TOWARDS BETTER ABANDONED MINE HAZARD PRIORITIZING AN EXPERT SYSTEM APPROACH[1]

by

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Abstract. Making strategic decisions related to land rehabilitation is an important and a complex procedure. Any mistake could be very expensive. As a society we need to make decisions based on unbiased judgments. We propose a hazard rating system which allows a decision maker to compare different sites and to set priorities according to selected factors. It is important to have the risk evaluation determined by highly qualified, interdisciplinary experts. Another important factor in decision making procedure is public acceptance. Our system, which is based on examples of existing abandoned mines in Ontario, will provide a technique for taking into consideration both technical and social aspects of the decision making process. An implemented computer system will find the best possible alternative according to the selected preferences (by a panel of human experts). The methodology is based on Multicriteria Analysis and Pairwise Comparisons. The vector of weights (that is a relative importance of all combined objectives and criteria) is derived as the *eigenvector* of the pairwise comparison matrix, corresponding to the largest *eigenvalue*. The proposed expert system will allow us to use interdisciplinary knowledge provided by human experts to prioritize abandoned mine hazards. A reliable rating system will help to integrate diverse perspectives in reclamation for a better allocation of available resources.

Key Words: abandoned mines, hazard rating, human experts, expert system, resource allocation.

1. Introduction

The Ontario Abandoned Mining Lands Coordinating Committee, under the leadership of the Ministry of Northern Development and Mines, is responsible for coordinating the activities of government agencies involved in the reclamation of orphaned mines to ensure public health and safety and to protect the environment. The Committee mandate includes:

- locating, identifying and assessing all abandoned mine hazards for which the province has responsibility to rehabilitate,
- accelerating structural testing and further risk assessment,
- prioritising work and providing technical and procedural advice to appropriate ministries.

Our research focuses on the application of the latest results of *Multiple Criteria Decision Analysis* to data analysis and decision making. The final and the most important target of our

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research is to design an expert system which will provide the Ministry of Northern Development and Mines a solid device for making the important and complex decisions related to abandoned mines. Any decision related to abandoned mine hazards must contribute to the safe and secure living conditions of current and future generations. The best solution is to remove all signs of the abandoned mine which might be hazardous for people and the environment. This however is unrealistic in a short term perspective. This is why locating, identifying, assessing, and prioritising work on abandoned mine hazards is so important. Limited public and private funds should be allocated in a manner that will improve the public health and safety. An *expert system* approach is quite useful in this complex situation. We acknowledge that the *expert system* is based on the existing knowledge of the human experts and according to a current technology. Our approach is interactive in the sense that the solution depends on the input given by human experts. The input may (and usually is) altered by experts on the basis of the system analysis which shows the consequences of the given input to a decision making process. One function of the *expert system* is the creation of a standardized hazard rating system for abandoned mines. This paper summarizes the methodology and assumptions on which our hazard rating system is based. Wewill be trying to avoid mathematical terms which may only confuse the reader (details can be found in references provided).

Any decision related to abandoned mines impacts on a variety of groups of people. In particular the community which lives around the site is strongly affected by hazard. Taxpayers and different organizations want to know on which basis their money is spent. It is inescapable for a decision maker to arrive at a point in which economic and technical factors must be considered together with political and social factors for the basis of making a decision. All factors should be taken into consideration if a decision maker wants to have the decision based on the solid knowledge. A clear distinction should be made between technical and measurable factors and social or political factors. In the creation of this abandoned mines hazard rating system we propose a way to link these two (in many cases contrary) aspects of a decision. We believe that a decision maker should be given a broad variety of possible options to work with. It is his/her arbitrary judgment to take or not to take them into consideration. It is nevertheless better to know about all aspects of the decision.

The proposed hazard rating score will consist of a two factors. The first factor will be derived by interviewing mining experts, safety inspectors, environmental experts, medical officers (according to the possible impact to the health of the people living around the site). The second factor will be obtained by reviewing the opinions given by people, formal and informal organizations, local government institutions etc. In general, the second factor characterizes public opinion. For example, the public factor will probably be close to zero for an abandoned mine located in a remote area with airplane access only. This may be an important factor for a decision maker. It could be briefly reported, for instance, as "the given site does not generate any public concern or complaints".

On the basis of our present familiarity with the problem we have considered two groups of criteria. They are recorded by us as technical factors and social factors. The *expert system* is used to calculate a final score for each site according to human expert's assessment. The assessment is done by considering one criterium at a time. For example, the human expert will evaluate all sites according to surface water contamination and will assign certain values (e.g. ranks). This evaluation process will be repeated for all criteria. Our task is now reduced to finding the weights (or relative importance) of each factor. Once having these weights for all factors we will evaluate each mine with the help of the expert system. To do this one must find the *eigenvector* corresponding to the largest *eigenvalue* of a matrix which has been derived from the human experts' judgment of relative importance of criteria.

2. Abandoned Mine Hazards

Under the Mining Act (1992, p.67) for the Province of Ontario "abandoned" means the proponent has ceased or suspended indefinitely advanced exploration, mining, or mine production on the site, without rehabilitating the site.

In planing remedial action for abandoned mine hazards Four factors have been considered: public safety, public health, environmental impact and aesthetic consideration. The public interest commonly centres more on aesthetics concerns rather than on public health or environmental impact. The greatest urgency for government agencies however is the identification and remediation of safety hazards. Public health and environmental problems are for the most part associated with mine wastes and effluent. The degree of urgency in implementing remedial action depends on the severity of the effects produced in each individual situation. Work on some projects might be delayed where practical, pending additional research which could lower costs and produce better long term results.

Public safety is largely related to abandoned mine workings and openings to surface, such as open shafts, stopes, adits and raises and areas of potential surface pillar collapse (Mackasey, 1989). The conclusion is drawn from the number of accidents and near accidents related to mine workings and mine openings. The most serious type of accident is likely to occur where significant land development has encroached on mined out lands and the potential for cave-ins has not been investigated. Accidents can also generally be expected to occur near built up areas because the hazardous sites are frequented by a large number of people who do not appreciate the dangers involved. It is therefore more urgent not only to define and remedy hazardous conditions in built up areas and other easily accessible locations as soon as possible, but also the protective measures must be more secure to deter both inadvertent access and planned adventurism.

Because of the complex inter-relationship between the nature of physical hazards and public factors such as location, access, public awareness etc., a hazard cannot be evaluated from its physical characteristic alone. In judging a safety hazard the following factors should be considered:

1. Character of opening, size and attitude (i.e. a steeply inclined empty shaft, stope or steep-walled mining cut should be rated high, whereas an adit, small pit or water filled shaft, should be rated lower).

2. Unsafe ground conditions, such as decayed or loose rock can lead to collapse or burial even when reasonable caution is exercised. Current research on surface crown pillars indicates that the stability of many pillars should be verified.

3. Location near a population centre increases the hazard rating substantially because of the number of people involved. Situations which may not be dangerous to adults can be catastrophic for children.

4. Curiosity encourages exploration which may lead to accidents. Former mining operations with unsafe buildings and unsecured openings such as accessible mine workings are substantially more hazardous than isolated prospect shafts.

The greatest hazards are likely to be unknown or unrecognized ones as illustrated by the types of accidents which have occurred, such as subsidence of insecurely filled stopes and crown pillar failure. Whereas an open stope might also be considered a first order hazard, the false security of backfilled stope or a deteriorated shaft cover could be considered to have a high hazard potential. A mined out area with open stopes and shafts protected by the perimeter fence, cannot be considered safe if children living in the neighbourhood can find ways to enter and play in those areas. A building with decayed walkways and ladders may be more attractive and therefore more hazardous than an open water-filled shaft which is clearly visible and of very little interest. Because so many abandoned mines are located near built up areas, the character of the hazard and the location of the hazard are both important factors.

3. Technical Factors

It is important to have the risk evaluation determined by highly qualified, interdisciplinary experts. This evaluation will be expressed by the group of criteria called technical factors. The short narrative description of these factors is given below.

Technical factors represents the evaluation of the hazard of the site given by the highly qualified, interdisciplinary experts. According to the remarks given above, all technical factors could be clustered into four groups: public safety, public health, environment and aesthetics.

Public Safety contains the most important factors for the evaluation of the hazard rating score. These factors consider the possible death or serious injury of individuals. Severity can be described using the following terms (factors): the type of the site access, the state of the hazard, the type of the hazard and the magnitude of the hazard.

Public Health impact represents the possible level of the negative influence to the health of the individuals living in the vicinity of the site. This group is mostly associated with mine wastes and effluent. The major mine waste problem is mill tailings. These fall into two principal categories non-reactive and reactive tailings. The water or even blowing sand from the tailings areas may carry the harmful contaminants (e.g., mercury, arsenic, asbestos, radioactive substances, heavy metals) and be dangerous to the health of people residing in the area. The possible health impact might be considered according to long-term and short-term consequences.

Environmental impact estimates the degree of the possible contamination of the environment. This group is mainly related to mine wastes. The contamination of the environment might be considered in terms of contamination of ground water, surface water, air or soil.

Aesthetics and existing land use should be taken into consideration when developing the system. This group consists of two factors: alternate uses (or proximity to conflicting land uses) and aesthetic appearance.

In each group there are a number of factors according to which the individual site will be evaluated. It is important to have standardized assessment form. This is necessary if we want to have a uniform scoring system for different sites being evaluated. A description of the assessment form currently in use is given at the end of the paper. It is important to note that the risk assessment should be independent of the scoring methodology to be utilized in the next step (which is the risk management step). In other words the method of computing the final score of risk should be flexible enough to accommodate future changes of the assessment form which may be done following the progress of our knowledge of the problem. An interesting attempt of using the approach based on probability theory in risk assessment is presented in Burmaster and Lehr (1991).

We will consider the following criteria in the technical factors group:

Public safety:

Site Access will rate the accessibility of the site in terms of ease of access (paved road to the site, gravel road to the site, bush road to the site, 4x4 or foot access only, water/air access only).

Hazard State stands for the current state the hazard presents (present hazard, probable hazard in future, potential hazard in future)

Type of hazard will be used to rate the level of public safety presented by each hazardous item (equipment or property damage likely, personal injury likely, fatality likely or possible).

Magnitude of hazard will be used to describe the magnitude of the hazard. Two different types of risk are recognized: fixed risk and transient risk of the hazard. In the case of the fixed risk the possible magnitude depends on the "recognition" of the hazard (easily recognized, hard to recognized, hidden). In the case of the transient hazard its magnitude depends on the number of people likely to be affected by the hazard.

Public Health:

Short-term will represents the possible short-term consequences for the health of the people residing around the site. It might be related to the high degree of pollution and contamination of water or soil (in terms of the negative impact for the human health).

Long-term will represents the possible consequences for the health which might be very difficult to recognize at that moment, but might affect very sensitive individuals (for example newborns or children).

Environment:

Groundwater represents the possible contamination of the groundwater in terms of possibility (proven, potential), scale (the possible area affected) and the sensitivity of the surrounding environment (high, moderate or low sensitive).

Surface water represents the possible contamination of the surface water in terms of possibility (proven, potential), scale (the possible area affected) and the sensitivity of the surrounding environment (high, moderate or low sensitive).

Air represents the possible contamination of the air in terms of possibility (proven, potential), scale (the possible area affected) and the sensitivity of the surrounding environment (high, moderate or low sensitive).

Soil represents the possible contamination of the soil in terms of possibility (proven, potential), scale (the possible area affected) and the sensitivity of the surrounding environment (high, moderate or low sensitive).

Aesthetics:

Land use stands for the existing land use (residential, first nations traditional use, recreational, national/provincial park, commercial, industrial, crown land) and the proximity to other uses. This factor can play a very important role when determining whether planning or land use conflict might be a problem.

Aesthetics describes the appearance of the site (particulary mine wastes) in terms of access, visibility and area affected.

4. Social Factors

Social factors represent the perception of the possible dangerous consequences of the abandoned mine, express by the local community. It should be the additional (to the technical factors) but very important component for a decision maker. The information can be

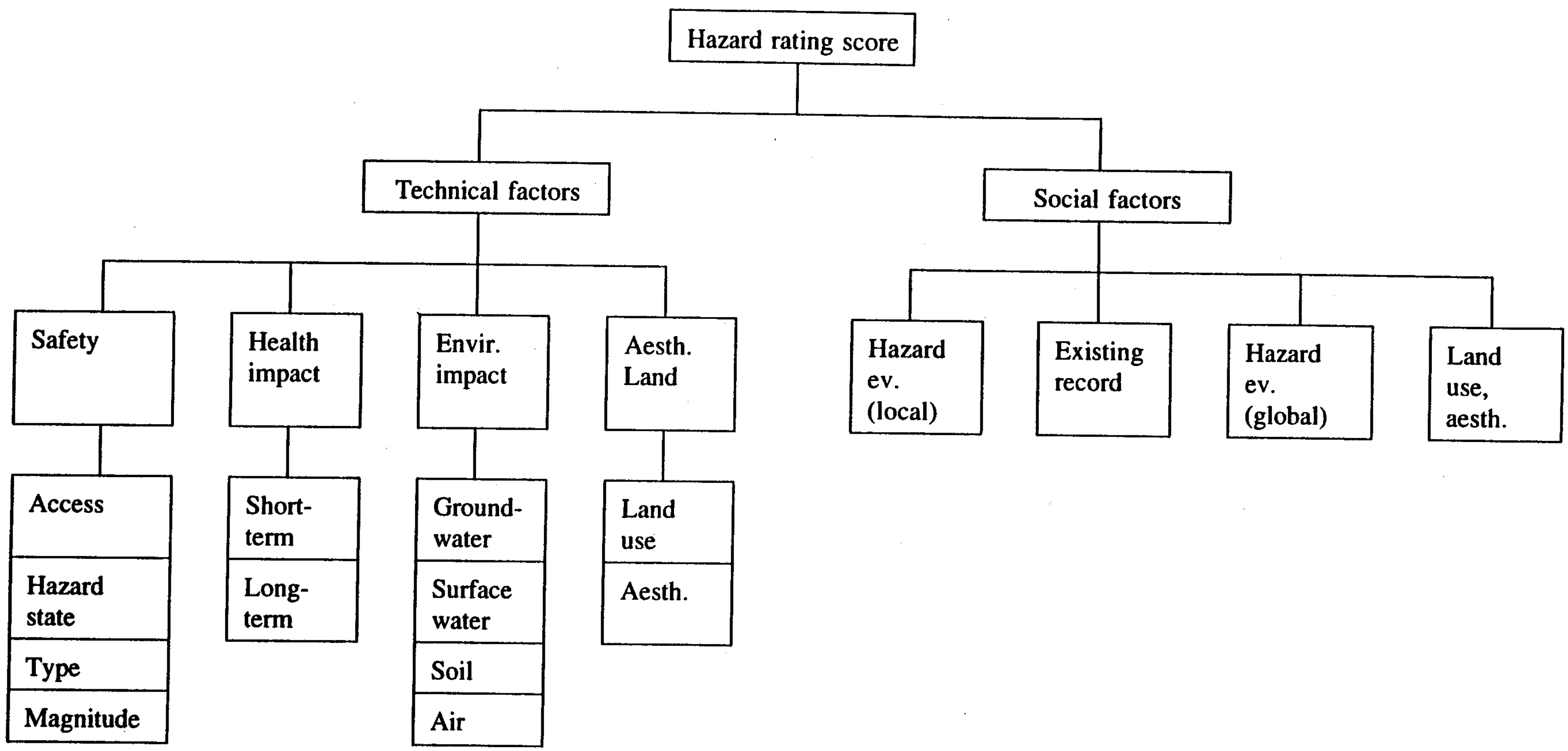

Figure 1. Structure of hazrd rating criteria

gathered by interviewing the individuals and the organizations which should, or want to, express their opinion about the existing situation. This would be obtained by asking people to fill in the simple questionnaires. For example to rate the listed number of items from the most to the least dangerous, according to their opinions. This information will, in all likelihood, represent wide variety of opinions. In many situation the opinions will be contradictory and dependent on the particular point of view of a respondent. The decision maker must take this variety of opinions into consideration during the decision making process. There is no doubt, we believe that it is better to recognise and consider these opinions. The proposed system will allow the decision maker to store, update and use this information as required.

In this group the following criteria are proposed:

Hazard evaluation (local) stands for the estimation of the hazardous state of the abandoned mine given by the local community, as well as any local organization which wants to express its opinion. It should be considered the most important factor in the group of social factors. Generally speaking the people living around the abandoned mine can be affected by a possible accident so their concerns should be given top consideration.

Existing record will cover the complaints which have been expressed by the individual citizens or organizations and the information about the accidents which happened in the past. The intention of this factor is to answer the following question: does the site liberate any negative perception in the community?

Hazard evaluation (global) stands for the opinions from a club or association which might create any human activity in the area close to the abandoned mine. For example: Snowmobile Association, Cross Country Skier Club, Hunting and Fishing Association, etc.

Aesthetics appearance and land use will stand for the possible land use or aesthetics appearance of the site. The information could be gathered from the local community, agencies, environmental groups and from the institutions responsible for the future land development.

5. Methodology

Having all above criteria listed, the most logical approach at this point is to evaluate each site according to only one criterion. The group of experts should have a standardized assessment form and during the evaluation should follow strictly the rules. Otherwise the results would be useless. We will give the description of the assessment form and point system which is currently in use in Ontario. The ideal assessment form should be designed in collaboration with experts in mining, safety inspectors, environmental experts and risk assessment experts. It would reflect the current state of knowledge related to the risk assessment.

The final goal is to rate all abandoned mines according to their hazards. We should have a procedure which is able to change the numerical values given in the assessment form into certain numerical values which reflect the hazardous condition of the site. We are then face with the problem of assigning a weight to each criterion. We must prioritize all criteria according to their contribution to the final score. The simplest approach to the problem would be to distribute a constant number of points (it might be 100) among the criteria in such a way that the number of points allocated to the criterion reflects its relative importance. In the next paragraph we will give a short description of the method based on *pairwise comparisons*. Having all weights for the criteria and the assessment for the abandoned mine one could simply multiply the score for each criterion by its weight add all results and obtain the score for the mine. This simple additive method can be easy written in a linear equation form. This procedure is rather widely used (see for example Fowkes, 1989) but has certain weaknesses which in our opinion can be overcome. Two major questions can be raised: 1) does the method of assigning the weights guarantee the proper prioritisation of all criteria and, 2) is the linear additive function the best in calculating the final score for the site?

6. Pairwise Comparisons of Criteria

Consider a matrix **C** with n rows and n columns in which the entry c_{ij} in i-th row and j-th column denotes the relative importance of the criterion (objective) i compared with objective j, as expressed by a decision maker or by an expert. Let w_i denote the unknown weight of the criterion i. How can the vector $w=[w_1,w_2,...,w_n]$ be estimated on the basis of **C**?

One possible solution can be the following. If the decision maker's or the expert's assessment would be completely consistent, one would have

$$c_{ij} = \frac{w_i}{w_j}$$

for all pairs (i,j). It is not difficult to see that in this case:

$$\sum_{j=1}^{n} c_{ij} w_j = C\ w_j \quad for\ all\ i,j$$

which reads in matrix form:

$$Cw = nw$$

The last expression is an *eigenvector* expression, indicating that n is the largest *eigenvalue* of **C**, an **w** would be the corresponding eigenvector. This result hold true in the case of complete consistency. In the case of inconsistencies this is no longer true, however. Therefore Saaty (1977) proposes to estimate **w** as the eigenvector corresponding to the largest eigenvalue in this case. It can be shown that the largest eigenvalue is never smaller then n. Although there is no analytical proof that this method works well for the inconsistent matrices the superiority of this approach is evident for the small number of criteria is as proven statistically (Duszak and Koczkodaj, 1992). A new definition of consistency (Koczkodaj, 1993) allows us to locate the most inconsistent judgments and reexamine them. New and more consistent judgements may be expressed in an interactive way. It will contribute to reduction of the overall of inconsistency.

In the case of the hazard rating system we have 16 different criteria. We must assign the weight to each criterion to reflect its relative importance. If we confine our attention only to technical factors we have 12 criteria to be compared. Assigning the weight to each criterion is a very difficult procedure in this case. Having for example 100 points to be distributed among at all criteria, or assigning the importance of a criterion in percentage one would probably have a difficult task. The obtained result must have a high degree of credibility. Is the expert absolutely sure that the weights he has obtained are indeed the best and most reliable? The task becomes much more difficult when we have a number of the experts coming from different fields. This is usually the case. Some of them are in favour of one group of criteria and others prefer the other groups of criteria. How can we find a compromise to satisfy all experts? How can the existing conflict of interests be resolved? These types of questions are addressed by the theory of Multiple Criteria Decision Analysis, Multiple Attribute Decision Making, and Concordance Analysis. The theoretical foundations were established at the beginning of the 1970's. The interested reader can find more information in (Nijkamp et al., 1991; Chin-Lai and Kwangsun, 1981).

For the purposes of our system we have selected and modified the part of the theory based on the *pairwise comparisons* and *hierarchy*. As the number of criteria is too large and in many cases very difficult to compare we must cluster them into groups and build a proper hierarchy. For example how does one compare the contamination of the air with the record of existing complaints from the local community, what is more important and what weights we should assign to these factors?. Instead of comparing all criteria at once the expert should compare criteria or groups of criteria in one level of the hierarchy only. In our approach the largest number of criteria to be compared in one step has been reduced to four. In this case the accuracy of the method based on *pairwise comparisons* and *eigenvectors* is much better than other methods, see Duszak and Koczkodaj (1992). In our case for example the expert or group of experts should answer the following type of questions:

- How many times in your judgment is the group public safety more important than the group environmental impact?
- How many times is the access more important than the magnitude of the hazard in regard to the public safety?
- How many times is the surface water contamination more important than the contamination of the air in regard to negative environmental impact?

The set of questions will be generated by the system according to the existing hierarchy. When the experts, individuals or organizations (in the case of recognition of public preferences) have answered all questions, the system will calculate the weights of all criteria (factors). It is mathematically proven that these weights are the best according to the given answers (judgments). Of course we need a certain standard scale is required to answer the question. The following scale seems to be the most appropriate (Harker and Vargas, 1986) and has been adopted for this study.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two criteria contributed equally to the objective
3	Weak importance of one over another	Experience and judgments slightly favour one criterion over another
5	Essential or strong importance	Experience and judgments strongly favour one criterion over another
7	Demonstrated importance	The criterion is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one criterion over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed

Table 1. Comparison Scale

7. Risk Assessment

The hazard rating system being proposed conforms with the existing data and existing method of risk evaluation under development by the Ontario Ministry of Northern Development and Mines. All factors in group *public safety*, *environment* and *aesthetics* have been selected to be consistent with available data. So far there is no available information for *public health*, but even without this data the system is able to evaluate the hazards of each abandoned mine.

The basic step is the evaluation of each site. This part of the problem is related to risk assessment. Of course in real-life situations the assessment of different sites might be given by different groups of experts. From the user and decision maker point of view, attention must be paid for selecting the best interdisciplinary highly qualified group of experts. Because the results gathered from different sites by different experts must be comparable the standardization of the assessment forms should be done before evaluations commence. A short description of the proposed assessment forms and point system used will be given below. It is important to emphasize again the distinction between risk assessment and risk management. Both factors are very important and closely related. Maximum effort should be taken to make sure both above mentioned factors are based on unbiased science, state of the art technology and up to date accumulated knowledge. In creating the hazard rating system our attention is mostly confined to the management of risk. It is clear that the better the risk assessment the better the results we can expect when the decision is made.

7.1 Public Safety category description and point system

This will list the type of hazard to be assessed. Each of the following hazards present on the site should be assessed individually:
- surface openings
- pits
- underground subsidence
- blowing fines
- dams/dykes
- buildings(>10sq.m.)
- fire hazard
- chemical hazard
- waste hazard
- explosion hazard
- other hazards

Each hazard should be assessed according to the following criteria: site access, hazard state, type of hazard, magnitude of hazard.

<u>Site access</u>. This section would rate the accessibility of the hazard in terms of ease of access. The following scores should be used:
- populated area, more than 50 people living within one km (paved road to the site), 5 points
- populated area, less than 50 people living within one km (gravel road to the site), 4 points
- remote area, easy access by road or other means (bush road to the site), 3 points
- remote area, poor access by road or other means (4x4/ foot access only), 2 points
- remote area, water or air access only, 1 point

<u>Hazard state</u>. This section would rate the current state the hazard presents. The following scores should be used:
- present or recurrent hazard (i.e. hazard exists), 3 points
- probable hazard in future (i.e. hazard is likely to exist in the near future), 2 points
- potential hazard in future (i.e. hazard may existing in the near future), 1 point

<u>Type of hazard</u>. This section would rate the level of public safety hazard presented by each hazard. The following scores should be used:
- fatality likely or possible, 3 points
- personal injury/ health affects likely, 2 points
- equipment/property damage likely, 1 point

Magnitude of hazard. Evaluation in this section should be preceded by the distinction between two types of risk: fixed and transient. The basic difference is that a person would have to go to a fixed hazard, but a transient hazard could come to a person.

The following score should be used to rate the magnitude of hazard for the fixed hazard (e.g. open shaft):
- hidden, 3 points
- obscured/hard to recognize, 2 points
- easily recognized, 1 point

For the transient hazard the magnitude of hazard could be expressed in terms of the number of people likely to be affected by the hazard. The following scores should be used:
- ten or more individuals, 5 points
- four to nine individuals, 4 points
- three individuals, 3 points
- two individuals, 2 points
- one individual, 1 point

7.2 Environment category description and point system

The hazard presented to the four ares of environmental concern:
- ground water e.g., tailings area seep
- surface water e.g., elevated metals in each lake or river affected
- soil e.g., metal contaminated soil in concentrator area or loading areas
- air e.g., blowing dust from tailings area

Each area is evaluated according to the following factors: potential, scale and sensitivity of the surrounding environment.

Potential. Weighs the potential of the described hazard to impair the environment. Two categories are defined:
- proven i.e., the hazard has been proven through field study, 2 points
- potential i.e. the hazard is anticipated in the future and could be proven through field study, 1 point

Scale. Reflects the extent of proven or potential impact that the hazard presents in hectares:
- more than 100 hectares, 4 points
- 10 - 100 hectares, 3 points
- 1-10 hectares, 2 points
- 0-1 hectares, 1 point

Sensitivity of the surrounding environment. Weighs the influence of the hazard on the surrounding environment (e.g. fish and wildlife habitat):
- highly sensitive, 3 points
- moderate sensitive, 2 points
- low sensitive, 1 point

7.3 Aesthetics and land use category description and point system

Land use. Other existing land use must be taken into account when determining whether planning or land use conflict will be a factor. A current list would be scored as follows:
- residential area, 5 points
- first nations traditional use, 5 points
- recreational area, 4 points
- national/provincial parks, 4 points
- commercial area, 3 points
- industrial area, 2 points
- crown land, 1 point

Other land uses can be designated as required.

Proximity to other uses can play a very important role in determining land use conflicts. A scoring for each conflict would be determined by the distance to the conflict:
- 0-100 meters, 4 points
- 100-1000 meters, 3 points
- 1000-10000 meters, 3 points
- more then 10000 meters, 1 point

It should be noted that only the highest score for each conflict is to be used in the final scoring for this section. For example a mine/mill is a 500m from a commercial area but is 1500m from a residential area. The first example would score 3+3=6. The second example would score 5+2=7. Therefore the score of 7 would be used for this mine/mill conflict.

Aesthetics is evaluated in terms of access, visibility and area affected by the site.
Access weighs ease of access public has to the site:

- paved road, 4 points
- gravel road, 3 points
- bush road, 2 points
- air/water access only, 0 points

Visibility category reflects visibility of mine site from a normal vantage point and is scored as follows:

- highly visible, 2 points
- moderately visible, 1 point
- slightly visible, 0 points

Area affected reflects the area in field of view from normal vantage point affected by special mine activities expressed in hectares:

- more than 100 hectares, 3 points
- 10-100 hectares, 2 points
- 1-10 hectares, 1 point
- less than 1 hectare, 0 points

8. Comparison of the Hazard Rating Systems

The previous hazard rating system can lead very easily to heavy misinterpretations of results. As a simple but illustrative example we can consider the following sites. Site A which is one 500 ft. deep shaft and site B approximately at the same place (with the same access) consists of one building, a piece of old machinery and steep embankment. Assume further that the hazards in site B are of the lowest possible category. In this case there is no doubt that the site A is more dangerous than site B and should be scored higher.

The possible evaluation of both sites is given in the table 2. The points assigned to each hazard follow exactly the rules given in the assignment form. Surprisingly the final score obtained by the previous system for the site A is equal to 140 (14 times 10, where 10 is a public safety factor) and for the site B is equal to 240 ((8+8+8) times 10. where 10 is the same public safety factor). This unwanted result is caused by addition of points for each selected hazard.

Site	Assessment points				Score by previous system	Score by new system
	Access	State	Type	Magnitude		
A	5	3	3	3	140	100
B	5	1	1	1	240	80
	5	1	1	1		
	5	1	1	1		

Table 2. Comparison of two sites.

The calculation of the score of the previous system is based on the simple additive formula. This method, however, favours the sites with many hazards. To avoid the situation we have described above we propose another formula for calculating the final score. Let us consider only one criterion. If we have a hazard with the maximal number of points assigned to it during the evaluation procedure, the score for this site is thus maximal according to this criterion. For all hazards smaller than maximal, we assign a score equal to its ratio to the maximal number of points assigned under this criterion multiplied by the weight of the criterion. The results obtained by our approach for the two simple examples A and B are summarized in the last column in Table 2. The site A is scored higher (standardized 100 points) than the site B (standardized 80 points) as it was expected. This simple example demonstrates that the scores obtained by our approach are more intuitive and credible than the score obtained by the old system.

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THE COBALT OPTIONS PROJECT - Rehabilitation of an old Silver Mining Town in North-Eastern Ontario, Canada [1]

by

W.O.Mackasey [2]

Abstract
In June 1987, Highway 11B collapsed into abandoned mine workings at the entrance to the Town of Cobalt. Although subsidence problems were not unknown to the town, this cave-in managed to cut off access to three communities and gained widespread attention of the media, government officials and politicians. Geotechnical investigation revealed a network of shallow unmapped mine workings beneath the highway. The possibility of similar shallow workings occurring elsewhere beneath the town had to be considered.

Mounting concern for public safety led some officials to believe that the town ought to be abandoned and this led to the establishment of the Cobalt Options Project in 1988. Four options were developed by a multi-agency provincial government committee:

1) maintain
2) buy-out
3) relocate
4) maintain and investigate, repair, relocate or buy-out

An abandoned mines inventory of the town was prepared as part of the Cobalt Options Project. A total of 17 areas designated for "caution status" were identified. This information, when combined with the geology of the area, influenced the committee to recommend option four.

This option was accepted by the Government of Ontario. A prioritised testing and remedial work program was initiated in the spring of 1989 and is expected to be completed by 1993.

Key Words: abandoned mines, rehabilitation, geothechnical testing, subsidence, public safety.

1.0 Introduction

The town of Cobalt is located in northeastern Ontario approximately 450 kilometres north of Toronto. (Figure 1) The area is underlain by Precambrian meta-sedimentary and metavolcanic rock forming the southern part of the Canadian Shield.

The town was founded with the discovery of high grade silver deposits in the early 1900's. Over 100 producing mines were created, some with spectacular native silver veins. The town grew from a bush camp to a full fledged metropolis by 1910, complete with electric trams and regularly scheduled railway service. Many of the Cobalt developments have since become Canadian folklore.

The discovery of high grade veins up to 12 inches wide and grading over 5,000 ounces silver per ton attracted miners and

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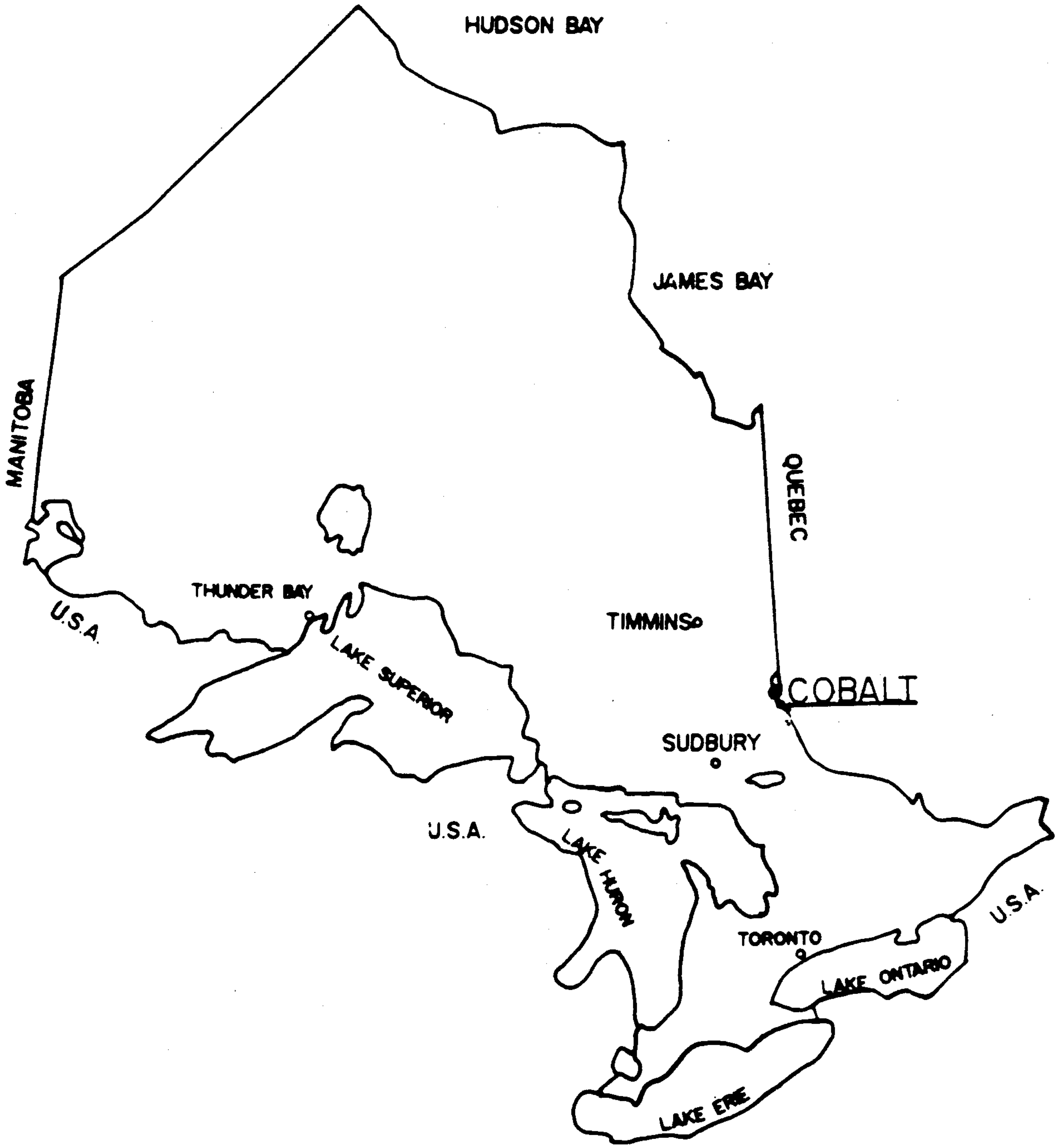


FIGURE I LOCATION MAP

prospectors from around the world. The development activities in Cobalt laid the foundation for much of Canada's existing mining infrastructure. Many prominent Canadian prospectors, geologists, mining engineers and metallurgists have Cobalt as part of their family history.

Silver mining peaked in Cobalt in the 1920's. The last of the mines in the area closed in 1990. Cobalt is now a residential community with a population of 1480 people, of which many are retired miners and engineers from past mining operations.

2.0 Public Safety

Many of the steeply dipping silver veins were mined close to or through to surface. As a result, safety fences, erected by mining companies and/or government agencies criss-cross throughout the community. In 1981, the Ontario government issued a study of underground workings in the municipality (Cunningham and Hurst, 1981). This study was used in the development of the town's official plan, in which zones of "mining use only" were designated. Reports exist of cave-in problems over the years. Due to the narrow nature of the mine workings, the cave-ins were generally small and quickly repaired by local mining companies.

3.0 Highway 11B Collapse

On June 22, 1987, a part of Provincial Highway 11B collapsed into abandoned mine workings. As a result, southern access was cut off into, not only Cobalt, but to two other towns as well. These three towns, Cobalt, Haileybury and New Liskeard form what is known in the province as the "Tri-town" area. The Ministry of Transportation quickly realized that a major crisis existed as road access was cut off for thousands of residents in the region.

The author was given the assignment of heading an action committee to investigate and develop recommendations. A multidisciplinary committee was struck, in the next few days, consisting of provincial government agencies, municipal officials and a geotechnical consultant.

As the cave-in was beneath a provincial highway, very rigid standards had to be met for both investigative work and reconstruction. Of particular concern was the fact that the Cunningham and Hurst Study (1981), did not report any near surface mine workings in the vicinity of the collapse. Cunningham did show, however, that suspicious areas occurred elsewhere along the highway corridor.

4.0 Highway 11B Corridor Investigation

It was agreed by the above committee that a five-fold geotechnical investigation be mounted. The five tasks (Carter et al, 1988) included:

i. Using data from old mine drawings, plans and sections, plot zones of potential concern onto a topographic map,

ii. Assembling old mining records and additional hearsay data from old miners and town officials to delineate other uncharted problem zones,

iii. Undertaking composite surface geological and geophysical surveys (including ground penetration radar) to delineate anomalous areas requiring further attention,

iv. Carrying out drilling investigations (air track and diamond drilling) to determine thickness and quality of rock mass in crown pillars overlying problem zones, and

v. Where possible, undertaking downhole camera and / or ultrasonic profiling to delineate geometry and extent of problem zones.

Investigative work at the highway cave-in revealed the presence of a maze of underground workings (Figure 2). A major advance was the discovery of an uncharted near-surface level of mine workings that had been established in the 1930's. Interviews with retired miners and examination of old sketch maps revealed that during the 1930's depression years, many of the abandoned workings were reactivated by lessors who exploited the remaining high grade surface crown pillars. The committee learned that excavation by the lessors was commonly taken right to the overburden interface. In

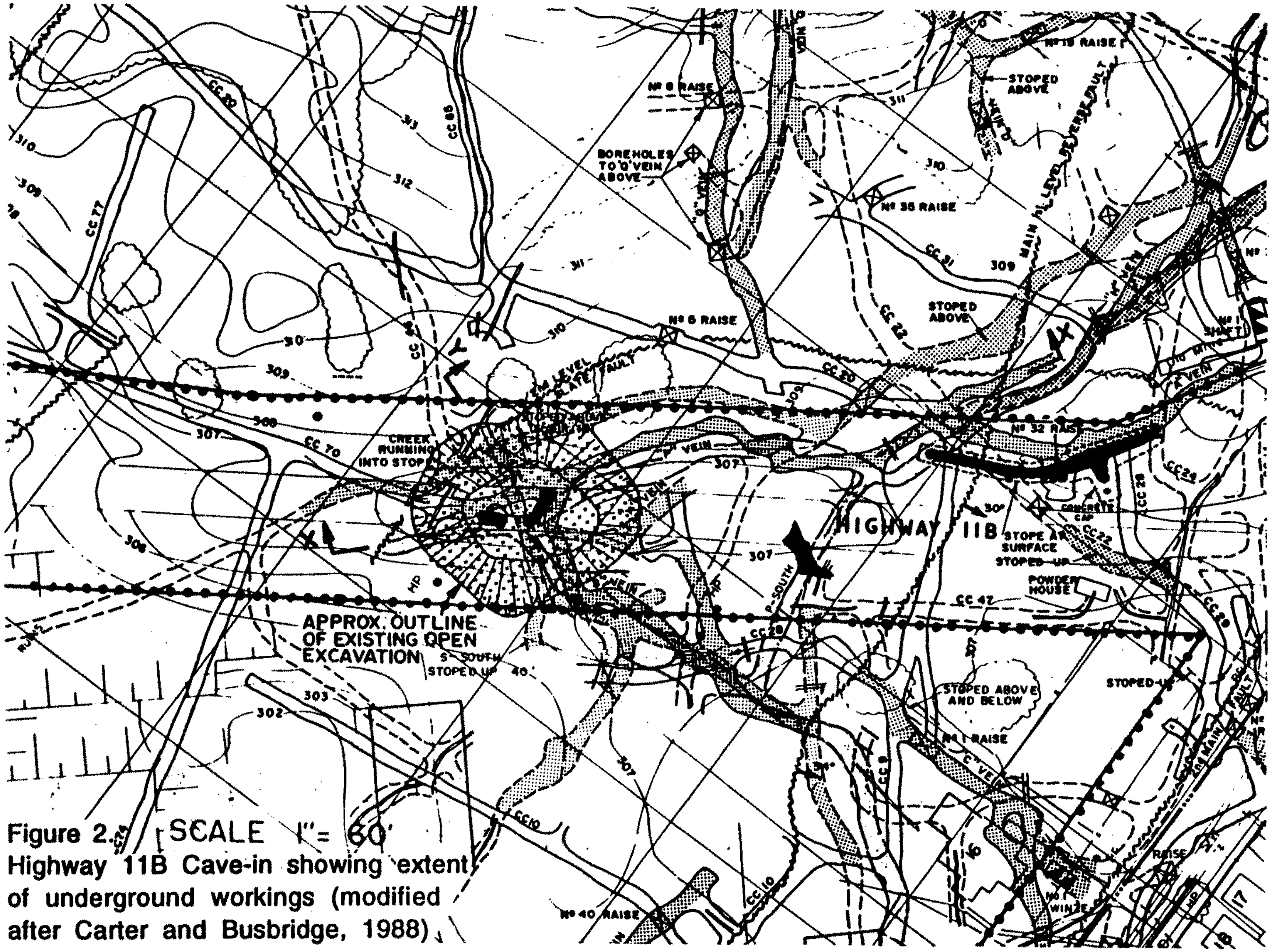


Figure 2. Highway 11B Cave-in showing extent of underground workings (modified after Carter and Busbridge, 1988)

some cases, timbering had been used to support the overburden.

As the geotechnical investigation progressed eastward along the highway corridor through the town, more uncharted mine workings were encountered. Of particular concern was the discovery of expansive empty workings adjacent to and beneath a home for senior citizens.

5.0 Concern for Public Safety

Maps produced by the Cunningham and Hurst Study (1981) showed that mine workings were widespread beneath the town. Most, however, were shown to be at sufficient depth to pose no public safety concern. The committee was faced with a dilemma in that the extent of the lessor's mining activity was largely unknown. It could easily be argued that if unsafe workings occurred beneath Highway 11B, then they certainly could or would be found elsewhere in town. Timber supports, now a half a century old may no longer be stable.

After several months of witnessing drilling, excavation and survey crew activity, some town residents and public officials began to question the wisdom of continuing residency in the town.

The Provincial government established a formal committee, the Cobalt Abandoned Mining Hazards Committee, to examine public safety issues, with representatives from the town (including the mayor), and the Ontario Ministries of Northern Development and Mines, The Environment, Transportation, Housing, Labour and Municipal Affairs. Members of this Committee soon began to realize that in addition to the public safety issues, the widespread presence of abandoned mine hazards seriously affected a number of government programs. For example the Ministries of Transportation and the Environment were working toward multimillion dollar improvement programs for road reconstruction and a new water and sewer systems respectively. These ministries were faced with potential for extreme cost over-runs on their projects if mine workings were encountered and had to be bridged. The blasting required for construction work could possibly induce collapse of unmapped nearby workings and pave the way for civil lawsuits. There was also risk that some sections of the town might have to be abandoned if serious large hazards were found. This would have the potential of rendering useless the millions of dollars expended collectively by the many government agencies on public works projects. The Cobalt committee thus became an interdisciplinary body whose real strength came from working together on a common front to solve each other's problems.

6.0 Cobalt Options Study

The Cobalt Abandoned Mine Hazards Committee was able to demonstrate that a formal review of the town's future must be done before any further public works projects be attempted.

A Cobalt Options Study was initiated in the fall of 1988 to analyze the pros and cons of:

a) Continuing remedial action in order to maintain and service the existing settlement,

b) Buying out the town, and

c) Relocating the town.

A task force of seven Ontario government ministries was formed and a critical time path established with completion date targeted for the spring of 1989. The following points formed part of the analyses:

* Feasibility of adoption

* Direct costs

* Social and economic consequences
* Municipal financial viability

* Co-ordination with other provincial initiatives

* Implications for other municipalities with similar abandoned mine hazards problems

* Funding of action

Specialists from Ontario ministries of Treasury and Economics, the Environment, Municipal Affairs, Housing, Transportation, Government Services, and Northern Development and Mines, formed a synergistic problem solving group which met together on a regular basis. Tasks varied from a review of market value of residential dwellings in the town by the Ministry of Government Services Real Estate Group, to water works cost projections by the Ministry of the Environment project engineers.

A central question which impacted all facets of the study was the abandoned mines issue. What was the extent of mine workings beneath the town? What was the potential for further cave-ins? Would abandoned mine workings interfere with municipal improvement projects? What would the public cost be to locate, test and remediate abandoned mine hazards? Because of this it was agreed that an abandoned mines inventory study be prepared for use by the committee.

7.0 Inventory Study

A geotechnical engineering firm was hired through the Abandoned Mines Program of the Ministry of Northern Development and Mines to prepare a map of the abandoned minesites within the town showing the relationship of mine workings to civic structures. This approach had been used successfully elsewhere in the province (Mackasey, 1989). Cost estimates on remedial action were also to be prepared.

The resulting study (Carter, 1989) outlined a total of seventeen "Areas of Sensitivity" within the town (Figure 3). These were plotted on a 1:2000 scale map for comparison with municipal planning maps. A description of each "area" was listed along with required investigations and scope of potential remedial measures. First order cost estimates were provided for each site.

Three basic hazard categories were used in the report:

i) areas recommended for mining use only,

ii) areas recommended for "caution" or "on notice" status, and

iii) sensitive areas and/or areas recommended for safeguards.

7.1 Areas Reserved for Mining Use Only

These outline areas of extensive past mine development and/or favourable mineral potential and are not recommended for multi-land use. Many of these areas are reflected in the town's official plan. As a result few land use conflicts occur.

7.2 Areas Recommended for "Caution" or "On Notice" Status

These areas differ from the former in that residential and commercial buildings exist in close proximity or on top of mining workings. "On Notice" status would be placed on areas where mining workings were known to be beneath buildings and roads. Owner would be notified. "Caution Status" applies to those areas not presently known to be hazardous, but are potentially hazardous because of:

a) Lack of information on geometry of under ground workings, surface crown pillar thickness, etc.

b) Adverse rock mass conditions or geology (faults, parallel veining, etc.)

c) Existing mining operations in proximity to mine workings related structures

d) Planned or ongoing surface infrastructure or development.

7.3 Sensitive Areas and/or Areas Recommended for Safeguarding

This is a subdivision of the "Caution Status". These are areas where existing conditions have the capacity to cause personal injury or property damage and occur outside of areas restricted to mining use only. These areas should be tested by drilling and protected as required. Included in this category are:

* Open shafts and raises in publicly accessed areas which should be concrete capped.

* Open stopes and near surface stopes which should be enclosed by fencing or backfilled.

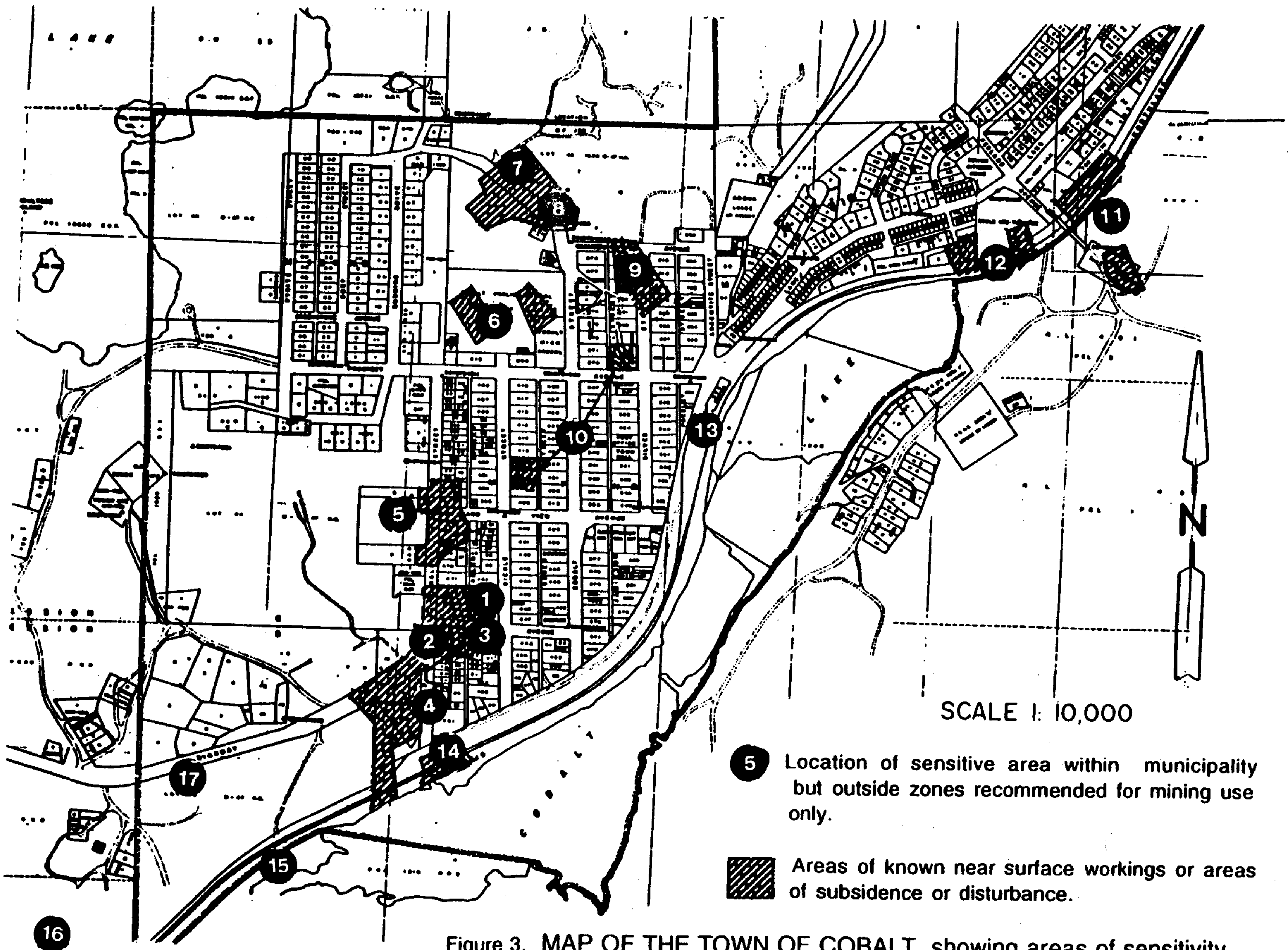


Figure 3. MAP OF THE TOWN OF COBALT showing areas of sensitivity.

* Adits, pits and isolated shafts in areas that may also be accessible to the public and which should also be filled.

* Public areas where workings occur under or in close proximity to highways, streets, schoolyards, and/or dwellings.

* Public areas where underground workings are known to extend within three to ten metres of surface.

* Public areas where the depth of overburden and/or the thickness of surface crown pillars are unknown or limited.

7.4 Mining Geology

Native silver mineralization in the Cobalt area occurs as narrow veins filling in criss-crossing fractures within the rocks along the contact between archean ("Keewatin") metavolcanic rocks and proterozoic ("Huronian") metasedimentary rocks. As described by Petruk, (1971, p.79) "The deposits occur as veins in fissures, fractures, minor faults and major faults in sedimentary rocks of the Coleman Member, which is the lower part of the Cobalt Group, Huronian System." He also indicates that the zone of silver mineralization follows the archean-proterozoic unconformity in what has been interpreted to be sediment-filled erosion troughs in the metavolcanic (Keewatin) terrain. The mineral bearing zone in the vicinity of the town of Cobalt is separated by the Cobalt Lake Fault (see Figure 4). Cobalt Lake (and the fault zone) parallels the eastern town boundary. As can be seen by Figure 4, the silver zones to the east and west of town are close to the surface. (To the east, a result of reverse faulting and to the west due to shallow dip of mineralized zone.) The silver veins beneath the main part of town were at a depth of 100-200 feet in highly competent Cobalt group metasedimentary rocks.

Access to these deposits was mainly by vertical shafts. Some adits were driven into the sides of cliffs and ridges. The shrinkage mining method was employed. Rock competency is high and as a result little or no backfill was used.

The fault line scarp east of town prominently displays many visible open cuts where the shrinkage stopes had been mined through to surface. The western part of town has many mined out areas recognizable by chain link safety fences. Any visitor to town would be quick to draw the conclusion that the central part of town was also underlain by close to surface mine workings. As Figure 4 illustrates, however, the likelihood of any major close-to-surface stopes is low.

8.0 Application Of The Inventory Report

This report became a useful tool in the Cobalt options exercise in that it provided the following information:

* a map showing limits of areas of concern

* a geological explanation of location of mine workings

* a list, complete with cost estimates, of required geotechnical testing and probable remedial work.

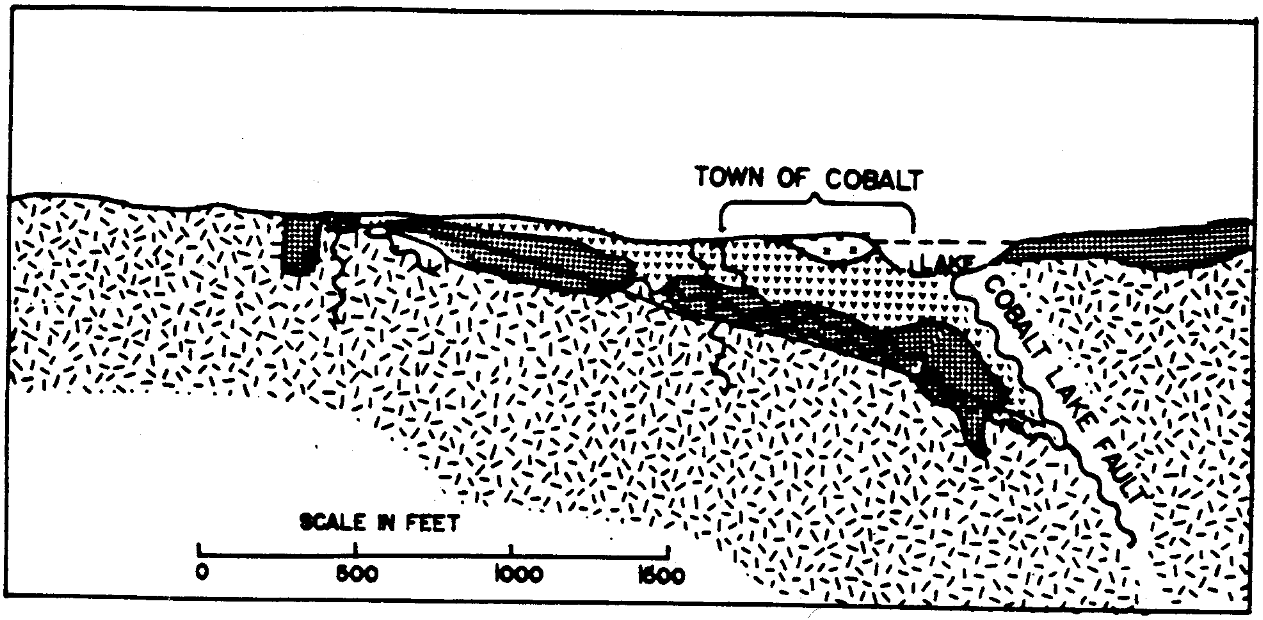
8.1 Factors to Consider

Tangible Factors

The various government agencies had to weigh out direct and indirect costs for each of the options. For example the town consisted of 500 households. To relocate the town would require the establishment of 300 single family dwellings, 200 townhouses, 2 senior citizen homes and a number of non-residential properties. On the other hand, if the town remained, the 17 hazardous areas would have to be investigated and dealt with, water and sewer system project completed, Highway 11B corridor reconstructed and a new bridge constructed.

Intangible Factors

To relocate or buy-out the town would place a significant strain on many of the residents, especially the seniors, who might feel a deep sense of loss. Again, if the town remained, the possibility existed that many residents would continue to be fearful of personal injury or loss of property due to subsidence.



LEGEND

NIPISSING DIABASE

COLEMAN FORMATION

KEEWATIN ROCKS

GEOLOGICAL CONTACT

ZONE OF SILVER MINERALIZATION

FAULTS

FIGURE 4. CROSS SECTION (LOOKING NORTH) THROUGH COBALT MINERALIZED ZONE (AFTER PETRUK, 1971)

9.0 Four Options

The Cobalt Options Task Force tabulated four options.:

1) Maintain
2) Buy-out
3) Relocate
4) Maintain and investigate, repair, relocate or buy-out on a case by case basis.

Direct costs along with pros and cons of each option were tabulated. The estimated direct costs for options 2 and 3 were identical and approximately 100% higher than options 1 and 4.

10.0 Recommending the Right Option

A key item in options 1 and 4 was that in both cases the planned public works (sewer, water and roads) would go ahead. The estimated cost of option 4, which included geotechnical testing and case by case relocation of affected residents amounted to 15% more than option 1.

Option 4 was recommended by the task force and accepted by the government May 9, 1989. This option was not only one of the lowest direct cost options, but also would present minimal disruption to the people of Cobalt.

11.0 Implementation

Upon receipt of the inventory report (Carter, 1989) the task force agreed that monitoring and communications programs were required immediately with testing and remedial work to follow.

11.1 Communications

An open house was held in the Town of Cobalt Council Chambers March 28, 1989. Residents were advised of this through advertisements in local newspapers and radio. Representatives of the geotechnical engineering consulting firm, along with municipal and provincial government officials were in attendance to answer questions. Photographs and maps were on display. Several residents came forward with positive suggestions for the testing program.

11.2 Monitoring

Monitoring within the town had been continuous since the Highway 11B cave-in. The inventory study helped focus attention on the 17 areas of caution. Monitoring has ranged from visual inspection, pre-condition and building surveys, to installation of crack gauges and pins, extensometers, time domain reflectometry (TDR) cables, vibrating wire devices and survey pins.

11.3 Testing

Testing has been conducted on a prioritized basis as recommended by Carter (1989). Techniques used, to date, include diamond, auger and air track drilling; geotechnical mapping; magnetic, seismic, ground penetrating radar and sonic surveys; video cameras were utilized with success at several sites. Applications varied from hand held and cable suspended, to bore-hole camera. For one project, a mini-submarine was mounted with video camera, aircraft lights, infra-red sensors and sonar. This vessel was lowered down the flooded shaft of an abandoned silver mine and by means of umbilical cord controls was used to map out the geometry of workings beneath a building.

11.4 Remedial Activity

Reinforced concrete caps have been designed and emplaced at several sites in town. Backfill has been used at two sites as a means of support for poured concrete capping plugs. A pneumatic blower was used for one backfill operation. A geogrid mat has been placed over one surface crown pillar where TDR monitoring has detected movement.

Two homes have been purchased by the municipality and demolished. In both cases the cost of acquisition of the home was substantially less than the cost of further drill testing and projected remediation. Care was taken to ensure the residents were treated in a fair and equitable manner.

A final techncial review of all 17 sensitive areas is scheduled for the 1993 field season as part of the project finalization phase.

12.0 Summary

A task force with specialists from seven Ontario government agencies worked over a period of five months to review the various options for maintaining or abandoning one of Canada's most famous mining towns. During this period a study of the current demographic and economic conditions of Cobalt was completed. An inventory study of abandoned mine hazards in the town was compiled. Cost estimates made for geotechnical testing and probable remediation were calculated. This study played a key role in the task force's recommendation to maintain the town and to test, remediate or relocate on a case by case basis.

13.0 Acknowledgements

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THE ONTARIO APPROACH TO MINERAL DEVELOPMENT AND REHABILITATION [1]

by Michael Klugman [2]

ABSTRACT

The new Ontario Mining Act[3] came into effect on June 3, 1991. The new Act introduces a new way of doing business relative to rehabilitation for the mining industry in Ontario.

This was embodied in Part VII of the Mining Act which requires rehabilitation of all disturbed mining lands. For those mines in operation Part VII requires the submission of the closure plan to be submitted as soon as is reasonable. For new mines, it is required that before production starts, a closure plan must be approved. For inactive and abandoned mines, for which a owner can be identified, closure plans are also required. For abandoned mines, which are the property of the Crown (State) or other government agency, the Abandoned Mines Hazards Abatement Program has been developed.

In order to implement the Mining Act, two new classifications of staff were created within the Act. The Mineral Development vested Officer and the Rehabilitation Inspector. These staff are supported and assisted by engineers, life and earth scientists, financial officers and administrative support staff.

The mandate and management of Part VII of the Mining Act is vested in the Mineral Development and Rehabilitation Branch. In combining mineral development with rehabilitation within one Branch, the mission of the Branch as well as of the Ministry, is to encourage and develop the mining industry in Ontario in an environmentally responsible way and to address the many abandoned mine hazards located throughout Ontario.

This presentation is a review of the first two years of this approach to development, rehabilitation and compliance. It will involve the techniques used in remedial measures,the need for attention to ongoing applied research, the handling of financial assurance and the initiative towards a "one window approach" which includes the memoranda of understanding with sister ministries.

Keywords: Mineral Development, Rehabilitation, Cooperative Management, Professional Experts, Environmentally Responsible

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[3] Mining Act, Revised Statutes of Ontario, Publications Ontario

INTRODUCTION

If Ontario were an independent country it would rank among the top ten in world mineral production. It is this creation of wealth through the development of mineral resources that is of prime importance to the economy of Ontario. For this reason, sustaining the mineral production of Ontario, in a world that is increasingly aware of the environmental impacts, represents a challenge which is being addressed in the Province of Ontario.

THE ACT

This new Mineral Development and Rehabilitation Branch is the product of the amended Ontario Mining Act which came into effect in June 3, 1991. Part VII of the Mining Act relates specifically to the obligations and the responsibilities of this branch. In writing the Act, a very conscious effort was made to ensure that the mining industry of Ontario managed mineral development and operations and closure in a responsible way, but would not be inhibited or penalized unnecessarily.

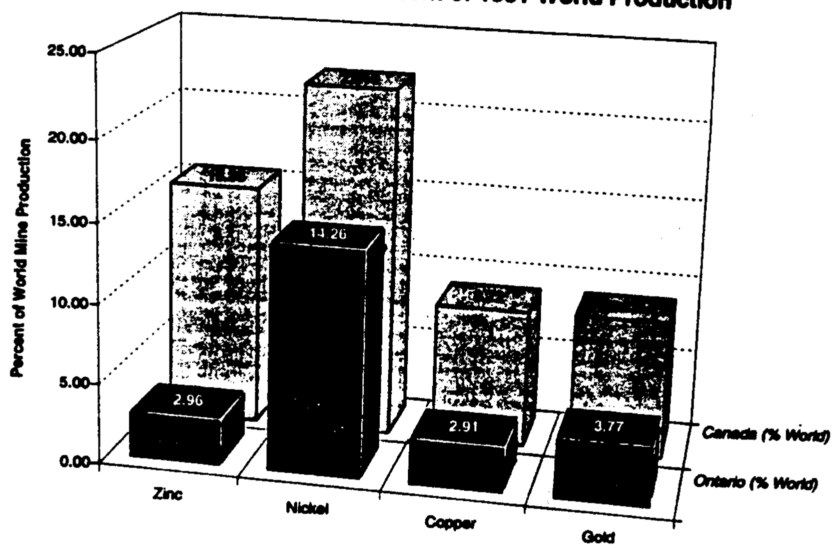

Figure 1. Mineral Production

This paper will present an overview of the approach the Ontario Ministry of Northern Development and Mines has developed in encouraging the continual development and extraction of mineral commodities, while recognizing the environmental impact on the sites and managing the resulting impacts in an environmentally responsible way.

In order to meet this challenge, the mission of the Division of Mines and Minerals of the Ministry of Northern Development and Mines is "To generate new wealth and benefits for the residents of Ontario by stimulating environmentally and economically sustainable use of the province's geological resources". To this end, the Mineral Development and Rehabilitation Branch was created.

In order to address the social values in which we live today, the Mining Act had to be brought up to date. Those of us in the mining industry must admit that mining has a very spotty track record relative to the disturbances left behind after the decommissioning of a mine or during the life of a mine. This is not to say that all mining companies or mine operators are remiss in how they close down a mine as there are some excellent examples going back for many years where eighty year old forests now grow in historic mining areas. Along with our own recognition, as the mining industry, for a need to update the legislation and update the ways of doing business, there was, across society, a demand for change relative to the management of the landscape by all users of that landscape.

As mentioned previously, because the mineral industry is so essential to the economy of Ontario, it was very important in amending the Act that we did not kill the goose that laid the golden egg but that we create a situation in which development could proceed in an environmentally acceptable way. It is also important that those who understand the mining industry and its economics should be the agency to regulate and, where necessary, enforce the amended Act.

There is no question that ensuring that mining properties are rehabilitated in a useful and acceptable way will add to the cost of doing business. Ontario, however, is not the only jurisdiction in which a concensus for responsible environmental management is growing. This is an increasing world wide concern and ultimately all jurisdictions will have to address responsible environmental management and acceptable rehabilitation and the cost of doing business would be reflected world wide in the price of mineral commodities.

THE BRANCH

As previously mentioned, the name of this branch is Mineral Development and Rehabilitation. This is a deliberate choice of name and a deliberate choice of structure. Our mandate and mission is to assist in and encourage, in whatever way is possible, the exploration, development and decommissioning of mining properties in an environmentally acceptable way. In meeting the mandate and the obligations of the Act, which includes both the development and the rehabilitation phases, we have, in addition to the encouragement of development, the role of enforcement. In the enforcement aspect of our program, we believe, that persuation and prevention are the best methods of ensuring that companies and other government agencies comply with the law. This is not to say that the Act contains no teeth, it does, and for those who choose to flaunt the Act it can be a very Draconian exercise. This approach however, was neither our objective nor our preference.

In structuring the branch, there were originally two sections. The Mineral Development Section, which embraces development counselling, assistance in permitting, access to incentive programs where financial incentives were provided to encourage exploration, specific commodity development and technical advice, where requested. The Rehabilitation Section includes approvals and engineering, compliance and inspection, financial assurance, management and the abandoned mine hazards program.

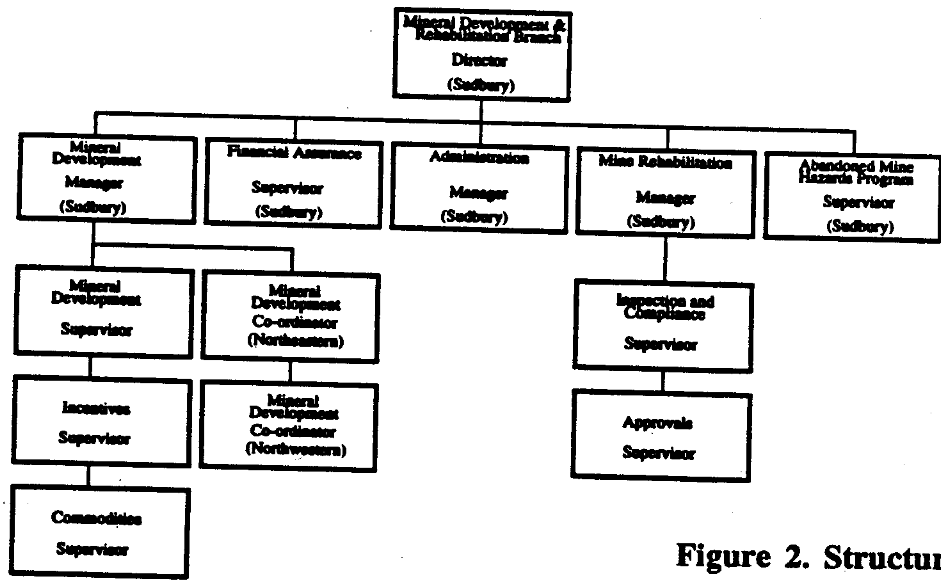

Figure 2. Structure of Branch

A third section of the branch is in the process of being designed. It will involve and enlarge the management of abandoned mines and abandoned mines' data and remediation. Emergency response is part of our mandate at this point but will be shifted to this new section once it becomes established. It will also address research coordination, because as you all know, there is considerable data out there but there is a need to draw it together and consolidate it. Besides the research-related activities, we fund research and remedial work in concert with other agencies, both private and public. Finally, a technology transfer and development unit will dispense this information to fellow agencies and to any

The inspectors however, have an interlocking role with the development officers in that they too assist the industry with advice and guidance, where necessary.

In staffing the positions throughout the branch, we not only included mining engineers, metallurgical engineers, geotechnical engineers, geological engineers but also, hydrogeologists, biologists, foresters, planners and technicians who relate to all of the natural science disciplines whether they be earth or life sciences.

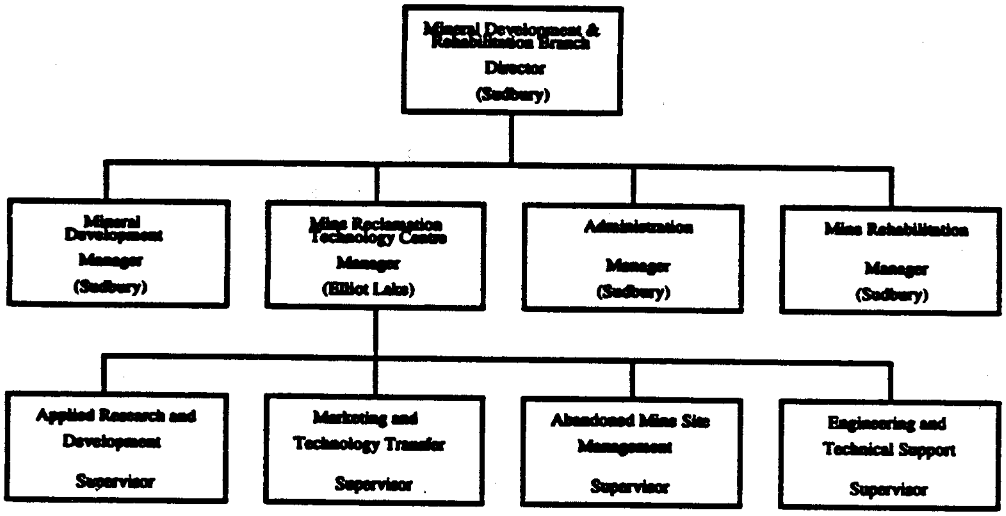

Figure 3.Relationship of Elliot Lake Section

who are interested. In addition, it will provide training for both Canadians and foreign technical people in the management and remediation of disturbed land.

In staffing the Mineral Development and Rehabilitation Sections, two new, and we feel, unique types of positions were created and these positions are enshrined in the Act. The first is a Mineral Development Officer whose role is to assist in the development of any mining exploration or development project and also to give guidance in the permitting and, hopefully take a lead in the creation of a one window approach to mineral development. The other type of officer created was the Rehabilitation Inspector who is responsible for site inspections and ensuring that the design for closure and the management of the environment is followed.

To head up the financial assurance management, a chartered accountant is on staff. In drawing up a closure plan or rehabilitation plan, part of a fundamental segment of that plan is the provision of financial assurance to ensure that should the company renege or default on their rehabilitation plan for whatever reason, that there will be sufficient funds available to do whatever remedial or rehabilitation work is necessary subsequent to the default of the company. This financial assurance is negotiated on an individual site specific basis between ourselves and the individual proponents. It does not necessarily require cash up front, the Director has the discretion to accept cash, letters of credit, bonds or any other asset the Director deems to be acceptable. This provides us with considerable latitude in negotiating the nature of the financial assurance. This segment of the closure plan is confidential whereas the remainder of the plan becomes a public document, once accepted by the Director.

PUBLIC AND PRIVATE INTERFACE

Much of what we do to meet these challenges is an educational process, both for ourselves, our fellow government agencies and for the private sector. In this, just as in developing the amended Mining Act, there is a continuing interface and discussions with the mining industry and all other interested stakeholders as they relate to management in a landscape. In this process, we are asking for understanding and acceptance from all sectors of the population. To accomplish this, we have developed a number of techniques.

We have put together teams who represent all disciplines related to mining development and rehabilitation. The teams travel and present seminars to all levels of personnel in the mining industry, to the other government agencies, to other stakeholders and interest groups and to the financial community, who ultimately enable us to develop mines.

In addition, we have developed a number of sets of guidelines to assist non-operators in understanding the mining industry as well as to assist the mining companies themselves in drawing up their closure or rehabilitation plans. The guidelines include a publication on how to hold public information sessions, "Guidelines for Public Notice and Consultation" and a second publication containing information and brief discriptions of techniques available to address certain aspects of remediation and rehabilitation "The Use of Vegetation in Land Reclamation", 1992; "Mine Closure Decommissioning Costs", 1992. These latter, in fact, form part of the appendix to our principle set of guidelines about which I will now speak.

As most are aware, reading legal wording in most legislation can be confusing. In our jurisdiction, besides providing the legislative Bill, regulations are also provided which are principally designed to better explain the legislation and to clarify its implementation. As these documents are very heavy reading, we decided to produce guidelines titled "Rehabilitation of Mines Guidelines for Proponents" to better explain the legislation, the regulations and to provide a "how to" for mining operators in preparing their closure or rehabilitation plans for their property.

This document was designed by engineers and technical staff for engineers and technical people and is designed as a practical work

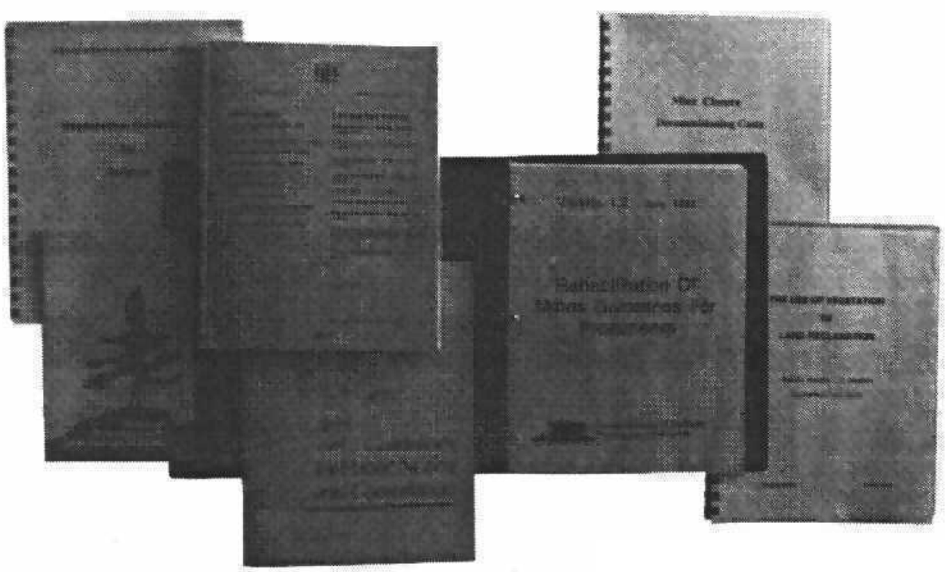

Figure 4. Guidelines

book. Furthermore, it is a dynamic document in the sense that we request suggestions and comments from the guideline users so that we can continue to improve it as we become more comfortable and confident and as rehabilitation becomes a natural exercise in mining. The minor changes to the guidelines, improvements, simplyfying of a procedure are accomplished simply by replacing a removable page. In the case of major revisions, we again return to the industry, to the stakeholders and our sister agencies for input and clarification.

As an aid to the companies and the public, a recently completed update of all the legislation that governs mining in Ontario is now available, "Guide to Mining Legislation in Canada, Province of Ontario". These are all the Acts that relate directly or have an effect on the exploration, development and closure of mines in Ontario. The actual closure of a mine is solely the responsibility of the Ministry of Northern Development and Mines through the Mineral Development and Rehabilitation Branch.

In order to further facilitate the development of mines and the preparation of rehabilitation plans, the Ministry has signed Memoranda of Understanding with four of its sister Ministries to clarify the relative jurisdiction which are the responsibilities of the individual Ministries and to avoid overlap. The ultimate objective of these Memoranda of Understanding is to work towards what we are calling a **"One Window Approach"** in which eventually a company or a proponent would only need to work with the Mineral Development and Rehabilitation Branch to expedite all of the necessary permitting for advanced exploration, development and closure or rehabilitation of a mine. The Mineral Development Officers would be lead people in this exercise and much of their responsibility would be to guide and assist the companies in putting their properties into production and in preparing their closure or rehabilitation plans.

In drawing up a closure plan or rehabilitation plan, part of a fundamental segment of that plan is the provision of financial assurance to ensure that should the company renege or default on their rehabilitation plan, that there will be sufficient funds available to do whatever remedial or rehabilitation work is necessary subsequent to the default of the company. This financial assurance is negotiated on an individual site specific basis between ourselves and the individual proponents. It does not necessarily require cash up front. The Director has the discretion to accept cash, letter of credits, bonds or any other asset the Director deems to be acceptable. This provides us with considerable latitude in negotiating the nature of the financial assurance. This segment of the closure plan is confidential whereas the remainder of the plan becomes a public document once accepted by the Director.

CONCLUSIONS

As mentioned earlier, the objective within this branch and within this Government, is to encourage and facilitate the development of the mineral industries in an environmentally acceptable way. We feel that the approach we have adopted takes one large step towards a better understanding and a better method of addressing the environmental concerns. Admittedly there is an increase in the cost of doing business but by addressing them in a manner which is most acceptable to the majority of the population we feel that we can continue to foster a healthy mining industry in Ontario.

In carrying out this program there is a need to educate all sectors of the population. There is a need for cooperation between the various sectors, both within the private sector and within the public sector. There is a need for a better understanding of the importance of mining to the economy of Ontario and Canada.

Our experience thus far has been positive, in spite of some hurdles we have had to leap. Industry, through the individual companies and through the industry associations, other stakeholder associations and groups, have been very understanding and cooperative while providing constructive criticism and suggestions. This is not to say that everything has been amicably settled at this point, but we have seen major progress in the direction of the understanding and in the direction of cooperation. We still have a significant way to go but feel that by taking the approach of walking gently, cooperating but having a big stick if necessary has been very fruitful thus far. We feel from the approach we have taken, that our staff who have the responsibility of ensuring responsible environmental management and compliance are people who are not simply enforcers, a name we do not like, but are people who understand the industry with whom they are working and ensuring compliance. This we feel is a far better approach than having a single enforcement agency.

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