Mined Rock and Overburden Piles
Consequence Assessment for Mine Waste Dump Failures
Interim Report

December, 1994
FOREWORD

Mine waste rock and overburden dumps are massive structures. Mountain top mines in B.C. are constructing the largest man-made structures on the face of the earth. These immense waste dumps are up to 400 meters high and may contain in excess of 1 billion cubic meters of material. Instability of some structures caused increased concern by mine operators and government regulators because of risks to the safety of personnel, equipment, infrastructure and the environment.

In mid 1990 representatives of industry, CANNMET and the Ministries of Environment, Lands and Parks; and Energy, Mines and Petroleum Resources formed the Mine Waste Rock Pile Research Committee, to foster research work and ensure a common understanding of waste dumps. Prominent geotechnical consultants and industry representatives have contributed their expertise to a series of studies. Studies have been sponsored by CANNMET, MDA (Canada-B.C. Mineral Development Agreement) and the mining industry.

This is the 8th publication on Mined Rock and Overburden Piles. Two of the studies have been published by CANNMET, the others by the province of British Columbia. They include:


The studies are being widely distributed in the hopes that all concerned with mine waste dumps will find them useful in establishing waste dumps that are stable, safe and economically feasible.

Tim Eaton, P.Eng.
Chair, Waste Dump Research Committee    November 18, 1994
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EXECUTIVE SUMMARY

This report presents and discusses the consequences of selected representative failures of mine dumps of coal mines in British Columbia.

The consequences are sub-divided into categories of impacts on the environment, the public and mine operations. The range of the severity of the reported impacts is broad. The overall impacts of most of the events studied is considered to be acceptable.

The information assembled in this report is intended to provide a basis for the objective assessment of potential impacts of future mine dump construction. This forms an important component of risk analysis.

The report briefly discusses approaches to the application of risk analysis for mine waste dumps. We recommend development of the risk based approach through practical applications for future mine dump designs, and through consultative workshops with the mining industry.
ACKNOWLEDGMENTS

We gratefully acknowledge the encouragement and funding provided by the B.C. Ministry of Energy Mines and Petroleum Resources.

Equally, we appreciate the time and effort expended by the coal mines of B.C., who have made information available. In addition, we have received very useful comments from the following:


1.0 INTRODUCTION

1.1 Background

The British Columbia Ministry of Energy Mines and Petroleum Resources (MEMPR) has initiated studies of the application of risk-based approaches to the design of mine waste dumps in the Province. The Phase 1 study, completed in 1992, developed a proposal for the Risk-based classification of Mine Waste Dumps (Reference 1). This proposal adapted accepted civil engineering risk assessment techniques to the large waste rock dumps commonly constructed at the coal mines in southeast and northeast British Columbia (Figure 1).

During the 1980s major expansion of the coal mining industry in British Columbia resulted in the construction of some of the largest and highest mine waste dumps in the world. In some cases, dumps over 400 m high have been advanced onto slopes steeper than 20 degrees to the horizontal. An increase in the frequency of major failures corresponded to the increasing rates of waste rock disposal and the increase in dump heights. This trend elevated concern among regulatory agencies and the public.

A risk-based classification of mine dumps has been suggested by the MEMPR as a tool that will assist designers to evaluate the scope of design effort and to demonstrate the present and future reliability of the structure to the client, regulator and public.

The explicit and defensible evaluation of hazards and consequences is important. Reference 1 describes a conceptually valid framework for a Risk Model. Ideally, the approach should be an integral part of good mine waste management. The proposed methodology would establish requirements for the scope of investigation and design, allowable site conditions, design criteria, monitoring requirements, and construction restrictions on the basis of a proposed dumping scheme.

The broad concept of risk-based management of mine waste is fundamentally important to achieving:

- a fair hearing from regulatory authorities and the public, by communicating clearly the relative likelihood of possible impacts
The Phase II study presented in this report was commissioned by the MEMPR in February 1993 for purposes of assessing the consequences of mine waste dump failures. The current study focuses on the assessment of the consequences of failures, and consists of an objective review of case histories in terms of documented consequences and costs. Wherever possible, subjective opinion has been excluded. Collection and compilation of this information was relatively straightforward given the current atmosphere of cooperation between the major mining companies, and government ministries. The motivation for this effort was to improve confidence in risk prediction, and to facilitate project assessment and acceptance. Risk acceptance criteria can evolve subsequently where common trends are evident.

1.2 Study Objectives

The purpose of this Phase II study was to characterize the consequences of mine waste dump failures. The study is one component in the development of a defensible risk assessment model suitable for selecting and designing waste dump sites. Also, it is envisaged that a risk-based approach may facilitate mine permit evaluation and approval. The results of this study would be incorporated in the Risk Assessment section of the proposed Mine Dump Handbook.

The objectives of the study were to:

- liaise with selected mines, scientists and government agency representatives for data collection, expert guidance and opinions; and
- compile a data base which documents the consequences of failure events;
- develop a methodology for assessing mine waste dump failure impacts on the environment, the public and the mine; and
- assemble commentary from four external reviewers.
1.3 Approach

1.3.1 Data Collection and Review

The waste dump failure events which were selected for this study by MEMPR are listed in Table I. Waste dump failure events were selected for this study on the basis of waste dump characteristics (height, length, volume) and the range of consequences that resulted from failure. The selection of dump failure events was intended to provide a representative range of scenarios.

Information covering the relatively recent waste dump failures is available in engineering reports encompassing the design of the dump structure, the geotechnical assessments of the failures, consequences to mine operations in terms of dumping interruption, crest rehabilitation, but do not cover consequences to the environment or public infrastructure. This report compiles into one comprehensive document the consequences in terms of the environment, loss of life or damage to public property and infrastructure, and damage to mine property and interruption of mine operations resulting from the failure events.

Key government and coal mining company representatives were interviewed to determine the consequences of waste dump failures at coal mines. Documentation in the form of reports, and letters or memos related to those consequences were examined. Limited field inspections of the slide sites were conducted where accessible.

1.3.2 Database

The database used in this study is an extension of the database contained in Reference 3. The questions forming the data base, the responses to those questions and the estimated consequence severity ratings were drawn from the interviews and supporting documentation. Consequences of a biological nature were rated in accordance with the impact significance definitions proposed by Conover et al (Reference 4) as presented in Table 2 and which are generally used to describe impact significance in current environmental impact assessments. Impacts related to total suspended solids (TSS) were related to the permitted levels specific to each waste dump, although the question of TSS duration above permitted levels has not been addressed in the literature. Rating methods related to land use, mine operations and infrastructure and public consequences, suggested by other authors (References 1, 2 and 5) were also reviewed during this study.

The overall impacts of the events were then derived using the database and consequence ratings for each failure event.

The questions and the rationale are described below.

Environmental Consequences

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event?

   The purpose of this question is to determine if water quality deteriorated, remained the same or improved immediately following the event and to what degree in terms of TSS levels.

2. Were there changes in TSS in the receiving waters following the event?

   This question was intended to find out if there were chronic problems as a result of the slide and how long it took for the water quality to improve.

3. Was the remedial action taken after the event effective?

   In some situations remedial action was not required to mitigate the effects of the slide. In cases where remedial action was implemented it is important to know what was done and how effective the results were.

4. Were fisheries resources impacted?

   The failure events either covered or approached fish bearing streams. The consequences to fisheries resources in these streams include the loss of fish populations, the loss of habitat where the slide covered the channel, the downstream effects from slide debris (waste dump material, overburden and organic matter), or flow interruption or reduction.

5. Were wildlife resources impacted?

   The purpose of this question is to determine if wildlife were affected in terms of mortality or loss of habitat.

6. Were vegetation/forestry resources impacted?

   The slide event may have created wind blast causing damage to vegetation adjacent to the slide runout or smothered the vegetation due to the dust coating. Ponding or backwater areas caused by a slide might result in the loss of vegetation as well. The slide material might have covered merchantable forested stands unless the affected area had been logged prior to the event.

7. Do major storms or precipitation events cause problems?
Heavy rains could result in saturation, and instability of slide debris; could cause increased surface erosion, or run-off could become ponded behind the slide mass. These situations would result in continuous or chronic problems.

8. Did the event have the potential for producing more significant environmental consequences?

This question addresses the possibility of the consequences being worse if the event occurred at a different time of year or if the runout travelled further. Stream runoff conditions vary throughout the year and would have presented a different set of consequences during spring runoff versus fall/winter low flow periods. The runout distance is critical in terms of the slide entering a major stream or river.

**Mine Operations Consequences**

1. Did the failure runout exit the ultimate dump limits?

In cases where the slide debris travelled for a long distance, the runout may have remained within the dump limits originally approved, the debris would eventually be covered with waste dump material over the life of the mine.

2. Did the failure runout exit the property?

If the slide crossed into a neighbouring lease or onto public lands, the area lost might be removed from future developed of resources or other land users.

3. Were mine operations affected?

The failure event could affect the waste material dumping and handling activities until the dump was determined to be safe or was to be abandoned for a new location. Loss of availability of dumping capacity also affects mine operations.

4. Was there damage to the mine infrastructure or equipment?

This question determines whether the slide impacted on roads, buildings, conveyor systems, equipment or facilities such as tailings ponds, sediment ponds, and diversion ditches related to mine operations.

5. Did runout debris adversely effect the ultimate dump stability or capacity?

The slide debris might not provide proper foundation conditions to support continued dumping if the base material remained saturated from stream flow or springs or consisted of a mixture of organics and overburden soils.

6. Have changes in failure debris occurred with time?

The slide debris might have been heavily eroded by surface runoff or stream action, might be functioning as a rock drain, or might be subject to continual movement and instability.

7. Was reclamation of slide debris required?

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The slide debris may require reclamation work in order to stabilize the mass and reduce surface erosion. Reclamation may not be planned until the waste dump is abandoned and wrapped or may not even be possible if the material is coarse or blocky and lacks the fine material needed to provide a growth medium. The costs associated with reclamation of the slide debris could be an added cost to the mine operation.

8. Was clean-up impractical or prohibitively expensive?

In some cases clean-up would not be required because the waste dump would be developed over the slide material. However, clean-up would be required where the material had covered a road or sediment pond for example. Depending upon the amount and type of material involved, the clean-up may be impractical or expensive.

9. Could the consequences to mine operations have been worse?

This question must be posed in order to develop a balanced assessment for use in future designs. Is it reasonable that the slide material could have run out further, crossed a roadway or railway, damaged mine facilities or caused the abandonment of the waste dump site, under different circumstances.

**Public Consequences**

1. Was there personal injury or loss of life?

This is self explanatory if the slide resulted in the loss of human life or serious injury.

2. Was there damage to the public infrastructure?

Damage to public infrastructure includes facilities such as highways, railways, powerlines, recreational facilities or any infrastructure owned or operated by private industry.

3. Was there public reaction to the failure immediately following the event and/or over the long term?

Small slide events that are contained within the mine operating limits would not expect to draw public attention unless there was an injury or loss of life associated with the failure. Larger slides that damage public infrastructure or were perceived to cause significant environmental damage would be expected to draw comment from the public.

4. Could the consequences to the public have been worse?

If the slide runout reaches a public facility and if the facility is occupied, then the consequences would be more severe than if the runout stopped short of the facility. In our experience, monitoring of the crest of the waste dump provides sufficient lead time required to implement closure of facilities that might be affected.
This study focused on consequences resulting only from the failure event, excluding those associated with normal mine operations. The consequences presented in this study were identified through discussions with knowledgeable individuals who were on site at the time of a failure or who had involvement in remedial action following the event.

1.3.3 Methodology

Section 3 presents efforts of previous authors to develop a methodology to assess mine waste dump failure impacts and suggests an approach based on the results of this study.

2.0 RESULTS

Representatives of the B.C. Ministry of Environment, Lands and Parks (MELP), MEMPR, and the operating mines which contained the failure events selected for this study were contacted. Field reconnaissance of selected sites in the Sparwood/Elkford and the Tumbler Ridge areas of the Province were completed during the week of February 22 to 26 and March 10 to 12, 1993 respectively. Table 3 presents a list of the individuals contacted and a list of key reviewers of the study. Discussions with these representatives were completed and failure event site visits were conducted where access could be gained. Literature pertaining to the consequences of failure consisted primarily of:

- the Stage II Environmental Impact Assessment Reports which contain the description of the background conditions and mine plans prior to the failure events occurring and on which the permitted conditions were based;
- the annual waste management summary reports compiled by the mine operating company representatives which contained the results of the mine water quality control and effluent monitoring data and comments related to the reasons that permit levels were exceeded;
- the sediment pond design, construction and maintenance reports which provide details of the effectiveness of these structures in trapping the sediment generated by mine operation, and particularly waste dump runoff; and
- the follow-up correspondence related to reclamation efforts, flocculants added, additional structures required, interruption to mine operations and compensation for damage to public lands or loss of life.

The sections and plans and the data base developed in the Failure Runout Characteristics Study, Volume II (Reference 2) are included in the Appendices along with the data base results from this Phase II study.

Golder Associates

The recent change in name and ownership of the former Balmer Mine (Westar Mining Ltd.) to Elkview Mine (Teck Corp.) caused some discontinuity in the information obtained for this study. However the present owners expressed a sincere interest in the objectives and purpose for the study and fully endorsed our efforts. We were also able to contact some of the former employees of the Balmer Mine who had knowledge of the failure events and who provided an excellent documentary of those events.

The study was carried out during winter so that many of the slides were not accessible, and obscured by snow and ice. However, the file libraries at MELP and MEMPR provided useful back-up towards developing the data base.

2.1 Fording River Mine

The Fording River Mine, operated by Fording Coal Limited (FCL), is located to the northeast of the community of Elkford, B.C. and straddles the Fording River upstream of the confluence with Kilmarnock Creek. The Eagle and Brownie Pits are located on Eagle Ridge which forms the east valley side slopes. The Greenhills Pit is located on the west valley side slopes of the Fording River valley. Waste Dump failure events of interest to this study include the South Spoil Slide and the Brownie Spoil Slides located on the south and east faces of Eagle Ridge respectively (Figure 2).

2.1.1 South Spoil Slide

Description

The South Spoil failure consisting of 2.5 million cubic meters of waste material occurred at approximately 0530 hrs. on October 26, 1989, two months after Fording Coal Limited (FCL) received approval to dump waste rock material at the South Spoil site. The event was documented in a report compiled by FCL (Reference 6) and the geotechnical evaluation was completed by Golder Associates Ltd. (Reference 7).

The waste dump was being monitored with extensometers placed at the crest of the dump. The failure of the dump was anticipated, dumping was halted, and the access road at the base of the dump was closed. Although the failure was anticipated it raised questions regarding dump stability and failure prediction.
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The 120 m failure scarp extended approximately 35 m back from the original crest and the toe of the failure had moved approximately 1000 m southward across Kilmarnock Creek, coming to rest against the base of Castle Mountain. The failure material, although remaining within the ultimate design limits for the South Spoil, covered approximately 600 m of Kilmarnock Creek and cut off all flow from the creek into the Fording River temporarily. The slide covered the original Kilmarnock Settling Pond System and the South Eagle Interceptor Ditch, which were constructed for purposes of mitigating sediment loading from Blackstone and Blackrill creeks located adjacent to the South Spoil and partial flows from Brownie Creek. A short section of a logging access road was also covered by the slide. The cause of failure was attributed to pore pressure along the dump-foundation contact, exacerbated by a face height of 435 m, and the steep terrain.

The following remedial steps were implemented immediately following the event (Reference 6).

- A Phase I emergency sump and exfiltration ditch was excavated adjacent to Kilmarnock Creek between the highway culverts and the Fording River on October 26, 1989 to act as a temporary sediment trap until the designs for the originally planned South Kilmarnock Sediment Ponds could be implemented.
- Approximately 50 - 100 fish were collected and relocated from Kilmarnock Creek to the Fording River and over-wintering ponds on October 26 and 27, 1989.
- Brownie Creek slide gate was closed to direct flow into Brownie Pond and to relieve pressure on the area upstream of the slide.
- A new 200 m channel was excavated to accommodate the upper section of Kilmarnock Creek covered by the slide on October 26 and an overflow flow was excavated on October 29, 1989.
- The Phase I emergency sump was expanded to 1000 m³ on October 30, 1989.

Minor ponding occurred at the upstream limit of the failure debris and flow did not resume out the western limit or toe of the debris until November 1, 1989, six days after the event.

Suspended solids levels of 5 mg/L were recorded in Kilmarnock Creek following the event. During spring runoff in 1990, flows were directed into the newly constructed South Kilmarnock Sediment Pond System (completed prior to spring runoff conditions) for treatment prior to discharge to the Fording River. Water quality parameters remained within permitted limits of 50 mg/L for all four quarters of 1989 and 1990 in Kilmarnock Creek except for the two day period of May 30 and 31, 1990, due to Q10 flows.

Environmental monitoring of surface water quality as required by Permit PE-424 had been carried out at selected stations on the mine property on a weekly or monthly basis depending upon the parameter and climatic conditions. Flows in Kilmarnock Creek ranged from 15000 m³/d to 21600 m³/d (0.17 m³/s to 0.25 m³/s) at the time of the failure event and went to ground or into the Phase 1 emergency sump.

**Environmental Consequences**

The South Spoil failure did not result in degradation of water quality or elevated levels of suspended solids in the Fording River due to minimal flows in Kilmarnock Creek and the efficiency with which the remedial action was implemented.

Since the slide took place in the month of October, fish populations were present in Kilmarnock Creek for purposes of over-wintering. An estimated 50 - 100 fish were found dead in the slide area (Reference 10) but there was no estimate of the total number of fish that were buried by the slide material. Had the slide taken place at another time of year the impacts to fish would have been minimal.

Disturbances to the floodplain at the Kilmarnock Creek/Fording River confluence for purposes of constructing deflection berms resulted in the loss of Elk winter range (Reference 10). However, these areas were discussed during the planning phase of obtaining approval for the South Spoil and it was determined that compensation would be provided in the form of future reclamation of the berms and the waste dumps.

Trees within the forested area adjacent to the southern limit of the slide were broken and stripped of their lower branches. Air blast created by the slide material travelling at high speed is suspected as the likely cause. A thin layer of dust covered foliage and the ground surface but with no apparent adverse effects. There were no impacts to the forestry resources since the Kilmarnock Creek valley had been logged by Crows Nest Industries (CNI) prior to South Spoil waste dump operations.
Public Consequences

There were no fatalities or loss of public property as a result of the South Spoil failure event. A short section of the CNI road that extended along the north flank of Castle Mountain was blocked, and was reopened on October 27, 1989, one day later.

Mine Operations Consequences

There were no losses of mine operating equipment as a result of the failure event. Following an assessment of the cause and rehabilitation of the waste dump, it was determined that spoil operations could safely be resumed starting at the western region of the dump crest and working towards the central region. Dumping operations were resumed on October 30, 1989, 4 days after the event occurred.

A rock drain was proposed for the Kilmarnock Creek drainage prior to the failure event. The presence of the failure debris that came to rest along the northern flank of Castle Mountain was determined not to adversely affect drainage performance of the Kilmarnock Creek rock drain since runoff conditions were handled with no upstream ponding. In this case the failure debris has continued to perform in a similar manner to the proposed rock drain. (Reference 7).

The South Spoil failure was larger than anticipated and the distance the slide travelled raised concern that possible future events could cover the Highway, the CP Rail line and the sediment ponds. Berms were constructed from coal waste and were positioned to deflect the slide and protect these facilities.

2.1.2 Brownie Spoil Slides

Description

The Brownie Spoil consisted of a series of dump platforms located along the east crest of the Brownie Pit above the Brownie Creek valley. These waste dumps failed individually between June 1983 and November 1986, followed by contained mass movement since that time. In March, 1991 a particularly large slide occurred involving approximately 30 million m$^3$ of mine waste. The Brownie Stage II Dump failed on February 10, 1993 in

Environmental Consequences

Environmental consequences associated with the Brownie Spoil slides, in terms of water quality were minimal since the Brownie Sediment Ponds were operational. Impacts to fisheries were not a concern since Brownie Creek did not support a fisheries population. Concerns related to wildlife were not raised following any of the Brownie Spoil failure events. The Brownie Creek valley did not contain merchantable timber prior to the spoil failures, mitigating concerns for forestry resources.

Public Consequences

There were no losses to public property or loss of life resulting from the Brownie Slides.

Mine Operations Consequences

The smaller Brownie Spoil failures resulted in the normal interruption to dumping operations and the main failure event resulted in only minimal interruption. There were no losses or damage to equipment or mine infrastructure.

2.1.3 Discussion

The data base and consequences rating related to the South Spoil and the Brownie Spoil failure events are presented in Appendix I.

The consequences of the South Spoil failure event were minimal as far as water quality was concerned due to the implementation of remedial measures immediately following the event. Although the South Kilmarnock Sediment Ponds had not been completed at the time of the slide, they were operational prior to spring runoff of the following year.

The Kilmarnock Creek over-wintering fish populations were affected due to the fish kill resulting from the event. Access to fish migration up Kilmarnock Creek would have been blocked at the outlet of the South Kilmarnock Sediment Ponds had they been completed prior to failure of the South Spoil waste dump. It should be pointed out that the loss of
over-wintering fish habitat in Kilmarnock Creek was an accepted part of approval of the South Spoil since lost habitat was mitigated by construction of off-site over-wintering habitat and therefore could not be considered a loss due to the slide event.

The consequences of the Brownie Spoil failures were minimal due to the absence of a fisheries population in Brownie Creek and because the Brownie Creek and Kilmarnock Creek sediment ponds were designed and constructed to handle the sediment loads generated by the Brownie Spoils, erosion generated by the southern face of Eagle Ridge and the Brownie Spoil failure events.

2.2 Greenhills Mine Ltd.

The Greenhills Mine, formerly operated by Kaiser Resources Ltd., followed by Westar Mining Limited, recently changed hands and is now operated by FCL. The mine is located on the southern portion of the Greenhills Ranges which form the headwaters of several small tributaries of the Fording and Elk rivers in southeast British Columbia. The waste dump failures of interest to this study are those associated with the East Dump, the North Dump, the Slump Block Dump and the Cougar 7 Dump (Figure 3).

2.2.1 East Spoil Slides

Description

The East Spoil was developed by Westar Mining Ltd. to accommodate waste material from the Eagle Pit. Two failures of small size occurred on March 11 and May 20, 1983. On May 30, 1985 a large area of the north end of the spoil involving an estimated 2.5 million m³ failed after a period of protracted heavy rainfall (Reference 11). The waste materials involved in the failure were predominantly fine-grained siltstones and mudstones. Subsequent to the failure, there was evidence of seepage from the bedrock exposed in the back of the failure scarp. The May 30, 1985 event did not run-out any appreciable distance, staying within the ultimate dump limits, but filled over the upper part of the Greenhills Creek channel. The sediment pond was in place and operational when the slide occurred.

The Greenhills Creek sediment pond was completed in mid January 1982. Upon examination of the water quality data it was noticed that the pond was not being effective in settling out the suspended solids, since suspended solids exceeded permitted levels on sixteen occasions in 1982 (Reference 12). To mitigate this situation, a channel was constructed along the back of the pond to reduce flow velocities into the pond in late October 1982. The Greenhills sediment pond outflow exceeded the permitted suspended solids levels of 50 mg/L between May 4 and June 8, 1983, corresponding to elevated flow conditions during this period but not due to the March 20 and May 11, 1983 failure events (Reference 12). In 1983, outflows from the sediment pond first appeared May 2 and stopped in August. A baffle was hung diagonally across the sediment pond to redirect flows and increase the retention time in the pond improving the gravity settling of fines. Flocculant injection was also examined as a mitigative measure. In 1984, decanting of the sediment pond began April 26 and ceased July 4 during which time suspended solids levels exceeded 50 mg/L on four occasions (range 51.0 to 76.0 mg/L) (Reference 13). Modifications to the sediment pond in 1984 included moving the baffle to the shallow end of the pond and cleaning out the inlet channel. Samples collected between April 15 and July 28, 1985 were all below permitted levels except on one occasion (55.2 mg/L on April 15) (Reference 14). Permit levels for suspended solids were exceeded on two occasions in May 1986 as a result of spring runoff. Greenhills Creek was well below permitted suspended solids levels in 1987 and subsequent years except for one or two exceedances during freshet (References 15 - 20).

Environmental Consequences

Environmental consequences associated with the East Spoil slides in terms of water quality were minimal since the Greenhills Creek sediment pond was operational during all failure events. Impacts to fisheries was not a concern even though Greenhills Creek did support a yellowstone cutthroat trout (Salmo clarki lewisi) population prior to the construction of the sediment pond near the confluence with the Fording River. Results of fisheries studies conducted during the Kaiser Resources Ltd. Stage II studies revealed the use of the lower 300 m of Greenhill Creek by cutthroat trout juveniles and areas upstream of this sections for spawning adults (Reference 21). Impacts to these fish populations were considered during applications for amendments to the Permit and were not a result of the failure events but of the overall mine project. Concerns related to wildlife were not raised following any of the East Spoil failure events. The Greenhills Creek valley had been logged prior to the spoil operations, mitigating concerns for forestry resources.
Public Consequences

There were no fatalities or loss of public property as a result of the East Spoil failure events.

Mine Operations Consequences

The East Spoil failures resulted in minimal interruption to Westar’s dumping operations. There were no losses or damage to equipment or mine infrastructure.

2.2.2 North Dump Slide

Description

On July 1, 1985, a 10 m by 150 m sliver failure of the 2025 bench of the North Dump occurred. The toe of the failure debris advanced up the west side of Cataract Creek disturbing soft, saturated organic soils in the valley bottom which flowed down the creek in the form of a semi-liquid mass. Subsequent to this failure event, several small failures developed on the west face of the 2025 bench. In each case, the toe region of the failure mass advanced up the west side of the valley, stability was restored, and the development of the North Dump was able to continue (Reference 11).

Cataract Creek suspended solids values complied with permitted water quality levels throughout 1983 (Reference 11). In August 1984 Westar Mining Ltd. applied for an amendment to its Pollution Control Permit for the construction of sediment control structures on Cataract Creek as a precaution against upper drainage basin disturbances from the North Dump and future pit development. The structures consisted of a main and primary sedimentation impoundment and six upstream filtration berms. Construction began September 17, 1984, and was completed on October 10 the same year. However, the July 1, 1985 failure event destroyed these sediment control structures. Sediment levels did not exceed the permitted levels in 1985 but did exceed the permit level on one occasion (75.4 mg/L on May 28) in 1986 (References 14 and 15). Cataract Creek was well below permitted suspended solids levels in 1987 (Reference 16). Cataract Creek carried elevated suspended solids on one occasion in 1988 due to an extreme precipitation event of 14.5 mm in one day which doubled flows from the previous week (Reference 17).

As the dump advanced toward the north, the toe of the dump approached the location where the bulk of the soft organic debris had come to rest following the previous failures. The thickness of this organic mass was estimated to be 5 to 10 m.

On November 22, 1989 an estimated 1.3 million cubic meters of material from the North Dump failed into the Cataract Creek drainage (References 19 - 22). The failure occurred as a result of strain induced liquefaction of the soft, saturated organic soils beneath the toe region of the dump. The failure debris consisted of clean broken rock with the exception of the distal 100 m which consisted of a mixture of mine rock and organic material scoured from the valley bottom and pushed ahead of the slide. Water from the northwest tributary began flowing over the slide immediately followed by the main stem flows several days later on November 28, 1989. Remedial action included the immediate construction of a new sediment pond below the toe of the slide and erosion protection. Construction began November 23 and was completed December 20, 1989.

The failure of the North Dump on November 22, 1989 resulted in suspended solids values of 90 mg/L on November 26 and 28, 1989 although these levels persisted for less than 24 hours in each case (Reference 18). There was only one minor instance of elevated suspended solids in Cataract Creek in 1990 occurring on May 30 at 69.3 mg/L at the pond outlet (Reference 19).

Environmental Consequences

Environmental consequences associated with the North Dump slides in terms of water quality were minimal even though the sediments control facilities were covered by the 1985 event. Remedial action following the 1989 event kept impacts related to that event minimal. Impacts to fisheries were not a concern since Cataract Creek did not support a fisheries population. Concerns related to wildlife were not raised following any of the North Dump failure events. The Cataract Creek valley had been logged prior to the spoil operations, mitigating concerns for forestry resources.

Public Consequences

There were no fatalities or loss of public property as a result of the North Dump failure events.
Mine Operations Consequences

There were no losses to mine equipment, but interruption of Westar's dumping practices did result from spoil failures. A consequence of the July 1, 1985 failure was a closure of the southern part of the dump and dumping restricted to a 100 m section at the north end of the spoil. Inspection of the south half of the spoil face, within 2 weeks of the failure, indicated slumping of up to 3 m but no evidence of major ongoing movement, and it was recommended that dumping could resume (Reference 11). There were lengthy interruptions to dumping following the 1989 event and the dumping sequences was managed carefully to ensure stability.

2.2.3 Slump Block Dump (Thompson Creek Slide)

Description

The Slump Block Dump was in its initial stages of development when the failure occurred over the weekend of June 18, 1988. A segment of ground extending from the dump toe for a distance of 250 m down slope from the toe, referred to as the Plate, moved essentially as a unit for a distance of 100 m (Reference 23). The movement of the Plate was a result of shearing within in-situ rock at depth on a pre-existing shear surface. Although the area had been logged prior to dumping activities, the trees left behind on the Plate remained standing. The downhill movement of the Plate resulted in bulldozing of the ground ahead of the Plate producing a mudflow which advanced an estimated 750 m into a tributary of Thompson Creek.

Thompson Creek was prone to erosion and water quality problems before the slide event occurred. High suspended solids in Thompson Creek in July 1981 was the result of wet, fine grained material being deposited in a gully which was a tributary of the creek. The company subsequently prepared a proposal to clean up the area and to implement sediment control works. The reclamation work was initiated by October 1981. Elevated suspended solids were measured between May and June 1981 resulting from spring runoff. Thompson Creek exceeded suspended solids on June 8, (135 mg/L) and July 5 (104 mg/L), 1983 due to heavy rains washing material from the main access road at the Cut Through Ridge. In 1984, suspended solids again exceeded permitted levels on sample occasions corresponding to spring runoff (April 17 at 262 mg/L, April 24 at 226 mg/L and May 14 at 55.2 mg/L) (Reference 13). Sediment control in Thompson

Creek consisted of small traps constructed on an abandoned exploration road during 1985. Suspected solids levels were below permitted levels for the 1985 season except for one occasion in November due to mild temperatures, heavy rains and drainage from the Eagle Pit (Reference 14). In 1986, a ditch was installed below the Eagle Pit which directed drainage into the Greenhills basin. Due to continued sediment load problems in Thompson Creek, Westar Mining Ltd. was requested by the Regional Manager, Waste Management Branch of MELP to prepare an integrated plan for environmental control works to manage and improve water quality in Thompson, Porter and Cataract creeks (Reference 16). A suitable location for sediment control was identified on Thompson Creek with construction scheduled for 1987. Water quality control continued to be a problem in 1987 at the mine property due to runoff from the Eagle Pit and the upper reaches of Thompson Creek. To augment the diversion ditch a small settling pond was constructed on the middle fork of the creek to provide additional protection and a flocculation of dirty water as needed. A larger second pond designed to handle the 10 year flood flows was completed on the lower reaches of the creek later in 1987. A series of mud flows in May and early June 1988 completely filled two of the upper ponds built in 1987. An additional series of three ponds were constructed early in 1988. The foundation failure associated with the Slump Block Dump that occurred on June 18, 1988 effectively buried all of the previous mudflow material, however the sediment ponds were extremely effective in reducing the suspended solids from 72,464 mg/L at the pond inlet to 368 mg/L at the outlet (Reference 17). The system completely cleaned up within a couple of days. Thompson Creek suspended solids were elevated above the permitted levels in 1989 on April 19 (90.0 mg/L) and May 3 (62.8 mg/L) due to re-suspension of sediments caused by increased flow velocities under ice conditions at the outlet of the pond (Reference 18).

Environmental Consequences

The Slump Block Dump failure released a high concentration of suspended solids (72,464 mg/L) into Thompson Creek following the slide event. However, the sediment ponds were efficient in settling out this suspended material, reducing suspended solids concentrations at the pond outlet to 368 mg/L, a condition that persisted for two days before levels dropped below 50 mg/L.
Public Consequences

There were no fatalities or loss of public property as a result of the Slump Block Dump failure events.

Mine Operations Consequences

A comprehensive water quality management and control plan was initiated by Westar Mining Ltd. because of the continuous problems of erosion and drainage control on the property, not because of the slide event.

2.2.4 Cougar 7

Description

This relatively small inactive waste rock road fill failed on the morning of May 11, 1992, crossing an access roadway located immediately beneath the toe of the fill. A service truck, together with the driver, were swept off the road by the failure debris, resulting in the loss of the driver’s life.

The slide contained approximately 158,000 bank cubic meters (BCM) of material consisting of blasted rock and excavated overburden which contained a greater-than-average proportion of fines (Reference 24). The spoil had remained stable for an interval of 13 months prior to failure. Snow had fallen during the night of May 10 and 11, 1992 and cracks were observed on the dump face indicating that the dump had undergone significant deformation strain. It was not realized that failure of the dump was imminent and the access road was not closed.

Environmental Consequences

Since the failure event took place within the existing dump and pit limits there were no perceptible environmental consequences associated with the slide.

Public Consequences

Regrettably, the slide claimed the life of one individual who was crossing the spoil area when it failed. Otherwise there were no further consequences to public property or infrastructure.

Mine Operations Consequences

The slide covered a small section of a pit access road which was cleared soon after the slide occurred. The loss of life magnified the point that the spoil failure was not anticipated, since otherwise the access road would have been closed and the dump face stabilized. However, mine operations were completely shut down for four days while search and rescue, safety inspections and geotechnical review of the failure event were completed. This resulted in the loss of revenues during the four day period for Westar Mining Ltd.

2.2.5 Discussion

The data base and consequence rating related to the East Dump, North Dump, Slump Block and Cougar 7 slides are presented in Appendix II.

Water quality monitoring as required by the Pollution Control Permit for the property was conducted at surface water sampling and effluent sampling stations throughout the Greenhills Mine property. Upon examination of the annual permit summary reports, it became evident that the creeks draining the mine site are highly responsive to rainfall events and spring runoff conditions, and were dry for extended periods throughout the annual hydrologic cycle (Reference 6). Suspended sediment loads in these creeks were also noted to be elevated above the permitted levels of 50 mg/L during periods of spring runoff and not necessarily as a result of waste dump failure events.

Water quality sampling stations located on some tributaries to the Elk River, draining the western portion of the mine property were dry except during spring runoff. However, Thompson Creek maintained consistent flows throughout the annual cycle with a maximum recorded flow of 0.8 m³/s (Reference 6). Suspended solids in the Elk River did not increase significantly from the upstream control to the monitoring station downstream of the Greenhills Mine operation, and generally were well below the permitted levels of
50 mg/L, with the occasional spike. Similarly, suspended solids did not vary significantly at the upstream control and the downstream station on the Fording River.

Westar Mining Ltd. encountered ongoing problems with water management and water quality control on Thompson, Porter, Cataract and Greenhills creeks throughout the first 10 years of operation, despite numerous efforts by Kaiser Resources and Westar Mining Limited, to redirect mine runoff and build sediment ponds and berms. The waste dump failures did not contribute to this problem and elevated suspended solids value following dump failures were of short duration and for the most part were adequately handled by the facilities in place.

The extensometer monitoring system was not in place at the time of the North and East spoil failure events (Reference 11). However, extensometer monitoring systems were in place by July 1985 immediately following the North Spoil failure. These monitoring systems provide the quantitative information with which to base dump management decisions. Maximum tolerable daily movements recommended on the basis of the East and North Spoil failures was determined to be 0.5 m pending further experience with the particular dump.

Waste dump recommendations made relating to the North Spoil included:

- maintain maximum length of active dump face,
- avoid concentrations in one part of the dump, and
- advance the dump toe onto the Cataract Creek valley floor before the dump advanced along the cliffs on the west face of the Limestone Ridge. This dump management approach was recommended for purposes of providing flexibility of dumping to the west and allowing the advance of a wider dump face northwards along the ridge.

The loss of life at the Cougar 7 slide brought about an extensive evaluation of the cause of the slide and recommendations for an expanded program of monitoring to provide advance warning of dump failures that could occur in the future. The MEMPR requested an audit of waste dumps and major fills at all operating mines in British Columbia as a result of investigations into the Cougar 7 slide.

2.3 Balmer Mine

The Balmer Mine, formerly owned by Kaiser Resources Ltd., followed by Westar Mining Limited, is now called Elkview Mine, owned and operated by Teck Corp. The mine is situated on Harmer Ridge at the confluence of the Elk River and Michel Creek near the community of Sparwood in southeast B.C. The waste dump failure event of interest to this study at the former Balmer Mine is the Harmer Knob Waste Dump failure into Six Mile Creek (Figure 4).

2.3.1 Harmer Knob Waste Dump (Six Mile Creek Slide)

Description

The Harmer Knob Waste Dump consisted of a high proportion of coal fines deposited on the steep valley side slopes. The deposit area also contained a spring which provided a continual source of water to the material. On May 31, 1971 part of the Harmer Knob Waste Dump failed, resulting in a mud flow which transported saturated overburden and rock material into the channel of Six Mile Creek blocking the CNI road and the CP Rail Line and entering the Elk River.

A number of mud flows developed over the ensuing period in Six Mile Creek some of which blocked the CNI road causing interruptions in both mine and CNI traffic and high sediment loads in the Elk River. The principal source of material that comprise the flows was from the sides of the channel that was incised into the debris deposited in the drainage by the waste dump failure (Reference 25). Failures of the sides of the channel resulted in temporary damming of the stream, leading to the development of mud flows down Six Mile Creek. Stream bank stability became an added problem brought about by the increased erosion and bank undercutting and by water that was ponded between the original valley walls and the lateral ridges formed at the time of the dump failure. Seepage of this ponded water through the failure debris maintained a saturated condition contributing to the instability of the material and channel banks.

Observations were recorded in an MELP memo to file dated July 20, 1977 of several streams including Six Mile Creek with contaminated runoff from the Harmer Knob Waste Dump (Reference 26). This memo suggested that there would be a good probability of contaminated runoff recurring in the future unless the Harmer Knob Waste Dumps were
reclaimed. On May 18, 1978, mud and large rocks plugged the culvert at the CNI road crossing of Six Mile Creek. Material flowed over the road and caused erosion of the road at the downstream end of the culvert. The problem arose from lobes of material that had moved down the drainage in stages, building up and washing out eventually reaching the CNI road. In response, Kaiser Resources Ltd. (Kaiser) diverted the creek into an old channel to the south of the culvert. Total suspended solids results from the weekly water samples taken during spring runoff in 1978 produced values of 3206 mg/L on May 25, 859 mg/L on May 31, 1153 on June 7, 212 mg/L on June 12 and 173 mg/L on June 22 (Reference 27). In a letter to Kaiser Resources Ltd. dated August 1, 1978, the Ministry of Environment, Water Rights Branch, recommended that Kaiser provide a proposal to take remedial action to rehabilitate Six Mile Creek. Kaiser initiated planning and design studies in 1978 for a mud catchment pond and exfiltration pond on Six Mile Creek near the Elk River.

Levels of suspended solids recorded in Six Mile Creek from 1975 to 1978 were variable and generally high with levels reaching 7100 mg/L (Reference 28). The erratic behaviour of the stream and high levels of sediment transport were attributed to the unstable nature of the slide material in and above the upper reaches of Six Mile Creek. The slide material had covered the original creek bed forcing the creek to develop and down cut a new channel through 5 to 15 m of slide material. The steep slope of the upper section increased the erosion and transport of finer sediment. In response to the over-steepened slopes in the upper reaches and increased peak flow velocities, the middle and lower reaches were rapidly down cut to achieve equilibrium exposing bedrock in these middle sections.

By March 1980, Kaiser had re-sloped and seeded the Harmer Knob dumps located at the top of Six Mile Creek, the exfiltration pond at the mouth of the creek had been constructed, a new culvert had been installed under the CNI road and the area proposed for the mud catchment pond had been cleared and prepared. Budget figures for this work were estimated to be $600,000.00 in 1978 dollars.

Environmental Consequences

The consequences of the Harmer Knob Waste Dump failure were primarily those of elevated suspended solids contribution to the Elk River from the waste material and erosion of the Six Mile Creek channel. There were no impacts to fisheries in Six Mile Creek or the Elk River documented immediately following the 1971 slide event or subsequent mud flows.

Public Consequences

The continual deposition of material on the CNI road and CP Rail Line caused interruptions to the traffic of these arteries. The significance of these interruptions to the railway traffic or associated costs were not reported or mentioned during discussions with individuals present at the site. There were no lives lost or losses to public property.

Mine Operations Consequences

Mine operations were not interrupted as a result of the Harmer Knob slides. However, the costs associated with the reclamation of the Harmer Knob Waste Dump, the design and construction of the mud flow catchment pond, the exfiltration pond and culvert replacement and operational costs of maintaining these facilities were the main consequences to Kaiser Resources Ltd.

2.3.2 Discussion

The data base and consequence rating related to the Harmer Knob Waste Dump are presented in Appendix III.

2.4 Line Creek Mine

The Line Creek Mine, formerly owned by Crows Nest Resources Ltd., is now owned by Line Creek Resources Ltd. The mine is located in the Line Creek valley bordered on the east by Horseshoe Ridge which forms the B.C./Alberta border. The Witsakitsak Range, to the west of the property, separates the Fording River and the Line Creek valleys immediately upstream of the confluence with the Elk River. The event of interest to this study was the West Line Creek Waste Dump slide (Figure 5).
2.4.1 West Line Creek Waste Dump

Description

On July 1, 1982, six months after commencing operations, the waste dump platform on the east valley wall of West Line Creek failed, involving an estimated mass of 250,000 m³ of waste rock material. Approximately one half of the initial slide material remained on the west side of the creek valley near the toe of the existing dump. The remaining slide material continued 2,000 m down the West Line Creek valley coming to rest within 400 m of the ultimate design limit near the confluence with Line Creek. The sedimentation ponds were in place between West Line Creek and Line Creek, and total suspended solids levels entering Line Creek were within permit values.

Water quality monitoring, which was underway at the time of the failure event, consisted of upstream control and downstream comparison stations on receiving waters such as the Elk and Fording rivers and a series of stations on Line Creek for purposes of monitoring mine site conditions. Water quality samples were collected in accordance with the permit requirements. However, there arose a discrepancy between the results reported after split sampling among several laboratories. The results of the 1982 program were considered by Crows Nest Resources Ltd. to be invalid and not representative of the correct values (Reference 29).

Mine personnel on site at the time of the slide reported that in West Line Creek the flow did not back up behind the slide because of the coarse nature of the material in the slide. The slide material functioned as a rock drain. The effluent from the toe of the slide ran dirty into the sediment pond at the confluence with Line Creek for approximately two days. However, flocculant additives were effective in settling out the suspended solids, mitigating loads to Line Creek.

The reason why the slide did not runout further was questioned. Methods of deflecting or containing possible future slides in the West Line Creek were examined. The conclusion was reached that the energy of the slide was dissipated as the slide spread out in the lower section of the West Line Creek valley. As a result the company avoided spending large amounts of money building deflection berms or containment structures.

Environmental Consequences

The West Line Creek slide is presently covered with mine waste material and material from slide events subsequent to the 1982 event including 100,000 m³ from the 2116 platforms in March, 1992, and 750,000 m³ from the 2116 platform in December 1992. Creek flows have been running clear since the original slide event in 1982.

Public Consequences

There were no fatalities or loss of public property as a result of the West Line Creek slide.

Mine Operations Consequences

The West Line Creek slide event resulted in minimal interruption to dumping operations. There were no losses or damage to equipment or mine infrastructure.

The slide event and subsequent construction of a rock drain over Line Creek further support the recognition that waste dump slide material will filter suspended solids.

2.4.2 Discussion

The data base and consequences rating related to the West Line Creek Dump are presented in Appendix IV.

The West Line Creek Dump failure raised the concern for ensuring positive protection against downstream sedimentation and prevention of similar situations in the future.
Recommendations put forward, following an assessment of the slide mechanism included a dump management strategy and the use of containment dykes (Reference 31). The primary protection against the occurrence of similar events in the future would be the use of dump development methodology which maintains a cross-valley alignment of the dump crest with development proceeding parallel to the axis of the valley and hence parallel to the topographic contours. Additional protection against the movement of debris out of the West Line Creek valley could be provided by the construction of a deflection dyke at the lower reaches of the valley, or using the morphology provided by the alluvial fan to spread out and dissipate slide energy.

2.5 Quintette Coal Mine

The Quintette Coal mine is operated by Quintette Operating Corporation (QOC). The mine is located in northeastern British Columbia approximately 10 km to the southeast of the community of Tumbler Ridge. The mine operates two mine areas; the Mesa/Wolverine Mine area, which is situated on the ridges at the confluence of the Wolverine River and Mast Creek, and the Shikano Mine area, which is located immediately to the east of the Murray River. All facilities are in the same general area and the mine is serviced by the Heritage Highway from Tumbler Ridge. Figure 6 illustrates the general mine operations layout. The waste dump failure events described in this report include the 1660/1690 Mesa Dump, the 1690 Wolverine North (WN) Dump and the Shikano Waste Dump slides.

2.5.1 1660/1690 Mesa Dump Slides

Description

On September 9, 1985 a major failure occurred on the 1660 Mesa Dump near the north end of the Mesa (formerly McKonkey) Pit at 0600 hrs. The estimated 2.5 million m$^3$ of slide material travelled down a tributary valley of Mesa Creek and continued down the Mesa Creek valley coming to rest 1.8 km from the toe of the original dump. The width of the slide varied from 360 to 500 m near the upper end of the slide to 50 m at the toe. The slide deposited a small quantity of material in the Mesa “A” Sediment Pond, buried the inlet channel, and blocked the emergency spillway from the pond. However, the material deposited in the pond did not reduce the pond’s effectiveness to control suspended solids.

The slide material consisted of coarse rock material and glacial till scoured as the slide moved downslope. Water was observed flowing at several locations on the surface of the slide mass but would then disappear below the surface within a short distance. There were no remedial steps taken immediately following the slide event other than to monitor water quality at the toe of the slide and in the Mesa “A” Sediment Pond.

Remedial action considered by QOC related to rehabilitating the inlet channel and the spillway, and to the need for a sediment pond in Mesa Creek downstream of the toe of the slide. Prior to the 1660 Mesa Dump slide, the inlet channel of the Mesa “A” Sediment Pond consisted of a diversion ditch which was designed to capture runoff from the waste dump and direct water to the sediment pond. The slide covered this inlet channel and raised the question for the need for a sediment pond located downstream of the toe of the slide material. Follow-up studies concluded that the 1660 Dump slide material was in fact acting as a sediment trap since the total suspended solids values in Mesa Creek at the outlet of the slide were equal to or less than the values obtained at the upstream or inlet end of the slide (Reference 32).

The Mesa “A” spillway was designed to direct flows in excess of the 10-year flood or maximum 24-hour runoff into Mesa Creek. Several alternatives were examined by Quintette to rehabilitate the spillway following the 1660 Dump slide. The most economical alternative was to rebuild a new spillway which would direct flows into Mast Creek. The increased potential for erosion in the small headwater channel of Mast Creek and the need for riprap scour protection was identified (Reference 33).

The 1690 Mesa Dump, located immediately to the north of the 1660 Dump, failed on October 3, 1985. This slide consisting of 2.2 million m$^3$ of waste material travelled 1180 m and covered the remaining upper section of the Mesa Creek drainage but did not approach the Mesa “A” Sediment Pond.

This combination of slide events brought about discussions between Quintette Coal Limited and the regulatory agencies related to a water management contingency plan for water quality protection in Mesa and Mast creeks and the Wolverine River.

A water management contingency plan was submitted to MELP, Waste Management Branch on November 15, 1985 detailing the concept of a “dumpsite filter” which would
treat water from the original Mesa A pond drainage (Reference 34). Several contingency scenarios were to be enacted in the event that problems arose. The water management plan was accepted on March 3, 1986 on the basis of continued monitoring and a sediment pond was not required downstream of the 1660 Mesa Dump slide. This represented a significant cost saving to Quintette Coal Limited.

**Environmental Consequences**

Total suspended solids remained well below the Permit # PE-6540 levels of 50 mg/L following the slide 1660 Dump failure event. Water first appeared out the toe of the 1660 Dump slide on September 16, 1985, seven days after the slide occurred. Total suspended solids in Mesa Creek, upstream of the slide material, were consistently 2 mg/L from September 16 to 19, increased to 16 mg/L on September 20 and decreased to 6 mg/L on September 21, 1985. Downstream of the slide in Mesa Creek total suspended solids were 31 mg/L on September 16, 3 mg/L on September 17, 21 mg/L on September 18, and ranged from 2 to 7 mg/L between September 19 and 21, 1985 (Reference 35). Since then upstream to downstream differences were the same or lower at the demonstration site.

There were no records of any consequences to fish or wildlife in the area following the slide events.

The 1660 Dump failure travelled beyond the original dump limits resulting in the loss of timber resources of marginal value. However, the Ministry of Forests requested that the timber debris located along the fringe of the dump material be burned in a controlled manner, a practice that sometimes is followed for purposes of reducing the fire hazard. Quintette experienced difficulty finding a contractor whose costs were not excessive to carry this request out. The contractor lost control of the fire resulting in the potential further loss of timber and raising concerns for the possibility of a major forest fire that would threaten the mine and the town of Tumbler Ridge. The fire was quickly controlled and the total loss of timber was confined to 3 ha located on a low hummock adjacent to the slide.
year due to runoff conditions in W9 Creek. After the slide event, suspended solids values were well below the permitted levels at all times of year.

There were no records of any consequences to fish or wildlife in the area following the slide events.

Controlled burning of the fringe timber was not requested by the Ministry of Forests following the 1660 WN Dump failure event.

**Public Consequences**

There were no fatalities or loss of public property as a result of the 1660 WN Dump failure event.

**Mine Operations Consequences**

The 1660 WN Dump failure resulted in minimal interruption to dumping operations. There were no losses or damage to equipment or mine infrastructure.

2.5.3 Shikano Waste Dump Slide

**Description**

The Shikano Waste Dump slide occurred on May 5, 1990 at 2300 hrs. Mine operations personnel were alerted to the slide event and immediately called the regulatory agencies. By day break QOC and representatives from MEMPR and MELP were examining the damage caused by the slide. The slide, with a volume of between 1.5 and 2.0 million m³, occurred mostly within natural ground, surcharged by a relatively small volume of waste rock from the Shikano Pit. The slide extended over an area of approximately 700 m x 700 m and crossed the Murray River blocking 600 m of river channel.

The Murray River is a major drainage of the Hart Ranges with an estimated watershed area of 2,400 km² and elevation range of 760 to 2,300 m (Reference 38). Runoff in the Murray River is characterized by low winter flows with minimums occurring in February or March due to winter freeze up and peak flows from May through June due to snowmelt and rainfall runoff. The floodplain is approximately 500 m wide at the slide site with dense forest cover along the banks and a large well vegetated sandbar on the west side of the channel. The river channel comprises a straight, low gradient section having a gravel substrata.

The slide blockage created a backwater to a depth of 2.5 to 3.0 m, the effect of which extended upstream for 7.5 km to Axis Creek, a small tributary to the Murray River. Downstream flows were significantly reduced as a result of the slide. The records from the water level recorder at the Water Survey of Canada (WSC) gauging station on the Murray River above the Wolverine River illustrated a drop from a stage of 1.84 m (Q of 124 m³/s) to 0.6 m (Q of 0.0 m³/s) starting at 2300 hrs on May 5. When the slide material was breached at 1100 hrs on May 6 the stage rose to 2.2 m (Q of 200 m³/s) and then dropped back to 1.8 m (Q of 124 m³/s) and remained steady (Reference 38).

The flow breached the slide mainly in the area of the original channel (east channel) which was well armored with course rock debris from the slide. The west channel did not contain the same type or size of material and the small amount of flow in the west channel began eroding the banks and downcutting the channel. By May 9 all flow was carried by the west channel. Quintette Coal Limited began building a rock weir on May 16, 1990 for purposes of directing flow back into the east channel against the toe of the slide. High flows of 490 m³/s in the Murray River interfered with construction of the weir and the project was abandoned on June 1, 1990. Within two weeks of the slide event, the instantaneous peak flow of 843 m³/s and mean daily flow of 774 m³/s were recorded at the WSC gauging station and these high flows (estimated 1 in 30 or 40 year return flows) caused further widening and entrainment of the west channel.

Most of the floating trees had been cleaned out of the upstream side of the slide by QOC prior to the flood peaks. However, many of the trees that were trapped in the slide material were gradually released and transported downstream to form log jams (Reference 38). Flood events of this magnitude cause increased rates of bank erosion and increased supply of fallen trees to the watercourse, lifting trees that fell in previous floods off gravel bars for downstream transport.
The channel morphology downstream of the slide was transformed from a straight single channel section prior to the slide to a meandering reach consisting of a wide channel containing numerous gravel bars (Reference 39).

Three problems were identified following the slide with potentially serious consequences including:

- a decrease in the navigability of the river reach through and immediately downstream of the slide;
- potential mobilization of log jams in a large raft which could destroy the temporary bridge over the Murray River; and
- potential sediment problems resulting from increased rates of bank erosion.

The solutions to these problems were to initiate a monitoring program over the five year period following the slide for future regime assessment purposes, remove the rock weir to improve the navigability of the river channel and ensure that the proposed new bridge structure across the Murray River would be capable of allowing the passage of peak flows and log jam material.

Remedial work completed by QOC included the reclamation of the boat launch ramp and weir at the slide site, placed riprap along the leading edge of the slide in the Murray River, and spread fines throughout the slide material to provide a growth medium and seeded these areas.

**Environmental Consequences**

The reduction in flows downstream of the slide had an immediate but short term impact on the fisheries populations in the Murray River. An estimated 21,000 m² of fish habitat was lost due to the slide and downstream areas (Reference 40). The effects of the slide further downstream were reduced, due to water inputs from tributary streams and the Wolverine River. No impacts to fisheries or aquatic resources were identified resulting from upstream ponding of the river.

There was an initial load of sediment and debris resulting from the slide plus the load caused by the erosion of the west channel. It was estimated that approximately 30,000 m³ of material was eroded as a result of the slide event (Reference 38). Water samples were collected twice daily following the slide event. Peak suspended solids levels of 3,630 mg/L occurred on May 6, 14.5 hours after the slide event followed by diminished concentrations of 405 mg/L on May 8, 1990 compared to TSS levels of 153 mg/L upstream of the slide (Reference 40). The river downstream of the slide returned to background levels within two months of the event.

The waste rock dump failure imposed major changes to the Murray River and displaced the former natural river channel (Reference 40). The floods that occurred in June 1990 caused the changes to occur in a relatively short time frame. Had the slide occurred following the flood season the erosional and depositional processes would have taken longer. However, the river processes assisted by the high flows in 1990 completed most of the rehabilitation naturally and within a short time frame.

Studies were carried out by Hardy BBT Limited in 1990 on the effects the backwater had on vegetation upstream of the slide (Reference 38). The study concluded that:

- no mortality was expected for the 92 ha of vegetation affected for <7 days;
- the merchantable timber in the 9.5 ha area for >7 days would be expected to have a >75% mortality primarily of white spruce;
- the growth rate of the balsam poplar would be set back for 1990; and
- all that would survive would be the willow and alder.

Discussions with QOC personnel confirmed that no trees were lost due to backwater effects of the river (Reference 41).

**Public Consequences**

Consequences to the public included the temporary loss of access to and navigability of the Murray River while QOC was implementing the remedial work to restore the river channel and rebuild the boat launch ramp on the west bank of the river.
Mine Operation Consequences

The Shikano Slide resulted in the loss of the Shikano Waste Dump location. Waste material from the Shikano Pit had to be placed at alternate dump locations while the company applied for another location, a process that took approximately one year before approval was granted for the revised waste dump. Although QOC did not reduce the level of production, the haul costs were significantly higher and the mine was potentially less profitable.

The conveyor crossing and the natural gas pipeline crossing were not considered to be adversely affected by the debris produced by the slide (Reference 40). There were no comments regarding the threat to these facilities from changes in river morphology.

2.5.4 Discussion

The data base and consequences rating related to the 1660/1690 Mesa Dumps, the 1660 Wolverine North Dump and the Shikano Dump slides are presented in Appendix V.

3.0 APPLICATION TO MINE WASTE DUMPS

3.1 Risk-based Approach

This study forms part of the development of a risk based methodology for the design of mine waste dumps.

Consider two examples of large mine waste dumps (100 to 400 m high), in steep mountainous terrain, operated under severe economic constraints:

1) A dump situated on very steep terrain, with a high probability of failing, i.e. having a high level of hazard, may be located well away from any infrastructure, and may be safeguarded by a large sediment control pond downstream. The consequence of the dump failing may be small in terms of the effect on water quality downstream of the sediment control pond. Thus, the overall level of risk posed by the dump to the environment may be low.

2) A high dump founded on relatively flat and competent terrain may pose an unacceptably high risk if the dump is located immediately adjacent to a major element of infrastructure such as a tailings pond or a busy railroad. The consequence of even a relatively small sliver failure may be unacceptable in terms of the cost of repair, lost production, or loss of life or injury.

Despite technical limitations of predictive modelling and of monitoring dump foundations, we have accumulated sufficient observational experience in the past 25 years to identify levels of hazard for each possible failure mode with reasonable certainty. Monitoring of dump platform deformation has proven very effective in ensuring safe operations with minimal loss of life, injury, or damage to infrastructure. Impacts on the environment have been varied.

One of the key tasks of the study reported herein is to develop part of the methodology for predicting the consequences of dump failures. The methodology is evolving in two parts:

- Prediction of the behaviour of the failure debris, i.e. runout distance and direction;
- Prediction of the consequences of the failure runout.

This study has investigated the consequences of past failure events. The study of mine dump failure runout has been carried out in a separate study (Reference 43).

3.2 Discussion of Past Failure Consequences

Data on the characteristics and runouts of over 40 mine dump failures have been collected, providing a basis for prediction based on analysis of selected comparable case histories (Reference 3).

Table 4 presents a summary of the range of consequence ratings assigned to the selected 9 case histories on the basis of interviews, discussions and documentation compiled in this report. The values in the columns are the number of times that a certain consequence rating (major, moderate, minor, negligible, none, positive) was assigned to each failure event in the environmental, mine operations and public categories. The total number of times each of the rating categories of major (19), moderate (28), minor (15), negligible (18), no consequence (191) and positive impact are presented in Table 5 to illustrate the severity of the consequences in each category (environment, mine operations, and public). Figure 7 shows a three-dimensional presentation of the results of rating the selected case histories.
Generally, the consequences related to the failure events examined in this study varied according to the time of year, the facilities in place, and the remedial action taken immediately following the event.

3.2.1 Boundaries

In the majority of cases, the slide runouts remained within the approved ultimate dump limits and have since been covered by waste material. The runouts extended beyond the final dump limits in very few cases.

3.2.2 Water Quality

The mine operators were diligent in implementing remedial action and contacting the regulatory authorities immediately following the slide events in all cases.

Settling ponds and drainage control structures, designed to handle sediment loads generated by spring runoff, 24 hour precipitation events, and Q-10 flows, generally were efficient in mitigating runoff from waste dump failure events in the short and long term. With the exception of one event, these facilities were in place at prior to the failures. The remedial action taken in this exceptional event included an emergency sediment pond which mitigated any water quality impacts in the receiving waters completely. However, fisheries resources were impacted by the slide because it occurred when the creek was populated with over-wintering fish. In this case, the consequences of the failure would have been worse in terms of water quality, but less in terms of fisheries resources, if the event occurred during spring runoff.

3.2.3 Mine Operations

Mine operations were affected by failure events because of the need to find alternate dumping locations while the stability of the waste dump was confirmed and the failure crest was rehabilitated. A dump completely was abandoned for an alternate location, but with no loss of production in only one case.

3.2.4 Public Consequences

Consequences to the public included the loss of life on only very few dump failure events. One early event in 1968 buried a vehicle when the slide debris crossed a highway. The incident would not have occurred today given the present knowledge of mine waste dump design and management. A second event, in 1992, claimed the life of a mine worker. The incident was not anticipated as the waste dump had been closed for over a year prior to the slide event and monitoring of displacements in the region of the dump crest had been discontinued. This situation re-newed awareness of the requirement for continuous monitoring of waste dumps and miscellaneous fills.

In general, most of the consequences of the failure events summarized in Table 4 were classified as none.

3.3 Classification of Mine Dumps

This section discusses several potentially useful approaches to the classification of waste dumps.

In B.C. several studies have focussed on the performance and design of mine waste dumps. In 1992 MEMPR initiated a study of the application of risk-based methodology to mine waste dump design (Reference 1). The essence of the concept was to classify dump alternatives simply, according to the consequence of their failure. This classification could serve to establish the minimum requirements for investigation, design and performance at an early stage of the regulatory approval process.

The need for classification deserves some discussion. Past failures have not occurred without warning, provided operational monitoring procedures have been in place to detect and to react to the signs of accelerating movement. However, the perception by some parties of a loss of control stems from the difference between predictions of performance, prepared for the permitting process, and the actual performance during operations. A number of dumps have received regulatory approval where some risk of failure has been clearly stated. Other failures have occurred as a result of technical issues that are not completely understood or which are impractical to model reliably.
Table 4 shows an example of the rating of the potential consequences of dump failures, as developed in the Phase I project. The proposed methodology would establish requirements for the scope of investigation and design, allowable site conditions, design criteria, monitoring requirements, and construction restrictions on the basis of a proposed dumping scheme.

Specific criteria cannot be established equitably until generic sensitivity analyses are performed to link the consequence of failure to the potential mode of failure and its predicted extent. These analyses span the disciplines of geotechnical, hydrological, and environmental sciences. Mine planning and economic aspects also need to be included in the risk analyses, if one accepts that trade-offs or compromises are inevitable for both economic and environmental criteria. Clearly both will have certain minimum acceptable standards.

The overall risk-based approach of explicitly describing the hazards and consequences is fundamentally desirable. We should neither classify nor define acceptance criteria for the consequences of failures until these consequences have been clearly defined.

In summary, Reference 42 offers a clear perspective on the application of three possible levels of classification, and is reproduced as follows:

LEVEL I: A classification based only on consequence. No direct consideration is given to the likelihood of the causative effect (e.g. a dump failure). This is however indirectly taken into account through the severity of the design and operating etc. requirements which become more rigorous with higher consequences of failure. This level of classification was described and proposed in Phase I (Reference 1).

LEVEL II: A classification based on consequence qualified with respect to the likelihood of the causative event and as such constitutes a somewhat rudimentary attempt to classify in terms of total risk. However this likelihood is usually based on obvious site specific factors requiring little or no analysis, debate or judgment. For example, a level I classification may restrict dump height to (say) 100 m or less for a particular (say moderate) consequence rating. However if the waste is strong, coarse and durable and the foundation is obviously sound bedrock, a level II classification would permit some variation from this restriction. The albeit somewhat more advanced procedures shown in Tables 6 and 7 fall under this classification.

LEVEL III: A classification based on total risk which requires the consequence and the causative event to be both expressed in probabilistic terms. This expression can be absolute (e.g. 1:100) or relative (e.g. high). However, note that many attempts at expressing relative probabilities end up relating them to absolute values such as the life of a structure or even a numerical probability range. The footnotes on Table 6 are typical (here, also, the contentious issue of a “dump lifetime” is raised). The ultimate of a level III classification is to quantitatively express the total risk of an adverse consequence (e.g. 1:1000 annual risk of a fatality). This permits cost-benefit analysis and comparison with quantified risks from other sources.

We recommend very careful discussion and analysis of potential classification systems for mine dumps. Appropriate levels of effort and types of classification should be evolved through as the result of experience gained from practical application.

3.4 Risk-based Methodology

The objective of the Phase II study was to compile a sound factual database of failure consequences in terms of the questions posed. It is intended that the assembled data will provide the basis for empirical prediction of failure consequences, providing the basis for fair evaluation of risk.

The use of the results of this study and the application of risk-based approaches to mine waste dumps should consider the following:

- Overall, the consequences of past mine dump failures have not been significantly out of compliance with mine operating permits.
- The precedents of the consequences of past failures should be used for future design with care, because proposed dump projects may be subject to more or less severe conditions.

Risk analysis is now being applied to mining projects with varying levels of sophistication, both qualitatively (Reference 2) and quantitatively (Reference 44). Examples of the results of each of these levels of study are shown on Table 6 and Figure 8 respectively. The analyses can be used to focus design studies cost-effectively in the areas of greatest risk. The explicit nature of the process can serve as a vehicle for
communicating both cost and risk to all concerned. The concept is simple, its execution
is often complex, but the effect of good communication with both regulatory authorities
and the public can pay great dividends.

3.4.1 Qualitative Analysis

Table 6 shows an example of a dump stability assessment and a qualitative risk analysis.

For a typical waste dump Table 6 would function as the basic framework for describing
each stage of development and for rating the various potential failure modes, their
resulting debris runout, and the consequences and costs of such an event. The
information presented in this table provides an explicit basis for subjectively or
qualitatively evaluating risk. This approach, while not difficult, requires thorough and
detailed analyses, and has been well received by both mine planners and regulators.

Overall, the explicit description of hazards and consequences, even if qualitative as in the
example shown in Table 6, will be very useful in allaying regulatory concerns. A
common-sense approach to evaluating this type of information, if applied objectively by
qualified individuals, is likely to be a defensible basis for approval without penalizing
industry.

Table 7 shows a complementary approach to qualitatively rating impacts of a single
element of the systems and sequences defined in the framework of Table 6.

3.4.2 Quantitative Approach

The successful use of quantitative risk analyses depends on the reliable mathematical
definition of relationships which calculate stability factors, and the magnitude of potential
failure impacts. The spreadsheet format of Table 6 would be amenable to the
construction of these relationships to form a system.

Reference 5 describes in considerable detail the development of mathematical models to
describe the impact on water quality of some 40 alternative mine waste disposal systems
for a mine in mountainous terrain. The input parameters were assumed to follow a
relatively simple triangular distribution of probable values. These distributions are
sampled randomly by software built onto the basic spreadsheet program, resulting in
output which defines the probability of occurrence of a given level of impact. Ultimately,
alternative waste disposal concepts can be compared systematically and ranked
accordingly. Figure 8 shows some of the output of the comparative computations for the
example described in Reference 5. The output shows the variation in levels of confidence
for each option. The decision maker is able to evaluate clearly the degree of uncertainty
for each option.

The quantitative risk calculations are very useful aids to decision-makers, provided that
the scientific relationships between cause and effect are reliable.

3.5 Method Selection

3.5.1 General

The Phase I study established an overall approach and framework for a risk-based design
methodology. The current study has compiled and evaluated failure consequences, which
provide a basis for adapting the general approach specifically to the mine dumps in
mountainous terrain in B.C.

Table 8 presents a suggested framework for rating the consequences of failure events in
each of the categories examined in this study. The method is qualitative and makes use
of accepted environmental impact rating criteria in combination with the other methods
presented in Tables 2 and 7.

The criteria presented in Table 8 are not all inclusive of the potential consequences
related to the design of a specific waste dump. However, they encompass the range of
potential consequences documented in Section 2.0 of this report. The gradations between
each rating level (major, moderate, minor, etc.) and the corresponding consequence
criteria must be discussed on a site specific basis in order to place realistic values on the
acceptability of the consequence within the overall risk framework.

Section 3.4 has presented and discussed a number of risk-based methods. We are
reluctant to recommend one method over another at this time. Readers of this report will
likely suggest other methods. We recommend that selection of any method remain the
prerogative of the proponent, provided that the approach is explicit and based on fundamentally sound scientific relationships and parameters.

3.5.2 Site-specific Study

A site-specific risk-based explicit approach is very desirable in:
- aiding defensible option selection;
- improving decision and design confidence;
- optimizing project costs; and
- optimizing investigation costs.

Uncertainty may be compounded by instituting generalized rating systems. We emphasize site specific evaluations based on:
- geotechnical analysis and prediction of performance;
- comparison with relevant precedent;
- engineering judgment; and
- consequence analysis.

3.5.3 Graduated Approach

Qualitative evaluations, based on conceptual engineering and judgment, should be performed first. Subsequently, quantitative risk computations may be considered if the effort and cost is justified and if the waste system model is well understood.

The approach of a risk-based assessment should be graduated, as follows:

a) Conceptual design of dump stages, evaluating risk and cost qualitatively;
b) Feasibility design, including focused site investigation;
c) Final design specifications, including management and monitoring procedures;
d) Monitoring during operations, with periodic design/performance review; and
e) Review of the abandonment/closure design, taking into account past dump performance.

3.6 Recommended Further Work

We recommend that the approaches outlined in this document be applied to future project evaluations, as the best way of adapting and refining their application.

Further detailed evaluation of existing numerical data collected at certain sites may yield useful parameters for the detailed design of environmental control measures such as settling ponds. Detailed analysis of this information was beyond the scope of the current study. Follow-up environmental assessments of selected past failure events may be worthwhile in order to resolve current uncertainty in their long-term consequences.

We recommend that a workshop/seminar on risk in mine waste dump management be held. The workshop would discuss the results of this study and of other current studies of runoff and dump failures. The primary purpose of the meeting should be to reach consensus on the methodology and criteria for assessing the consequences of potential dump failures. We recommend circulation of discussion papers on proposed methodology prior to the meeting, thus maximizing the time available for debate.

We trust that this report meets your requirements.

GOLDER ASSOCIATES LTD.

Bill Johnson, BSc.
Senior Environmental Scientist

Alistair Kent, P.Eng.
Associate

BJ/AK/1c
932-1417
FR:
WORDS3RPT-94SEP/BJ-1417.DOC
REFERENCES


15. Westar Mining Ltd., 1986, “Annual Report of Sampling and Monitoring Program in Conjunction with Pollution Control Permit PE-6248”


27. B.C. Ministry of Environment, Pollution Control Branch, 1978, “1978 Spring Runoff Sampling Results for the Area Influenced by Kaiser Resources Ltd”


43. Golder Associates Ltd., 1994, Runout Characteristics of Debris from Dump Failures in Mountainous Terrain Stage II - Analysis, Modelling, and Prediction, Dept. of Supply and Services Contract 23440-0-9198/01-X8G.

<table>
<thead>
<tr>
<th>COMPANY NAME</th>
<th>OPERATING MINE</th>
<th>LOCATION</th>
<th>WASTE DUMP FAILURE EVENT</th>
<th>FAILURE DATE(S)</th>
<th>RUNOUT STUDY DATA BASE #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fording Coal Limited</td>
<td>Fording River Mine</td>
<td>SE-BC</td>
<td>South Spoil</td>
<td>Oct. 26, 1989</td>
<td>155</td>
</tr>
<tr>
<td>Fording Coal Limited</td>
<td>Fording River Mine</td>
<td>SE-BC</td>
<td>Brownie Spoil</td>
<td>July 1983 to November, 1986 and March, 1991</td>
<td>1, 3, 5, 6, 7, 11, 13, 162</td>
</tr>
<tr>
<td>Westar Mining Ltd.</td>
<td>Greenhills Mine</td>
<td>SE-BC</td>
<td>Greenhills East</td>
<td>May 30, 1985</td>
<td>N/A</td>
</tr>
<tr>
<td>Westar Mining Ltd.</td>
<td>Greenhills Mine</td>
<td>SE-BC</td>
<td>Greenhills North</td>
<td>July 1, 1985</td>
<td>89</td>
</tr>
<tr>
<td>Westar Mining Ltd.</td>
<td>Greenhills Mine</td>
<td>SE-BC</td>
<td>Greenhills North</td>
<td>November 22, 1989</td>
<td>156</td>
</tr>
<tr>
<td>Westar Mining Ltd.</td>
<td>Greenhills Mine</td>
<td>SE-BC</td>
<td>Shump Block</td>
<td>July 18, 1988</td>
<td>N/A</td>
</tr>
<tr>
<td>Westar Mining Ltd.</td>
<td>Greenhills Mine</td>
<td>SE-BC</td>
<td>Cougar #7</td>
<td>May 11, 1992</td>
<td>N/A</td>
</tr>
<tr>
<td>Westar Mining Ltd.</td>
<td>Balmer Mine</td>
<td>SE-BC</td>
<td>Harmer Knob</td>
<td>May 31, 1971</td>
<td>43</td>
</tr>
<tr>
<td>Crows Nest Resources Ltd.</td>
<td>Line Creek Mine</td>
<td>SE-BC</td>
<td>West Line Creek</td>
<td>July 1, 1982</td>
<td>62</td>
</tr>
<tr>
<td>Quintette Operating Corporation</td>
<td>Quintette Coal Mine</td>
<td>NE-BC</td>
<td>1660 Mesa</td>
<td>Sept. 9, 1985</td>
<td>54</td>
</tr>
<tr>
<td>Quintette Operating Corporation</td>
<td>Quintette Coal Mine</td>
<td>NE-BC</td>
<td>1600 Mesa</td>
<td>Oct. 3, 1985</td>
<td>113</td>
</tr>
<tr>
<td>Quintette Operating Corporation</td>
<td>Quintette Coal Mine</td>
<td>NE-BC</td>
<td>1660 Wolverine North</td>
<td>Nov. 7, 1987</td>
<td>157</td>
</tr>
<tr>
<td>Quintette Operating Corporation</td>
<td>Quintette Coal Mine</td>
<td>NE-BC</td>
<td>Shikano</td>
<td>May 5, 1990</td>
<td>N/A</td>
</tr>
</tbody>
</table>

An effort was made to standardize the evaluation process by applying a standard set of impact criteria, along with risk of injury and I.C.S. (1980) systems to evaluate the impact magnitude and geographic extent of the consequences. The environmental impact assessment for this study was based on the objectives of this study was to assist regulatory agencies and biologists in evaluating the consequences of mine failures and to assist with planning the mine site. The study employed numerical rating systems to evaluate the magnitude and geographic extent of the consequences associated with mine failures and the potential for adverse environmental effects.
<table>
<thead>
<tr>
<th>RATING</th>
<th>LOSS OF LIFE</th>
<th>ECONOMIC LOSS</th>
<th>ENVIRONMENTAL-AND CULTURAL LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>Potential for multiple loss of life affecting travelling and/or recreating public and/or work force. Development within runout area typically includes main highways and railways, service roads, haul roads and mine facilities.</td>
<td>High economic losses affecting public, commercial, and mine facilities in runout area. Typically includes direct damage to highways, railways, power lines, pipelines, buried telephone cables etc. Direct and indirect (interception of service) costs could exceed $5 millions.</td>
<td>Loss or significant deterioration of nationally or provincially important fisheries habitat (including water quality), wildlife habitat, rare and/or endangered species, unique landscapes or sites of cultural significance. Feasibility and/or practicality of restoration and/or compensation is low.</td>
</tr>
<tr>
<td>MODERATE</td>
<td>Potential for loss of life affecting work force only. Development within runout area includes service roads, haul roads and mine facilities but no public facilities.</td>
<td>Appreciable economic losses affecting commercial and/or mine facilities. Direct and indirect (interception of service) costs could exceed $500,000.</td>
<td>Loss or significant deterioration of nationally or provincially important fisheries habitat (including water quality), wildlife habitat, rare and/or endangered species, unique landscapes or sites of cultural significance. Feasibility and practicality of restoration and/or compensation is high.</td>
</tr>
<tr>
<td>LOW</td>
<td>Limited potential for loss of life affecting work force only. No facilities within runout area other than service roads and/or haul roads.</td>
<td>Economic losses do not exceed $500,000 and impact affects mine facilities only. However, there is reasonable potential for future development of other land uses within the runout area.</td>
<td>Loss or significant deterioration of regionally important fisheries habitat (including water quality), wildlife habitat, rare and/or endangered species, unique landscapes or sites of cultural significance. Feasibility and practicality of restoration and/or compensation is high. Includes situations where the potential for impact is seasonally specific, but where such seasonal fish or wildlife use has a high probability of being avoided by adopting more conservative construction practices or cessation of dump construction during the period of hazard exposure.</td>
</tr>
<tr>
<td>VERY LOW</td>
<td>Minimal potential for loss of life. No facilities within runout area.</td>
<td>Economic losses do not exceed $500,000 and impact affects mine facilities only. Virtually no potential for future development of other land uses within the foreseeable future.</td>
<td>No significant loss or deterioration of fisheries habitat, wildlife habitat, rare or endangered species, unique landscapes or sites of cultural significance.</td>
</tr>
</tbody>
</table>

SOURCE: G. MORGAN
I/RPT-099/1ULTS-1417
### Table 5: Consequence Assessment

<table>
<thead>
<tr>
<th>FAILURE EVENT</th>
<th>ENVIRONMENTAL CONSEQUENCES</th>
<th>PUBLIC CONSEQUENCES</th>
<th>MINI OPERATIONS CONSEQUENCES</th>
<th>MINI DUMP RATING</th>
<th>MAX DUMP RATING</th>
<th>MINI DUMP MIN.</th>
<th>MAX DUMP MIN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event 1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Event 2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

**Rating Levels**
- **Major Consequence** (N = 19)
- **Moderate Consequence** (N = 16)
- **Negligible Consequence** (N = 10)
- **No Interaction** (N = 19)
- **Positive Consequence** (N = 1)

Note: Additional data and information for further analysis are available in Appendix A.
### TABLE 7 (A)

**EXAMPLE OF QUALITATIVE RISK ASSESSMENT**

<table>
<thead>
<tr>
<th>HAZARD</th>
<th>EXPOSURE</th>
<th>CONSEQUENCE</th>
<th>RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INITIATING EVENT</strong></td>
<td><strong>IMMEDIATE EFFECT</strong></td>
<td><strong>MITIGATION</strong></td>
<td><strong>EXTENT OF IMPACT</strong></td>
</tr>
<tr>
<td>Major Dump Slide</td>
<td>Sediment Erosion</td>
<td>Pond Spill</td>
<td>Contaminated Water</td>
</tr>
<tr>
<td>Low Likelihood</td>
<td>High Likelihood over Short-Term</td>
<td>Sediment Spill</td>
<td>Concentration</td>
</tr>
<tr>
<td><strong>LOW HAZARD</strong></td>
<td><strong>LOW EXPOSURE</strong></td>
<td><strong>LOW CONSEQUENCE</strong></td>
<td><strong>VERY LOW OVERALL RISK</strong></td>
</tr>
</tbody>
</table>

SEE TABLE 1 (B) SEE TABLE 1 (C)

---

### TABLE 7 (B)

**EXAMPLE OF QUALITATIVE DESCRIPTIONS FOR CONSEQUENCE ASSESSMENT**

<table>
<thead>
<tr>
<th>RATING</th>
<th>TERRITORIAL ECOSYSTEM</th>
<th>AQUATIC ECOSYSTEM OR BIOTA</th>
<th>FISHER POPULATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>No Impact</td>
<td>No Impact</td>
<td>No Impact</td>
</tr>
<tr>
<td>Very Low</td>
<td>Productivity or biomass (&lt;5%)</td>
<td>Slight loss in aquatic benthos or species diversity (&lt;5%)</td>
<td>Slight effects on growth or mobility (&lt;5%)</td>
</tr>
<tr>
<td>Low</td>
<td>Loss in species or productivity (5 - 10%)</td>
<td>Reduction in species or productivity (5 - 10%)</td>
<td>Loss in growth or mobility, reproduction (5 - 10%)</td>
</tr>
<tr>
<td>Medium</td>
<td>Large or long-term loss in species or productivity (&gt;10%)</td>
<td>Large reduction in species diversity or productivity (&gt;10%)</td>
<td>Sublethal effects on large fish population. Mortality and loss of reproduction (&gt;10%)</td>
</tr>
<tr>
<td>High</td>
<td>Total destruction of terrestrial ecosystem in a large area (&gt;100 ha)</td>
<td>Total or long-term degradation of a long reach of stream (&gt;5 km) or a large body of water (&gt;75 ha)</td>
<td>Large and permanent fish kill (&gt;5,000 or one cohort) or destruction of spawning habitat in a total stream</td>
</tr>
</tbody>
</table>

---

### TABLE 7 (C)

**BASIS FOR QUALITATIVE RISK CHARACTERIZATION**

<table>
<thead>
<tr>
<th>HAZARD ASSESSMENT</th>
<th>EXPOSURE ASSESSMENT</th>
<th>CONSEQUENCE ASSESSMENT</th>
<th>RISK CHARACTERIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible to High</td>
<td>Negligible to Very Low</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Negligible to High</td>
<td>Very Low to Low</td>
<td>Negligible to Very Low</td>
<td>Very Low</td>
</tr>
<tr>
<td>Very Low to High</td>
<td>Low to Medium</td>
<td>Very Low to Low</td>
<td>Low</td>
</tr>
<tr>
<td>Low to High</td>
<td>Medium to High</td>
<td>Medium to Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Low to High</td>
<td>Medium to High</td>
<td>Medium to High</td>
<td>High</td>
</tr>
</tbody>
</table>

Golder Associates

1RPT-97SEP83-1417
<table>
<thead>
<tr>
<th>RATING</th>
<th>ENVIRONMENTAL</th>
<th>MINE OPERATIONS</th>
<th>PUBLIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>Whole Population Affected</td>
<td>Waste Dump Lost</td>
<td>Loss of Life</td>
</tr>
<tr>
<td></td>
<td>Natural Recruitment Takes</td>
<td>Infrastructure Lost</td>
<td>Infrastructure Lost</td>
</tr>
<tr>
<td></td>
<td>Several Generations</td>
<td>Equipment Lost</td>
<td>Land Uses Lost</td>
</tr>
<tr>
<td></td>
<td>TSS (failure enters water course)</td>
<td>Extreme Rehabilitation Costs</td>
<td>Extreme Rehabilitation Costs</td>
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<tr>
<td>Moderate</td>
<td>Portion of Population Affected (&gt;= one generation)</td>
<td>Long Term Interruption</td>
<td>No Loss of Life</td>
</tr>
<tr>
<td></td>
<td>TSS (elevated for long duration)</td>
<td>Excessive Hauls</td>
<td>Infrastructure Damaged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infrastructure Damaged</td>
<td>Land Use Temporarily Lost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equipment Damaged</td>
<td>High Rehabilitation Cost</td>
</tr>
<tr>
<td>Minor</td>
<td>Localized Population Affected (&gt; one generation)</td>
<td>Short Term Interruption</td>
<td>Potential for Loss of Life</td>
</tr>
<tr>
<td></td>
<td>TSS (elevated for short duration)</td>
<td>Extra Hauls</td>
<td>Infrastructure Within Run Out Zone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Damage to Infrastructure</td>
<td>Potential for Loss of Land Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low Rehabilitation Costs</td>
</tr>
<tr>
<td>Negligible</td>
<td>Specific Group Affected</td>
<td>Temporary Interruption</td>
<td>Potential for Loss of Life</td>
</tr>
<tr>
<td></td>
<td>Population Changes Due to Environmental Irregularities</td>
<td>Costs Not a Factor</td>
<td>Infrastructure Outside Run Out Zone</td>
</tr>
<tr>
<td></td>
<td>TSS Not a Concern</td>
<td></td>
<td>No Potential for Loss of Land Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cost Not a Concern</td>
</tr>
<tr>
<td>No Impact</td>
<td>No Interaction</td>
<td>No Interaction</td>
<td>No Interaction</td>
</tr>
<tr>
<td>Positive</td>
<td>Population Increase</td>
<td>Cost Savings</td>
<td>Cost Savings</td>
</tr>
<tr>
<td>Impact</td>
<td>Habitat Improved</td>
<td></td>
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</tr>
</tbody>
</table>

1/LJULY18-1417
Fording River Mine
South Spill
Runout Study Data Base #155
October 26, 1989

ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? No.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? Yes, very effective resulting in No Interaction.
   Rating: No Interaction

4. Were fisheries resources impacted? Yes overwintering, fish mortality in Kilmarnock Creek.
   Rating: Moderate

5. Were wildlife resources impacted? Yes, elk winter range lost to berms.
   Rating: Minor

6. Were vegetation/forestry resources impacted? No, area previously logged. Minor damage to bordering vegetation caused by 'wind blast'.
   Rating: Negligible

7. Do major storms or precipitation events cause problems? No, sediment ponds demonstrated capability to handle runoff. Waste material demonstrated rock drain characteristics.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? Without sediment ponds in place, consequences to water quality would have been higher during spring runoff. Fisheries consequences would have been lower in Kilmarnock Creek during spring or summer seasons.
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? No.
   Rating: No Interaction

2. Did runout exit the property? No.
   Rating: No Interaction

3. Were mine operations affected? Temporary interruption to mine waste dumping.
   Rating: Negligible

4. Was there damage to the mine infrastructure or equipment? Temporary loss of access road along Kilmarnock Creek.
   Rating: Negligible

5. Did runout debris adversely affect the ultimate dump stability or capacity? No.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? No changes, rock drain operating satisfactorily.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? Yes, if runout reached access highway.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? No, crest was monitored, dumping was stopped and Kilmarnock Creek access road was closed. Yes, if runout to highway and CP Rail.
   Rating: No Interaction
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 155
MINE NAME: FCL
DUMP DESIGNATION: SOUTH SPOIL
LOCATION:

PRE-FAILURE CONDITION
CEMENT ELEVATION: 2195 M
TOE ELEVATION: 1860 M
DUMP FACE HEIGHT: 335 M
QUALITY OF WASTE:
FOUNDATION - TOE SLOPE: 23 DEG
- PROFILE: A/B
- MATERIAL: THIN COLLUVIUM ON ROCK
PRECEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 10/26/89
WEATHER:
FAILURE TRIGGER: DOUBLE WEDGE, BASE OVERSTRESSED. 3D EFFECT ON STABILITY IMPORTANT
PROPAGATION: RAPID FAILURE BRANCHES BLOWN FROM TREES ESTIMATED 0 >100 KN/HR
(DUST ON PLANTS)

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:5000 COMPOSITE
PRE - FAILURE: ESTIMATED
POST - FAILURE: 1:5000 PARTIAL COVERAGE
FAILURE VOLUME: 2500 CUBIC METRES X 1000
RUN-OUT DISTANCE: 850 M. FROM TOE
RUNOUT SHAPE: FANNEO OUT
RUNOUT PATH SURFICIAL SOIL:
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION:
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: NOTE IN ZONE (A) RELATIVELY LITTLE DEBRIS DEPOSITED IN CREEK BED.
SLIDE DEBRIS DEPOSITED IN CREEK BED I.E. SUFFICIENT MOMENTUM SO THAT MOST OF DEBRIS DEPOSITED ON SOUTH SIDE OF RIVER. SLIDE DEBRIS COVERED AREA 650 M WIDE, BUT INITIAL WIDTH OF FAILING TOE 250 M WIDE.

AIR PHOTOS - NUMBERS: N/A
REMARKS: ORTHONAT AVAILABLE
GROUND PHOTOS:
SOURCE OF DATA:
GOLDER ASSOCIATES 882-1277 REPORT FAILURE ANALYSIS
GOLDER ASSOCIATES 872-1056 DESIGN, TOPO
C. BRAKER REPORT TO FCL, NOVEMBER 14, 1989

COMPILATED BY: A. KENT
DATE: 08/30/91
UPATED BY: / /
Photo 1 - Side view of spoil pile movement. Note (1) Steep upper scarp, (2) Uniform upper parallel sloped to top of Blackwood Pit, (3) Runout area in the valley bottom. The material developed high velocity and scoured the terrace top and valley bottom. The present conditions provide better spoil pile foundations than previously.

From report by C. Brawner to Fording Coal Ltd. November 14, 1989.

Photo 6 - Toe runout zone looking from above. The toe ran up the far mountain as a result of the velocity. The spoil appears to have slid into the creek terrace and possibly liquefied when it encountered the valley bottom softer and wetter sediments. The toe acted much like the toe of the Hope-Princeton rock slide when it hit the valley bottom. The valley bottom is now obviously more stable.
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No, sediment ponds were in place.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? Sediment ponds in place. No changes.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? No remedial action was required.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

   Rating: No Interaction

7. Do major storms or precipitation events cause problems? No problems recorded.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction

9. MINE OPERATIONS CONSEQUENCES

1. Did runoff exit the ultimate dump limits? No.
   Rating: No Interaction

2. Did runoff exit the property? No.
   Rating: No Interaction

3. Were mine operations affected? Temporary interruption to mine waste dumping.
   Rating: Negligible

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction

5. Did runoff debris adversely affect the ultimate dump stability or capacity? No.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? Overfilled.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction
**PUBLIC CONSEQUENCES**

1. Was there personal injury or loss of life? No.
   
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? Some media attention through information provided by MELP.
   
   Rating: Negligible

4. Could the consequences to the public have been worse? No.
   
   Rating: No Interaction

**MINE WASTE DUMP FAILURE**

**RUNOUT DATA SUMMARY**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>EVENT NUMBER: 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINE NAME: BROWNE E GULLY</td>
<td></td>
</tr>
<tr>
<td>DUMP DESIGNATION: EAGLE MOUNTAIN PROJECT</td>
<td></td>
</tr>
</tbody>
</table>

**PRE-FAILURE CONDITION**

- CREST ELEVATION: 2360 M
- TOE ELEVATION: 2120 M
- DUMP FACE HEIGHT: 240 M

**QUALITY OF WASTE:**
- MATERIAL: COLLUVIUM ON ROCK
- FOUNDATION: CONCAVE, TYPE A

**FAILURE ACTIVITY:** ACTIVE

**FAILURE DATA**

- DATE: 06/11/83
- WEATHER: NOT BELIEVED TO BE A FACTOR
- FAILURE TRIGGER: UPPER 30 M BULGING TO 40 DEG, DUMPING STOPPED JUNE 6, STEEP FOUNDATION.
- PROPAGATION: "SMALL STUPESTRUM"

**RUNOUT DATA**

- SURFACE TOPOGRAPHY - ORIGINAL: 1:2000
- PRE - FAILURE: FCL REPORT SHOWS CREST LOCATION
- POST - FAILURE: FCL REPORT SHOWS SLIDE OUTLINE
- FAILURE VOLUME: 115 CUBIC METRES X 1000
- RUN-OUT DISTANCE: 600 M, FROM TOE
- RUNOUT SHAPE: CURVED
- SPECIAL FEATURES: COLLUVIUM ON TILL
- TYPICAL TRANSVERSE SECTION: PART CONFINED
- NATURE OF RUNOUT DEBRIS: VELOCITY ESTIMATE:

**COMMENTS:** VIRTUALLY ENTIRE DUMP KENT, SCARP WENT 10-12 M BEHIND CREST TO NATIVE GROUND

**AIR PHOTOS**

- NUMBERS: M/A
- REMARKS: ORTHOPHOTO ENLARGEMENT

**GROUND PHOTOS:**

- TOE, SEE FIGURE 1P

**SOURCE OF DATA:**

- FCL REPORT JUNE 24, 1983
- GOLDEN ASSOCIATES REPORT 812-1258

**Compiled by:** A. Kent
**Updated by:** / /
PROFILE FOR DATA FILE # 1
FCL BROWNIE SPOIL - F GULLY
FAILURE DATE: JUN. 11, 1983

Golder Associates

Figure 1 S
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

<table>
<thead>
<tr>
<th>LOCATION</th>
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</tr>
</thead>
<tbody>
<tr>
<td>EVENT NUMBER</td>
<td>3</td>
</tr>
<tr>
<td>MINE NAME</td>
<td>FCL</td>
</tr>
<tr>
<td>DUMP DESIGNATION</td>
<td>BROWNIE SPOIL D &amp; E GULLY</td>
</tr>
<tr>
<td>LOCATION</td>
<td>EAGLE MOUNTAIN</td>
</tr>
</tbody>
</table>

PRE-FAILURE CONDITION

| CREST ELEVATION | 2305 M |
| TOE ELEVATION   | 2057 M |
| DUMP FACE HEIGHT | 216 M |
| QUALITY OF WASTE | THIN COLLUVIUM ON ROCK |

FOUNDATION - TOE SLOPE: 27 Deg S toe
- PROFILE: TYPE A
- MATERIAL: THIN COLLUVIUM ON ROCK
- PRECURSING ACTIVITY: ACTIVE

FAILURE DATA

| DATE       | 09/21/84 |
| WEATHER    | 88 MM PRECIP IN SEPT. |
| FAILURE TRIGGER | VERY STEEP TERRAIN |

PROPAGATION: DISTAL PORTION SPREAD

RUNOUT DATA

| SURFACE TOPOGRAPHY - ORIGINAL | 1:2000 |
| PRE - FAILURE               | FCL REPORT SHOWS CREST |
| POST - FAILURE              | FCL REPORT SHOWS SLIDE LIMITS |
| FAILURE VOLUME              | 500 CUBIC METRES X 1000 |
| RUN-OUT DISTANCE            | 640 M, FROM TOE |
| RUNOUT SHAPE                | LINEAR |
| RUNOUT PATH SURFICIAL SOIL  | COLLUVIUM |
| SPECIAL FEATURES            | PREVIOUS SLIDE |
| TYPICAL TRANSVERSE SECTION  | PARTLY CONFINED |
| NATURE OF RUNOUT DEBRIS     | VELOCITY ESTIMATE |

COMMENTS: NOTE PREVIOUS FAILURE IN (E) GULLY IN JUNE 83

AIR PHOTOS
- NUMBERS: N/A
- REMARKS: ORTHOPHOT ENLARGED AVAILABLE

GROUND PHOTOS: REFER TO FIGURE 1P

SOURCE OF DATA: FCL INTERNAL REPORT

| COMPILED BY | A. KENT |
| DATE        | 08/30/91 |
| UPDATED BY  |        |
| DATE        |         |
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 5
MINE NAME: FCL
DUMP DESIGNATION: BROWNIE GULLY F
LOCATION: EAGLE MOUNTAIN PROJECT

PRE-FAILURE CONDITION
CREST ELEVATION: 2315 M
TOE ELEVATION: 2100 M
DUMP FACE HEIGHT: 210 M
QUALITY OF WASTE:
FOUNDATION / TOE SLOPE: 28 DEG
- PROFILE: A/B
- MATERIAL: TILL
PRECEEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 07/24/84
WEATHER:
FAILURE TRIGGER: GROUNDWATER PREVIOUSLY SEEN IN TOE REGION
PROPAGATION: FAILURE DID NOT REACH CREST

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:2000
PRE - FAILURE: REF FCL REPORT
POST - FAILURE: REF FCL REPORT
FAILURE VOLUME: 330 MOVES METRES X 1000
RUNOUT DISTANCE: 780 M. FROM TOE
RUNOUT SHAPE: N/A
RUNOUT PATH SURFICIAL SOIL: COLLOVUM
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION: CONFINED
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: NO DUMPING IN 10 DAYS PRIOR. NOTE THAT FILE 3 SHOWS F Gully SLIDE TOE, HAS REACHED MAIN CREEK.

AIR PHOTOS:
- NUMBERS: N/A
- REMARKS: ORTHOSHOT ENLARGED, REFER TO IN FIGURE 6

GROUND PHOTOS:

SOURCE OF DATA:
FCL INTERNAL REPORT (NOT DATED)
GA 812-1258

COMPILED BY: A. KENT
DATE: 08/30/91
UPDATED BY:
DATE: / /
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 6
MINE NAME: FCL
DUMP DESIGNATION: BROWIE "H"
LOCATION: EAGLE MOUNTAIN PROJECT

PRE-Failure CONDITION
CREST ELEVATION: 2280 M
TOE ELEVATION: 2085 M
DUMP FACE HEIGHT: 195 M
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 24 DEG
- PROFILE: TYPE A
- MATERIAL: COLUVIUM ON ROCK
PRECEDING ACTIVITY: ACTIVE

Failure Data
DATE: 08/16/85
WEATHER: 50 MM RAIN PRIOR 2 WEEKS
FAILURE TRIGGER: UPPER SLOPE VERY STEEP, SPILLING STOPPED AUG. 15, CREST OVERSTEPP AND TOE RULING.
PROPAGATION: GRADUAL, TOE CREPT ALONG CREEK.

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:2000
PRE - FAILURE: POST - FAILURE:
FAILURE VOLUME: 140 CURRIC METRES X 1000
RUN-OUT DISTANCE: 610 M FROM TOE
RUNOUT SHAPE: LINEAR/SEE COMMENT
RUNOUT PATH SURFICIAL SOIL: COLLUVIUM
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION: PART CONFINED
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: MOST OF SPOIL DERIVED FROM ADJACENT SPOIL (A) TO NORTH SINCE TOO STEEP TO INITIATE IN DILLY (B) ITSELF. ADVANCED 800 M INITIALLY, THEN ADVANCED FURTHER 150 M DOWN CREEK.

AIR PHOTOS - NUMBERS: N/A
- REMARKS: ORTHOSLIP ENLARGEMENT AVAILABLE
GROUND PHOTOS:

SOURCE OF DATA: FCL REPORT SEPT. 25, 1985

COMPILED BY: A. KENT
UPDATED BY:
DATE: 08/30/91
DATE:
MINING WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 7
MINING NAME: YCL
DUMP DESIGNATION: "Y" SPOIL
LOCATION: EAGLE MOUNTAIN PROJECT

PRE-FAILURE CONDITION
CREST ELEVATION: 2300 m
TOE ELEVATION: 2100 m
DUMP FACE HEIGHT: 200 m
QUALITY OF WASTE: FOUNDATION = TOE SLOPE: 27 DEG
- PROFILE: TYPE A
- MATERIAL: COLLUVIUM ON ROCK
PRECEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 06/29/85
WEATHER: NOT A FACTOR
FAILURE TRIGGER: TOE RELEASE, FOLLOWING PROMINENT BULGE IN PRECEDING 2 WEEKS.
PROPAGATION: FAILURE DEBRIS DID NOT RUN OUT INTO SLIDE DEBRIS FROM ADJACENT GULLY (F)

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:2000
PRE - FAILURE:
POST - FAILURE:
FAILURE VOLUME: 50 CUBIC METRES x 1000
RUN-OUT DISTANCE: 310 m, FROM TOE
RUNOUT SHAPE: PATH NOT DEFINED
RUNOUT PATH SURFICIAL SOIL: COLLUVIUM ON TILL
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION: PART CONFLORED
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: CROSS SECTION LOCATION AND POSITION OF CREST AND TOE ARE ESTIMATES
SINCE NO DATA AVAILABLE, DUMPING TERMINATED JUNE 27.

AIR PHOTOS - NUMBERS: N/A
- REMARKS: ORTHOPHOTO ENLARGED AVAILABLE

GROUND PHOTOS:

SOURCE OF DATA: FORGING LETTER TO MINING INSPECTION

COMPILED BY: A. KENT  UPDATED BY: / /
MINER WASTE DUMP FAILURE
RUNOUT DATA SUMMAR

LOCATION
EVENT NUMBER: 11
MINE NAME: FCL
DUMP DESIGNATION: NEW CREEK BETWEEN G & H GULLIES
LOCATION: EAGLE MOUNTAIN

PRE-Failure CONDITION
CREST ELEVATION: 2270 M
TOE ELEVATION: 2010 M
DUMP FACE HEIGHT: 260 M
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 25 DEG
- PROFILE: TYPE A
- MATERIAL: COLLUVIUM ON ROCK
PRECEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 09/16/85
WEATHER: 36 MM OF RAIN WITHIN 6 DAYS
FAILURE TRIGGER: VERY STEEP TERRAIN, PROMINENT SLUDGE PRECEDING WEEK.
PROPAGATION: SUSPECT SLOW

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 14400
PRE - FAILURE: N/A
POST - FAILURE: N/A
FAILURE VOLUME: 225 M3 CURRIC METRES X 1000
RUN-OUT DISTANCE: 560 M, FROM TOE
RUNOUT SHAPE: LINEAR
RUNOUT PATH SURFICIAL SOIL: COLLUVIUM
SPECIAL FEATURES: PRE-EXISTING SLIDE DEBRIS
TYPICAL TRANSVERSE SECTION: UNCONFIRMED
NATURE OF RUNOUT DEBRIS: VELOCITY ESTIMATE:

COMMENTS: NOTE THAT DEBRIS SLIDE OVER TOP OF PRE-EXISTING SLIDE DEBRIS.
SUSPECT THAT FAILURE GRADUAL, NOT RAPID.

AIR PHOTOS - NUMBERS: N/A
- REMARKS: ORTHOSHOT ENLARGEMENT AVAILABLE
GROUND PHOTOS:

SOURCE OF DATA: FC LETTER TO INSPECTOR OF MINES (OCT 8/85). SEE JUN 11/83 FILE FOR ORIGINAL TOPOGRAPHY (RENT). ALSO SEE GEN BROWNIE FILE.

COMPILED BY: A. KENT
DATE: 05/03/93
UPDATED BY: / /

Golder Associates

PROFILE FOR DATA FILE # 11
FCL BROWNIE GULLY GALLERY 1985
Note: Profile estimated based on written description (FCI report).
LOCATION
EVENT NUMBER: 162
MINE NAME: FCL
DUMP DESIGNATION: F. GULLY
LOCATION: BROWNIE

PRE-Failure Condition
CREST ELEVATION: 2350 M
TOE ELEVATION: 2180 M
DUMP face HEIGHT: 170 M
QUALITY OF WASTE:
FOUNDATION - TOE SLOPE: 33 DEG
PROFILE: A/C
MATERIAL: COLLOUVIL/ROCK
PRECEDING ACTIVITY:

FAILURE DATA
DATE: 06/01/83
WEATHER:
FAILURE TRIGGER: STEEP FOUNDATION

PROPAGATION:

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL:
PRE-Failure:
POST-Failure:
FAILURE VOLUME: N.A.
RUN-OUT DISTANCE: 670 M FROM TOE
RUNOUT SHAPE: CURVED
RUNOUT PATH SURFICIAL SOIL:
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION:
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS:

AIR PHOTOS:
- NUMBERS:
- REMARKS: ORTHOSHOT AVAILABLE
GROUND PHOTOS:

SOURCE OF DATA:

COMPILED BY: A. KENT
DATE: 08/30/91
UPDATED BY:
DATE: / /
APPENDIX II

Westar Mining Ltd.
Greenhills Mine
East Spoil
Runout Study Data Base #NA
May 30, 1985
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? No.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? No remedial action was required.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

   Rating: No Interaction

7. Do major storms or precipitation events cause problems? No effects on water quality from slide material.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? No.
   Rating: No Interaction

2. Did runout exit the property? No.
   Rating: No Interaction

3. Were mine operations effected? No effects.
   Rating: No Interaction

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction

5. Did runout debris adversely effect the ultimate dump stability or capacity? No.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? Waste material dump extended onto failure debris.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? No.
   Rating: No Interaction
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION:
EVENT NUMBER: 75
MINE NAME: WESTAR
DUMP DESIGNATION: BANK PIT DUMP
LOCATION: GREENHILLS

PRE-Failure CONDITION:
CREST ELEVATION: 2158 M
TOE ELEVATION: 2000 M
DUMP FACE HEIGHT: 158 M
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 27.5 DEG
- PROFILE: A
- MATERIAL: COLLUVIUM WITH 0.6 M OF SNOW
PRECEEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 05/20/83
WEATHER: DRY, RIVER LEVEL LOW, COLD
FAILURE TRIGGER: STEEP FOUNDATION, POOR WASTE ROCK QUALITY, AGRAGATED BY SNOW
OVERSTEEPENED FACE NEAR CREST
PROPAGATION: STURZSTROM

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:5000 (COMPRESS RE-DRAWN FROM NATURAL)
PRE - FAILURE: OUTLINE ONLY
POST - FAILURE: OUTLINE ONLY
FAILURE VOLUME: 360 CURBIC METRES X 1000
RUN-OUT DISTANCE: 850 M. FROM TOE
RUNOUT SHAPE: SLIGHT DEFLECTION
RUNOUT PATH SURFICAL DOIL: FROZEN COLLUVIUM
SPECIAL FEATURES:
TYPICAL TRANVERSE SECTION: PARTIALLY CONFINED
NATURE OF RUNOUT DEBRIS: POOR, WEATHERED
VELOCITY ESTIMATE: METER FROM RUNUP

COMMENTS: DUMP INACTIVE 8 DAYS PRECEDING FAILURE. CALCULATION OF VELOCITY FROM RUN UP OPPOSITE VALLEY SLOPE.

AIR PHOTOS - NUMBERS: G.A.S.I. W9015-2-23
REMARKS:
GROUND PHOTOS: AVAILABLE

SOURCE OF DATA:
WESTAR GREENHILLS MEMO MAR 29/83 BY D. PARSONS. VELOCITY CALC'S ATTEMPTED

COMPILED BY: A. KENT
UPATED BY: DATE: 10/30/91
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 76
MINE NAME: WESTAR
DUMP DESIGNATION: 2200 EAST DUMP
LOCATION: GREENHILLS

PRE-FAILURE CONDITION
CREST ELEVATION: 2207 M
TOE ELEVATION: 2039 M
DUMP FACE HEIGHT: 168 M
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 14
- PROFILE: CONCAVE
- MATERIAL: COLLUVIUM
PRECEEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 05/11/83
WEATHER: PREMATURE BEGIN BUT NOT AT PEAK
FAILURE TRIGGER: EXCESS P.W.P. IN COLLUVIUM, BACK ANALYSIS DUMPING IN PROGRESS AT TIME FAILED, QUASI-CIRCULAR SLUMP.
PROPAGATION: NOT CONSIDERED TO BE STURGEON

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:2500 (WESTAR DWG. 301, MAY/83)
PRE - FAILURE: SHOWN ON ABOVE DWG.
POST - FAILURE: REFER TO PROFILE ON FIGURE 3
FAILURE VOLUME: 700 CUBIC METRES X 1000
RUNOUT DISTANCE: 380 M. FROM TOE
RUNOUT SHAPE: MOSTLY LINEAR
RUNOUT PATH SURFICIAL SOIL: COLLUVIUM ON ROCK
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION: P.C.
NATURE OF RUNOUT DEBRIS: PROBABLY RELATIVELY POOR
VELOCITY ESTIMATE:

COMMENTS: WESTAR BACK ANALYSIS INFERS EXCESS PORE PRESSURE AS CAUSE OF FAILURE

AIR PHOTOS: NUMBERS: G.A.S.E. WP9015-2-23
REMARKS:
GROUND PHOTOS:
SOURCE OF DATA: WESTAR INTERNAL REPORT MAY/83, REF. 2.11 #27

COMPILRED BY: A. KENT
DATE: 08/30/91
UPDATED BY: / /
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 79
MINE NAME: WESTAR
DUMP DESIGNATION: EAST WASTE DUMP (2560 DUMP)
LOCATION: GREENHILLS

PRE-FAILURE CONDITION
CEST ELEVATION: 2145 M
TOE ELEVATION: 1905 M
DUMP FACE HEIGHT: 160 M
QUALITY OF WASTE: POOR
FOUNDATION - Toe SLOPE: 15 DEG
- PROFILE: TYPE A
- MATERIAL: THIN COLLUVIUM ON BEDROCK
PREVIOUS ACTIVITY: ACTIVE

FAILURE DATA
DATE: 07/12/86
WEATHER: WASH, 12MM IN PAST WEEK, 32MM IN 2 WKS
FAILURE TRIGGER: FOUNDATION SEEPAGE, POOR QUALITY SOIL STEEP TOPOGRAPHY
PROPAGATION: RAPID

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:5000
PRE - FAILURE: 1:2500 (ORIGINAL TOPO)
POST - FAILURE: 480 CUBIC METRES X 1000
RUN-OUT DISTANCE: 530 M FROM TOE
RUNOUT SHAPE: LINEAR
RUNOUT PATH SURFICIAL SOILS: SLIDE DEBRIS
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION: P.C.
NATURE OF RUNOUT DEBRIS: POOR

COMMENTS: MOST OF RUNOUT OVER TOP OF PREVIOUS SLIDE DEBRIS FROM MAY 30/85 SLIDE

AIR PHOTOS - NUMBERS: G.A.S.I. W9015-2-23
- REMARKS: REFER FIGURE 7RP
GROUND PHOTOS: N/A
SOURCE OF DATA:
GOLDER FILE 862-1400
GOLDER FILE 920-120, 120B

COMPILED BY: A. KENT
DATE: 08/30/91
UPDATED BY: /
DATE: / /
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 80
MINE NAME: WESTAR
DUMP DESIGNATION: EAST WASTE DUMP (2140 DUMP)
LOCATION: GREENHILLS

PRE-FAILURE CONDITION
CREST ELEVATION: 2144 M
TOE ELEVATION: 2020 M
DUMP FACE HEIGHT: 119 M
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 35
- PROFILE: B
- MATERIAL: FROZEN COLLUVIUM ON ROCK
PROCEEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 02/12/87
WEATHER: 
FAILURE TRIGGER: POOR QUALITY ROCK, FOUNDATION CONDITIONS MAY HAVE BEEN AFFECTED BY PREVIOUS FAILURES, VERY STEEP FOUNDATION TERRAIN.
PROPOSITION: NOT KNOWN

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:500
PRE - FAILURE:
POST - FAILURE: 1:2500 PRE OR POST UNEVEN
FAILURE VOLUME: 580 CUBIC METRES X 1000
RUNOUT DISTANCE: 580 M. FROM TOE
RUNOUT SHAPE: LINEAR
RUNOUT PATH SURFICIAL SOIL: WET FINE GRAINED DEBRIS FROM PREVIOUS SLIP
SPECIAL FEATURES: PREVIOUS SLIP
TYPICAL TRANSVERSE SECTION: P.C.
NATURE OF RUNOUT DEBRIS: VELOCITY ESTIMATE:

COMMENTS:

AIR PHOTOS - NUMBERS: G.A.S.L. W9015-2-23
GROUNDS PHOTOS: AVAILABLE
SOURCE OF DATA: GOLDER QUARTERLY REVIEW 862-1409
GOLDER ASSOCIATES 792-1120

COMPILED BY: A. KENT
UPDATED BY: / / DATE: 08/30/91

PROFILES FOR DATA FILE # 80
GREENHILLS EAST WESTAR DUMP DUMP SURFACE
GREENHILLS EAST POINT 2140 DUMP DUMP SURFACE
GREENHILLS EAST POINT 2140 DUMP CENTRE DUMP SURFACE
GREENHILLS EAST POINT 2140 DUMP NORTH DUMP SURFACE
GOLDER ASSOCIATES 792-1120
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? Very little effect on receiving waters.
   Rating: Negligible

2. Were there changes in TSS in the receiving waters following the event? Very little effect on receiving water.
   Rating: Negligible

3. Was the remedial action taken after the event effective? No remedial action was required.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

   Rating: No Interaction

7. Do major storms or precipitation events cause problems? Slight elevation of TSS and flows.
   Rating: Minor

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction

MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? No.
   Rating: No Interaction

2. Did runout exit the property? No.
   Rating: No Interaction

3. Were mine operations effected? Yes, temporary interruptions to mine waste dumping.
   Rating: Moderate

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction

5. Did runout debris adversely effect the ultimate dump stability or capacity? Yes, organic material at the toes caused later instability and resulted in 1989 failure.
   Rating: Moderate

6. Have changes in failure debris occurred with time? No, subsequent failure has covered debris.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction
PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? No.
   Rating: No Interaction

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**MINE WASTE DUMP FAILURE**

**RUNOUT DATA SUMMARY**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>EVENT NUMBER</th>
<th>MINE NAME</th>
<th>DUMP DESIGNATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>89</td>
<td>WESTAR GREENHILLS</td>
<td>2100 PLATFORM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NORTH DUMP</td>
</tr>
</tbody>
</table>

**PRE-FAILURE CONDITION**

| CREST ELEVATION | 2100 M |
| TOE ELEVATION   | 1950 M |
| DUMP FACE HEIGHT| 150 M  |

**FOUNDATION**

- TYPE: CULTIVATION ON ROCK
- PROFILE: B/A
- MATERIAL: COLLUVIUM ON ROCK

**PRECEDING ACTIVITY:** ACTIVE

**FAILURE DATA**

- DATE: 07/01/85
- WEATHER: NORMAL
- FAILURE TRIGGER: STEEP FOUNDATION, HIGH RATE OF LOADING AND POOR ROCK QUALITY.
- PROPAGATION: HIGH LOADING RATE ON SURFICIAL ORGANIC SOIL; FLOW DOAH VALLEY.

**RUNOUT DATA**

- SURFACE TOPOGRAPHY - ORIGINAL: 1:5000
- PRE - FAILURE: OUTLINE ON ORIGINAL
- POST - FAILURE: OUTLINE ON ORIGINAL
- FAILURE VOLUME: 300 CUBIC METRES X 1000
- RUN-OUT DISTANCE: 1200 M. FROM TOE
- RUNOUT SHAPE: DEFL.
- RUNOUT PATH SURFICIAL SOIL: ORGANIC, SATURATED
- SPECIAL FEATURES: N/A
- TYPICAL TRANSVERSE SECTION: CONFINED
- NATURE OF RUNOUT DEBRIS: VELOCITY ESTIMATE

**COMMENTS:** WEAK VALLEY FLOOR SOIL DISTURBED AND DISPLACED 350 M BEYOND WASTE ROCK DISTAL REGION.

**AIR PHOTOS**

- NUMBERS: N/A
- REMARKS: N/A

**GROUND PHOTOS:** AVAILABLE

**SOURCE OF DATA:**

- GOLDER ASSOCIATES REPORT 862-1409
- GOLDER ASSOCIATES REPORT 852-1551

**COMPILED BY:** A. KENT
**DATE:** 08/30/91
**UPDATED BY:**
**DATE:** / /
Westar Mining Ltd.
Greenhills Mine
North Spoil
Runout Study Data Base #156
November 22, 1989

ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? Yes, elevated TSS values for short duration.
   Rating: Minor

2. Were there changes in TSS in the receiving waters following the event? Yes, elevated TSS values for short duration.
   Rating: Minor

3. Was the remedial action taken after the event effective? Yes.
   Rating: Minor

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

   Rating: No Interaction

7. Do major storms or precipitation events cause problems? No adverse effects.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? Yes, it could have reached the Fording River.
   Rating: Major

MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? Yes.
   Rating: Major

2. Did runout exit the property? No.
   Rating: No Interaction

3. Were mine operations affected? Yes, mine waste dumping interrupted and resumed under careful management and in specific sequence.
   Rating: Moderate

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: Moderate

5. Did runout debris adversely affect the ultimate dump stability or capacity? Yes, required dumping at specified rates in specified places on the dump.
   Rating: Moderate

6. Have changes in failure debris occurred with time? Yes, channel is well established and stable.
   Rating: Negligible

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction
PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? No.
   Rating: No Interaction
PROFILE FOR DATA FILE # 156
WESTAR GREENHILLS, NORTH DUMP 2031m
FAILURE DATE: NOV. 22, 1989

Golder Associates
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? TSS levels elevated to 72,464 mg/L in Thompson Creek. TSS levels of 368 mg/L entering receiving waters (Elk River).
   Rating: Moderate

2. Were there changes in TSS in the receiving waters following the event? TSS values were below permit levels within two days.
   Rating: Negligible

3. Was the remedial action taken after the event effective? No action taken.
   Rating: No Interaction

4. Were fisheries resources impacted? No fish in Thompson Creek.
   Rating: No Interaction

5. Were wildlife resources impacted? No wildlife concerns noted.
   Rating: No Interaction

   Rating: No Interaction

7. Do major storms or precipitation events cause problems? Storms resulted in chronic TSS loads in Thompson Creek prior to but not because of the failure event.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? Yes.
   Rating: Minor
2. Did runout exit the property? No.
   Rating: No Interaction
3. Were mine operations affected? Temporary interruption to mine waste dumping.
   Rating: Negligible
4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction
5. Did runout debris adversely affect the ultimate dump stability or capacity? Yes.
   Rating: Moderate
6. Have changes in failure debris occurred with time? Recurring release of material into Thompson Creek.
   Rating: Moderate
7. Was reclamation of slide debris required? Yes, reclamation was implemented.
   Rating: Moderate
8. Was cleanup impractical or prohibitively expensive? Cleanup not necessary once sediment ponds were operating.
   Rating: No Interaction
9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction
2. Was there damage to the public infrastructure? No.
   Rating: No Interaction
3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction
4. Could the consequences to the public have been worse?
   No. Rating: No Interaction
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? No.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? No.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

   Rating: No Interaction

7. Do major storms or precipitation events cause problems? No adverse effects.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction

9. MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? No.
   Rating: No Interaction

2. Did runout exit the property? No.
   Rating: No Interaction

3. Were mine operations effected? Yes, major interruptions due to loss of life.
   Rating: Major

4. Was there damage to the mine infrastructure or equipment? Yes, temporary closure of the pit access road.
   Rating: Minor

5. Did runout debris adversely effect the ultimate dump stability or capacity? No, dump was inactive.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? No changes.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No, minor job to reopen the pit access road.
   Rating: Negligible

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction
PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? Yes, one life lost.
   Rating: Major

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No general public reaction; reaction from immediate family and friends.
   Rating: Minor

4. Could the consequences to the public have been worse? Yes, potentially more than one worker could have been killed.
   Rating: Major

APPENDIX III
Westar Mining Ltd.
Balmer Mine
Harnier Knob Dump
(Six Mile Creek
Runout Study Data Base #43
May 31, 1971
ENVIROMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? Yes, slide entered the Elk River but did not block the river.
   
   Rating: Major

2. Were there changes in TSS in the receiving waters following the event? Yes, increased TSS in receiving waters.
   
   Rating: Major

3. Was the remedial action taken after the event effective? No, remedial action took nine years to implement.
   
   Rating: Major

4. Were fisheries resources impacted? Possible, no impact in Six Mile Creek but likely in the Elk River.
   
   Rating: Moderate

5. Were wildlife resources impacted? Yes. Temporary loss of several hectares of wildlife habitat in the Elk valley due to placement of energy dissipation berms.
   
   Rating: Negligible

6. Were vegetation/forestry resources impacted? Yes, moderate impact to vegetation on stream banks.
   
   Rating: Moderate

7. Do major storms or precipitation events cause problems? Yes, every storm increases erosion in Six Mile Creek.
   
   Rating: Moderate

8. Did the event have the potential for producing more significant environmental consequences? Yes, possible if mudflows reach the Elk river more frequently.
   
   Rating: Moderate
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? Yes.
   Rating: Major

2. Did runout exit the property? Yes.
   Rating: Major

3. Were mine operations affected? No interruptions.
   Rating: No Interaction

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction

5. Did runout debris adversely affect the ultimate dump stability or capacity? Yes.
   Rating: Moderate

6. Have changes in failure debris occurred with time? Yes, chronic erosion following event.
   Rating: Moderate

7. Was reclamation of slide debris required? Yes, reclamation was required for purpose of mitigation.
   Rating: Moderate

8. Was cleanup impractical or prohibitively expensive? No, cleanup was initiated following the slides.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? Yes, crossed CNI Road, CP Rail.
   Rating: Moderate

3. Was there public reaction to the failure immediately following the event and/or over the long term? No recorded reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? Yes, if there were more traffic on CNI Road or CP Rail line.
   Rating: Moderate
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 43
MINE NAME: KAISER RESOURCES
DUMP DESIGNATION: HAMER KNOB
LOCATION: SIX MILE CREEK

PRE-FAILURE CONDITION
CREST ELEVATION: 6600 FT
TOE ELEVATION: 6250 FT
DUMP FACE HEIGHT: 400 FT
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 23 DEG
- PROFILE: A
- MATERIAL: COLUVIUM/ROCK
PRECEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 05/31/71
WEATHER: SPRING RUNOFF, WET.
FAILURE TRIGGER: STEEP FOUNDATION, POSSIBLE WATER PRESSURE. CREEP/SLUMP INITIALLY.
PROPA GATION: "MUD FLOW" DOWN PRE-EXISTING CHANNEL.

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: FEBRUARY 1965 AVAILABLE
PRE - FAILURE:
POST - FAILURE: APRIL 1978
FAILURE VOLUME: N.A.
RUN-OUT DISTANCE: 3200 M. FROM TOE
RUNOUT SHAPE: DEFLECTED
RUNOUT PATH SURFICIAL SOIL:
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION:
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: EXPOSED DEBRIS IN RUNOUT CHANNEL IS WASTE ROCK.

AIR PHOTOS: NUMBERS: FLL 8049-L3-43
- REMARKS:
GROUND PHOTOS: AVAILABLE
SOURCE OF DATA: GOLDER ASSOCIATES V77151

COMPILED BY: A. KENT
DATE: 08/30/91
UPDATED BY:
DATE: / /
APPENDIX IV

Crows Nest Resources Ltd.
Line Creek Mine
West Line Creek Valley Slide
Runout Study Data Base #62
July 1, 1982
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No, no influx of TSS to Line Creek.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? Yes, water cleared up within two days of regaining flow.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? No remedial action was required.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

   Rating: No Interaction

7. Do major storms or precipitation events cause problems? No adverse effects.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? Yes, the slide reached Line Creek and covered the sediment ponds.
   Rating: Minor
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? No.
   Rating: No Interaction

2. Did runout exit the property? No.
   Rating: No Interaction

3.Were mine operations effected? Temporary interruption to mine waste dumping.
   Rating: Negligible

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction

5. Did runout debris adversely effect the ultimate dump stability or capacity? No.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? Yes, debris is under the added waste.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? Yes, if runout reached Lined Creek and access road.
   Rating: Minor

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? No.
   Rating: No Interaction
APPENDIX V

Quintette Operating Corporation
Quintette Coal Mine
1660 Mesa ‘A’ Dump Slide
Runout Study Data Base #54
September 09, 1985
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No changes or increase in TSS downstream of slide.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? No changes; slide material acted as rock drain.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? No remedial action was required.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

6. Were vegetation/forestry resources impacted? Moderate impact to adjacent forest resources from burial and slash burning.
   Rating: Moderate

7. Do major storms or precipitation events cause problems? No adverse effects in terms of erosion or stability.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? Yes.
   Rating: Minor

2. Did runout exit the property? Yes.
   Rating: Minor

3. Were mine operations affected? Temporary interruption to mine waste dumping and loss of power.
   Rating: Moderate

4. Was there damage to the mine infrastructure or equipment? Yes; Mesa A sediment pond inlet destroyed and emergency spillway was blocked, loss of 69 kV powerline, and new line constructed on top of dumps.
   Rating: Major

5. Did runout debris adversely effect the ultimate dump stability or capacity? No adverse effects to dump stability or capacity.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? No changes.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation required; material was too coarse and fertilizer application a concern. Patches of liner material were scheduled for reclamation.
   Rating: Minor

8. Was cleanup impractical or prohibitively expensive? Yes, cleanup of vegetation debris along slide fringe became an expensive, difficult task.
   Rating: Moderate

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life?
   No. Rating: No Interaction

2. Was there damage to the public infrastructure?
   No. Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse?
   No. Rating: No Interaction
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 54
MINE NAME: QUINTETE
DUMP DESIGNATION: 1660 M DUMP
LOCATION: MARMOT

PRE-FAILURE CONDITION
WEST ELEVATION: 1660 M
TOE ELEVATION: 1420 M
DUMP FACE HEIGHT: 240 M
QUALITY OF WASTE: WET FINES PRESENT
FOUNDATION TOE SLOPE: 18-20 DEG
- PROFILE: A CONCAVE
- MATERIAL: THIN COLLUVIUM ON ROCK
PRECEEDING ACTIVITY: INACTIVE

FAILURE DATA
DATE: 09/09/85
WEATHER: 25MM RAIN PRECEDING WEEK & SOME SNOW
FAILURE TRIGGER: SEEPAGE IN TOE REGION, (1982 OBSERVATION) TOGETHER WITH FINE GRAINED ROCK, DUMP ITSELF NOT ACTIVE BUT ADJACENT DUMPS ACTIVE.
PROPAGATION: "MUD FLOW" OF WET FINE GRAINED WASTE

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIINAL: 1:5000
PRE - FAILURE: K/A
POST - FAILURE: 1:5000 BASED ON SEP 10/85 FLIGHT
FAILURE VOLUME: 2500 CUBIC METRES X 1000
RUN-OUT DISTANCE: 2200 M. FROM TOE
RUNOUT SHAPE: DELECTED
RUNOUT PATH SURFICIAL SOILS: COLLUVIUM/TILL OR BEDROCK
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION: CONFINED
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: MAY BE FEASIBLE TO CALCULATE VELOCITY AT DEFLECTION POINT.

AIR PHOTOS - NUMBERS: G.A.S.I. 8806025-3-95
GROUND PHOTOS: AVAILABLE (SEP/87)
SOURCE OF DATA: PITEAU FILE 925-15, REPORT OCT 28/85

COMPILED BY: A. KENT UPATED BY: / /
DATE: 08/30/91 DATE: / /
ENVIROMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No changes or increase in TSS downstream of slide.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? Yes, slide material acted as rock drain clearing up TSS levels. No adverse changes.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? No remedial action was required.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

6. Were vegetation/forestry resources impacted? Very minor impact to forestry resources.
   Rating: Negligible

7. Do major storms or precipitation events cause problems? No adverse effects.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? Yes.
   Rating: Negligible

2. Did runout exit the property? No.
   Rating: No Interaction

3. Were mine operations effected? Temporary interruption to mine waste dumping and power outage.
   Rating: Major

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction

5. Did runout debris adversely effect the ultimate dump stability or capacity? No.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? No changes.
   Rating: No Interaction

7. Was reclamation of slide debris required? Yes, below ultimate dump limit only.
   Rating: Negligible

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? No.
   Rating: No Interaction
MINE WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION

EVENT NUMBER: 113
MINE NAME: GUINTETTE
DUMP DESIGNATION: MARNO
LOCATION: MARNO

PRE-FAILURE CONDITION

CREST ELEVATION: 1690 M
TOE ELEVATION: 1450 M
DUMP FACE HEIGHT: 240 M
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 21 DEG
- PROFILE: A CONCAVE
- MATERIAL: COLLUVIUM, SLIDE DEBRIS
PRECEEDING ACTIVITY: ACTIVE

FAILURE DATA

DATE: 10/04/85
WEATHER: 200MM OVER PRECEDING 2 MONTHS
FAILURE TRIGGER: SAME AREA AS PREVIOUS AUG/85 EVENT, Y OLD SHOW
PROPAGATION: NOTE BUILDING OF BLOCKS OF GLACIAL TILL

RUNOUT DATA

SURFACE TOPOGRAPHY - ORIGINAL: 1:5000
PRE - FAILURE: CREST LOCATION KNOWN
POST - FAILURE: 3220 CUBIC METRES x 1000
FAILURE VOLUME: 1180 M. FROM TOE
RUNOUT SHAPE: LINEAR
RUNOUT PATH SURFICIAL SKILL: COLLUVIUM & TILL
SPECIAL FEATURES: TILL BLOCKS PUSHED UP
TYPICAL TRANSVERSE SECTION: UNCONFINED
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: WET WEATHER, POOR QUALITY ROCK AND STEEP FOUNDATION. PREVIOUS SLIDE IN SAME AREA.

AIR PHOTOS - NUMBERS: G.A.S.L. 0800025-3-95
- REMARKS: REFER FIGURE 5A
GROUND PHOTOS:

SOURCE OF DATA: PETERS REPORT 923-15 (NOV/85)

COMPILLED BY: A. KENT
UPDATED BY: / /
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? No changes or increase in TSS downstream of slide.
   Rating: No Interaction

2. Were there changes in TSS in the receiving waters following the event? Yes, but only in sediment pond, not in Wolverine River. TSS improved.
   Rating: No Interaction

3. Was the remedial action taken after the event effective? No remedial action was required.
   Rating: No Interaction

   Rating: No Interaction

5. Were wildlife resources impacted? No.
   Rating: No Interaction

6. Were vegetation/forestry resources impacted? Very minor impact to forestry resources.
   Rating: Negligible

7. Do major storms or precipitation events cause problems? No adverse effects.
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No potential problems.
   Rating: No Interaction
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? No.
   Rating: No Interaction

2. Did runout exit the property? No.
   Rating: No Interaction

3. Were mine operations affected? Temporary interruption to mine waste dumping.
   Rating: Negligible

4. Was there damage to the mine infrastructure or equipment? No damage.
   Rating: No Interaction

5. Did runout debris adversely effect the ultimate dump stability or capacity? No.
   Rating: No Interaction

6. Have changes in failure debris occurred with time? No changes.
   Rating: No Interaction

7. Was reclamation of slide debris required? No reclamation planned until closure.
   Rating: No Interaction

8. Was cleanup impractical or prohibitively expensive? No cleanup required.
   Rating: No Interaction

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? No.
   Rating: No Interaction

3. Was there public reaction to the failure immediately following the event and/or over the long term? No reaction.
   Rating: No Interaction

4. Could the consequences to the public have been worse? No.
   Rating: No Interaction
MINING WASTE DUMP FAILURE
RUNOUT DATA SUMMARY

LOCATION
EVENT NUMBER: 157
MINE NAME: QUINTETTE
DUMP DESIGNATION: 1660 Area
LOCATION: Wolverine North

PRE-Failure Condition
CREST ELEVATION: 1660 M
TOE ELEVATION: 1600 M
DUMP FACE HEIGHT: 250 M
QUALITY OF WASTE: POOR
FOUNDATION - TOE SLOPE: 15 DEG
- PROFILE: V, SLIGHT CONCAVE
- MATERIAL: COLLUVIUM
PRECEDING ACTIVITY: ACTIVE

FAILURE DATA
DATE: 11/07/87
WEATHER: 10MM OCT 22 - NOV 3; 3MM NOV 3
FAILURE TRIGGER: SHEAR ON DUMP FOUNDATION CONTACT, WITH EXCESS PORE WATER PRESSURE.
RAINFALL A TRIGGER BUT FOR LOW DUE TO OTHER FACTORS
PROPAGATION: FOUNDATION SHEAR STRAIN GENERATED ADDITIONAL PORE PRESSURE

RUNOUT DATA
SURFACE TOPOGRAPHY - ORIGINAL: 1:5000
PRE - FAILURE: POSITION OF CHEST & TOE ONLY
POST - FAILURE: 11/25 (QCL DUG, 87-200-27-001)
FAILURE VOLUME: 5600 CUBIC METRES X 1000
RUNOUT DISTANCE: 2300 M. FROM TOE
RUNOUT SHAPE: DEFLECTED
RUNOUT PATH SURFICIAL SOIL: PART OLD SLIP DEBRIS/COLLUVIUM
SPECIAL FEATURES:
TYPICAL TRANSVERSE SECTION: PART CONFINED
NATURE OF RUNOUT DEBRIS:
VELOCITY ESTIMATE:

COMMENTS: USED AIR PHOTOS TO ESTIMATE EXTENT OF RUNOUT

AIR PHOTOS
- NUMBERS: 0903006.5-49...55,0806025.3-55,56 POST
- REMARKS: 0903006.6-30...37 POST, 0806023.26...32
GROUND PHOTOS:
SOURCE OF DATA: GOLDER ASSOCIATES 872-1265 FEB/88

COMPILED BY: A. KENEL
DATE: 06/30/91
UPDATED BY: 06/30/91
ENVIRONMENTAL CONSEQUENCES

1. Were there changes in the total suspended solids (TSS) in the receiving waters at the time of the event? Major increase in TSS in the Murray River.
   
   Rating: Major

2. Were there changes in TSS in the receiving waters following the event? TSS was significantly reduced within three days of the event and returned to background levels within 62 days.
   
   Rating: Moderate

3. Was the remedial action taken after the event effective? Deflection weir not very effective because of flood event immediately following the slide.
   
   Rating: Major

4. Were fisheries resources impacted? Yes, due to temporary flow reduction and loss of habitat.
   
   Rating: Moderate

5. Were wildlife resources impacted? No mention of impact on wildlife.
   
   Rating: Negligible

6. Were vegetation/forestry resources impacted? Yes, low impact due to loss of trees and upstream ponding.
   
   Rating: Minor

7. Do major storms or precipitation events cause problems? No adverse effects to slide material erosion or stability.
   
   Rating: No Interaction

8. Did the event have the potential for producing more significant environmental consequences? No, slide event could not have been worse.
   
   Rating: Major
MINE OPERATIONS CONSEQUENCES

1. Did runout exit the ultimate dump limits? Yes.
   Rating: Moderate

2. Did runout exit the property? Yes.
   Rating: Moderate

3. Were mine operations effected? Seriously effected due to loss of dump site, increased haulage to alternate site for one year while going through approval process for new site.
   Rating: Major

4. Was there damage to the mine infrastructure or equipment? Moderate damage, loss of sediment pond at toe of dump and forestry road blocked, no loss of equipment.
   Rating: Moderate

5. Did runout debris adversely effect the ultimate dump stability or capacity? Yes, dump site closed indefinitely.
   Rating: Major

6. Have changes in failure debris occurred with time? No changes.
   Rating: No Interaction

7. Was reclamation of slide debris required? Reclamation plan implemented.
   Rating: Moderate

8. Was cleanup impractical or prohibitively expensive? Yes, cleanup in the river was attempted but was impractical and expensive.
   Rating: Major

9. Could the consequences to mine operations have been worse? No.
   Rating: No Interaction

PUBLIC CONSEQUENCES

1. Was there personal injury or loss of life? No.
   Rating: No Interaction

2. Was there damage to the public infrastructure? Forestry road temporarily blocked, boat launch replaced.
   Rating: Negligible

3. Was there public reaction to the failure immediately following the event and/or over the long term? Very little public reaction.
   Rating: Negligible

4. Could the consequences to the public have been worse? Yes, loss of life could have occurred if slide had taken place during working hours.
   Rating: Major

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