BIG PROBLEMS/LITTLE PROBLEMS?

APPLYING "FIRST THINGS FIRST" PRINCIPLE TOWARDS ESTABLISHING A MANAGEMENT SYSTEM (AMHAZ) FOR PRIORITIZING ABANDONED MINE HAZARDS[1]

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Abstract: AMHAZ is a management system developed by the Ontario Ministry of Northern Development and Mines and Laurentian University. Its purpose is to prioritize hazardous conditions at abandoned mine sites in the province of Ontario, Canada and to identify rehabilitation options. At the present time, over half of the more than 6,000 abandoned exploration and mining sites in the province have been inspected, and over 5,000 mine features have been identified and rated. Features rated at mine sites include open holes, crown pillars, tailings areas, buildings, equipment, rock piles, chemical storage areas, etc. The ratings reflect the seriousness of potential hazards, taking into account public safety, public health and environmental concerns as well as social and economic impacts. The AMHAZ model was developed using Expert System Technology. AMHAZ has proven to be an effective tool for identifying short-term and long-term rehabilitation options. This information is available to guide decision makers in planning cost-effective rehabilitation programs. AMHAZ provides a consistent approach for decision makers to manage liabilities associated with a wide variety of abandoned mine problems.

Key Words: mine rehabilitation, abandoned mines, hazards, environmental hazards, decision support systems, expert systems, rating.

Introduction

Effective management tools are based on the principle of "First Things First": "Things which matter most must never be at the mercy of things that matter least" (1). This philosophy was important in the design and implementation of the Abandoned Mines Hazard Rating System (AMHAZ).

In 1991, Ontario amended the Mining Act (2) which set out a legislature framework for mine rehabilitation and mine closure (3). The Mining Act applies to advanced exploration as well as producing, temporarily suspended, inactive or abandoned mines. Under this Act, abandoned means that "the proponent

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has ceased or suspended indefinitely advanced exploration, mining, or mine production on the site, without rehabilitating the site".

There are over 6,000 abandoned exploration and mining sites in Ontario. Each abandoned mine may have a different number of features to be inspected and rehabilitated. Site assessment work indicates that there are approximately two or three features per site on average, but sites have been found with over 100 features. Examples of different kinds of features found at mine sites are depicted in Figure 1 below.

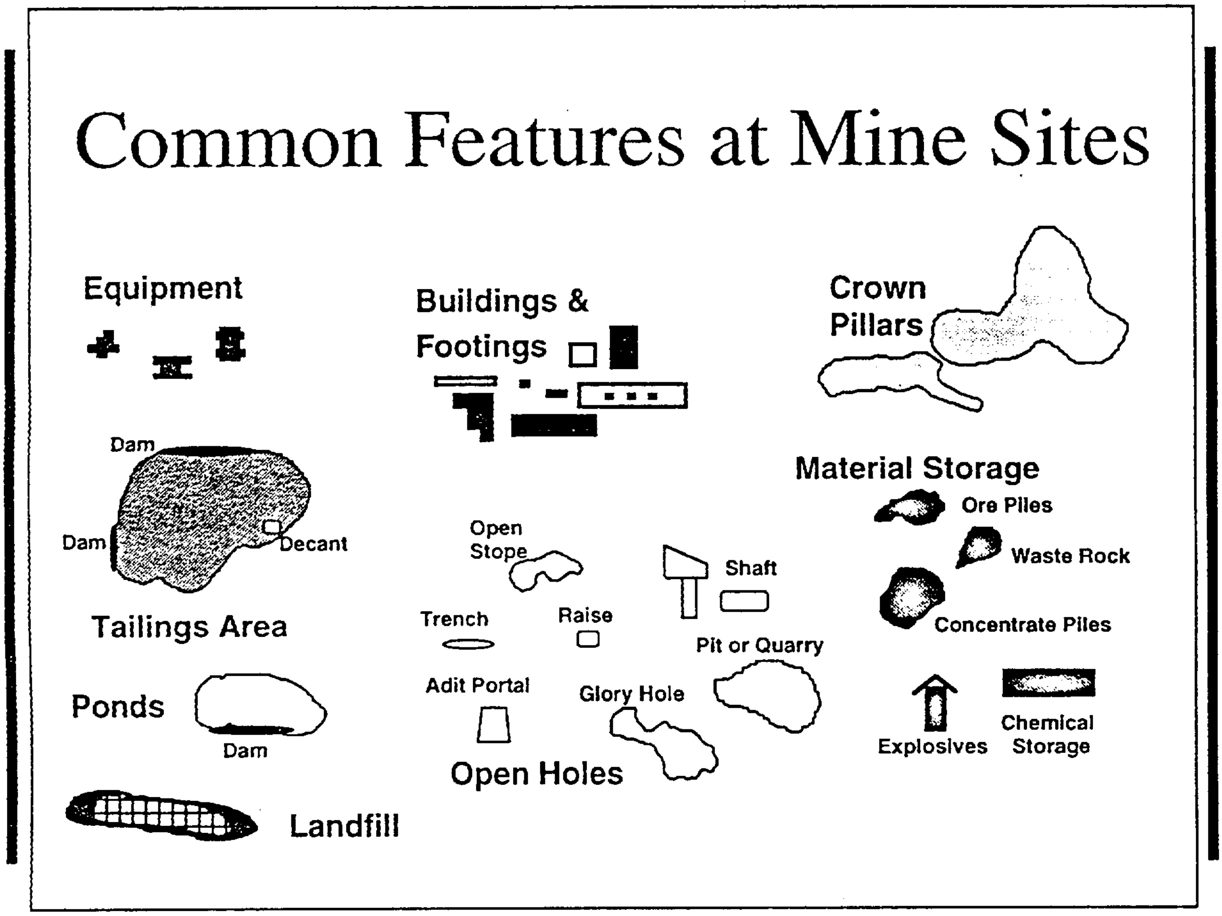

Figure 1. Abandoned mine site features

The best scenario would be to rehabilitate all sites before a serious incident occurs (4). This is, however, not always feasible because of limited resources. AMHAZ has been developed to make the most effective allocation of available resources.

Decision makers require a ranking and prioritization system in order to determine which problems need to be rehabilitated first. AMHAZ provides not only the total rating, but can also be broken down into five primary components: public safety, public health, environment, social and economic. AMHAZ is one of three components of Ontario's abandoned mines rehabilitation process. The other two components are called the Abandoned Mines Information System (AMIS) and the Abandoned Mines Rehabilitation

Program (AMREHAB). AMIS provides the decision maker with an inventory of historical and physical data. AMREHAB integrates the data from AMIS and AMHAZ and provides the decision maker with options for rehabilitating the hazards (see Figure 2).

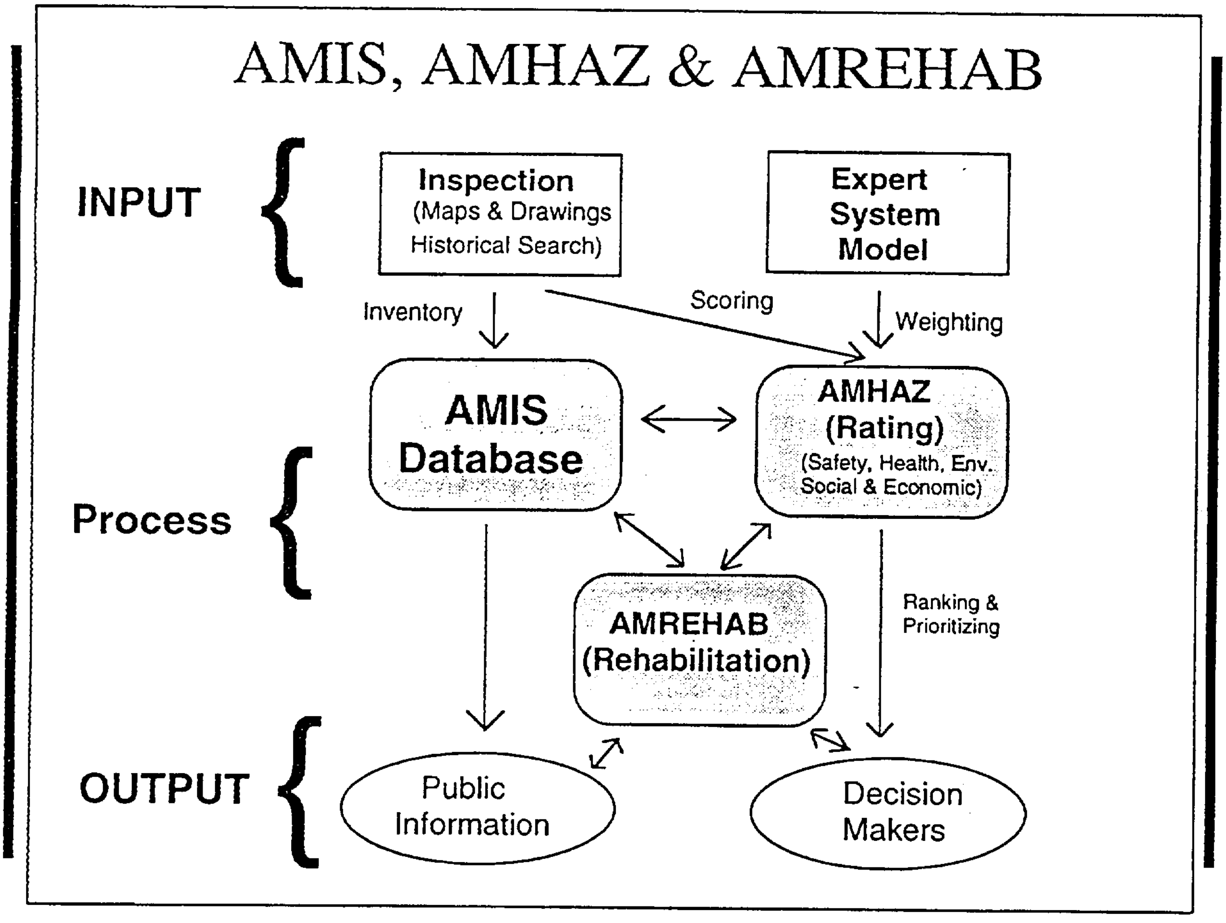

Figure 2. Major components of the abandoned mines rehabilitation process

Details about the assessment of the abandoned mine hazards are outlined in another paper presented at this conference (5). Information from field assessments is integrated with the Expert System Model to produce the AMHAZ rating. The background development of the Expert System Model has been described in other publications (6, 7).

The data flow diagram for the AMHAZ system is provided in Figure 3. Inspection data are received from the inspectors in electronic form. The data are validated by the Data Transportation and Validation subsystem. Only successfully validated data are stored in the SCORED HAZARDS database. The report regarding incomplete records is sent back to the inspectors with a request for review. Data stored in the SCORED HAZARDS database are processed by the RATING HAZARDS subsystem to come up with the RATED HAZARDS database. This database is the source of reports provided to the decision makers.

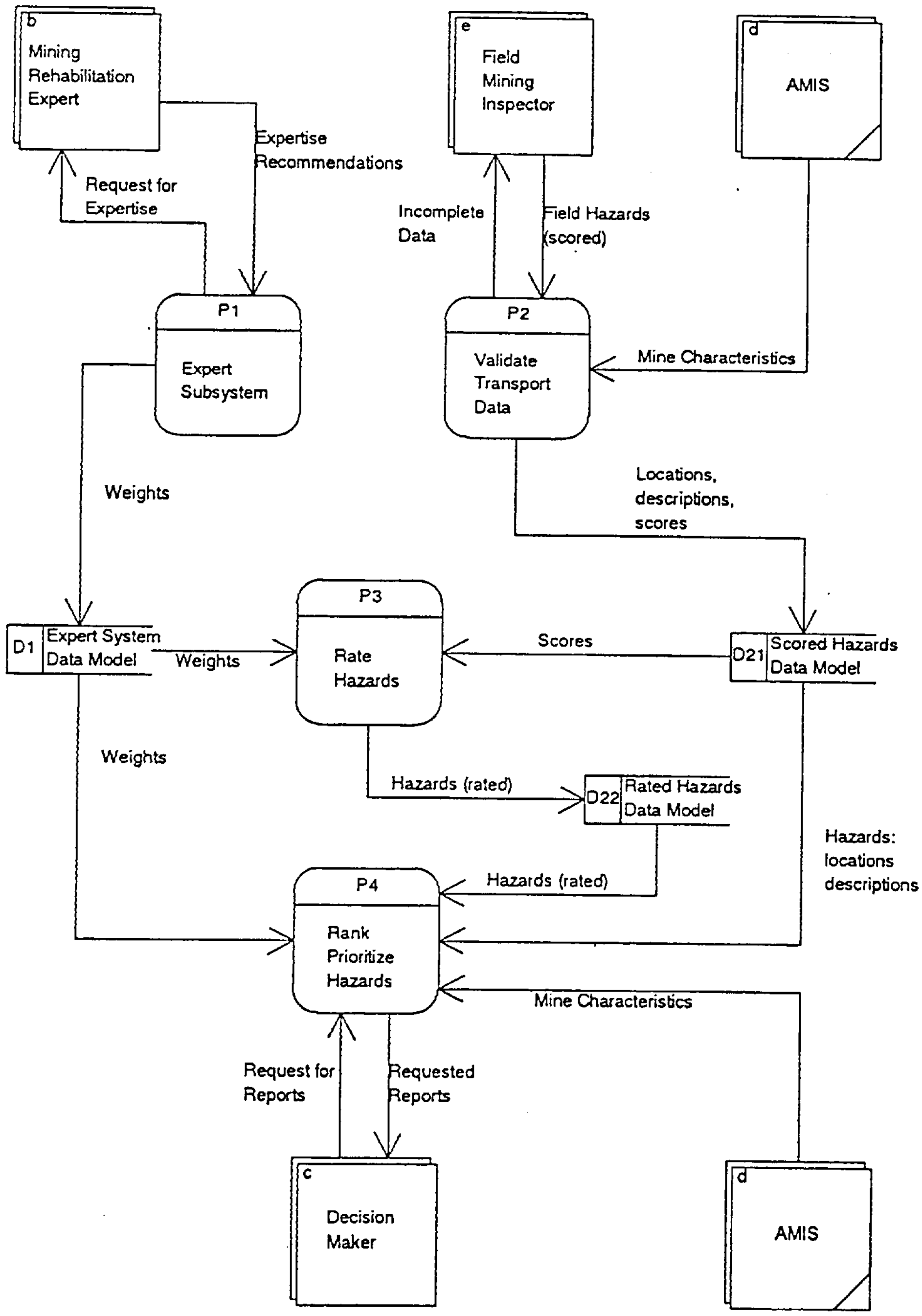

Figure 3. AMHAZ Data Flow Diagram

Conceptual Model of Mine Hazards

The Expert System Model was developed jointly by rehabilitation experts from the Ontario Ministry of Northern Development and Mines and researchers from Laurentian University in Sudbury, Ontario. A pairwise comparison method and a measure of consistency of experts' judgments was used to develop the conceptual model of mine hazards (8, 9, 10, 11). The new consistency definition (12, 13) is a theoretical framework for improving the consistency of the experts' judgments.

The Expert System model provides the relative weights for the criteria and factors, all of which are used in calculating the final hazard rating. The weights reflect the current expertise and judgments of the mine rehabilitation experts obtained through a consensus process. For example the question is asked "How important is public safety compared with environment?". The rating values determined by AMHAZ are an integration of the scores submitted by the field inspectors with the weights provided by the Expert System Model.

In developing rehabilitation plans, the decision maker should consider all aspects of the problem including technical and socio-economic consequences. All criteria are clustered into two major groups: ***technical factors*** and ***socio-economic factors.***

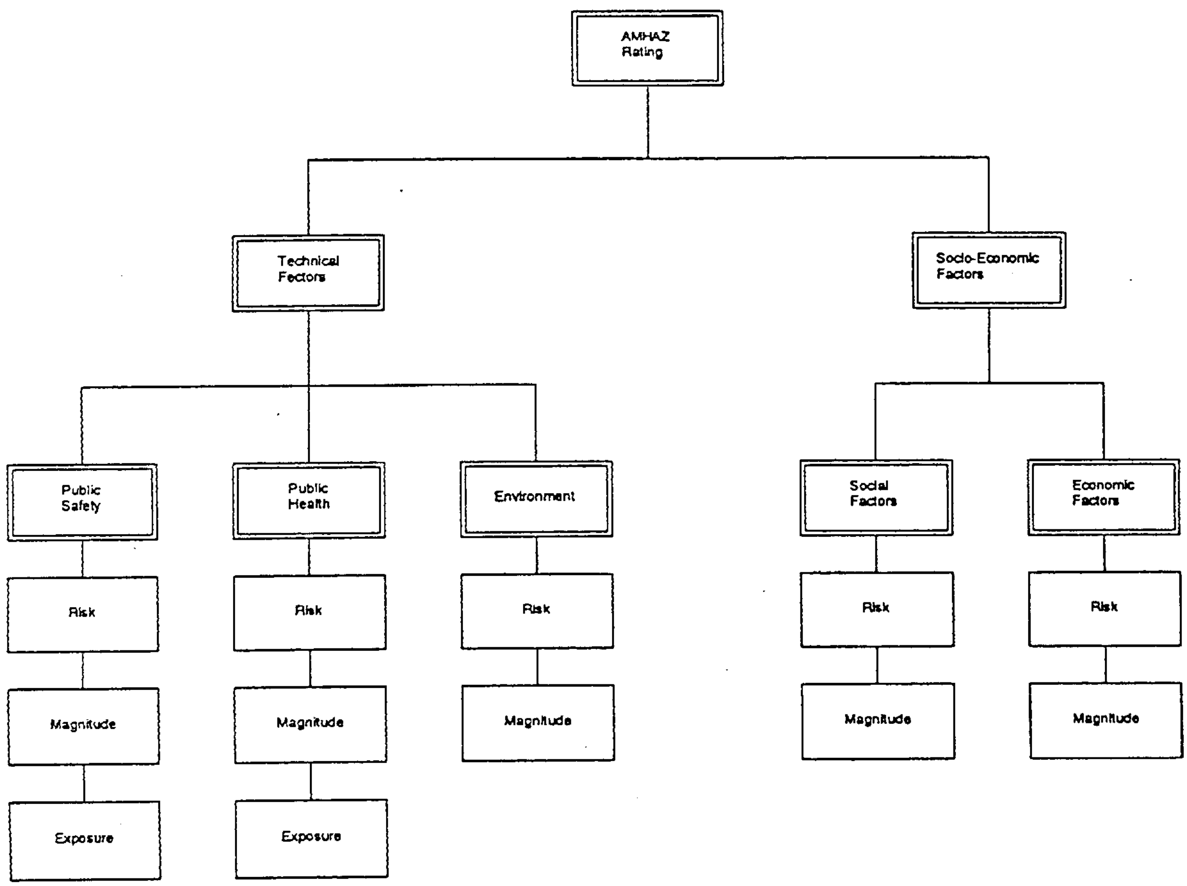

Figure 4. Components of AMHAZ rating

Technical factors are clustered into three groups: public safety, public health and environment.

Social and economic factors are related to the possible social disruption and economic losses which might be caused by the hazard. For example, if a group of citizens has to be relocated to another area after a tailings dam failure, this would be a social impact. If the major highway to a town has to be closed because of a surface crown pillar collapse, it would cause certain social disruption for the population of this town. In this case, the town does not have to be in the immediate vicinity of the hazard to be exposed to the social consequences. Both examples would cause certain economic losses and should also be scored in the economic group. Another example of economic losses might be the value of houses or the value of land, which might be decreased by the presence of a hazard.

Public safety examines the level of danger presented by a mine feature. Three criteria are used in the evaluation of the *public safety* hazard score, i.e., the risk (how dangerous is it?), the magnitude (how many people might be affected?) and the exposure (how many people are likely to be nearby?). Each hazard is scored individually.

The public can be affected by a mine feature in many ways. The term "incident" is used to describe many kinds of events that could affect public safety including falls, being struck by objects, drowning, asphyxiation, etc. The challenge for the inspector therefore is to determine the likelihood that the person would be affected due to the nature of the feature, i.e., the likelihood that an incident will occur and the likelihood that the feature is dangerous enough to seriously injure or kill the person.

Public safety also relates to the number of people that would likely be affected by the incident. With respect to an open hole, for example, it is typical that only one or two people would be impacted by a single incident. In contrast, a crown pillar or a tailings area might influence many people. For example, if a residential subdivision was built below a large and unstable tailings dam or on top of a weak crown pillar, an incident (dam break or pillar collapse) could result in many people being affected.

Public health is another factor used to identify mine features which could impact the health and wellbeing of the public. Three criteria are used in the evaluation of the *Public health* hazard score, i.e., the risk (how much contamination is present?), the magnitude of impact (how many people might be affected?) and the exposure (how many people are likely to be nearby?).

The important point with regard to the public health, is that before people's health can be harmed by the feature, there must first of all be a significant level of contaminants known to be harmful to humans. Examples of contaminants that are known to be hazardous to human health are: lead, cadmium, mercury, arsenic, cyanide, radioactivity, methane, etc. If there are high levels of contaminants present, then there may be a high risk of people being impacted. The exposure and magnitude criteria take into account the likelihood that people would be exposed to the contaminants and the number of people that could be affected.

There are three basic mechanisms in which the health of the public might be impacted by contaminants, i.e., ingestion, inhalation and absorption. In some instances, it is difficult to determine if a situation should be scored under the health factor or the safety factor. For example, methane gas in an underground working could be considered a safety concern as well as a health concern. Rather than score it under both factors, the following has been set up as a general rule of thumb to guide the inspector and help in determining which factor to use in the scoring. This will prevent the overlap that would occur for some situations. If problems occur quickly from a single or short-term exposure to a contaminant, then the inspector should score it under safety (effects occur in a time of minutes or hours - acute). If problems occur slowly because of multiple or long-term exposures to a contaminant, the inspector should score it under health (effects occur in a time period of a day or longer - chronic). For example a person might walk into an adit or underground working and be overcome by methane gas or lack of oxygen. The situation would act on a person quickly and acutely. The one-time exposure could result in immediate death and would be rated under the safety factor. If a person became ill as a result of ingesting lead or arsenic contaminants present in their drinking water well, which was impacted by a nearby tailings area, then this would be scored under the health factor. It would represent a slow accumulative long-term response of a chronic nature.

Environment. Mine features can cause a significant impact on the environment through two mechanisms: contamination and physical disruption. Examples of impact from contamination would include the impairment of a water course by acid drainage or the impairment of vegetation by heavy metal contaminated dust. Examples of physical disruption would include the collapse of a crown pillar or the breaking of a tailings dam. When evaluating the environmental impact of a hazard, this refers to the impact beyond what is typical for the particular feature. Examples of the environmental impact caused by different abandoned mines features are given below.

> Tailings site: when tailings material is deposited in a storage area, there is a localized physical disturbance. AMHAZ does not rate the effects caused by the construction of the site but the effects beyond it. For example, clearing trees or excavating land is a typical procedure in the construction of a tailings area. It is an expected and necessary part and the consequence of its design. What is scored under this factor (environment), however, would be the discharge of acid drainage into the groundwater or surface streams, blowing dust, radioactivity, failure of a dam, etc. The baren nature of the site might be scored under socio-economic factors.
>
> Rock pile: the storage of waste rocks in piles causes some physical disruption. The rating system evaluates the extent of any impact beyond the typical localized physical disturbance.
>
> A crown pillar will impact the environment when it begins to deteriorate and cause eventual catastrophic collapse. The scoring system would relate to the impact if the pillar collapsed.

The *social factors* relate to the impacts on society from a social point of view. The following are some examples of the situations in which there might be a significant social disruption: the only access road to a community is cut off by the crown pillar collapse, a community is flooded by a breach of a tailings dam, a town needs to be evacuated due to the possibility of a tailings dam failure or a crown pillar collapse, the water supply for town is contaminated by a tailings material, etc. The inspector estimates the likelihood that the serious event will occur, as well as the degree of social disruption.

The ***economic factors*** relate to the impacts on society from an economic point of view. The inspectors are asked to determine what economic losses or economic impacts may occur as a result of the abandoned mine feature. For example, if it was likely that a crown pillar would collapse and cut off the only road to a community, there would be economic losses incurred to providing an alternate access. If there were houses and buildings located over a crown pillar that could be destroyed, there would be economic losses related to these structures. If the tailing dam broke and submerged a town with tailings, there could be significant economic losses. If the abandoned mine feature causes a significant depreciation of property values, this can be considered as an economic loss.

Application of AMHAZ

Field inspections provide **scoring** (see Figure 5) for potentially hazardous features present at abandoned mine sites. The Expert System Model provides the **weighting** values of the different criteria and factors so that a rating can be calculated. The **rating** for the various features are sorted by AMHAZ to provide a **ranking** of hazards. The ranking results can be reported in a variety of ways. For example, they can be listed from the most serious to the least serious problems. They can be reported separately for each of the individual factors (safety, health, environment, social and economic) or they can be reported as the total rating.

AMHAZ provides a decision makers with a solid and consistent basis for setting **priorities**. The decision maker is provided with information about the most viable rehabilitation options and the costs of carrying out the work. With this information, the decision makers can decide on the most effective allocation of the limited resources available. They can better manage liabilities. They can achieve the maximum benefit from a safety, health, environmental, social and economic viewpoint.

Important Terms - AMHAZ

- **Scoring** (Variable) (Consensus of 2 Inspectors)
  (0.0 to 5.0) - Number chosen for feature from field assessment to best describe risk, magnitude and exposure
- **Weighting** (Constant) (Consensus of Panel of Experts)
  (0 to 100%) - Percentage indicating the relative importance of the criteria and factors
- **Rating** (Derived)
  (0 to 100%) - Value assigned to the feature by calculating (scoring x weighting)
- **Ranking** (Derived)
  - Features listed from highest to lowest rating
- **Prioritizing** (Derived)
  - Features selected for rehabilitation dependant upon available resources , "first things first "

Figure 5. The terms used in AMHAZ

Conclusions

AMHAZ is an effective management system for use in **prioritizing** mine hazards. In keeping with the "First Things First Principle", the decision maker can make judgments about the most effective allocation of the limited resources available .

The AMHAZ system provides a comprehensive review of hazards based on technical and socioeconomic considerations. By providing safety, health, environmental, social and economic evaluations, decision makers are aware of actual or potential impacts. AMHAZ is a useful tool for the management of liabilities.

The rehabilitation component of the system lists the most viable short-term (intermediate) and long-term (final) rehabilitation options. Cost estimates and predicted ratings are provided. This information is critical when allocating funds and planning rehabilitation projects.

Faced with the situation shown in Table 1 an administrator (government/mining official) may normally select feature A or D because of public pressure.

Feature	Description	Complaints
A	Open shaft - 1000 ft deep, near town	Residents/Town/Media
B	Open shaft - 1000 ft deep, adjacent to ski trail	Reported by prospector
C	Crown Pillar - 150 ft, under major highway to town	None
D	Tailings Area - Non-vegetated, near cottage area	Cottage Association/Cottagers

Table 1. A list of hypothetical mine features

With the use of AMHAZ, the administrator would be guided towards selecting feature C as top priority (Table 2). He/she would be better equipped to deal with the public and the media, and to explain the basis for any decision made.

Ranking of Features AMHAZ	Rational
C	Highway frequently used by school buses, access to large industrial park
B	Shaft hidden, open and beside highly used ski trail
A	Good quality secure chain link fence already in place
D	Unsightly, but no environmental impacts

Table 2. The list of hypothetical mine features from Table 1 prioritized by AMHAZ

AMHAZ provides the ability to identify "**Things which matter most**".

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