spans due to death from cancer than the control animals. These studies have also demonstrated a dose-dependent leukemogenic effect for ionizing radiation.

Dose		
(rem)	*(mrem)*	*Effect*
10,000	*10,000,000*	*Immediate prostration, comma, followed by death within 1 or 2 days from severe central nervous system damage.*
1,000	*1,000,000*	*Immediate nausea, vomiting, diarrhea. Death within 1 or 2 weeks from blistering of small intestine. Complications from depressed bone marrow activity.*
100	*100,000*	*No overt effects. Some depression of white cell count. Statistical increase in probability of radiogenic leukemia and life shortening (1 to 5 days/rem).*
10	*10,000*	*Effects are difficult to measure. In early embryo, developmental defects are possible. Subtle abnormalities of brain structure and perhaps also function may occur above 10 rem.*
1	*1,000*	*No measurable effects except a statistical increase of tumor incidence before age of 10 in infants exposed in utero.*
		Subacute - clinical effects are unmeasurable with current technology

Table 10. A Summary of Acute Dose-Response Effects in Humans

b. Carcinogenic and mutagenic effects

Although the toxic effects of high doses of radiation are well understood (Table 10), the health effects associated with low level exposure (less than 1,000 mrems) to radiation are questionable. This is due to the uncertainties associated with dose-response projections in the low dose range and specifically, whether the dose-response relationship is linear or nonlinear and whether there is a no-effect threshold.

Low level exposure to radiation has been associated with various somatic effects such as leukemia, cancer and shortened lifespan in addition to genetic mutations. Unlike the cell damage and death associated with acute radiation, low level radiation is less likely to kill or damage cells, thus allowing the body's repair processes to correct the damage. However, if cell division occurs before the damage is corrected, serious genetic flaws may be incorporated into future generations of cells which may later manifest themselves as malignacies or genetic changes. Since the appearance of these effects may be delayed for years, they present a serious concern in dealing with low level exposure.

Several mechanisms have been postulated that could explain radiation-induced carcinogenesis. One of the most popular theories proposes the production of breaks or mutations in the DNA molecule from either a direct hit of radiation energy or from the production or reactive radicals such as those generated by irradiation of water in the cell. Another theory suggests that rather than direct damage to the genetic material, irradiation may damage various mechanisms that regulate the expression of genetic material. For example, information regulating cell growth may be repressed. Other investigators have proposed mechanisms that involve the activation of an inert virus resulting in destructive infection and changes in the antigens of the cell membrance which could disrupt the control of cell growth by contact inhibition.

The genetic effects from low level exposure to ionizing radiation can occur because of the high radiosensitivity of spermatogonia and oocytes in the early states of differentiation. Irradiation of these cells may result in an alteration or breakage of their own DNA. If this is sufficiently extensive, the genes responsible for carrying the genetic information necessary to govern cellular functions and the nature of future offspring may be changed.

Alteration of a single gene can result in several types of mutations. Dominant mutations show up quickly in successive generations of cells and include such anomalies as neurofibromatosis and achrondoplasia. Recessive mutations are usually delayed in their expression resulting in diseases such as cystic fibrosis and Tay-Sachs. In addition to dominant and recessive mutations, there are sex-linked mutations such as color blindness in males. Multifunctional-type mutations are another type which include complex disorders involving the interaction of an altered genome and environmental factors. Birth defects and diseases developing later in life such as heart disorders, asthma, diabetes and hypertension are included in this group.

Besides the induction of mutations in the DNA strand, chromosomal breaks may also occur following exposure to radiation. Although the majority of these defects are spontaneously aborted, several are expressed, the most common being Downs Syndrome.

Genetic effects from radiation can range from trivial to lethal. However, as stated earlier, the incidence and severity of these effects is generally dose-dependent. Though genetic effects are well documented in laboratory animals exposed to high levels of ionizing radiation, the frequency and nature of genetic effects in humans exposed to low level radiation is unclear. For example, long term studies of bomb survivors at Hiroshima have as yet been unable to detect an increased incidence of genetic effects in offspring of this group.

c. Specific effects associated with uranium mining

Radon and its daughter products have been studied in relation to uranium mining and are known to cause serious health effects if inhaled over long periods of time. Radon daughters attach themselves to larger dust particles and water droplets and can be inhaled. Once in the lungs, they become lodged in close contact with tissue. Radon daughters emit radiation, which can cause the cellular changes that induce cancer.

Epidemiological studies of uranium miners in Colorado and Ontario indicate a higher incidence of lung cancer than expected. The investigators suggest that the higher incidence of cancer was related to radon gas which emanates into the mines and whose radioactive daughters then become attached to dust particles. Inhalation of this dust by the workers resulted in alpha irradiation of the lung. This lung cancer is believed to be the result of high level exposure which occurred before control measures were enforced in uranium mines.

d. Risk assessment of low dose of radiation

The health effects associated with low-level radiation, as produced by uranium ore, is a controversial issue. While there are many uncertainties associated with health effects of low-level radiation, there appears to be general agreement that no specific level of radiation, including background levels, can be characterized as safe or risk free. In other words, there is no definitive radiation level above which exposures are generally agreed to be "unsafe" and below which exposures are generally thought to be "safe" (56).

Risk assessment is an analytical process to estimate the probability of occurrence of an adverse health effect in humans from work or recreational activities or following exposure to a specific toxic agent. This process involves an assessment of the toxicological properties of the agent in addition to its exposure potential for a given situation. It is not limited only to radiation hazards.

Before a calculation of risk to human health from exposure to radioactive material can be performed, several decisions must be made regarding which harmful effect of radiation best serves as an index of risk and which mathematical extrapolation model will provide an accurate calculation of risk. Most studies of radiation exposure select carcinogenicity or mutagenicity (birth defects, specifically) as suitable endpoints for determining risk. Their selection is based on the assumption that these adverse effects lack a dose-response threshold and therefore, will occur in the exposed population at some frequency down to zero dose.

The absence of a threshold for carcinogenicity and mutagenicity is difficult to prove as only a small proportion of exposed individuals will demonstrate any effects at low levels of exposure. This is complicated further by the delayed time for expression of these effects. For example, various types of cancer may not show up in the exposed population until 5 to 40 years after the initial exposure.

Therefore, because it's not possible to prove conclusively that a threshold exists below which no effects would occur, it is assumed for purposes of risk assessment that there is no threshold limit and the fraction of individuals affected would be proportional to the dose down to zero.

The choice of an accurate extrapolation model is complicated by the same factors that do not allow demostration of the absence or presence of a threshold. Given that a threshold does not exist for these effects, there are still a number of paths the dose-response curve can follow as it approaches zero. (Figure 12). Since none of the hypotheses that generate these various curves can be clinically proven, the dose-response curve is assumed to be linear (Figure 12, curve a) and therefore may be used in an estimation of risk.

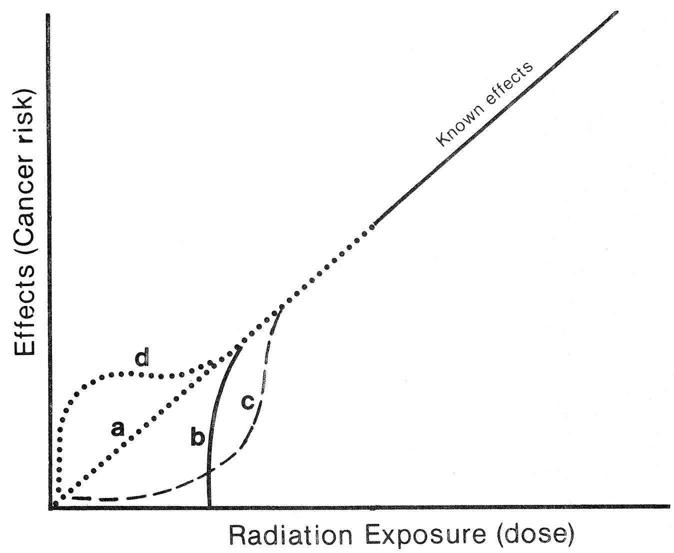

Figure 12. Some proposed models of how the effects of radiation vary with doses at low levels.

At present, the assessment of the risk from low levels of radiation exposure is estimated by extrapolation of the results obtained from populations exposed to high doses of radiation (e.g., atomic bomb survivors, individuals treated with x-rays, laboratory animals exposed to high doses, and uranium miners exposed to radon gas) by application of the linear model. The Biologic Effects of Ionizing Radiation (BEIR) Report (57) assumes the validity of the linear extrapolation model for risk assessment and has used it to estimate the excess number of cancer deaths per year in the United States population following exposure to 100 mrem per year.

The calculations indicate that this level of exposure would cause between 1,700 to 9,000 cancer deaths per year. There are approximtaly 311,000 naturally occurring cancer deaths per year. Since naturally occurring background radiation is approximately 100 mrem per year, about 0.6 percent to 2.9 percent of the naturally occurring cancer deaths are the result of exposure to this background radiation. Using these figures the lifetime risk of cancer death for a population exposed to 100 mrem of radiation per year is between 9.0 to 46.0 deaths per one million individuals. Therefore, an individual receiving a dose of 100 mrem per year would have a probability of death from cancer of 0.9 to 4.6 in 100,000.

In the occupational setting, where there is a 5 rem per year maximum permissible level for workers, a risk of 4.5 to 24.0 in 10,000 is calculated. Approximately one-fifth of these deaths would be from leukemia.

The International Commission on Radiological Protection is currently considering an acceptable level of annual mortality due to radiation exposure of 1 in 10,000. This would be 4.5 to 24.0 times lower than the risk calculated above for the worker's exposure to 5 rem per year. However, it should also be pointed out that studies by the International Commission on Radiological Protection have shown that the average radiation worker is exposed to only 0.5 rem per year and that very few workers receive a dose approaching the 5 rem per year maximum level. In view of this finding, the Commission has agreed to use the 0.5 rem level as the average dose received by radiation workers. This level of exposure would result in a risk of 0.45 to 2.4 in 10,000 which now brackets the 10^{-4} (1 in 10,000) proposed acceptable risk.

As a means of comparison, Table 11 lists the risks of death per 10,000 individuals per year for various occupations and recreational activities.

Besides the induction of cancer, radiation may also cause genetic effects as the result of damage to the DNA of sperm and ova. Estimates of the frequency of all genetic effects are based primarily on animal experiments. Epidemiological studies of humans exposed to radiation, specifically atomic bomb survivors, have not as yet shown any genetic effects. Therefore, the animals studies may provide an upper limit for the risk of genetic effects due to radiation exposure.

<u>Recreational Activities</u>	
Football	*0.4*
Skiing	*0.3*
Canoeing	*4.0*
Motorcycle racing	*180.0*
<u>Occupations</u>	
Coal Mining, black lung disease	*1000*
Firefighters	*100*
Steel workers	*6*
Railroad workers	*40*

Reference: Chemical and Engineering News, January 309 p.35 (1978)

Table 11. Risks of Death per 10,000 per Year.

To minimize the genetic effects the International Commission of Radiological Protection has recommended a 5 rem maximum exposure level over a reproductive lifetime of 30 years for the general public. This corresponds to approximately 170 mrem per year which is slightly higher than the 100 mrem background value.

The BEIR Report has estimated the number of genetic effects produced by a radiation exposure of 170 mrem per year and they are expressed as the number of first generation genetic effects per one million live births. These estimates range from 120 to 1080 in one million or in other words, given an annual total of 3 million live births in the United States, from 0.012 to 0.11 percent of live births would be affected. Although many of these genetic effects will have a minimal impact on the individuals health, 10 to 20 percent may result in early death.

Assuming a worst case situation of a worker exposed to the maximum permissible level of 5 rem per year using the above figures, the incidence of genetic effects would range from 3,500 to 32,000 per one million live births (0.4 to 3.2%). A 0.5 rem average level of exposure to the radiation worker results in a risk of 350 to 3200 in one million (0.04 to 0.32%).

Given a normal incidence of 180,000 to 300,000 genetic effects per 3 million live births. the 170 mrem per year exposure to the general population would correspond to an increase in those born with genetic effects of 0.0012 to 0.018 percent. For workers exposed to doses of 0.5 rem per year and 0.5 rem per year this would result in ranges of 0.0035 to 0.05 percent and 0.035 to 0.5 percent, respectively.

Epidemiological studies of uranium miners in Colorado and Ontario strongly indicate a relationship between high exposure to radon gas and increased incidence of lung cancer. The risk of lung cancer from low level exposure was determined in the BEIR Report by applying the linear extrapolation model to data obtained from uranium mines in the United States over the period of 1951 to 1971. The report concluded that each Working Level Month (WLM) of exposure resulted in approximately 3.2 excess cases of lung cancer per one million workers per year. Given that the maximum permissible exposure to radon daughters is 4 WLM per year for uranium miners and 0.02 WL per year for the general public, estimation of the risk would be 13 and 0.064 excess cases of lung cancer per one million individuals, respectively.

Given the above calculations of risk to cancer or genetic anomalies from exposure to ionizing radiation it is important and appropriate to reexamine the numerical risk assessment process and underscore the assumptions necessary for its use. Given the absence of well defined epidemiological studies in terms of levels of exposure and corresponding response rates, the dose-response relationship of chronic health effects versus radiation dose are based on laboratory animal studies. Extrapolation from these studies to the human situation calls for the assumption that there are no basic metabolic or kinetic differences between laboratory animals and man. The use of mathematical models which serve as vehicles for this extrapolation also dictates the acceptance of various assumptions which further restrict the scientific basis of risk assessment such as: linear extrapolation outside the experimental data from one point on the dose-response curve and the absence of any repair mechanisms. All of these assumptions tend to influence conservatively the estimation of risk, however, from the standpoint of establishing guidelines which are designed to adequately protect human health, this approach to risk assessment is necessary especially when faced with the alternative "wait-and-see" approach.

Assuming the non-threshold nature of the risk assessment models means there will always be some risk associated with any level of radiation above zero. It now becomes a matter of defining a level of acceptable risk. Mantel and Bryan (54) define "virtual safety" as a risk less than or equal to 1 In 100 million for a lifetime. The FDA however, in 1977, considered a risk of 1 in 1 million for a lifetime to be acceptable in terms of impact on public health (55). C. L. Comar suggests several guidelines for dealing with risks (56):

1. eliminate all voluntary or involuntary risks that have no benefit and are avoided without great cost.

2. eliminate any large risk, 10^{-4} (1 in 10,000) or greater, having no overriding benefits.

3. ignore any small risk, 10^{-5} (1 in 100,000) or less, that is not covered in number 1 above and most importantly,

4. actively study risks falling between these limits and do not proceed with action until benefits and risks are evaluated carefully.

These are very general statements and are certainly open to subjective interpretation depending on the situation. However, they serve to emphasize a very important point concerning acceptable risk. The determination of acceptable risk is not a scientific decision but rather one which must be made by society and only after a clear understanding of the benefits and the risks.

5. Radiation Standards

Recognizing that natural and manmade sources of radiation have caused lethal and may cause sublethal impacts on humans, standards for protecting the general public and occupational workers from radiation hazards have been developed. The standards have been developed primarily by three organizatons; the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurement and the American National Standards Institution (53).

Since World War II, several federal agencies in the United States have been responsible for the enforcement of radiation standards. The include:

Environmental Protection Agency (ERA), successor to
Federal Radiation Council (FRC)

Nuclear Regulatory Commission (NRC), successor to Atomic Energy Commission (AEC)

Department of Health and Human Services (HHS)--Bureau of Radiological Health (BRH)

Interstate Commerce Commission (ICC)

Department of Defense (DOD)--military application only

Occupational Safety and Health Administration

Table 12 indicates the three major areas of federal regulation over radiation hazards: Standards for Protection Against Radiation (10 CFR 20), Environmental Radiation Protection Standards for Nuclear Power Operations (40 CFR 190) and Interim Primary Drinking Water Regulations-Radionuclides (40 CFR 141). Table 13 identifies the array of subjects included in the radiation standards or the advisory recommendations on development of federal radiation standard policy (61).

The Standards for Protection Against Radiation (10CFR20) generally cover two areas; exposure standards for occupational workers and exposure standards for the general public. There are five general occupational areas associated with radiation exposure:

1. Medical
2. Industrial
3. Research
4. Nuclear Power Plants
5. Military

In each category all workers exposed to ionizing radiation in the course of their normal duties are regulated. The standards address the maximum permissible dose and the long-term accumulated maximum permissible whole-body dose.

	Regulations
10 CFR 20,	*Standards for Protection Against Radiation*
40 CFR 190,	*Environmental Radiation Protection Standards for Nuclear Power Operations*
40 CFR 141,	*Interim Primary Drinking Water Regulations - Radionuclides*
	Recommendations
NCRP Report 39,	*Basic Radiation Protection Criteria*
NCRP Report 42,	*Radiological Factors Affecting Decision-Making in a Nuclear Attack*
NCRP Report 43,	*Review of the Current State of Radiation Protection Philosophy*
NCRP Report 46,	*Alpha-Emitting Particles in Lungs*
NCRP Report 48,	*Radiation Protection for Medical and Allied Health Personnel*
NCRP Report 50,	*Environmental Radiation Measurements*
NCRP Report 52,	*Cesium-137 from the Environment to Man: Metabolism and Dose*

NCRP Report 53,	*Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally-Exposed Women*
NCRP Report 54,	*Medical Radiation Exposure of Pregnant and Potentially Pregnant Women*
NCRP Report 55,	*Protection of the Thyroid Gland in the Event of Releases of Radio-iodine*
NCRP Report 56,	*Radiation Exposure from Consumer Products and Miscellaneous Sources*
HEW/BRH,	*Regulations, Standards, and Guides for Microwaves, Ultraviolet Radiation, and Radiation from Lasers and Television Receivers-An Annotated Bibliography*
NBS Handbook 69,	*Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure*
ICRP Publication 6	*Recommendations of the International Commission on Radiological Protection*
ICRP Publication 8	*The Evaluation of Risks from Radiation*
FRC Report 1,	*Background Material for the Development of Radiation Protection Standards*
Federal Register 9/26/81,	*Federal Radiation Council: Radiation Protection Guidance for Federal Agencies*
FRC Report 5,	*Background Material for the Development of Radiation Protection Standards (Iodine-131)*
FRC Report 8,	*Guidance for the Control of Radiation Hazards in Uranium Mining*
NAS Analytical Studies for US EPA, Vol. VI, Implications of Environmental Regulations for Energy Production and Consumption	

Table 12. United States Government and advisory organization's documents describing regulations and recommendations on radiation standards.

The National Council on Radiation Protection and Measurements (NCRP) defines the maximum permissible dose as the highest dose of ionizing radiation (from external and internal sources) that is not expected to cause appreciable bodily injury to a person at any time during his or her lifetime. This standard is set in light of present knowledge and is subject to continual review by the NCRP. The standard varies for different parts of the body. For example, the maximum permissible occupational dose for whole-body (internal and external organs) exposure is not to normally exceed 1,250 mrem (1.25 rems) per quarter year. Occupational dose of the skin of the whole body is set at 7,500 mrems (7.5 rems) per quarter year. The dose to hands, forearms, feet and ankles is not to exceed 18,750 mrem (18.75 rems) per quarter year.

	10 CFR 20	40 CFR 190	40 CFR 141	NCRP Report 39	NCRP Report 42	NCRP Report 43	NCRP Report 46	NCRP Report 48	NCRP Report 50	NCRP Report 52	NCRP Report 53	NCRP Report 54	NCRP Report 55	NCRP Report 56	HEW/BRH	NBS Handbook 69	ICRP Publication 6	ICRP Publication 8	FRC Report 1	Federal Register 9/26/61	FCR Report 5	FCR Report 8	NAS Analytical Studies for US EPA
Personal dosage limits	X	X	X	X		X		X		X	X			X	X	X	X			X	X	X	X
Minors	X			X		X				X													
Pregnant women and fetuses				X		X				X	X	X							X				
Medical and dental exposure	X			X				X				X		X									
Drinking water contamination			X																				
Environmental effects - radioecology		X	X	X					X											X	X		X
Biological effects - somatic and genetic				X		X	X	X		X			X	X	X	X	X		X	X	X	X	X
Manmade sources - consumer products								X						X	X								
TV sets														X	X								
Lasers															X								
Radionuclides (general)	X													X		X	X			X			
Tritium			X																				
Iodine		X											X							X	X		
Cesium			X							X													
Radium			X																	X			
Radon and daughters		X																				X	
Uranium		X																				X	
Plutonium and transuranics		X																					
Alpha emitters		X	X				X																
Beta and photon emitters			X																				
Strontium			X																	X			
X-rays						X		X						X	X								
Microwaves														X	X								
Ultraviolet radiation														X	X								
Nuclear power		X																					X
Uranium fuel cycle		X																					X
Uranium mining																						X	X
Workroom standards	X	X																					
Occupational exposure	X	X		X		X		X			X					X			X			X	X
Waste disposal	X																						X
Caution sign	X																						
Records and reports	X							X															
Loss and theft of radioactive material	X																						
Risks of radiation																		X				X	X
Radiation protection criteria				X																X			
Radiation protection costs																						X	X
Radiation protection philosophy						X																	X
Accidents, terrorism, or nuclear attack	X			X	X								X										X

Table 13. Array of subject areas covered by federal government and advisory organizations in regulations and recommendations for radiation standards.

Since it is known that most tissue and organs are more sensitive to radiation in the early stages of fetal development, the most restrictive standards are directed at pregnant women. Women who are exposed to ionizing radiation in the course of their work are limited to a radiation dose no greater than 500 mrem (0.5 rem) for the entire period of gestation.

As noted earlier, occupational workers exposure is regulated not only for the maximum permissible dose, but also regulated for the long-term accumulated maximum whole-body dose. This latter standard recognizes the accumulated effect of continual exposure to ionizing radiation. The standard does not allow any person 18 years or younger to be occupationally exposed. To calculate a worker's long-term accumulated maximum permissible whole-body dose, the following formula is used which takes into account the person's age.

5000 (N-18) = maximum accumulated dose in mrem. N is the age of each worker in years.

Thus, a 20-year old worker can receive only 10,000 mrem in accumulated dose while a 40 year old worker can receive up to 110,000 mrem, but neither can receive more than 3000 mrem/quarter year during one year.

For the general public the National Council on Radiation Protection recommends that exposure from all man-made radiation sources to a single maximally exposed individual should not exceed 500 mrems/year. However, to account for very young (under 18), very old and pregnant individuals, the recommended average annual dose rate is 170 mrem/year. Specific regulations limit the contribution to this total from the uranium fuel cycle. Members of the public are not to receive more than 25 mrems/year from the total nuclear fuel cycle (uranium mining, milling, fuel fabrication, power plant operation and waste disposal). Out of these five stages, a nuclear power plant is to be designed and operated to meet a dose limit of 5 mrems/year at the property boundary of the facility. This limit assumes conditions under which a member of the public would remain continuously at the property boundary for one year.

Sources controlled by the Nuclear Regulatory Commission include byproduct material, source material, and special nuclear material. By definition, source material means uranium or thorium, or any combination thereof, in any physical or chemical form or ores which contain by weight 1/20 of 1% (0.05%) or more of uranium, thorium, or any combination thereof. Source material does not include special nuclear material. Also, by definition, special nuclear material in quantities not sufficient to form a critical mass means uranium enriched in the isotope U-235 in quantities not exceeding 350 grams of contained U-235; uranium-233 in quantities not exceeding 200 grams; plutonium in quantities not exceeding 200 grams; or any combination of them in accordance with the following formula: for each kind of special nuclear material, determine the ratio between the quantity of special nuclear material and the quantity specified above for the same kind of special nuclear material. The sum of the ratios for all kinds of special nuclear material in combination shall not exceed "l" (i.e., unity).

In Michigan, the promulgation and enforcement of ionizing radiation regulations is divided between the federal and state governments. As can be seen in Table 14, the Michigan Department of Public Health has adopted the standards recommended by the National Council on Radiation Protection (NCRP).

Occupational Exposure	
Dose to the whole	*1.25 rem per quarter*
Skin of whole body	*7.5 rems per quarter*
Hands	*18.75 rems per quarter*
Fertile women (with respect to fetus)	*0.5 rem in gestation period*
Non-Occupational Exposure	
Individual	*0.5 rem in any one year*
Population Exposure	
Genetic	*0.17 rem average per*
Somatic	*0.17 rem average per*

Table 14. Maximum Permissible Dose Equivalent for Occupational Exposure, Non-Occupational Exposure and General Population Does Limits.

Radiation levels from external sources in unrestricted areas, concentrations in effluents to unrestricted areas, and disposal by release into sewerage systems are also addressed in Michigan and NRC standards. In addition to the exposure limits in Table 14, state standards require that unauthorized persons shall not receive, acquire, possess, use, or transfer sources of radiation in such a manner as to result in an individual in an unrestricted area receiving a dose in excess of: (a) 2 millirems in any 1 hour, (b) 100 millirems in any 7 consecutive days, and (c) 500 millirems in any 1 year.

A person may apply for proposed limits of radiation in unrestricted areas in excess of those specified above resulting from the applicant's possession or use of sources of radiation. The application shall include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Michigan Department of Public Health shall approve the proposed limits if the applicant demonstrates to the satisfaction of the MDPH that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem.

State controlled radiation sources include x-ray machines, particle accelerators, material rendered radioactive by bombardment in an accelerator, radium and other naturally-occurring radioactive material, except source material and special nuclear material in quantities not sufficient to form a critical mass.

VI. REGULATORY FRAMEWORK IN MICHIGAN FOR URANIUM MINING AND MILLING

Mining and milling are considered together because these operations are generally performed in close proximity to each other. It is often uneconomical to transport crude ores very far from the mine site. Mining refers to the process of removing crude metal ores from the ground either through underground or open pit mines while the milling process concentrates and refines the ore prior to marketing and shipping.

The ore is initally crushed into a fine powder. The powder is then mixed with a liquid acid solution which dissolves the uranium oxide. The liquid with the dissolved uranium is decanted off and ammonia is added to precipitate the uranium from solution. This precipitate is dried, pulverized and is shipped as powdery "yellowcake". The liquid solution is recycled for reuse.

The disposal of waste products which must be controlled include: (1) the mill tailings which are finely ground solids in a slurry and are deposited in a settling pond and (2) small amounts of spent acid solution not recycled for reuse. Although no information was found in the literature as to how spent solvents were typically disposed, it is assumed that they are disposed in the tailings ponds.

A. Local Government

Local units of governments may impose restrictions upon mining through the promulgation of zoning ordinances as discussed previously in the IV. ENVIRONMENTAL IMPACTS AND REGULATORY FRAMEWORK ASSOCIATED WITH URANIUM EXPLORATION (page 28). Although most counties in Michigan do not have zoning ordinances for metallic mineral mining, the public reaction to proposed uranium mining may cause such ordinances to be promulgated.

B. State Government

The Federal Atomic Energy Act of 1954 established certain materials as “licensable materials” to be regulated by the Atomic Energy Commission (now the Nuclear Regulatory Commission - NRC). Uranium mill tailings (the byproduct of the milling process) and yellowcake produced by milling are to be licensed. However, uranium ores and mining wastes are not licensable and states retain control over the management of these materials. In addition, the Atomic Energy Act specifically notes that nothing in the act will affect the authority of states to regulate any aspect of mining or milling operations except for regulation of radiation hazards which is reserved to the U.S. government.

The state of Michigan currently does not have promulgated regulations dealing specifically with the mining of uranium. However, Part 135 of the Public Health Code (Act 368, P.A. of 1978) does provide for control of certain radioactive materials by the Department of Public Health. Radioactive mine wastes are subject to state control while source material, byproduct material and special nuclear material are exempt.

The Department of Public Health also has the responsibility to monitor radioactive emissions from facilities which emit or could emit significant quantities of radioactive effluents in order to assess the effect on public health and safety. Thus, if uranium mining were to take place in Michigan, the Department of Public Health could exercise a certain degree of control over their activity under the auspices of this act.

1. Surface and Groundwater Discharge

All surface water and groundwater discharges from mining and ore milling facilities are subject to state regulation. Existing mining operations with surface water discharges must have a National Pollutant Discharge Elimination System (NFDES) permit issued by the Water Resources Commission under the authority of the Water Resources Commission Act (Act 245 P.A. of 1929, as amended) and the Federal Clean Water Act (P.L. 95-217). Surface water discharges are subject to maximum effluent limits for various pollutants as set forth in Part 4 of the General Rules of Act 245. Rule 58 states that the control and regulation of radioactive substances discharged to surface waters shall be subject to standards prescribed by the Nuclear Regulatory Commission in Title 10, Part 20 of the Federal Code of Regulations. The standards presented in 10 CFR 20 are the maximum effluent concentrations that could be discharged to waters in, or which flow into, unrestricted areas. The state, in its review of an NPDES permit application, could establish more stringent effluent limits if more stringent limits were shown to be necessary to protect public health and the environment. Such a permit application would be reviewed by Department of Natural Resources, Water Quality Division and by the Division of Radiological Health within the Department of Public Health.

The Water Resources Commission Act also provides for the nondegradation of the state's groundwaters. Because seepage into the ground is likely to occur from mill tailings basins, a groundwater discharge permit could be required under the newly promulgated groundwater rules (Part 22). A permit application requires a detailed study of site geology and hydrology to evaluate the feasibility of each site to insure that groundwater degradation will not occur if a discharge is permitted. Further, if it is likely that critical materials, such as heavy metals, would be associated with the uranium ore and be present in the mill tailings, Part 5 of the Water Resources Commission rules requires the development of a Pollution Incident Prevent Plan (PIPP) to develop a method to contain accidental spills from entering the surface or groundwater.

2. Air Protection

Radioactive air emissions are regulated by the Nuclear Regulatory Commission or by the state depending on the source of the contaminants. The NRC retains control over the emissions of radioactive air contaminants from licensed facilities (i.e., milling operations) in non-agreement states. The state is only delegated control over licensed facilities upon the development of a federal-state agreement. Presently, Michigan has not entered into an agreement and any uranium milling facilities constructed in Michigan would be licensed and radioactive emissions regulated by the Nuclear Regulatory Commission. Air emissions associated with uranium mining and defined as nonlicensed are open to regulation by the state whether or not it is an agreement state.

In Michigan, regulatory control over radioactive air pollutants lies with the Department of Public Health under the Public Health Code. The administrative rules under the act establish maximum public exposure rates to radioactivity which are based upon, but not identical to the federal limits set in 10 CFR 20. Standards for radioactive isotope emissions from federally licensed facilities are presented by NRC in 10 CFR 20. State standards have been determined by the NRC to be adequate. This is a prerequisite to delegation of authority to the state by NRC.

The Department of Public Health does maintain monitoring stations off-site of nuclear power plants to test for compliance with the state exposure limits. It could do so for uranium mining or milling operations in Michigan even if federal delegation was not received.

The Department of Natural Resources would regulate non-radioactive air pollutants from a mining or milling operation under Michigan's Air Pollution Act (Act 348 P.A. of 1965). Under this act, emission limits are placed on the criteria pollutants of carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbons and total suspended particulates. The Air Quality Division within DNR would issue construction and operation permits on all large process machinery to control the level of emissions from this equipment. Airborne dust from the milling process can be a significant source of radioactivity if it is not controlled. For mines where fugitive dust might pose a problem, any air quality permit would also include an approvable fugitive dust control plan.

Michigan's Hazardous Waste Management Act (Act 64, P.A. of 1979), administered by the DNR, specifically excludes radioactive mill tailings from the list of substances controlled under this act. However, spent nonradioactive solvents from in-situ acid leaching processes and certain chemicals used in milling processes may fall under the purview of the act. Such wastes would have to be disposed at a licensed hazardous waste facility and would have to be manifested and transported by licensed hazardous waste haulers.

Michigan's Underground Injection Control (UIC) program administered by DNR Geological Survey Division under the Mineral Wells Act requires a permit for solution mining such as uranium acid-leach mining. Since no permit application has ever been made for a solution mining activity, specific permit application requirements are not developed. However, safeguards similar to those required for a disposal well permit would be required including initial and periodic testing fo the integrity of the well. Table 15 lists the divisions within the Department of Natural Resources which would be involved in the review of a proposed uranium mine and mill seeking permission through permits or licenses to carry out uranium mining or milling in Michigan. Table 16 lists the Michigan Department of Public Health divisions with regulatory control over uranium exploration, mining and milling.

3. Michigan Environmental Review Board

In addition to specific environmental legislation administered by the Department of Natural Resources or the Department of Public Health, the Governor, through Executive Order 1974-4, established the Michigan Environmental Review (MERB) to review commercial, industrial, agricultural and natural resource projects with significant environmental or human health impact prior to the issuance of public health or environmental permits. This 17 member citizen and state agency board can request the preparation of an environmental impact statment by the state agency with major statutory responsibility for regulation of the project.

The approval of a uranium mining or milling permit or permits by the Department of Natural Resources and Public Health would undoubtedly be considered a major state action, especially in light of the public controversy that has been generated. Public involvement in the development of the environmental impact statement (EIS) and the use of public hearings is encouraged by the Executive Order.

<u>*Water Quality Division*</u>

Permits for wastewater or process water discharges to surface waters

Permits for groundwater discharges

Permits for construction and operation of a sanitary waste treatment system

<u>*Air Quality Division*</u>

Air quality permits (installation and operation permits) for point source discharges

Permits for fugitive dust control

<u>*Geological Survey Division*</u>

Permits to drill test wells under Mineral Wells Act

Administers mine reclamation statute

Permits for in-situ mining under Mineral Wells Act

<u>*Land Resource Programs Division*</u>

Permits under Soil Erosion and Sedimentation Control Act (Act 374, P.A. of 1972)

Permits under Inland Lakes and Streams Act (Act 346, P.A. of 1972)

<u>*Environmental Services Division*</u>

Administers Hazardous Waste Management Act (Act 64, P.A. of 1979)

Permits for hazardous waste disposal sites

Permits for waste manifest system

<u>*Resource Recovery Division*</u>

Permits for solid (non-hazardous) waste landfills

Table 15. Department of Natural Resources programs involved in review of uranium mining and milling site specific applications.

<u>*Radiological Health Division*</u>

Licenses for non-NRC licensed material contained in mine and/or mill tailings

Environmental monitoring of exploration, mining and milling operations

Coordination of radiological aspects of other State programs acting within their statutory authority

<u>*Water Supply Division*</u>

Radiological monitoring of community public water supplies for natural radionuclides

Table 16. Department of Public Health Regulatory programs involved in uranium exploration, mining and milling.

4. Worker Protection

In 1967 the Michigan Mine Safety Act was passed. The Act provided for the health and safety of persons employed in and about mines; provided for the appointment, qualification, duties and compensation of mine inspectors; and created a mine safety board in the Department of Labor and prescribe its powers and duties; and to provide penalties for violations. However, this act was repealed (October 25, 1977) primarily because funding was not provided to the Department of Labor to carry out the provisions of the act. Presently, the Michigan Department of Public Health, through the occupational safety act does not have responsibility for insuring the safety of workers in uramium mining and milling. The major source of regulation lies with the federal Mine Safety and Health Act of 1977.

C. Federal Government

Federal regulations address two environmental and health issues related to uranium mining and milling operations; the control of health conditions within uranium mines and control over materials "licensed" under the Atomic Energy Act.

1. Worker Protection

The Federal Mine Safety and Health Act of 1977, under the Department of Labor, sets guidelines in Title 30 of the Code of Federal Regulations to regulate the exposure of miners to airborne radioactive contaminants. Adequate ventilation of mine shafts is required to limit exposures to threshold limits on radon gas, radioactive dust and other radioactive isotopes produced by radon decay. The act requires that complete individual personnel exposure records be maintained. The Mine Safety and Health Act does not provide for the delegation of authority over these functions to the states. However, the states can enact more stringent health standards.

2. Environmental Protection

The Nuclear Regulatory Commission and the U.S. Environmental Protection Agency exercise regulatory control over mining and milling operations primarily through three federal laws; the Atomic Energy Act of 1954, the Resource Conservation and Recovery Act of 1976 and the Uranium Mill Tailings Radiation Control Act of 1978.

Under the Atomic Energy Act, the Nuclear Regulatory Commission has jurisdiction over licensed source materials (yellowcake) and mill byproduct materials (mill tailings). The Nuclear Regulatory Commission licenses milling operations only after the applicant has demonstrated the capability to comply with regulations contained in 10 CFR, Part 20 and Part 40. Part 20 in addition to setting exposure limits to radioactive iotopes requires the licensee to initiate and maintain both a preoperational and operational radiological monitoring program of air, water and soil samples. The Atomic Energy Act also permits the NRC to delegate to individual states some of its regulatory authority through a state-NRC agreement.

The Uranium Mill Tailings Radiation Control Act of 1978 (P.L. 95-604) was enacted to expand NRC jurisdiction over radioactive mill tailings and waste rock and to make more explicit the responsibilities of states under state-NRC agreements. The Act requires that prior to the construction of any milling operation an environmental impact statement be prepared. This EIS may be prepared under the auspices of the National Environmental Policy Act of 1970, or under an analogous state requirement. Title II of the Act established requirements for the decontamination, decommissioning, and reclamation of mill tailings at presently operating and future facilities. Although it is unclear to what extent states retain control over mill tailings prior to the full enactment of the Act in November 1981, this confusion has little significance in Michigan since no milling operation will exist before that time. The Federal Environmental Protection Agency is currently promulgating standards applicable to the hazards associated with the processing, transfer and disposal of mill tailings.

Under the Federal Resource Conservation and Recovery Act of 1976, regulations have been proposed, but not yet adopted, which delineate two basic requirements for the ultimate disposal of radioactive waste rock from uranium mining operations. Wastes are prohibited for use as a building material (e.g., for use in cement) and the radioactive overburden must be buried under "clean" overburden.

3. State-Federal Cooperative Agreements

The Atomic Energy Act enables states to enter into a cooperative agreement with the Nuclear Regulatory Commission (62). Under such an agreement, a state can assume some of NRC's regulatory control over "licensable" materials, including uranium mill tailings and yellowcake. It also grants the state ability to license mill operations. A state-NRC agreement can also provide for joint inspections of facilities and permit the NRC to provide training and other assistance to the state.

The jurisdictional transfer is accomplished through an agreement between the Nuclear Regulatory Commission and the Governor of the state. The basic prerequisite for the development of a state-NRC agreement is that the state's regulatory program be substantially equivalent to the Federal program in respect to insuring the public health and wefare and that it be in accordance with section 274(o) of the Atomic Energy Act. The state must demonstrate that its rules and regulations are sufficient for the protection of the public and that there is an adequate administrative structure to enforce the regulations. Michigan is not currently an agreement state. Although the Governor is authorized to enter into such agreements by Part 135 of the Public Health Code (Act 368, P.A. 1978) and the NRC has found the Division of Radiological Health program to be adequate with regard to byproduct, source, and special nuclear material. Citing economic conditions, the decision to enter into an agreement with the NRC has been postponed by the Governor.

VII. Post Operational Regulatory Framework in Michigan for Uranium Mines

Postoperational treatment of a uranium mining and milling operation focuses primarily upon reclaiming the site to its natural condition and reducing the radioactive emissions from the site as close to background levels as possible. The most important single activity must be the isolation of radioactive mill tailings from the environment. Radium-226 remaining in the tailings can contain 70 to 80 percent of the ore's original radioactivity and can be a significant source of radon gas. A Presidentially-appointed interagency work group in 1979 has recommended that due to their very long half lives, these mill wastes should be as carefully managed as high level radioactive wastes.

A. Local government

Local regulatory controls will be limited to zoning ordinances and would focus on site reclamation. Typical mining zoning ordinances would require a site reclamation plan as part of any application for a mining permit. The reclamation plan would include such measures as erosion control, landscaping and revegetation, the removal of structures, roads, other facilities and the final disposal or treatment of any harmful or toxic materials left on-site. However, a municipality cannot regulate radioactive emissions by way of setting standards nor may it require the registration of radioactive materials as such local control is prohibited in Part 135, Public Health Code.

B. State government

The administrative rules under the Mine Reclamation Act (Act 92, P.A. 1979) provide for the reclamation of mine sites. The Department of Natural Resources, Geological Survey Division administers this Act. The rules provide for the landscaping of the site, backfilling holes and open pits with overburden and stockpiles and for the use of vegetative plantings to stabilize areas where erosion is occuring or likely to occur. Tailings basins are to be drained and reclaimed within practical limitations.

However, the Department of Natural Resources has no permitting authority under the Act and regulatory control is not really sufficient to insure that reclamation efforts are thoroughly carried out. In addition, the rules do not address the special problems associated with radioactive waste rock and tailings. This is one area where state regulations could be strengthened.

C. Federal government

Title II of the Uranium Mill Tailing Radiation Control Act of 1978 requires that all mill tailing licensees make necessary financial agreements for whatever postoperational maintenance and monitoring will be necessary prior to license termination. The NRC and agreements states are given the authority to require a licensee to furnish bonding in some cases. These requirements are to induce licensees to adopt decommissioning schemes that will be reliable, permanent and that will minimize the need for active care of a disposal site.

The Act also requires that following decommissioning, the licensee will transfer ownership of the mill tailings without cost to either the state or Federal government. The option as to which government, state or federal, will acquire the mill tailing and disposal site is the state's. The state retains this option whether or not the state is an agreement state.

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