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Exploration and Geological Services Division, Yukon Region

WHITEHORSE COPPER MINE RECLAMATION REVIEW YUKON TERRITORY

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WHITEHORSE COPPER MINE RECLAMATION REVIEW

Prepared for:

Indian and Northern Affairs Canada
Exploration & Geological Services
Mineral Resources Directorate
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Yukon Region
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Table of Contents

Introduction

Mining activity at the Whitehorse Copper Mine has resulted in a disturbed land area of approximately 800 acres, as shown on Figure 1. Within this area there are about 53 acres with active slope instability and subsidence associated with the mine and underground workings. The mine is located within the city limits of Whitehorse, about six miles from the city center. Although the mine has been decommissioned to a level acceptable to the mine inspector, there is still some concern for public safety. In addition, the current decommissioning plan is expected to result in the permanent loss of useful land from within the city limits. This report presents an assessment of the site conditions and options for reclamation to address these concerns.

The specific objectives of this project are to:

- estimate how long the slope deterioration process will continue,
- predict the final configuration of the area immediately surrounding the mine,
- identify options which could be considered to improve the public safety and land use issues, and,
- evaluate the options with respect to improving the reclamation configuration of other open pit mines.

Documentation

The following documents were reviewed in preparing this report:

- topographic map of Little Chief Deposit, 1 inch = 400 feet,
- Plans and sections of mine development and reclamation prepared by Gadsby Consultants Ltd. et al for Hudson Bay Mining and Smelting Co. Ltd., Sept. 1991,
- Whitehorse Copper Mine - Conceptual Decommissioning Plan, prepared by Gadsby Consultants Ltd. et al for Hudson Bay Mining and Smelting Co. Ltd.(HBM&S), Sept. 1991,
- The Whitehorse Copper Belt: Mining Exploration and Geology (1967 - 1980) by D. Tenny, DIAND., 1981,
- Air photographs taken in 1976 (approx. 1:20,000) and 1992 (approx. 1:10,000).

Background

The Whitehorse Copper Mine operated from 1967 to 1982. Copper ore was produced by open pit mining (1,128,500 tonnes between 1967 and 1969) and by underground mining (7,407,900 tonnes between 1973 and end of 1982) using block caving and sub-level retreat methods. Underground mining extended from about 2300 foot elevation down to 1400 foot elevation. The top of the ore zones were about 300 to 400 feet below original ground surface.

Reclamation has been carried out on an intermittent basis since mine closure and is now essentially complete. This work has included reclamation of the tailings impoundment, waste dumps and mill site area. Reclamation in the pit area has included backfilling of a caving area on the south side of the pit, capping or sealing of shafts and raises from the underground workings, and construction of berms on roadways to prevent access into the area.

Site Inspection

A site investigation was carried out on October 27, 1995 with Ms. Diane Emond and Mr. N. Prasad, a mine inspector who is very knowledgeable of the site. The site inspection consisted of a walking tour around the pit. Observations relative to the assessment of slope stability and reclamation options are presented below. The location of the observations as numbered are shown on Figure 2.

Observation 1, Cave area south of open pit;
Cave first broke through to surface in the early 1980's. The first breakthrough was a hole about 2m x 2m. This was backfilled; it subsequently reformed and was then backfilled a second time in the mid 1980's. No further signs of collapse have been observed in the last five years.

Observation 2, South edge of pit;
Tension cracks are present about 20 m back from the south crest of the pit, but not as far south as the caved area in item 1, above.

Observation 3, Pit bottom and east slope;
The pit bottom is dry. It is reported that there is a small pond in the bottom of the pit in some years. Tires and other mine waste which was dumped into the pit in 1984 or 1985 are still visible on the pit bottom. This implies that the ground movement on the east side of the pit has not involved downslope movement and filling of the pit bottom.

Observation 4, Subsiding area on east side of pit;
Ground movement on the east side of the pit has resulted in a blocky ground with numerous tension cracks. Based on mine records and air photographs, this movement commenced shortly after underground mining commenced in 1972. The limits of the subsiding area form a rough rectangle as indicated on Figure 2 and are described as follows. The northern boundary of the subsiding area is delineated by a prominent scarp which is up to 15 m high. It is reported that there are some tension cracks in the stand of trees north of this fault. The western limit of the area appears to roughly coincide with the original eastern crest of the pit. The south limit of the area appears to follow a projection of the south limit of the pit. The eastern limit of ground movement appears to be about 400 feet from the original edge of the pit.

Nearly all of the trees in the subsiding area are within a few degrees of vertical. None of the trees show curved trunks which would indicate that the ground has been tilting over a period of time. An original pit access road crossed this area at about the 2720 foot elevation. Remnants of this road suggest that vertical ground movement has been at least 150 feet.

Observation 5, Subsiding area north of pit;
Active subsidence is occurring over the ore zones north of the pit. Tilted trees, up to 30^0 from vertical are present and do not show any trunk curvature which implies that they have moved within the last year. Subsidence within this area is bounded by the east valley wall. The west valley wall is cracking and blocks are moving down slope.

At this time, only the east pit wall and adjoining segments of the south and north walls are experiencing instability. Essentially all of the south, west and north pit walls are stable. The only subsidence observed was that described above, east and north of the pit.

Some of the above observations can be seen in photographs one and two, attached.

Discussion

Little Chief Pit & Underground

Based on the lack of infilling of the pit bottom and the near vertical trees in the subsiding area east of the pit, it appears that all of the subsidence involves only vertical movement. Current topographic data regarding the surface of the subsiding area is not available, therefore the following is an estimate of the vertical extent of subsidence. The extent of vertical movement ranges from essentially zero at the eastern boundary (furthest from the pit) to 150 feet at the original edge of the pit, and about 50 feet on the northern boundary to about 40 feet on the southern limit. The average vertical movement of the whole subsiding area is estimated to be 60 feet.

A rough evaluation of the progression of the subsidence process and the potential for future ground movement can be made by evaluating the quantity of rock removed by mining relative to the amount of movement of the overlying rock to fill the void, as follows

Ore and dilution removed from the Little Chief ore zone was about 6,523,000 tonnes. Dilution was about 20%. D. Tenny reports the ore specific gravity of ore at 3.53 and waste at 2.91, to give a volume of 1,913,000 m^3 of rock removed from the mine. It is reported that the crown pillars above blocks 1 and 2 of the Little Chief zone collapsed during mining. These zones represent about 50 % of the rock recovered from the Little Chief or about 957,000 m^3. The caving and subsidence involves a well defined surface expression. Assume that the volume of rock above these zones is 120 m by 230 m by 91 m high and that vertical movement and swelling of this rock is required to replace the volume of removed rock and that rock swells about 20% upon caving. The volume filled by the swell is 502,000 m^3. The remaining 455,000 m^3 must be taken by the downward movement of the rock mass. The average vertical displacement of the block with a plan view of 120 m by 230 m is estimated to be about 16.5 m or 54 feet. This is consistent with the observed vertical movement of the ground surface.

The evaluation above is sufficient only to gain an order of magnitude estimate of the potential for future subsidence. Additional air photographs and survey records of the subsidence would be required in order to improve any prediction.

Based on the evaluation presented above, the majority of the subsidence associated with the upper blocks of ore in the Little Chief deposit has already occurred. Ongoing ground movement may be limited to settlement of the rock mass and is likely to occur in brief intervals such as during spring runoff and during any earthquake which may occur. This movement is likely to continue on a decelerating basis over the next 50 to 100 years. The total vertical extent of this movement may be up to 20 % of that which already occurred, or about 10 feet.

Additional subsidence is likely to occur if the 1700 level crown pillar collapses. This may be up to 30 feet in addition to the 10 feet of settlement of the already subsided area. If the crown pillar did not collapse during mining or upon flooding of the lower part of the mine then the potential for future collapse is low because after flooding the vertical stress on the pillar is reduced due to the buoyant effect of the water.

Subsidence is resulting in vertical ground movement within a well defined area. At the north end of this area there is a 50 foot high scarp and a scarp up to 100 feet high within the pit on the southern boundary. Ground deterioration beyond the current limits of movement is likely to be confined to break back of the scarps to 2H:1V slopes from the toe of the scarps. This will result in ground movement by slope failure extending about 100 feet north of the north scarp and about 200 feet south of the south pit wall. These limits are within the berms constructed to restrict access into the unstable area. This ground movement will likely take place over a period of time ranging up to 50 or more years.

Essentially all of the south, west and north pit walls are stable. Except for part of the south wall of the pit, instability of these slopes will be primarily raveling of loose material and collapse of the benches. Instability which progresses back beyond the crest of the pit is unlikely to occur. Some of the south wall is steep and recent failures have occurred, probably associated with the subsidence over the underground mine. Ultimate slope failure will progress beyond the current crest of the pit, possibly up to 300 feet or about as far as the pit access berm by the Kewinaw Haul Road.

<u>Middle Chief Ore Zone</u>

Ore recovered from the Middle Chief ore zone was about 847,000 tonnes. Based on density and dilution values used above, the volume of rock removed from the Middle Chief was 249,000 m^3. The irregular shape of the ore zone and the hill and valley topography above it, make it difficult to produce a calculation similar to the evaluation above for the Little Chief ore. Such an evaluation would be of questionable accuracy even with the aid of detailed mine plans and before and after topography. The observation of recent subsidence suggests that subsidence should be expected to continue in this area for at least as long as over the Little Chief ore zone.

Options For Further Reclamation

Based on the observations and evaluations presented above, the ground movement observed at both areas of unstable ground at the Whitehorse Copper Mine is essentially entirely due to collapse of underground workings and in not a slope stability issue. Consequently, reclamation measures suitable for control of slope stability are not applicable to this site.

Considering the nature of the ground movement, it is the author's opinion that measures to stabilize the ground will be excessively costly. Such measures could include: injecting tailings sand to provide support, or accelerating the subsidence by cycling the water level in the mine by flooding and dewatering the mine. Imported fill could be placed conducted to restore the surface of the land; however, if done too soon then the final stages of settlement would result in cracking of the new surface.

The surrounding regional topography includes cliffs and unstable slopes all along the banks of the Yukon River. Rock cliffs in the order of 10 m high are present in the area to the east of the mine along the side of the access road, and to the south and west of the mine. Considering the nature of the surrounding topography, additional measures to address concerns for public safety do not appear to be justified.

The Conceptual Decommissioning Plan introduces HBM&S's proposal to conduct an engineering assessment of the possible extent of subsidence and a survey program to monitor the rate of ground movement. Considering the nature of the problem and the uncertainty associated with any prediction of subsidence, an engineering assessment may not provide greater confidence in setting the expected limits of subsidence. The subsidence is occurring within well defined boundaries and gradual changes in the rate of movement are unlikely to affect land use or public safety. Therefore, additional knowledge on the rate of movement would be of acedemic interest only. This work could consist of a program of visual monitoring plus a survey record of ground movement once or twice per year. In conjunction with the survey work, a visual survey of the perimeter of the subsiding area could be conducted to identify any new cracks which form.

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Options for alternative use of the land in its current form include:

- development as a disposal site for municipal or other waste,
- tailings disposal from any future mining operation in the area.

There may be other marginal uses of the land, such as a Christmas tree farm, which could be considered for parts of the disturbed area. Any such use would create some value to the disturbed land and provide restriction of access into the area to those workers who would be educated as to the hazards.

Mined out open pits are often viewed as potential sites for disposal of municipal waste. However, current measures for control of the potential adverse environmental effects of landfill disposal of municipal waste call for control of leachate from the waste and means to collect methane produced from the decay of the waste. The bottom of the open pit is hydraulically connected to the underground mine due to the subsidence which has occurred. This connection and the potential for additional ground movement will make it very difficult to demonstrate that effective control of leachate from new waste could be achieved. Any leakage into the underground workings could be considered as an uncontrolled discharge to groundwater, which is usually unacceptable. Similar concerns would apply to the water associated with any proposal to use the pit for tailings disposal.

Considerations For Other Underground Mines

Underground mining is practised when ore bodies cannot be more economically extracted by open pit mining. Ore bodies can be continuous or occur in small volumes with large barren zones in between. Mines generally attempt to remove as much of the economic material as possible and this can result in very large underground excavations. These excavations might collapse, either during operations or after mining has ceased.

Underground mining generally requires a complex system of access, service and stoping excavations to recover the ore These excavations will have different levels of stability. The larger excavations may be backfilled or allowed to collapse. Depending on the resulting subsidence, the ground surface may be affected to varying degrees.
Most mining methods fall within the following broad categories:

- concurrent caving: the ore is extracted by caving and the overlying rock must cave concurrently with extraction of the ore.
- post caving: extraction of ore takes place without backfill and caving is expected to occur at some indeterminate time after the ore has been extracted.
- open stoping with rigid pillars: pillars are left to maintain stability whilst the ore is extracted, collapse and surface disruption could occur in the future.
- fill mining: the openings left by the extraction of ore are backfilled with material which may be cemented. This technique greatly reduces potential surface disturbance.

The analysis methods available to engineers for evaluating the stability and behaviour of underground excavations are accurate for homogeneous material. The variability of the natural materials and the difficulty in accurate characterisation can result in significant inaccuracy in the prediction of stability. This inherent uncertainty coupled with the deterioration of the natural material with time makes the prediction of stability over periods of hundreds of years almost valueless. Therefore, analysis becomes a question of "extent of collapse", "type of damage or hazard", "degree of hazard" not a consideration of whether collapse may take place.

Factors which should be considered in evaluating alternative mining methods to control or reduce the surface effects of mining include ore grade and geometry, best mining method, the natural topographic hazards of the area, and the value of the land to be potentially effected by mining.

D. Tenny reports, "Mining costs are limited by the ability of the ore grade to support them, and as grades at Little Chief were considered low, inexpensive mining methods were adopted." This statement applies to all mining operations. The ore geometry, rock strength and structure, ore grade and depth below surface must be considered together in order to develop the most economical mining method. The value of the overlying land is usually not considered in the mine development and is usually treated as having zero value. In reality, the land does have a small value; however, considering the remote location of most mines the value is very small. In most cases, the cost of revising the mining method to maintain the value of the overlying land is not justified.

An example of how to determine the trade-off between mining method and surface land value can be created based on the Little Chief underground operation, although in the specific case of the Little Chief, additional mining costs may have made the operation uneconomic. If the mining method had been modified to incorporate backfilling with tailings then mining costs would have been increased and there would be a small savings in tailings disposal. In most mines it is not possible to place all tailings back in the mine due to fines in the tailings. Measures to increase the strength of the tailings with cement and/or provide sufficient total volume by adding imported material to the backfill may be required.

The cost of the effort to backfill the mine may be up to several dollars per tonne of ore. For the 5,280,000 tonnes of ore in the Little Chief underground mine, and using a $2/tonne incremental mining cost this would cost $10.5 million. The savings in tailings disposal would be in the order of $1.5 million for a net cost of $9 million. The subsiding area above the Little Chief underground mine is 400 feet by 640 feet (5.9 acres). If we allow a 50% margin for a total area of 8.8 acres. The cost of maintaining this land is estimated to be $1,000,000/acre. Table 1 shows a comparison of this cost to the cost of land in the district of Whitehorse. Note that this economic evaluation would have to be made on a net present value basis considering the incremental cost of the modified mining method versus the future value of the land after mining has ceased.

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Table 1
Hypothetical Comparison Of
Incremental Land Value Due To Modified Mining Method
With Cost Of Land In Whitehorse Area

REGION	COST $/ACRE
Incremental mining cost at Whitehorse Copper to maintain land value over Little Chief Ore zone	$1,000,000
Multi-listed residential land in business district, fully serviced	$287,000
Commercial business district, fully serviced	$1,442,000 to $1,551,000
Rural residential land in area similar to location of Whitehorse Copper	$12,000

References: NRS Redwood Realty, Whitehorse; and YTG Lands Branch, Whitehorse

The above cost comparison applies to the Whitehorse area, the most populated region in the Yukon Territory. Much lower land values will apply in more remote areas. In most remote areas it is unlikely that modifying the mining method to maintain the land value will be justified on an economic basis alone. This evaluation would become more difficult if it is necessary to consider less objective parameters such as heritage sites or wilderness value. If environmental factors such as control of acid rock drainage or disruption of surface drainage are important for a particular project, then it will be necessary to address those issues before land value.

Conclusions

Based on the available data and the assessments presented above the following conclusions have been reached regarding surface land disturbance at mining operations in general and for the specific case of Whitehorse Copper.

1. Subsidence over the Little Chief ore zone has resulted in about 60 feet of primarily vertical movement.

2. The volume rock which has subsided over the Little Chief ore zone is estimated to have filled the underground void, such that future ground movement will be limited to settlement of the subsided material. Future ground movement may be in the order of ten feet on average over the subsiding area, with most of the movement occurring near the western edge of the subsiding area (original eastern edge of the pit). This movement may continue for 50 or more years.

3. Active subsidence is occurring over the Middle Chief ore zone. The irregular shape of

this ore zone and the hill and valley topography above it, make it difficult to estimate the extent or potential duration of subsidence in this area.

4. The ground movement observed at both areas of unstable ground at the Whitehorse Copper Mine is essentially entirely due to collapse of underground workings and in not a slope stability issue.

5. Considering the nature of the ground movement, it is the author's opinion that measures to stabilize the ground, such as injecting tailings or flooding to accelerate the subsidence to a stable configuration, will be excessively costly.

6. Options for alternative use of the land in its current form could include development as a disposal site for municipal waste or tailings disposal from any future mining operation in the area. These may be difficult to implement due to the difficulty of providing water management measures which meet current standards for environmental protection.

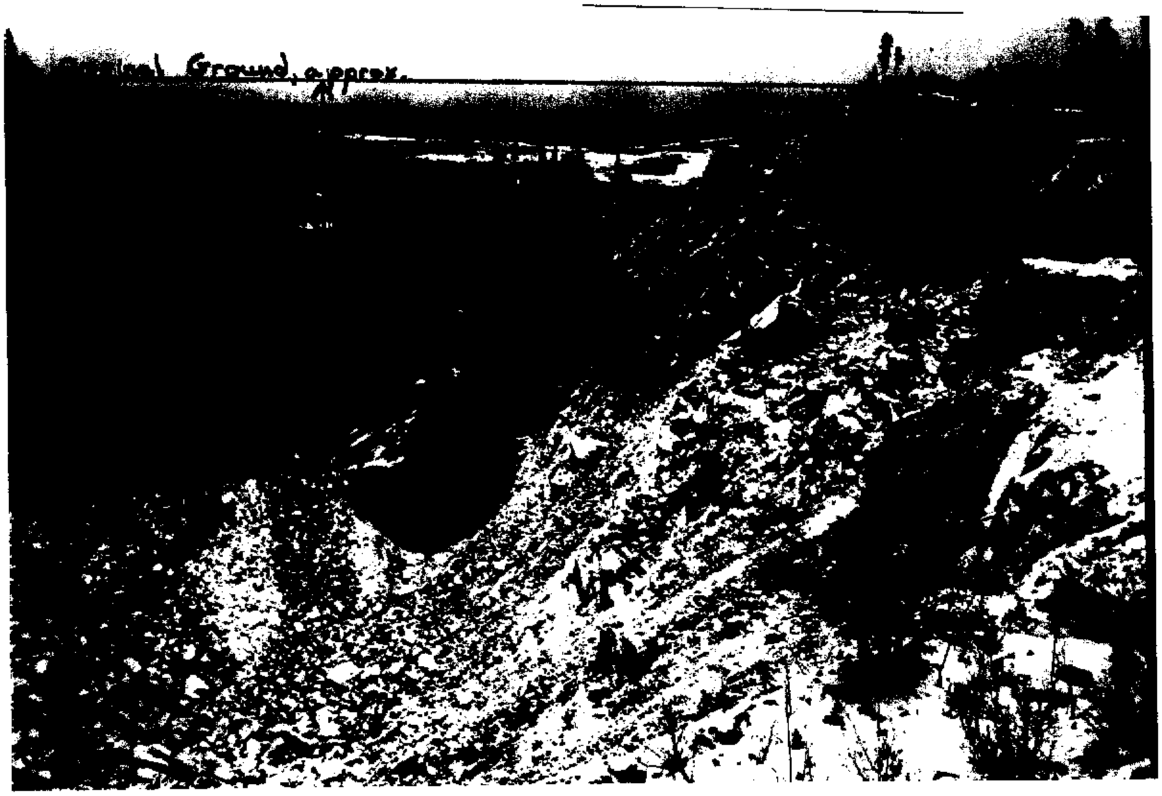
7. Factors which should be considered in evaluating alternative mining methods to control or reduce the surface effects of mining include: ore grade and geometry, best mining method, the natural topographic hazards of the area, and the value of the land to be potentially effected by mining.

8. Based on Whitehorse Copper example, it is estimated that the cost of modifying a mining operation to reduce the surface effects of mining may require a land value roughly equivalent to that in the prime business district. Measures to reduce the surface effects of mining are unlikely to be justified based on economics alone, especially in remote areas.

Refer to Colour CD

Photograph 1, View looking eastward over the open pit towards the subsiding zone over the Little Chief ore zone. The approximate elevation of the original ground surface and the extent of subsidence are indicated. Note the trees on the lower most subsided area are still vertical, as are the smaller trees up the slope to the left.

Refer to Colour CD



Photograph 2, View looking eastward over the open pit towards the subsiding zone over the Middle Chief ore zone. The apparent eastern limit of subsidence is the barren rock face in lower section of the valley. Tilted blocks of rock appear in the foreground with several trees which have not curved in response to the tilting which indicates active ground movement.

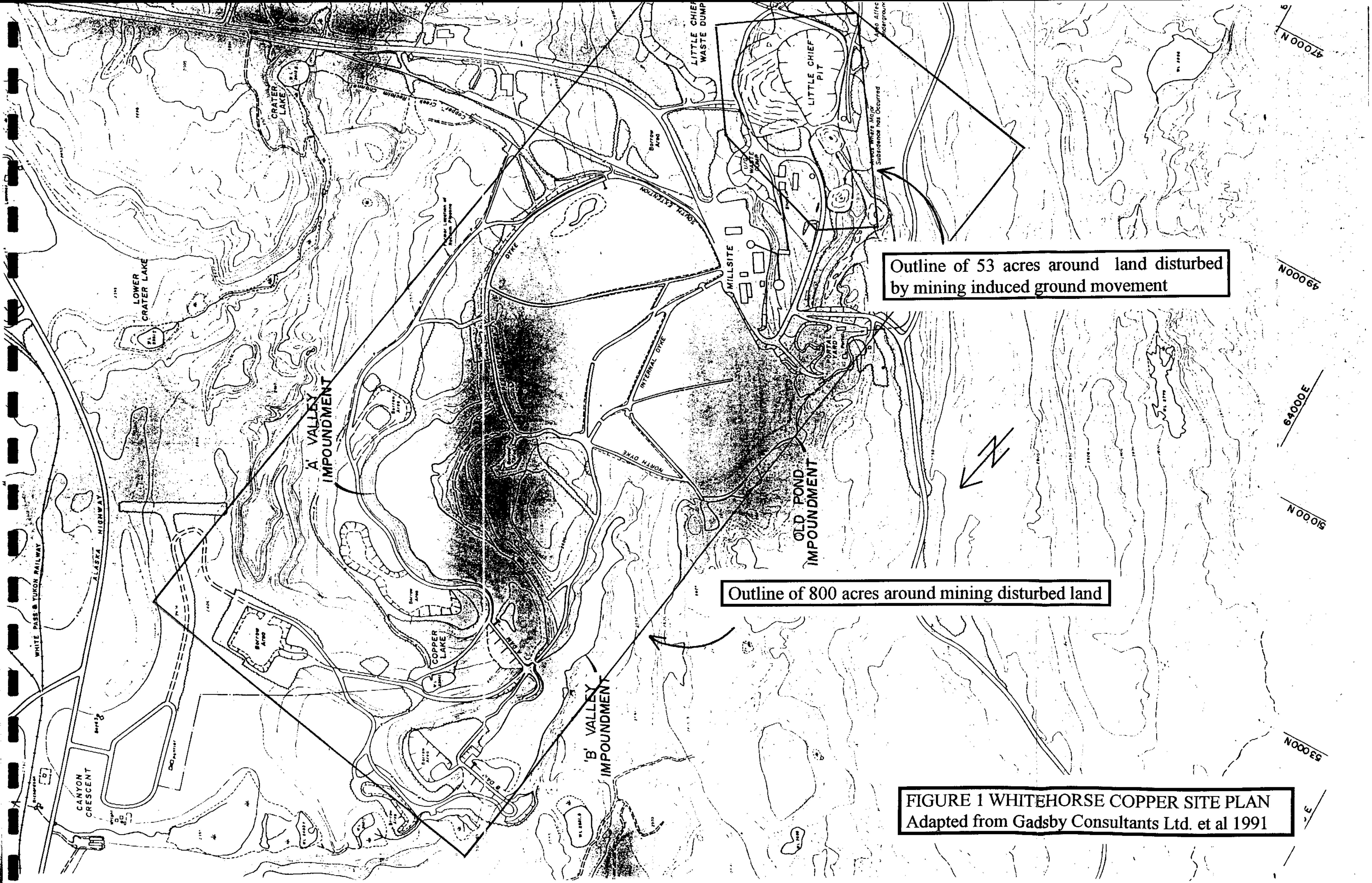


FIGURE 1 WHITEHORSE COPPER SITE PLAN
Adapted from Gadsby Consultants Ltd. et al 1991

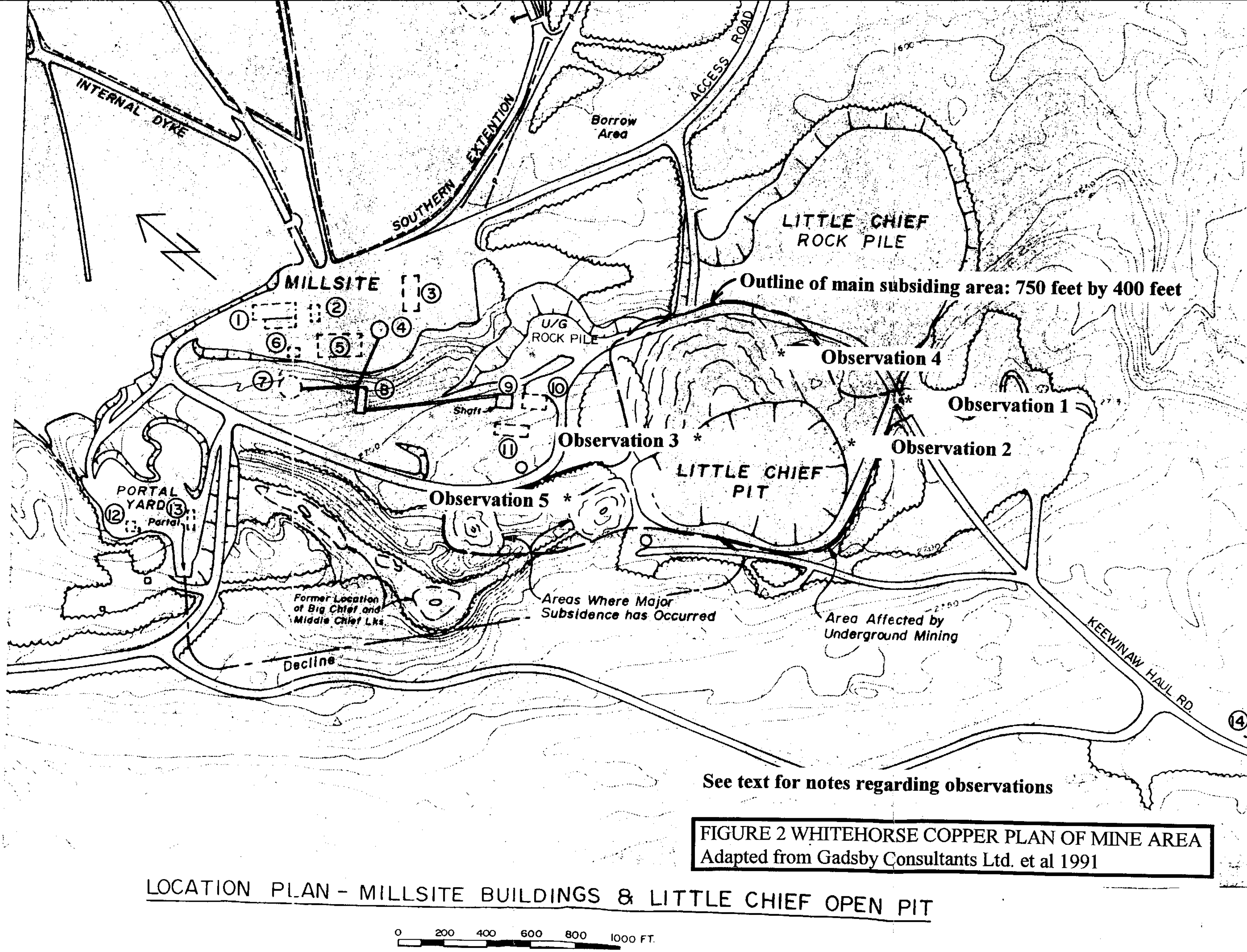


FIGURE 2 WHITEHORSE COPPER PLAN OF MINE AREA
Adapted from Gadsby Consultants Ltd. et al 1991

LOCATION PLAN - MILLSITE BUILDINGS & LITTLE CHIEF OPEN PIT