CERTIFICATE

As a co-author of the report on the Due Diligence Review of the Mining Operations of Boliden AB, I hereby make the following statements:

1. My name is Harry Burgess and I hold the position of Vice President of Micon International Limited, Mineral Industry Consultants. My office address is Suite 900, 390 Bay Street, Toronto, Ontario, M5H 2Y2.

2. (a) I have received the following degrees in Mineral Sciences:

   - B.Sc., Mechanical Engineering, 1966 - University of London, England.
   - B.Sc., Mining Engineering, 1968 - University of London, England.
   - M.Sc., Engineering, 1980 - University of Witwatersrand, Johannesburg, South Africa.

   (b) I am registered as a Professional Engineer in the Province of Ontario and am a Member of the Canadian Institute of Mining, Metallurgy and Petroleum, The Australasian Institute of Mining and Metallurgy, and The Institution of Mining and Metallurgy.

   (c) I have been practising as a professional mining engineer for 25 years.

3. This report is based on an examination and analysis of data and records provided by Boliden AB, and its associated companies, as well as personal on-site observation by the undersigned. It is a statement of material facts and opinion and may be used by Trellegborg AB, Trelleborg International BV and/or Boliden Limited for a prospectus in connection with an offering of common shares.

4. I have neither received, nor do I expect to receive, any interest, direct or indirect, in the properties described herein. I do not beneficially own, directly or indirectly, any securities of the companies or any affiliates involved in the ownership of these properties.

Harry Burgess
Harry Burgess, P. Eng.

April 25, 1997
Toronto, Ontario

CERTIFICATE

As a co-author of the report on the Due Diligence Review of the Mining Operations of Boliden AB, I hereby make the following statements:

1. My name is Kenneth A. Grace and I hold the position of Vice President of Micon International Limited, Mineral Industry Consultants, an independent mining consulting firm. My office address is Suite 900, 390 Bay Street, Toronto, Ontario, M5H 2Y2.

2. (a) I have received the following degrees in Mineral Sciences:

   - B.Sc., University of Cape Town, 1959.
   - M.Sc., New Mexico Institute of Mining and Technology, 1965.

   (b) I am registered as a Professional Engineer in the Province of British Columbia and am a Member of the Canadian Institute of Mining, Metallurgy and Petroleum, The Institution of Mining and Metallurgy, London, a Fellow of The Australasian Institute of Mining and Metallurgy, a member of the Society for Mining, Metallurgy and Exploration and other professional bodies.

   (c) I have been practising as a geologist for more than thirty-five years.

3. This report is based on an examination and analysis of data and records provided by Boliden AB, and its associated companies. It is a statement of material facts and opinion and may be used by Trelleborg AB, Trelleborg International BV and/or Boliden Limited for a prospectus in connection with an offering of common shares.

4. I have neither received, nor do I expect to receive, any interest, direct or indirect, in the properties described herein. I do not beneficially own, directly or indirectly, any securities of the companies or any affiliates involved in the ownership of these properties.

<u>*Kenneth A. Grace*</u>
Kenneth A. Grace, P. Eng.

April 25, 1997
Toronto, Ontario

NESBITT BURNS INC.

Due Diligence Review of Smelter/Refinery Operations of Boliden AB

APRIL, 1997

micon INTERNATIONAL LIMITED mineral industry consultants

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1.0 INTRODUCTION

Nesbitt Burns Inc. has been retained by Trelleborg AB as lead manager for an international public offering of approximately 50 per cent of Trelleborg's holdings in Boliden AB. Boliden AB is engaged in mineral exploration, the mining and processing of ores produced in Sweden, Spain and Saudi Arabia, where it has a 50 per cent interest in The Saudi Company for Precious Metals (SCPM), and in the smelting and refining of copper, lead, silver, gold and zinc in Sweden and Norway (zinc smelting and refining is carried out through its 50 per cent interest in Norzink A/S, Norway), see Figure 1.1. The company is also engaged in the production of fabricated copper and brass, copper recycling and markets technology developed within the company relating to production of minerals, metals and sulphuric acid.

In connection with the international public offering, Trelleborg AB has retained Micon International Limited (Micon) to examine the mineral operations of Boliden AB and to prepare an independent report in compliance with the Toronto Stock Exchange. In undertaking this assignment, Micon has visited the offices of Boliden AB in Stockholm and Boliden, as well as the operations of Boliden Apirsa SL (Apirsa) in Spain; has inspected the mining and processing operations of all of the company's active mines; has held discussions with responsible technical, financial and environmental personnel and has reviewed the relevant data pertaining to geology, reserve/resource estimation, mining, processing, environmental issues and exploration. This report discusses Micon's opinions with respect to these matters. The operations of SCPM were not visited in connection with this assignment, but had been visited in November, 1996 by a member of Micon's team.

Review of the smelting, refining, fabricated metal, copper recycling and technology business areas of Boliden AB were excluded from the scope of the present report.

Metric units of measurement are used throughout this report. Where appropriate, quantities of metal have been expressed as % Cu (per cent copper), % Zn (per cent zinc) or % Pb (per cent lead), and g/t Au (grams per tonne gold) or g/t Ag (grams per tonne silver). References to currency are expressed in Swedish kronor (SEK), Spanish pesetas (pesetas or ESP), United States dollars (US$) and Saudi Riyals (riyals). The historical and future rates used for conversion of currency values to US dollars are as follows:

Date	SEK per US$	ESP per US$
1992	5.81	102
1993	7.78	127
1994	7.70	134
1995	7.12	125
1996	6.70	127
1997	7.00	131
1998-2001	7.00	135

[Figure 1.1 - Business Area Mining Operations]

1.0.1 Information Sources

The principal written information sources relied upon in the preparation of this report are internal documents prepared by Boliden AB and related companies, Apirsa and SCPM. A bibliography of published information sources is provided in this report.

Within Boliden AB, individual mining areas have different formats for reporting production and production costs. Micon has attempted, within the time available for this review, to present data in a consistent manner.

1.0.2 Acknowledgement

The cooperation of Boliden AB and Apirsa in providing information and in being freely available for discussion is acknowledged with thanks.

1.0.3 Qualifications

This report is based on information provided by Boliden AB and its agents, supported by personal observation by members of the project team. Micon did not drill any holes, take any samples, estimate any in-place or recoverable resources/reserves, nor did Micon carry out any studies regarding the feasibility of production from the properties or calculate any financial projections.

The description of the properties and ownership thereof provided in this report is for general information purposes only; Micon did not perform any legal investigation and makes no assertions as to title of the various parties.

1.1 HISTORY OF BOLIDEN AB

Boliden AB was incorporated in the early 1920's to exploit the Boliden orebody, after its discovery in 1918. Mining of this large, exceptionally gold-rich massive sulphide orebody at Boliden commenced in 1924 and continued until 1967. The mine provided a stable financial base for the company, allowing it to expand rapidly in the 1930's and 1940's. During the expansion, a copper smelter was constructed at Skelleftehamn in 1930, the Kristineberg mine was opened in 1940 and the Laisvall mine was opened in 1943. In excess of 20 massive sulphide deposits were discovered during these two decades and entered production continuously up to the 1970's. Boliden AB acquired the Garpenberg mine in 1957 and commenced mining operations at Aitik in 1969. By the mid-1980's, Boliden had 17 mines in Sweden feeding eight concentrators and two smelters.

During the 1960's Boliden AB began to develop its downstream operations when it acquired a 50 per cent interest in the Norzink zinc smelter in Norway, held today with Rio Tinto Minerals Development Ltd. It also diversified into metals trading, chemicals, advanced materials and wholesale building and construction materials.

Boliden AB, which first listed on the Stockholm Stock Exchange in 1952, became a part of the Trelleborg Group in 1986 when that company acquired 44 per cent of the shares. In 1988, Trelleborg acquired all of the outstanding shares of Boliden AB and became its sole owner. At the time of the purchase, Sweden was experiencing a prolonged period of 10 to 15 per cent per annum inflation. As a result, after acquiring its majority interest, Trelleborg instituted a major restructuring programme at Boliden AB, focusing on its core business activity, metal mining and smelting. As part of this restructuring, Boliden AB modernized facilities, closed high-cost, non-performing mines and concentrators and reduced unit costs through expansion. It also became a more vertically integrated company and acquired value-added manufacturing enterprises such as copper tubing mills in France and Belgium and brass foundries in Holland and England.

At the time of the acquisition by Trelleborg, the only international asset owned by Boliden AB was a 50 per cent interest in the Sukhaybarat mine in Saudi Arabia. As part of the expansion programme, Boliden AB increased its international exposure. By 1990 it had acquired Black Angel in Greenland (now closed), Perkoa in Burkina Faso and Minas Santa Rosa in Panama (both later divested), and Apirsa in Spain.

Today Boliden AB operates 12 mines, (10 in Sweden and one each in Spain and Saudi Arabia) six mills/concentrators and two smelters. It explores for base and precious metals throughout Europe, Africa, South America and Asia.

1.1.1 Resources/Reserves

As noted above, all of the operating mining areas, with exception only of Sukhaybarat in Saudi Arabia, were visited by Micon geologists and/or engineers to assess Boliden's resource/reserve position. The Sukhaybarat joint venture mine was examined by Micon in the recent past.

For each mining property, Micon reviewed the geological setting, local geology, and mineralization type, assessed the appropriateness of the deposit model and the adequacy of the data base, and evaluated the methodology of resource/reserve estimation and the engineering and economic factors incorporated in the determination of Ore Reserves. Wherever possible, discussions were held with those Boliden AB personnel responsible for the resource/reserve determination.

Boliden AB bases its resource/reserve classification on the "Australasian Code for Reporting Mineral Resources and Ore Reserves". Micon has first-hand familiarity with this Code, and is satisfied that it is an appropriate and acceptable system for the deposits. For the purposes of this due diligence review, Micon applied its experience and best judgement to reclassify the reported resource/reserve quantities in terms of Canadian National Policy 2-A.

Resources/reserves are reported by Boliden AB for its active mines, properties under development and other properties.

1.1.2 Resource/Reserve Classification

Boliden AB has recently undergone an internal review of its ore reserve reporting practices. In the past, the company only reported two categories, ore reserves and mineralization. After examining reserve and resource reporting practices throughout the world, the company, since 1995, has reported its resources/reserves according to the classification scheme included the Australasian Code, noted above, and which divides known mineralization into two categories, Resources and Ore Reserves.

Delineated mineralization that has not been evaluated for economic viability is referred to by Boliden AB as Resources and is classified into three different confidence categories, namely Measured, Indicated and Inferred, defined as follows:

> **Inferred Resources:** "Mineralization has been identified and sampled. There is insufficient data to allow a geological framework. The continuity of the mineralization cannot be predicted." Level of confidence is assumed to be plus/minus 100 per cent.
>
> **Indicated Resources:** "There is confidence in geological interpretations and continuity in mineralization. The confidence in the estimate allows the application of technical and financial parameters and to enable an evaluation of economic viability." Level of confidence is assumed to be plus or minus 40 per cent.
>
> **Measured Resources:** "Tonnage and grade of the in-situ mineralization can be estimated to within close limits and .... any variation from the estimate would not significantly affect the potential economic viability. This degree of confidence necessarily requires a firm understanding of the geology and controls of mineralization." Level of confidence is assumed to be plus or minus 20 per cent.

Although these definitions are couched in Boliden AB's terms, they broadly reflect those of the Australasian Code.

Resources that have been evaluated for economic viability with positive results are classified as Ore Reserves and are defined as follows:

> "The ore reserve mined shall yield at least the required rate of return on capital employed necessary to meet the company objectives, as long as each separate position in the reserve or parts thereof covers its own costs."

Ore reserves are classified as Proven or Probable. Measured resources produce Proven ore reserves by having a feasibility study completed on them, whereas Indicated resources produce Probable ore reserves by having at least a pre-feasibility study completed on them. Micon notes, however, that mineable quantities derived from Inferred resources may be included in mine planning and mine scheduling.

The feasibility and pre-feasibility studies adjust the tonnage and grade of the resource to reflect expected waste dilution and mining losses.

Micon has reviewed the ore reserve estimation methodology used at Boliden AB and has determined that it conforms to international industry standards. The reporting standards and nomenclature used at Boliden AB for resources and reserves reflect those of the Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves. Micon has determined the following equivalencies between the resource/reserve classification and nomenclature as used by Boliden AB and the reporting requirements as set out in Canadian National Policy 2-A:

Boliden AB Terminology	**National Policy 2-A**
Proven Ore Reserve	Proven Ore
Probable Ore Reserve	Probable Ore
Measured Resource	Proven Mineralized Concentrations
Indicated Resource	Probable Mineralized Concentrations
Inferred Resource	Possible Mineralized Concentrations

1.1.3 Mineral Processing Technology

The development of mineral processing technology within the Boliden mines has, in several respects, followed a distinctly different route from much of the rest of the world. The following are general observations which highlight these differences.

Grinding: With the exception of the Sukhaybarat gold mine in Saudi Arabia, all of the grinding installations built by Boliden since the late 1970's have used the Boliden fully autogenous grinding system. This uses a primary and a secondary mill operated in tandem. The primary mill is a grate discharge mill equipped with a pebble extractor which discharges pebbles to provide the grinding media for the secondary mill. The primary crushed ore (<150 to 200 mm) is fed to the primary mill and both mill discharges are classified.

The Boliden system is claimed to reduce the operating costs for grinding by eliminating the cost of grinding media. It is also claimed that it uses very little more energy, if any at all, than the conventional systems, although it may be that the conventional systems with which Boliden AB is comparing the energy consumption are not the most efficient.

Since the re-invention of autogenous grinding in the 1960's and 1970's, semi-autogenous grinding, often combined with ball milling, has been widely applied to non-ferrous metal ores world wide. In many cases, this has amounted to little more than run-of-mine ball milling. As such it has led to significant reductions in capital cost and operating and maintenance complexity, at the expense of an approximate 20 per cent increase in comminution energy consumption. It has not generally reduced the cost of grinding media.

It is not claimed that the Boliden system is universally applicable and it does depend on the availability of competent media within the ore. It has, however, been applied to a wide variety of hard rock ores with success and could be a significant technological strength as Boliden seeks to expand.

Boliden AB uses steel capped rubber liners in its primary autogenous mills and rubber liners in its pebble mills. For rod mills, steel liners are used for the ends, steel capped rubber liners for the barrel adjacent to the ends and rubber liners for the rest of the barrel. A new innovation is the leasing of mill liners on the basis of payment per kilowatt-hour (kWh) of energy used or per tonne of ore milled. Responsibility for the maintenance of the liners and for the expense and the task of replacing them is passed to the supplier. This has reduced the mill liner costs where it has been used.

Flotation: A variety of flotation machines is in use in the Boliden concentrators. A few of Boliden AB's own design remain but the majority are either Sala or Outokumpu machines. Over the years, as larger machines have become available, they have been installed in the Boliden concentrators in an appropriate way. Flotation columns have been installed for cleaner duties and are operating successfully. Spargers from Control International have been installed and this is claimed to have improved column operations.

The reagents used vary considerably from concentrator to concentrator and have been optimized for each ore. It is of interest that cyanide is not used at all for the depression of zinc in the copper/lead circuits, but this probably reflects the relatively high precious metal contents of these ores. The use of sulphur dioxide as a zinc depressant at Garpenberg is notable, and is particularly suitable in view of the natural alkalinity of this ore. Both xanthates and dithiophosphates are used as collectors in a conventional manner and lime is generally used as a pyrite depressant.

On-stream Analysis: Boliden AB has installed its own "Boxray" on-stream analysis systems at its concentrators and these are routinely employed for process control. They consist of a central system, comparable with the Outokumpu Courier systems, to which sub-samples of process streams are delivered. On some applications, a carousel of measuring cells through which individual samples pass continuously, is rotated in front of the X-ray measuring head. Other systems, such as that at Aitik, feed successive samples through two fixed cells, which requires a sample selection system above the machine and a flushing period before measurement of the sample.

The merits of on-stream analysis are not in question. The Boxray system claims to be able to analyze for a greater number of elements than competitors' machines.

Process Control Systems: All of the Boliden concentrators have modern process information and management systems. These have been regularly updated and have contributed to the very high productivity at these concentrators. Garpenberg, for example, has just two operators on each shift.

Concentrate Dewatering: Concentrate thickeners are almost the only items of original equipment which remain in the Boliden area concentrators. Wooden thickeners are still widely used and modern high-capacity thickeners are generally not seen. Since the main benefit of high capacity thickeners lies in their reduced capital cost, this should not be surprising.

The Sala vertical plate pressure filters were developed together with Boliden AB and have been applied at the Boliden and Laisvall concentrators. They operate entirely automatically, with the diaphragm pressing and air blow parts of the cycle controlled by the reduction in the weight of the press. Filter cake moisture levels are 5 to 7 per cent and this eliminates oil-fired dryers. They are clearly expensive machines and have only been installed where the volumes of concentrate are high. Limits on dust and metal emissions from both vacuum filters and rotary dryers are requiring the installation of remedial equipment which is making conventional equipment more expensive and it seems likely that any new installations in Boliden will be of the pressure filter type.

Management Structures: Very low labour intensity is a common feature of Boliden AB's concentrator operations with total reliance being placed on automated control systems to maintain optimum operations. It is common to tour a plant without seeing any operating staff except in the control rooms. In Sweden, workers are all represented by a single union and union and management co-operate closely to ensure the future of the operation. Most of the workforce has been employed in the mines for a long time and is evidently very capable. There is very little metallurgical manpower working in the concentrators.

The Central Technology and Development Department situated at Boliden, is divided into three sections covering mining technology, mineral processing and process control, with a total of 55 staff. About 60 per cent of the budget of this department comes from the operating budgets of the mines, with the remainder coming from central funds and from work in support of Boliden Contech and external work.

2.0 SUMMARY AND CONCLUSIONS

Nesbitt Burns Inc. has been retained by Trelleborg AB as lead manager for an international public offering of approximately 50 per cent of Trelleborg's holdings in Boliden AB. In connection with this public offering, Trelleborg AB has retained Micon to undertake a due diligence examination of the mineral operations of Boliden AB and to prepare an independent report in compliance with the requirements of the Toronto Stock Exchange.

Boliden AB operates 10 mines in Sweden, one in Spain, through Boliden Apirsa SL, and has a 50 per cent interest in SCPM in Saudi Arabia. It has active exploration programmes in Sweden, Finland, Spain, Saudi Arabia, Burkina Faso, Mexico and Argentina.

Boliden AB is a major international producer of zinc and lead, and a significant producer of copper, gold and silver. The company operates copper and lead refinery facilities at Rönnskär, Sweden and has a 50 per cent interest in the Norzink AS zinc refinery in Norway. The flow of concentrates from each of the mining areas in Sweden, Boliden, Garpenberg, Laisvall, and Aitik, and in Spain, to Boliden AB and other smelter/refinery facilities is shown in Figure 2.1.

2.1 RESOURCES AND RESERVES

For each of the mining properties, whether operating, under development or being considered for development, the Ore Reserves and other mineralized concentrations reported by Boliden AB were evaluated as to their propriety. For each property, this included an assessment of the appropriateness of the geological model, the adequacy of the data base, the methodology of resource estimation, and the engineering and economic parameters used to determine the mineable Ore Reserves.

Micon concludes that Boliden AB's resource/reserve determination procedures follow accepted mining industry practice and that the quantities and grades reported have been carefully estimated from sufficient data, with due recognition of geological, engineering and economic factors. It is Boliden AB's internal practice to closely follow the Australasian system for reporting resources and reserves.

By applying its judgement and experience, Micon has reclassified and restated the resources and reserves, reported by Boliden AB, in terms of Canadian National Policy 2-A, as set out in Tables 2.1 and 2.2.

2.2 EXPLORATION POTENTIAL

2.2.1 Boliden Area

More than 70 years of exploration in the Boliden area (also known as the Skellefteå mining district) have probably come close to exhausting the possibilities for finding deposits near surface similar to those being mined in the area. Nevertheless, given the known mineralization at depths of over 1,500 metres (m), there appears to be significant potential for the existence of new, deep, blind orebodies.

[Figure 2.1 - Destination of Concentrates]

Table 2.1
BOLIDEN AB ORE RESERVES AS AT 1 JANUARY, 1997

Location	**Mine**	**Proven**						**Probable**						**Total**					
		Tonnes	**Au g/t**	**Ag g/t**	**Cu %**	**Zn %**	**Pb %**	**Tonnes**	**Au g/t**	**Ag g/t**	**Cu %**	**Zn %**	**Pb %**	**Tonnes**	**Au g/t**	**Ag/ g/t**	**Cu %**	**Zn %**	**Pb %**
Boliden	Kristineberg	2,245,000	1.2	58	1.2	5.9	0.4	-	-	-	-	-	-	2,245,000	1.2	58	1.2	5.9	0.4
	Petiknäs South	2,671,000	2.7	111	1.2	5.1	1.0	1,546,000	2.2	93	0.5	5.3	1.0	4,217,000	2.5	104	0.9	5.2	1.0
	Renström	394,000	2.5	171	0.4	6.2	1.5	-	-	-	-	-	-	394,000	2.5	171	0.4	6.2	1.5
	Sub-Total : Polymet.	5,310,000	2.1	93	1.1	5.5	0.8	1,546,000	2.2	93	0.5	5.3	1.0	6,856,000	2.1	93	1.0	5.5	0.8
	Åkerberg	356,000	5.0	-	-	-	-	-	-	-	-	-	-	356,000	5.0	-	-	-	-
	Åkulla	150,000	2.2	15	1.8	-	-	-	-	-	-	-	-	150,000	2.2	15	1.8	-	-
	Sub-Total : Gold	506,000	4.2	5	0.5	-	-	-	-	-	-	-	-	506,000	4.2	5	0.5	-	-
Garpenberg	Garpenberg	1,264,000	0.5	71	0.2	6.4	3.1	-	-	-	-	-	-	1,264,000	0.5	71	0.2	6.4	3.1
	Garpenberg North	2,883,000	-	144	-	4.0	1.9	930,000	-	166	-	4.0	1.9	3,813,000	-	149	-	4.0	1.9
	Sub-Total	4,147,000	-	122	-	4.70	2.3	930,000	-	166	-	4.0	1.9	5,077,000	-	130	-	4.6	2.2
Laisvall	Laisvall	9,622,000	-	11	-	0.5	5.0	-	-	-	-	-	-	9,622,000		11	-	0.5	5.0
Aitik	Aitik	202,000,000	0.2	4	0.40	-	-	-	-	-	-	-	-	202,000,000	0.2	4	0.40	-	-
	Liikavaara	9,549,000	0.1	5	0.45	-	-	-	-	-	-	-	-	9,549,000	0.1	5	0.45	-	-
	Sub-Total	211,549,000	0.2	4	0.40	-	-	-	-	-	-	-	-	211,549,000	0.2	4	0.40	-	-
Apirsa (Spain)	Los Frailes	46,400,000	-	60	0.3	3.8	2.2	-	-	-	-	-	-	46,400,000	-	60	0.3	3.8	2.2
SCPM (Saudi Arabia)[1]	Sukhaybarat	750,000	2.2	-	-	-	-	-	-	-	-	-	-	750,000	2.2	-	-	-	-

[1] Total tonnage of SCPM : Boliden AB owns 50% of SCPM

Table 2.2
BOLIDEN AB ADDITIONAL MINERAL RESOURCES[1], AS AT 1 JANUARY, 1997
(Equivalent to Mineralized Concentrations as per Canadian National Policy 2-A)

Location	Mine	Pillars (Measured)						Measured & Indicated (excl. pillars)						Total					
		Tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %	Tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %	Tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %
Boliden	Kristineberg	467,000	1.2	53	0.9	6.4	0.5	100,000	1.1	48	0.8	6.1	0.3	567,000	1.2	52	0.9	6.3	0.5
	Långdal	-	-	-	-	-	-	246,000	5.1	10	0.3	0.5	0.1	246,000	5.1	10	0.3	0.5	0.1
	Petiknäs North	-	-	-	-	-	-	1,340,000	4.3	48	1.6	2.6	0.2	1,340,000	4.3	48	1.6	2.6	0.2
	Petiknäs South	496,000	2.7	111	1.2	5.1	1.0	-	-	-	-	-	-	496,000	2.7	111	1.2	5.1	1.0
	Renström	394,000	2.2	141	0.7	5.4	1.3	-	-	-	-	-	-	394,000	2.2	141	0.7	5.4	1.3
	Sub-Total : Polymet	1,357,000	2.0	100	1.0	5.6	0.9	1,686,000	4.2	42	1.4	2.5	0.2	3,043,000	3.2	68	1.2	3.9	0.5
	Åkerberg	35,000	4.0	-	-	-	-	-	-	-	-	-	-	35,000	4.0	-	-	-	-
	Åkulla	-	-	-	-	-	-	60,000	1.4	12	1.3	-	-	60,000	1.4	12	1.3	-	-
	Sub-Total : Gold	35,000	4.0	-	-	-	-	60,000	1.4	12	1.3	-	-	95,000	2.4	8	0.8	-	-
Garpenberg	Garpenberg	316,000	0.3	52	0.1	7.3	2.8	600,000	0.2	40	-	6.8	2.3	916,000	0.2	44	na	7.0	2.5
	Garpenberg North	531,000	-	159	-	4.8	2.5	-	-	-	-	-	-	531,000	-	159	-	4.8	2.5
	Dammsjön	-	-	-	-	-	-	3,300,000	-	127	-	2.9	1.2	3,300,000	-	127	-	2.9	1.2
	Sub-Total	847,000	0.1	119	-	5.7	2.6	3,900,000	-	114	-	3.5	1.4	4,747,000	-	115	-	3.9	1.6
Laisvall	Maiva	-	-	-	-	-	-	1,150,000	-	-	-	0.1	4.9	1,150,000	-	-	-	0.1	4.9
Aitik	Aitik	-	-	-	-	-	-	774,000,000	0.2	2	0.3	-	-	774,000,000	0.2	2	0.3	-	-
	Liikavaara	-	-	-	-	-	-	32,450,000	0.1	3	0.3	-	-	32,450,000	0.1	3	0.3	-	-
	Sub-Total	-	-	-	-	-	-	806,450,000	0.2	2	0.3	-	-	806,450,000	0.2	2	0.3	-	-
Apirsa (Spain)	Los Frailes	-	-	-	-	-	-	30,000,000	-	60	0.3	3.6	2.2	30,000,000	-	60	0.3	3.6	2.2
SCPM (Saudi Arabia)[2]	Bulghah	-	-	-	-	-	-	40,000,000	1.0	-	-	-	-	40,000,000	1.0	-	-	-	-

[1] Economic viability not yet determined.
[2] Total tonnage of SCPM: Boliden AB owns 50% of SCPM.

Table 2.2 Cont.
BOLIDEN AB ADDITIONAL MINERAL RESOURCES[1], AS AT 1 JANUARY, 1997
(Equivalent to Mineralized Concentrations as per Canadian National Policy 2-A)

Location	Mine	Inferred					
		Tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %
Boliden	Kristineberg Petiknäs South Renström Deep	1,500,000 3,000,000 2,000,000	1.2 2.6 4.5	58 95 270	1.2 1.0 0.5	5.9 4.7 12.7	0.4 0.8 2.7
	Sub-Total : Polymet	6,500,000	2.9	140	0.9	7.4	1.3
	Åkulla East	1,500,000	7.0	18	-	-	-
Garpenberg	Garpenberg Garpenberg North Dammsjön Tyskgårdsgruvan	500,000 6,000,000 5,000,000 1,000,000	0.2 - - -	40 166 150 150	- - - -	6.8 4.0 4.0 3.0	2.3 1.9 1.3 1.0
	Sub-Total	12,500,000	-	152	-	4.0	1.6
SCPM (Saudi Arabia)[2]	Sukhaybarat	16,000,000	1.3	-	-	-	-

[1] Economic viability not yet determined.
[2] tonnage of SCPM: Boliden AB owns 50% of SCPM.

Boliden AB is in a unique position to perform such a programme in the Skellefteå district. It has sole access to a proprietary, 20,000 drill hole database and a large, well organized core storage facility where core from many of these old holes still exists. Boliden AB's experience and the extent of its geological knowledge exceeds any other company's knowledge base. In addition, Boliden AB has been an innovator in the development and introduction of new technologies, including a downhole EM (electro-magnetic) instrument, which was recently responsible for the discovery of the blind southern ore zone at Petiknäs.

The Skellefteå mining district must be considered as a prospective, under-explored area for vein type gold deposits. The traditional massive sulphide exploration and prospecting techniques, as practiced by Boliden AB in the past, would be unlikely to recognize or detect gold deposits of the types recently discovered in a terrain extensively covered by glacial till. The exploration personnel of Boliden AB have recognized this and will be using their unique database of geological information to revisit various areas in the search for gold.

2.2.2 Garpenberg Area

Development of deeper ores and exploration is ongoing. Micon concurs that down-dip extensions of ore are likely for the Garpenberg mine and the Garpenberg North mine. The Garpenberg North mine, in particular, appears to have significant potential down-dip. Exploration drilling to deeper levels is scheduled for both mines.

In addition, surface exploration is being carried out, comprised of mapping, sampling and EM methods. A prime target is the Dammsjön prospect, about mid-way between Garpenberg and Garpenberg North, where zinc and high grade silver mineralization has been discovered.

2.2.3 Laisvall

Since 1992, Boliden AB has spent 8.6 million SEK on exploration in the immediate vicinity of the mine. Potential exists at the Laisvall deposit itself for expanding ore reserves, most notably under Lake Laisan between the Laisan and Skorro mineralized zones.

Among small satellite deposits identified, the Maiva deposit contains some 1.2 million tonnes of lead resources at 4.9% Pb and 0.1% Zn, classified by Micon as additional mineralized concentrations. The area between Laisvall and Maiva which is potentially very prospective, has not yet been explored.

2.2.4 Aitik

The Kiruna-Ladoga shear zone is a very favourable area for exploration, with numerous known copper-gold mineralized zones in the metasediments and metavolcanics. A number of prospective geophysical anomalies immediately to the east of the Aitik mine are being followed up with a geochemical sampling programme. Several other targets further afield have been investigated, with the Liikavaara deposit explored in detail and evaluated to the reserve determination stage.

Open pit ore reserves at Liikavaara are reported as 9.55 million tonnes at 0.45% Cu, 0.11 g/t Au and 4.65 g/t Ag (Proven Ore). Additional resources are reported at 32.45 million tonnes at 0.32% Cu, 0.08 g/t Au and 2.8 g/t Ag and classified by Micon as additional mineralized concentrations.

2.2.5 Apirsa

The Los Frailes deposit, at the eastern end of the Iberian Pyrite Belt, has not been closed off to depth, or to the west. Mineral zoning suggests that at least half of the deposit remains untested. Gravity and electromagnetic surveys point to the same conclusion. An exploration drilling programme to test the depth extent of the massive sulphide zone is under way. There is significant potential for increased measured resources.

The adjacent Salome prospect on the Los Frailes concession may be the eastward continuation of the Los Frailes orebody across the Los Frailes fault, and further geophysical work is planned for 1997.

2.2.6 Saudi Arabia

There is potential for developing ore in the margins of the existing pit and below the pit floor. A drilling programme is currently under way.

About 65 kilometres (km) away, SCPM is evaluating the Bulghah deposit which is estimated to contain potentially open-pittable resources on the order of 40 million tonnes averaging about a gram of gold per tonne. Micon has identified this reported tonnage as Proven and Probable mineralized concentrations and has concluded that ore reserves may be determined in the near future.

2.3 MINING AND MILLING OPERATIONS

Historical and projected production and production costs for each of the operations, except SCPM in Saudi Arabia, are summarized in Tables 2.3 and 2.4.

2.3.1 Boliden Area

The total capacity of the Boliden mill is about 1.5 million tonnes per year and this exceeds the presently anticipated requirements for the production plans of the mines.

Boliden is a very competent mine owner and efficiency improvements are constantly being made. The mines are well run and clean, with good safety records, and high morale is evident, although Kristineberg and Renström are handicapped by their old infrastructure.

Mine operating costs appear to be reasonably under control and forecast operating costs at the three principal mines are in line with recent experience, with some adjustments where necessary for expected changes in conditions.

Capital expenditures for mobile equipment and local mine development appear adequate. However, because of the lack of knowledge of resources that are expected to be outlined, developed and mined within the five-year period, major capital expenditures may be underestimated. For example, at Kristineberg, drilling is under way for totally new ore sources and, if found, expenditure on development should start in 1998/1999.

Micon's analysis indicates that approximately 20 per cent of the ore tonnage, 40 per cent of the gold, 20 per cent of the silver, 10 per cent of the copper, and 20 per cent of both the lead and zinc arise from resources that have not yet been sufficiently outlined to be classed as ore reserves. As noted in the descriptions of the mines, development, exploration, and infrastructure work will have to be completed in order to bring material presently classified as resources into the reserve category.

Table 2.3
HISTORICAL MINE PRODUCTION AND OPERATING COST

	1992	1993	1994	1995	1996
Boliden Area					
Ore Production ‘000 tonnes					
Petiknäs	91	176	245	335	390
Renström	237	172	122	133	161
Kristineberg	462	469	474	463	507
Åkerberg	91	196	160	184	209
Långdal	324	194	281	203	39
Åkulla	-	-	-	-	-
Kankberg	155	107	122	113	106
Direct Mining Cost SEK/tonne					
Petiknäs	222	187	165	175	140.26
Renström	187	267	357	420	374.53
Kristineberg	227	227	225	272	239.25
Åkerberg	71	63	54	50	54.55
Långdal	36	43	28	59	151.28
Åkulla	-	-	-	-	-
Kankberg	101	120	102	116	122.64
Milling Cost SEK/tonne	60.09	56.36	54.18	52.25	52.80
Total Cost SEK/tonne	**297.79**	**318.46**	**297.64**	**332.25**	**348.28**
US$/tonne	**51.25**	**40.93**	**38.65**	**46.66**	**52.03**
Garpenberg Area					
Ore Production, ‘000 tonnes					
Garpenberg Mine	301	324	316	314	346
Garpenberg North	523	476	495	436	496
Direct Mining Cost SEK/tonne					
Garpenberg Mine	253	248	266	273	267.63
Garpenberg North	152	158	152	203	185.89
Milling Cost SEK/tonne	50	57	56	63	63.30
Total Cost SEK/tonne	**272**	**286**	**285**	**333**	**335.04**
US$/tonne	**46.80**	**36.80**	**37.00**	**46.80**	**50.01**
Laisvall					
Ore Production, ‘000 tonnes	1,775	1,752	1,679	1,650	1,784
Direct Mining Cost SEK/tonne	61.40	62.90	62.40	71.80	71.13
Milling Cost SEK/tonne	35.90	35.70	40.70	42.20	40.81
Total Cost SEK/tonne	**116.4**	**116.6**	**120.1**	**131.7**	**128.6**
US$/tonne	**20.03**	**14.98**	**15.66**	**18.49**	**19.20**
Aitik					
Ore Production, ‘000 tonnes	15,369	16,047	16,411	17,465	17,899
Waste production, ‘000 tonnes	11,211	13,583	14,362	14,277	16,896
Direct Mining Cost SEK/tonne	14.85	13.79	14.83	14.44	14.42
Milling Cost SEK/tonne	15.04	15.05	14.25	14.02	13.97

	1992	1993	1994	1995	1996
Total Cost SEK/tonne **US$/tonne**	**35.44** **5.06**	**35.08** **5.01**	**36.24** **5.18**	**35.69** **5.10**	**36.29** **5.18**
Boliden Apirsa*					
Ore Production	1,962	957	1,621	2,440	1,648
Direct Mining Cost ESP/tonne Milling Cost ESP/tonne	263.5 1,420.7	262.6 1,386.6	301.2 1,334.3	282.1 1,147.6	452.7 1,336
Total Cost ESP/tonne **US$/tonne**	**2,265.6** **22.21**	**3,452.5** **27.19**	**2,961.0** **22.10**	**2,132.4** **17.06**	**3,462** **23.04**

* Aznalcóllar

Table 2.4
ESTIMATED FUTURE MINE PRODUCTION AND OPERATING COST

	1997	1998	1999	2000	2001
Boliden Area					
Ore Production, '000 tonnes					
Petiknäs	445	500	500	500	500
Renström	160	160	200	250	250
Kristineberg	500	500	500	500	500
Åkerberg	120	140	-	-	-
Långdal	45	102	86	-	-
Åkulla	150	-	140	250	250
Kankberg	106	24	-	-	-
Direct Mining Cost SEK/tonne					
Petiknäs	150.11	145.00	138.40	135.60	135.40
Renström	306.88	306.25	289.50	277.20	286.80
Kristineberg	229.40	228.00	223.60	221.00	220.80
Åkerberg	122.50	77.14	-	-	-
Långdal	166.67	120.59	109.30	-	-
Åkulla	85.33	-	115.00	111.60	111.60
Kankberg	120.83	-	-	-	-
Milling Cost SEK/tonne	55.84	55.83	57.03	58.53	58.00
Total Cost SEK/tonne	**335.19**	**364.84**	**382.26**	**383.40**	**388.20**
US$/tonne	**47.88**	**52.12**	**54.61**	**54.77**	**55.46**
Garpenberg Area					
Ore Production, '000 tonnes					
Garpenberg Mine	360	360	360	400	400
Garpenberg North	600	650	650	650	650
Direct Mining Cost SEK/tonne					
Garpenberg Mine	254.72	224.44	228.89	217.25	203.50
Garpenberg North	143.50	140.00	141.85	141.54	141.08
Milling Cost SEK/tonne	54.69	54.26	53.96	53.05	52.95
Total Cost SEK/tonne	**298.96**	**287.13**	**291.29**	**291.24**	**288.76**
US$/tonne	**42.71**	**41.02**	**41.61**	**41.61**	**41.25**
Laisvall					
Ore Production, '000 tonnes	1,840	1,900	1,900	1,800	1,433
Direct Mining Cost SEK/tonne	65.92	62.84	63.47	65.94	68.81
Milling Cost SEK/tonne	40.54	40.11	40.11	41.39	34.12
Total Cost SEK/tonne	**121.74**	**117.16**	**117.16**	**121.78**	**120.94**
US$/tonne	**17.39**	**16.74**	**16.74**	**17.34**	**17.28**
Aitik					
Ore Production '000 tonnes	17,000	17,000	17,000	17,000	17,000
Waste production '000 tonnes	15,600	23,000	23,000	21,000	21,000
Direct Mining Cost SEK/tonne	15.92	16.96	16.07 14.92	16.08	16.43
Milling Cost SEK/tonne	15.64	14.87		14.95	15.02

	1997	1998	1999	2000	2001
Total Cost SEK/tonne **US$/tonne**	**38.79** **5.54**	**39.12** **5.59**	**38.90** **5.56**	**38.91** **5.56**	**39.25** **5.61**
Boliden Apirsa*					
Ore Production '000 tonnes Waste production '000 tonnes	2,307 18,772	4,000 33,080	4,100 33,010	4,200 33,090	4,200 28,050
Direct Mining Cost ESP/tonne Milling Cost ESP/tonne	969 1,234	954 923	928 846	930 826	886 826
Total Cost ESP/tonne **US$/tonne**	**3,818** **29.15**	**2,938** **21.76**	**2,809** **20.81**	**2,741** **20.30**	**2,716** **20.12**

* Los Frailes

2.3.2 Garpenberg Area

The Garpenberg and Garpenberg North mines are well-organized, safe and efficient mining operations with opportunities for increased productivity. Infrastructure, equipment, personnel and production methods are well-suited to the job at hand. In the short term, however, both mines are somewhat tight on primary development. This situation is being corrected, but can be expected to result in a shortfall in production of about 50,000 tonnes of ore during 1997.

Depletion of reserves at the Garpenberg mine has previously been scheduled to occur in 2000 or 2002. Present indications are that additional ore may be available at depth, but the quantities and grades are yet to be defined. Additional exploration in this area is ongoing.

Operating cost projections, notably at Garpenberg North, may be somewhat optimistic.

2.3.3 Laisvall

It is the opinion of Micon that the ore reserves for Laisvall have been estimated in an appropriate manner and represent a reasonable basis for the future projection of production of the mine. The anticipated increases in annual production rate are considered reasonable, as are the estimations of future operating and capital costs.

2.3.4 Aitik

The production plan and estimates of future operating and capital cost are based on historical performance and are considered reasonable. The only concern with regard to the operation's ability to achieve predicted performance is the unlikely occurrence of major, uncontrollable slope failure. Given the monitoring procedures and levels of technical input provided to the operation, such an outcome is considered unlikely.

2.3.5 Apirsa

Boliden Apirsa, SL is the Spanish subsidiary of Boliden AB, which owns and operates the

Aznalcóllar-Los Frailes mine in Spain.

Boliden AB acquired Apirsa in December 1987, when the remaining life of the Aznalcóllar mine was only four years and closure was planned for 1992. By the end of 1990, the company had evaluated measured resources of 70 million tonnes in the Los Frailes orebody, and had expanded the operating life of the Aznalcóllar pit to the end of 1996.

The Los Frailes project concept is strongly focused on the means to generate a profit from low value ores, with difficult metallurgy, by maximizing the benefits of high production rates, large equipment and sophisticated process control systems.

2.3.6 Saudi Arabia

The Saudi Company for Precious Metals is equally held by Boliden AB and Petromin. The Sukhaybarat mine was brought on-stream in 1991 and is one of only two gold mines in Saudi Arabia.

With the impending exhaustion of reserves, the Sukhaybarat property is reduced to an attractive exploration target. However, a successful outcome to the present drilling campaign would extend mine life to 2001.

As noted above, ore reserves may be established at the Bulghah property from the present Measured and Indicated mineral resources.

2.4 ENVIRONMENT

Boliden AB developed a formal environmental management system in the 1980's characterized by: environmental policy, strict responsibility structure, internal auditing, and regular reporting to the government, employees and the public.

Micon was impressed with the qualifications and knowledge of all members of the environmental management team. They have a good understanding of international mining environmental activities, and promote knowledge sharing activities with North American mining companies.

Environmental audits have been completed since approximately 1989, on an annual basis at all mines in Sweden, as well as at operations in Spain and Saudi Arabia. The audits are completed by personnel not directly responsible for day to day activities at the site. This practice is acceptable, although periodic independent environmental audits should be conducted, at key sites.

Environmental issues related to mining are regulated under the Swedish Environmental Protection Act (SEPA). The legal obligation for mining reclamation in Sweden is not well defined. A draft of proposed amendments apparently holds land owners responsible for the reclamation of all lands active after 1969. For the purposes of environmental liability assessment, it has been assumed that Boliden AB will be responsible for reclamation costs associated with all properties that were active after 1968. There are no current or expected future requirements for reclamation bonding, although it is becoming common in other industrialized countries.

The total reclamation cost for the Boliden AB properties has been defined by Boliden AB as US$75.2 million to US$80.2 million. Micon's review has resulted in an estimate of US$81.4 million to US$88.7 million, as summarized on Table 2.5. It is believed that the company's estimates for decommissioning and reclamation of the industrial areas at Boliden, Kristineberg and Apirsa are optimistic. Despite these factors, the Micon estimate is within the ± 20 per cent accuracy that Boliden AB stated for its estimate.

The Micon estimate assumes that all costs will be realized as a capital cost on closure of the property. In fact, Boliden AB is current with international management strategies in this respect, and conducts progressive reclamation during operation whenever possible. As a result, a portion of Micon's estimate of US$81.4 million to US$88.7 million may be realized as an operating cost. Considerable effort is required to be able to assess the operating and capital reclamation costs independently. Micon believes that allocation of 50 per cent of the reclamation cost to on-going operating costs is reasonable.

Boliden AB has indicated verbally (R. Jonsson, Vice President, Finance) that an estimate of 400 million SEK (US$57 million) has been assumed for long term liability. This is less than the total reclamation cost estimate recently provided by Boliden AB to Micon (Table 10.3, US$75.2 million to US$80.2 million), and the Micon estimate of US$81.4 million to US$88.7 million.

Table 2.5
SUMMARY OF ENVIRONMENTAL LIABILITY BY GEOGRAPHIC AREA

	Closure Plan Status	Boliden AB Estimate (US$)	Micon Estimate (US$)
Boliden Area			
Boliden - industrial area	Pe	1.7-2.1	2-4
Boliden - mines	Pe	0.57	0.57
Boliden - tailings area	P	1-2	2-4
Kristineberg - industrial, tailings area	Pe, A	5.54	5.57-6.57
Kristineberg - mines	-	1.85	1.85
Åkulla West	A	na	0.1
Renström / Petiknäs	A	1	1
Åkerberg	A	0.43	0.43
Holmtjärn	C	0.007	0.007
Kimheden	C	0.021	0.021
Långdal	A	0.71	0.71
Kankberg	A	1	1
Rakkejaur	Pe	1-2	2
Näsliden	C	0.036	0.075
Rudtjebäcken	C	0.004	0.004
Rävlidmyr	C	0.043	0.043
Hornträsk	C	0.029	0.029
Lainejaur*	-	0.007	0.042-0.080
Total		**14.9-17.3**	**17.5-22.5**
Laisvall			
Total		**2.4-2.9**	**2.4-2.9**
Aitik			
Aitik	P	41.0	41.0
Laver*	-	0	0.25-0.5
Total		**41.0**	**41.3-41.5**
Garpenberg			
Garpenberg and Garpenberg North	P (tails)	5.36-6.93	5.36-6.93
Enåsen	C	0.75-1.28	1.28
Vassbo*	-	0.014	0.014
Saxberget	C	0.71	0.71
Kalvsbäcken*	-	0	0.38
Total		**6.8-8.9**	**7.7-9.3**
International Operations			
Apirsa	Pe	9.0	10.5
Sukhaybarat (50% of total)	Pe	1.1	1.5
Total		**10.1**	**12.0**
Exploration Properties			
Estimate for All Areas Total	**-**	**0**	**0.5**
Grand Total		**75.2-80.2**	**81.4-88.7**

Closure Plan Status: C, completed / under completion; A, approved plan; P, under permit review / preparing for application; Pe, pending. This information is listed to provide a general qualification of the level of accuracy of Boliden AB's estimate.
* Boliden AB does not accept responsibility for reclamation of the property, but Micon believes these costs will be incurred.

2.5 EXPLORATION PROPERTIES

Boliden AB has an active exploration programme in areas outside those surrounding its existing mining operations. These are in:

Sweden (away from current mining operations)
Finland
Spain
Burkina Faso
Argentina
Mexico
Saudi Arabia

In Sweden, targets include the Mardsel and Laver areas of the Norrbotten region. Exploration in Spain is conducted in Sevilla and Huelva provinces, principally for massive sulphides, but also for gold. Gold exploration is planned in the province of Asturias.

In Burkina Faso, the Bouboulou property is a gold target in the Birimian greenstone belt, where mineralization similar to the Ashanti gold belt is sought in a three-year programme.

As noted above, exploration in Saudi Arabia by SCPM has delineated the Bulghah gold deposit.

Reconnaissance exploration is planned for 1997 in Finland, and joint venture agreements have recently been signed for programmes in Argentina (Chubut Province) and Mexico (Sonora State), with Oro Belle Resources Corporation and Silver Eagle Resources Ltd., respectively.

3.0 MINES IN THE BOLIDEN AREA

3.1 INTRODUCTION

The Boliden area (see Figure 3.1) in Sweden's Vasterbotten region is one of the company's oldest mining areas. Operations started in 1924. The original Boliden mine, which closed in 1967, contained the highest grade gold ore known in Europe.

The area today has six mines and one concentrator that processes ore from all the mines, of which the most distant is Kristineberg, 95 km to the northwest. The ores are complex, with copper, lead, zinc, gold and silver. An exploration programme is under way to maintain the ore reserves for production to 2005.

Three of the mines, Kristineberg, Renström and Petiknäs, will provide approximately 80 per cent of the area concentrator's ore intake in the near future. New ore sources are due to be developed at several of the mines, and are included in the production plans, but require evaluation and capital expenditure before they can be considered viable. Approximately 20 per cent of the forecast ore tonnage due in 1997 to 2001, containing 40 per cent of the gold and about 20 per cent of the other metals' output, is still classed as "resources", mostly in the "inferred" category (equivalent to "additional mineralized concentrations" and "Possible" resources, respectively).

Mining operations are predominantly underground, and the cut-and-fill method is applied to obtain maximum extraction in the complex and narrow orebodies. Occasionally, variations on the cut-and-fill method are employed, such as rill mining (the "Avoca" method). Sub-level open stoping is also used. Ore from the mines is trucked to the central concentrator by contractors.

In 1996, the Boliden area mines produced 1.412 million tonnes of ore. The mill treated 1.447 million tonnes, and produced approximately 1,961 kilograms (kg) gold, 65,443 kg silver, 8,944 tonnes copper, 56,850 tonnes zinc, and 3,607 tonnes lead. Total on-site costs for mining through to concentrates transportation including exploration, depreciation, and administration were 492.2 million SEK, or 348 SEK per tonne ore mined (US$52 per tonne). Average mining costs were 189 SEK per tonne, (US$28 per tonne) including transport to the concentrator, depreciation, and local services.

Cost data were collected for each of the three principal mines, Kristineberg, Renström, and Petiknäs.

Data for 1993 to 1996 were presented by activity for each mine. For example; direct costs comprise eight activities, while indirect and area costs comprise six activities each. A total mine cost per tonne of ore milled was thus derived, together with a direct mining cost per tonne mined.

Historic cost data for 1993 to 1996 are provided in the discussion for each of the principal mining operations. It can be seen that production increased in 1996 over 1995, and that cost reductions were effected.

[Figure 3.1 - Mines and Concentrators in Sweden]

Data for the period 1997 to 2001 were presented by cost category format for each mine. Total costs at each mine were summarized in seven cost categories; for personnel, materials, energy, contractors, milling and area services, central Boliden services, and depreciation. Because of the difference in presentation of historic costs and strategic plan costs, it is not possible to relate past trends to future cost estimates in any detail. However, certain factors contributing to cost and efficiency changes were explained by the Boliden staff, and are included in the notes below on each mine.

The four remaining mines, Åkerberg, Långdal, Åkulla and Kankberg, are described briefly. They are either being redeveloped or operate at low levels of output. They are expected to supply 1.391 million tonnes, or only 19 per cent of total area production in the period 1997 to 2001. Most of the ore scheduled for production is still under investigation, and these mines were not visited.

3.1.1 1997 Budget

The budget, being more up to date than the Strategic Plan, differs slightly from the 1997 forecast in the Information Memorandum, principally in depreciation charges in 1997 and in the prices for zinc (US$0.50 per pound) and lead (US$0.26 per pound).

It had been expected that a central Boliden Area Mines summary planning document would be available to back up the Information Memorandum, in which each mine's ore reserves by location, production tonnage and grade, main activities schedule, income and costs would be laid out according to a uniform procedure. Such a summary does not appear to exist. Forward plans are made at each mine, and these were prepared to different standards at each location.

The central mine planning office prepares the mine's income and costs forecasts, income is derived from the concentrator department's report on the products attributable to each mine. This production forecast is understood to be based on average grade of ore from each mine. The concentrator head tonnage and grade figures (while not exactly similar) appear to confirm this.

3.2 CHARACTERISTICS OF THE PROPERTY

The Boliden area mining operations are located in Norrland's (northern Sweden) Västerbotten region, one and one half degrees south of the Arctic Circle. The mines are clustered around the town of Boliden (Figure 3.1). Boliden, a small single industry town of a few thousand people, is located approximately 30 km west-northwest of the regional/industrial centre of Skellefteå (population 75,000). The Åkerberg, Åkulla/Kankberg, Kristineberg, Långdal and Petiknäs/Renström mines are respectively, approximately 40 km northeast, 8 km northwest, 95 km west-northwest, 6 km south and 19 km west-northwest of Boliden. The Rönnskär smelter is located 20 km east-southeast of Skellefteå on the coast of the Gulf of Bothnia.

All of the mines and the town of Boliden are served by a good quality, all weather, secondary paved highway from Skellefteå and good quality secondary roads connecting to that highway. The highway is a part of the Swedish national system of paved highways and connects at several points, including Skellefteå, to highways going north-south.

Skellefteå is served by six daily jet and turboprop flights connecting to Sweden's capital city of Stockholm. In addition, Skellefteå also has deepwater ocean port facilities at nearby Skelleftehamn and Rönnskär. The Swedish government uses ice breakers to keep the Gulf of Bothnia open to shipping year round. There is a railway running west from Rönnskär, through Skellefteå, to the Norwegian border, connecting with the line to southern Sweden.

Northern Sweden has an abundance of rivers suitable for the development of hydro electric projects and a large number have been built. Electrical power and water supplies for the mines are more than adequate.

In addition to the city of Skellefteå and town of Boliden, a number of smaller communities can be found dotting the countryside in the area of the mines. These towns provide the support required for the mine facilities and have an adequate supply of trained and experienced workers of the types required to run a mine.

3.2.1 Topography and Climate

The Skellefteå area was glaciated 10,000 years ago and this event has had a significant effect on the local topography. Extensive deposits of glacial till have covered the district resulting in rolling hills and lake-filled valleys. Only limited outcrop exposure occurs. Total vertical relief is under 100 m.

The land, where not cleared for farming, is covered in a boreal forest consisting of pine and spruce. Moose, deer, fox and free range domesticated reindeer are common. Wolf, lynx, bear and wolverine are known to exist but are rare. The topography and vegetation is very similar to that seen in northeastern Ontario or northwestern Quebec.

The Skellefteå area has a climate much warmer than its latitude would suggest. The Gulf Stream, which passes up the Atlantic coast of Norway, moderates both summer and winter temperature extremes. Monthly average temperatures peak in mid-July at about 15 to 17° C and day-time highs in mid-winter are typically -10 to -15° C. Annual precipitation is moderate at less than 700 millimetres (mm). Due to the high latitude, days are extremely long in late spring-early summer and very short in early winter.

3.3 GEOLOGICAL SETTING

The Skellefteå mining district (see Figure 3.2) occurs in an Early Proterozoic (approximately 1.89 to 1.87 billion years old), mainly northwest-southeast-trending belt of Svecofennian, subaqueous, dominantly felsic volcanic rocks, known as the Skellefteå Group, which is overlain by, and partly intercalated with, a sequence of younger (1.87 to 1.85 billion years) sedimentary and mainly mafic volcanic rocks, known as the Vargfors Group. The supracrustal rocks of both groups have been intruded by synvolcanic granitoid rocks and younger post-volcanic, intrusive rocks of granitic to gabbroic composition. To the south, the rocks of the Skellefteå Group are in conformable contact with the older, highly metamorphosed graywackes, turbiditic mudstones and sandstones of the

Bothnian Basin. To the north, the Vargfors Group is in contact with subaerial volcanics of the Arvidsjaur Group which are likely of similar age to the sedimentary units of the Vargfors Group.

[Figure 3.2 - Generalized geological map of the Skellefteå region]

The rocks of the Skellefteå district have experienced two major phases of folding. The district contains isoclinal to open folds, cut by shear zones and numerous brittle faults. The rocks show greatly varying cleavage intensities and have been regionally metamorphosed to upper greenschist-lower amphibolite facies during the Svecokarelian orogeny. The metamorphic grade generally increases towards the southeast as one approaches the Bothnian Basin.

The Skellefteå district, one of the most important mining districts in Sweden, is 120 by 30 km in size and is host to at least 85 pyritic, zinc-copper-gold-silver massive sulphide deposits and a few vein gold and subeconomic porphyry copper-gold-molybdenum deposits. The massive sulphide deposits vary widely in size, grade, metallurgy and economic viability, but 52 are known to be larger than 100,000 tonnes and contained a total pre-mining tonnage of 161 million tonnes at an average grade of 1.9 g/t Au, 47 g/t Ag, 0.7% Cu, 3.0% Zn and 0.4% Pb. The median deposit size is 1.1 million tonnes. The deposits frequently show highly anomalous levels of arsenic, antimony and mercury.

The massive sulphide deposits occur mainly within or at the top of a regional, felsic volcanic-dominated suite of rocks within the upper part of the Skellefteå Group, but are also found in the lower portions of the Vargfors Group. The deposits are hosted by volcanic rocks or volcaniclastic sedimentary rocks of generally rhyolitic to dacitic composition. They span a range in ore deposit styles from deep water, sea floor ores of the Kuroko-VMS style, to subsea-floor replacements, to shallow water and possibly subaerial synvolcanic replacements.

The gold-bearing quartz vein deposits of the Skellefteå mining district are hosted within both intrusive and extrusive rocks and are clearly epigenetic in character. Some have been interpreted to be epithermal, others mesothermal. The epithermal deposits are believed to be pre-metamorphic and are associated with the magmatic and hydrothermal activity which gave rise to the massive sulphide and porphyry mineralization in the area. The mesothermal deposits are likely only slightly younger than the epithermal gold and massive sulphide deposits and are probably associated with the Svecokarelian orogeny.

3.4 HISTORY OF EXPLORATION

The Skellefteå District has been extensively explored for base metals since the first discovery, the exceptionally gold-rich massive sulphide ore of the Boliden Mine, found in the late 1910's. Boliden AB was formed to mine the Boliden deposit and commenced production in 1924. Since 1924, over 85 massive sulphide occurrences have been discovered (the majority by Boliden AB) and a total of 21 deposits have been mined. Boliden AB has extracted in excess of 85 million tonnes of ore from the Skellefteå mining district and currently operates five mines there. A sixth, small open pit mine was being stripped and prepared for production at the time of Micon's site visit in March, 1997.

The Skellefteå district has been recently glaciated and there is an extensive cover of Quaternary sediments of glacial derivation. As a result, there is less than one per cent outcrop exposure in the belt. Due to this paucity of exposure, most of the massive sulphide deposits discovered to date have been found by tracing mineralized boulder trails in the glacial sediments to their bedrock source or by using ground and airborne EM geophysical surveys. The former technique is limited to exploration for deposits which outcrop or subcrop at the bedrock-glacial till interface, while the latter technique is effective in the search for deposits within approximately 250 m of the surface.

Boliden AB has a long tradition of research and development in geophysical instrumentation. It has designed and built many of the instruments used to discover the known orebodies in the Skellefteå mining district. Boliden AB treats these instruments as proprietary technology and does not sell, rent or lease them. In recent years it has developed a borehole EM instrument which can be lowered down a diamond drill hole to search for massive sulphide mineralization at depths which cannot be reached from surface geophysical surveys. This instrument was recently successful in discovering the south zone at the Petiknäs Mine.

3.5 GEOLOGICAL RESOURCES AND MINEABLE RESERVES

3.5.1 Resource/Reserve Classification

Resources and reserves at the Boliden area operations are classified and defined in section 1.1.2 in the Introduction to this report.

3.5.2 Exploration Database

The Boliden Area Operations of Boliden AB are informally divided into two operating districts, the Kristineberg District, containing the Kristineberg Mine, and the Boliden District, containing the Långdal, Renström, Petiknäs, Åkerberg and Åkulla Mines. Each district has a central mine geology office, core logging and storage facility and sample preparation room. A team of mine geologists and technicians works out of each district office and is responsible for the collection of data and for the maintenance of each mine's database. The original database of geologic data for each mine is kept at one of the two district mine geology offices.

The Boliden District office shares its geologists' and technicians' time among five mines. The district's mines have their mine planning engineers located at the mine sites, many kilometres away from the mine geology staff located at the district office in the town of Boliden. In order to maintain access to the database, these mines have a dedicated HF radio data link to the district mine geology office and the Boliden Central Technical Office. Each mine's database is duplicated at the Boliden Central Technical Office and updated on a regular basis.

Drill Hole Data: The only assay data used in the calculations of ore reserves at the Boliden area operations are from diamond drill holes. These data, combined with geological mapping performed by the technicians at the mine, comprise the database used to estimate the ore reserves.

Boliden AB is in the final stages of converting to a paperless, electronic, calculation of ore reserves and mine planning system. In the pursuit of this goal, all diamond drill holes from all of the mines as well as all new drill holes by the exploration group, have been entered into computer databases. Each minesite has its own drill hole database. These databases are maintained using the programme Visual dBASE. The file type is the standard .dbf format and supports both SQL and ODBC protocols. It therefore can be read by other software packages which support these protocols.

Diamond drill holes are logged on hand written, paper logs with graphic log, text and tabular observation sections. The tabular observation section of the log, along with assay results, collar coordinates and downhole survey information, subsequently are entered manually into the computer database. No rock mechanics data are routinely recorded during drill hole logging. Certain selected drill holes, in areas of specific concern to the engineers, have been geotechnically logged. The results of the geotechnical logging are in the computer database, in a relational table.

Assay Data: Boliden AB maintains its own assay laboratories at the Rönnskär smelter, 20 km southeast of Skellefteå and 50 km southeast of Boliden, and at the Boliden concentrator. Samples from the Boliden concentrator, the Boliden area mines and the Rönnskär smelter are assayed at the Rönnskär laboratory.

Samples are prepared at the district mine geology offices in the same facilities in which core is logged. At each sample preparation facility, samples are crushed to an appropriate size for the material being sampled and split using a cross stream, rotary splitter. The splits are then shipped to Rönnskär for pulverizing and assaying. The Rönnskär laboratory is involved in a round-robin, analytical check procedure with other analytical laboratories in Europe. Micon inspected both sample preparation facilities used in the Boliden area operations and found them to be clean, well-designed, properly equipped and in good working order.

Assay results, once available, are entered onto the paper logs and into the computer database at the district mine geology offices.

Mapping Data: Geological mapping, of as many blasts as possible, is done at each mine. Typically, at least 50 per cent of the blasts in each stope are seen by the geological technicians who map the face and back (if the shotcreting cycle allows) of each blast that they see. The results of the mapping are plotted and compiled by hand on plan views of the stopes. On completion of each lift in a stope, a true ore outline, for that lift's mining, is interpreted and digitized into a computer database using a CAD programme called MICROSTATION. In addition, a projected ore outline for the next lift is prepared and digitized. These ore outlines are available to any authorized user in an ore reserve estimation or mine planning position.

Other Sampling Data: Boliden AB has found that grab samples or chip/channel samples are not required for grade control in its stopes in the Boliden area mines. Most lifts in most of the stopes are stopped because the massive sulphide bed has become too thin and dilution with waste too high, not because the grade of the massive sulphide has dropped off. For this reason, grade control can be done visually and only rarely are faces or muck piles sampled. As a result, there is no database of underground ore sampling data available for ore reserve estimation purposes or for reconciliation of credited production to individual stopes.

3.5.3 Estimating Procedures

Two different procedures are used for estimating resources/reserves at the Boliden area operations.

These are a conventional, sectional procedure and a block model-kriging procedure. Boliden AB is in the process of converting to a system of using the block model-kriging procedure at all of its mines. This conversion was only begun in 1995 and, consequently, only two of the mines, Renström and Kristineberg, have had ore reserves calculated in this manner. All of the other mines and advanced exploration projects including Långdal, Petiknäs, Petiknäs North, Åkerberg, Åkulla and Åkulla East, use the conventional sectional resource/reserve determination method. Several of the mines with limited lives are unlikely to be converted to the geostatistical ore reserve determination.

The ore reserves are calculated at each district mine geology office using ore outlines generated by the mine geologists. This process is usually completed with technical help available from the Boliden Central Technical Office. The calculations for the block model, variography and kriging are normally done by the more powerful computers available at the Central Technical Office but are completed with the mine geologist's involvement. In addition, the Central Technical Office audits all ore reserve estimations and tabulations before they can be published or used within the company.

NSR Calculations: The mines of the Boliden area produce mostly polymetallic ores of differing and relatively complex metallurgy. These ores are milled at a single concentrator in the town of Boliden. Typically, three to five metals are recovered from each mine's ore and the recoveries, work indices and penalty elements vary significantly from one ore to the next.

As a result of this, Boliden AB uses a Net Smelter Return (NSR) value instead of individual or equivalent assay values for resource/reserve evaluation and estimation. Each mine receives, on a monthly and annual basis, a metallurgical balance for the ore it provided to the Boliden concentrator. As part of this balance, each mine receives a factor for the five metals (gold, silver, copper, lead and zinc) recovered from the ore. These factors, when multiplied by the grade of the respective metals and then summed, will provide the precise value of individual blocks of ore to Boliden AB. The factors, which are unique to each mine and/or ore zone within each mine, include adjustments for smelter charges as well as that mine's/zone's different penalty elements, milling rates and known variances in recovery.

Boliden AB uses long-term commodity price and exchange rate forecasts to determine the factors for the NSR resource/reserve calculation. These forecasts are reviewed annually before ore reserves are calculated. The forecasts currently in use for ore reserve calculations are:

Lead		US$ 0.27/lb
Zinc		US$ 0.52/lb
Copper	US$ 1.00/lb	
Silver		US$ 5.00/troy oz
Gold		US$ 390.00/troy oz
1 SEK	=	US$ 0.1429
1 US$	=	SEK 7.00

These price forecasts may differ slightly from those used elsewhere at Boliden AB, for example for corporate budgeting or other financial purposes which operate on shorter time scales.

Sectional Resource/Reserve Procedures: The sectional resource estimation technique used by Boliden AB is a conventional one except that it has been largely computerized and automated. Geological interpretation is done on plan views of stope mapping, longitudinal section and computer generated cross sections. Boliden AB uses proprietary, add-on programmes for the MICROSTATION CAD software package to plot its cross sections and drill holes. Sections are typically generated every 20 m and have a 10-metre zone of influence on either side. Any drill hole passing through this 20-metre wide corridor is plotted on the section. Grades of individual or multiple elements are not plotted on the sections. Instead, the results of the NSR calculation are plotted on one side of the drill hole and a rock type code on the other side.

The mine geologist uses stope and/or sill drift mapping from above and below each stoping block or, in its absence, estimated ore outlines created by interpretation of drill sections and projection of developed ore zones. From these sources, a longitudinal section of each ore lens is generated and an upper and lower plunge line interpreted.

Each ore lens is interpreted on cross section by projecting the geology and ore grade intercepts (that is, intercepts with an NSR value exceeding the cash cost cutoff value) between drill holes. Resource blocks are outlined on the projection of the lenses using the following rules:

> 1) All ore grade intercepts (composites) used to produce a resource block must meet a minimum true width (typically 4 to 5 m in the Boliden area mines) which is determined by the equipment and mining method in use at each stope.
>
> 2) Resource blocks are outlined by projecting the hanging and footwall edges of each composite halfway to the next composite and closing off the block. In the absence of an ore grade composite to project to, the block is projected to the upper or lower plunge line transferred from the longitudinal section.
>
> 3) Care is taken to check the individual assays which make up each ore grade composite to ensure that the composite shows geological consistency with the NSR. For instance, if an ore grade composite is relying on a high silver value for its high NSR value but does not have a correspondingly high zinc value, it must be considered suspect. At the Boliden area mines, silver normally occurs in high concentrations only in the presence of high sphalerite.

Once the resource blocks have been outlined on section, the CAD package determines the surface area of each block, then tabulates and exports the data to a spreadsheet. Resource block volumes are calculated in the spreadsheet by multiplying the block area by the depth of influence for each section. This is typically the 20 m mentioned above, but may be less as a plunge line is approached. These depth values are determined by measurement on the longsection. Resource block tonnages are determined by multiplying the block volume by the specific gravity (SG), which is determined using the formula described in the section on Specific Gravity, below.

The feasibility and pre-feasibility studies adjust the tonnage and grade of the resource to reflect expected waste dilution and mining losses. Different dilution rates are used in different ore zones in the Boliden area mines. The dilution typically varies between 10 and 20 per cent and is determined so as to reflect known ground conditions, stope widths and stoping types in each lens at each mine. Micon has visited several stopes in the Boliden area mines and considers the dilution factors chosen to be reasonable.

Block Model Kriging Procedures: As stated above, block modelling-kriging is a relatively recent innovation at the Boliden area operations. It was first utilized at the Kristineberg mine for its January 1, 1995 ore reserve calculation. At that time, the mine calculated a conventional, sectional ore reserve and a parallel block model-kriged ore reserve. It was concluded that the kriged reserve was a more accurate estimate of ore grade as the zinc grade compared more closely with actual production grade. (The geologists had long felt that the conventional ore reserve estimation technique was slightly overestimating zinc content). The new kriged ore reserve lowered the average zinc grade while not significantly changing the estimated concentrations of any of the other metals (see Table 3.1).

Table 3.1
KRISTINEBERG MINE CONVENTIONAL AND GEOSTATISTICAL ORE RESERVES COMPARISON

	Tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %
1995 Conventional Reserve	2,385,000	1.4	62	1.14	7.18	0.55
1995 Block Model Reserve	2,370,000	1.3	59	1.13	6.61	0.50
Difference	-15,000	-0.1	-3	-0.01	-0.57	-0.05

As a result of the more accurate ore reserve numbers that geostatistics appeared to be producing, it was decided to expand the use of the technique. Ore reserves at Renström have now been calculated with a block model. While the Renström block model is a 3D one, the Kristineberg block model was a simplified 2D model and some of the comments made here (as noted) do not apply to it.

The deposit block model uses blocks with horizontal length by horizontal width by vertical dimensions of 10 x 3 x 5 m. The block grade-kriging estimation technique used by Boliden AB has been tailored to fit the established characteristics of the Boliden area deposits in order to easily accommodate changes in orebody configuration that may become apparent as mining progresses. This involves geologically-unconstrained kriging on which is superimposed the outline of the deposit, as known from drilling and mining, at the time of resource/reserve determination. The ore outline is obtained by joining together ore outlines created at 10-metre elevation intervals throughout each ore lens, with the upper and lower limiting outlines typically being actual ore outlines from stopes or exploration/sill development. The intermediate level ore outlines are derived from interpreted diamond drill sections and extrapolation of developed ore from the sills and stopes. While somewhat unconventional, Micon concludes that this technique is a practical and acceptable one.

For the estimation process, individual drill hole composites are constructed using similar techniques as in the conventional sectional estimation method described above. Waste grade composites, from the ore-bearing horizon surrounding each lens, are included. The assay results are then kriged using a search ellipse developed from 3D variography (2D at Kristineberg).

Assay/NSR data from the kriging can be used to fine tune the strike extents of the individual ore outlines. Each outline is then digitized, in 3D, into the CAD software. The CAD software extracts the volumes and grades of the blocks which lie within the ore outline and exports the data to a spreadsheet where SG, NSR and tonnage calculations are performed and the results tabulated and summarized.

Specific Gravity (SG): Boliden AB has recognized that within each mine in the Boliden area there is significant, local variability in the SG of the ore, with measured SG's in core ranging between 3.1 and 4.2. This range of possible SG values represents a significant potential for error in the estimation of resource/reserve tonnages and makes it prudent to determine the SG for each drill intercept in ore.

Measurement of SG's on such a frequent basis is an onerous and expensive task. Accordingly, Boliden AB calculates the SG for a drill hole composite, with reasonable accuracy, from the base metal and sulphur analyses, using the following formula:

$$SG = 2.7 + (.004 * Cu\%) + (.004 * Zn\%) + (.020 * Pb\%) + (.0375 * S\%)$$

This formula has been tested against numerous actual measurements of SG from core and has been found to be more accurate than previous estimation methods, except at high lead concentrations, for which Boliden AB has developed a modified version of the formula. SG calculated from assay values also has the attraction of automatically being kriged with the ore reserves as, after kriging, each block in the block model has an individual copper, lead, zinc and sulphur grade assigned to it from which the SG is derived by means of the formula. It is anticipated that the detailed changes in SG throughout the block model, produced by this method, will allow for more accurate production scheduling in the future.

3.5.4 Reconciliations

All of Boliden AB's mines in the Boliden operating area feed their ore to a central processing plant in the town of Boliden. This situation complicates any attempt to perform a metallurgical balance or ore reserve reconciliation to the mines. Boliden AB has taken several steps to limit these complications.

The mill at Boliden maintains six separate ore bins and two completely separate grinding and flotation sections before the concentrates from the various circuits are combined. The B Section (A Section has been decommissioned) mills a blend of Kristineberg and Renström ore with a small amount of Åkerberg ore to aid in grinding in the autogenous mill. The C Section batch mills the other four mines' ore (Åkerberg, Åkulla, Långdal and Petiknäs) in campaigns that last one to three weeks.

As can be seen from the schematic mill flow sheet (see Figure 3.3), all feed sources to the B and

C Sections are kept separate as the ore is trucked in. The trucks are weighed as they arrive on site at the plant, providing a known weight of the ore to be milled from each mine. This weight is defined, for reporting purposes, as the accepted tonnes produced from each mine. Samplers have been installed on both the B and C Sections so that all streams leaving each section (gold concentrate,

[Figure 3.3 - Boliden Concentrator]

copper-lead concentrate, zinc concentrate and tails) are sampled on a regular basis. At month-end the quantities of metal in the concentrate streams are reconciled with the Rönnskär smelter, added to the tails losses and a true production from, and headgrade for, each circuit are obtained.

As a result of the fact that C Section batch mills in long campaigns of one to three weeks, it is a relatively simple matter to allocate production from that circuit, between certain dates, to each of the four mines. Allocating production from B Section is somewhat more problematic and requires making some assumptions. Åkerberg ore in B Section is assumed to be the same grade as the most recent determination for Åkerberg in C Section. The remaining metal is distributed between Renström and Kristineberg based on the tonnes of each ore milled and the predicted production grades that each mine geologist provided for his mine's monthly production schedule. Despite the questions raised during reconciliation, Åkerberg, Renström and Kristineberg ores are blended and not batch milled because it was discovered that both overall throughput and recoveries increased by doing this.

Boliden AB does not require that all mines in the Boliden operating area produce an annual reconciliation between what the ore reserves predicted, what was produced and what the concentrator credited them with. However, Kristineberg, Renström and Petiknäs, the three largest producers, have been doing these reconciliations since 1986, 1991 and 1994 respectively. The results of the reconciliations for the last three year's production are set out in Table 3.2 below.

Table 3.2
PER CENT DIFFERENCE OF CREDITED PRODUCTION FROM ORE RESERVES

Year	Tonnes %	Au %	Ag %	Cu %	Zn %	Pb %
Petiknäs						
1994	1.8	-1.3	15.0	0.0	9.5	2.6
1995	-5.8	27.6	0.0	28.6	12.4	3.1
1996	-1.1	0.4	-5.4	39.5	-3.5	-4.0
Renström						
1994	3.9	-3.7	-1.9	0.0	-17.1	-5.6
1995	5.9	32.0	16.9	1.8	-9.9	0.1
1996	2.1	-4.0	-10.2	-12.5	-9.8	-11.2
Kristineberg						
1994	1.5	-6.3	1.6	-16.2	-2.9	23.4
1995	-0.4	7.1	5.4	-9.3	-5.2	25.0
1996	0.2	0.0	-1.5	-7.8	-3.3	2.4

With the exception of the copper production from Petiknäs and lead production from Kristineberg, the ore reserve estimates are predicting production within their stated accuracy limits and there are no apparent, consistent biases.

3.5.5 Reported Reserves and Resources

The Proven and Probable Ore Reserves as reported by Boliden AB for mines in the Boliden area are as follows:

Polymetallic ore reserves: 6.856 million tonnes at 2.1 g/t Au, 93 g/t Ag, 1.0% Cu, 5.5% Zn, 0.8% Pb

Gold ore reserves: 0.506 million tonnes at 4.2 g/t Au, 5 g/t Ag, 0.5% Cu

The Proven reserves and Probable reserves are classified by Micon as Proven Ore and Probable Ore, respectively, as defined in National Policy 2-A. Details are set out in Table 2.1 in the Summary section of this report.

Boliden AB has delineated substantial amounts of resources that, as yet, have not been subjected to detailed economic study. Measured and Indicated polymetallic resources total 1.686 million tonnes. Mine pillars of undetermined recoverability amount to a further Measured resource of 1.357 million tonnes. Additionally, Boliden AB reports Inferred polymetallic resources of 6.5 million tonnes. All of these resources are of similar grade as the reported Ore. Measured and Indicated gold resources, including mine pillars, total 95,000 tonnes at 2.4 g/t Au; Inferred gold resources are estimated as 1.5 million tonnes at 7 g/t Au.

Boliden AB's reported resources are classified by Micon as additional mineralized concentrations in accordance with National Policy 2-A. Details of these resources are set out in Table 2.2 in the Summary.

3.6 EXPLORATION POTENTIAL

Approximately 80 per cent of the production to date from all of Boliden AB's mines has come from above the 300-m level. With the exception of Petiknäs, the remaining production from below the 300-m level comes from deposits which subcrop or come very close to the surface. Still, massive sulphide mining is currently taking place below the 1,000 metre level at Renström and Kristineberg and the mineralization at Renström is known to extend to depths below 1,500 m. This deep ore was discovered because at some point the orebody was very shallow and was later extended to great depth by following mineralization down dip.

More than 70 years of exploration have probably come close to exhausting the possibilities for finding similar deposits in the area. Nevertheless, given the known mineralization at depths of over 1,500 m, along with the lack of outcrop in the Skellefteå district and the associated difficulties, in such terrain, of exploring for deposits which do not come close to surface, there appears to be significant potential for the existence of new, deep, blind orebodies.

Discovery of such orebodies would not occur through prospecting or conventional ground and airborne geophysics. A programme designed to search for deep, blind deposits would involve geologically led exploration. It would include compilation of all known structure, lithologies and geochemistry from mapping and drilling data, the resultant identification of prospective horizons and the projection of these horizons to unexplored ground. In addition, there would need to be a willingness to drill in new areas for structure and stratigraphy, rather than for ore, and to make use of innovative techniques such as down hole geophysics.

Boliden AB is in a singularly unique position to perform such a programme in the Skellefteå district. It has sole access to a proprietary, 20,000 drill hole database and a large, well organized core storage facility where core from many of these old holes still exists. As a result of over 70 years of mining at almost two dozen mines, Boliden AB has acquired a depth of geological knowledge, with respect to the details of the massive sulphide occurrences, that exceeds any other company's knowledge base. In addition, Boliden AB has been an innovator in the development and introduction of new technologies. As part of this programme, Boliden AB has developed certain proprietary geophysical instruments such as one for EM which was recently responsible for the discovery of the blind southern ore zone at Petiknäs.

Exploration for vein type, epithermal and mesothermal gold deposits is at an early stage in the Skellefteå mining district. The potential for such styles of mineralization was not properly recognized in the district until the 1980's when the mesothermal style Åkerberg deposit was discovered outcropping at surface, with no glacial cover. Since that time, the Åkulla epithermal gold deposit has been found in the Boliden area.

The Skellefteå mining district must be considered as a prospective, under-explored area for vein-type gold deposits. The traditional massive sulphide exploration and prospecting techniques, as practiced by Boliden AB in the past, would be unlikely to recognize or detect gold deposits of the types recently discovered in a terrain extensively covered by glacial till. The exploration personnel of Boliden AB have recognized this and will be using their unique database of geological information to revisit various areas in the search for gold.

Boliden AB controls 40 concessions covering 139,622 hectares in the Skellefteå mining district in Vasterbotten County.

3.7 PETIKNÄS MINE - CURRENT MINING OPERATIONS

Proven reserves at end-1996 amounted to 2,671,000 tonnes at a grade of 2.7 g/t Au, 111 g/t Ag, 1.2% Cu, 5.1% Zn, 1.0% Pb. Probable reserves amounted to 1,546,000 tonnes at a grade of 2.2 g/t Au, 93 g/t Ag, 0.5% Cu, 5.3% Zn, 1.0% Pb in the proven and probable category. Some 496,000 tonnes of additional mineralized concentrations exist in pillars (ie. proven) at a grade of 2.7 g/t Au, 111 g/t Ag, 1.2% Cu, 5.1% Zn and 1.0% Pb, while a further 3,000,000 tonnes of possible additional mineralized concentrations are reported. At Petiknäs North, 1,340,000 tonnes of additional mineralized concentrations are identified, with a grade of 4.3 g/t Au, 48 g/t Ag, 1.6% Cu, 2.6% Zn, 0.2% Pb.

The Petiknäs mine started production in 1992, is adjacent to the older Renström mine and shares many of its surface facilities. Mining by cut-and-fill is carried on in the South zone, B and C lenses, at a rate of 500,000 tonnes per year. Ore is currently being mined on levels down to the 575 level and haulage is by trucks (operated by a contractor), through a ramp that connects from surface through to the 600-metre level. A new 2.5-km diesel powered rail haulage is to be completed shortly, on the 750 level, linking Petiknäs lower levels to the Renström hoisting shaft and eventually eliminating the truck haulage requirement.

This mine is highly efficient, using modern equipment and techniques and a well-motivated and trained workforce. Sixty workers and four staff produce at a rate of approximately 5.5 tonnes per man-hour. These manning levels exclude contractors and some centrally provided services, so the real efficiency on ore extraction is probably about 4.0 to 4.5 tonnes per man hour, or roughly 35 tonnes per man-shift, which is a high level by any standard.

Mining cuts are 6.5 m high, and up to 25 m wide, so blasts of up to 2,000 to 2,200 tonnes can be fired with the current 3.8-metre round length. Grade control was very good in the workplace visited, facilitated by a well defined geological contact. Good control of the roof contour is achieved by using electronic jumbo boom alignment aids.

Ground conditions are good and routine bolting with cement grouted rebar is standard practice in backs and walls.

Stoping rounds of 7.0 m length, and the use of frozen fill in bottom cuts to improve sill pillar recovery economics, have been tested in the mine and will be introduced routinely. These systems are referred to in the later section on technical matters.

The introduction of the longer stoping rounds may have an adverse effect on dilution and/or recovery, where wall rock irregularities occur, at least until the method has been well established.

3.7.1 Historical Production Performance

Historical production figures are shown in Table 3.3.

Table 3.3
PETIKNÄS MINE - HISTORICAL PRODUCTION SUMMARY

	Unit	1992	1993	1994	1995	1996
Ore milled	'000 tonnes	90.6	150.9	244.6	336.6	389
Grade copper	%	0.54	0.78	0.61	0.63	0.75
lead	%	0.91	0.90	1.18	1.31	1.00
zinc	%	4.58	4.85	6.34	6.62	5.30
Concentrate						
Copper	tonnes	1,770	3,796	4,763	7,156	9,906
Grade copper	%	18.0	23.2	22.8	21.2	21.8
Lead	tonnes	727	1,258	3,257	4,903	4,903
Grade lead	%	32.8	25.2	32.2	31.2	27.2
Zinc	tonnes	6,027	11,477	25,287	35,924	32,941
Grade Zinc	%	52.5	52.1	52.3	51.5	52.8
Gold	tonnes	7	39	47	52	71
Grade gold	g/t	993	878	430	1,514	2,436

The northern A zone, being a 1.34 million tonnes resource with good values, contains penalty elements (0.2% antimony and 0.4% arsenic). Metallurgical testing is in progress on a bulk sample. (The ore is not yet scheduled for production.)

3.7.2 Historical Cost Performance

Production and production cost data are presented in Table 3.4 below.

Table 3.4
PETIKNÄS MINE - HISTORICAL PRODUCTION AND COST FIGURES
(Thousand SEK, Thousand Tonnes)

	1993	**1994**	**1995**	**1996**	**1996 unit cost/t milled**
Ore produced	176	241	335	390	SEK
Ore milled	151	245	337	389	
Direct costs					
Drill/blast	12965	9399	13666	12731	32.7
Loading	67	183	1473	1701	4.4
Scaling	102	147	506	129	0.3
Reinforcement	448	740	1030	1495	3.8
Fill	986	1344	1382	1344	3.5
Hoist/Transport	1274	1939	4382	4906	12.6
Construction	334	1960	2112	841	2.1
Others	3921	3966	6477	4305	11.1
Sub-total	**20097**	**19678**	**31028**	**27452**	**71.0**
Indirect costs					
Environment	1879	2910	4107	3565	9.2
Comp air/water	4769	4917	6498	6562	16.9
Maintenance	6055	7600	9921	9321	24.0
General mine	-244	4620	6721	7394	19.0
Other general	271	97	262	383	1.0
Depreciation	8194	10361	10909	12703	32.6
Sub-total	**20924**	**30505**	**38418**	**39928**	**103.0**
Area costs					
Transport	1317	3147	4388	4718	12.1
Stockpiling	3013			1547	4.0
Milling	9326	16066	21543	24506	63.0
Concentrate transport	371	600	1018	1031	2.7
Rönnskär stockpiling	353	969	1304	1212	3.1
Commissioning	454	660	727	5609	14.4
Sub-total	**14834**	**21442**	**28930**	**33583**	**86.3**
Total costs	**55855**	**71625**	**98376**	**100963**	**260**
Total cost/tonne milled	**370**	**292**	**292**	**260**	
Mining costs less depreciation	**32827**	**39822**	**58537**	**54677**	
Mine cost/tonne mined	**187**	**165**	**175**	**140**	
Total cost US$/tonne milled	**47.55**	**37.97**	**41.00**	**38.74**	
Mine cost US$/tonne milled	**23.97**	**21.46**	**24.54**	**20.92**	

Petiknäs mine costs are generally favourable in all respects compared to the other mines.

3.7.3 Outlook for Operating Cost

Future estimated costs for the Petiknäs mine are slightly higher than in 1995 and 1996. No allowance has been made in the costing for improved efficiencies due to drilling of longer rounds. Haulage costs have been reduced, to reflect the more efficient rail transportation which will replace the existing truck haulage to surface.

Table 3.5
PETIKNÄS MINE - ESTIMATED OPERATING COSTS 1997 TO 2001
(Million SEK, Thousand tonnes)

	1997	1998	1999	2000	2001
Ore milled	**430**	**500**	**500**	**500**	**500**
Personnel	22	23	23	23	23
Material	20	23	23	23	23
Energy	5	5	5	5	5
Contractors	20	20	18	18	18
Milling & services	36	42	42	41	40
Central services	6	7	7	7	7
Depreciation	18	29	31	32	33
Sub-total	127	150	150	150	151
Total cost SEK/tonne milled	**295**	**300**	**300**	**300**	**302**
US$/ tonne milled	**42.14**	**42.86**	**42.86**	**42.83**	**43.14**
Mine cost SEK/tonne mined	**150**	**145**	**138**	**136**	**135**
US$/tonne milled	**21.43**	**20.71**	**19.71**	**19.43**	**19.29**

The reduction in unit operating costs is due to the higher production rate while fixed costs remain constant, and to the savings in haulage costs when the track haulage is commissioned to the Renström shaft. A further small reduction is included to reflect the reduction in advance expense on cement for sill pillar extraction, the cemented fill being replaced by frozen fill (see the technical note later in this report). No cost reduction has been assumed as a result of the proposed change to drilling longer stoping rounds, but one is definitely expected in due course.

3.7.4 Outlook for Capital Expenditure

The basis for the capital expenditure forecast in the Information Memorandum has been revised by the addition of 3.8 million SEK per year (on average) from 1997 to 2001. This appears to be due to the omission of "miscellaneous equipment" in the document tables.

The previous forecast stands for mine development and equipment purchases, comprising 42.6 million SEK for completion of the lower levels and haulage, 27.5 million SEK for other development, and 27.5 million SEK for equipment including one 7-m drill jumbo, one 5-m drill jumbo, two loaders, one scaler, two platform trucks, and one boltsetting jumbo.

3.8 RENSTRÖM MINE - CURRENT OPERATIONS

Proven reserves at end-1996 amounted to 394,000 tonnes at a grade of 2.5 g/t Au, 171 g/t Ag, 0.4% Cu, 6.2% Zn, 1.5% Pb. It is estimated that 394,000 tonnes of additional mineralized concentrations exist in pillars (ie. proven) at the Renström mine, while the Renström "1500" or

"Deep" deposit contains 2,000,000 tonnes of possible additional mineralized concentrations at 4.5 g/t Au, 270 g/t Ag, 0.5% Cu, 12.7% Zn and 2.7% Pb.

The Renström mine has operated since 1952 and is producing 160,000 tonnes per year of ore, which will rise to 250,000 tonnes per year by 2000. It is served by a main hoisting shaft to the 910-metre level, above which conventional cut-and-fill mining methods are used, with sublevel stoping to a small extent. Extraction is going on between the 600 and 800 levels. A major resource zone has been outlined below the mine bottom, extending to the 1,500 metre horizon. This requires new shaft sinking and main development work to enable extraction, and a two-phase development programme has been proposed, first to 1,350 level, then to 1,550 level or 1,850 level, depending upon exploration results.

In the time allocated for mine visits, only the surface facilities could be seen.

The mine employs 62 people, and this indicates an efficiency of only 1.6 tonnes per man hour. Efficiency increases up to 2.0 tonnes per man hour are expected with the introduction of similar improvements to those at Petiknäs, but narrow ore widths prevail against much higher efficiency factors.

An internal exploration shaft will be sunk immediately below the existing main shaft and then connected to it following favourable exploration results. This is the basis of the capital expenditure programme in the current plan. However, Petiknäs ore will be hauled across to the Renström shaft (as noted earlier) and displace much of the Renström hoist capacity. The size and depth of the new lower zone indicate that a new Renström shaft to surface may be required, and studies are in hand.

3.8.1 Historical Production Performance

Historical production data are provided in Table 3.6.

Table 3.6
RENSTRÖM MINE - HISTORICAL PRODUCTION SUMMARY

	Unit	1992	1993	1994	1995	1996
Tonnes ore	'000 tonnes	237.0	215.6	118.9	121.9	162.0
Grade copper	%	0.78	0.79	0.76	0.61	0.62
lead	%	1.44	1.36	1.26	1.32	1.09
zinc	%	5.56	5.08	4.65	4.88	4.88
gold	g/t	2.2	2.4	2.3	3.0	2.3
Concentrate						
Copper	tonnes	6,831	5,870	3,572	2,774	3,879
Grade copper	%	21.7	23.2	21.4	22.1	21.6
Lead	tonnes	3,533	3,073	1,566	1,825	1,565
Grade lead	%	53.6	53.2	56.0	56.9	52.3
Zinc	tonnes	20,686	17,541	8,816	9,593	12,526
Grade Zinc	%	53.9	55.3	55.4	54.9	54.3

	Unit	1992	1993	1994	1995	1996
Tonnes ore	'000 tonnes	237.0	215.6	118.9	121.9	162.0
Gold	tonnes	108	65	50	48	25
Grade gold	g/t	718.5	952.8	420.6	2,097	1,575

Some small rockbursts have occurred at present mining depths in Renström and good ground control will become increasingly important as the deeper ore comes into production. The rock mechanics department has shown innovation in many geotechnical aspects and is competent to deal with this question. It is not yet known whether the talc alteration zones along the ore contacts, and which are known to provide a natural stress relief medium, exist at depth. Some production disruption by poor ground events should be expected until real experience is gained.

Studies to select the optimum deep hoisting configuration at Renström are in hand. If the internal shaft option is considered, some disruption to the hoisting of Renström and Petiknäs ore could occur. There has been no major new shaft sinking project in the Boliden group for years and Boliden states that it would likely need to rely on overseas contractors for such work. This might introduce costs and scheduling problems, adversely affecting project completion.

The lower Renström orebody, known as "1500" or "Renström Deep" is as yet only classified as a resource, and an exploration drifting and drilling programme is under way on the 800 level. Approximately 350,000 tonnes of this ore is scheduled for extraction within the period 1999 to 2001, on completion of the necessary orebody delineation, access and extraction planning.

3.8.2 Historical Cost Performance

Production and cost data for 1993 through 1996 are shown in Table 3.7.

Table 3.7
RENSTRÖM MINE - HISTORICAL PRODUCTION AND COST FIGURES
(Thousand SEK, Thousand Tonnes)

	1993	1994	1995	1996	1996 unit cost SEK/t milled
Ore produced	**172**	**122**	**133**	**161**	
Ore milled	**216**	**119**	**122**	**162**	
Direct costs					
Drill/blast	4612	3221	7762	7429	46.1
Loading	1499	1014	109	37	0.2
Scaling	2314	1685	175	10	0.1
Reinforcement	4647	4534	6918	9406	58.4
Fill	3117	3073	2718	2363	14.7
Hoist/Transport	763	750	122	590	3.7
Construction	1409	921	1462	2328	14.5
Others	2166	2183	3610	3910	24.3
Sub-total	**20527**	**17381**	**22876**	**26073**	**162.0**
Indirect costs					
Environment	1569	2305	2797	3792	23.5
Comp air/water	5070	5108	8112	8691	54.0
Maintenance	11227	10771	12932	14305	88.8
General mine	6958	7598	8778	7251	45.0
Other general	616	348	352	230	1.5
Depreciation	8209	7836	8064	9597	59.6
Sub-total	**33649**	**33966**	**41035**	**43866**	**272.0**
Area costs					
Transport	1582	868	941	1198	7.4
Stockpiling	8994			123	0.7
Milling	13327	7806	7803	10070	62.1
Concentrate transport	528	250	307	394	2.4
Rönnskär stockpiling	704	351	366	458	2.8
Commissioning	734	240	203	195	1.2
Sub-total	**25869**	**9515**	**9620**	**12438**	**76.7**
Total costs	**80045**	**60862**	**73531**	**82377**	**508**
Total cost/tonne milled	**370**	**511**	**602**	**508**	
US$/tonne milled	**47.56**	**66.36**	**84.55**	**75.82**	
Mining costs less depreciation	**45967**	**43511**	**55847**	**60342**	
Mine cost/tonne mined	**267**	**357**	**420**	**375**	
US$/tonne milled	**34.35**	**46.32**	**78.44**	**55.94**	

Ground reinforcement costs are high at Renström in comparison to other costs, and the low tonnage rate adversely affects the indirect costs elements of the overall unit cost.

3.8.3 Outlook for Operating Cost

Renström's costs are forecast to dip below the 1995 and 1996 range of 500 to 600 SEK per tonne milled in 1997 and 1998 (see Table 3.8). The absence of activity-based forecasts to compare to historic cost reports makes such checks impractical without a detailed audit of the costing system.

Table 3.8
RENSTRÖM MINE - ESTIMATED OPERATING COSTS 1997 TO 2001
(Million SEK, thousand tonnes)

	1997	1998	1999	2000	2001
Ore milled	**160**	**160**	**200**	**250**	**250**
Personnel	21	21	24	24	24
Material	12	12	16	21	22
Energy	5	5	7	9	10
Contractors	5	5	5	7	9
Milling & services	16	17	20	25	23
Central services	4	4	5	7	7
Depreciation	12	13	28	39	49
Sub-total	74	76	104	132	143
Total cost SEK/tonne milled	**463**	**475**	**520**	**528**	**572**
US$/tonne milled	**66.14**	**67.86**	**74.29**	**75.43**	**81.71**
Mine cost SEK/tonne mined	**307**	**306**	**290**	**277**	**287**
US$/tonne milled	**43.86**	**43.71**	**41.43**	**39.57**	**41.00**

3.8.4 Outlook for Capital Expenditure

The investments for mine deepening reflected in the Information Memorandum have not yet been approved, and are thought by Boliden to be (at 197.4 million SEK) approximately 150 million SEK too low, following an independent study by consulting engineers J. S. Redpath. An appropriate adjustment should be made in the strategic plan investments in 1998 to 2000, say 50 million SEK each year. There are as yet no reliable estimates for comparing the internal shaft option with the alternative new deep shaft. Boliden has engaged a specialist engineer to begin to drive this project. This work is critical to the Renström programme.

Other capital expenditures include 13.2 million SEK on development of the 1,050 level in 1997 and 1998, and 14 million SEK on miscellaneous equipment over the 5-year plan period. Major equipment items will total 46.5 million SEK for purchases of one drilling jumbo, one bolting jumbo, one platform truck, and one loader.

3.9 KRISTINEBERG MINE - CURRENT OPERATIONS

Proven and probable reserves at end-1996 amounted to 2,245,000 tonnes at a grade of 1.2 g/t Au, 58 g/t Ag, 1.2% Cu, 5.9% Zn, 0.4% Pb. In addition, 567,000 tonnes of proven and probable additional mineralized concentrations are identified, with a grade of 1.2 g/t Au, 52 g/t Ag, 0.9% Cu, 6.3% Zn, 0.5% Pb. A further 1,500,000 tonnes of possible additional mineralized concentrations have been identified, of which 500,000 tonnes lie in the Kristineberg A4 zone.

This is the oldest operating mine in the Boliden group and was started in 1940. Production is at the rate of 500,000 tonnes per year, at present from depths between 700 and 1,100 m, with the bulk coming from approximately 900 m. Periodic deepenings have resulted in a complex and inefficient ore hoisting system. Ore from lower levels is trucked up a ramp to the crusher at 620 level (i.e. 300 m vertically), and from there is loaded into the No. 1 shaft and hoisted to 30 level. It is dumped and transferred by a loading bin to the No. 4 shaft, in which it is hoisted to surface. Annually, 200,000 tonnes of waste rock are generated from main and stope development. This is expected to reduce from now onwards for the next five or six years as the known orebody development approaches completion.

Predominantly, horizontal cut-and-fill methods are used, but about 30 per cent of stoping is by the ("Avoca") method with waste rock fill. The ore contacts are altered and sheared, necessitating costly ground control efforts including rockbolting of backs and walls in stopes and, frequently, shotcreting in stopes with steel fibre reinforced concrete.

3.9.1 Historical Production Performance

Historical production data are presented in Table 3.9.

Table 3.9
KRISTINEBERG MINE - HISTORICAL PRODUCTION SUMMARY

	Unit	1992	1993	1994	1995	1996
Ore milled	'000 tonnes	458.6	473.9	480.5	467.0	508.0
Grade copper	%	0.91	1.01	0.95	1.00	1.08
lead	%	0.62	0.56	0.58	0.57	0.46
zinc	%	6.84	6.31	6.46	6.03	5.96
Concentrates						
Copper	tonnes	14,351	14,882	15,531	16,197	19,464
Grade copper	%	23.5	26.8	25.0	25.0	24.3
Lead	tonnes	3,037	2,879	3,497	3,246	2,609
Grade lead	%	31.9	31.5	32.0	35.0	28.7
Zinc	tonnes	48,374	46,760	48,531	44,055	47,099
Grade Zinc	%	55.9	57.4	57.4	56.8	55.8

Several problems in the 1980's, including high cost inflation, ground problems, and lack of investment, led to the mine becoming quite run down, and mineable reserves dropped from 15 years production, to about four to five years as of today. An effort to introduce new ground control techniques and improve general efficiencies showed results in 1992/93, and following years, but reinvestment has been limited.

Exploration is in progress on structures to the north, west, and south of current mining areas, at depths below 600 m. The potential new resource locations appear to be quite distant and may require substantial investment and time to verify them and (if justified) prepare for production.

The objective is to prove up to 10 million tonnes of ore in order to encourage further investment in the mine.

In the meantime, the mine has to maintain extraction in deeper workings, with continuing poor ground conditions, and in fewer areas, as the production zones become concentrated towards the bottom of the present reserve.

The haulage by truck of both ore and waste up to the 620 level crusher (or into waste dump stopes) is handled by a contractor, who also has responsibility for road maintenance. Haulage and hoisting account for almost 25 per cent of total direct mine costs.

Ground control and scaling account for a further 31 per cent of direct costs and are well ahead of drilling and blasting costs (22 per cent).

In 1997, the Boliden PowerVent fan control system will be installed at 15 new fan installations. It is expected that this programme will save 1 million SEK per year, or 2 SEK per tonne. Another benefit will be the better distribution of the limited available air volumes.

Manpower efficiency is approximately 1.7 tonnes per man hour, but this ignores the contractor's crew on haulage, so the real mine-wide efficiency is probably around 1.3 to 1.5 tonnes per man hour, 11.0 tonnes per manshift, or one-third of the Petiknäs efficiency.

The reducing quantities of waste rock available for filling will lead to greater sand fill tonnage requirements and the fill system may need upgrading. Although the waste development reduction itself may help to reduce costs, this benefit may be offset by increased sandfill material and fill distribution costs. The mine staff say that local sand sources or tailings from the Boliden concentrator could be used and further study is needed on this topic.

It is possible that increasing concentration of mining at depth in the next four years or so will lead to higher costs for ground control. The increasing haul lengths will raise the costs of ore and waste transport.

The A4 orebody to the west of the main zones is under active exploration from the 600 level. It is presently classified as an inferred resource but it is scheduled for mining in 1997/1998, and in total contributes 465 000 tonnes to production until 2001.

3.9.2 Historical Cost Performance

The relatively high cost at Kristineberg of ground reinforcement, hoisting/transport, and transport to the mill are evident from Table 3.10.

Table 3.10
KRISTINEBERG MINE - HISTORICAL PRODUCTION AND COST FIGURES
(Thousand SEK, Thousand Tonnes)

	1993	1994	1995	1996	1996 unit cost

					SEK/t milled
Ore produced	**469**	**474**	**463**	**507**	
Ore milled	**474**	**481**	**467**	**508**	
Direct costs					
Drill/blast	12541	11947	13606	13039	25.7
Loading	3470	2993	4623	4630	9.1
Scaling	2833	2825	4623	4630	9.1
Reinforcement	10842	11808	12817	14442	28.4
Fill	6435	6099	7614	6211	12.1
Hoist/Transport	8372	9595	13530	13819	27.2
Construction	5863	5745	6663	6177	12.2
Others	1716	194	-1773	3510	6.9
Sub-total	**52072**	**51206**	**61141**	**58868**	**116**
Indirect costs					
Environment	4152	5780	5875	5736	11.3
Comp air/water	9183	10353	11606	10434	20.5
Maintenance	26131	23614	29496	28108	55.3
General mine	13694	14677	16311	16808	33.1
Other general	1038	1023	1335	1321	2.6
Depreciation	16245	18663	17865	24401	48.0
Sub-total	**70443**	**74110**	**82488**	**86808**	**171**
Area costs					
Transport	15135	15319	14909	14806	29.1
Stockpiling	1456	1154	997	1488	2.9
Milling	27487	29792	28956	31600	62.2
Concentrate transport	1327	1311	1373	1376	2.7
Rönnskär stockpiling	1559	1730	1516	1598	3.1
Commissioning	1768	1202	842	686	1.3
Sub-total	**48732**	**50508**	**48593**	**51554**	**101**
Total Costs	**171247**	**175824**	**192222**	**197230**	**388**
Total cost/tonne milled	**361**	**365**	**412**	**388**	
US$/tonne milled	**46.40**	**47.40**	**57.87**	**57.91**	
Mining costs less depreciation	**106270**	**106653**	**125764**	**121275**	
Mine cost/tonne mined	**227**	**225**	**272**	**239**	
US$/tonne mined	**29.18**	**29.22**	**38.20**	**35.67**	

3.9.3 Outlook for Operating Costs

Costs at Kristineberg are forecast to continue at a similar level to 1995 and 1996 as shown in Table 3.11. This is largely due to the reducing amount of ramping and stope access near the mine bottom, and consequent saving in waste rock haulage. Some power savings are also expected, from the fan control system that will be installed, starting in 1997.

Table 3.11
KRISTINEBERG MINE - ESTIMATED OPERATING COSTS 1997 TO 2001
(Million SEK, Thousand tonnes)

	1997	1998	1999	2000	2001
Ore milled	**500**	**500**	**500**	**500**	**500**
Costs					
Personnel	45	45	45	45	45
Material	37	37	37	37	37
Energy	8	8	7	7	7
Contractors	39	39	39	39	39
Milling & services	34	35	35	34	34
Central services	5	5	5	5	5
Depreciation	29	30	29	29	25
Sub-total	197	199	198	197	192
Total cost SEK/tonne milled	**394**	**398**	**396**	**394**	**384**
US$/tonne milled	**56.71**	**56.86**	**56.57**	**56.29**	**54.86**
Mine cost SEK/tonne mined	**229**	**228**	**224**	**221**	**221**
US$/tonne mined	**32.71**	**32.57**	**32.00**	**31.57**	**31.57**

These forecasts include the benefits of the power control system, the reducing waste development, and corresponding reduction in haulage costs.

3.9.4 Outlook for Capital Expenditure

A total of 89.7 million SEK is scheduled for expenditure from 1997 to 2001, comprising 22.9 million SEK in 1997, 23.1 million SEK in 1998, 9.7 million SEK in 1999, 8.2 million SEK in 2000, and 0.5 million SEK in 2001. The principal items of expense are the service ramp to the mine bottom, some ventilation raises, fan control systems, hoisting system improvement, and small vehicles.

3.10 ÅKERBERG MINE - CURRENT OPERATIONS

Proven and probable reserves at end-1996 amounted to 356,000 tonnes at a grade of 5.0 g/t Au. The Åkerberg mine, being of little significance in the strategic plan, was not visited by Micon. It is scheduled to produce 260,000 tonnes of low-grade gold ore from the remaining ore reserves in 1997 and 1998. Mining was converted from open pit to underground (using horizontal cut-and-fill) in mid-1996.

Single-shift operation is in effect, with seven to eight men. Supervision and services are shared with the Långdal and Åkulla mines.

In 1997, 120,000 tonnes are planned for production at a mining cost of 122 SEK per tonne. For 1998, it is projected that output will reach 140,000 tonnes, at a mining cost of 77 SEK per tonne.

There are no planned capital expenditures at Åkerberg.

3.11 LÅNGDAL MINE - CURRENT OPERATIONS

246,000 tonnes of proven and probable additional mineralized concentrations are identified, with a grade of 5.1 g/t Au, 10.0 g/t Ag, 0.3% Cu, 0.5% Zn, 0.1% Pb.

The Långdal mine, being of little significance in the strategic plan, was not visited by Micon. It is scheduled to produce a total of 233,000 tonnes of low-grade mixed ore from the remaining ore reserves and from a newly discovered low-grade gold lens, in 1997 through 1999. Ore is classed as "marginal" and is used to fill spare capacity in the Boliden concentrator.

Mining was converted from underground to open pit in 1991, following diversion of the Skellefteå River. Mining of the new gold-bearing lens will be underground, and development and trial mining is in hand.

The mine is operated on 2 shifts per day, 4.5 days per week, using a contractor. Boliden will take over the operation in 1997.

Production and mine cost data for the next three years are summarized below:

1997: 45,000 tonnes production at 167 SEK per tonne
1998: 102,000 tonnes production at 120 SEK per tonne
1999: 86,000 tonnes production at 109 SEK per tonne

In 1997, expenditure of 4.4 million SEK is planned for the decline and other construction.

3.12 ÅKULLA MINE - CURRENT OPERATIONS

Proved and probable reserves at end-1996 amounted to 150,000 tonnes at a grade of 2.2 g/t Au, 15 g/t Ag, 1.8% Cu. In addition, 60,000 tonnes of proven and probable additional mineralized concentrations are identified, with a grade of 1.4 g/t Au, 12 g/t Ag, 1.3% Cu. A further 1,500,000 tonnes of possible additional mineralized concentrations are reported. A programme of in-fill drilling is under consideration.

The Åkulla mine is an open pit containing gold and copper, which will be mined out during 1997. The new Åkulla East mine will extract a gold-bearing resource found between the 300 and 600 levels, starting in 1999. Possible additional mineralized concentrations at Åkulla East are estimated at 1,500,000 tonnes containing 7.0 g/t Au and 18 g/t Ag. Mining methods are uncertain and studies are under way into an open stoping system that could extract 5.0 million tonnes at 3 to 4 g/t, and a cut-and-fill system that could extract 1.0 million tonnes at 7 to 8 g/t. (The latter system has been adopted to represent Åkulla production in the long-term plan.)

Access is currently being planned with a 1,000-metre long decline from the now closed Kankberg open pit mine, to reach the 400 metre level.

The gold ore production, totalling 640,000 tonnes over three years to 2001 and containing approximately 4,500 kg gold, is based on inferred resources. These may only be upgraded to the indicated category after exploration and testing has been completed.

The forecast mining cost appears to be much lower than other Boliden area underground mine costs. The project has only reached the pre-feasibility stage, and so it cannot be assumed that the forecast production or costs will be achieved.

Production and cost data for 1999 through 2001 are summarized below:

1999: 140 000 tonnes production at 115 SEK per tonne
2000: 250,000 tonnes production at 112 SEK per tonne
2001: 250,000 tonnes production at 112 SEK per tonne.

In 1997, expenditure of 3.0 million SEK is planned for the open pit. In 1997, 1998, and 1999, sums of 26.7 million SEK, 17.8 million SEK and 27.5 million SEK, respectively, will be spent on the decline and other construction, and mining equipment, subject to approval.

3.13 KANKBERG MINE - CURRENT OPERATIONS

There are no reserves reported, the mine is effectively worked out.

This mine is scheduled to produce only 24,000 tonnes in 1997, at a cost of 120 SEK per tonne, and will then be exhausted. The mine will be maintained, to provide access to the Åkulla East underground mine development.

3.14 BOLIDEN AREA PRODUCTION PLANNING

Production planning is carried out at each mine. At Kristineberg, the forward plan was clearly laid out and showed development activities, and production tonnages and grades of both ore reserves and mineral resources until 2005.

At Renström and Petiknäs, no long term production planning details were available. It was said that, because of the wide spread of workings in the vertical sense, it was usual to simply quote a tonnage and an average ore reserve grade. While this seems over-simplified, it is based on operating experience. Although a block model is not used, work is in progress to facilitate more detailed projections of ore grade.

Concentrator output is forecast by the concentrator staff, on the basis of the average ore reserve grades from the mines and tonnage forecasts from the mines. Micon was provided with documents showing these forecasts and they are the basis for the Strategic Plan concentrate production and smelter revenue table, “Revswede” in the form of an Excel spreadsheet.

3.15 BOLIDEN AREA TECHNICAL MATTERS

Mine ventilation appeared good in the two underground operations visited. Swedish regulations call for a maximum of 1.0 parts per million (ppm) NO_x in the mine air. This level is achieved by using “city oil” or low sulphur diesel fuel.

Safety standards are high, and housekeeping is noticeably good.

Boliden aims to achieve 365-day working (as at Aitik) at all its operations. This is now being effected at some underground mines, in a 99-hour, three-week cycle comprising 12 shifts of 8.25 hours, (the K2 scheme) worked as five dayshifts, then two days off, seven afternoon shifts, then seven days off. The next cycle starts with seven afternoon shifts followed by two days off, five day shifts, then seven days off. The result is effectively a 33-hour week and the men will work 1,618 hours per year, after allowing for holiday time.

Sill pillar mining economics, and consequently pillar recovery, are expected to be improved by the use of frozen fill in the bottom cut, instead of the traditional high-cost cement-rich fill that demands a high investment when it is placed several years before mining eventually occurs. Fill preparation includes the positioning of regular bulkheads and fill, in which are buried freezing fluid circulation pipes. The installations are similar to those in an ice-rink. A few weeks before mining is due, a mobile refrigeration plant is connected and the fill is frozen prior to pillar mining. The method has been tested and proved at the Petiknäs mine. This fill also has good load-bearing qualities, allowing deformations up to 15 per cent, plastically, resulting in improved safety conditions while ore is extracted below the frozen mass.

The need for high strength cemented fill is evident in Boliden’s Garpenberg mines that use undercut and fill methods with relatively quick filling cycles. Failure of this fill can occur under high loads that lead to only small deformations. Boliden has designed a yielding element that is inserted into the fill block; namely, a vertical slab of polystyrene foam, the compression of which under sideways load allows the fill to move while retaining its integrity. The thickness and density of the foam can be selected to match the qualities of the fill block to be controlled. This principle may turn out to be of use in the future deep mining at Renström.

Stoping efficiency improvements are expected to result from the introduction of 7.0-metre long rounds, to be drilled with extension steel. Face preparation time and equipment moving will be reduced. The method has already been tested at Petiknäs. Boom alignment will be automatic, using an on-board computer to relate to a survey point and follow a pre-determined stoping configuration based on mapping in the previous cut. Boliden recognizes the potential risk of loss of selectivity when drilling long rounds at the stope wall limits and is investigating possibilities of in-hole ore/waste recognition by drilling condition sensors and on-board cuttings analysis. This could be applied to rockbolt hole drilling (uppers into next cut) and to horizontal blastholes.

To reduce power costs, Boliden is introducing automatic fan control into working areas. The fans are two-speed, with an automatically adjustable throttle, and allow a wide variation in fan throughput in one installation. Mining equipment in a working area transmits its location and its activity through the radio system and the central control automatically sends an appropriate configuration requirement to the fans ventilating that area, as well as adjusting circuits mine-wide for any changes in major flow patterns. The systems are now being tested at Renström, and a 15-unit system will be installed at Kristineberg. Energy costs savings of 25 per cent are expected, underground. The control signals are sent through the powerline. Dedicated control lines are unnecessary.

3.16 BOLIDEN AREA - CURRENT MILLING OPERATIONS

Ores in the Boliden area contain five metals of economic interest, copper, lead, zinc, gold and silver, and these are separated into gold, copper, lead and zinc concentrates.

The Boliden central mill was built in 1951 to 1954 with two separate sections in order to permit the processing of two different ores simultaneously.

Primary crushing, where necessary, is by jaw crushers underground and the ore is hoisted and conveyed to two separate bins ahead of milling in Sections B and C, as shown in Figure 3.4. (Section A of the concentrator is not presently used, see note on Future Operations, below).

Ore from the Renström and Kristineberg mines is tipped in the same bins and blended before milling in Section B. The main reason for the blending is that the Kristineberg ore is too friable for autogenous grinding and the Renström ore provides the necessary grinding media for the autogenous mill. The copper to lead ratio in the Kristineberg ore is also high and this makes the separation of copper and lead concentrates difficult. The blending of Renström ore improves the ratio and the quality of the copper and lead separation.

Ore from Petiknäs, Långdal, Kankberg and Åkerberg is stockpiled at the mine and processed in batches through Section C, as they each require slightly different fineness of grind and reagent additions.

Ore is drawn by vibrating feeders to batchwise belt weighers before feeding to the autogenous mills. Both sections of the concentrator use the Boliden system of fully autogenous grinding. This comprises an autogenous primary mill situated in line with, and slightly higher than, a secondary pebble mill. The grate of the primary mill is equipped with a pebble extractor which withdraws pebbles from the primary mill and delivers them by gravity to provide the media for the secondary mill. The primary mill discharge is passed through a low intensity, wet magnetic separator to remove

[Figure 3.4 - Boliden Central Concentrator - Flowsheet] tramp steel, before being combined with the secondary mill discharge and classified on screens and hydrocyclones. The screen oversize and cyclone underflow feed the secondary pebble mill.

Cyclone overflow passes to a gravity concentration circuit comprising Reichert cones, spirals and a shaking table, which produces a gold concentrate.

The gravity tailings pass to copper-lead flotation, where zinc is depressed by the addition of zinc sulphate, and copper and lead are floated using sodium iso-butyl xanthate. Rougher concentrates are cleaned and scavenger concentrates are reground and returned to rougher flotation. The copper-lead concentrates from Sections B and C are combined. The lead is then depressed using sodium dichromate and the copper concentrate is floated leaving the lead concentrate in the tailings. Lead concentrates are further cleaned using high gradient magnetic separation which extracts chalcopyrite, sphalerite and pyrite from the lead concentrate. The magnetic concentrate is directed to the zinc flotation circuit.

Copper-lead tailings pass to zinc flotation where the zinc is re-activated by the addition of copper sulphate and a combined zinc concentrate is produced.

The concentrates are thickened and filtered. Copper and zinc concentrates are filtered on Sala automatic plate and frame presses which are continuously weighed. The filters are filled under pressure with thickened concentrate. The filter cake is then compressed by compressed air behind a diaphragm. The cake is finally dewatered by passing air through it from the other side of the diaphragm. The filter then automatically discharges the cake and shakes the cloth to remove any adhering cake. The cloth is then washed and the cycle repeated.

Lead concentrate is filtered on a vacuum drum filter and dried in an oil-fired rotary drier. All concentrates are despatched to Rönnskär by road.

Tailing is classified in two stages of cyclones in the concentrator and the coarse fraction is dewatered by a vacuum drum filter and stored in a silo. It is transported back to the mines for underground backfill by the trucks which bring the ore from the mines.

The fine fraction of the tailing is pumped to the tailing dam. It is a very large dam which has been in use since the concentrator was built. The walls are periodically raised using borrow material from the area. The pH of the tailing entering the dam is 12.4 and the overflow is monitored and its pH adjusted to ensure that the permitted levels of metals in the overflow are not exceeded. It is reported that the pyrite in the tailing reports preferentially to the sandfill fraction but the tailing in the dam still contains more than 10 per cent sulphur.

The concentrator at Boliden is washed down during each shift, mainly to ensure minimum levels of dust in the atmosphere, particularly in view of the lead content of the ore.

3.16.1 Boliden Concentrator Operating Costs

The breakdown of the concentrator operating costs for 1996 is shown in Table 3.12 below:

Table 3.12
BOLIDEN AREA CONCENTRATOR - 1996 OPERATING COSTS
(Thousand SEK)

Item	Cost	
Energy (direct purchased)		**555**
Electricity	13	
Heating oil (for dryers)	542	
Materials		**25,058**
Spare and replacement parts	7,095	
Explosives	20	
Reagents	9,500	
Other material	8,443	
Labour		**21,578**
Wages	16,378	
Salaries	4,375	
Sick Pay	355	
Other labour costs	470	
Outside Services		**3,572**
Contract maintenance	1,788	
Other outside services	1,784	
Re-distributed costs		**19,484**
Electric power	14,904	
Other services	1,122	
Overhead	3,458	
Re-distributed services		**5,524**
Other departments	3,810	
Technical and administration	1,714	
Depreciation		**13,960**
Total Costs		**89,731**
Total Cost SEK/tonne milled		**62.01**
less depreciation		**52.36**
Total Cost US$/tonne milled		**9.26**
less depreciation		**7.82**

3.16.2 Boliden Concentrator Performance

The ores in the Boliden area contain five metals of economic interest, separated into four concentrates, gold, copper, lead and zinc. The proportion of the contained metal values which is recovered into concentrates ranges from 29 per cent for the Petiknäs North mine to 73 per cent for the ores from Renström. The recoveries for the year 1995, to the various concentrates for Petiknäs, Renström and Kristineberg are listed in Table 3.13 below. These data should be interpreted with caution since the Renström and Kristineberg ores are blended before processing so that their individual processing characteristics are not precisely known.

Table 3.13
BOLIDEN AREA CONCENTRATOR PERFORMANCE, 1995

	Unit	Petiknäs	Renström	Kristineberg
Ore Milled	tonnes	336,607	121,920	467,030
Gold	g/t	2.73	3.00	1.60
Silver	g/t	146	154	58
Copper	%	0.63	0.61	1.00
Lead	%	1.31	1.32	0.57
Zinc	%	6.62	4.88	6.03
Gold Concentrate				
Gold recovery	%	8.6	27.5	
Silver recovery	%	0.4	0.8	
Copper Concentrate				
Gold recovery	%	47.5	50.5	47.7
Silver recovery	%	45.2	61.0	46.9
Copper recovery	%	71.5	82.4	86.7
Lead recovery	%	17.4	5.1	32.4
Zinc recovery	%	1.8	1.8	3.3
Lead Concentrate				
Gold recovery	%	3.9	3.3	2.0
Silver recovery	%	17.7	17.5	9.3
Copper recovery	%	6.2	1.7	1.1
Lead recovery	%	34.7	64.5	42.6
Zinc Concentrate				
Zinc recovery	%	83.0	88.5	88.9

The concentrates for each metal from both circuits at Boliden are combined and the complete specification of all of the concentrates is provided in Appendix I.

3.16.3 Future Milling Operations

The major development planned in the near future at Boliden mill is the reinstatement of Section A. This section will be used for the re-processing of slag from the Rönnskär smelter for the recovery of copper. Most of the equipment is already available at Boliden and at the other concentrators in the group.

The total capacity of the Boliden mill is about 1.5 million tonnes per year and this exceeds the presently anticipated requirements for the production plans of the mines.

Improvements are planned for the information management systems in the concentrator. Although the present systems are more advanced than are found in many concentrators, they are quite old, and their replacements will improve the efficiency of working.

Table 3.14 presents the budget costs for 1997.

Table 3.14
BOLIDEN AREA CONCENTRATOR - 1997 BUDGET OPERATING COSTS
(Thousand SEK)

Item	Cost	
Energy (direct purchased)		**378**
Electricity	18	
Heating oil (for dryers)	360	
Materials		**30,160**
Spare and replacement parts	10,900	
Explosives	40	
Reagents	10,020	
Other material	9,200	
Labour		**23,942**
Wages	17,884	
Salaries	5,258	
Sick Pay	304	
Other labour costs	469	
Outside Services		**9,164**
Contract maintenance	7,760	
Other outside services	1,404	
Re-distributed costs		**20,490**
Electric power	18,030	
Other services	0	
Overhead	2,460	
Re-distributed services		**1,896**
Other departments	0	
Technical and administration	1,896	
Depreciation		**14,280**
Total Costs		**100,310**

The budget cost for 1997, at 100.3 million SEK, is 12 per cent higher than total concentrator costs in 1996. Unit cost per tonne milled in 1997 is 68.4 SEK compared with 62.01 SEK in 1996.

No major replacements of concentrator equipment are planned and none should be expected. The planned future performance of the concentrator is based on past performance and can be expected to be achieved.

3.17 CONCLUSIONS

Mine operating costs appear to be reasonably under control and forecast operating costs at the three principal mines are in line with recent experiences, with some adjustments where necessary for expected changes in conditions. But, operating costs for some of the future producers, such as Renström "1500", Åkulla gold, and the Kristineberg A4 zone cannot be properly estimated until studies are completed. They may be underestimated. Operations at increasing depths, particularly at Renström, may be adversely affected by poor ground conditions.

Capital expenditures for mobile equipment and local mine development appear adequate.

However, because of the lack of knowledge of resources that are expected to be outlined, developed and mined within the five-year period, major capital expenditures are likely to be underestimated. For example, the Renström "1500" (deep) project is only just beginning a major project study, and new shaft installations are probably to be called for. At Kristineberg, drilling is under way for totally new ore sources, and if found, expenditure on development should start in 1998/1999. The Åkulla gold project is also in the study phase.

On the operations side, Boliden is a very competent mine owner and efficiency improvements are constantly being made. The mines are well run and clean, with good safety records, and high morale is evident. Two mines, Kristineberg and Renström, are handicapped by their old infrastructure.

Notable advances in mining systems are evident with the introduction of long (7-metre) rounds in cut-and-fill stopes, which will lead to cycle time improvements, and the use of frozen backfill which will reduce fill preparation costs and enable recovery of otherwise uneconomic sill pillars.

While mining practices are sound, the five-year plan requires further consideration as to major mine development expenditures, and mining costs may need to be reconsidered in some areas.

Micon's analysis indicates that approximately 20 per cent of the tonnage, 40 per cent of the gold, 20 per cent of the silver, 10 per cent of the copper, and 20 per cent of both the lead and zinc arise from resources that have not yet been sufficiently outlined to be classed as reserves. In several cases, as noted in the descriptions of the mines, considerable development, exploration, and infrastructure will have to be completed before these tonnages (if proven) can be exploited.

4.0 THE GARPENBERG AREA

4.1 INTRODUCTION

Boliden's mining operations at Garpenberg, Sweden, include two underground mines: Garpenberg and Garpenberg North. The mines are located approximately three kilometres apart, but utilize a wide range of common supporting facilities including administration and milling. These common facilities are located at the Garpenberg mine. Ores mined contain recoverable values of lead, zinc, copper, silver, and gold. Precious metals, lead, copper and zinc concentrates are produced.

Historical production figures for these two mines are shown in Table 4.1 below.

Table 4.1
GARPENBERG AREA MINES - HISTORICAL PRODUCTION FIGURES

	Unit	1992	1993	1994	1995	1996
Tonnes ore	tonnes	823,608	800,009	810,620	749,990	841,954
Grade copper	%	0.16	0.20	0.15	0.15	0.13
lead	%	2.30	2.40	2.30	2.20	2.24
zinc	%	4.10	4.26	4.30	4.30	4.52
gold	g/t	0.50	0.57	0.51	0.43	0.47
silver	g/t	165	160	152	133	141

4.2 CHARACTERISTICS OF THE PROPERTY

Garpenberg is located in south-central Sweden. In a straight line, it is approximately 177 km northwest of Stockholm. It is almost equidistant from the Norwegian border and the Gulf of Bothnia. The area is accessible all year by means of good roads from the east coast cities of Stockholm or Uppsala, or the west coast city of Göteborg (see Figure 4.1).

Almost all of Sweden forms part of the Baltic Shield with rocks of lower Proterozoic to Archean age predominating. Glaciated terrain dominates most areas, covered with morain material and till. In general, the undulating topography is quite similar in character to glaciated Archean-Proterozoic terrain in Canada.

Over much of Sweden, elevations range up to 800 m, but are commonly only up to 500 m above sea level. However, along the Norwegian border, mountainous areas occur and elevations ranging from 1,000 to 2,000 m above sea level occur.

The town of Hedemora lies on the coastal plain, whereas Garpenberg lies on a ridge estimated to be some 200 m higher than the town.

The climate of Sweden is one of cool summers and cool to cold winters. In the Garpenberg area, the winter weather appears moderate with the mean January temperature slightly below freezing.

[Figure 4.1 - Location of Garpenberg within the Bergslagen Mineral District]

Annual precipitation in Sweden ranges between 500 mm to 750 mm. The central and northern areas are dryer than the coastal areas.

The Garpenberg property comprises 500 hectares in exploitation concessions and 15,000 hectares in exploration permits. According to the "Guide to Mineral Legislation and Regulations in Sweden", issued by the Geological Survey of Sweden, exploitation concessions are granted in 25-year periods, which are automatically renewed, as long as production is being carried out. The exploration permits are granted for three years and can be extended, upon application, for up to an additional three years, if suitable exploration has already been carried out. "In exceptional cases the period of validity of the permit may be further extended but for no more than a total of four years."

A rail line passes through the town of Hedemora terminating in Stockholm, and an airport at the town of Borlänge, about 36 km northwest of Hedemora, provides commuter flights to Stockholm and other cities.

4.3 GEOLOGICAL SETTING

The region is characterized by a Lower Proterozoic sequence of rocks consisting mainly of quartz feldspar gneisses, quartz gneisses, calc-silicate gneisses, marbles, amphibolites, and mica schists. These have been interpreted as being felsic volcanics and limestones which have been folded, metamorphosed and intruded by synorogenic granitoids. High grade metamorphism has occurred with the rocks metamorphosed to the amphibolite facies. Both polymetallic sulphide deposits and iron deposits (magnetite) occur and are dominantly strata-bound. Generally, the iron deposits dominate in a lower stratigraphic zone, whereas the sulphides dominate in a higher zone.

The rocks of the area have been isoclinally folded and folds plunge to the northeast. Post-fold faulting is recognized.

The magnetite deposits contain variable amounts of sulphide and manganese minerals. The sulphide deposits consist mainly of pyrite, pyrrhotite, sphalerite, galena, chalcopyrite and minor silver minerals. These deposits have been classified as zinc-lead-silver-copper-(gold) deposits and are considered to be of volcanic-exhalative origin. The iron and sulphide deposits are strata-bound and show strong stratigraphic control, being located near the contact between metasedimentary and felsic metavolcanic rocks.

A sketch map showing the general character of the Garpenberg area is shown in Figure 4.2. The Garpenberg deposits occur on the north flank of the syncline.

Boliden AB has two underground mines in the Garpenberg ore field, a mineralized field about 5 km in length trending northeast-southwest. The mine in the southwestern part of the field is called Garpenberg. The mine in the north is called Garpenberg North. Between these two mines lies a significant prospect, called the Dammsjön, on which zinc and high-grade silver resources have been delineated.

[Figure 4.2 - Garpenberg mineral area showing the general character of the geology and location of principal sulphide deposits]

The host rocks are calc-silicate gneiss (tremolite skarn), dolomitic zones in marble, quartz gneiss, or mica schist. The orebodies occur as a series of lenses, generally parallel to the bedding and schistosity. Parallelling the metamorphosed beds, the ore deposits are steeply dipping, on the order of 80 degrees to the southeast (see Figure 4.3).

4.3.1 Mineralization

The minerals which make up the sulphide deposits in the Garpenberg area are pyrite, pyrrhotite, sphalerite, galena, chalcopyrite and very minor amounts of such silver minerals as native silver and argentite. Tetrahedrite, a copper-antimony mineral, also reportedly contains silver. (Silver-rich tetrahedrite is commonly called freibergite). Trace amounts of a variety of copper minerals occur but these are of negligible interest.

Garpenberg (south) is made up of a variety of mineralized bodies as shown previously in Figure 4.3. The stockwork copper ores are, stratigraphically, the lowest orebodies in this section. A network of chalcopyrite-pyrite-pyrrhotite-bearing quartz-fluorite veins cut a quartz gneiss. In contrast, the main orebodies, such as the Strand, are parallel to bedding or schistosity.

The Strand orebody (see Figure 4.3) is a zinc-lead-copper-(gold) deposit. This deposit occurs largely in a tremolite skarn, but also, partly, in quartz gneiss and mica schists. The ores occur in massive lenses or in very thin bands. The contact with the wall rock is sharp. The main ore minerals are sphalerite, galena and chalcopyrite. Pyrite and pyrrhotite occur in significant quantities. Tetrahedrite, argentite and native silver are accessory ore minerals. Gold occurs with the copper and iron sulphides.

The Garpenberg North orebody is generally similar in character to the other Garpenberg deposits, but differs in that it is enriched in silver, which adds significantly to the value of the ore. Zinc and lead concentrations are somewhat less in this deposit than in Garpenberg; copper and gold concentrations are negligible.

4.4 HISTORY OF EXPLORATION

Garpenberg lies within the mineral-rich Bergslagen Mining District in south-central Sweden. The district has a long history of mining both magnetite and polymetallic sulphide deposits and mining has been carried out in the Garpenberg area for some 700 years.

Past production and proven reserves of the two producing mines at Garpenberg total 21.5 million tonnes.

Boliden AB became the operator at Garpenberg in 1957 (in the acquisition of Zinkgruvor AB). No information was obtained by Micon pertaining to exploration in the general Garpenberg area during the period 1957 to 1985. Boliden AB has stated that no exploration external to the mines was carried out during the 1985 to 1995 period. From 1995 to the present, extensive and intensive exploration, both internal (the mine areas) and external to the mining concession, has been carried out.

[Figure 4.3 - Cross section showing the Strand ore body and other mineralized ore bodies]

4.5 GEOLOGICAL RESOURCES AND MINEABLE RESERVES

Micon carried out an audit of the Garpenberg reserves by (1) reviewing the methods used by Boliden to calculate reserves; (2) comparing Boliden's estimated reserves in selected reserve blocks with the actual ore mined from those blocks; and (3) comparing a block grade model, utilizing kriging, with average grades calculated from cross sectional reserve/resource blocks.

4.5.1 Resource/Reserve Classification

Resources and reserves at Boliden AB's Garpenberg operations are classified and defined in section 1.1.2 in the Introduction to this report.

4.5.2 Estimating Procedures

Until 1993, Boliden AB used the cross-sectional method for calculating reserves at Garpenberg. In 1993, Boliden AB began computerizing reserve calculations using a block grade model with kriging. Boliden AB describes the grade model in use as follows:

- Ore sections in drill holes are identified. Minimum ore width is 4.5 m.

- Horizontal interpretations of all ore lenses, based on drill hole information and mapping in the mine, are made every 5 m.

- Average grades and co-ordinates are determined for the ore sections in the drill holes.

- The ore sections are coded such that the specific ore lens under study is identified.

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Variograms are calculated and the parameters are controlled with point kriging. Block grades are calculated with ordinary 3D kriging for Garpenberg ores but inverse distance squared will be used for the Garpenberg North orebodies. The dimensions of the blocks are 3 m x 5 m x 10 m.

Grades from each mine are determined by analyses of cores and mine samples by atomic absorption spectrometry for copper, lead and zinc, and by fire assay for precious metals. All analyses are done in an assay laboratory at the Garpenberg mill.

Boliden AB has been gradually introducing the new method to its mines. As of January 1, 1997, the computerized method is used in all the Garpenberg mines, and the estimated reserves and resources for the Garpenberg mine and the Garpenberg North mine, at January 1, 1997, are based on this method.

The cutoff "grade" for estimating ore reserves, as established by Boliden AB, is based on the value of the total metal content of the ore (Zn, Pb, Ag, Cu, Au), based on projected metal prices, and the cost of operations. This cutoff is determined annually for each mine (in SEK) by Boliden. For 1997, Boliden AB established the following cutoffs for the mines in Garpenberg:

Garpenberg:
Strand orebody - 380 SEK
Kanal orebody(s) - 320 SEK

Garpenberg North:
Norra orebody - 250 SEK

4.5.3 Reconciliation

Tonnage Comparison: Micon compared the actual production from selected areas with the previously-reported reserves for those areas. Figure 4.4 shows areas, designated herein for all levels as Area A, within three different levels in the Strand orebody. These areas were selected as data were readily available.

Ore reserves were estimated for these selected areas in 1994 and the areas were mined in 1996. The following table provides a comparison of the production with the reported reserves.

Table 4.2
COMPARISON OF ESTIMATED RESERVE TONNAGES WITH PRODUCTION TONNAGES

Level (m)	Estimated Reserve Tonnes	Mined Tonnes
635	1,530	1,556
670	1,180	1,091
698	512	1,063

The comparison shows that there is a close correlation between the estimated ore reserve tonnages and the quantity of ore extracted from levels 635 and 670, but that level 698 produced about twice as much ore than had been estimated in the reserve calculation. The discrepancy for level 698 appears to be due to the lack of drill hole data and the conservative approach of projecting only 10 m outward from an ore section when data are lacking. This, in Micon's opinion, was the correct procedure for this type of orebody.

Grade Model Compared with Ore Sections: Boliden AB provided data to compare grades obtained using the computerized kriging method with average grades obtained using drill hole ore sections. It will be noted that percentage differences for gold and copper are relatively high, but slight variables at very low grades can cause significant percentage differences. Silver and lead compare favourably between the two methods. Zinc assays at Strand and Norra show about an 11% difference. The reason for this is unknown. The following table shows the comparisons.

[Figure 4.4 - Comparison of estimated reserves with quantity of reserves mined]

Table 4.3
GARPENBERG KRIGED GRADES COMPARED WITH ORE SECTION GRADES

	Au (g/t)	Ag (g/t)	Cu %	Zn %	Pb %	Number Considered
Kriged Block Model						
Strand	1.0	163	0.4	6.9	4.6	1235 blocks
Kanal	0.3	60	0.1	8.0	3.2	3714 blocks
Norra	0.04	164	0.03	4.6	2.2	3175 blocks
Drill Sections						
Strand	1.1	159	0.5	6.1	4.5	64 ore sections
Kanal	0.3	62	0.1	7.8	3.3	89 ore sections
Norra	0.1	173	0.04	4.1	2.1	313 ore sections

The degree of accuracy obtained in estimating ore reserves and resources depends upon whether a method appropriate to the type of orebody was properly applied, and whether the estimator has the knowledge and experience with the method and type of orebody. In Micon's opinion, the methods used by Boliden to estimate ore reserves and resources at Garpenberg were appropriate, properly applied and up to industry standards. Micon believes the reserves and resources, as estimated at January 1, 1997, are reasonable expectations for each of the mines in the Garpenberg area and, as such, the ore reserves and resources are accepted by Micon.

4.5.4 Reported Reserves and Resources

Boliden AB reports total Ore Reserves for the Garpenberg mines as at January 1, 1997, as follows:

> **Proven and Probable Reserves: 5.08 million tonnes averaging 4.6% Zn, 2.2% Pb and 130 g/t Ag.**

Details are set out in Table 4.4.

Table 4.4
GARPENBERG ORE RESERVES

Mine	Proven						Probable					
	Million tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %	Million tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %
Garpenberg	1.264	0.5	71	0.2	6.4	3.1	-	-	-	-	-	-
Garpenberg N.	2.883	-	144	-	4.0	1.9	0.930	-	166	-	4.0	1.9
Totals	**4.147**	**-**	**122**	**-**	**4.7**	**2.3**	**0.930**	**-**	**166**	**-**	**4.0**	**1.9**

It is Micon's opinion that the quantities and grades of Proven Ore reserves and Probable Ore reserves reported by Boliden can be classified as Proven Ore and Probable Ore, respectively, as defined in National Policy 2-A

In addition to the Ore Reserves, Boliden AB also reports significant quantities of Measured plus Indicated as well as Inferred mineral resources for the Garpenberg area deposits, as set out in Table 4.5. These resources as yet have not been subjected to detailed economic study. In terms of National Policy 2-A, Micon classifies these resources as Additional Mineralized Concentrations. Provisions are being made for an in-fill drilling programme in order to bring additional tonnage into measured and indicated categories.

Table 4.5
ADDITIONAL MEASURED, INDICATED AND INFERRED RESOURCES

Deposit	Measured and Indicated						Inferred					
	Million tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %	Million tonnes	Au g/t	Ag g/t	Cu %	Zn %	Pb %
Garpenberg	0.9	0.2	44	na	7.0	2.5	0.5	0.2	40	-	6.8	2.3
Garpenberg N.	0.5	-	159	-	4.8	2.5	6.0	-	166	-	4.0	1.9
Dammsjön	3.3	-	127	-	2.9	1.2	5.0	-	150	-	4.0	1.3
Tyskgårdsgruvan	-	-	-	-	-	-	1.0	-	150	-	3.0	1.0
Totals	**4.8**	**-**	**115**	**-**	**3.9**	**1.6**	**12.5**	**-**	**153**	**-**	**4.0**	**1.6**

4.6 EXPLORATION POTENTIAL

Development of deeper ores and exploration is ongoing. The Garpenberg mine is approaching 800 m in depth and Garpenberg North, 900 m. Micon concurs that down-dip extensions of ore are likely for the Garpenberg mine and the Garpenberg North mine. The Garpenberg North mine, in particular, appears to have significant potential down-dip. Exploration drilling to deeper levels is scheduled for both mines.

In addition, surface exploration is being carried out, comprised of mapping, sampling and geophysical methods. A prime target is the Dammsjön prospect, about mid-way between Garpenberg and Garpenberg North, where zinc and high grade silver mineralization has been discovered. An extensive evaluation programme planned for 1997 to 1998 includes 30,000 m of core drilling to delineate the resources and preliminary economic studies. It is planned to extend an underground drift from the Garpenberg mine into the Dammsjön prospect in order to carry out underground sampling.

Boliden AB has been exploring, and plans to explore a number of mineralized prospects, as well as potential areas based on favourable geology. It has 17 exploration permits covering 307,261 hectares.

The major exploration project areas are described below.

4.6.1 Garpenberg Volcanic Centre

Garpenberg South: System is about one kilometre in length, with lead/zinc and copper/gold mineralization types. 1997 plans: 1,800 m of drilling.

G9N North Project: Geophysical anomaly related to remobilized lead/zinc zone. 1997 plans: 1,200 m of drilling

Stora Jälken Project: Geophysical anomaly on projected extension of Tyskgården mineralization. 1997 plans: 500 m of drilling.

Ryllshytan: Iron ore skarn with lead-zinc mineralization. 1997 plans: geophysics and 500 m of drilling.

Smältarmossen: Investigation of depth extension of large iron ore lens between Garpenberg and Garpenberg North; stratigraphically below the Tyskgården lead-zinc deposit. Hypothesis is that iron ore changes to lead-zinc at depth. Plans: 600 m of drilling.

Trehörningen: Indications of zinc mineralization associated with geophysical anomaly 8 km northeast of Garpenberg North.

Northeast Tyskgården: Reconnaissance in dolomitic limestone terrane for Tyskgården-type mineralization.

4.6.2 Bergsladen Gold Exploration

Evidence exists for volcanogenic epithermal gold and metamorphic lode gold deposits. Boliden AB has claimed large areas of potential copper-lead-zinc mineralization away from the Garpenberg volcanic centre and some of these areas have indications of gold.

Two areas, namely Kalvbäcken and Stalldalen, have been identified as major target areas for gold-polymetallic mineralization.

Kalvbäcken: Located 30 km north of Garpenberg, lead-zinc was previously mined from fine-grained rhyolitic ash sandstone. Potential for skarn mineralization. One drill hole with two shallow (30 m) thin intersections of 3.3 and 3.7% Cu, 3.0 and 0.6% zinc, 62 and 70 ppm Ag. Also surface boulder float with gold-silver-copper-zinc-lead mineralization. Plans: 800 m of drilling.

Ställdalen: 0.2 to 1.6 g/t Au plus 0.2 to 1.8% Cu in 2 km long by 500-m wide altered and silicified zone.

4.7 GARPENBERG MINE - CURRENT MINING OPERATIONS

Mining operations at Garpenberg have been conducted under the auspices of numerous groups since the thirteenth century.

Boliden purchased the Garpenberg mine in 1957 from Zinkgruvor AB. Since that time, the mine has been deepened to over 700 m and production has totalled approximately 8.9 million tonnes of ore. Present proven and probable reserves are somewhat limited at 1.4 million tonnes and it has been expected that the mine would be depleted no later than in 2002. Recent renewed emphasis on exploration, however, has provided strong indications of additional ore at depth and a good potential to continue operation of the Garpenberg mine beyond 2002.

Between 1985 and 1990, production increased from 200,000 tonnes to 300,000 tonnes per year and, in 1996, reached 346,302 tonnes. Future mine output is scheduled at approximately 360,000 tonnes of ore per year.

A centrally-located personnel/ventilation shaft provides direct access to the 420-m level. Access to all deeper levels is via a ramp system which presently terminates at about 750 m. Ore is hoisted to the surface through a main production shaft from the 595 m level. Crushing and skip loading facilities are located on this same level.

Essentially all primary development work is conducted in the lower portions of the mine from a spiral ramp driven downward at a slope of about minus 12 to 14 per cent. Off of this ramp, crosscuts to the orebody are driven each time the spiral reaches a point nearest the orebody. Each crosscut provides access for about four slices of stoping, or about 20 m of orebody height. Main access levels are established at about 50-m intervals. Waste rock from development headings is typically disposed of in stope backfill and no significant quantities need be hoisted to the surface. In 1995, for example, 106,000 tonnes of waste were produced but, of that, only 10,200 were hoisted to surface.

Ventilation to all workings at Garpenberg totals about 320,000 cubic metres (m^3) per hour. The main ventilation circuit is at the 390-m level which is served by the central personnel/ventilation shaft as well as a primary ventilation shaft located on the far side of the orebody. From this level, fresh air is circulated through ventilation raises and the ramp to all lower levels. Ventilation capacity is presently somewhat limited and needs to be optimized in order to fully service future deep levels as well as any exploration drift that might be driven toward the nearby Dammsjön deposit. Allowance has been made in the capital expenditure schedule for the necessary improvements to the ventilation system.

Ore haulage within the Garpenberg mine from the various stopes to the 640 crushing level is provided by 25-tonne trucks. These trucks dump into ore and waste pockets located just above the crusher level. Haulage capacity is more than adequate for present operations, but would need to be augmented if substantially greater depths are penetrated. A jaw crusher with a capacity of about 400 tonnes per hour reduces the rock to less than 30 centimetres (cm). Crushed material is transferred by conveyor in weighed quantities to a single 4.5-tonne skip at the main hoisting shaft. Hoisting speed is 8.4 m per second and the capacity of the fully automated system is 75 tonnes per hour.

Both cut-and-fill and undercut-and-fill methods are presently utilized at Garpenberg. The choice of method depends primarily on ground conditions with cut-and-fill being used where conditions are moderate and undercut-and-fill being used where conditions are severe. In 1995, cut-and-fill provided 176,000 tonnes of ore, 56 per cent of the total. Larger-scale undercut-and-fill provided 118,000 tonnes, or 38 per cent. Selective undercut-and-fill provided the remaining 20,000 tonnes, or 6 per cent.

In the cut-and-fill method, mining proceeds upward from a primary access level in a series of slices some four to six metres in height over the full width of the orebody. A mining face is drilled with a two-boom jumbo. Blasting is principally with ammonium nitrate, but incorporates light loading with trim powder or primacord on the periphery. Broken rock is loaded out with front-end loaders into trucks. Average haul distance for the loaders is 100 m. Mechanical scaling proceeds on the back, face and ribs, and is followed by bolting with grouted rebar and friction bolts as required from hydraulic platforms. Backfill consists of classified tailings from the mill introduced through boreholes. The next higher slice is mined off of this backfill floor. At this time, a normal round is about 3.5 m in length. Boliden AB has tested a 7.5-m long by 5 to 7-m high round drilled with a larger jumbo. This larger round, if implemented, would increase the overall efficiency of the mining operation by reducing the amount of equipment movement required and by eliminating the dead time between smaller rounds. While such a long round might increase the amount of dilution introduced into the ore, Boliden AB has provide for increased directional control of the drilling unit. This increased control should at least offset some of the potential for dilution.

Presently, the final slice under the next higher main access level is not removed since it is overlain by un-cemented tailings used as fill in the overlying level. Garpenberg is currently testing the fill system used in the undercut and fill scheme to fill stopes above future sill pillars. The company has tested a system of ground freezing on the first backfilled slice overlying this sill pillar which seems to offer a good potential for recovering the sill pillar itself. Implementation of this system would increase total mine recovery and extend the life of existing reserves. “Normal” recovery of initial reserves has amounted to about 90 per cent.

In the undercut-and-fill method, mining of slices proceeds downward and mined-out slices are backfilled with cemented backfill. This stabilized fill then becomes the roof for the next slice. The method is particularly suited to mining where higher ground pressures exist as it provides additional control of the stope environment. Boliden AB has implemented an additional measure of ground control integral to this method. A vertical slab of styrofoam is embedded in the centre of the cemented backfill. This slab provides some “give” to the system and has reduced subsequent ground control problems. Recovery is higher with this system since no sill pillar is required, but costs are higher because of cement in the backfill and poorer ground conditions, in general.

A small area in the upper levels of the Garpenberg mine is being selectively mined for high grade ores with a smaller scale version of undercut-and-fill method. Since the ore is particularly friable and, when wet, turns to mud, additional ground support in the form of three-piece timber sets is necessary during the mining cycle.

All mining equipment utilized at Garpenberg is diesel-powered and rubber-tired as mobility is critical to the efficiency of the operation. Adequate equipment levels exist in all sectors and an underground service/repair facility provides much of the routine maintenance. The cost of capital equipment replacement is fully specified in the budget. A listing of most of the major mobile equipment presently available at Garpenberg is provided below:

MAJOR MOBILE EQUIPMENT LISTING - GARPENBERG		
Classification	**Specification**	**Number of Units**
Drilling	Atlas Copco Boomer 126 Atlas Copco Boomer 127 Atlas Copco Boomer 128 Atlas Copco Boomer 135 Atlas Copco But 10 Baskaggregat 10	1 1 3 1 1 1
Platforms	Carl Strom CS 2800 PT 60 PT 100 PK 1000 PK 3000 Normet NT 80	2 2 2 1 1 1
Loaders	Toro 200 Volvo BM L120 Volvo BM L120 B	3 3 1
Trucks	Volvo BM A25	5
Shotcrete	Brock 3000 on BM 4400	2

Total employment at the Garpenberg mine during January, 1997 was 116, up somewhat from previous years, but temporarily, in order to bring development up to date.

The mine is 100 per cent unionized. Incentives are used in several situations, most notably in driving the primary development ramp where a bonus is paid on all progress in excess of 55 m per month. All indications are that the work force is well-trained, motivated, safe and efficient.

Mining productivities for period 1994 to 1996 are summarized in the following table.

Table 4.6
GARPENBERG MINE - PRODUCTIVITY SUMMARY

Item	1992	1993	1994	1995	1996
Ore Production (1,000 tonnes)	300.7	324.1	315.1	313.9	346.3
Labour Expended (1,000 man-hours)	168.6	169.3	167.5	165.4	164.2
Productivity (tonnes ore/man-hour)	1.79	1.91	1.88	1.90	2.11

For the period 1992 to 1996, productivity at the Garpenberg mine has increased by 17.8 per cent, a compound rate of 4.2 per cent per year. Opportunities for further increases in productivity are available through longer, larger drill rounds and by providing an increased number of working faces.

4.7.1 Historical Production Performance

From 1958 through 1990, ore production records were kept in detail individually for the Garpenberg and Garpenberg North mines. Since 1990, however, ore grade production records have been combined for both mines. Available information for the Garpenberg mine is summarized in Table 4.7.

Table 4.7
GARPENBERG MINE - PRODUCTION SUMMARY

Year	Tonnes Ore	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
1986	227,573	0.6	106	0.21	3.70	5.01
1987	227,400	0.8	106	0.31	3.66	5.17
1988	266,069	0.8	109	0.25	3.48	5.38
1989	278,974	0.7	107	0.26	3.39	5.22
1990	298,423	0.9	110	0.33	3.62	5.01
1991	318,199	NA	NA	NA	NA	NA
1992	300,698	NA	NA	NA	NA	NA
1993	324,056	NA	NA	NA	NA	NA
1994	315,591	NA	NA	NA	NA	NA
1995	313,888	NA	NA	NA	NA	NA
1996	346,302	NA	NA	NA	NA	NA

4.7.2 Historical Cost Performance

Historical mining costs for the Garpenberg mine are available for the years 1992 - 1996 and are summarized in the following table.

Table 4.8
GARPENBERG MINE- HISTORICAL MINING COST SUMMARY
(SEK/tonne)

Item	1992	1993	1994	1995	1996
Labour	107.7	99.9	105.5	108.4	104.8
Material	83.9	86.1	84.9	91.0	87.2
Energy	3.8	3.0	2.7	3.9	3.8
Contract	12.4	18.5	25.0	20.4	30.6
Overhead	45.5	40.9	47.5	49.1	49.1
Depreciation	15.3	21.4	18.3	13.5	10.1
Total	**268.5**	**269.8**	**283.9**	**286.3**	**285.7**
less depreciation	**253.2**	**248.4**	**265.6**	**272.8**	**275.6**
Total cost per tonne, US$/tonne	**46.11**	**34.67**	**36.79**	**40.14**	**42.60**
less depreciation	**43.48**	**31.92**	**34.42**	**38.25**	**41.10**

4.8 GARPENBERG MINE - FUTURE MINING OPERATIONS

Future ore production from the Garpenberg mine is scheduled at 360,000 tonnes per year for the period 1997 through 1999 and 400,000 tonnes per year from 2000 through depletion of reserves. Proven reserves were listed as 1,264,000 tonnes as of January 1, 1997. On this basis, depletion could occur as early as 2000. Projected production schedules supplied to Micon indicate depletion in 2002 on the basis of 2,180,000 tonnes of reserves and resources as of January 1, 1997. Garpenberg management personnel, however, have expressed the belief that production will continue for a longer period of time due to: 1) an extension of the present orebody to greater depths than originally forecast, and/or 2) development of the nearby orebodies, Dammsjön and Tyskgårdsgruvan. Inferred resources for these two deposits are 6.0 million tonnes and either or both could be mined via the 700-m level of the Garpenberg mine.

4.8.1 Outlook for Operating Cost

Projections of direct mining costs compiled by Boliden for the Garpenberg mine for the period 1997 through 2001 show a decrease from 276 SEK per tonne of ore mined in 1996 to 203 SEK per tonne of ore mined in 2001, a compound decrease of approximately 5.0 per cent per year. Two factors influence this decrease: scale of operation as output moves from 360,000 tonnes of ore per year in 1999 to 400,000 tonnes of ore per year in 2000 as a result of the new Gruvsjö shaft, coming on stream in January, 1997, and gains in technology such as the proposed longer and larger drill rounds. Additional costs for exploration and depreciation are included in the forecast. No royalties or severance taxes are payable on mine production at Garpenberg.

The following table summarizes Boliden's forecast of future mining costs at the Garpenberg mine.

Table 4.9
GARPENBERG MINE - SUMMARY OF FUTURE MINING COSTS
(SEK/tonne of ore mined)

Year	1997	1998	1999	2000	2001
Direct Mining	255	224	229	217	203
Exploration	9	8	8	7	7
Depreciation	30	42	45	42	43
Total	**294**	**274**	**282**	**266**	**254**
Total US$/tonne	**42.00**	**39.14**	**40.29**	**38.00**	**36.29**

In Micon's opinion, these cost estimates are appropriate.

4.8.2 Outlook for Capital Expenditure

In considering capital expenditures for the Garpenberg mine, it is notable that the cost of continued ramp development to increasingly lower levels is expensed because, with the undercut-and-fill system presently in use in the deeper levels, stoping progresses downward in parallel with ramp development. Proposed capital expenditures for the period 1997 through 2001 are summarized in the following table. Micon regards these expenditure forecasts as reasonable.

Table 4.10
GARPENBERG MINE - CAPITAL EXPENDITURE PROGRAMME
(Thousand SEK)

Item	1997	1998	1999	2000	2001
Increased ventilation capacity	3,300				
Underground trucks		1,500	1,500		
Drilling equipment	5,000				
Load-haul-dump units		4,000	2,000		
Service equipment	600				
Service truck		1,500			
New backfill system	1,200				
Pumpstation 680 level	1,000				
Total	**11,100**	**7,000**	**3,500**	**0**	**0**

4.9 GARPENBERG NORTH MINE - CURRENT MINING OPERATIONS

The Garpenberg North mine, developed by Boliden, commenced production in 1972 and has now progressed to operating depths in excess of 800 m. Total production to date has been 8.4 million tonnes of ore. Future production is scheduled at a rate of 650,000 tonnes of ore per year.

Vertical hoisting and personnel shafts are centrally located and extend to a depth of just over 800 m. Crushing and skip loading facilities are located at the 800-m level. A spiral ramp extends the full distance from surface to the 800-m level. A new production level has been developed at 900 m.

Primary development includes the spiral ramp at a decline of about 14 per cent and crosscuts driven to the orebody at each full turn. Each crosscut provides access to about four slices, or about 20 m of vertical height in the orebody.

Primary development has lagged badly during the last several years and is now the bottleneck in the mining system. Because of this lag the number of working places is usually limited to about four to six. In this circumstance, actual production is 1,500 tonnes of ore per day, with a possible increase to 1,800 to 2,000 tonnes per day, the amount necessary to meet the production goal for the year. Any unplanned occurrences which might reduce production for even a day will ultimately be reflected in annual production since there is presently no slack in the system. This situation is expected to improve as progress on the spiral ramp improves and more working faces can be opened. Only 429 m of ramp were completed in 1995. Sufficient faces are not presently available to utilize the full production capability of the work force and its equipment. As a consequence, production during 1997 is expected to fall some 50,000 tonnes short of the forecast goal of 650,000 tonnes. A recent reemphasis on primary development is likely to correct the situation within six to twelve months, and future production should meet the targeted goal.

Waste rock production in 1995 amounted 177,000 tonnes. As at Garpenberg, most was placed in the fill underground.

Ventilation capacity at Garpenberg North is 500,000 m^3 per hour through the personnel and production shafts to the 560 level and through only one shaft to the 800 level. Most of the exhaust is pulled upward and out via the ramp to the surface. Present ventilation capacity is seen to be adequate.

Ore haulage at Garpenberg North is provided by an independent contractor using two 35-tonne trucks on two shifts per day. An additional truck is available as a spare. These trucks are loaded at the face by company personnel with front-end loaders and hauled to the ore and waste dump pockets on the 800 level. Rock is crushed to minus 30 cm by a jaw crusher with a capacity of 1,000 tonnes per hour. Crushed rock is automatically weighed and loaded into skips by conveyor. A single 9-tonne skip is hoisted at 7.3 m per second. The capacity of the fully-automated hoisting system is 100 tonnes per hour. This capacity is adequate for the budget ore production rate of 2,000 tonnes of ore per day.

Cut-and-fill is the only mining method employed at Garpenberg North. It is the same in all essentials as that employed at Garpenberg.

Rubber-tired, diesel equipment is used throughout the Garpenberg North mine. Major equipment items are listed below:

MAJOR MOBILE EQUIPMENT LISTING - GARPENBERG NORTH		
Classification	**Specification**	**Number of Units**
Drilling	Atlas Copco ROC 600	1
	Atlas Copco Boomer 135	1
	Atlas Copco Boltec H 330	1

	Atlas Copco Swellbolter Atlas Copco 352 Tamrock DCR 222 Stromnes DC 252	1 1 1 1
Platforms	Carl Strom CS 2800 Stromnasbryggor PT 100 PT 60	2 3 2 1
Loaders	Wagner ST 2 Toro 350 D Toro 500 CD Toro 501 D	1 1 1 2
Shotcrete	Bask on Wagner ST 8	2

A service/repair facility is presently located at the 350 level, but plans are in place to establish a new facility at a much lower level. Estimated costs for this and for equipment replacement are included in the capital budget.

Productivity at Garpenberg North is higher than at Garpenberg mainly because rock conditions are better and the less-productive undercut-and-fill method is not used. In January 1997, the mine employed 94 people. With 1996 production at almost 500,000 tonnes of ore, productivities can be calculated to be approximately 5,300 tonnes of ore per employee year, 27 tonnes of ore per man-shift, and 3.2 tonnes of ore per man-hour. This productivity is somewhat overstated because contractor's personnel undertake haulage and shotcreting.

4.9.1 Historical Production Performance

Available production details for the Garpenberg North mine are summarized in the following table.

Table 4.11
GARPENBERG NORTH - PRODUCTION SUMMARY

Year	Tonnes Ore	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)
1986	339,279	0.3	151	0.03	0.76	1.69
1987	571,207	0.2	153	0.04	0.80	1.85
1988	440,362	0.3	145	0.04	0.81	1.95
1989	456,968	0.3	116	0.04	0.78	1.98
1990	448,812	0.3	151	0.06	0.99	2.58
1991	554,710	NA	NA	NA	NA	NA
1992	522,910	NA	NA	NA	NA	NA
1993	475,953	NA	NA	NA	NA	NA
1994	495,029	NA	NA	NA	NA	NA
1995	436,102	NA	NA	NA	NA	NA
1996	495,652	NA	NA	NA	NA	NA

4.9.2 Historical Cost Performance

Historical mining costs for the Garpenberg North mine for the period 1992 to 1996 are summarized in the following table.

Table 4.12
GARPENBERG NORTH - HISTORICAL MINING COST SUMMARY
(SEK/tonne)

Item	1992	1993	1994	1995	1996
Labour	47.9	52.9	50.6	58.4	59.4
Material	33.4	39.5	37.1	51.1	53.1
Energy	5.2	4.5	4.0	6.3	4.2
Contract	28.3	35.4	35.5	56.7	47.0
Overhead	37.9	25.2	25.1	31.0	32.9
Depreciation	18.4	16.3	16.0	20.3	32.7
Total mining cost, SEK/tonne	**171.2**	**173.9**	**168.2**	**223.8**	**229.2**
less depreciation	**152.8**	**157.6**	**152.2**	**203.5**	**196.5**
Total US$/tonne	**29.39**	**22.34**	**21.80**	**31.37**	**34.17**
less depreciation	**26.23**	**20.24**	**19.73**	**28.53**	**29.30**

4.10 GARPENBERG NORTH - FUTURE MINING OPERATIONS

Future ore production from the Garpenberg North mine is scheduled at 600,000 tonnes in 1997 and 650,000 tonnes per year for the period 1998 through 2006. Proven and probable reserves are listed as 3,813,000 tonnes of ore as of January 1, 1997, which indicates that depletion could occur as early as 2002. An additional 6,000,000 tonnes of ore are, however, carried as inferred resources. As indicated previously in this report, production for 1997 is expected to fall some 50,000 tonnes short of the goal of 650,000 tonnes. While the mine should be able to meet its full production goals from 1998 through at least 2002, the situation can be expected to be somewhat tight in the short term until additional working faces can be developed.

4.10.1 Outlook for Mine Operating Cost

Projections of direct mining costs compiled by Boliden AB for the Garpenberg North mine for the period 1997 through 2001 are stable at about 140 SEK per tonne of ore mined, but show a decrease of 53 SEK per tonne from 1996. This decrease is attributed to an increase in the scale of output from 496,000 tonnes of ore in 1996 to 600,000 tonnes of ore in 1997 through utilization of a new shaft which came into operation early in 1996, and development of production at the 900-m level. Additional costs for exploration and depreciation are included in the forecast. No royalties or severance taxes are payable on mine production at Garpenberg North.

The following table summarizes Boliden AB's forecast of future mining costs at the Garpenberg North mine.

Table 4.13
GARPENBERG NORTH - SUMMARY OF FUTURE MINING COSTS
(SEK/tonne of Ore Mined)

Year	**1997**	**1998**	**1999**	**2000**	**2001**
Direct Mining	143	140	142	142	141
Exploration	13	8	8	8	8
Depreciation	31	36	41	43	47
Total	**188**	**184**	**191**	**193**	**197**
Total US$/tonne	**26.86**	**26.29**	**27.29**	**27.57**	**28.14**

In 1995 and 1996, direct mining costs at Garpenberg North were about 200 SEK per tonne. The projected decrease to a level of approximately 140 SEK per tonne for the years 1997 to 2001 is regarded by Micon as optimistic.

4.10.2 Outlook for Capital Expenditure

In contrast to the Garpenberg mine, ramp development at the Garpenberg North mine is capitalized since the ramp must proceed to the lowest part of the next cut-and-fill stope before mining begins. Thus, mine development forms a significant portion of future capital expenditures at the Garpenberg North mine. All future capital costs for equipment are for equipment replacement. Future capital costs for the Garpenberg North mine are summarized in the following table.

Table 4.14
GARPENBERG NORTH - CAPITAL EXPENDITURE PROGRAMME
(Thousand SEK)

Item	1997	1998	1999	2000	2001
Ramp to 900 level	7,800				
Ramp to 980 level		18,000	4,000		
Ramp to 1045 level				16,000	2,000
Shotcrete equipment	3,000				
Workshop 800 level	5,000	1,000			
Upgrade personnel shaft	1,000				
Platforms			1,500		
Drilling equipment	5,000	5,000			5,000
Load-haul-dump units			4,000	4,000	
Rock bolting equipment	4,000				
Scaling equipment	3,500	3,500			
Service tractor	600			1,300	
Service truck			1,500		
Total	**29,900**	**27,500**	**11,000**	**21,300**	**7,000**

4.11 SUMMARY OF GARPENBERG AREA MINING OPERATIONS

Historical mining costs for the combined operation of Garpenberg and Garpenberg North are summarized in the following table.

Table 4.15
GARPENBERG TOTAL - HISTORICAL MINING COST SUMMARY

Item	1992	1993	1994	1995	1996
Production (‘000 tonnes)	823.6	800.1	810.6	750.0	842.0
Total SEK/tonne mined	206.7	212.8	213.2	250.0	252.4
Total US$/tonne mined	35.49	27.34	27.64	35.04	37.64

Certain detailed mining cost summaries are available for the years 1994 to 1996 which provide a good comparison of direct mining costs for the different stoping methods presently used at the Garpenberg mines. These costs are presented in the following table.

Table 4.16
GARPENBERG MINES - STOPING COST COMPARISON BY METHOD
(US$/tonne of Ore Mined)

Location and Method	1994	1995	1996
Garpenberg			
Cut-and-Fill	6.36	6.81	8.11
Undercut-and-Fill	13.78	16.67	15.26
Selective U-a-F	23.16	17.59	18.36
Garpenberg North			
Cut-and-Fill	5.35	6.49	6.86

4.11.1 Future Mine Production

Scheduled mine production and ore grade projections for the Garpenberg mines for the period 1997 through 2001 are made on a combined basis as set forth in the following table.

Table 4.17
GARPENBERG MINES - ORE PRODUCTION AND GRADE PROJECTIONS

	Unit	1997	1998	1999	2000	2001
Tonnes ore	'000 tonnes	960	1,010	1,010	1,050	1,050
Grade gold	g/t	0.41	0.38	0.36	0.34	0.32
silver	g/t	140	140	140	140	140
copper	%	0.14	0.15	0.14	0.12	0.10
zinc	%	4.49	4.50	4.60	4.80	4.80
lead	%	2.27	2.30	2.40	2.30	2.20

The progressive improvement in zinc grade is believed to reflect increasing grade with depth of mining.

Cost projections for operation of the Garpenberg mines for the period 1997 through 2001 are summarized in the following table.

Table 4.18
GARPENBERG MINES - SUMMARY OF FUTURE MINING COSTS
(US$/tonne of Ore Mined)

Mine	1997	1998	1999	2000	2001
Garpenberg	42.00	39.14	40.29	38.00	36.29
Garpenberg North	26.86	26.29	27.29	27.57	28.14
Average	32.54	30.87	31.92	31.54	31.24

4.12 GARPENBERG AREA - CURRENT MILLING OPERATIONS

The present Garpenberg concentrator building dates back to the 1950's and was taken over by

Boliden AB in 1957. As with the other concentrators, it has been progressively modernized and altered to optimize its performance.

Primary crushing of the ore is carried out underground at both the Garpenberg mines. Ore from the North mine is hoisted and transported in 100-tonne side tipping truck and trailer units to a transfer bin close to the concentrator. Ore from the south mine is hoisted and conveyed to the same bin. The combined stream is transferred by an inclined conveyor to the bin ahead of the primary mill.

Ore is drawn by vibrating feeders to a batchwise belt weigher before feeding to the 1,450 kilowatt (kW) primary autogenous mill. The mill discharge gravitates to the 900 kW secondary pebble mill which is fed with pebbles extracted from the primary mill and transported by conveyor belt. Secondary mill discharge is pumped to a vibrating screen which returns the fraction coarser than three millimetres to the primary mill. The screen underflow is pumped to hydrocyclones, whose underflow is concentrated on Reichert cones from which the dense concentrate is further concentrated on shaking tables to produce a gold-silver concentrate. The tailings from the Reichert cones return to the pebble mill.

The hydrocyclone overflow is conditioned by the addition of sulphur dioxide to depress zinc and this is controlled by maintaining the pH at 8.5. The ore contains 13% carbonates and has a natural pH of 10.5. Aerophine 3418 is used as the promoter for copper lead-flotation with D200 frother. Copper and lead are floated in two parallel banks of Sala BFR 300 cells, one bank of eight cells and the other of twelve. Rougher concentrates are cleaned in three stages in similar cells, with the first cleaner tailing being reground in a 300 kW ball mill before returning with the scavenger concentrate to the head of the circuit.

The copper-lead concentrate is then segregated by depressing the lead by the addition of sodium dichromate and floating the copper in a bank of Sala BFR 140 cells. The rougher concentrate is cleaned in three stages with cleaner tails and scavenger concentrates returning to the head of the segregation circuit. Final copper concentrate is thickened, filtered on a vacuum drum filter and despatched.

The primary lead concentrate which is the tailing from the segregation, then passes a low intensity wet magnetic separator and a trommel screen before being thickened in a lamella thickener and separated on a Sala wet high gradient magnetic separator. This removes some copper, zinc and iron sulphides to upgrade the final lead concentrate. The concentrate is then thickened, filtered on a vacuum drum filter and dried in an oil fired rotary drier before despatch by road to the port of Gävle. The magnetic fraction is reground in a Sala 30 kW agitated ball mill before returning to the head of the flotation circuit.

Copper-lead flotation tailings are conditioned with lime to a pH of 11 and copper sulphate to re-activate the zinc. Zinc is then floated in Sala BFR 300 cells using SIBX as a collector, although Danafloat 145 (sodium butyl dithiophosphate) is being tried and is presently found to be weaker and more selective against iron, but requiring more copper sulphate. The rougher concentrate is cleaned in three stages, with the first cleaner tailing and the scavenger concentrate being re-ground in a 30 kW ball mill and returned to the head of the zinc circuit. Final zinc concentrate is thickened, filtered on a vacuum drum filter and dried in an oil-fired rotary drier before despatch by road to the port of Gävle.

Tailings are classified in two stages in hydrocyclones and the coarse fraction is dewatered on a vacuum drum filter for return to the mines for use as backfill. The fine fraction is pumped by four stages of pumps to the tailings dam. There are other old tailings dams in the area, but that which is presently in use is on the site of a smaller lake. Apparently at the behest of the authorities, a dam has been built across the middle of this lake and only the western part has been filled with tailings to a depth about 10 m higher than the rest of the lake. The partition wall appears to have been built on existing sub-aqueous deposited tailings and its security is questionable. The management is presently negotiating with the authorities with a view to putting tailings in the lower part of the lake in future so as to reduce the stress on this wall. It appears likely that this will be permitted.

Water decanted from the tailings dam is returned to the concentrator.

The Garpenberg concentrator flowsheet is shown in Figure 4.5.

As with other mills in the Boliden AB group, the plant is regularly washed down to minimize the dust content of the air particularly in view of the lead content of the ore. At Garpenberg, an additional potential concern is the presence of tremolite in the ore.

4.12.1 Garpenberg Area Concentrator Costs

Table 4.19 below summarizes the operating costs of the Garpenberg concentrator.

[Figure 4.5 - Garpenberg Concentrator]

Table 4.19
GARPENBERG CONCENTRATOR OPERATING COSTS, 1996
(Thousand SEK at 842,000 tonnes per year)

Item	Cost	
Energy (direct purchased)		**467**
Electricity		
Heating Oil (for dryers)	467	
Materials		**15,878**
Spare parts & Wear parts	5,338	
Electrical equipment	720	
Reagents	7,187	
Other material	2,633	
Labour		**9,038**
Wages	8,654	
Sick Pay	52	
Other labour costs	332	
Outside Services		**11,475**
Ore Transport	0	
Concentrate Transport	4,906	
Concentrate, Port Charges	1,282	
Other Transport charges	104	
Contract Maintenance	2,111	
Other Outside Services	3,072	
Re-distributed costs		**15,038**
Electric Power	10,527	
Maintenance Workshops	2,050	
Other Services	1,160	
Overhead	1,310	
Re-distributed services		**1,435**
Other departments	387	
Technical and administration	1,048	
Depreciation		**7,615**
Total Costs		**60,946**
Total cost SEK/tonne milled		**72.38**
less depreciation		**63.33**
Total cost US$/tonne milled		**10.80**
less depreciation		**9.45**

It is estimated that 72% of the contained metal values in the ores of Garpenberg are recovered into payable concentrates. The plant performance over the last three years is summarized in Table 4.20 below.

Table 4.20
GARPENBERG CONCENTRATOR PERFORMANCE

	Unit	1994	1995	1996
Ore Milled	000 tonnes	811	750	842
Gold	g/t	0.51	0.44	0.47
Silver	g/t	152	133	141
Copper	%	0.15	0.15	0.13
Lead	%	2.31	2.21	2.24
Zinc	%	4.34	4.26	4.52
Gold Concentrate	tonnes	150	110	120
Gold recovery	%	12.0	5.0	9.3
Silver recovery	%	2.6	0.9	1.3
Lead recovery	%	0.5	0.4	0.42
Copper Concentrate	tonnes	4,005	3,452	3,297
Copper recovery	%	68.1	66.4	62.2
Gold recovery	%	50.8	53.8	56.0
Silver recovery	%	48.9	45.3	47.3
Lead Concentrate	tonnes	21,176	18,875	20,833
Lead recovery	%	78.9	78.0	765
Gold recovery	%	8.4	10.9	9.0
Silver recovery	%	24.7	28.0	25.8
Zinc Concentrate	tonnes	56,543	52,144	65,572
Zinc recovery	%	85.6	86.9	88.9

Complete specifications of the concentrates are included in Appendix I.

4.12.2 Garpenberg Area - Future Milling Operations

Future developments at the Garpenberg concentrator will depend on the success of exploration activities in the area. The Garpenberg Mine reserve is open at depth and appears to increase in grade with depth. The resources are comparatively small. The North mine has lower grades but potential for extension both along strike and at depth. Its grade also improves with depth. The exploitation of inferred resources at Dammsjön and Tyskgårdsgruvan will depend on their economic viability. If mining these deposits will lower the combined grade, then it may be desirable to increase the concentrator throughput.

Tests are to be carried out this year to explore the possibility of using an APC grinding circuit at Garpenberg. This would use the existing primary autogenous mill and a larger pebble mill. The pebble extractor would be used to extract critical size pebbles from the primary mill both to provide media for the pebble mill and to provide a surplus which would be crushed and returned to the primary mill. This might enable an increase towards 1.3 million tonnes per year to be achieved without replacing the primary mill.

It is proposed also to install the mill lifter transducers, which are presently being tested at Aitik, in the pebble mill in order to maximize the power draw of that mill. It is generally found that finer grinding improves the recovery of silver and zinc at the expense of some loss of lead. On balance, finer grinding is economically beneficial. The 300 kW regrind ball mill in the copper-lead circuit is a new innovation and is improving the lead concentrate grade and the silver recovery.

The capacity of the copper-lead cleaner cells is being doubled using cells from the redundant talc flotation circuit. The talc content of the ore has declined and its separate flotation is no longer necessary.

It is intended to revert to the original fine matrix in the high gradient magnetic separator as the present coarser matrix is giving an inferior separation.

An experimental 130 m^3 Sala flotation cell is to be installed in the original grinding bay and will be tested as an additional scavenger in the copper-lead circuit and also as a scavenger in the zinc circuit. The installation is being done at Sala's expense and while it is doubtful that such a large machine will ultimately be suitable at Garpenberg, the experiment will give a clear guide to the benefits that might be obtained from a substantial increase in flotation capacity.

Some experimental work has been done on the cyanide leaching of silver and gold from the copper-lead tailings in support of efforts to improve the recovery of precious metals at Garpenberg.

There are at present no plans for capital expenditure in the concentrator at Garpenberg and no replacement capital expenditure is expected. The projected plant performance is based on past performance and should be achieved. When an agreement has been reached with the authorities to define the future tailings disposal strategy, some capital expenditure is likely to be required to enlarge the tailings disposal area.

4.13 CONCLUSIONS

The Garpenberg and Garpenberg North mines are well-organized, safe and efficient mining operations with opportunities for increased productivity. Infrastructure, equipment, personnel and production methods are well-suited to the job at hand. In the short term, however, both mines are somewhat tight on primary development. This situation is being corrected, but can be expected to result in a shortfall in production of about 50,000 tonnes of ore during 1997.

Depletion of reserves at the Garpenberg mine has previously been scheduled to occur in 2000 or 2002. Present indications are that additional ore may be available at depth, but the quantities and grades are yet to be defined. Additional exploration in this area is ongoing.

Operating cost projections, notably at Garpenberg North, are regarded as somewhat optimistic over the short term.

5.0 THE LAISVALL AREA

5.1 INTRODUCTION

Laisvall, in Sweden's Arjeplog Municipality, is Europe's largest lead mine and has been operating since 1943. At present, the mine feeds an ore-processing plant, at site, at a rate of some 1.7 million tonnes of ore per year. The ore also contains zinc and silver. Lead concentrate is transported 280 km by truck to the Rönnskär smelter, with the balance of about 50 per cent exported. The zinc concentrate is transported to the port of Skelleftehamn and shipped to zinc smelters elsewhere in Europe.

5.2 CHARACTERISTICS OF THE PROPERTY

The Laisvall mine is located in the foothills of the Swedish mountain range, close to the Norwegian border, approximately 300 km to the north-west of the city of Skellefteå. Although situated close to the Arctic circle, between longitude 16 and 18 degrees east, the climate is moderated by the relative proximity to the Atlantic Gulf Stream. Summer temperatures reach the mid-20° C range, while winter temperatures rarely fall below minus 25° C. Elevation ranges from 424 m above sea level at Lake Stor-Laisan, to 600 m above sea level in the mountainous area to the west of the lake.

Access to the mine is via a good tarred road from Skellefteå and Boliden. The smelter and port are connected to the mine and processing plant by 282 km of good road. Electricity is supplied from the local utility which generates hydro-power from rivers in the area. A small village, essentially privately owned, exists close to the mine and provides accommodation and basic services.

The operation is solely owned by Boliden AB. The properties are located north of the village of Laisvall on both sides of, and under Lake Stor-Laisan. The properties comprise 15,000 hectares in exploration permits and approximately 1,000 hectares in exploitation concessions. The former are granted for 10 years and the latter are licences of occupation and are held in perpetuity.

Mining operations at Laisvall originated with the discovery of some lead-bearing boulders in Lake Stor-Laisan in 1938. Shaft sinking commenced after the outbreak of the second world war threatened to cut off Sweden's supply of the strategically critical metal, lead. Production began in 1943 and, at that time was considered a war-time provision. The facility was later made permanent and production expanded in successive stages to reach 1.784 million tonnes of ore in 1996. Production of a zinc concentrate in addition to lead commenced in 1972.

The shallow, flat-lying orebody is mined using a highly mechanized room-and-pillar operation. The ore exists in two horizons of sandstones, with extraction in heights ranging from 5 to 18 m. The ore is initially top-cut with development headings and then benched to the final thickness by breast benching. Water inflows require attention and a significant amount of future production will be recovered from areas under the lake.

The processing plant utilizes conventional flotation to separate and produce lead and zinc concentrates.

In 1996, the operation mined and processed 1.784 million tonnes of ore at average grades of 4.2% lead and 0.81% zinc and produced 85,100 tonnes of lead concentrate, grading 77.9% lead and 163 g/t silver, and 18,800 tonnes of zinc concentrate, grading 58.6% zinc. Total on-site cash costs for mining, milling and administration were 128.6 SEK (US$19.20) per tonne of ore.

5.3 GEOLOGICAL SETTING

The morphology of the area is mainly inherited from the rock structures and has been accentuated during the glacial erosion in the Pleistocene.

The Laisvall deposit (see Figure 5.1) is one of a series of sandstone lead-zinc deposits at the border of the Caledonian mountains and is estimated to contain resources totalling about 80 million tonnes of 4 per cent lead and zinc.

On a Precambrian basement (syenites and granites) a succession of late Precambrian, Cambrian and Ordovician sedimentary rocks were deposited. During Caledonian deformation, large-scale thrusting took place with the emplacement of nappes. The autochthonous sedimentary rocks, around the Laisvall Mine, were subjected to minor faulting, while to the northwest of the mine the sediments were highly folded, contorted and broken. The last tectonic event in the area resulted in faults and joints. Dominant joint sets are 030 and 300 degrees.

On the basement lies a sedimentary breccia passing transitionally into an overlying arkose which, in turn, is followed by an arenaceous shale or siltstone. The sedimentary sequence continues with a 40-m thick formation of quartzitic sandstone divided into a lower, a middle and an upper member. The Upper Sandstone member passes upwards into a shale conglomerate about half a metre thick (this unit marks the boundary between the late Pre-Cambrian and the Cambrian). This sedimentary succession is referred to as the Laisvall Formation. It is overlain by shale and siltstone of the Siltstone Formation and by a dark graphitic shale of the Alum Shale Formation which passes upwards into the Greywacke Formation.

These sedimentary units are overthrust by units of the Kaskajvre and the Yraf nappe complexes. In general, only the uppermost Cambrian shales have been strongly affected by the thrust movements. To the south and east of Laisvall, the Lower and Middle sandstones grade laterally into shale and siltstones.

5.3.1 Mineralization

The sulphide mineralization occurs in the sandstones of the Laisvall Formation. The minerals of the ore association, galena, sphalerite, barite, calcite, fluorite and pyrite, are situated in the interstices between the sand grains and are cemented by quartz. The compacted sandstone, prior to mineralization, probably had a porosity of 30 per cent. Except in massive sandstone where the ore is as spots of galena, the galena normally follows the bedding planes; cross-bedding, horizontal bedding, contacts between shale layers, load structures and other sedimentary structures. In the very rich areas, galena may occupy the whole of the pore space.

[Figure 5.1 - Geological Map of the Maiva Area]

The minerals are commonly mutually exclusive and several generations of each mineral exist. However, there is a marked tendency for sphalerite to be generally older than galena, which in turn usually precedes the calcite, barite and fluorite. The deposit is zoned with respect to galena and sphalerite, with sphalerite being dominant in the Upper Sandstone to the northwest and very minor in the galena-rich Lower Sandstones. Zinc grades average 1.3 per cent in the Upper Sandstone and 0.1 per cent in the Lower Sandstone.

The distribution of the mineralization is mainly controlled by permeability (and porosity) variations in the sandstones caused by the distribution of shale layers and sedimentary structures. Lateral mineralized contacts are generally diffuse whereas cross cutting contacts are generally sharp. These sharp ore contacts indicate that the mineralization was formed after the deposition of the sandstones.

Metalliferous, low sulphide brines encountered sulphidic waters, leading to precipitation of the mineralization. The brines were zinc-rich initially, lead-rich in the main phase of mineral deposition and became metal-poor in the later stages.

The mineralization is strata-controlled, and the vertical variation is far greater than the horizontal. Layers of sandstone with fairly constant lead and zinc contents can be traced up to several hundred metres. The mineralization occupies the Upper Sandstone in the west and is concentrated in the Lower Sandstone to the east of the Laisvall mine. The mineralization is bounded to the northeast by a basement high, which cuts through the sequence to the top of the Lower Sandstone. In the northwest the mineralization (exclusive to the Upper sandstone) is limited by overlying siltstones and shales.

The mineralized sandstones generally are very little disturbed tectonically. They are weakly undulating. The sediments have been affected by a number of steeply-dipping faults and small thrusts. The Kautsky disturbance forms the southwestern mineralization boundary (north-south striking, steeply dipping, reverse fault zone with a 30-metre throw). The Nadok disturbance is a small, nearly vertical northeast-southwest striking normal fault with a throw of about 20 m.

The mineralization predates these faults and, also, the Caledonian thrust movements.

At Laisvall, the lead-zinc mineralization is contained in two gently west-northwest dipping, thin quartzitic sandstone sheets. The Lower Sandstone forms a thin elongate mineralized body with a major elongation at 040 degrees (N40E). In the Upper Sandstone, the mineralization occurs as an even thinner body with a major elongation at 040 degrees (N40E) and a minor elongation at right angles (130 degrees). The Upper Sandstone is eroded in the area of Lake Stor-Laisan.

The dimensions of the Lower Sandstone body are 3 km in length by 200 to 600 m in width and 2 to 24 m in thickness. In the Upper Sandstone the dimensions are 3 km by 300 to 1,000 m by 2 to 8 m. It has been estimated that the mineralization contained in these two thin sheets amounts to some 80 million tonnes of 4% Pb + Zn, with an overall lead:zinc ratio of 8:1.

5.4 HISTORY OF EXPLORATION

The first geological investigation in the Laisvall area started in 1931 after the discovery of glacial boulders containing galena. Further exploration in 1938 discovered ore boulders in many new localities. In 1939, an exploration drilling programme was undertaken around and on Lake Stor-Laisan and the Laisvall lead deposit was discovered. Since 1939 more than 1,600 drill holes totalling over 120,000 m of drilling have been completed, and exploration is continuing today. Development of the Laisvall mine was started in 1943.

Mining operations have followed the ore from the eastern side of Lake Stor-Laisan, southwestwards under the lake to Kramaviken on the western side. The mine extends 6,500 m underground at a depth of 80-170 m below surface. Initially the ore had been mined mainly from the Lower Sandstone member (galena), but from 1969 the Upper Sandstone unit (Nadok orebody) was developed (galena and sphalerite).

5.5 GEOLOGICAL RESOURCES AND MINEABLE RESERVES

5.5.1 Classification

Resources/reserves at Laisvall are classified as set out in section 1.1.2 in the Introduction to this report.

5.5.2 Database

A total of 1,609 core holes have been drilled in the Laisvall area to date. The cores were geologically logged, sampled and analyzed for lead, zinc and silver. The core was split or sawn in half and 50 per cent of the core sent for analysis. Sample intervals were picked by the geologist. The laboratory stored the sample discards which has allowed Laisvall to run composite samples for additional elements as required.

Information held in the computerized database includes for each borehole: identification number, coordinates, elevation and inclination of the hole; geological units encountered; sampling interval; and analytical results for each sample interval. The database has been designed to hold analytical results for lead, zinc, copper, silver, gold, sulphur, arsenic and antimony.

5.5.3 Estimating Procedures

A block model has been created for the Laisvall deposit, with a block size of 40 m x 40 m in the horizontal plane and with a variable thickness in the vertical plane, depending on the thickness of the mineralization. The block model is created at Boliden AB's central office in Boliden and a copy held on-site at Laisvall.

The block model in the Upper Sandstone is based on information from 249 drill holes with roughly a 70 m x 70 m grid pattern. The Upper Sandstone varies in thickness from 6 to 8 m and is more affected by folds and thrusting than the Lower Sandstone, consequently requiring a closer drill spacing. Average grades are 3%Pb and 2% Zn but can range up to 20% Pb or 20% Zn.

The block model in the Lower Sandstone is based on information from 416 drill holes with roughly 100 m x 100 m drill spacing. The Lower Sandstone varies between 4 and 24 m in thickness, with average grades of 3% Pb and 0.1% Zn, but lead grades reach 20 to 30 per cent in very rich zones.

Mean grades were calculated for lead, zinc and silver over the mineralized horizons, according to drill hole intersection length. Variograms were run for each element and various other parameters such as unit thickness. Lead, zinc and silver grades were estimated for each block using a 2D - kriging model. The orebody is a thin sheet exhibiting strong lateral continuity of mineralization and poor vertical continuity.

The model is used to determine the mineable reserves using the following parameters:

5. Cutoff grade : 3.5% Pb equivalent;
   (Pb equivalent = 1.0 (Pb%) +1.3 (Zn%) + 0.02 (Ag g/t))

6. Minimum rock sill beneath Lake Stor-Laisan of 20 m;

7. Minimum mining height in the Upper Sandstone of 3 m;
   (dictated by the size of the mining equipment)

   Minimum mining height used in the Lower Sandstone of 4 m;
   (up to four vertical levels (blocks) were allowed for in the mine plan
   LFR - Initial drift; P1, P2, P3 - Horizontal benches)

8. Mining recovery factor of 80 per cent;

9. Dilution factors:

drifting	- 10 per cent
benching/roof cut	- 5 per cent
secondary mining	- 5 per cent

Production block model: The three-monthly mine plan, the monthly mine plan and the weekly mine plan are based on mine grades, the objective being to provide the mill with a daily feed of 4.3%Pb and 0.5% Zn. Mine grades are estimated for each working face. The estimator visits each working face and records geology and estimates lead and zinc grades over appropriate vertical intervals for the exposed face. The uniformity of the orebody and 50 years of mining experience make for consistent results. Samples are taken regularly by the estimator both as cross-checks and in areas where the estimator is unsure of grades. Up to 18 mining faces were being worked in March 1997.

5.5.4 Reconciliation

A comparison of 14 years production data, 1987 to 1996, mill head grades versus the planned mine grades, shows variations of ± 0.5% Pb on an annual basis, at approximately 4.0% Pb, that is, a variation of plus or minus 12.5 per cent.

Reconciliation of 1995 planned mineable reserves versus ore mined (1.65 million tonnes) is set out below:

	Planned Grade	Mined Grade	Difference	Per Cent
Pb%	4.64	4.38	(-0.26)	- 6
Zn%	0.95	0.98	+0.03	+3

On average, Boliden AB has estimated that the lead head grade of the processed ore may be 0.20% Pb (that is, about 5 per cent) lower than the reserve grade as estimated for the mine plan. It is stated that this factor will be used in future to lower reserve grade for mine planning. In primary mining areas there is less confidence regarding the grade, as the estimate is based entirely on drill hole data, whereas in the secondary mining areas the amount of information available is considerably more, obtained from previous mining, and thus the degree of confidence in the grade is much greater.

Overall extraction rates in the ore zone are estimated as 78 to 80 per cent with 20 to 22 per cent of the ore left as pillars. Exceptions to this general rule are noted in two areas both in the vicinity of Lake Stor-Laisan. A 20-m thick in situ rock roof is left below the lake for support (Upper Sandstone has been removed by erosion and the Lower Sandstone in certain areas forms the in situ rock base to the lake). A sub-vertical, north-northeast trending fault zone cuts the Lower Sandstone under the lake, in the Laisan zone. The fault acts as a major aquifer.

5.5.5 Reported Reserves and Resources

Laisvall has been mined for over 50 years, from 1943 to 1996 producing 55.257 million tonnes of ore at an average grade of 4.0% Pb and 0.65% Zn. In 1943 30,000 tonnes were mined with an average grade of 12.1% Pb; twenty years later in 1963 annual mined tonnage exceeded a million tonnes with an average grade of 3.8% Pb and 0.12% Zn. In 1996, 1.784 million tonnes of ore were mined with grades of 4.2% Pb and 0.81% Zn.

Production is planned to increase to 1.9 million tonnes per annum in 1998 through 2000, but to decline to 1.21 million tonnes in 2001, the last year of mine life.

Mineable Reserves for the Laisvall mine, as at March 5, 1997, determined as set out above, and included in the 5-year mining plan, 1997 to 2001, are reported to be as follows:

Proven Ore Reserves: 9.621 million tonnes at 5.02%Pb and 0.49% Zn

These reserves will be extracted by the following mining techniques:

Technique	Million tonnes	Pb%	Zn%
1. Primary drifting in the upper part of the ore	1.660	3.80	0.60
2. Horizontal benching in several steps	1.713	5.79	0.20
3. Roofcuts	1.379	5.82	0.40
4. Secondary mining	4.870	4.94	0.57

Total mined ore	**9.621**	**5.02**	**0.49**

Micon classifies the Proven Ore Reserves of the Laisvall mine as Proven Ore in terms of National Policy 2-A.

5.6 EXPLORATION POTENTIAL

The Laisvall deposit is located in quartzitic sandstone of Precambrian - Cambrian age. The sandstone is part of an extensively distributed autochthonous sedimentary sequence along the Caledonian Mountain Range. Since the 1930's, Boliden AB has identified several similar geological environments along the Swedish mountain range from the Vassbo mine in the south to the Laisvall mine in the north, a distance of over 700 km.

Since 1992, Boliden AB has spent 8.6 million SEK in exploration in the immediate vicinity of the mine, notably 3.5 million SEK in 1993 and 3.0 million SEK in 1996. Exploration techniques currently being used by Boliden AB include boulder mapping, geophysics, geochemistry, drilling, ore modelling techniques, hydrocarbon printing.

Potential exists at the Laisvall deposit itself for expanding ore reserves, most notably under Lake Laisan between the Laisan and Skorro mineralized zones.

To date, a number of small satellite deposits have been identified. The Maiva deposit, located 6 km to the northeast of Laisvall (Lake Storr Jutas - Bjorklund), contains approximately 1.2 million tonnes of lead resources at 4.9% Pb and 0.1% Zn. This mineralization has been identified in a truncated Lower Sandstone member (2.5 to 3 m thick). Approximately 100 drillholes have been put down in the area and drilling is continuing as of March, 1997. The Maiva resources are classified by Micon as additional mineralized concentrations.

A number of other targets both to the north and to the east of Laisvall have been identified through boulder mapping, geophysics and drilling. One project, 10 km to the northeast of Laisvall, has identified lead mineralization close to the surface where the basement granitic complex and the Lower Sandstone member outcrop at surface. This material is potentially open-pittable.

The area between Laisvall and Maiva, potentially a very prospective area, has not yet been explored.

Boliden AB holds 11,153 hectares of exploration lands in the Laisvall area.

5.7 CURRENT OPERATIONS

5.7.1 Mining Operations

The mine is accessed via two vertical shafts to a depth of some 200 m below surface. One shaft provides personnel access with the other reserved for ore hoisting. A ramp to surface provides access for large mobile equipment and materials.

Apart from a small amount of infrastructural development, all mining is carried out in the flat-lying ore horizon. Access to the production areas is via roadways in ore through the mined-out production areas. Ore transport is via a truck haulage, operated by contractors, to a central crusher station which feeds the hoisting shaft.

Two fresh air intake shafts provide 320 m^3 per second of ventilating air to the operations. Most of the secondary fans underground are linked to a central control system which can be operated from the computer keyboard in the office of the shift boss. The conditions at the working faces visited by Micon were entirely satisfactory.

Mining operations are carried out under Lake Stor-Laisan and water seepage is significant at some 400 litres per second. Four large pump stations handle this inflow and return some 14 million cubic metres per year to the lake. Strict controls are applicable to the quality of the water pumped to the surface. The underground cleaning plants provide settling, sand filtering and chemical treatment to minimize concentrations of lead in the water pumped to Lake Stor-Laisan. The capacity of these cleaning plants has not, as yet, restricted production, but if inflows were to increase this could become the case.

The flat-lying orebody, which has mineable thicknesses up to 18 m, is ideally suited to large scale mechanized room-and-pillar mining using drill-and-blast methods. The mining area is opened up by the development of parallel 10-m wide rooms, 5-m high, separated by 8-m wide pillars. When the headings have been advanced 50 m, connecting cross-cuts are developed. Horizontal benching is then carried out until the lower ore limit is reached. Cross-cuts are mined between the primary rooms. The crosscuts and lower portion of the rooms are then backfilled with tailings to provide pillar support and access to mine the ore overlying the cross-cuts. The final size of the pillars left between these cross-cuts determines the ultimate extraction percentage from the area. The extraction ratio typically ranges between 80 and 90 per cent, depending on the mining height, the general rock conditions and the proximity to the lake.

Cover holes of 21 m are drilled ahead of the primary rooms to provide security against the intersection of a major water inflow. When water is intersected by the cover holes the flow is contained by cement grouting. Where mining takes place under the lake, a minimum cover of 20 m is left between the lake bed and the top of the mining room. The position of the lake bed is determined from the original exploration drilling and by the use of seismic techniques.

Mining equipment comprises large scale, trackless mobile units. Drilling of 43-mm to 54-mm holes is carried out by six Atlas Copco electric-hydraulic jumbos. One of these jumbo rigs is fitted with booms and feeders capable of drilling 20-foot holes, while the other five drill 14-foot holes. Capital is budgeted in 1997 to provide for the modifications of two drill units to drill 20-foot holes as part of the programme to increase production to 1.9 million tonnes per year. The drilling rigs are complemented by a fleet of four scaling machines and three charging units. Roof support is carried out with 2.8-metre resin grouted rebar bolts installed by Tamrock and Atlas Copco roof bolting rigs. Loading and truck haulage is carried out by a contractor utilizing 40-tonne trucks and 16-tonne front-end-loaders.

The underground mining workforce is 84 persons, including nine technical and planning positions. Three shifts of 19 persons per shift and three shift foremen carry out the stoping operations on two 7½ hour shifts per day. Crushing, hoisting, pumping and ventilation involve an additional 13 persons and one supervisor.

In addition to the above Laisvall personnel, the contractor responsible for loading, truck haulage and roadway maintenance employs 13 persons underground. The total mining personnel amounts to 98.

Productivity has increased over the last few years as output has grown with a reducing labour force. Productivity in 1996, for the total mining personnel was 18,000 tonnes per man-year and some 150 tonnes for direct stoping per person shift.

5.7.2 Milling Operations

The Laisvall concentrator started operation in 1943 and its throughput has been progressively expanded up to the present time. Up until 1972, only lead concentrate was produced, but with the opening of areas in the mine with significant zinc content, differential flotation was introduced and zinc concentrates have been produced since then.

Ore is delivered underground by contractor's trucks to the primary crusher station. A Blake type, double toggle jaw crusher reduces the ore to less than 150 mm and discharges into a 6,000 tonne bunker. The ore from the bunker is screened at 70 mm and the oversize goes to a 5½-foot Symons standard crusher, whose product is screened again at 70 mm and the oversize is finally crushed in a 7-foot Symons shorthead crusher. The crusher product is combined with the screen products in a 1,500-tonne bunker which feeds the hoist.

The ore is hoisted and fed to a screen above the fine ore bin. This separates the 30 mm to 70 mm fraction of the ore and delivers it to the 500-tonne pebble bin. The screen undersize falls into the 3,300-tonne fine ore bin. Ore is fed to clamshell weighers which discharge to the feed belts of three rod mills. The rod mill products are combined and fed to two pebble mills which operate in closed circuit with hydrocyclones.

The hydrocyclone overflow goes to lead rougher and scavenger flotation, where zinc is depressed by zinc sulphate addition. Lead rougher concentrates are cleaned in conventional cells and re-cleaned in a flotation column. Scavenger concentrates are combined with cleaner tailings and re-ground in a small ball mill before returning to rougher flotation.

Lead concentrate is thickened and then filtered on Sala automatic plate and frame presses which are continuously weighed. The filters are filled under pressure with thickened concentrate. The filter cake is then compressed by compressed air behind a diaphragm. The cake is finally dewatered by passing air through it from the other side of the diaphragm. The filter then automatically discharges the cake and shakes the cloth to remove any adhering cake. The cloth is then washed and the cycle repeated.

Lead flotation tailings are then directed to zinc flotation where the zinc is reactivated by copper sulphate addition and the pH is raised to 12.4. Rougher concentrates are again cleaned in conventional cells and re-cleaned in a flotation column. Scavenger concentrates and cleaner tailings are returned to the head of the zinc flotation circuit.

Zinc concentrate is thickened in two thickeners, filtered on a vacuum drum filter and dried in an oil fired rotary dryer.

Tailings are classified by two cyclone stages and the coarse fraction is delivered underground for sandfill. The fine fraction is pumped in a five-stage pumphouse to a dam situated to the north of the mine just over the watershed in the Skellefteå river catchment. It overflows to a clarifying pond and follows a drain to a second pond before leaving the property via a sampling station. Laisvall ore contains very little pyrite so the sulphur content of the tailings is approximately 0.4 per cent.

The flowsheet for the Laisvall concentrator is shown in Figure 5.2.

The concentrator at Laisvall is washed down throughout at the start of each shift, mainly to ensure that dust levels are kept to a minimum, particularly in view of the lead content of the ore.

The mill superintendent at Laisvall reports, together with the maintenance superintendent, to the surface superintendent who in turn reports to the area manager. There are five shift crews, each of five men including the shift supervisor. The laboratory has a staff of three and the total for the concentrator is 33 employees. A further 70 are employed in maintenance, warehouse and administration functions.

5.7.3 Historical Production Performance

The introduction of larger capacity equipment underground and complementing modification in the processing plant has resulted in improved production performance over recent years. Table 5.1 below, presents mined and milled ore tonnes and grade, metallurgical recovery and concentrate tonnes and grade for the period 1992 to 1996.

[Figure 5.2 - Laisvall Concentrator Flowsheet]

Table 5.1
LAISVALL - HISTORICAL PRODUCTION FIGURES

	Unit	1992	1993	1994	1995	1996
Tonnes ore	‘000 tonnes	1,775	1,752	1,679	1,650	1,784
Grade lead	%	4.35	4.69	5.09	4.38	4.18
zinc	%	0.87	0.82	0.71	0.98	0.81
silver	g/t	n.a.	n.a.	n.a.	9.88	9.04
Metallurgical Recovery						
Lead	%	91.30	91.10	90.70	90.70	89.03
Zinc	%	76.90	75.20	69.00	79.70	76.80
Silver	%	87.67	86.70	83.80	86.40	85.53
Concentrate						
Lead	‘000 tonnes	89.30	94.90	98.40	83.30	85.10
Grade lead	%	79.00	78.80	78.60	78.55	77.99
Zinc	‘000 tonnes	20.70	18.60	14.40	21.60	18.80
Grade Zinc	%	57.60	58.10	58.40	58.60	58.60
Contained Metal						
Lead	‘000 tonnes	70.50	74.80	77.30	65.40	66.30
Zinc	‘000 tonnes	11.90	10.80	8.40	12.70	11.10
Silver	tonnes	15.20	17.40	17.20	14.10	13.80

5.7.4 Historical Cost Performance

In the last five years, production costs have been held relatively steady in current SEK. Mining, processing and administration costs for the period 1992 to 1996 are presented below in Table 5.2.

Table 5.2
LAISVALL - HISTORICAL UNIT MINING COSTS PER TONNE OF ORE MILLED
(SEK/tonne)

Mining	**1992**	**1993**	**1994**	**1995**	**1996**
Engineering	2.08	2.11	1.89	2.39	2.72
Drilling, Blasting	30.38	32.01	29.90	34.01	36.17
Ventilation, pumping	13.77	13.50	13.66	16.22	16.58
Crushing, hoisting, etc	19.39	19.28	21.08	22.97	18.99
Sub Total	65.62	66.90	66.53	75.59	74.46
Processing	35.20	34.22	36.08	39.40	37.97
Concentrate transport	5.56	5.72	6.05	5.81	5.33
Port handling and sales	n.a.	0.77	2.87	1.53	1.28
Administration and overhead	9.99	8.94	8.53	9.35	9.59
Total	**116.36**	**116.55**	**120.06**	**131.67**	**128.63**
Total US$/tonne	**20.03**	**14.98**	**15.66**	**18.49**	**19.20**

The operating costs of the Laisvall concentrator are summarized in Table 5.3 below.

Table 5.3
LAISVALL - 1996 CONCENTRATOR COSTS

Item	1996 Actual SEK'000		SEK/tonne milled	
Energy (direct purchased)		**366**		**0.205**
Heating oil (for dryers)	366		0.205	
Materials		**19,209**		**10.77**
Spare and replacement parts	6,500		3.64	
Rods and mill balls	4,457		2.50	
Reagents	4,235		2.37	
Other material	4,017		2.25	
Labour		**11,950**		**6.70**
Outside Services		**18,992**		**10.65**
Concentrate transport	9,513		5.33	
Sales costs	615		0.34	
Contract maintenance	7,117		3.99	
Other outside services	1,747		0.98	
Re-distributed costs		**18,559**		**10.40**
Electric power	11,028		6.18	
Materials procurement	1,507		0.84	
Mechanical/ electrical workshops	4,240		2.38	
Cleaning and laundry	1,784		1.00	
Re-distributed services		**3,737**		**2.09**
Concentrate handling & port	1,677		0.94	
Technical and administration	2,060		1.15	
Depreciation		**6,733**		**3.77**
Less miscellaneous income	0		0.0	
Total Costs		**79,546**		**44.59**

The 1996 unit cost is equivalent to US$6.66 per tonne of ore milled.

It is estimated that 77 per cent of the contained metal value in the ores at Laisvall is recovered into payable concentrates. Concentrator metallurgical performance during the past three years has been summarized previously in Table 5.1.

Complete specifications of the concentrates are included in Appendix I.

5.8 FUTURE OPERATIONS

5.8.1 Plans and Potential For Expansion

In order for Boliden AB to maintain the hurdle rate of return on capital employed, Laisvall management is implementing a capital investment programme in 1997 in order to increase the current level of production of some 1.8 million tonnes per year to 1.9 million tonnes per year. This requires expenditure for modification of underground drilling rigs to permit the drilling of 20-foot holes. This has been tested successfully in one rig and two additional jumbos will be modified accordingly. In addition, modifications are required to the central underground crushing facility and certain areas of the processing plant will be modified.

Micon considers that the proposed expenditures for increased production are reasonable and that the anticipated production rate is reasonable.

Table 5.4 below presents the five-year outlook, for 1997 to 2001, for mined tonnes and grade, metallurgical recovery, concentrate tonnes and grade.

Table 5.4
LAISVALL - FIVE-YEAR PRODUCTION OUTLOOK

	Unit	1997	1998	1999	2000	2001
Ore Production	'000 tonnes	1,840	1,900	1,900	1,900	1,210
Grade lead	%	4.30	4.50	4.70	4.90	5.50
zinc	%	0.57	0.60	0.60	0.54	0.18
silver	g/t	10.00	10.00	10.00	10.00	10.00
Metallurgical Recovery						
Lead	%	90.20	91.00	91.00	91.00	91.00
Zinc	%	70.00	70.00	70.00	70.00	70.00
Silver	%	84.00	84.00	84.00	84.00	84.00
Concentrate						
Lead	'000 tonnes	90.34	98.49	102.87	107.24	76.66
Zinc	'000 tonnes	12.66	13.76	13.76	12.38	0.38

It is possible that production could be extended beyond 2001. However, this would require increases in metal prices, or additional increases in productivity to reduce operating costs.

5.8.2 Outlook for Operating Cost

The projection of on-site cash operating cost estimated by Laisvall personnel for the period 1997 to 2001 is presented below in Table 5.5.

Table 5.5
LAISVALL - ESTIMATED OPERATING COSTS 1997 TO 2001

Mining	**Unit**	**1997**	**1998**	**1999**	**2000**	**2001**
Ore Production	000's tonnes	1,840	1,900	1900	1,800	1,433
Mining cost	Million SEK	121.3	119.4	120.6	118.7	98.6
Milling cost	Million SEK	74.6	76.2	76.2	74.5	48.9
General and Administration	Million SEK	11.5	11.5	11.3	10.7	8.0
Exploration	Million SEK	0.7				
Decommission	Million SEK	3.4				17.0
Depreciation	Million SEK	12.5	15.5	14.5	15.3	5.8
Total Cost	Million SEK	224.0	222.6	222.6	219.2	178.3
Mining cost/tonne ore	SEK/tonne	65.92	62.84	63.47	65.94	68.81
Milling cost/tonne ore	SEK/tonne	40.54	40.11	40.11	41.39	34.12
Total Cost/tonne ore	**SEK/tonne**	**121.74**	**117.16**	**117.16**	**121.78**	**120.94**
Less depreciation	**SEK/tonne**	**111.08**	**109.00**	**109.53**	**113.28**	**116.89**
Total Cost/tonne ore	**US$/tonne**	**17.39**	**16.74**	**16.74**	**17.40**	**17.28**
Less depreciation	**US$/tonne**	**15.87**	**15.57**	**15.65**	**16.18**	**16.70**

Micon has discussed with mine management the proposed increase in production rate at Laisvall, which is necessary to maintain the above estimated future operating costs. Micon considers that the achievement of the proposed increase in production and estimates of future operating costs are reasonable.

The operating costs of the Laisvall concentrator in 1997 are summarized in Table 5.6 below.

Table 5.6
LAISVALL - ESTIMATED CONCENTRATOR COST, 1997

Item	1997 Budget SEK '000	
Energy (direct purchased)		**635**
Heating oil (for dryers)	635	
Materials		**20,515**
Spare and replacement parts	7,032	
Rods and mill balls	5,281	
Reagents	4,222	
Other material	3,980	
Labour		**13,550**
Outside Services		**17,222**
Concentrate transport	10,195	
Sales costs	642	
Contract maintenance	4,571	
Other outside services	1,814	
Re-distributed costs		**20,012**
Electric power	10,674	
Materials procurement	1,422	
Mechanical/ electrical workshops	5,347	
Cleaning and laundry	2,569	
Re-distributed services		**2,668**
Concentrate handling & port	1,464	
Technical and administration	1,204	
Depreciation		**5,785**
Less miscellaneous income	12	
Total Costs		**80,375**

The budget unit milling cost, at US$6.24 per tonne, is slightly reduced from 1996.

5.8.3 Outlook for Capital Expenditure

The capital budget in 1997 essentially provides for expansion of throughput for from 1.75 million tonnes to 1.9 million tonnes per annum. This requires modification to the central underground crusher, rebuilding two drilling jumbos to permit drilling 20-foot holes, expansion of the mill capacity and raising of the tailings dam.

No major items of replacement capital expenditure are foreseen in the concentrator. Micon considers that the estimates of capital expenditure are reasonable for the work planned. The projected plant performance is based on past performance and is expected to be achieved.

The 1997 capital budget and five-year programme are presented in Table 5.7 below. Micon considers the programme to be reasonable.

Table 5.7
LAISVALL - CAPITAL EXPENDITURE PROGRAMME
(Thousand SEK)

Item	1997	1998	1999	2000	2001
Drilling Rig Modification	5,550				
Rebuild Central Crusher	5,300				
Expand Mill Capacity	5,600				
Raise Tailings Dam	4,860				
Other Mining Expenditures	4,000	2,550	1,300	250	250
Other Miscellaneous	3,000	3,400	3,400	500	-
Total	**28,310**	**5,950**	**4,700**	**750**	**250**

Further capital requirements beyond the above will be required only if other deposits are found in the area or increased metal price renders an extension to the reserve life.

5.9 CONCLUSIONS

It is the opinion of Micon that the ore reserves for Laisvall have been estimated in an appropriate manner and represent a reasonable basis for the future projection of production of the mine. The anticipated increases in annual production rate are considered reasonable, as are the estimations of future operating and capital costs.

The most significant uncertainty relating to the achievement of the strategic plan is the potential increase in water inflow, either gradually or rapidly, especially from the mining areas under Lake Stor-Laisan. The probability of occurrence of such an event is considered to be low, since 90 per cent of the ore has been mined from under the Lake, and the remaining areas are monitored closely.

6.0 THE AITIK AREA

6.1 INTRODUCTION

The Aitik open pit mine has been in operation since 1968 and is the most northerly of Boliden AB's mining operations, lying 60 km north of the Arctic circle. Copper is the primary metal and the mine is Sweden's largest gold producer. Silver by-product credits are also significant. The on-site concentrator has a capacity of 18 million tonnes per year. Copper concentrate is trucked a distance of 20 km to Gällivare and then shipped by rail to the smelter at Rönnskär, 400 km to the south.

6.2 CHARACTERISTICS OF THE PROPERTY

The Aitik deposit occurs in a shear zone that extends from Kiruna in northern Sweden to Lake Ladoga in Russia. The orebody consists of thin veins and disseminated pyrite and chalcopyrite which occur over an area of 2,000 m by 200 to 400 m.

Exploration permits held by Boliden AB total 4,000 hectares and exploitation concessions total 320 hectares.

In 1996, the operation mined and processed 17.9 million tonnes of ore at average grades of 0.32% copper, 0.15 g/t gold and 3.7 g/t silver, to produce 179,200 tonnes of copper concentrate grading 28.8% copper. Total on-site cash costs for mining, milling and administration were 31.03 SEK (US$4.41) per tonne of ore.

6.3 GEOLOGICAL SETTING

The Aitik open pit copper mine lies along the Kiruna - Ladoga shear zone, a major northwest-southeast trending suture which extends from Lake Ladoga in Karelia (Russia) to Kiruna in northern Sweden. This break marks the boundary between the Karelian plate to the northeast and the Svecofennian plate to the southwest.

The low grade copper mineralization at Aitik occurs as disseminated and thin veinlets of chalcopyrite within westerly-dipping supracrustal and metamorphosed rocks of Precambrian age (see Figure 6.1). These units are enclosed by the Lina granite and gabbro which have been dated at 1,540± 90 million years.

The Aitik deposit is enclosed by shear zones which also divide the mineralization into north and south deposits. The depth of mineralization is 330 m at the south deposit, but the north deposit is open at depths below 800 m. The mineralization is hosted within a package of metamorphosed volcanic and sedimentary rocks which is divided into three zones, namely the main, the hanging wall and the footwall zones. The mineralization, essentially confined to the main zone, is fault-bounded.

Main zone: The main mineralized zone can be divided into two units, a fine-grained, grey quartz-biotite gneiss and a muscovite schist. The gneissic unit hosts garnet porphyroblasts and underlies the schist. The muscovite schist unit is typically tectonized in contact with the hanging wall rocks.

[Figure 6.1 - Aitik Mining Area]

Hanging wall zone: There is a sharp thrust-faulted contact separating the units of the hanging wall and the main zone. The hanging wall rocks are generally well-preserved and display various sedimentary features and structures. The lowermost unit is a banded hornblende gneiss, overlain conformably by a fine-grained, quartz-biotite gneiss. This unit passes upwards into a dark green, strongly-foliated plagioclase-hornblende gneiss with highly sericitized quartz-feldspar "eyes".

Footwall zone: The footwall zone is separated from the mineralized main zone by faults and shear zones. Four different lithologic units have been distinguished: fine-grained, quartz-biotite gneiss, hornblende-biotite schlieren gneiss, porphyritic quartz-biotite gneiss and coarse-grained amphibolite-epidote gneiss. The porphyritic quartz-biotite gneiss is extensive within the footwall, cross-cuts the stratigraphy, has sharp contacts and has been interpreted as being a phase of a quartz monzodiorite intrusion. The coarse-grained amphibolite-epidote gneiss typically occurs within the fault zone marking the boundary between the footwall and the main mineralized zone. This unit dips 65 degrees to the west, which differs from the average 40 to 45 degree dip prevailing throughout the main area of the mine.

Sub-vertical pegmatite bodies, 0.1 to 15 m in thickness, are ubiquitous throughout the mine area, typically cross-cutting the stratigraphy at high angles. These bodies are barren of mineralization, although specks of molybdenite do occur and tourmaline is a common component.

6.3.1 Mineralization

Chalcopyrite is the only mineral of economic importance at Aitik. Mineralization of potentially economic grade is hosted exclusively within the main mineralized zone. Minor copper is present in the footwall quartz-biotite gneiss. The hanging wall is completely barren, containing less than the detection limit of 4 ppm copper. The mineralization generally dips 45 degrees to the west, but with the dip of the footwall contact typically steeper than that of the hanging wall. In the deeper part of the mine, the mineralization dip averages 35 degrees.

Mineralization occurs as disseminated and thin veinlets of chalcopyrite. Locally, remobilization of chalcopyrite into quartz veins, alteration zones and, particularly, tectonized zones is evident. Bornite, chalcocite, pyrrhotite and malachite are present in minor amounts. Pyrite and magnetite occur throughout the deposit. The pyrite content increases towards the hanging wall.

The gold is interpreted as occurring in roughly equal proportions as free gold within quartz veins and as inclusions within chalcopyrite. Higher gold concentrations are found in the southern part of the mine. Gold grades appear to be increasing slightly with depth in the pit. Generally, areas with higher copper grades tend to be associated with higher gold values. Silver mineralization, of low grade, is not fully understood, but higher silver concentrations are found in the northern part of the mine and correspond with higher bismuth and mercury values.

Zinc, lead and arsenic are found as trace elements in the mineralization. Barite occurs in veins and within the ore zone. Molybdenite, as noted above, is present within the late stage pegmatite veins.

6.4 HISTORY OF EXPLORATION

The Aitik mineralization was first noted by Boliden AB in 1930 with the discovery of boulders with disseminated chalcopyrite. Various phases of prospecting have taken place over the next 30 years:

- 1932-33 : Mapping of mineralized outcrops; EM Survey;
- 1948-56 : Further EM Surveys and geochemical studies;
- 1957 : Airborne EM and magnetic surveys; geological mapping and core drilling;
- 1960-64 : Resistivity and core drilling;
- 1965 : Feasibility study.

Production started at a rate of two million tonnes of ore per annum in 1968. Capacity was expanded in 1972 to 8 million tonnes, then to 11.3 million tonnes in 1981 and, in 1991, annual production reached 15 million tonnes. Currently, the open pit operation is mining at a rate of 17 million tonnes of ore and 16 million tonnes of waste per annum.

6.5 GEOLOGICAL RESOURCES AND MINEABLE RESERVES

6.5.1 Resource/Reserve Classification

Resources and reserves for the Aitik mine are classified and defined by Boliden AB as set out in section 1.1.2 of the Introduction to this report.

6.5.2 Database

Over 500 cored drill holes have been completed at Aitik to date. Drilling was undertaken in vertical sections some 80 m apart, with holes angled at approximately 55 degrees to cross-cut the mineralized body at right angles, that is, from hanging wall to footwall. Some infill drilling was undertaken in more complex areas and a proportion of the boreholes was drilled to 600 m below surface.

The cores were geologically logged and sampled (½ core - sawn or split). Sample lengths chosen by the geologist vary between 0.5 and 5 m. Samples were originally only analyzed for copper, but currently all are assayed for copper, gold and silver. Core from older drill holes has now been analyzed for gold and silver, using composite samples.

Information held in the database includes, for each drill hole: identifier, coordinates, elevation and inclination; geological units encountered; sampling interval; and analytical results for each sample interval. Provision has been made for the record scheme to hold analytical results for copper, gold, silver, bismuth and mercury.

6.5.3 Estimating Procedures

A block model, referred to as the Planning Block Model, has been built for the Aitik deposit, with block size 20 m x 20 m x 15 m. The drill hole spacing is roughly on a 80 to 100-m grid pattern and block height conforms to the mining bench height of 15 m. The block model is created at the Boliden AB central office, with a copy held on site at Aitik. The Planning Block Model is used for the mineable and geological reserve calculation and running the Pit Optimization programme and is updated, essentially continuously.

Average grades for copper, gold and silver were calculated from drill hole assay data weighted according to intercept length (15-m composites). The specific gravities used to calculate tonnages were 2.80 for ore and waste and 2.0 for overburden.

Variograms run on the composite drill-hole grade data indicate an anisotropic mineral distribution. This is to be expected as the mineralization is tightly contained within a defined unit. The variogram generally mirrors the shape of the orebody. The mineralization is 4 km in length, 400 m wide, and over 600 m deep, and dips 45 to 65 degrees to the west. Copper, gold and silver grades are calculated for each block using a 3D kriging model.

The following range of grades for copper, gold and silver were noted in the block model:

Element	Minimum	Maximum	Average	Standard Deviation
Cu (%)	0.0	1.92	0.28	0.16
Au (g/t)	0.0	1.60	0.16	0.12
Ag (g/t)	0.0	26.2	2.16	1.97

One of the other geological parameters included in the mineral model is the grindability (hardness) of the ore as this affects mill throughput and thus daily copper concentrate production, and also the energy cost per tonne of ore milled.

The grindability of the ore has been related to rock type, with the Grindability Index (increasing hardness with lower index) established as follows:

G.I.		**Rock type**
1.3 - 1.4	:	Muscovite Schist
1.2	:	Biotite Schist
1.1	:	Hornblende Gneiss
0.7	:	Monzodiorite

The Grindability Index of each block has been defined and is factored into the milling costs in the pit optimization programme model. An experiment with Boliden Central Technical Services is ongoing to study if drillability of blastholes can be used to predict ore grindability for the mill. A data logger on the drill registers pulldown force, penetration rate, torque and revolutions per minute.

To maintain copper production, a higher copper head grade is required for ore with a low Grindability Index, that is, hard ore. In general, there is an improvement in copper recovery in harder ores, but not sufficient to offset the lower mill throughput. It is also feasible to take marginal ore, below the 0.17% Cu cutoff, where the grindability index is high, that is, softer material which requires less energy to process. In 1996, lower head grade ore from the southern pushback was processed because of its high Grindability Index.

The block model is used as a basis for defining the mineable reserves. Commercial software, Whittle 4D, is used to produce various pit options. Two alternatives are run, one using a copper cutoff of 0.10% Cu and a second using a cutoff of 0.17% Cu; currently, both alternatives use a copper price of US$1.00/lb (15,432 SEK per tonne).

The model includes parameters from the block model, such as copper, gold and silver grades, Aitik mine coordinates, specific gravities of the various rock types, elevation data, overburden depth et cetera. Limitations can be placed on the model, for example, to avoid mining out the mill. Slope angles are defined. Annual production rates are input, recoveries for copper, gold and silver are defined. Metal prices are input (currently, copper US$1.00/lb; gold US$390/troy oz; silver US$5.00/troy oz). Mining costs for overburden, waste and ore are input, and processing costs are input, (including incorporation of the Grindability Index). Block ore grades are converted to a block value in SEK (The formula used depends on the block copper grade, being above or below 0.36% Cu). A 12 per cent discount rate was used.

In addition to the planning block model used for resource/reserve determination, a production block model has been built using a 10 m x 10 m x 15 m block size. This model is used for short term planning, that is, for weekly, monthly and annual mining plans, and is regularly updated on a weekly basis. The kriging model incorporates both the blasthole data and the core hole data. Representative samples (grab samples) are taken from the blasthole cuttings for copper analysis using a portable analyzer, X-MET 880.

Three rigs are used to drill 311-mm diameter holes. The blasthole spacing is roughly a grid pattern of 8 m x 10.5 m with a 15-m bench height (plus 2 m of sub-drilling). There is one 0.4 to 0.5 million tonne blast each week. The production block model is restricted to permit blast hole samples to influence grades for no more than two bench levels, that is a vertical restriction of 30 m. In-pit grade control, ore and waste, is based on the copper assay only.

Process recovery of gold is running at 55 per cent. Improved gold recoveries could have a significant impact on the value of the ore in each block. It is only in recent years that the geology of the deposit has been recognized as being important in this regard. Boliden AB is undertaking further work to improve understanding of the gold mineralization and thus aid in designing a process to improve gold recovery.

6.5.4 Reconciliation

A comparison of planned versus actual mined grades, on an annual basis, was made for the period 1984 to 1996.

During this period, annual mined grades varied between 0.35% and 0.42% Cu, except for 1996, when a lower grade of ore was mined and the mined grade was 0.325% Cu. The planned grades for the same period varied between 0.32% Cu (1996) and 0.38% Cu. The variation between actual mined grade and planned grade, therefore, was - 0.02% to + 0.02% Cu, with the exception of one year, 1992, when it was +0.06% Cu.

Overall, between 1984 and 1996, there were 10 years where the mined grade was higher than the planned grade and only 3 years where the mined grade was lower than the planned grade.

The data imply that for a planned head grade of 0.40% Cu, the mined grade will most likely lie within the range 0.38% Cu to 0.42% Cu, (ie. ± 5%), on an annual basis.

An examination of recent production data, on a weekly basis, showed the following for the years 1995 and 1996:

Year	Planned	Actual
1995	0.26 to 0.59% Cu	0.26 to 0.60% Cu
1996	0.26 to 0.45% Cu	0.25 to 0.39% Cu

This shows that on a weekly basis, mined grades compared to planned grades could vary between +0.06% Cu to - 0.07% Cu, approximately ± 15 per cent of the predicted grade of 0.40% Cu.

The ore is a disseminated type with high grade veinlets and concentrations of minerals, giving a relatively high nugget effect. It should also be noted that the mineable ore reserve is based on approximately one drillhole per 100 m x 100 m block with a planning model block size of 20 m x 20 m x 15 m, while the production block model is based on 10 m x 10 m x 15 m blocks with approximately one blasthole per block.

In Micon's opinion, the comparisons of actual versus predicted grade are good.

6.5.5 Reported Reserves and Resources

Boliden AB reports open pit Ore Reserves for the Aitik mine, at a cutoff of 0.17% Cu, as follows:

Proven Ore Reserves: 202 million tonnes at 0.40% Cu, 0.22 g/t Au and 4.0 g/t Ag

Micon classifies these reserves as Proven Ore as defined in National Policy 2-A.

At the current mining rate of 17 million tonnes of ore per year, the reported mineable reserves imply a 12-year mine life. In 1996, head grades were 0.32% Cu, 0.18 g/t Au and 5.0 g/t Ag. The south pit is planned to go down to a depth of 330 m (1997) and the north pit, which is currently at approximately 245 m, will be deepened to approximately 430 m. The orebody is open below this depth in the area of the north pit. Process recoveries are currently in the order of 91 per cent for copper, 55 per cent for gold and 68 per cent for silver.

In addition to the reserves, Boliden has delineated a large quantity of mineralization that, as yet, has not been evaluated as to its economic viability. This material is reported as Measured and Indicated resources, as follows:

> **Measured and Indicated Resources: 774 million tonnes at 0.30% Cu, 0.17 g/t Au and 1.9 g/t Ag**

Micon classifies these reported resources as additional Proven and Probable mineralized concentrations as described in National Policy 2-A.

6.6 EXPLORATION POTENTIAL

The Kiruna-Ladoga shear zone is a very prospective area for exploration, with numerous known copper-gold mineralized zones in the metasediments and metavolcanics. Boliden AB controls 109,214 hectares of exploration land in the Aitik area in the Norrbotten region. A number of prospective geophysical anomalies immediately to the east of the Aitik mine are being followed up with a geochemical sampling programme. Several other targets further afield have been investigated, with the Liikavaara deposit explored in detail and evaluated to the reserve determination stage.

Liikavaara: Liikavaara is located 3 km to the east of Aitik. The mineralized zone is 1,000 m in length by 100 m in width, dipping to the west and plunging to the south. The disseminated copper-gold mineralization is contained in a biotite schist (sheared andesite). The deposit has been drilled to a depth of 300 m. Approximately 100 drill holes have been drilled on drill sections 100 m apart. The mineralization is open at depth.

A block model has been constructed and reserves and resources at a cutoff grade of 0.20% Cu have been estimated. Due to the presence of aplite veins, the ore tends to have a low Grindability Index. Open pit reserves, to a depth of about 125 m, are reported as follows:

> **Proven Mineable Reserves: 9.55 million tonnes at 0.45% Cu, 0.11 g/t Au and 4.6 g/t Ag**

Micon has classified these reserves as Proven Ore in accordance with National Policy 2-A.

Boliden AB also reports additional resources, at a cutoff grade of 0.20% Cu, as follows:

> **Measured and Indicated Resources: 32.45 million tonnes at 0.32% Cu, 0.08 g/t Au and 2.8 g/t Ag**

Micon classifies these resources as additional Proven and Probable mineralized concentrations as defined in National Policy 2-A.

Snalkok: Snalkok is located 10 to 15 km north of Aitik. This is an old test mining area, with copper and gold mineralization. A geophysical anomaly is being followed up with percussion drilling of the overburden and sampling of the lower overburden and bedrock contact. In addition, some core drilling is taking place.

Purnuvara: Purnuvara is east of Aitik. Grassroots exploration has been ongoing for the last two years.

6.7 CURRENT OPERATIONS

6.7.1 Mining Operations

The open pit mining operation had an initial capacity of 2 million tonnes per year. It was increased to 6 million tonnes per year in 1971 and, then, in the 1980's, a series of expansions brought capacity to the present 18 million tonnes per year. The pit is developed in two sections, north and south. The southern section will be mined out in 1997/98 at a final depth of 330 m. The northern section, which currently is planned to a depth of 430 m, is expected to remain in operation for 15 years.

Production is undertaken with a fleet of four hydraulic shovels and 18 trucks, supported by three blasthole rigs, drilling 311-mm holes. Emulsion explosive is supplied "in-hole" by Nitro Nobel from its plant at Gällivare. Smooth blasting of the final walls is carried out by contract drilling of two final rows of small diameter blast holes adjacent to the wall.

The equipment fleet presently comprises the following:

MAJOR MOBILE EQUIPMENT LISTING - AITIK		
Classification	**Specification**	**Number of Units**
Drilling	Bucyrus-Eire 49RH Bucyrus-Eire 55R	2 1
Shovels	Demag 485 Demag 455 Bucyrus-Eire 295	2 1 1
Trucks	Caterpillar 789 Caterpillar 793 Unit Rig MT 4000	6 6 4
Miscellaneous	Grader, Cat 16H & G 2 Doser, Cat D10N Front-end loader, Cat 992	 1 1

Within the pit, which is approximately 2,500 m long, 500 m wide and between 250 m and 300 m deep, benches are 15 m high, with two metres of subdrilling. In 1996, 17.9 million tonnes of ore were mined, together with 16.6 million tonnes of waste. Average ore grade was 0.32% copper. Blasthole cuttings are routinely assayed for copper grade to assist in ore grade control.

The in-pit crusher is located at a depth of 165 m, between the northern and southern sections of the mine. It comprises two Allis gyratory crushers which reduce the ore to a maximum of 350 to 400 mm. The crushed ore is fed to a system of 8 conveyors, installed in underground drifts, and lifted to the surface processing plant. The capacity of the conveyor system is 4,000 tonnes per hour. The two main conveyor flights are 368 m and 402 m long, respectively, travelling at a speed of 3 m per second.

Mining manpower totals 206, of which 57 are employed in maintenance. Productivity has improved from just over 65,000 tonnes per employee in 1992 to nearly 90,000 tonnes per employee in 1996.

Development projects are under way related to global positioning systems for locating drilling and loading equipment and ore/waste boundaries; driverless haul trucks and ultimate final overall maximum slope angles. None of the potential benefits of these development projects has been incorporated in Boliden AB's economic forecasts for Aitik.

6.7.2 Milling Operations

The Aitik concentrator has been progressively expanded to its present capacity of just under 18 million tonnes per year. The original hoist, crushing plant and fine ore bins are a notable local landmark but are no longer in use.

Ore is crushed by two large gyratory crushers in the open pit. This substantial facility has ample capacity and discharges the ore to a system of 1.8 m wide, inclined steel cord conveyor belts, which transport the ore through tunnels to the surface ore storage facilities. The ore stream is split between the new ore storage facility for the D section of the concentrator and the older facility for B and C sections. The original A section is no longer in use. The older ore storage is largely open as the original sheeting was extensively damaged by blasting in the pit and has not been replaced. The ore storage conveyor areas are quite dusty. Clean-up in these un-heated areas is difficult in winter as any wash-down water would immediately freeze.

All primary grinding at Aitik is by Boliden-type, fully autogenous mills. Section B has two installations each of one 3,600 kW primary mill and one 1,250 kW pebble mill. Section C has one 6,600 kW primary mill and one 2,500 kW pebble mill and Section D two installations each of one 6,600 kW primary mill and one 3,000 kW pebble mill. The mills all run at fixed speed, sections B and D at 75 per cent critical speed while section C's primary mill runs at 76 per cent and the pebble mill at 73 per cent of critical speed. The primary mill discharge is fed directly to the pebble mills. The pebble mill discharge is classified in all cases by spiral classifiers using rubber flights, the coarse fraction from which is returned to the primary mill. This may reflect the comparatively coarse grind (80% passing 180 μm). Hydrocyclones are also installed and sometimes used but have a high maintenance cost.

Outokumpu flash flotation cells have been installed with the cyclones in the grinding circuits but they are not used having shown no overall benefit.

The ore from the grinding circuits is combined in a conditioner at a pH of 10.5 and then distributed to four flotation banks of OK38 (38 m^3) cells, each comprising four rougher cells and five scavenger cells. The copper and most of the pyrite is floated. Scavenger concentrate is reground in a 1,100 kW pebble mill operating in closed circuit with a hydrocyclone. The cyclone overflow is directed to the flotation feed conditioner. Rougher concentrates are raised to a pH of 12.4, reground in a 430 kW ball mill and floated in four consecutive Denver flotation columns. Concentrate from the first two columns goes to the Sala BFR 300 (2.84 m^3) cleaner and re-cleaner flotation cells. Concentrate from the third and fourth columns returns to the regrind ball mill. Tailings from the fourth column go to a bank of four OK50 (50 m^3) cells, whose concentrate also goes to the regrind ball mill, while its tailing is combined with that from the primary scavengers and goes to the tailings dam.

Final concentrate is dewatered in thickeners, vacuum drum filters and oil fired rotary dryers and despatched by road and rail to the smelter at Rönnskär.

The flowsheet for the concentrator at Aitik is shown in Figure 6.2

Tailings from flotation are pumped by two out of four sets (two standby) each of five, sixteen inch pumps in series along two of four, rubber-lined pipes (three 500 mm, one 400 mm) to the tailings dam, 5 km away.

Water at Aitik is controlled by two drains which surround the property. The inner drain collects all run-off and also the water decanted from the tailings dam. This water flows to a pond from which it is returned to the mill. Every summer, some water is released from the system into the outer drain and the rivers. The solids and metal content of the water which is discharged is carefully controlled. A maximum of 300 kg of copper per year is permitted. In 1996, 1.5 million cubic metres were discharged containing 1.5 kg of copper. The outer drain catches all water outside the property and diverts it around the mine to the river system.

6.7.3 Historical Production Performance

Changes to the equipment fleet have resulted in increased production of ore and waste, from 15.4 million tonnes and 11.2 million tonnes, respectively, in 1992 to just under 18 million tonnes of ore and 16.6 million tonnes of waste in 1996, as shown in Table 6.1. In 1996, however, due to planned and temporary drop in copper grade, production of concentrate fell to 180,000 tonnes, compared with over 210,000 tonnes in 1995.

[Figure 6.2 - Aitik Concentrator]

Table 6.1
AITIK - HISTORICAL PRODUCTION FIGURES

	Unit	1992	1993	1994	1995	1996
Tonnes ore	000 tonnes	15,369	16,047	16,411	17,465	17,899
Tonnes waste	000 tonnes	11,211	13,583	14,362	14,277	16,596
Grade copper	%	0.38	0.40	0.36	0.38	0.32
gold	g/t	0.20	0.22	0.21	0.22	0.15
silver	g/t	4.9	4.5	2.9	3.2	3.7
Metallurgical Recovery						
Copper	%	88.5	90.9	91.0	90.5	87.9
Gold	%	51.4	55.2	53.2	50.7	47.6
Silver	%	68.7	66.4	71.7	75.2	72.6
Concentrate						
Copper	000 tonnes	200.4	205.0	182.9	210.5	179.2
Grade copper	%	28.2	28.3	29.0	28.5	28.8
Contained Metal						
Copper	000 tonnes	56.70	58.10	53.0	59.98	50.52
Gold	kg	1,686	1,919	1,858	1,913	1,248
Silver	kg	51,906	47,625	34,734	41,324	47,026

6.7.4 Historical Cost Performance

Production costs, per tonne of ore milled, excluding depreciation but including general and administration costs have been held at approximately 31 SEK per tonne over the past five years. Table 6.2 shows historical mining and milling costs per tonne of ore milled for 1992 through 1996.

Table 6.2
AITIK - HISTORICAL UNIT COSTS

	Unit	1992	1993	1994	1995	1996
Ore production	000 tonnes	15,369	16,047	16,411	17,465	17,899
Waste production	000 tonnes	11,211	13,583	14,362	14,277	16,596
Mining cost	Million SEK	228.3	221.4	243.4	252.2	256.8
Milling cost	Million SEK	231.2	241.5	233.9	244.9	260.2
General and administration	Million SEK	19.7	32.4	33.3	37.0	38.4
Exploration	Million SEK	-	-	-	-	1.9
Decommissioning	Million SEK	-	-	-	-	-
Depreciation	Million SEK	65.5	67.7	84.1	89.2	92.3
Total Cost	Million SEK	544.7	563.0	594.7	623.3	649.6
Mining cost/tonne	**SEK/tonne**	**14.85**	**13.79**	**14.83**	**14.44**	**14.35**
Milling cost/tonne	**SEK/tonne**	**15.04**	**15.05**	**14.25**	**14.02**	**14.54**
Total cost/tonne	**SEK/tonne**	**35.44**	**35.08**	**36.24**	**35.69**	**36.29**
less depreciation	**SEK/tonne**	**31.23**	**30.87**	**31.11**	**30.58**	**31.14**
Total cost per tonne	**US$/tonne**	**5.06**	**5.01**	**5.18**	**5.10**	**5.18**
less depreciation	**US$/tonne**	**4.46**	**4.41**	**4.44**	**4.37**	**4.45**

6.8 FUTURE OPERATIONS

6.8.1 Plans and Potential for Expansion

Future plans, under the current reserve and resource position, call for push-backs three and four in the north-wall, and to depth, up to the year 2011. Further push-backs will depend on future economic evaluations depending principally on projections of metal price at the time.

6.8.2 Production Outlook

Table 6.3 presents the five-year outlook, 1997 to 2001, for mined tonnes of ore and waste, ore grade, metallurgical recovery, concentrate tonnes and concentrate grade.

Under the currently optimized pit design the anticipated life of the present operation is until 2011, at the planned rate of production of 17 million tonnes ore per year. The in-pit crushing system may be relocated to the northern section, depending on future economic evaluations of additional push-backs to the north and to depth.

Another deposit, Liikavaara, lies some 3 km to the east of Aitik and may be developed to replace the southern section of the pit.

The possibility of steepening sidewall slopes in the existing and future operations is also being studied. This would have the benefit of reducing stripping ratio, lowering unit costs per tonne of ore mined and ultimately extending mine life.

Table 6.3

AITIK - FIVE YEAR PRODUCTION OUTLOOK

	Unit	1997	1998	1999	2000	2001
Ore Production	000 tonnes	17,000	17,000	17,000	17,000	17,000
Waste	000 tonnes	15,600	23,000	23,000	21,000	21,000
Grade copper gold silver	% g/t g/t	0.39 0.18 5.0	0.39 0.18 4.2	0.39 0.19 5.4	0.39 0.23 4.2	0.39 0.21 3.4
Metallurgical Recovery						
Copper Gold Silver	% % %	90.9 52.5 70.0	91.0 52.6 70.0	90.9 52.5 70.0	90.7 52.3 70.0	90.8 52.4 70.0
Concentrate						
Copper Grade copper Gold Silver	000 tonnes % g/t g/t	211.6 28.5 7.6 281.3	211.7 28.5 7.6 236.1	211.6 28.5 8.0 303.8	211.1 28.5 9.7 236.8	211.3 28.5 8.9 191.5

Generally speaking, the production forecast reflects a continuation of past performance and, as such, is regarded by Micon as reasonable.

6.8.3 Outlook for Operating Cost

Estimated operating costs for the next five years are provided in Table 6.4. Total cost is expected to remain in the range of 33 to 34 SEK per tonne, equivalent to approximately US$4.80 per tonne.

Micon is of the opinion that the cost estimates prepared by Aitik and Boliden personnel are reasonable, based on historical performance, and do not reflect projections of productivity improvements or cost reductions.

Table 6.4
AITIK - ESTIMATED OPERATING COSTS 1997 TO 2001

	Unit	1997	1998	1999	2000	2001
Ore production	000 tonnes	17,000	17,000	17,000	17,000	17,000
Waste production	000 tonnes	15,600	23,000	23,000	21,000	21,000
Mining cost	Million SEK	265.7	288.4	273.2	273.4	279.3
Milling cost	Million SEK	262.9	252.8	253.6	254.1	255.4
General and administration	Million SEK	32.8	33.2	33.2	33.2	33.2
Exploration	Million SEK	-	2.0	3.5	3.5	2.0
Decommissioning	Million SEK	8.5	-	-	-	-
Depreciation	Million SEK	89.6	88.6	97.8	97.3	97.3
Total Cost	Million SEK	659.5	665.0	661.3	661.5	667.2
Mining cost/tonne	**SEK/tonne**	**15.63**	**16.96**	**16.07**	**16.08**	**16.43**
Milling cost/tonne	**SEK/tonne**	**15.64**	**14.87**	**14.92**	**14.95**	**15.02**
Total cost/tonne	**SEK/tonne**	**38.79**	**39.12**	**38.90**	**38.91**	**39.25**
less depreciation	**SEK/tonne**	**33.52**	**33.91**	**33.15**	**33.19**	**33.52**
Total cost per tonne	**US$/tonne**	**5.54**	**5.59**	**5.56**	**5.56**	**5.61**
less depreciation	**US$/tonne**	**4.79**	**4.84**	**4.74**	**4.74**	**4.79**

The breakdown of the budgeted operating costs of the Aitik concentrator is shown in Table 6.5 below.

Table 6.5
AITIK - 1997 BUDGET MILLING COSTS
(Thousand SEK)

Item	Cost	
Energy		**80,860**
Electricity	79,660	
Heating Oil (for dryers)	1,200	
Materials		**49,760**
Spare parts & Wear parts	26,000	
Steel	5,000	
Reagents	8,000	
Other material	10,760	
Labour		**43,540**
Outside Services		**87,080**
Mill Liner Leasing	31,000	
Concentrate Transport	25,000	
Contract Maintenance	28,000	
Other Outside Services	3,080	
Re-distributed services		**3,110**
Other departments	0	
Technical & Admin services	3,110	
Depreciation		**46,650**
Total Costs		**311,000**

Complete specifications of the concentrates are included in Appendix I.

The throughput of the Aitik concentrator has been expanded four times and the original crushing and grinding installations are no longer in use. The most recent expansions have added increments of 490-tonnes per hour grinding units. Any further expansion of throughput will depend on the development of increased reserves. The ore mineralization in the north end of the pit continues at depth but the economic viability depends on pit slopes and the rising stripping ratio.

The present mill capacity is 17 million tonnes per year and a further increment of grinding capacity would increase this to about 21 million tonnes per year.

The primary crushers are presently installed in the middle of the pit at the 165-m level. The extension of the conveyor system down into the pit and the movement of the primary crushers has been considered but would be very expensive and is probably only justifiable in connection with an increase in the reserves.

The grindability of the ore varies and it is now possible to relate the grindability to the location in the reserves for planning purposes. In this way, harder ore can be mined together with softer so that throughput can be maintained and the concentrator can adjust the throughput to suit the ore. Transducers on the lifters in the pebble mills have been installed to detect the volume of the mill charge. It is intended to use these devices to optimize the power drawn by these mills.

A significant proportion of Aitik's revenue comes from the gold and silver content of the ore. At present, the silver recovery is about 72 per cent but the gold recovery was less than 50 per cent in 1996. Attention is being focused on the pyrite tailing which contains about one gram per tonne of gold.

6.8.4 Outlook for Capital Expenditure

The 1997 capital budget and five-year expenditure programme are summarized in Table 6.6.

Capital expenditures appear reasonable in terms of the maintenance of present levels of output over the next five years.

Table 6.6
AITIK - CAPITAL EXPENDITURE PROGRAMME
(Thousand SEK)

	1997	1998	1999	2000	2001
Compressor		600			600
Drill equipment			1,700		
Shovel		60,000			
Graders			3,400		
Trucks		18,000			
Tailings dam	10,700	7,200	8,600	5,500	6,800
Mill equipment replacement	24,400	18,000	18,000	18,000	19,700
Total	**35,100**	**103,800**	**31,700**	**23,500**	**27,100**

Additional pushbacks may require additional waste removal capacity. Such expenditure would be studied and justified at the time, depending on prevailing economic criteria.

There are no plans for the replacement of major items of concentrator equipment and no such replacements should be expected in the foreseeable future. The projected plant performance is based on past performance and should be achieved.

6.9 CONCLUSIONS

The production plan and estimates of future operating and capital cost are based on historical performance and are considered reasonable. The only concern with regard to the operation's ability to achieve predicted performance is the unlikely occurrence of major, uncontrollable slope failure. Given the monitoring procedures and levels of technical input provided to the operation, such an outcome is considered unlikely.

Accordingly, Micon concurs with the physical cost inputs to the Aitik financial projections.

7.0 MINING OPERATIONS IN SPAIN

7.1 INTRODUCTION

Boliden Apirsa, SL is the Spanish subsidiary of Boliden AB, which owns and operates the Aznalcóllar-Los Frailes mine in Spain (see Figure 1.1 shown previously in the Introduction to this report).

The Aznalcóllar area has a long history of mining, dating from 3,000 years BC. The Aznalcóllar deposit was discovered in 1956 by the company Peńaroya. In 1960 Andaluza de Piritas, SA (Apirsa), owned by Banco Central SA, acquired the rights over the 612-hectare mining concessions and carried out the investigation and feasibility stages between 1969 and 1974. Waste rock stripping and plant construction started in 1975 and, in 1979, production started at the rate of 2.0 million tonnes per year of complex pyrite ore and 1.4 million tonnes per year of pyritic chalcopyrite ore.

Boliden AB acquired Apirsa in December 1987, when the remaining life of the Aznalcóllar mine was only four years and closure was planned for 1992. By the end of 1990, the company had evaluated measured resources of 70 million tonnes in Los Frailes orebody, and had expanded the operating life of the Aznalcóllar pit to the end of 1996.

Boliden Apirsa, SL is the owner of the mineral rights, land holdings and all other mining assets.

The concentrates are shipped from the port of Huelva, 90 km from Apirsa. The Aznalcóllar zinc concentrate was sold to European smelters under long term contract and Los Frailes concentrates will be sold under similar conditions. The increased quantity has largely been allocated through letters of intent and expansion of existing long term contracts. The Aznalcóllar copper concentrate was sold to Japan and, as the quantity and quality from Los Frailes will be similar, the continuation of existing long term contracts is anticipated by Boliden.

Aznalcóllar lead concentrate was sold to European smelters under long term contract. Since the Los Frailes project will produce larger amounts of lead concentrate, it may be necessary to allocate some quantities outside Europe.

7.2 CHARACTERISTICS OF THE PROPERTY

The town of Aznalcóllar is located 45 km west of the city of Seville, in southern Spain. The Aznalcóllar-Los Frailes mining area (see Figure 7.1), occupies the southeast edge of the Iberian Pyrite Belt, a 230-km long, east-west trending mineral belt which contains orebodies such as Neves Corvo, Rio Tinto and Tharsis, as well as many medium and small mines.

Geographically, the area is located in the Guadiamar River basin, a tributary of the Guadalquivir River, and its main economic activities are agriculture and food industries. The climate is Mediterranean subtropical, with an average annual temperature of 17ş C and average rainfall of 646 mm.

[Figure 7.1 - Boliden-Apirsa Mineral Rights]

The minesite may be accessed by road from Seville. Madrid and Seville are linked by high speed train and frequent air service. Employees live in Aznalcóllar, the nearby town of Gerena, and in Seville.

7.2.1 The Los Frailes Project

The feasibility study for Los Frailes was completed in 1995. The scope of the project includes the development of the Los Frailes open pit and the upgrading and expansion of the existing Aznalcóllar plant to treat 3.8 million tonnes per year of ore, at a capital cost of 14,982 million Spanish pesetas (pesetas).

Design improvements during the detailed engineering stage resulted in revised capacity of 4.0 million tonnes at startup, increasing to 4.2 million tonnes by the end of 1999.

Mining ore at Los Frailes was scheduled for December, 1996, on closure of the Aznalcóllar pit. However, the Aznalcóllar pit had to be closed in October, 1996, due to slope stability problems affecting operations, when 200,000 tonnes of ore remained in the pit.

The first ore from Los Frailes was mined in September, 1996 and, as of February 28, 1997, some 200,000 tonnes of ore and 40.1 million tonnes of waste had been mined and the mill had treated 68,771 tonnes of ore.

At the time of Micon's site visit, the Los Frailes pit had reached normal operation at three shifts per day. Present mine production rates are 3.7 million tonnes per month of waste and 150,000 to 200,000 tonnes per month of ore.

According to the latest project schedule, mechanical completion and commissioning of the plant expansion will be completed in October, 1997. The company expects both mine and plant to perform at the full production rate of 333,400 tonnes per month after October 1, 1997.

In 1996, the Boliden Apirsa operations mined 1.6 million tonnes of ore and 1.2 million tonnes of waste from the Aznalcóllar pit and 34.2 million tonnes of waste from the Los Frailes pit. The mill processed 1,827,000 tonnes of ore grading 0.53% Cu, 1.67% Pb, 3.48% Zn and 58 g/t Ag.

Production comprised:

- 25,945 tonnes of copper concentrate grading 20.9% Cu.
- 29,325 tonnes of lead concentrate grading 48.9% Pb.
- 96,986 tonnes of zinc concentrate grading 47.2% Zn.

Total on site cash cost for mining, milling, administration and concentrate freight was 2,926 pesetas per tonne, equivalent to approximately US$24 per tonne at the 1996 exchange rate.

7.3 GEOLOGICAL SETTING

The Los Frailes deposit is part of the volcanic-sedimentary Iberian Pyrite Belt (Figure 7.2). The massive sulphides are underlain by a Devonian-age, shale-quartzite series and overlain by Carboniferous-age sediments. The west-northwest-east-southeast striking, moderate north-dipping Paleozoic formations are folded, and thrust faulted parallel to the regional dip, and cut by north-northeast steeply-dipping transverse faults, and finally overlain by Miocene-age conglomerates, sandstones, limestones and marls.

Some repetition of the mineralized horizons occurs due to north-south thrusting along north dipping thrust planes that steepen near surface.

In the pit area (see Figure 7.3), Miocene sediments consisting of unconsolidated conglomerates, slates, claystone and shell-grit, up to 30 m thick, discordantly overlie the volcano-sedimentary rock sequence. An ash tuff is, in places, interbedded with graphitic shales and dacitic tuffs. The contact to the underlying acid tuff appears to be tectonic as indicated by strong schistosity, abundant quartz veining and clay gouge in the contact zone.

The acid tuff, up to 300 m thick, is partly agglomeratic with jasperoids, felsic, porphyritic and chloritic fragments, with scattered sections of banded chert and jasper. The rock is partly silicified and in places slightly sericite-altered with minor disseminated sulphides.

The dacitic tuff, up to 120 m thick, is feldspar porphyritic and agglomeratic. The upper part is unaltered to slightly altered with weak sulphide dissemination, with alteration and the schistosity increasing towards the massive sulphide.

The contact with the massive sulphide mineralization is probably of a tectonic nature. The mineralization is massive pyrite up to 90 m thick, with banded sphalerite and galena. It is usually fine- to medium-grained.

The footwall rock sequences are similar to the hanging wall rocks described above, but the altered unit is thicker, up to 60 m.

7.3.1 Mineralization

The mineralization is syngenetic and predominantly pyritic with zinc, lead, copper and silver values.

The orebody has east-west strike with investigated strike length between 400 m at the +45-m level and over 1,000 m at the -200-m level. It is open towards the west. The dip is 40 to 50 degrees north in the upper sections and flattens to 30 to 40 degrees at depth. The orebody has been drilled from 45 m above sea level to -300 m below sea level, and remains open at depth. The orebody is generally thinner in the upper parts and thickens downdip, up to a maximum of about 90 m.

[Figure 7.2 - Geology of the Pyrite Belt]

[Figure 7.3 - Cross section showing geology and ultimate pit outline of the Los Frailes mine.]

Like other deposits in the Iberian Pyrite Belt, the Los Frailes deposit is zoned, with higher zinc-lead and lower copper values towards the hanging wall. The banded pyrite-sphalerite-galena unit is believed to indicate the top of the mineralization.

7.4 HISTORY OF EXPLORATION

The Iberian Pyrite Belt has been actively mined since ancient times. The Los Frailes deposit, lying under the Miocene cover, was not known until discovered by Boliden AB personnel after the acquisition of the adjacent (1.5 km to the west), and now exhausted, Aznalcóllar mine in 1987.

The deposit was explored by drilling by Boliden AB (using a contract drilling company) in 1989 and 1990.

7.5 GEOLOGICAL RESOURCES AND MINEABLE RESERVES

7.5.1 Resource/Reserve Classification

Resources and reserves for the Los Frailes project are classified and defined as set out in section 1.1.2 in the Introduction to this report.

7.5.2 Database

The database at Los Frailes consists of 31,000 m of drilling in 105 diamond core drill holes on approximately 50-m sections. The hole spacing on sections ranges from 25 to 160 m, averaging approximately 70 m. Massive sulphide sections of the core from holes 11 to 105 have been quartered and assayed for silver, lead, zinc and copper. Down-hole deviation was measured. Holes 1 to 10 did not include silver assays, and the collar positions were estimated from maps.

Core was logged by geologists from the drill contracting company into Boliden AB's computer-coded format for use in geologic modelling.

7.5.3 Estimating Procedures

Variograms were drawn for each metal. Ranges were the same for all, 80 m, and in all cases the chaotic component was about 2/3 of the sill value, which would indicate a large uncertainty in the calculated grade of any individual block.

The resource was estimated by block modelling using 10-m east-west, 5-m north-south and 8.5-m thick blocks. The drill holes with histograms of zinc assays were plotted on 50-m sections, and interpreted grade zones corresponding to high, medium, low and very low zinc grades were drawn between holes. These grade zones were transferred to bench height plans, and the amount of each grade zone and the amount of massive sulphide in each block was calculated. Assay intervals in the drill holes were coded using the same zinc grade zones. Block grades were calculated by estimating the grades within each grade zone in each block by kriging from assay data of the same grade zone, and combining the assays in the block. The final calculated data for each block is a percentage of the block which is massive sulphide, and the silver, lead, zinc and copper grade of the mineralization. Isolated waste blocks in ore were reclassified as ore, and isolated ore blocks in waste were reclassified as waste.

7.5.4 Reconciliations

This is a new mine and there are as yet no production data on which to carry out reserve/production reconciliation.

7.5.5 Reported Reserves and Resources

Resources: Boliden AB utilized the above block modelling and interpolation to attempt to simulate the grade variability that the banded ore will produce. It recognized that the detail of the calculation goes beyond the limits of the data and that normal grade control drilling will be required for detailed mine planning. Specific gravities used for converting volumes to tonnes were 4.65 for massive sulphide, 2.75 for waste rock and 2.20 for Miocene-age overburden material. Micon notes that for the massive sulphide ore to have a specific gravity of 4.65 requires the material to contain not less than 90 per cent sulphides, a high, but not abnormal percentage for this type of ore.

Total measured resources are reported by Boliden AB at 71 million tonnes averaging 60 g/t Ag, 3.85% Zn, 2.09% Pb, 0.34% Cu.

A block model built by Boliden AB without the detailed zoning model had slightly lower overall grades.

Micon is familiar with the block modelling used by Boliden AB and Micon personnel examined portions of the model in detail as a check. Micon concludes that the Measured resources reported for the Los Frailes deposit represent a reasonable estimate.

Reserves: Mineable reserves were estimated from a base "floating cone" pit optimization calculated by Independent Mining Consultants of Tucson, Arizona.   This base case optimized pit was then completed by Boliden AB engineers to include roads, safety berms, et cetera. The reserves are developed in an initial pit containing 7.37 million tonnes with a waste:ore ratio of 10.2:1.

Internal dilution of 2 per cent by weight at zero grade is included in the reported ore reserves to allow for isolated waste blocks. This, in Micon's opinion, is reasonable. External (or "operating") dilution, that is, diluting material along the fringes of the deposit that gets incorporated with ore during mining, was allowed for by incorporating 0.7 m of waste beyond the ore/waste contact; this also amounts to 2 per cent at zero grade. It is Micon's opinion that, due to the difficulty of mining cleanly to the ore/waste contact, operating dilution, as a practical matter, is likely to be somewhat higher than allowed for. Conversely, to minimize this potential dilution, mining recovery of the orebody will be somewhat less than claimed. In either case, Micon believes that the overall difference in grade or tonnage will not be significant.

The cutoff grade for reserves is calculated by Boliden AB on the NSR value as in Sweden (see

Boliden area mines section), that is, with allowance for all payable metals. At Los Frailes, the cutoff generally equates to resources that grade about 1.5% Zn.

The total reported Ore Reserves for Los Frailes at January 1, 1997, are:

Proven Ore Reserves: 46.40 million tonnes at 60 g/t Ag, 2.2% Pb, 3.8% Zn, and 0.3% Cu, with 340.80 million tonnes of waste for a waste:ore stripping ratio of 7.2:1.

The waste includes 3.62 million tonnes of pyrite with an NSR value below the cutoff grade, but for which there may be a market as pyrite.

Micon classifies the reported Ore Reserves as Proven Ore in terms of National Policy 2-A.

The Proven Ore Reserves (including the tonnage mined between September and December, 1996), with details of the initial pit and subsequent pushbacks, are set out in Table 7.1.

Table 7.1
LOS FRAILES - PROVEN ORE RESERVES

Pushback	Ore (t'000)	Py (t'000) below cutoff	Waste (t'000)	Cu %	Pb %	Zn %	Ag g/t	Waste to Ore
Initial Pit-St. 1	196	0	54,868	0.36	3.73	5.45	84	279.94
Initial Pit-St. 2	7,172	295	20,041	0.36	2.22	4.09	58	2.79
Pushback - 1	7,282	98	54,518	0.33	2.33	3.87	62	7.49
Pushback - 2	7,106	348	50,598	0.37	2.18	4.01	57	7.12
Pushback - 3	6,647	119	52,808	0.31	2.12	3.50	66	7.94
Pushback - 4	7,546	451	38,432	0.36	2.39	4.09	69	5.09
Pushback - 5	11,421	2,313	65,907	0.36	1.88	3.46	52	5.77
Total	47,370	3,624	337,172	0.35	2.17	3.82	60	7.12

Additional resources are reported as follows:

Measured and Indicated Resources: 30 million tonnes at 60 g/t Ag, 0.3% Cu, 3.6% Zn, 2.2% Pb.

These resources are classified by Micon as additional mineralized concentrations as per Canadian National Policy 2-A.

7.6 EXPLORATION POTENTIAL

Los Frailes lies in the easternmost portion of the Iberian Pyrite Belt, a trend of volcanogenic massive sulphide deposits that also include the Aznalcóllar and Las Cruces orebodies. The Los Frailes landholdings consist of a mining concession at Aznalcóllar, valid for 90 years from 1973, and mining concessions at Los Frailes-Salome, valid for 30 years from 1980 and renewable for 30-year periods (see Figure 7.4). These concessions cover a total of 2,850 hectares.

The Los Frailes deposit has not been closed off to depth or to the west. Mineral zoning suggests that at least half of the deposit remains untested. Gravity and EM surveys point to the same conclusion. An exploration drilling programme to test the depth extent of the massive sulphide zone is under way. Conceptual planning for potential underground mining below the pit bottom is also being studied.

The adjacent Salome prospect on the Los Frailes concession may be the eastward continuation of the Los Frailes orebody across the Los Frailes fault.

7.6.1 Extension of Los Frailes Orebody at Depth

The Los Frailes orebody has been drilled down to a maximum depth of 350 m, and is open to depth and along strike to the east, with gravity and EM survey anomalies indicating potential to increase measured resources significantly.

During 1997, Boliden plans to drill 6 diamond drill holes totalling approximately 3,500 m with the objective of identifying new mineral resources mineable by underground mining methods. The exploration target is 4.5 million tonnes at 4% Cu and 6% Zn.

7.6.2 Extension of Los Frailes Orebody to the East

Within the "Salome" Target , the objective is to cover 20 square kilometres to the east of Los Frailes with a ground magnetic survey on a 40-m by 20-m pattern and a gravity survey of 160 m by 40 m, to check for anomalies to the east of Los Frailes. The Salome target is along the same trend and aligned with the Aznalcóllar, Los Frailes and RTZ Las Cruces orebodies.

The cost of planned exploration for 1997 is estimated at US$650,000.

7.7 CURRENT OPERATIONS

Exploration and Development of Los Frailes

Boliden AB acquired Apirsa in December 1987, when the remaining life of the Aznalcóllar mineable reserves was only four years and closure was planned for 1992. Immediately after acquisition, the company started a intensive exploration programme in the vicinity of Aznalcóllar.

At the end of 1988, the importance of the 'Los Frailes' orebody, only one kilometre east of the Aznalcóllar pit, became evident. Exploration was focused on the geological interpretation and evaluation of this orebody and, also, on the extension of the life and reserves of the Aznalcóllar pit.

[Figure 7.4 - Boliden-Apirsa Exploration 1997]

The feasibility study for the Los Frailes project was started in 1991 and completed in 1995, based on open pit mining and milling of 3.8 million tonnes per year of massive sulphides. Later in 1996, the study was reassessed to increase production capacity to 4.0 million tonnes per year, the production rate for which the project was finally engineered and constructed.

An addition to the development of the Los Frailes open pit, the existing Aznalcóllar treatment plant and ancillary facilities were upgraded and expanded to treat four million tonnes of ore.

As of February, 1997, Boliden Apirsa employed 524 people, of whom 458 are permanent employees and 66 are on temporary contracts. Once the Los Frailes project is in operation, the company will require 430 people, and the reduction will be achieved according to the following schedule :

Item	February 1997	December 1997	December 1998
Management & finance	13	13	10
Mining	132	131	113
Mine Planning	16	15	15
Mine Maintenance	51	28	28
Mill operation	142	120	120
Plant maintenance	98	79	79
Procurement & warehouse	22	19	19
Personnel services	29	30	26
Commercial	4	1	1
Los Frailes Project team	17	2	2
TOTAL	**524**	**438**	**413**

7.7.2 Mining Operations

Overburden stripping of the Los Frailes pit was approved in August, 1995, when all official permits had been granted by the Government, and started on October 27, 1995. Stripping was scheduled to remove 36 million tonnes of overburden and gain access to the 40-level bench, the upper bench in ore, on time to start mining ore at Los Frailes when, by December, 1996, the Aznalcóllar pit would be depleted and closed.

The loss of two months due to the early closure of Aznalcóllar, together with a delay of one month in the overburden stripping and the treatment problems experienced with the initial 200,000 tonnes of ore mined, due to oxidation, caused the shut down of ore mining and milling operations between November, 1996 and February, 1997.

The first ore from Los Frailes was mined on February 19, 1997 and, as of February 28, 1997, 139,515 tonnes of ore and 40.1 million tonnes of overburden waste had been mined under normal operating conditions and at normal production rates.

The ultimate pit at Los Frailes reaches a depth of approximately 350 m below surface, and is 1,400 m long and 900 m wide at surface.

Long term mining plans include an initial pit followed by five pushbacks. The pushbacks are designed with sufficient space for high productivity waste stripping. The outlines of the initial pit and pushbacks are shown in Figure 7.5.

The mine will operate with three shifts per day, 360 days per year. The equipment for ore production will be one drill machine for 165-mm holes, one hydraulic shovel and the existing 218-tonne and 80-tonne trucks. The ore will be transported to the existing primary crusher, modified to allow dumping by the 218-tonne trucks.

For waste stripping, existing equipment used in the Aznalcóllar mine will be utilized. Two drill rigs for 10-5/8-inch holes, one electric shovel with a 45 m^3 dipper, one hydraulic shovel with a 20.5 m^3 dipper and 218-tonne trucks. Waste rock stripping will reach a peak of 33 million tonnes per year during 1996, 1997 and in 2000.

Most of the auxiliary equipment, such as dozers and graders, will be owned and operated by contractors.

Production drilling in ore is performed using 6-1/2-inch diameter down the hole drills on 7.5-m half benches (15-m bench for bench waste), using one Bucyrus Erie BE 35R DHD drill. A new Ingersoll Rand DTH 6-1/2-inch drill rig was purchased in 1996 to ensure the foreseen drilling requirements after the expansion. One of the DTH drills working three shifts is considered adequate for the total drilling required for four million tonnes per year.

Drilling in waste is performed using 10-5/8-inch diameter holes using two existing Bucyrus-Erie BE49-R rotary crawler drills, drilling 17-m benches in a single pass.

Total waste drilling capacity is estimated at 34.8 million tonnes per year, adequate for the maximum requirements of 33.0 million tonnes per year.

The following loading and hauling equipment is already available and is being used at Los Frailes:

Electric shovel	1 unit	PH 4100	44 m^3
Electric shovel	1 unit	PH 2300	20.6 m^3
Hydraulic shovel	1 unit	Demag H285	12, 18, 20 m^3 buckets
Front-end Loader	1 unit	CAT 992	9.5 m^3
Unit Rig trucks	12 units	MT-4000	240 s.ton
CAT Trucks	8 units	CAT 777B	85 s.ton

The PH 4100 shovel, a Demag shovel and the Unit Rig truck fleet were purchased in 1995 to be used in Los Frailes overburden stripping. The PH 2300 shovel, the CAT 992 loader and the CAT 777B truck fleet have been recently transferred to Los Frailes from the Aznalcóllar pit.

Loading of pyrite will be carried out with the new Demag 12.5-m^3 shovel. This will have a capacity of 1,800 tonnes per hour, or 4.9 million tonnes per year. A front-end loader CAT 992 with an

[Figure 7.5 - Boliden-Apirsa Los Frailes Pushback Outlines] estimated capacity of 1.3 million tonnes per year will be used as a back-up unit for ore loading and ore rehandling at the emergency coarse ore stockpile.

The P&H 4100 45-m^3 shovel will be the main production unit for waste removal. This loads the Unit Rig trucks in three passes, at a rate of approximately 64,000 tonnes per day, or some 23.0 million tonnes per year. The Demag H285 20.5-m^3 shovel will produce an additional 29,000 tonnes per day or 10.3 million tonnes per year. For additional capacity and loading in narrow places, the existing CAT 777-B truck fleet and a wheel loader from contractors will be used.

The existing Unit Rig MT-4000 trucks will be used for hauling both ore and waste. For grading purposes and in narrow faces, the smaller Cat-777 B will be used. Minor waste tonnage for tailings dam construction also will be transported using Cat 777-B trucks.

The average length of the haulage cycle for ore to plant will be 6.3 km in 1997 and will gradually increase as the pit gets deeper, to reach 12.1 km in 2009. In this cycle, the one-way haulage distance in the 8 per cent pit ramps will increase from 0.7 km in 1997 to 4.3 km in 2009. Similarly, the waste-to-dump haulage cycle will be 4.0 km in 1997 and will gradually increase as the pit gets deeper, to reach 11.6 km in 2009, with in-pit ramp haulage distances similar to those for ore.

The Unit Rig fleet size requirements for ore and waste is estimated at 9 units in 1997 and will increase to 12 units in 2006. Similarly, the number of Unit Rig truck-hours per year will increase from 48,000 hours in 1997 to a maximum of 63,000 in 2006.

Heavy auxiliary and service equipment is owned and operated by contractors.

7.7.3 Milling Operations

The ore at Los Frailes is a complex polymetallic sulphide ore, with a pyritic matrix containing sphalerite, galena, chalcopyrite, tetrahedrite and other subordinate minerals. Grain size ranges from 15 to 60 microns and grinding to K_{80} = 35 microns is needed in order to achieve a good liberation of the different minerals.

The Aznalcóllar plant started operation in 1979, and was designed to treat 3.4 million tonnes per year of ore from the Aznalcóllar pit of which 2.0 million tonnes per year was complex polymetallic sulphide similar to Los Frailes, and the balance, pyritic chalcopyrite ore.

The process is a conventional milling-flotation process, producing copper, zinc and lead concentrates and pyrite tailings which, depending on the market, may be discharged to the tailings dam or sold to sulphuric acid manufacturers.

As part of the Los Frailes project, the Aznalcóllar plant is being modernized and expanded to a capacity of 4.0 million tonnes per year of complex polymetallic pyrite from Los Frailes. Full production is scheduled for October 29, 1997.

The treatment process will remain fundamentally the same as in the past 20 years. Significant modifications are the introduction of autogenous grinding, conversion of the existing ball mills into secondary pebble mills and installation of new, larger flotation cells. The dewatering system will be changed to pressure filtration and a state-of-the-art process control system will be implemented to improve recovery and quality of concentrates.

Pilot plant flotation tests were conducted at the Aljustrel plant of EDM in Portugal to establish the metallurgical balance for Los Frailes ore, using autogenous grinding.

It is expected that the Los Frailes ore will give zinc recoveries of 75 per cent with concentrate grades of 48 per cent, three recovery units and one grade unit higher than the average 72 per cent recovery with 47 per cent grade obtained with Aznalcóllar ore. The expected increase in recovery has been justified by considering that Aljustrel results were in line with historical Aznalcóllar results, despite the fact that the zinc grade of the Los Frailes ore which was used in this test was 3.24% Zn, lower than the average 3.55% Zn for Aznalcóllar and the 3.86% Zn average of Los Frailes.

Also of economic significance is the expected improvement in the recovery of lead and silver. Lead recovery is expected to increase from 47 to 52 per cent, justified by the results obtained in the pilot plant testing at Aljustrel (Portugal), where a recovery of 53 per cent with grades of 46 per cent was achieved with head grade of 2.2% Pb.

Also, silver payable recovery is expected to increase from previous 26 per cent with Aznalcóllar ore to 40 per cent in Los Frailes.

The expected copper recovery for 1997 is 41 per cent, increasing to 43 per cent in 1999. This recovery is lower that achieved in the past for the Aznalcóllar ores and is mainly related to a significant reduction in copper grades at Los Frailes pit.

Overall, the above metallurgical assumptions are well justified by past experience at Aznalcóllar and extensive R&D work. However, failure to achieve the projected zinc recovery grades would have an important impact on the economics of the project.

The ore from the Los Frailes open pit is trucked to the primary 54-inch gyratory crusher station, where ore size is reduced from 600 mm (run of mine) to minus 200 mm. Crushing capacity is estimated at 1,600 tonnes per hour, more than sufficient for the planned four million tonnes per year.

In the new arrangement, ore from the primary crusher will bypass the existing secondary-tertiary crushing building and will be fed directly to the existing 2,300 ore bins, each set of two bins feeding one of the two new autogenous grinding circuits.

The new grinding section consists of two parallel circuits, each with a new 6.7 m x 7.1 m primary mill and two existing 4.2 m x 6.0 m ball mills, converted to pebble mills.

The capacity rate in the 1995 Feasibility Study was estimated at 3.8 million tonnes per year, based on an hourly rate of 244 tonnes, 89 per cent availability and a design safety factor of 1.14 to account for variations in ore properties. However, in the 1996 revision of the Feasibility Study, a capacity of four million tonnes per year or greater is expected, on the basis of a more realistic estimation of the design safety factor, down to 1.08.

The mill product, K_{80} = 35 microns, is pumped to a 50-m diameter thickener to increase pulp density to 40 per cent. The resulting pulp is fed to the rougher stage, for stepwise conditioning with $S0_2$ and lime to depress the pyrite, sphalerite and galena, and with KAX to collect chalcopyrite and tetrahedrite. The conditioned pulp, at a pH of 10.5, is discharged to the copper flotation line to produce a rougher concentrate containing approximately 2 per cent copper.

The rougher product is cleaned in three steps at acid pH using $S0_2$ to get a concentrate of approximately 20 per cent in copper. The first cleaner tails are reground to liberate interlocked chalcopyrite and pyrite particles and are pumped back to rougher flotation head.

The copper circuit consists of two rougher and three cleaner flotation stages.

Mill product thickening and copper flotation will remain basically unchanged, with the existing system and equipment being adequate and sufficient for future operations.

Once chalcopyrite and tetrahedrite have been recovered, the pulp proceeds to the lead circuit. New 50-m^3 cells have been installed in the rougher and first cleaner stages, replacing the original 500 and 300 cubic feet (ft^3) cells, and new 38-m^3 cells have been installed in the second cleaner stage. For the third cleaner stage, the existing 500-ft^3 (14-m^3) cells have been retained and for the fourth stage two column cells, one new and one existing, have been used.

Lead flotation conditioning consists of a strong aeration to oxidize pyrite and conditioning with Aerophine 3418 A to collect galena.

Lead circuit tails are pumped to the primary zinc circuit head where the pulp is conditioned with lime at pH 8-8.5 for pyrite depression, copper sulphate for sphalerite reactivation, a mixture of AXK and EXNA to collect sphalerite, and MlBC frother.

Flotation in the primary zinc circuit consists of a double rougher stage and three cleaning steps. Rougher flotation is carried out using new 38 m^3 cells. The rougher concentrate with approximately 25 per cent zinc is cleaned in three steps at pH 9 to 1 1.5 using lime only. For the first and second cleaning stages, new 38-m^3 and 16-m^3 cells will be used, respectively. For the third cleaning stage, the existing 500 and 300-ft^3 cells will be maintained.

In order to optimize the metallurgical results, the first cleaner tails will be intensively reground and then floated in a secondary flotation circuit which consists of a rougher and three cleaning steps, using the existing cells from the old copper ore circuit.

The pulp, at pH 7.5 to 8, goes to the pyrite plant for separation of a commercial product. Decant water is treated prior to its recirculation to the mill.

As part of the Los Frailes project, the existing installations will be modified to replace vacuum filter dewatering and thermal drying with pressure filters, for lead and copper concentrate and to install an additional pressure filter for zinc concentrate.

The layout of the Los Frailes plant is shown in Figure 7.6.

As of February, 1997, the mill and mill services department employed a total of 240 people. This will be reduced to 199 by December, 1998.

The tailings pond was originally designed for 70 million tonnes of tailings, equivalent to a volume of 32.6 million cubic metres, when built up to the maximum dam height of 72 m. It is estimated that approximately 14 million cubic metres of tailings from the Aznalcóllar operation have been discharged and, therefore, a storage capacity of 18.6 million cubic metres is available for Los Frailes tailings. The present height of the tailings dam is approximately 23 m and will have to be raised to a final height of 30 m. Otherwise, the tailings disposal system will remain as is, with only minor changes in operational practice.

7.7.4 Water Supply and Treatment Systems

The company has a fresh water reservoir located some 2 km from the plant, with a capacity of 20 million cubic metres, equivalent to almost 2.5 years of operation. This storage capacity is adequate for the present and future water needs.

In recent years, southern Spain has suffered from drought and the operation experienced water supply problems. The Los Frailes project has therefore focused on minimizing fresh water consumption and the existing 1,000 m^3 per hour water treatment plant will be expanded to capacity of 1,500 m^3 per hour. The water treatment plant receives process water from the tailings dam, treats it and supplies treated water to the beneficiation process, discharging the surplus to the Rio Agrio stream. Water coming from the tailings pond is usually at pH 2-4 and has copper, lead, zinc and iron as the principal metals in solution. Effluent discharge quality is monitored to comply with environmental regulations.

7.7.5 Environmental Permitting

The Los Frailes project has been granted all official permits required for construction. These are :

- Consejería de Industria for Mining permit and mine reclamation and closure aspects.
- Consejería de Medio Ambiente for Environmental Permit.
- Confederación Hidrográfica for effluent discharge and fresh water supply.

The letter of concession of the permits includes a list of several conditions to be fulfilled by Boliden Apirsa in order to get final approval to startup normal operation of the Los Frailes project. These

[Figure 7.6 - Layout of the Los Frailes industrial plant] conditions imply the execution by Apirsa of several studies, civil work and corrective actions which are required to ensure that all environmental requirements are met.

The main activity related to the permitting process is the increase in capacity of the water treatment plant by 50 per cent to 1,500 m^3 per hour and this is under way.

The condition of the tailings dam, which is being modified to control seepage, is discussed in the environmental review for this report.

7.7.6 Production Performance

Table 7.2 summarizes the production and metallurgical performances of the Aznalcóllar operations for the period 1992 to 1996. The five-year forecast for 1997 to 2001, the initial five years of production from Los Frailes, is shown in Table 7.3. Production is scheduled to reach 4.2 million tonnes of ore per year in 2000, 200,000 tonnes per year more than the engineered production rate. Longer term plans include the possibility of further expansion to 4.5 million tonnes per year.

Table 7.2
BOLIDEN APIRSA* - HISTORICAL PRODUCTION FIGURES

	Unit	1992	1993	1994	1995	1996
Tonnes ore	'000 tonnes	1,962	957	1,621	2,440	1,648
Grade copper	%	0.50	0.41	0.44	0.53	0.53
lead	%	1.61	1.67	1.92	1.58	1.67
zinc	%	3.37	3.27	3.76	3.37	3.48
silver	g/t	56	57	66	51	58
Metallurgical Recovery						
Copper	%	61	53	52	58	56
Lead	%	44	48	47	45	47
Zinc	%	74	69	70	73	72
Silver	%	26	26	26	27	25
Metal Content						
Copper	tonnes	7,565	1,961	3,064	8,993	5,509
Lead	tonnes	13,988	7,217	11,640	16,737	13,504
Zinc	tonnes	49,454	20,237	34,424	57,220	43,205
Silver	kg	28,686	13,284	22,410	31,593	24,130

* Aznalcóllar mine

Table 7.3
BOLIDEN APIRSA* - FIVE YEAR PRODUCTION OUTLOOK

	Unit	1997	1998	1999	2000	2001
Tonnes ore	'000 tonnes	2,307	4,000	4,100	4,200	4,200
Grade copper	%	0.35	0.33	0.35	0.35	0.39
lead	%	2.15	2.29	2.36	2.23	2.21
zinc	%	4.00	4.14	4.00	3.76	4.17
silver	g/t	55	58	63	61	55
Metallurgical Recovery						
Copper	%	40.00	41.00	43.00	43.00	44.00
Lead	%	49.00	52.00	52.00	52.00	52.00
Zinc	%	72.00	75.00	75.00	75.00	75.00
Silver	%	34.00	40.00	40.00	40.00	40.00

* Los Frailes

The comparison of past Aznalcóllar results with Los Frailes objectives, indicates the following :

· The average dollar value of metal content of Los Frailes ore is approximately 8 per cent higher than for Aznalcóllar.

· A planned improvement of zinc metallurgy by three per cent recovery units (from 72 to 75 per cent) and one per cent concentrate grade units (from 47 to 48 per cent). This represents some 325 million pesetas per year to the operating margin of Los Frailes, relative to past Aznalcóllar results.

· A planned improvement in lead recovery by 6 per cent units, from an average 46 to 52 per cent. This improvement represents some 160 million pesetas per year to the operating margin of Los Frailes, relative to past Aznalcóllar results.

· A planned increase in annual production from the 4.0 million tonnes per year, to 4.2 million tonnes per year by the end of 1999, which is obtained through operational improvements during the first two years of operation. This increase represents a 10 per cent production increase over the original rate of 3.8 million tonnes per year proposed in the 1995 Feasibility Study, representing an additional 900 million pesetas per year to the operating margin relative to the 1995 Feasibility Study assumptions.

7.7.7 Cost Performance

Tables 7.4 and 7.5, summarize the operating costs for the Aznalcóllar operations for the period 1992 to 1996, and the 5-year forecast for 1997 to 2001, the initial five years of production from Los Frailes.

Table 7.4
BOLIDEN APIRSA* - HISTORICAL UNIT COSTS PER TONNE OF ORE MILLED

(Pesetas per tonne)

Unit	1992	1993	1994	1995	1996
Mining Milling General and administration Transportation	263.5 1,420.7 272.4 309.0	262.6 1,386.6 1,318.4 484.9	301.2 1,334.3 908.0 417.5	282.1 1,147.6 296.6 406.1	452.7 1,335.5 675.4 462.5
Total	**2,265.6**	**3,452.5**	**2,961.0**	**2,132.4**	**2,926.1**
Total US$/tonne	**22.21**	**27.19**	**22.10**	**17.06**	**23.04**

*Aznalcóllar mine

Table 7.5
BOLIDEN APIRSA* - ESTIMATED OPERATING COSTS 1997 TO 2001

Mining	Unit	1997	1998	1999	2000	2001
Ore Production	000's tonnes	2,307[1]	4,000	4,100	4,200	4,200
Waste Production	000's tonnes	18,772	33,080	33,010	33,090	28,050
Mining cost Milling cost Transport General and administration Depreciation	Million pesetas Million pesetas Million pesetas Million pesetas Million pesetas	2,236 2,620 1,119 1,334 797	3,814 3,693 1,599 484 2,160	3,805 3,469 1,606 484 2,154	3,905 3,469 1,528 484 2,135	3,720 3,469 1,661 484 2,075
Total Cost	Million pesetas	8,106	11,750	11,518	11,521	11,409
Mining cost/tonne milled Milling cost/tonne milled	Pesetas/tonne Pesetas/tonne	1,053.2 1,234.1	953.5 923.3	928.0 846.1	929.8 826.0	885.7 826.0
Total Cost/tonne **Less Depreciation**	**Pesetas/tonne** **Pesetas/tonne**	**3,818** **3,443**	**2,938** **2,398**	**2,809** **2,284**	**2,743** **2,235**	**2,716** **2,222**
Total Cost/tonne **Less Depreciation**	**US$/tonne[2]** **US$/tonne**	**29.15** **26.28**	**21.76** **17.76**	**20.81** **16.92**	**20.30** **16.56**	**20.12** **16.46**

* Los Frailes
[1] 2.123 million tonnes milled
[2] Exchange rate: US$1 = 131 pesetas, 1997. US$1 = 135 pesetas, 1998 to 2001

From the figures, it is noted that a reduction of approximately 1,000 pesetas per tonne is expected for Los Frailes unit costs relative to Aznalcóllar and this, together with the sales increase, will bring the operating margin from negative or marginally positive value to levels of 4,000 million pesetas per year.

From the analysis of the cost information supplied by Apirsa, Micon has identified and evaluated the main operational and management changes which will cause this cost reduction :

- A planned reduction of 16.7 per cent in the price of electric power from 8.4 pesetas/kWh in 1996 down to 7.0 pesetas/kWh in 1997. This price cut would represent a cost reduction of 70 pesetas per tonne, equivalent to an incremental margin of 270 million pesetas per year. It must be stated that, although the Spanish government has announced a progressive price cut spread over several years, as of today this reduction has only been applied to small companies and, hence, has not yet affected Apirsa. It is considered by Micon that it would have been more realistic to apply this reduction progressively starting in 1999.

- A reduction of 58 pesetas per tonne in crushing due to the elimination of secondary and tertiary crushing, achieved by lower power consumption, and lower maintenance variable cost, for an incremental benefit of approximately 230 million pesetas per year.

- A reduction of 115 pesetas per tonne in flotation, due to the use of larger more efficient flotation cells, also is achieved through lower power and maintenance variable costs for an incremental benefit of approximately 460 million pesetas per year.

- A reduction of 120 pesetas per tonne in grinding cost due to lower consumption of grinding media and lower maintenance variable costs. This represents an incremental benefit of 480 million pesetas per year.

- A reduction of 38 pesetas per tonne in the cost of dewatering due to switching from the conventional vacuum filter-dryer system to pressure filtration and is achieved by savings in fuel and operation materials and lower maintenance variable cost. This represents an incremental benefit of approximately 150 million pesetas per year.

- A reduction of plant fixed cost of some 400 pesetas per tonne achieved by the reduction of 111 people from the present 524 people down to 413 people, mainly due to higher plant automation and lower maintenance requirements and lower general and indirects. This represents an incremental benefit of approximately 400 million pesetas per year.

With respect to overall reduction, Micon believes that a more realistic approach would have been to apply the reduction over a period of, say, 5 years at a rate of 20 people per year.

7.7.8 Capital Expenditures

The pre-production capital expenditures and sustaining capital for the Los Frailes project (see Tables 7.6 and 7.7), are summarized as follows:

Item	Million Pesetas
Land, permits, etc.	630
G&A, commissioning	231
Preproduction mine develop	5,837
Mine equipment	1,720
Plant and infrastructure	6,566
TOTAL (1995 Feasibility Study)	**14,984**
February 1997 Forecast	17,264
Variance (+15.2%)	2,280

The sustaining capital amounts to 1,271 million pesetas for the life of the project, which does not allow for the purchase of major pieces of mining equipment.

Table 7.6
BOLIDEN APIRSA - CAPITAL EXPENDITURE PROGRAMME
(Million Pesetas)

Year	Replacement of mining equipment	Relocation of Los Frailes creek	Pumping and piping	Decommis-sioning	Miscellan-eous	Total
1998	34.0				41.0	**75.0**
1999					28.0	**28.0**
2000	20.0		85.5		38.0	**143.5**
2001	40.0	195.0			28.0	**263.0**
2002					38.0	**38.0**
2003	87.2				28.0	**115.2**
2004					35.0	**35.0**
2005	15.0				28.0	**43.0**
2006	60.0				28.0	**88.0**
2007					33.0	**33.0**
2008					20.0	**20.0**
2009				375.0	15.0	**390.0**
Total	**256.2**	**195.0**	**85.5**	**375.0**	**360.0**	**1,271.7**

Table 7.7
BOLIDEN APIRSA - INITIAL CAPITAL COSTS FOR LOS FRAILES PROJECT
(Thousand Pesetas)

Item	**1995**	**1996**	**1997**	**Total**
Land Purchase	565,000			565,000
Studies, Applications and Permits	65,000			65,000
G&A and commissioning			231,000	231,000
Mine preproduction*	1,502,918	3,278,709	1,055,250	5,836,877
Mine equipment and installations:				
Drill rig 165 mm		75,000		75,000
New motors to unit rig trucks		34,000	34,000	68,000
Spare dipper to P&H 4100 shovel		82,900		82,900
Hydraulic shovel Demag H285			467,500	467,500
Auxiliary and service equipment		179,800		179,800
Miocene Removal four million tonnes	526,000			526,000
Pumping and piping	85,500			85,500
Miscellaneous	149,200	48,000	38,000	235,200
Sub-total	760,700	419,700	539,500	1,719,900
Mill and infrastructure:				
Crushing, conveying and storing	52,495	281,810	94,795	429,100
Grinding	355,355	1,077,720	363,125	1,796,200
Flotation and reagents	402,510	1,085,815	226,375	1,714,700
Concentrate dewatering and storing	96,750	326,885	77,965	501,600
Tailings disposal	18,895	75,945	28,460	123,300
Water supply and treatment	14,315	50,330	12,655	77,300
Power supply	40,000	6,300		46,300
Power distribution	15,000	17,000	5,000	37,000
Process control and instruments	85,860	143,100	27,240	286,200
Project management	260,000	425,000	154,000	839,000
Temporary facilities	17,500			17,500
Equipment spares		110,700	110,700	221,400
Miscellaneous	44,370	73,950	29,580	147,900
Contingency	60,000	91,000	117,500	328,500
Sub-total	1,463,050	3,765,555	1,337,395	6,566,000
Total	**4,356,668**	**7,463,964**	**3,163,145**	**14,983,777**

* Includes 5 per cent contingency.

A non-returnable subsidy has been granted by the central and regional Government, which amounts to approximately 35 per cent of total capital investment. Having reviewed the estimation procedure in the feasibility study, the following observations can be made:

- The calculation procedure includes 5 per cent contingency, much lower than the normal practice of at least 15 per cent for mining projects.

- Despite the projected increase in sales volume, the project evaluation procedure does not allow for an increase in working capital for the operation. This working capital may be estimated as 60 days of incremental operating costs, or approximately 600 million pesetas.

- Approximately 50 per cent of the above budget deviation is due to an additional capital appropriation of 1,100 million pesetas. This was approved to achieve the increase in the production target from 3.8 to 4.0 million tonnes per year.

- No specific budget allowance was made for environmental work required to obtain permits, however this has been recently budgeted at 621 million pesetas, and most of this amount will show up as additional deviation in the future

- Mining of waste up to the end of August, 1997, plus a part of the operating costs of mine and mill, is capitalized until start-up. Therefore, any time delay in the start-up will cause a significant deviation in project cost.

Overall, the original budget clearly underestimated the cost of the Los Frailes project. The 5 per cent contingency is considered on the low side and no allowance was made for additional working capital, environmental costs and increased indirects due to project delays.

7.8 CONCLUSIONS

At the time of Micon's visit, the Boliden Apirsa operations were going through the implementation of the Los Frailes project, which involves the development of a new open pit and modification of the existing Aznalcóllar mill.

As a general comment, it is evident that the Los Frailes project concept is strongly focused on the means to generate a profit from low value ores, with difficult metallurgy, by maximizing the benefits of high production rates, large equipment and sophisticated process control systems.

Capital commitments as of February 1, 1997, are 15 per cent higher than estimated in the 1995 Feasibility evaluation. Apart from other possible reasons, the 5 per cent contingency considered was probably too low for a project of this type, and no allowance was made for additional working capital, environmental costs and increased indirects due to project delays.

In accordance with the revised feasibility parameters, the Los Frailes project is forecast to achieve a reduction of approximately 1,000 pesetas (US$7), in unit operating cost, in 1998, related to:

- A manpower reduction of 111 during 1997 and 1998.

- A reduction in maintenance costs for grinding, flotation and dewatering.

- A reduction in power consumption per tonne of ore.

- A reduction in steel balls for grinding.
- A reduction in price of 16.7 per cent per kWh of electricity.

Gross revenue from the Los Frailes project is projected to be almost 90 per cent higher than 1995 Aznalcóllar levels. This revenue increase is related to :

- An increase in ore tonnes produced.
- An improvement in zinc recovery from 72 to 75 per cent, and in lead recovery from 47 to 52 per cent.
- An increase of approximately 8 per cent in the value of metals contained per tonne of ore, assuming constant metal prices.

8.0 MINING OPERATIONS IN SAUDI ARABIA

8.1 INTRODUCTION

The Saudi Company for Precious Metals (SCPM) is equally held by Boliden AB and Petromin. The Sukhaybarat mine was brought on-stream in 1991 and is one of only two gold mines in Saudi Arabia.

The approximately 50 km^2 property is held as mining lease by SCPM and was granted by Royal Decree in 1988.

8.2 CHARACTERISTICS OF THE PROPERTY

The Sukhaybarat mine is located at an elevation of approximately 850 m asl. on the Nuqrah plateau in central Saudi Arabia, (Figure 8.1). The region is gravel desert and has low relief. Apart from sand filled wadis, the overburden is very thin, on the order of centimetres. Annual precipitation averages 100 mm, but rain is a local phenomenon; an area may remain without rain for several years. Rainfall occurs mainly between November and April. Winter temperatures may range from below 0º to 20º C in January and February, while August temperatures may rise to 50º C, moderating to 30º C at night.

Approximate geographic coordinates of the centre of the lease are: 25º 27'N, 42º 01'E.

Access is by way of 36 km of first class pavement to the Medina-Buraidah highway to the north. Medina lies 330 km to the west. The major commercial centre, airport and seaport of Jeddah is a further 400 km from Medina. There is a 900 m paved airstrip at the Sukhaybarat mine.

Living accommodation for the mine personnel is at the Sukhaybarat mine-site. Water supply is from wells. Some desalination is required for potable water. Power supply is from the national grid.

The majority of the labour force is expatriate, with the operating personnel from the Philippines and the supervisory staff from Scandinavia. Saudi personnel are employed as security guards, equipment operators and office staff.

The area has been mined since ancient times. Modern exploration began in 1935, and Boliden AB and Petromin were granted an exploration license in 1983 over an area of 4,400 km^2.

The Sukhaybarat operation consists of a 7,000 tonne per day open pit mine, a three stage crushing plant, a closed circuit 3.0-m diameter by 3.6-m rod mill and CIL (carbon in leach) gold recovery plant. A 500,000-tonne per year heap leach facility covers an area of 120,000 square metres (m^2).

The Sukhaybarat mine produced 2,657 kg of gold in 1966, at a cost of 47.3 millions of Saudi riyals (riyals), equivalent to US$4,629 per kilogram (US$149 per ounce).

[Figure 8.1 - Saudi Company for Precious Metals Location Map]

8.3 RESOURCES AND RESERVES

8.3.1 Geological Setting and Exploration History

The Sukhaybarat mine is hosted by gently folded, very fine grained Proterozoic volcanic sediments, siltstones, argillites, and feldspathic to lithic wackes of the Murdama group, intruded by a small, medium-grained, multi-phase granodiorite stock. The Murdama group rocks are hornfelsed within 50 to 100 m of the stock.

Mineralization is localized in ribboned and simple quartz veins that occur within well-defined shear zones in the intrusive and hornfelsed volcanic sediments. The main ore zone strikes east-northeast, and gently dips south-southeast, with a strike length of about 300 m and a dip extent of 150 to 200 m. A second, vertical ore zone occupies an area of about 50 m by 50 m in plan, with a vertical extent of 100 m on the southern edge of the intrusive, approximately coincident with a tonalite phase of the intrusive. Visible gold is very uncommon.

Rio Tinto Finance and Exploration examined the Sukhaybarat area during the early 1980's and recommended further exploration. Shortly afterwards, the area was included in an exploration concession granted to Granges AB and Petromin. Boliden AB assumed the Granges interest in 1983. The discovery work, drilling and trenching occurred in 1983, and continued to 1985. This work outlined preproduction reserves of 8.4 million tonnes at a grade of 2.5 grams gold per tonne. Mineable ore reserves were estimated at 6.4 million tonnes at a grade of 2.8 g/t.

8.3.2 Resource/Reserve Classification

The resource/reserve classification scheme follows that of Boliden AB, as described in section 1.1.2 of the Introduction to this report.

8.3.3 Database and Estimation Procedures

The database consists of 465 drill holes containing 9,011 assay intervals. Percussion drilling in 63 holes with 1,034 assay sections was used in exploration from the pit bottom. One hundred to 150 holes are planned in a programme to be completed by the end of April, 1997. Additional resources are being sought outside and beneath the present pit using two reverse circulation and one diamond drill.

The resources and reserves were originally estimated by block modelling, kriging 5-m cubes in several different lithologic zones. This model was updated in 1991.

8.3.4 Reconciliation

Production since startup has been 3.734 million tonnes of CIL ore at 3.57 g/t Au, 1.145 million tonnes of heap leach ore at 1.17 g/t Au, and stockpiles of 1.786 million tonnes at 1.02 g/t Au. With planned production in 1997 of 0.627 million tonnes at 2.38 g/t Au, the total mined tonnage amounts to 7.292 million tonnes averaging 2.47 g/t Au, or 18.0 million tonnes of contained gold. The preproduction reserves consisted of 8.4 million tonnes of CIL ore at 2.50 g/t Au and 1.10 million tonnes of potential heap leach ore at 0.70 g/t Au, for a total of 9.50 million tonnes at 2.29 g/t containing 21.77 tonnes of gold.

The overall gold produced and the total tonnage are lower by 17 and 23 per cent, respectively, with a commensurate increase in the average grade.

8.3.5 Reported Reserves and Resources

As at January 1, 1997, Boliden AB reports mineable reserves as follows:

Proven Ore Reserves: 750,000 tonnes at a grade of 2.2 g/t Au.

Micon classifies this reserve as Proven Ore in accordance with National Policy 2-A.

The reported reserve is due to be exhausted in August 1997.

Additional geological resources, which is the remainder of the original resource less the reported mineable reserve which is due to be exhausted in August of 1997, are 16.4 million tonnes at 1.32 g/t Au at a cutoff of 0.5 g/t Au. In Micon's opinion, this resource must be categorized as an Inferred resource due to the paucity of reliable data. (See comments above under Database). The Inferred resource is currently being evaluated by Boliden AB staff with the plan being to have Measured and Indicated Resources defined and a reserve calculation completed by September 1997[1].

Micon classifies this resource as a Possible additional mineralized concentration per Canadian National Policy 2-A.

8.4 EXPLORATION POTENTIAL

There is potential for developing ore in the margins of the existing Sukhaybarat pit and below the pit floor. A drilling programme is currently under way.

About 65 km away, SCPM is evaluating the Bulghah deposit. Approximate geographic coordinates of the centre of the proposed pit are: 24°59.262'N, 41°35.629'E. The area has been mined since ancient times, as attested by the presence of waste dumps, tools, grinding mills and filled workings.

The Bulghah project is within the Mawan concession. The Mawan concession, granted by the Ministry of Petroleum and Mineral Resources in 1992, gives the owner, SCPM, the exclusive right to explore for gold and silver. An application for a mining lease was made in June, 1996. Access is by way of 67 km of dirt track from the end of pavement at the Sukhaybarat Mine to the north-east, and 36 km of first class pavement to the Medina-Buraidah highway to the north.

[1]At the end of April, 1997, drilling has upgraded part of these resources to the Measured plus Indicated category and SCPM is evaluating the economic viability thereof.

SCPM began investigations in October, 1992, and has been active to the present day.

8.4.1 Geology

The Mawan concession area is underlain by Upper Proterozoic Nuqrah Formation, tuffite, conglomerate, marble, chert, jasper, rhyolite, keratophyre and andesite with related pyroclastics, the upper member of the Hulayfah Group. Elongate, generally concordant granitic to dioritic post-Hulayfah intrusives of uncertain age (probably Upper Proterozoic), localize gold deposits, with the smallest intrusive being the most productive.

The bulk of the known mineralization at Bulghah occurs within an elongate, north-trending medium grained biotite quartz diorite. The less mafic portions of the quartz diorite are locally mapped as tonalite. The unaltered, unweathered rock shows fresh feldspar and biotite with approximately 15 per cent quartz in a typical hypidiomorphic-granular texture. Occasionally the biotite is mixed with hornblende. A smaller intrusive immediately to the south is dioritic.

The Nuqrah Formation rocks forming prominent out-crops to the west of the intrusive are medium-grey marble, while those to the east are hornfelsed meta-volcanics, andesitic in composition.

Two late-stage intrusives cut the quartz-diorite and Nuqrah rocks, a series of narrow, steeply dipping mafic dykes, and an irregular, generally flatter-lying felsite dyke or sill, latite in composition and with a crowded porphyritic texture. The latite dykes are barren, while there seems to be some controversy as to whether or not the diabase dykes are mineralized. Ancient workings are often found adjacent to the latite dykes.

Modern exploration began with the examination of old workings in 1935 by the Saudi Arabian Mining Syndicate. Recent detailed mapping in closely spaced trenches has identified the structure controlling mineralization to be a set of northerly-trending, westerly-dipping quartz veinlets. The veinlets dip at about 35 degrees in the central portion of the mineralized body. Unfortunately, the greatest proportion of the drilling is inclined to the west, almost parallel to this structure. A second, distinctly different structure occurs on the west side of the deposit, thicker, near-vertical quartz veins with no associated iron staining. Visible gold is rarely observed.

The database consists of 18 diamond drill holes and approximately 350 reverse circulation drill holes (3.5 inch diameter). The majority of the holes are inclined at 60° to the west, with samples taken at 2-m intervals, and total samples amounting to about 16,800.

Resources/reserves: Measured and Indicated resources potentially amenable to open pit extraction are estimated at about 40 million tonnes at a grade of about a gram of gold per tonne. Resource definition and reserve estimation is under way, and a full feasibility report is due to be completed in 1997.

Micon classifies the reported resources as Measured and Indicated resources, equivalent to Proven and Probable mineralized concentrations as defined in National Policy 2-A, and concludes that the

Bulghah mineralization represents a valuable asset from which, based on SCPM's operating experience in the area, ore reserves may be determined in the near future.

8.5 CURRENT OPERATIONS

8.5.1 Mining Operations

Mining is done by two teams. The SCPM crew handles drilling and blasting, utilizing three Atlas Copco ROC 642 units. Blasting is done with Prillite and Emulite. Loading and hauling is done by a contractor. Performance has been poor, and efforts are under way to improve the situation. Mining is done on two 10-hour shifts per day, 6 days a week, 330 days per year. On average, 2.5 million tonnes is moved per year, about 7,000 tonnes per day.

Mining cost in 1996 was 6.1 riyals per tonne.

Excluding the contractor, 12 people are planned for mine operations in 1997.

8.5.2 Milling Operations

Ore is fed directly to the crushing plant from the pit. The ore is crushed in three stages by a primary jaw crusher and two cone crushers, the tertiary crusher being in closed circuit with the secondary. The final product is 100 per cent minus 14 mm and 80 per cent minus 11 to 12 mm.

The crushing plant has a capacity of 240 tonnes per hour in weathered ore and 180 tonnes per hour in fresh ore.

CIL Plant: For the CIL plant, crushed ore is fed to the grinding circuit via a 4,000-tonne fine ore bin, or by loader via a crushed ore stockpile. Heap leach ore, once crushed, is diverted to the heap leach conveyor system by reversing the collector conveyor for the final product.

Grinding in two stages in closed circuit with hydrocyclones using high saline water. The circuit consists of a 3.0-m diameter by 3.9-m long rod mill drawing about 380 kW and a secondary ball mill, 3.6-m diameter by 4.6-m long with a power input of about 900 kW. Capacity ranges from 75 to 90 tonnes per hour depending on rock hardness, for an energy consumption of 14 to 17 kWh per tonne.

Fineness ranges from k_{80} of 105 microns to k_{80} of 150 microns.

Recovery is by carbon-in-leach in one pre-leach and seven 600-m^3 adsorption tanks, in which pH is controlled by the addition of quicklime at the mill head. Sodium cyanide is added to each tank. Carbon is advanced counter-current to the feed stream. The barren pulp is pumped to the tailing pond for settling and water recovery. Gold is stripped from the carbon in an AARL process. The gold and silver in the eluate is recovered by electrowinning on steel wool which is calcined and smelted to doré bars. The doré normally contains 90 to 92 per cent gold, with the balance essentially made up by silver.

Heap Leaching: The heap leach facilities are designed to treat 600,000 tonnes per year at an irrigation time of 100 days. Cement and water are added to the ore to create a permeable agglomerate during transportation by the conveyor system to the pad area. The agglomerate is stacked on the 120,000-m^2 pads by a radial stacker in 4-m by 6-m lifts. Cyanide leaching solution is applied at a rate of 13 litres/m^2/hour. Pregnant solution is pumped from the collector pond to a five-stage carbon column circuit consisting of 2-m diameter by 4-m high tanks filled with about 2 tonnes of carbon. Flow is by gravity from tank to tank. Gold stripping and recovery from carbon is in the same facility used by the CIL process. Barren solution is treated with lime to precipitate magnesium and to adjust pH.

Milling and gold recovery costs are 19.0 riyals per tonne for CIL ore, and 5.2 riyals per tonne for heap leach ore. Mill operations and the heap leach facility will employ 35 people in 1997.

8.5.3 Historical Performance

The mine and processing plants have performed as planned. During the initial years of production, grade was lower than expected. Recently, however, more gold than predicted has been produced from fewer tonnes of ore.

Five year cash costs have ranged from US$110 to US$175/oz, total costs US$175 to US$300/oz.

8.6 FUTURE OPERATIONS

A second pushback is planned for the open pit.

Presently defined reserves will be exhausted in December, 1997. However, a pushback is scheduled to begin in April, 1997 as part of mining plans which anticipate a successful outcome of the drilling campaign noted above. Drilling is scheduled to end in April and engineering studies completed in September, 1997. Approximately 1 million tonnes of waste are planned to be removed before September, and 400,000 tonnes of ore per year in 1998 to 2001.

Once this ore has been processed, the remaining low grade, stockpiled material will be processed.

8.6.1 Cost Outlook

Saudi regulations regarding the importation or in-house manufacture of explosives are in the process of being revised. If imported explosive are allowed, explosive costs will be greatly reduced. Present planning includes the old explosive costs.

Expected capital expenditures for the planned pushback are 8 million riyals in 1997. Replacement costs between 1997 and 2001 are planned at 2 million riyals per year.

8.7 CONCLUSIONS

With the impending exhaustion of reserves, the Sukhaybarat property is reduced to an attractive exploration target. However, a successful outcome to the present drilling campaign would extend the life of the mining operation to 2001.

At the Bulghah property, reserves may be established from the Measured and Indicated mineral resources.

9.0 EXPLORATION

Boliden AB has an active programme of exploration at its mines and in the districts surrounding those mines. This exploration effort is described in each of the sections of this report that deals with the company's mining activities.

In addition, Boliden AB has an active exploration programme in several regions, these being:

- Sweden (away from current mining operations)
- Finland
- Spain
- Burkina Faso
- Argentina
- Mexico
- Saudi Arabia

9.2 SWEDEN

In addition to the extensive exploration programmes planned for the known mining districts, Boliden has several target areas scattered about northern Sweden. These include the Mardsel (45,350 hectares) and Laver (27,891 hectares) areas in the Norrbotten region. Exploration of a general reconnaissance nature also is pursued.

9.3 SPAIN

All of Boliden AB’s mineral rights in Spain (held through Apirsa) are located in the provinces of Sevilla and Huelva, and cover 10, 235 hectares (see Figure 7.4). The Spanish exploration programme is conducted by Boliden AB’s exploration group out of Sweden. For 1997, exploration expenditures in Spain are budgeted at 120 million pesetas (about US$850,000).

The exploration of the Los Frailes deposit and adjacent areas, including the Salome prospect, is described in the section on the Los Frailes project.

The remainder of the exploration programme is described below.

9.3.1 Pilar Exploration Project

Within this exploration permit, the objective for 1997 and 1998 is to drill 4 diamond drill holes to check two targets (“La Jarosa” and “Pilar Viejo”) having gravity and induced polarization (IP) anomalies, and a copper-lead soil geochemistry anomaly at the contact of Eocene-age sediments and the volcano-sedimentary lavas.

9.3.2 Patricia Exploration Project

In this holding, the El Tintillo deposit was previously drilled with 25 holes totalling 14,000 m which intersected the volcanic sequences overlain by Devonian slate and sandstone. El Tintillo contains a resource of 2.5 million tonnes of massive sulphides averaging 0.7% Cu, 6.5% Zn, 3% Pb and 50 g/t Ag. This deposit is located at a depth of about 200 m.

Total land holdings consist of mining concessions covering 6,000 hectares, with the Patricia concessions valid for 30 years from 1983; the El Tintillo concession dates from 1973 and is valid for 90 years.

The objective for 1997 is to drill 800 m in 4 holes to check a soil anomaly southwest of the El Tintillo deposit in order to expand the resources identified to date. The planned work for 1997 is estimated at C$160,000 (US$120,000), with C$300,000 (US$220,000) budgeted for each of 1998 and 1999.

9.3.3 Targets in Huelva Province

The targets are massive sulphides with zinc-copper-(gold) with attention focused on an area 10 to 15 km northwest of the famous Rio Tinto mining area. Geology and sampling plus ground magnetic and gravity surveys are planned to check possible extensions of known mineralization at the identified Esperanza, Angostura and San Eduardo targets. Esperanza is currently estimated to contain massive sulphide resources of 1.2 million tonnes at 2% Cu.

Land holdings total 282 hectares. Cost of the planned 1997 exploration programme is C$200,000 (US$150,000).

9.3.4 Exploration

The Esperanza target area (Huelva province) will be re-examined to evaluate its gold potential. The company also plans to carry out gold exploration in other areas of Spain, specifically in the province of Asturias, where the Rio Narcea Gold Project is being developed by Rio Narcea Gold Mines Ltd.

9.4 BURKINA FASO (WEST AFRICA)

Boliden AB is actively exploring for gold in the Birimian greenstone belt of Early-Proterozoic age. The geologic setting is made up of tholeitic to calc-alkaline volcanic rocks, separated by basins of volcaniclastics, greywackies and argillitic sediments. Isoclinal folding and regional-scale faulting are widespread. Major faults with associated shear zones mark the transition between the volcanics and the sediments, and localize gold deposits of the Ashanti type.

Boliden AB's Bouboulou property is a 500-hectare exploration permit located at 12^{o} 14'N, 2^{o} 15'W, northwest of Ouagadougou. The permit was granted in 1996 and is valid for 4 years and extendible for an additional 4 years.

A 3-year programme of rotary air-blast drilling, soil geochemistry and geologic mapping, to be followed by core and reverse circulation drilling of defined targets, is under way. Total cost of the 3-year programme is C$4.2 million (US$3.0 million).

9.5 FINLAND

A 2 to 3-m boulder of Boliden-type massive sulphide has been located in glacial debris in an area mapped as paragneiss-mica schist, intruded by granitic plutonic rocks, 35 km southeast of Karleby.

Boliden AB has 9 exploration permits covering 80 km^2; these are renewable in one-year increments.

A 5-month programme of till sampling and geological data compilation is planned for 1997 at a cost of C$60,000 (US$45,000).

9.6 ARGENTINA

Boliden AB has signed a joint-venture agreement, subject to regulatory approval, with Oro Belle Resources Corporation of Vancouver. (Oro Belle is 46 per cent controlled by Viceroy Resource Corporation). The joint-venture will explore an area in Chubut Province, sharing costs 50:50. Oro Belle will be the operator.

The joint venture does not have any land holdings as at April 1, 1997.

9.7 MEXICO

Boliden AB has announced (1997) that it has executed an agreement with Silver Eagle Resources Ltd. of Vancouver to explore the Minera Serrana project in Mexico. Under this agreement, Boliden AB can earn a 51 per cent interest in Silver Eagle's working interest in the project by expending US$1.4 million over a four-year period. Silver Eagle holds the property by agreement with Serrana SA de CV.

The property comprises several concessions totalling 57,189 acres (23,144 hectares) in the San Felipe, El Gachi and Moctezuma lead-zinc-silver districts in north-central Sonora state. The property contains zinc-lead-silver resources as well as potentially retreatable old mine tailings.

Boliden AB also will assist Silver Eagle with its exploration efforts for zinc, copper and gold elsewhere in Mexico by providing US$100,000 for this purpose in the first year of the agreement.

9.8 SAUDI ARABIA

Exploration by the SCPM joint venture has resulted in the discovery of the Bulghah gold deposit of some 40 million tonnes of one gram per tonne of gold, which is described in detail in Section 7.0 of this report.

10.0 ENVIRONMENTAL CONSIDERATIONS

10.1 INTRODUCTION

This portion of the report addresses the environmental aspects of the Boliden AB mining operations. The focus has been placed on environmental liability since it impacts on the value of the properties reviewed. For mining properties, the largest form of environmental liability is the cost for final reclamation of the site to a form acceptable to the local authority. A brief review is also completed of Boliden AB's environmental management system since it reflects on the company's ability to comply with directives from authorities during operation and at closure.

10.2 ENVIRONMENTAL MANAGEMENT

Direction for environmental management at the mines and mills is provided by Mr. Lars-Åke Lindahl, Vice President, Environment for Boliden AB. The environmental management group for mining and milling is based at Boliden, Sweden, and is coordinated by Mr. Manfred Lindvall. The group's function is to provide consulting services to individual operations, conduct internal audits, and coordinate site environmental activities. Day-to-day activities at each property are completed by trained site personnel, who may have additional responsibilities beyond environmental issues.

Boliden AB developed a formal environmental management system in the 1980's characterized by: environmental policy, strict responsibility structure, internal auditing, and regular reporting to the government, employees and the public.

Micon was impressed with the qualifications and knowledge of all members of the environmental management team. They have a good understanding of international mining environmental activities, and promote knowledge sharing activities with North American mining companies. Boliden AB has a significant amount of reclamation work proposed for the next several years, and includes two international operations in Spain and Saudi Arabia which require significant travel time to inspect. Additional personnel are required in the environmental management team to ensure that high quality of environmental management is continued.

Proposed mining projects in Sweden are individually licensed according to whether they are: ecologically justified, technically practicable and economically feasible. Effluent standards are defined on a case-by-case basis, and are not country-wide. Environmental monitoring is conducted at all sites according to permit requirements, as well as best management practices. There are no known compliance problems at any of the operations.

Boliden AB has made a concerted effort to reduce its emissions to the environment at all properties. Documents reviewed show that this has been successful. Figure 10.1 demonstrates the success that Boliden AB has had releasing metal emissions to the environment during the last number of years (1996 data are preliminary). The most striking changes in environmental emissions occurred during the 1980's. Between 1970 and early 1990, emissions of copper, lead and zinc to water from Boliden AB's mining and milling operations were reduced by more than 95%.

FIGURE 10.1

Boliden AB is a member of the International Council on Metals and the Environment (ICME), a non-governmental organization that promotes sound environment and safety management, in the production of metals. A recent publication by ICME and the United Nations Environment Programme (UNEP) highlighted Boliden AB's Environmental Management System.

Environmental audits have been completed since approximately 1989, on an annual basis at all mines in Sweden, as well as operations in Spain and Saudi Arabia. Environmental audits are reviewed by area managers as well as the Vice President of Environment. The audits are completed by personnel not directly responsible for day to day activities at the site. This practice is acceptable, although periodic independent environment audits should be conducted, at key sites.

10.3 RECLAMATION OBLIGATIONS

Environmental issues related to mining are regulated under the Swedish Environmental Protection Act (SEPA). This act was promulgated in 1969. Prior to that time, there was no environmental legislation, or legal requirement for environmental management in Sweden. Sweden does not have specific mining reclamation legislation or regulations. The first stated requirement for reclamation of damaged lands was in the 1989 revision of the SEPA. The legal obligation for mining reclamation in Sweden is not well defined. There are no current or expected future requirements for reclamation bonding.

The SEPA's position is that land owners cannot avoid responsibility for any damage on lands under its control, but its responsibility should be proportional to the time since operations ceased. Boliden AB's position (and apparently that of most Swedish industry) is that companies are responsible for reclamation of only operations which were active after 1969 (the date of promulgation of the SEPA). A draft of proposed amendments apparently holds land owners responsible for the reclamation of all lands active after 1969. Boliden AB has no expectation that land owners will become responsible for historical activities pre-dating 1969.

Boliden AB has indicated that it may continue voluntarily to cooperate and provide financial support to the Swedish Environmental Protection Agency for the reclamation of abandoned mining sites. This appears to be an acceptable arrangement to both Boliden AB and the SEPA at this time, and promotes good industry-government relations.

For the purposes of environmental liability assessment, it has been assumed that Boliden AB will be responsible for reclamation costs associated with all properties that were active after 1968. Table 10.1 contains a listing of these properties, as well as basic information such as dates of operation and type of property.

Table 10.2 provides a similar listing, of properties which became inactive prior to 1969. Boliden AB does not expect to be responsible for the reclamation of these sites. Micon's technical opinion is that if Boliden AB conducted work on the sites after 1969 (such as reclamation), they may have some reclamation responsibility, although it is anticipated to be at a level of less than 100%. Three of the operations reviewed were closed prior to 1969, but have been re-entered by Boliden AB to conduct repairs, environmental studies or reclamation work (see Table 10.1). The liability for these properties is currently unknown. Responsibility for one of these operations, the Boliden Waste Dump, is considered a test case to assess the SEPA's position on environmental liability at older properties.

The obligation for Boliden AB to prepare closure plans is on a site-by-site basis. Boliden AB is gradually preparing closure plans for all active sites. Table 10.3 lists the current status of closure planning for each of the operations listed in Table 10.1.

10.4 RECLAMATION COSTING

Reclamation costs and potential environmental liability are addressed in this report for all operations active after 1968. In general, liability associated with properties closed prior to 1969 is as listed in Table 10.2. Three operations have been assigned costs by Micon for which Boliden AB considers to have no responsibility: Lainejaur, Laver and Kalvsbäcken. For these sites, Boliden AB has assigned only minor costs if any, relating primarily to repair work. Micon has assessed Boliden AB 50% of the estimated reclamation costs for these operations for reasons outlined in the tables in Appendix II. The cost for reclamation of these properties is not material to the total reclamation cost for all of the Boliden AB properties.

Environmental liability associated with potential future operations is not assessed, since there is no existing liability. This liability should be addressed within the economic evaluation for the project.

The environmental liability associated with each of the properties which have not been closed, and a few that are closed but required additional work, are addressed in individual tables in Appendix II. An asterisk (*) has been placed beside the names of the operations in Table 10.1 that are considered in detail in Appendix II.

The cost estimates provided to Micon were based on a summary table prepared in December 1996, which stated an accuracy of ± 20%. The table itself was based on estimates from various Boliden AB employees dating from 1993 to 1996, escalated to 1996 currency values. Boliden AB revised some of its estimates in April, 1997, as reflected in Table 10.3.

10.4.1 Accuracy

The accuracy of the reclamation cost estimates should be considered as a function of each site's closure plan status. The properties are at various stages of reclamation planning, and accuracy, in the liability assessment. In some cases, preliminary reclamation design has not been completed, and plans are only at a conceptual level. Boliden AB indicated that it does not have a high confidence in some of the estimates provided. As a result, in some instances, Micon has felt it necessary to modify Boliden AB's estimates, or develop independent reclamation estimates. In these cases only, Micon has included a 15 per cent contingency to its estimates.

10.4.2 Administration / Project Management

Boliden AB has included an allowance of 20 per cent in each of its cost estimates to address contingency and project management fees. Costs associated with Boliden AB personnel involved in reclamation are addressed under the operating budget for Boliden AB's environmental management group. This is reasonable, given that Boliden AB is proactive and attempts to reclaim projects on a progressive basis. If the salaries and expenses associated with internal management were to be taken out of the operating costs, it could be expected to be in the order of 5 per cent of the reclamation cost.

Administration and project management costs are often expressed as a percentage in the range of 5 to 20 per cent of a total reclamation budget, exclusive of contingency. There are a large number of operations involved, and liaison is expected to be required with government officials. If sudden closure of all operations was required, the administration costs could be expected to rise substantially, to up to a total of 20 per cent of the final cost. This reflects an expected requirement for consulting support or additional personnel.

As per industry standards, Micon has not included an assessment of property, building or equipment value in its estimate. Salvage value for scrap was also excluded. It is impossible to assess market conditions at some future time for these materials. At more remote sites even highly marketable equipment such as mill may have limited value. The Boliden AB estimate for Apirsa assumed that reclamation of the industrial site would be financially supported by the sale of equipment and materials contained therein.

It is believed that Micon's estimates are reasonable, and ranges of costs have been provided in several instances where the information available is insufficient.

10.5 ENVIRONMENTAL LIABILITY

The sections that follow summarize the findings regarding environmental liability by geographic area. An overall summary follows the section on exploration properties. The liability by individual property is summarized in Table 10.3.

10.5.1 Boliden Area

The Boliden Area contains more than twenty operations which were active after 1968. The highest environmental liability costs are associated with the large industrial complexes at Boliden and Kristineberg. These areas also have had little to no formal reclamation planning to date. Over half of the total cost estimated by Micon applies to reclamation of these operations.

Micon has assessed the environmental liability for the Boliden Area as between US$17.5 million and US$22.5 million including contingency and project management allowances. Boliden AB's revised April 1997 estimate is US$14.9 million to US$17.3 million.

10.5.2 Laisvall Area

Micon has accepted Boliden AB's estimated reclamation cost for the Laisvall operation. Boliden AB's estimate was US$2.4 million to US$2.9 million.

10.5.3 Aitik Area

The Aitik Area includes the operating Aitik operation and the closed Laver Mine. Micon has accepted Boliden AB's April, 1997, revised cost estimate for Aitik and considers it reasonable to conservative. Micon has also allowed a cost for reclamation of the Laver Mine for which Boliden AB currently does not accept responsibility. Micon's estimated liability for the Aitik Area is US$41.3 million to US$41.5 million. Boliden AB's estimate is US$41.0 million.

10.5.4 Garpenberg Area

The Garpenberg Area consists of two primary mines, Garpenberg and Garpenberg North, an associated industrial area, and with a number of closed mines. Several reclamation cost estimates have been prepared by Boliden AB and the SEPA for these operations and other areas of historical environmental degradation (Appendix II). Boliden AB has assigned costs for reclamation of Garpenberg and Garpenberg North, along with its perception of responsibility for other areas. Boliden AB's estimate for the area is US$6.8 million to US$8.9 million. Micon's estimate (US$7.7 million to US$9.3 million) is somewhat higher and reflects the addition of costs associated with the Kalvsbäcken site.

10.5.5 International Operations

Several reclamation cost estimates for the Apirsa operation were available for Micon's review. A revised April, 1997, estimate addressed reclamation of the concentrator and industrial area. Micon's estimate is US$10.5 million, increased from Boliden AB's estimate of US$9.0 million.

Boliden AB has not developed detailed costs for reclamation of the Sukhaybarat operation in Saudi Arabia. Micon developed a crude total estimate of US$3.15 million (including contingency and project management factors), based on its experience and understanding of the site. Boliden AB is expected to support 50 per cent of this cost (US$1.6 million). There is an additional environmental liability for this operation associated with pumping a contaminated groundwater plume to the surface. Micon has allowed US$0.75 million in this amount, to address the cost of on-going pumping and environmental monitoring of the programme. It has been assumed that capital costs for the pumping programme will not exceed US$0.5 million.

10.5.6 Exploration Properties

Boliden AB exploration properties are not expected to pose a major environmental liability. Reclamation requirements for these properties can be expected to include: capping of diamond drill holes, infilling of trenching or pits, removal of site infrastructure, minor regrading, and revegetation.

In the time frame available, insufficient information is available to review outstanding reclamation liability associated with each exploration property. The total reclamation cost for these exploration properties has been assumed to be in the order of US$0.5 million.

The primary concern, which cannot be quantified at this time, is the level of environmental liability Boliden has accepted by entering historical mining sites for exploration purposes. While there is limited concern for the Swedish exploration properties, this may not be the case in other parts of the world. For example, the Minera Serrana project in Mexico includes a tailings deposit. It is unknown whether Boliden will become wholly, or partly responsible for reclamation of the deposit, if tailings samples are collected for exploration purposes. In North America this might be the case.

10.5.7 Summary of Environmental Liability

The total reclamation cost for the properties as outlined previously has been defined by Boliden AB in its revised 1997 estimate as US$75.2 million to US$80.2 million. Micon's review has resulted in an estimate of US$81.4 million to US$88.7 million. Costs for reclamation of the exploration properties were not included in the Boliden AB estimate. In addition, it is believed that Boliden's estimates for decommissioning and reclamation of the industrial areas at Boliden, Kristineberg and Apirsa are somewhat optimistic. The Micon estimate is well within the ± 20% accuracy Boliden AB stated for its estimate.

The Micon estimate assumes that all costs will be realized as a capital cost on closure of the property. In fact, Boliden AB is current with international management strategies in this aspect, and conducts progressive reclamation during operation whenever possible. As a result, a portion of Micon's estimate of US$81.4 million to US$88.7 million may be realized as an operating cost. Considerable effort is required to be able to assess the operating and capital reclamation costs independently. Micon believes that allocation of 50 per cent of the reclamation to on-going operating costs is reasonable.

Table 10.1
SUMMARY OF PROPERTIES ACTIVE AFTER 1968

	Operating Period	Current Status	Characteristics
Boliden			
Boliden*	1953-	O	concentrator
Boliden*	1925-1967	S	open pit, underground mine
Kristineberg*	1940-91	S	concentrator
Kristineberg*	1940-	O	underground mine, open pits
Åkulla West*	1997-	DEV / O	open pit
Petiknäs*	1992-	O	underground mine
Akerberg*	1990-	O	open pit, underground mine
Åsen West	1988-93	C	open pit, underground mine
Holmtjärn*	1984-92	C	underground mine
Udden	1971-91	C	underground mine and open pit
Kimheden*	1968-74	C	open pit and underground
Långdal*	1967-	O	underground mine, open pit
Kankberg*	1966-69, 89-97	O	open pit, underground mine
Kedträsk	1966-71, 89-91	C	underground mine (exploration)
Brännmyran		-	government owned
Rakkejaur*	1966-75	S	open pit and shaft
Näsliden*	1966-71	C	underground mine and open pit
Långsele	1965-89	C	underground mine and open pits
Renström*	1956-91	O	underground mine
Rudtjebäcken*	1952-	C	underground mine
Åkulla East	1951-75	S / DEV	open pit
Rävliden Group*	1947-57	C	underground and open pit mines
Lainejaur*	1943-91	C	underground mine
Boliden Waste Dump*	1941-45	C	waste rock stockpile
Boliden Tramway*	1926-28[1]	C	overhead tramway
	-		
Laisvall			
Laisvall*	1943-	O	concentrator, underground mine
Stekenjokk	1976-88	C	conc., open pit, underground mine
Aitik			
Aitik*	1968-	O	concentrator, open pit
Laver*	1936-46[1]	C	open pits
Garpenberg			
Garpenberg*	1956-	O	conc., und. mine, open pits
Garpenberg North*	1972-	O	open pit, underground mine
Enåsen*	1984-91	C	conc., open pit, underground mine

	Operating Period	Current Status	Characteristics
Hallefors	1978-79	C	underground mine, waste rock
Gränsgruvan	1972-78	C	underground mine
Vassbo*	1960-82	C	conc., underground mine, open pit
Kaveltorp	1967-71	C	underground mine, wasterock
Saxberget*	1958-88	C	concentrator, underground mine
Ljusnarsberg	1957-75	C	underground mine, wasterock
Silvergruvan	?-1978	C	underground mine
Kalvsbäcken*	1957-63[1]	C	underground mine, tailings area
International Operations			
Apirsa*	1979-	O	concentrator
Los Frailes*	1997-	O	open pit
Aznalcóllar	1979[2]-96	D	open pit
Sukhaybarat*	1991-	O	concentrator, open pits

Current Status: DEV, in development; O, operating; S, suspended; D, being reclaimed; C, closed
* Detailed review of liability contained in Appendix II
[1] Environmental work / reclamation conducted after 1968
[2] Acquired by Boliden AB in 1987

Table 10.2
SUMMARY OF PROPERTIES OPERATED PRIOR TO 1969

	Operating Period	Current Status	Characteristics
Östra Hogkulla	1951-59	C	underground mine, open pit
Mensträsk[1]	1945-48	C	underground mine
Bjurfors	1941-45	C	underground mine
Varuträsk	1936-46	C	quarry

[1] Hoist house has been redeveloped for tourism as a restaurant / pub, and is an important terminal for the local cableway.

Table 10.3
SUMMARY OF ENVIRONMENTAL LIABILITY BY GEOGRAPHIC AREA

	Closure Plan Status	Boliden AB Estimate (US$)	Micon Estimate (US$)
Boliden Area			
Boliden - industrial area	Pe	1.7-2.1	2-4
Boliden - mines	Pe	0.57	0.57
Boliden - tailings area	P	1-2	2-4
Kristineberg - industrial, tailings area	Pe, A	5.54**	5.57-6.57
Kristineberg - mines	-	1.85	1.85
Åkulla West	A	na	0.1
Renström / Petiknäs	A	1	1
Akerberg	A	0.43	0.43
Holmtjärn	C	0.007	0.007
Kimheden	C	0.021	0.021
Långdal	A	0.71	0.71
Kankberg	A	1	1
Rakkejaur	Pe	1-2	2
Näsliden	C	0.036	0.075
Rudtjebäcken	C	0.004	0.004
Rävlidmyr	C	0.043	0.043
Hornträsk	C	0.029	0.029
Lainejaur*	-	0.007	0.042-0.080
Total		**14.9-17.3**	**17.5-22.5**
Laisvall			
Total		**2.4-2.9**	**2.4-2.9**
Aitik			
Aitik	P	41.0**	41.0
Laver*	-	0	0.25-0.5
Total		**41.0**	**41.3-41.5**
Garpenberg			
Garpenberg and Garpenberg North	P (tails)	5.36-6.93	5.36-6.93
Enåsen	C	0.75-1.28	1.28
Vassbo*	-	0.014	0.014
Saxberget	C	0.71	0.71
Kalvsbäcken*	-	0	0.38
Total		**6.8-8.9**	**7.7-9.3**
International Operations			
Apirsa	Pe	9.0**	10.5
Sukhaybarat (50% of total)	Pe	1.1**	1.5
Total		**10.1**	**12.0**
Exploration Properties			
Estimate for All Areas **Total**	**-**	**0**	**0.5**
Grand Total		**75.2-80.2**	**81.4-88.7**

Closure Plan Status: C, completed / under completion; A, approved plan; P, under permit review / preparing for application; Pe, pending. This information is listed to provide a general qualification of the level of accuracy of Boliden AB's estimate.
* Boliden AB does not accept responsibility for reclamation of the property, but Micon believes these costs will be incurred.
** Revised April 1997.

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APPENDIX I

CONCENTRATE SPECIFICATIONS

APPENDIX I

CONCENTRATE SPECIFICATIONS FOR THE BOLIDEN AB MINES

The following pages describe the detailed specifications of the concentrates produced by the mines of Boliden AB in Sweden. In order to interpret these, it should be explained that the suffix “1” refers to the Boliden central concentrator, “3” refers to Laisvall, “5” to Aitik and “9” to Garpenberg. Los Frailes refers to the concentrates produced in Spain by Boliden Apirsa from the Los Frailes mine.

ZINC CONCENTRATES

Type analyses		Zn-1-N	Zn-3-N	Zn-9-N	Los Frailes
Zn	%	54.4	58.8	53.2	47
Au	g/t	2.0	<0.1	0.28	0.8
Ag	g/t	149	23	108	110
Cu	%	0.56	0.042	0.22	0.45
Fe	%	7.5	1.55	9.2	10.8
Co	%	0.022	0.007	0.023	0.0005
Ni	%	0.017	0.018	0.015	0.0005
Pb	%	1.22	1.58	1.92	1.7
Cd	%	0.19	0.23	0.15	0.16
Hg	%	0.024	0.0015	0.0015	0.0475
Ti	%	<0.002	<0.002	<0.002	0.002
Ge	%	<0.005	<0.005	<0.005	<0.0025
Sn	%	<0.2	<0.2	<0.2	0.008
Bi	%	0.002	<0.002	<0.002	0.0058
Sb	%	0.018	0.002	0.006	0.06
As	%	0.16	0.008	<0.005	0.2
Mo	%	<0.005	<0.005	<0.005	0.0015
Te	%	<0.002	<0.002	0.004	<0.005
Se	%	0.002	0.003	0.012	<0.005
S	%	29.7	30.3	32.1	35
SiO_2	%	1.72	6.0	1.25	0.15
Al_2O_3	%	0.19	0.43	0.13	<0.05
MgO	%	0.54	0.31	0.40	<0.05
Mn	%	0.066	0.03	0.93	0.05
CaO	%	0.40	0.28	0.45	<0.05
Na_2O	%	0.017	0.014	0.010	<0.05
K_2O	%	0.04	0.18	0.03	<0.05
F	%	0.014	0.022	0.028	<0.001
Ci	%	<0.001	0.038	<0.001	<0.001
BaO	%	0.02	0.09	0.03	<0.01
TiO_2	%	0.03	0.13	0.02	<0.005
Cr	%	0.015	0.023	0.010	0.001
In	%	<0.005	<0.005	<0.005	0.0035
Sieve analysis accumulated weight percentage	<180um <90um <45um <20um	100.0 99.0 91.0 77.5	99.7 92.9 71.7 53.1	99.0 93.7 70.7 46.7	100.0 100.0 97.5 825
Density compacted	t/m³	2.6-2.7	2.6-2.7	2.6-2.7	1.8
Stowage factor	m³/t	0.37-0.39	0.36-0.38	0.36-0.38	0.55
Angle of repose at moisture content. %		46-52° 2-10	48-53° 3-9	44-47° 2-8	43° -
Transportable moisture limit (at Proctorindex 70) mc %		10.5-11.4	9.9-10.8	9.6-11.1	10.9
Normal moisture content at dressing plant %		8.2	7.1	7.6	10.2

COPPER CONCENTRATES

Type analyses		Cu-1	Cu-5	Cu-9	Los Frailes
Cu	%	21.7	28.5	22.1	21
Au	g/t	42.9	9.2	50.6	1.5
Ag	g/t	1,553	196	12,890	1,600
Pb	%	5.6	0.10	8.5	5
Fe	%	24.8	28.8	23.1	27.5
Co	%	0.050	0.062	0.042	-
Ni	%	0.033	0.024	0.028	0.0007
Zn	%	4.9	0.26	7.3	5.0
Cd	%	0.018	0.001	0.025	0.02
Hg	%	0.0136	0.0054	0.0041	0.0075
Ti	%	<0.002	<0.002	<0.002	0.002
Ge	%	<0.005	<0.005	<0.005	<0.0025
Sn	%	<0.2	<0.2	<0.2	0.03
Bi	%	0.011	0.010	0.004	0.010-0.018
Sb	%	0.16	0.029	0.47	0.70-1.60
As	%	0.34	<0.005	<0.005	0.40
Mo	%	<0.005	0.052	<0.005	0.0025
Te	%	0.005	0.003	0.003	<0.005
Se	%	0.023	0.003	0.002	<0.002
S	%	31.8	33.4	30.9	35
SiO_2	%	2.5	4.3	2.5	0.15
Al_2O_3	%	0.29	1.10	0.18	<0.05
MgO	%	2.65	0.41	1.32	<0.05
Mn	%	0.02	0.05	0.26	0.0125
CaO	%	0.38	0.43	0.42	<0.05
Na_2O	%	0.30	0.31	0.29	<0.05
K_2O	%	0.03	0.39	0.03	<0.05
F	%	0.054	0.009	0.062	<0.001
Ci	%	0.004	<0.001	<0.001	<0.001
BaO	%	0.01	0.07	0.02	<0.001
TiO_2	%	0.05	0.05	0.02	<0.005
Cr	%	0.023	0.090	0.020	0.001
In	%	0.005	<0.005	<0.005	0.003
Sieve analysis accumulated weight percentage	<180um <90um <45um <20um	99.9 96.8 81.0 55.2	99.1 90.6 62.7	99.9 92.7 68.3 42.6	100.0 100.0 98.0 82.0
Density compacted	t/m³	2.5-2.7	2.7-2.8	-	2.0
Stowage factor	m³/t	0.37-0.39	0.35-0.37		0.49
Angle of repose at moisture content. %		- -	- -	- -	42° -
Transportable moisture limit (at Proctorindex 70) mc %		10.7-12.8	8.9-9.9	-	10.7
Normal moisture content at dressing plant %		7.7	6.4	8.2	10.0

GOLD SILVER CONCENTRATES

Type analyses		Cu-1-Au	Pb-9-Au
Au	g/t	1,500	150
Ag	g/t	2,204	8,257
Pb	%	6.4	57.8
Cu	%	0.54	0.071
Fe	%	40.2	14.4
Co	%	0.15	0.030
Ni	%	0.11	0.014
Zn	%	1.69	1.75
Cd	%	0.005	0.006
Hg	%	0.026	0.0011
Ti	%	0.002	<0.002
Ge	%	<0.005	<0.005
Sn	%	<0.2	<0.2
Bi	%	0.012	0.023
Sb	%	0.086	0.16
As	%	1.34	0.039
Mo	%	<0.005	<0.005
Te	%	0.004	0.003
Se	%	0.019	0.003
S	%	45.5	22.0
SiO_2	%	0.67	1.48
Al_2O_3	%	0.05	0.22
MgO	%	0.70	1.1
Mn	%	0.05	0.24
CaO	%	0.26	0.63
Na_2O	%	0.31	0.2
K_2O	%	0.01	0.02
F	%	0.004	0.024
Ci	%	0.002	0.003
BaO	%	0.01	0.07
TiO_2	%	1.16	0.04
Cr	%	0.037	0.035
In	%	<0.005	<0.005
Sieve analysis accumulated weight percentage	<180um <90um <45um <20um	61.1 38.7 9.4 1.2	93.8 67.1 14.0 1.5
Density compacted	t/m^3	-	-
Stowage factor	m^3/t	-	-
Angle of repose at moisture content. %		-	-
Transportable moisture limit (at Proctorindex 70). mc %		-	-
Normal moisture content at dressing plant %		7.8	8.8

LEAD CONCENTRATES

Type analyses		Pb-1	Pb-3	Pb-9	Los Frailes
Pb	%	40.1	78.5	68.4	48
Au	g/t	6.2	<0.1	2.0	2
Ag	g/t	1,482	169	1,530	650
Cu	%	1.79	0.011	0.64	1.7
Fe	%	12.9	0.31	4.3	15
Co	%	0.034	0.010	0.017	0.001
Ni	%	0.017	0.015	0.020	0.0005
Zn	%	10.7	1.21	5.7	6.5
Cd	%	0.036	0.008	0.019	0.02
Hg	%	0.0065	0.0001	0.0003	0.0078
Ti	%	0.004	<0.002	<0.002	0.033
Ge	%	<0.005	<0005	<0.005	<0.0025
Sn	%	<0.2	<0.2	<0.2	0.01
Bi	%	0.055	<0.002	0.028	0.060
Sb	%	0.36	0.015	0.10	0.50
As	%	0.36	<0.005	0.006	0.32
Mo	%	<0.005	<0.005	<0.005	<0.0025
Te	%	0.008	0.003	0.003	0.006
Se	%	0.037	0.003	<0.002	<0.0025
S	%	25.8	13.3	16.7	27
SiO_2	%	3.47	4.53	2.21	0.1
Al_2O_3	%	0.28	0.65	0.12	<0.05
MgO	%	2.1	0.02	0.82	<0.05
Mn	%	0.05	0.03	0.26	0.015
CaO	%	0.65	0.40	0.56	<0.05
$Na_2 O$	%	0.4	0.3	0.014	<0.05
K_2O	%	0.03	0.30	0.02	<0.05
F	%	0.034	0.026	0.046	<0.001
Ci	%	<0.001	0.002	<0.001	<0.001
BaO	%	0.04	0.16	0.08	<0.01
TiO_2	%	0.04	0.12	0.04	<0.005
Cr	%	0.027	0.017	0.040	0.0005
In	%	<0.005	<0.005	<0.005	0.001
Sieve analysis accumulated weight percentage	<180um	99.8	99.9	99.9	100.0
	<90um	96.0	97.6	97.3	100.0
	<45um	82.6	85.5	82.0	97.5
	<20um	50.4	64.7	62.8	82.0
Density compacted	t/m^3	2.9-4.2	3.7-4.2	3.7-3.9	2.8
Stowage factor	m^3/t	0.24-0.35	0.24-0.27	0.26-0.27	0.36
Angle of repose at moisture content. %		46-49° 3-7	46-48° 2-6	49-51° 3-7	38° -
Transportable moisture limit (at Proctorindex 70) mc %		7.1-10.8	6.9-8.0	7.4-8.4	7.7
Normal moisture content at dressing plant %		8.7	5.6	5.7	8.0

APPENDIX II

RECLAMATION COSTS/ENVIRONMENTAL LIABILITY

PER PROPERTY

BY GEOGRAPHIC AREA

BOLIDEN AREA

Operation	BOLIDEN (INDUSTRIAL AREA)
Location	Northern Sweden, Boliden Area
Status	Operating
Main Features	Industrial area, 'Korea' pond (zinc pyrite storage)
Proposed Reclamation	No defined plan. Expect to demolish buildings, place contaminated soil in silos underground, cover with fresh material and revegetate. Although drainage from 'Korea' pond reports to tailings area, after drying the pond will be capped and revegetated.
Boliden AB Reclamation Cost Estimate	No detail available. Total Estimate US$1.7 to 2.1 million (12 to 15 million SEK)
Micon Confirmation	The industrial area includes approximately 36 ha that has been impacted by up to seventy years of mining and related operations. The 'Korea' pond covers and area of approximately 3.4 ha. There are an estimated 34 buildings or building complexes, that require demolition. It is believed that the amount allocated by Boliden AB is optimistic. Costs for reclamation of the Boliden AB industrial area are anticipated to be in the following range: Micon Estimate (including contingency) US$2 to 4 million
Other Issues	As per industry standards, there has been no assessment of cost recovery potential in the industrial site reclamation. It is expected that part of these costs could be recovered if the market allowed at time of closure.

Operation	BOLIDEN (MINES)
Location	Northern Sweden, Boliden Area
Status	Suspended
Main Features	Underground mine, open pit (7 ha)
Proposed Reclamation	No defined plan. Currently infilling open pit on a sporadic basis with tailings and waste
Boliden AB Reclamation Cost Estimate	No detail available. Total Estimate US$0.57 million (4 million SEK)
Micon Confirmation	Assuming that the pit continues to be filled during operations, and additional filling is not required at closure, the cost above is reasonable. This should provide sufficient funds to cover the in-filled pit and revegetate. Micon Confirmation US$0.57 million (4 million SEK)
Other Issues	None known

Operation	BOLIDEN (TAILINGS AREA)
Location	Northern Sweden, Boliden Area
Status	Operating
Main Features	Tailing management facility, lime treatment plant, associated internal settling pond, clarifying pond
Proposed Reclamation	Not as yet defined. Several options being considered.
Boliden AB Reclamation Cost Estimate	No details available. Preliminary estimate only. Total Estimate US$1 to 2 million (7 to 14 million SEK)
Micon Confirmation	The tailings area covers an area of approximately of approximately 240 ha. Flooding is a reasonably economic reclamation solution for an area of this size that will prevent acid generation. Maintenance of saturated conditions and placement of wetland plants may also be feasible. These alternatives may require raising of the dams. It is assumed that raising of the dam will be carried as an operating cost. The clarifying pond will be left in place. All dams will likely require resloping to ensure long term stability. Based on these scenarios, and comparison of costs to Aitik tailings area (US$2.89 million excluding dams), it is believed that the Boliden AB estimate is optimistic. The following cost estimate is believed to be more reasonable: Micon Estimate (including contingency) US$2 to 4 million
Other Issues	None known

Operation	KRISTINEBERG (INDUSTRIAL AND TAILINGS AREAS)
Location	Northern Sweden, Boliden Area
Status	Suspended
Main Features	Concentrator and tailings area
Proposed Reclamation	Decommission concentrator, demolition of buildings, excavation of contaminated material for burial on site (likely in open pit), and cap impacted areas with till for revegetation. It is expected that the facility was constructed, at least in part, on top of waste rock. Soil contamination is known to be present in the vicinity of the concentrator. Environmental issues were one of the reasons that operation of the concentration was suspended. Tailings facility is comprised of five areas. Areas 1, 1b, and 2 have been reclaimed, supported in part financially by the Environmental Protection Agency. Limited work remains to be completed on these areas. Areas 3 and 4 will be joined by lowering the separating dam, and flooded to the extent possible. Approximately 40% will remain dry (unflooded) and will be capped, and revegetated. It is assumed that the lower dam will be resloped, capped and revegetated. A spillway will be constructed in order that natural drainage can be restored.
Boliden AB Reclamation Cost Estimate	No detail available. Cost Estimate, Industrial area, US$2.0 million (Revised April, 1997) Cost Estimate, Tailings area, US$3.57 million (25 million SEK). Note reclamation of Areas 1 and 2 cost approximately US$1.7 million. Total Estimate US$5.57 million
Micon Confirmation	Industrial Area: The industrial area covers approximately 15 ha, and contains eight major buildings or building complexes (excluding headframe / hoist), along with additional support structures. The Boliden AB estimate is believed to be optimistic. Micon Estimate (including contingency) US$2 to 3 million Tailings Area: The portion of tailings area 3 and 4 not expected to flood has a surface area of 41 ha. This surface as well as the dams will require capping and revegetation. Micon accepts the cost estimate above as reasonable, assuming that the lower dams do not need to be raised substantially. Micon Confirmation US$3.57 million (25 million SEK)
Other Issues	None known

Operation	KRISTINEBERG (MINES)
Location	Northern Sweden, Boliden Area
Status	Operating (underground) / closed (2 open pits)
Main Features	Two non-operating open pits, operating underground mine, waste rock storage area (adjacent to tailings area 2
Proposed Reclamation	Fill two open pits after sealing ramp to underground, remove headframe and hoist, transfer the waste rock either to open pits or flood in tailings area.
Boliden AB Reclamation Cost Estimate	No detail available. Cost summarized as US$0.71 million (5 million SEK) for open pits and US$1.15 million (8 million SEK) for mine closure. Total Estimate US$1.85 million(13 million SEK)
Micon Confirmation	Insufficient information is available to fully assess cost. The cost assigned appears reasonable. Micon Confirmation US$1.85 million
Other Issues	None known

Operation	ÅKULLA WEST (Åkulla East is only at exploration stage)
Location	Northern Sweden, Boliden Area
Status	Previously closed operations now in redevelopment
Main Features	Small surface disturbance expected.
Proposed Reclamation	Sulphidic soil and waste rock to be deposited in pit, covered and revegetated. Pit is expected to flood in the long term.
Boliden AB Reclamation Cost Estimate	Not defined
Micon Confirmation	Insufficient information available to accurately assess. Costs are expected to be in the range of: Micon Estimate (including contingency) US$100,000
Other Issues	None known

Operation	RENSTRÖM / PETIKNÄS
Location	Northern Sweden, Boliden Area
Status	Operating
Main Features	Underground mine (2), service buildings, sedimentation basin, large waste rock storage area (Renström), temporary waste rock area (Petiknäs). No acid generation concerns.
Proposed Reclamation	Renström: demolish buildings, cover waste rock with overburden and revegetate, reclamation of impacted areas Petiknäs: remove buildings (all mobile), transfer any remaining waste rock material underground, reclaim impacted areas
Boliden AB Reclamation Cost Estimate	No detail available. Total Estimate US$1 million (7 million SEK)
Micon Confirmation	Review of site plans for the area suggests that this estimate is reasonable. Micon Confirmation US$1 million (7 million SEK)
Other Issues	None known

Operation	AKERBERG
Location	Northern Sweden, Boliden Area
Status	Operating
Main Features	Open pit, underground mine, waste rock stockpile, marginal ore stockpile
Proposed Reclamation	Recontour existing waste rock pile and pit slopes to 3:1. A fence will be established around the pit to prevent inadvertent entry, since the pit is not expected to flood.
Boliden AB Reclamation Cost Estimate	No detail available Total Estimate US$0.43 million (3 million SEK)
Micon Confirmation	The estimate is reasonable, assuming that the authorities do not require the waste rock to be capped. Acid mine drainage is not of concern. Micon Confirmation US$0.43 million (3 million SEK)
Other Issues	None known

Operation	LÅNGDAL
Location	Northern Sweden, Boliden Area
Status	Operating
Main Features	Underground mine, open pit situated in the Skellefteå River, waste rock and

	marginal ore stockpiles, dyke system separating the open pit from the river
Proposed Reclamation	Building and headframe will be demolished. Waste rock with the highest acid generation potential will be transferred to the open pit. The material will be covered by stockpiled river sediment. Steel dykes currently controlling the river's channel will be removed. The pit will be allowed to flood, and the river will return to its original course.
Boliden AB Reclamation Cost Estimate	No detail available. Total Estimate US$0.71 million (5 million SEK)
Micon Confirmation	The cost for removal of the dyke and allowing the pit to flood will be low. Removal of the building and headframe is not expected to exceed US$150,000. This allows approximately US$500,000 for remaining site work, including reclamation of the waste rock storage areas. This is expected to be sufficient. Micon Confirmation US$0.71 million (5 million SEK)
Other Issues	None known

Operation	KANKBERG
Location	Northern Sweden, Boliden Area
Status	Suspended Operation, may be used to access Åkulla East Mine
Main Features	Open pit, underground mine, waste rock (pyritic) storage area, support buildings
Proposed Reclamation	Waste rock will be transferred to the open pit if access to underground is not required. The pit will flood once the underground is sealed, maintaining much of the waste rock under saturated conditions. A cap may or may not be required. Support buildings will be demolished and the area revegetated. The mine water treatment system removed and mine water pond resloped. If the pit is to remain open for underground access, the waste rock could be capped in place.
Boliden AB Reclamation Cost Estimate	No detail available. Total Estimate US$1 million (7 million SEK)
Micon Confirmation	The volume of waste rock at site was not available. Micon reviewed the proposed reclamation cost based on a capping scenario. This alternative is expected to be as costly as transferral of the waste rock to the open pit. Based on this assessment, and an assumption that the pit will flood without additional costs, Micon agrees with the estimate. Micon Confirmation US$1 million (7 million SEK)
Other Issues	None known

Operation	RAKKEJAUR
Location	Northern Sweden, Boliden Area
Status	Suspended, ore is not treatable
Main Features	Open pit, exploration shaft, waste rock / crushed ore stockpile, water treatment plant
Proposed Reclamation	Ore and sides of open pit are strongly acid generating. Ore will be transferred to the open pit. Estimated tonnage on surface is 10 to 15 million tonnes. Pit slopes and the ore will be covered and revegetated. Once reclamation is complete and acceptable water quality is obtained in any site runoff, the treatment plant will be removed.
Boliden AB Reclamation Cost Estimate	No detail available. Total Estimate US$1 to 2 million (7 to 14 million SEK)
Micon Confirmation	The largest cost will be transferring the crushed ore to the open pit. Depending on the amount of ore taken off-site, there may not be sufficient room for all of the crushed ore in the pit. Material that can not be placed in the open pit should be left in place. A cap will be required over the open pit and remaining stockpile area. Without details regarding the pit capacity, it is not possible to derive an accurate cost. Based on placement of 50% of the material back in the pit, and capping of the remainder, Micon developed a crude estimate (+/- 50%) of US$2 million. This is at the upper range of the Boliden AB estimate. Micon Confirmation US$2 million
Other Issues	None known

Operation	NÄSLIDEN
Location	Northern Sweden, Boliden Area
Status	Closed - some additional work required
Main Features	Site was previously reclaimed, but only a 0.3 m cap was placed on acid generating waste rock. Acidic seepage from waste rock impacting surrounding area.
Proposed Reclamation	Placement of additional compacted till over area slope of concern.
Boliden AB Reclamation Cost Estimate	No detail available Total Estimate US$36,000 (0.25 million SEK)
Micon Confirmation	Cover should be placed over entire waste rock area to alleviate any future acid generation concerns. An increased cost is suggested to allow for placement of a second cap and replanting of affected forest area. Micon Estimate (including contingency) US$75,000
Other Issues	None known

Operation	BOLIDEN TRAMWAY
Location	Northern Sweden, Boliden Area
Status	Cables have been removed, poles and three junctions remain. One section has been ret cableway
Main Features	Approximately 100 km of periodic wooden poles, with some infrastructure
Proposed Reclamation	None proposed. Tourist / historic resource
Boliden AB Reclamation Cost Estimate	No work expected
Micon Confirmation	No work expected
Other Issues	None known

Operation	BOLIDEN WASTE DUMP
Location	Northern Sweden, Boliden Area
Status	Inactive
Main Features	Historic waste rock stockpile (approximately 6 ha) associated with original commissioning of the Boliden Mine (1926 to 1928). Local people have constructed small storage sheds on top of the stockpile. Acidic seepage from the stockpile has impacted the creek below (Klintforsån). A lime treatment plant was constructed with cooperation of authorities in 1991.
Proposed Reclamation	None proposed. Considered a strategic legal case to clarify the responsibility for pre-1969 environmental issues.
Boliden AB Reclamation Cost Estimate	None expected. Options available include: remove waste rock and process; deposit in Boliden open pit or tailings area; and cap at existing location. Investigations are to be conducted in 1997 to better assess the reclamation options.
Micon Confirmation	Based on current understanding it appears that Boliden AB has no responsibility. It is expected that they may voluntarily provide assistance, either financially or in the active reclamation.
Other Issues	The issue is primarily legal. To date, Boliden AB has invested approximately US$150,000. Final reclamation costs are expected to be in the order of US$1 to US$2 million.

OTHER BOLIDEN AREA OPERATIONS
WITH MINOR OUTSTANDING RECLAMATION

OPERATION	OUTSTANDING RECLAMATION COSTS[1]	
	US$	SEK
BOLIDEN AREA		
Kimheden	21,000	150,000
Rävlidmyr (Rävliden I and II)	43,000	300,000
Hornträsk (Rävliden IV)	29,000	200,000
Holmtjärn	7,000	50,000
Lainejaur	7,000	50,000
Rudtjebäcken	4,000	25,000
Total	111,000	775,000

[1] Micon accepts Boliden AB's estimates as reasonable, since even a 100% increase does not substantially affect Boliden AB's overall environmental liability.

Lainejaur property operated only until 1945. Boliden AB does not accept responsibility for reclamation. Boliden AB has assigned only minor costs. Reclamation of the property to improve visual aesthetics and reduce environmental impacts is expected to cost in the order of US$70,000 to US$145,000 (0.5 to 1 million SEK). Micon has assigned 50% of this reclamation cost in Table 10.3.

LAISVALL

Operation	LAISVALL
Location	Northern Sweden, Laisvall Area
Status	Operating
Main Features	Concentrator, underground mine, three tailings areas (one active area, two areas revegetated), clarifying pond
Proposed Reclamation	Decommission industrial area, reslope clarifying pond dam (approximately 500 m length), revegetate active tailings area (approximately 22 ha). The ore is a sandstone-quartz and acid generation is not of concern.
Boliden AB Reclamation Cost Estimate	No detail is available. A 1993 estimate which was escalated in 1996 to US$2.43 to US$2.86 million (17 to 20 million SEK). Boliden AB believe the cost is conservative. Total Estimate US$2.43 to 2.86 million
Micon Confirmation	The cost estimate is reasonable based on the information reviewed. The largest proportion of the cost is assigned to decommissioning the industrial area. The concentrator has operated since the 1940's and as a result there may be considerable contamination with lead, zinc, as well as other materials. It has been assumed that contaminated materials could be stored underground on site. Micon Confirmation US$2.43 to 2.86 million
Other Issues	There is an outstanding legal action associated with a dam failure and tailings spill last year. Approximately 100,000 m^3 of tailings were spilled from the active tailings area over a 4 hour period. The tailings spilled through existing ditches and was controlled from reaching Lake Aisjaure. The majority of the tailings have been cleaned up and ditching restored. While the water quality of the effluent released from the clarifying pond and discharge was affected, the exceedance was apparently within normal operating variations.

AITIK

Operation	AITIK
Location	Northern Sweden, Aitik Area
Status	Operating
Main Features	Concentrator, large open pit, large shallow tailings management facility, waste rock stockpiles (east and west)
Proposed Reclamation	Decommission of industrial area; open pit allowed to flood; dams resloped to 3:1 from current 2:1; 90% to 95% of tailings area will flood, options for beach include vegetate with or without a simple till cap, or redistribute tailings to ensure sulphide material is buried Extensive testing has been completed to assess the acid generating potential of the tailings and waste rock. The tailings has been shown to be non-acid generating. A portion of the waste rock is acid generating, and has been segregated from the remaining material as much as possible. Future waste rock handling operations will attempt to place waste rock to reduce the amount of resloping required of the upper tailings dam (and cause a significant reclamation cost reduction).
Boliden AB Reclamation Cost Estimate	A preliminary estimate has been completed by Boliden AB which assumes that capping of the tailings surface will not be required: Industrial area: US$1.43 million (10 million SEK) Dams: US$21.51 million (150.6 million SEK) Tailings facility: US$2.89 million (20.25 million SEK) Waste rock: US$4.94 million (34.6 million SEK) Contingency and project management (20%): US$6.16 million (43.09 million SEK) Total Estimate US$36.9 million (258.54 million SEK) Total Estimate (Revised April, 1997) US$41.0 million
Micon Confirmation	Approximately 58% of the proposed reclamation costs are associated with the resloping of the tailings and clarifier pond dams. A significant cost reduction can be obtained by using a 2.5:1 angle on the upstream slopes (approximately US$2 million). While it may make it more difficult to revegetate the slopes, it should not affect dam stability. Further cost savings may be possible with placement of future waste rock directly in mined out portions of the open pit. The unit costs used for placement of a cover over the waste rock and for revegetation appear low, but may be accurate given Boliden AB's expertise and the large scale of the reclamation project. There is no allowance provided for reclaiming the open pit, such as resloping exposed benches to allow revegetation. Overall, Micon believes that the Aitik reclamation cost estimate is reasonable to conservative, particularly given the inclusion of a 20% contingency / administration amount. Micon Confirmation of revised estimate (including contingency) US$41.0 million

Other Issues	There is an outstanding issue of dust releases from the tailings area. Compensation has been paid to neighbours. Boliden AB are currently trying to mitigate the issue, but to date have not been entirely successful. Maintenance of a water cover and vegetation of exposed areas will ensure that the problem does not continue after closure.
Operation	LAVER
Location	Northern Sweden, Aitik Area
Status	Closed - operated only until 1946
Main Features	Waste rock area, open pit, tailings area
Proposed Reclamation	No work proposed by Boliden AB.
Boliden AB Reclamation Cost Estimate	No work is proposed
Micon Confirmation	Although the property was only operated until 1945, Boliden AB entered the property and conducted reclamation work in the 1970's. Acid generation is of concern. Micon believes that by entering the property, Boliden AB may have accepted some responsibility for clean up of the remainder of the property. In the worse case, this may require development of a cap over the unsaturated portion of the tailings area (8.1 ha) to help prevent acidic drainage, and further revegetation work. In the worse case where Boliden AB might be asked to support 50% of the cost. This could amount to US$250,000 to $500,000. Micon Estimate (including contingency) US$250,000 to $500,000
Other Issues	None known

GARPENBERG

<table>
<tr><td>Operation</td><td>GARPENBERG AND GARPENBERG NORTH</td></tr>
<tr><td>Location</td><td>Central Sweden, Garpenberg Area</td></tr>
<tr><td>Status</td><td>Operating</td></tr>
<tr><td>Main Features</td><td>Concentrator, underground mine (2), tailings area (Ryllshyttemagasinet)</td></tr>
<tr><td>Proposed Reclamation</td><td>Decommission industrial area and cap shafts, saturate tailings and seed directly. Small areas which can not maintain saturation will be capped prior to revegetation</td></tr>
<tr><td>Boliden AB Reclamation Cost Details</td><td>Several estimates have been made of the costs for this area as listed below (in million SEK):
<table>
<tr><td></td><td colspan="3">Boliden AB Estimates</td><td>EPA</td></tr>
<tr><td></td><td>1996</td><td>1995</td><td>1993</td><td>1993</td></tr>
<tr><td>Industrial Area*</td><td>11</td><td>9 / 9</td><td>8</td><td>na / 5</td></tr>
<tr><td>RyllshyttemTailings Area*</td><td>6[1]</td><td>20 / 31</td><td>31.2</td><td>55 / 45</td></tr>
<tr><td>L. Bredsjön Tailings Area**</td><td>na</td><td>13 / 13</td><td>16.6</td><td>20 / 15</td></tr>
<tr><td>Västra Sand. Tailings Area</td><td>na</td><td>7 / 8</td><td>7.1</td><td>15 / 10</td></tr>
<tr><td>Odalfältet Waste Rock</td><td>na</td><td>5 / 5</td><td>6.8</td><td>na / 5</td></tr>
</table>
* Active after 1969
** Operated by Boliden AB 1957-1963
[1] M. Lindvall indicated low confidence in this assessment and suggested that the 1995 estimate of 20 to 31 million SEK is likely to be more realistic (and is carried forward to the next estimate).</td></tr>
<tr><td>Boliden AB Reclamation Cost Estimate</td><td>It is believed that Boliden AB will only be strictly financially responsible for the clean up of the areas noted above which were active after 1969. They may choose provide additional support on a voluntary or negotiated basis in the future, should government monies be allocated.

Mr. Lindvall, Environmental Coordinator for Boliden AB estimated that in the worse case Boliden AB could be responsible for approximately 50% of the reclamation costs for the Lilla Bredsjön tailings area that they operated from 1957 to 1963, and 20% of the reclamation costs of the historical waste rock area (Varp inom Odalfältet) at Garpenberg. Based on this assessment which appears reasonable, the following costs could be allocated to Boliden AB (in US$ million):
<table>
<tr><td></td><td colspan="2">Recent Estimate</td><td colspan="2">Boliden AB's Proportion</td></tr>
<tr><td></td><td>SEK</td><td>US$</td><td>SEK</td><td>US$</td></tr>
<tr><td>Industrial Area*</td><td>11</td><td>1.57</td><td>11</td><td>1.57</td></tr>
<tr><td>RyllshyttemTailings Area*</td><td>20-31</td><td>2.86-4.43</td><td>20-31</td><td>2.86-4.43</td></tr>
<tr><td>L. Bredsjön Tailings Area**</td><td>13</td><td>1.86</td><td>13</td><td>0.93</td></tr>
<tr><td>Västra Sand. Tailings Area</td><td>7.5</td><td>1.07</td><td>0</td><td>0</td></tr>
<tr><td>Odalfältet Waste Rock</td><td>5</td><td>0.72</td><td>1</td><td>0.14</td></tr>
</table>
Total Estimate US$5.36 to 6.93 million</td></tr>
<tr><td>Micon Confirmation</td><td>Based on the information currently available Boliden AB's estimate as listed immediately above is considered reasonable. The greatest uncertainty relates to reclamation of the two tailings areas (Ryllshyttem and Lilla Bredsjön), and waste rock issues which are not well defined at this time.

Micon Confirmation US$5.36 to 6.93 million</td></tr>
<tr><td>Other Issues</td><td>The Garpenberg area is a historical mining district that shows evidence of long term environmental degradation. The majority of these activities occurred before Boliden AB entered the area in 1956. There are on-going negotiations regarding the clean-up of the some the historical areas. Boliden AB has previously offered voluntary financial support to the region, however the government was unable to support its portion of the costs, and the negotiated agreement was revoked.</td></tr>
</table>

	The reclamation plan proposed retains the dam that currently separates the tailings basins. Micon has some concern regarding the stability of this structure since it was built on top of tailings.

Operation	ENÅSEN
Location	Central Sweden, Garpenberg Area
Status	Closed in 1991 - some additional work required
Main Features	Concentrator, open pit (partially flooded), underground mine (ramp access from open pit), waste rock storage, tailing facility (revegetated)
Proposed Reclamation	Open pit is currently flooding, and will reach an equilibrium level in approximately 16 years. Additional work required for waste rock area which is currently under observation. Capping of the waste rock is proposed. The industrial area is being maintained in suspension, and will require demolition and decommissioning. There is no schedule for proposed work.
Boliden AB Reclamation Cost Estimate	Industrial Area: US$0.71 million (5 million SEK) Waste Rock Area: US$0.04 to 0.57 million (0.3 - 4 million SEK) Total Estimate US$0.75 to 1.28 million
Micon Confirmation	Sufficient funds are allocated for decommissioning of the mine site, particularly since it is relatively modern in operation. Boliden AB is apparently attempting to find additional ore to feed the mill, or alternatively, to sell the operation. The variation in the costs to reclaim the waste rock area is because it is currently unknown whether the material is acid generating. Since sulphides were present in the ore, it is believed that the upper estimate may be more realistic. Micon Confirmation US$1.28 million
Other Issues	None known

Operation	SAXBERGET
Location	Central Sweden, Garpenberg Area
Status	Closed in 1989 - some additional work required
Main Features	Concentrator (decommissioned), underground mine, tailings facility (capped and revegetated), old industrial areas (decommissioned). Work was completed by Boliden AB in conjunction with the Swedish authorities.
Proposed Reclamation	Mill has been removed and the immediately surrounding area cleaned. Remaining buildings on site require decommissioning and demolition. The industrial area was constructed on top of limited quantities of waste rock. Waste rock is acid generating, but to date, seepage has not been of concern. Surfaces require reshaping, capping and revegetation. There is an area of subsidence that requires resloping. No additional work on the tailings area is expected to be required.
Boliden AB Reclamation Cost Estimate	No detail available. Total Estimate US$0.71 million (5 million SEK)
Micon Confirmation	Considerable reclamation has already been successfully completed on this site. It is expected that Boliden AB will close the rest of the site with the same level of competency. Based on the information reviewed, the cost assessed by Boliden AB does not appear to be overly conservative, but is accepted as reasonable. Micon Confirmation US$0.71 million
Other Issues	None known

Operation	KALVSBÄCKEN
Location	Central Sweden, Garpenberg Area
Status	Closed in 1963
Main Features	Acid generating tailings area, minor waste rock storage, underground mine
Proposed Reclamation	None proposed, no communication from authorities
Boliden AB Reclamation Cost Estimate	No work proposed
Micon Confirmation	Property was operated from 1957 to 1963. Boliden AB does not accept responsibility for the property. The tailings area (maximum of 10 ha) was revegetated by Boliden AB in 1974-4, but the slope has subsequently eroded. There is clear evidence of acid generation on the slopes. There are also small quantities of waste rock on the surface, and it is expected that the shafts were only capped with timber. No buildings remain. In addition, Trelleborg has a recreational complex at the property. It is therefore expected that Boliden AB may complete reclamation of the property, despite its position on responsibility. US$0.75 million is a very crude estimate based on the expected area of impact. No maps were available for review. Micon has assumed that Boliden AB would be responsible for 50% of the cost. Micon Estimate (including contingency) US$0.38 million
Other Issues	None known

OTHER GARPENBERG AREA OPERATIONS
WITH MINOR OUTSTANDING RECLAMATION

OPERATION	OUTSTANDING RECLAMATION COSTS[1]	
	US$	SEK
GARPENBERG AREA		
Vassbo	14,000	100,000

[1] Micon accepts Boliden AB's estimates as reasonable, since even a 100% increase does not substantially affect Boliden AB's overall environmental liability.

Vassbo was reclaimed under approval in 1980's. Subsequently, there were instances of lead poisoning of local dogs. Additional work was completed including removal of contaminated soil and revegetation. Recently, the local community has been using the area for a landfill. Improper site management has caused the revegetated area to degrade, and initiated a dust problem. The community asked the Environmental Protection Agency to force Boliden AB to complete additional work on the site, apparently not recognizing that its operator was the cause. The Environmental Protection Agency refused to act. The cost listed above is the cost required to reclaim the area disturbed by the municipal landfill, although Boliden AB does not accept responsibility. They may of goodwill reclaim the area since they have the knowledge to undertake the project successfully.

INTERNATIONAL OPERATIONS

Operation	APIRSA
Location	Southern Spain
Status	Operating (one open pit mine non-operating)
Main Features	Concentrator, operating open pit mine (Los Frailes Mine), mined out open pit (Aznalcollar Mine), several large areas of waste rock storage (acid generating), tailing management facility (acid generating)
Proposed Reclamation	Concentrator and infrastructure: no detail is available. Boliden AB has assumed that sale of buildings / equipment will cover the cost of decommissioning. Aznalcollar Mine: infilling with new waste rock (assumed to be addressed under current operating costs), natural flooding to within 10 to 20 m of surface. Los Frailes Mine: will flood at closure. Waste rock areas: to be covered with overburden. Tailings: conceptual plan is for tailings area to be dried, covered with clay cap and revegetated.
Boliden AB Reclamation Cost Estimate	Three cost estimates were provided as follows: March 1997, Boliden AB estimated of the cost of a four year abandonment programme: reclamation of tailings facility and treatment of water US$6.84 million (924 M pesatas) December 1996, Dames & Moore estimated costs for reclamation of only the tailings facility (no water treatment included) US$1.60 million (216 M pesatas) June 1996, Anexo Plan de Restauration, estimated cost for reclamation of waste rock storage areas over the period of 1996 to 2005, excludes cost for placing cap. This will be funded as an on-going operating cost for the Los Frailes pit. US$1.14 million (153.282 M pesatas) Total Estimate (Revised April, 1997) US$9.0 million
Micon Confirmation	The March 1997 estimate for reclamation of the tailings facility may be reasonable, but is not considered conservative by Micon, and portions of the plan may require modification. The plan proposes to plant shrubs and trees on top of a shallow 0.3 (slopes) to 0.5 m (primary surface) clay cap. This is strongly discouraged, since the roots will increase the permeability of the clay cap, and provide an easy pathway for water and oxygen to enter the tailings, and could cause an acid generation problem. If plants with deep root systems are to be planted a thicker cap at a substantially increased handling cost, will be required. Boliden AB developed June 1996 estimate of US$1.14 million for reclamation of approximately 425 ha of waste rock, excluding placement of low permeability cap. Boliden AB's plan is to cover the existing waste rock areas with material

	removed during development of the Los Frailes pit. This cost is apparently addressed within Los Frailes operating costs for removal of overburden. A cost in the order of US$5 million is expected to be required to cap this area if it were costed solely as a reclamation activity. Revegetation of the cap will be required to reduce dust problems, and enhance runoff from the stockpiles. Boliden AB has estimated a cost of US$1.14 million for completion of reclamation work outside of placement of a overburden cap. Micon believes that this may be inadequate to ensure revegetation success. Micon has added an allowance of US$1 million to allow for additional work, such as placement of an organic supplement. As with the tailings described above, planting of shrubs and trees on top of a shallow clay cap is strongly discouraged. An additional sum is required to address decommissioning of the concentrator and removal of infrastructure. Limited detail was reviewed, however a cost in the order of US$1.5 million would not be unreasonable. Micon Qualified Confirmation / Estimate US$10.5 million
Other Issues	The tailings management facility is currently seeping, and may have impacted an adjacent river (already heavily contaminated). Investigations have been conducted to remedy the situation, and it is believed that Boliden AB has the problem in hand. Apirsa is the only Boliden AB operation known to have a reclamation bond. A 90 million pesatas (US$0.67 million) irrevocable bank guarantee has been submitted to the Mines Authority.

Operation	SUKHAYBARAT
Location	Saudi Arabia
Status	Operating
Main Features	Mill, heap leach, associated ponds, main open pit, Red Hill satellite open pit, rock stockpiles (ore, waste rock, low grade ore, marginal ore), active tailings basin, historical tailings dams
Proposed Reclamation	No defined plan; verbally, remove buildings and infrastructure, surround open pits with brick walls, minor reshaping of site, pumping and evaporation of a contaminated groundwater plume
Boliden AB Reclamation Cost Estimate	No detail available. Note comments under 'Other Issues' below. Crude estimate of US$20,000/a to maintain pumping of contaminated groundwater to surface for evaporation. Boliden Revised Estimate (April, 1997) US$1.1 million
Micon Confirmation	Major costs are not expected for this site. The mill and existing infrastructure must be removed (waste material may be able to be deposited in the open pit). The heap leach and waste rock can be left virtually in the existing condition. Recontouring of the site and removal of ponds will be necessary. Sludge can be buried in the tailings facility. Dams associated with the modern and historical tailings facility may require reshaping for stability purposes and to ensure that water is not held. The pits should be surrounded by walls for safety. Micon Crude Estimate (including contingency) US$1.75 million Boliden AB Portion (50%) US$ 0.875 million
Other Issues	The original tailings facility was active from 1991 to 1995. The facility did not contain liquids effectively, and a plume of highly saline water (60,000 mg/L total dissolved solids) was released into the aquifer. The plume is not contaminated with high level of metals or cyanide. On discovery of the problem, a new tailings facility with an impermeable liner and drainage collection system was constructed. This facility has operated successfully. The plume of saline water is travelling toward a local bedouin village, which has multiple water sources. Natural water quality at the village contains approximately 2,500 mg/L total dissolved solids. The plume will reach the village in approximately 3 to 4 years if no actions are taken.

	Investigations are currently being completed to assess the corrective actions required. Boliden AB does not accept the 'no action' alternative. It is expected that the only reasonable form of remediation is to pump the contaminated water to the surface. During operation, this water can be re-used in the mill without treatment. If the plume has not been fully removed by the time the operation closes, pumping will continue to be required. The easiest form of treatment will be to allow the water to evaporate, and create a surface salt pan. A powerline, or solar cells will be required to maintain the pumps at closure until the plume is withdrawn. Boliden AB has provided a rough estimate of the on-going cost for pumping as US$20,000/a. Micon's crude estimate of cost for on-going pumping and an allowance for associated capital costs: US$1.25 million Boliden AB Portion (50%) US$0.625 million