Technical Report Summary
Salobo Operations
Pará State
Brazil

Report current as at: December 31, 2021

Qualified Persons	**Signature**	**Date**
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1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

This technical report summary (the Report) was prepared for Vale S.A. (Vale) on the Salobo Operations in the Carajás Mining District, Pará State, Brazil.

1.2 TERMS OF REFERENCE

The Report was prepared to be attached as an exhibit to support mineral property disclosure, including mineral resource and mineral reserve estimates, for the Salobo Operations in Vale's Form 6-K and Form 20F for the year ending 31 December 2021.

Mineral resources and mineral reserves are reported for the Salobo deposit.

The Salobo Operations consist of the Salobo open pit, and associated processing facilities producing a copper–gold concentrate.

Unless otherwise indicated, all financial values are reported in US currency. The metric system is used in the Report unless otherwise noted. Mineral resources and mineral reserves are reported using the definitions in Subpart 229.1300 – Disclosure by Registrants Engaged in Mining Operations in Regulation S–K 1300 (SK1300). The Report uses Canadian English.

1.3 PROPERTY SETTING

The Salobo Operations are situated in the Carajás Mining District, Pará State, Brazil, 90 km northwest of the city of Carajás.

The property is connected via an all-weather road network to the cities of Parauapebas (80 km), Marabá (240 km), and there is a commercial airport at Carajás (90 km). Railroads link Carajás with the port city of São Luis.

The Salobo Operations are located in an area that has significant mining activity. As a result, local and regional infrastructure and the supply of goods available to support mining operations is well-established. Personnel with experience in mining-related activities are available in the Carajás district.

Salobo is in the northwest of the Carajás region and is within the Tapirapé–Aquiri National Forest. In the mine area, the topography is steep, varying between 190–520 m in elevation. The area is heavily forested and dominated by relative dense trees with substantial underbrush.

The Carajás region is within the eastern Amazon humid tropical rainforest and has distinct wet and dry seasons. Mining operations are conducted year-round.

1.4 OWNERSHIP

Vale uses its wholly owned subsidiary, Salobo Metais S.A. (Salobo Metais), as operator of the Salobo Operations. The Salobo Operations are wholly-owned by Salobo Metais S.A., an indirect subsidiary of Vale S.A.

The term "Vale Base Metals" refers to the base metals division of Vale S.A. led by its wholly owned subsidiary, Vale Canada Limited, comprised of nickel and copper mining, smelting and refining assets in Canada, Brazil, Indonesia, the United Kingdom and Japan, including the production and sale of cobalt, platinum group metals, and other precious metals as by-products of nickel and copper mining and processing operations. Vale Canada is the corporate head for the Base Metals operations and assets globally. Vale Canada is also the ultimate holding company / parent company for all Base Metals assets except for Salobo Metais, Onca Puma and Sossego Operations, which fall under Vale SA.

1.5 MINERAL TENURE, SURFACE RIGHTS, WATER RIGHTS, ROYALTIES AND AGREEMENTS

Salobo Operations are located within one mining concession, granted for copper ore by the National Mining Agency (*Agência Nacional de Mineração – ANM)* former National Department of Mineral Production (DNPM), licence 807.426/74 on 16 July 1987, and defined as a polygon covering 9,180.6 ha. In 2002, changes to the Exploitation Economic Plan allowing Vale to extract silver and gold were approved by ANM. An annual report is required to be lodged with the ANM, detailing the production for the year. This reporting obligation has been met for each year since concession grant.

There are no property agreements relevant to the Salobo Operations.

Three water permits are current. Vale also has water usage permits for surface and groundwater, granted in 2020, that are valid for a 10-year period. Renewal of all permits can be requested and renewed by the relevant regulatory authority.

Brazilian legislation separates surface ownership from sub-surface ownership. The Salobo Operations are located entirely within the National Forest of Tapirapé–Aquiri, therefore the surface rights belong to the Federal Government. There are no associated payments related to surface rights for the operations.

The Financial Compensation for Mineral Exploitation (CFEM in the Brazilian acronym) was enacted by legislation in 1989 and varies depending on the mineral product. The Salobo Operations are subject to the CFEM. The state of Pará imposes a tax on mineral production, which the Salobo Operations must also pay.

Wheaton Precious Metals entered into three different life-of-mine (LOM) gold stream agreements on the Salobo Operations with Vale (through a wholly-owned subsidiary), each for 25%, for a total of 75%. In each of the agreements, Wheaton Precious Metals agreed to ongoing payments of the lesser of US$400/oz (subject to a 1% annual inflation adjustment that commenced in 2019 on the entire 75% stream) and the prevailing market price for each ounce of gold delivered under the agreement. Also, Wheaton will be required to make an additional payment to Vale, that is expected to range from $550 million to $670 million depending on certain contractual completion tests.

1.6 GEOLOGY AND MINERALIZATION

The Salobo deposit is an example of an iron oxide copper–gold (IOCG) deposit.

The deposit is hosted in the Carajás Mining District within Carajás Province, a sigmoidal-shaped, west–northwest–east–southeast-trending late Archean basin.

The Archean basin contains a basement assemblage that is dominated by granite–tonalitic ortho-gneisses of the Pium Complex, and amphibolite, gneisses and migmatites of the Xingu Complex. The basement rocks are overlain by volcanic and sedimentary rocks of the Itacaiúnas Supergroup, which includes the Igarapé Salobo Group, the Igarapé Pojuca Group, Grão Pará Group and the Igarapé Bahia Group. The Itacaiúnas Supergroup hosts all the Carajás IOCG deposits, including Salobo.

The deposit mineralization is hosted by upper-greenschist-to-lower-amphibolite-metamorphosed rocks of the Igarapé Salobo Group. The major host units are biotite and magnetite schists. The Salobo hydrothermal system has a core of massive magnetite that is surrounded by less intensely altered rocks. Away from the massive magnetite, the magnetite content gradually diminishes, giving way to biotite–garnet schist and/or garnet–grunerite schist.

The deposit extends over an area of approximately 4 km along strike (west–northwest), is 100–600 m wide, and has been recognized to depths of 750 m below the surface. The Salobo mineralization is limited in strike extent but remains open at depth below the current design pit.

Sulphide mineralization typically consists of assemblages of magnetite–chalcopyrite–bornite and magnetite–bornite–chalcocite. Accessory minerals include hematite, molybdenite, ilmenite, uraninite, graphite, digenite, covellite, and sulfosalts.

1.7 HISTORY

All exploration and development was conducted by Vale or predecessor companies Docegeo, the exploration division of Companhia Vale do Rio Doce (CVRD), and CVRD. CVRD changed its name to Vale in 2007.

Copper mineralization was discovered in the Igarapé Salobo region in 1974. Detailed exploration commenced in 1977.

A scoping study was completed in 1981, and pilot studies ran from 1985 to 1987, culminating in the grant of a mining concession. A prefeasibility study was concluded in 1988, an initial feasibility study was conducted in 1998, updates to the feasibility study were undertaken in 2001 and 2002, and a final study was completed in 2004. The Salobo Operations commenced pre-stripping in 2009, and the first concentrate was produced in 2012. The process plant was upgraded in 2014 and is currently undergoing a second upgrade.

1.8 EXPLORATION, DRILLING, AND SAMPLING

1.8.1 EXPLORATION

More regional exploration continues to be executed in the mining concession, but current exploration results are not the focus of this report.

1.8.2 DRILLING

The primary drill method is core drilling, with a total of 577 core holes (206,768 m) completed.

The surface drilling was initiated with HQ diameter core (63.5 mm) and usually continued with NQ diameter (47.6 mm). The minimum diameters were BX (42 mm) and BQ (36.4 mm). Underground drilling in the exploration adits was performed using BX rods.

1.8.3 SAMPLING

Exploration core sample intervals averaged 1 m in mineralized zones, and between 2 m and 4 m in barren zones. Core was halved, and one half was bagged and submitted for sample preparation and analysis, and the remaining half core was retained as a backup in the same original boxes.

Blastholes are currently drilled on a 5 m x 5 m (or 5 m x 7 m) grid and are channel sampled. All blastholes located in ore zones are sampled; however, as the blasthole reaches the barren zones, the proportion of sampled holes decreases to include only those holes in the mineralized envelope.

1.8.4 DENSITY DETERMINATIONS

The density determination methodology consisted of the water-displacement method. Specific gravity (SG) was measured on approximately 132,000 samples collected across the entire deposit.

1.8.5 SAMPLE PREPARATION AND ANALYSIS

Vale used both internal and external laboratories for its sample analysis.

Quality assurance and quality control (QA/QC) programs varied over time and initially (pre-2002) mostly included seldom submission of external assay checks and, to lesser extent, standard reference material (standard) samples and coarse duplicates. In the 2002–2003 drilling campaign, the QA/QC program consisted of the sample preparation blanks, standard samples, pulp duplicates and external assay checks. The most recent QA/QC program (2017 to present) includes sample preparation blank (2.5% frequency), standard samples (2.5%), twin or core duplicate samples (1%), coarse reject duplicates (2.5%), the SAG

Same and different batch pulp duplicates (both at 2.5% frequency) and external assay checks (5%). The results are monitored regularly either by third-party consultants retained by Vale, or by Vale staff.

The sample preparation, analysis, quality control, and security procedures used by the Salobo Operations have changed over time to meet evolving industry practices. Practices at the time the information was collected were industry-standard. The sample preparation, analysis, quality control, and security procedures used by the Salobo Operations are considered sufficient to provide sample results that are reliable to support estimation of mineral resources, mineral reserves, and in mine planning.

1.9 DATA VERIFICATION

Checks were performed by software data checking routines that rigorously verify data acceptance. All new assay data being added to the database were monitored daily and validated monthly for accuracy and consistency by comparing the data transferred to the database to the assay certificates received from the laboratories.

Vale had data collection procedures in place that included several verification steps designed to ensure database integrity. Vale staff also conducted regular logging, sampling, laboratory and database reviews. In addition to these internal checks Vale contracted independent consultants to perform laboratory, database and mine study reviews. The process of active database quality control and internal and external audits generally resulted in quality data.

Vale currently uses a system of “layered responsibility” to ensure that only appropriately verified data are used for estimation purposes. The concept of a system of “layered responsibility” is that individuals at each level within the organization assume responsibility, through a sign-off or certification process, for the work relating to preparation of mineral resource and mineral reserve estimates that they are most actively involved in. Mineral reserve, mineral resource and exploration target estimates are prepared and certified by qualified persons at the mine site level and are subsequently reviewed by qualified persons at the Vale Base Metals corporate level. Where there is more than one mine, the mine qualified persons prepare and sign on the estimates for their mine and provide them to the operations qualified persons, and then to the qualified persons at the Vale Base Metals corporate level.

Vale and its predecessor companies commissioned several audits and third-party reviews of block models, mineral resources and mineral reserves.

As a result of these activities, data that have been verified on upload to the database, and checked using the layered responsibility protocols, are acceptable for use in mineral resource and mineral reserve estimation.

1.10 METALLURGICAL TESTWORK

The mineralogy and metallurgical performance of the Salobo deposit is well understood, based on a combination of the initial metallurgical testwork programs and a decade of production data.

1.11 MINERAL RESOURCE ESTIMATES

1.11.1 ESTIMATION METHODOLOGY

Vale has a set of protocols and guidelines in place to support the estimation process, which the estimators must follow.

Estimation was performed as a team effort involving several technical disciplines. The mineral resource estimate is supported by core drilling. Software used included LeapFrog, Deswik and Isatis.

Block grades and density were estimated using ordinary kriging (OK) in Isatis software.

Classification of blocks was assigned by drilling density in which the measured category required four drill holes in a 60 m radius window, indicated required three drill holes in a 110 m radius window, and inferred needed two drill holes within a 250 m radius window. Subsequently, this automated classification was adjusted to recode any anomalous blocks situated in an area that otherwise had a common category.

Mineral resources were confined within a conceptual pit shell. External mining dilution and mine loss were not applied. The resulting pit extents were considered for reasonableness, such as any potential impact on planned mine infrastructure (waste laydown areas, processing facilities), distribution of deleterious elements, and adequateness of the current waste rock storage facility (WRSF) capacities. Pit inter-ramp slope angles range from 27–61º.

The commodity pricing forecasts were established using a consensus approach based on long-term analyst and bank forecasts, supplemented with research by Vale's internal specialists. This approach is considered reasonable for support of mineral resource estimates. The estimated timeframe used for the price forecasts is the 32-year LOM that supports the mineral reserve estimates.

Mineral resources are reported using a break-even cut-off grade approach. The copper equivalent (CuEq) grade is calculated using the formula:

- (CuEq)_%=(Cu)_%+(Au)_((g/t))*k

  where "k" represents the equivalence between gold and copper net values, including flotation recoveries percentage and smelter returns percentage.

The mineral resource estimate for Salobo is reported above a 0.25% CuEq cut-off.

1.11.2 MINERAL RESOURCE STATEMENT

Mineral resources are reported using the mineral resource definitions set out in S–K1300 and are reported exclusive of those mineral resources converted to mineral reserves. The reference point for the estimate is in situ. Mineral resources are current as at 31 December, 2021.

A summary of the mineral resource estimates is provided in Table 1-1 for the measured and indicated mineral resources and in Table 1-2 for the inferred mineral resource estimate. Tonnages are metric tonnes. The Qualified Person for the estimate is Chris Gauld, P.Geo., a Vale employee.

Areas of uncertainty that may materially impact the mineral resource estimates include: changes to long-term metal price and exchange rate assumptions; changes in local interpretations of mineralisation geometry, structures, and continuity of mineralised zones; changes to geological and grade shape and geological and grade continuity assumptions; changes to metallurgical recovery assumptions; changes to the input assumptions used to derive the conceptual open pit shell used to constrain the estimates; changes to the forecast dilution and mining recovery assumptions; changes to the CuEq cut-off applied to the estimates; variations in geotechnical (including seismicity), hydrogeological and mining assumptions; and changes to environmental, permitting and social license assumptions.

Table 1-1: Measured and Indicated Mineral Resource Statement

Classification	Tonnage (Mt)	Grade	
		Cu (%)	Au (g/t)
Measured	30.2	0.39	0.17
Indicated	439.4	0.49	0.25
Total measured + indicated	469.7	0.48	0.24

Table 1-2: Inferred Mineral Resource Statement

Classification	Tonnage (Mt)	Grade	
		Cu (%)	Au (g/t)
Inferred	268.9	0.5	0.3

Notes to accompany mineral resources tables:

1. Mineral resources are reported using the mineral resource definitions in S-K 1300. The reference point for the mineral resource estimate is in situ. The mineral resource estimate is current as at 31 December, 2021. The Qualified Person for the estimate is Chris Gauld, P.Geo., a Vale employee.
2. Mineral resources are not converted to mineral reserves as they have not demonstrated economic viability. Mineral resources that are reported, are those exclusive of those mineral resources converted to mineral reserves.
3. The estimate uses the following key input parameters: assumptions of open pit mining methods; copper sale price of US$7,000/t, gold sale price of US$1,300/oz; mining cost of US$3.47/t mined, process and general and administrative costs of US$9.07/t processed; the sustaining costs are included in the mining, process and G&A costs; variable metallurgical recoveries for copper based on (-2.5362*(1/Cu))+90.674 and for gold based on (1.0173*RecCu)-20.357; pit inter-ramp slope angles that vary from 27–61º. The estimate is reported above a copper equivalent cut-off grade of 0.25% CuEq.
4. Rounding as required by reporting guidelines may result in apparent summation differences.

1.12 MINERAL RESERVE ESTIMATES

1.12.1 ESTIMATION METHODOLOGY

Mineral reserves were converted from measured and indicated mineral resources. Inferred mineral resources were set to waste. The mine plan assumes open pit mining using conventional mining methods and equipment.

The optimized pit was not constrained by surface infrastructure as all such infrastructure is located beyond the economic pit limit. A discount rate of 7.5% and an assumed mining decent rate of five benches per year were applied during the optimization process. Pit slope inter-ramp angles were variable, ranging from 27–61º. An unplanned dilution allocation of 3% was incorporated in the mine plan scheduling. Mining recovery of 100% was assumed during the pit optimization. Metallurgical recoveries were variable.

To calculate payable metal, average payable factors of 96.7% for copper and 93.94% for gold were applied to the recovered metal. Concentrate was modeled with a copper grade of 38%, 9.5% moisture, and a 0.5% loss in transit. Refining costs inclusive of any penalties were modeled as a cost of $0.672/lb Cu and $0.52/oz Au. The total freight cost allocation was $0.115/lb Cu or $92.9/wet tonne of concentrate.

The mineral reserve estimate was reported above a cut-off of 0.25% CuEq.

1.12.2 MINERAL RESERVE STATEMENT

Mineral reserves were classified using the mineral reserve definitions set out in S-K 1300. The reference point for the mineral reserve estimate is the point of delivery to the process plant. Mineral reserves are reported in Table 1-3. Mineral reserves are current as of 31 December, 2021. The Qualified Person for the estimate is Nick Gardner, P.Eng., a Vale employee.

The following factors may affect the mineral reserve estimate: commodity prices; US dollar exchange rate; Brazilian inflation rate; geotechnical (including seismicity) and hydrogeological assumptions; changes to inputs to capital and operating cost estimates; changes to operating cost assumptions used in the constraining pit shell; changes to pit designs from those currently envisaged; stockpiling assumptions; ability of the mining operation to meet the annual production rate; process plant recoveries and the ability to control deleterious element levels within LOM plan expectations; assumptions that Salobo III will perform as predicted, based on the performances of Salobo I and II; ability to meet and maintain permitting and environmental licences, and the ability to maintain social licence to operate. The long-term storage of the medium- and low-grade material in a tropical environment may lead to some oxidation of contained sulphide minerals, which may in turn impact recovery of metals during eventual processing of the stockpiles.

Table 1-3: Proven and Probable Mineral Reserve Statement

Pit/Operation	**Classification**	**Tonnage (Mt)**	**Grade**	
			Cu (%)	**Au (g/t)**
Salobo Pit	Proven	231.0	0.69	0.40
	Probable	696.4	0.66	0.38
	Subtotal proven + probable	927.3	0.66	0.39
Stockpiles	Proven	—	—	—
	Probable	206.1	0.42	0.20
	Subtotal proven + probable	206.1	0.42	0.20
Total	Proven	231.0	0.69	0.40
	Probable	902.4	0.60	0.34
	Total proven + probable	1,133.4	0.62	0.35

Notes to accompany mineral reserves table:

1. Mineral reserves are reported using the mineral reserve definitions set out in S-K 1300. The reference point for the mineral reserve estimate is the point of delivery to the process plant. The estimates are current as at December 31, 2021. The Qualified Person for the estimate is Nick A. Gardner, P.Eng., a Vale employee.
2. The pit optimization estimate uses the following key input parameters: open pit mining methods; copper sale price of US$7,000/t, gold sale price of US$1,300/oz (Revenue Factor = 1); mine operating costs of US$3.47/t mined, processing cost of US$7.79/t processed, selling cost of US$0.67/t processed, corporate overhead of US$0.43/t processed, general and administrative cost of US$0.39/t processed; variable metallurgical recoveries for copper based on the equation (-2.5362*(1/Cu)) + 90.674 and gold, based on the equation (1.0173*RecCu) - 20.357; inter-ramp slope angles ranging from 27–61º; mining recovery of 100%, and a dilution average of 3% over the life-of-mine.
3. Inside the pit shell, the mineral reserves are restricted by the capacity of the tailings dam.
4. Rounding as required by reporting guidelines may result in apparent summation differences.

1.13 MINING METHODS

Conventional open pit mining methods are used, with the operations strategy based on Owner-operator mining equipment and labour. Mining plans and engineering studies were completed for the mineral reserve estimates. All engineering studies were at a minimum prefeasibility level.

The base case mine production schedule discussed in this Report involves the movement of 130 Mt/a to feed 36.0 Mt/a of ore to the process plant with a ramp up commencing December 2022, by immediately processing a portion of the ore that would have been stockpiled in the previous 24 Mt/a production plan.

The open pit mine life is approximately 24 years, ending in 2045 (Reserve only). The process plant will continue to operate by reclaiming stockpiled material until 2053.

1.14 PROCESSING AND RECOVERY METHODS

The process flowsheet has evolved through various study phases, incorporating the additional knowledge gained from metallurgical testwork and the relative importance of the identified lithologies in the mineral resource and mineral reserve estimates. HPGR were retained instead of SAG mills because of the high magnetite (and copper) content of critical-size pebbles that would have been removed with the magnet protecting the pebble crushers, and therefore requiring additional re-handling. In addition, the relatively high ore hardness and its expected variability as different mixtures of ore lithologies are introduced as plant feed, would have caused high-frequency variability in plant throughput in a typical SAG mill–ball mill–pebble crusher (SABC) circuit.

The process design was de-bottlenecked during operations where operating conditions deviated from forecasts.

The existing processing plants, line 1 and line 2 (Salobo I and II), each have a nominal 12 Mt capacity. Vale is currently implementing the Salobo III line to provide a third line that is an identical nominal 12 Mt circuit, to increase the process capacity to a total of 36 Mt/a.

Apart from the inclusion of HPGR for tertiary crushing duty, ahead of ball milling, the circuits are conventional, but with the flotation cleaning circuit making extensive use of flotation columns, to reduce entrainment of fluorine-bearing non-sulphide gangue minerals such as fluorite and biotite.

Concentrate produced at the Salobo Operations is transported 85 km by road to a rail load-out facility near the town of Parauapebas. There it is loaded onto cars for rail transport using the 892 km long Carajás Railroad Extension that links Carajás with the city of São Luis, where the sea port terminal of Itaqui is operated by Vale. At the port, there is one ship loading system that is shared by Vale’s Salobo and Sossego Operations.

Consumables used in the process plant include potassium amyl xanthate (PAX), dithiophosphate, propylene glycol, methyl isobutyl carbinol (MIBC), sodium hydrosulphide, and lime. The bulk of the process water needs are covered by the recirculation from the TSF. The consumption of fresh water is limited to systems requiring better water quality and is pumped from Mirim and Salobo Creeks.

A total of 450 persons are currently employed in the process area.

1.15 INFRASTRUCTURE

The majority of the infrastructure to support mining operations is in place. An expansion to the mill is underway and will add an additional 12 Mt/a capacity when the Salobo III line is completed in 2022. There is no on-site accommodations camp. The workforce resides in Carajás, Parauapebas, and surrounding settlements.

The Tailings Storage Facility (TSF) is a cross-valley impoundment comprising a compacted earth and rock-fill embankment with internal drainage and transition zones, and a concrete lined spillway. Tailings are deposited by gravity. There is sufficient capacity within the facility for LOM plan purposes. Geotechnical inspections and monitoring of the TSF are conducted according to the governmental agency regulation (DNPM Act 70.389/17).

Water can be captured from selected water courses under granted water licences. Non-contact water is diverted around the mine, TSF, stockpiles, and Waster Rock Facilities (WRSF) where possible. There are three sediment control ponds. Process make-up water primarily consists of runoff and direct precipitation within the tailings storage basin. The Salobo Operations monitor levels, flows and water balances on a regular basis.

Electrical energy is supplied from a hydroelectric-generating station on the Tocantins River. The 180 MW of power required by the Salobo Operations is transmitted 87 km by an overhead 230 kV transmission line. There is sufficient power availability to support the LOM plan.

1.16 MARKET STUDIES

Vale has established contracts and buyers for the products from the Salobo Operations. Vale has an internal marketing group which monitors markets for its key products. Together with public documents and analyst forecasts, these data support that there is a reasonable basis to assume that for the LOM plan, that the key products will be saleable at the assumed commodity pricing.

The commodity pricing forecasts were established using a consensus approach based on long-term analyst and bank forecasts, supplemented with research by Vale’s internal specialists. For the economic analysis, we selected a single price per commodity that was within range of analyst pricing or in line with Vale’s long-term view and simplified the product premiums/discounts. The intent is to demonstrate that the mineral reserves are economically viable, and the sensitivity analysis shows the potential upside or risks of the economics to factors such as price.

The long-term commodity price forecasts for the Salobo Operations are:

- Copper: US$7,500/t;
- Gold: US$1,450/oz.

The long-term exchange rate assumptions are:

- BR$/US$: 5.00.

The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance.

Customers for the Salobo concentrate are well established. Vale has agreements at copper–gold concentrate benchmark terms for metal payables, treatment charges and refining charges for concentrates produced. Treatment costs and refining costs vary depending on the destination smelter. The terms contained within the concentrate sales contracts are typical and consistent with standard industry practice and are similar to contracts for the supply of copper–gold concentrate throughout the world.

Contracts may be entered into for goods and services required for the mining operations. On occasion, mining contractors may be employed for specific mine development projects. The largest in-place contracts include transportation, purchase of fuel, reagents and other process consumables, and mining equipment leases. The terms contained within the contracts are typical of, and consistent with, standard industry practices.

1.17 ENVIRONMENTAL, PERMITTING AND SOCIAL CONSIDERATIONS

1.17.1 ENVIRONMENTAL STUDIES AND MONITORING

Environmental and social baseline study areas were defined to characterize the current conditions in the areas potentially affected by mine components or activities. Social and environmental management plans detail best practices and Brazilian legislation to prevent and mitigate potential impacts and manage compliance specifically for the Salobo Operations.

The site maintains a monitoring program for total suspended particulates (TSP). Static acid base accounting and non-acid generating (NAG) test work concluded that all wastes were non-acid forming. Low-grade oxides are comingled with non-potentially acid-generating (PAG) waste rock within the centre of the WRSF as a preventive measure to neutralize potential acid generation for low-grade oxides.

1.17.2 CLOSURE AND RECLAMATION CONSIDERATIONS

The Salobo Closure Plan assumes that there will be partial recovery of infrastructure for future alternative usage. The closure plan is included in the Environmental Control Plan. The overall objective is to return the Project area to a natural condition to support the local vegetation and wildlife biodiversity of the Tapirapé–Aquiri National Forest.

There are no reclamation bonds required for the mine. Rehabilitation and re-vegetation work are ongoing during operations.

Closure costs are included in the mine site financial model as cash costs on an annual basis. The largest closure costs are associated with the process facility, WRSFs and stockpiles.

The current closure plan was developed by Sete Soluções e Tecnologia Ambiental Ltda in 2015 and updated in 2021 by Arcadis. The escalated closure cost estimate for the Salobo Operations, as at year-end 2021, is US$211 million.

1.17.3 PERMITTING

The Operating License was renewed in October 19, 2018 and is valid for six years. The Salobo Operations have all necessary permits to support the current mining and processing activities. Renewals have been requested as they come due. In some instances, the Brazilian government does not have a date limit as to when a licence must be renewed by. In these instances, as the renewal was requested prior to licence expiry, the current licence remains valid.

The operations have a control and monitoring system to ensure that permits remain current, and to ensure that the requirements of each permit are monitored to comply with the relevant regulatory conditions imposed.

Six environmental licenses were issued for the Salobo III expansion, as were three water capture and discharge concessions. Together, these licences are sufficient to support construction of Salobo III. The project schedule outlines the additional permits that must be obtained prior to operation of the third line. Permits on the critical path that are still to be obtained include incorporation of the Salobo III line in the Environmental Operation License, following completion of Salobo III installation.

1.17.4 SOCIAL CONSIDERATIONS, PLANS, NEGOTIATIONS AND AGREEMENTS

The Project is not located on Indigenous lands. The nearest Indigenous lands include the Xikrin do Bacajá and Xikrin do Cateté, all located 25 km or more from the Project area. This area is used by Xikrin to practice some traditional and cultural activities.

Vale currently maintains a Communication Plan that commits to continued communication with the local Indigenous peoples to maintain community health and safety, cultural preservation, transparency of activities and harmony between mine workers and the Indigenous communities.

There are several social management plans carried out by the Social Communications Department. The Environmental Compensation and Social Inclusion plan objectives are to support sustainable development by capitalizing on positive effects of Project development and minimizing potential negative effects.

1.18 CAPITAL AND OPERATING COST ESTIMATES

1.18.1 CAPITAL COST ESTIMATES

Capital cost estimates are at a minimum at a pre-feasibility level of confidence, having an accuracy level of ±25% and a contingency range not exceeding 15%. Costs are presented for a 36 Mt/a operation.

Capital costs are based on recent prices or operating data. Unit costs for in-house mine development are based on historical actual costs. Mobile equipment that is leased is included in operating costs. Lease periods typically range from two to five years. Lease costs are charged to capital while the equipment is doing capital work. Purchased equipment is allocated for in the capital plan. Mobile equipment and fixed asset costs are based on supplier quotations and/or current examples. Sustaining capital cost forecasts are based on forecast mine development and construction needs, mobile equipment re-build/replacement schedules and fixed asset replacement and refurbishment schedules.

The overall capital cost estimate for the LOM is US$3,288 M, as summarized in Table 1-4. The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance.

Table 1-4: Capital Cost Summary

Area	Allocation	Unit	Value
Mining	Sustaining	U$ M	1,435
Processing	Sustaining	U$ M	972
Other	Sustaining	U$ M	515
Salobo III	Project	U$ M	365
Total		***U$ M***	***3,288***

Note: Numbers have been rounded.

1.18.2 OPERATING COST ESTIMATES

Operating cost estimates are at a minimum at a pre-feasibility level of confidence, having an accuracy level of ±25% and a contingency range not exceeding 15%. Costs are presented for a 36 Mt/a operation.

Operating costs are based on actual costs seen during operations and are projected through the LOM plan.

Historical costs are used as the basis for mine operating cost forecasts, which are estimated using a long-term cost model. This model accounts for the impact of varying production rates and labour complement. Operating cost forecasts are based on a combination of historical performance and calculations from first principles to take account of variation in production rates and expected process improvements. The cash mining costs include the direct operating costs, mine operating expenses and transportation to the mill. As the mine approaches the end of mine life, forecast mine overhead and distributed overhead costs are reduced in line with the projected lower production rates.

Mining operating costs are estimated in conjunction with the mobile equipment fleet selection process, using a cost model containing annually reviewed production indicators in line with budget assumptions (five years and annual). In addition to the equipment direct operating costs, other key costs include maintenance, labour, salaries, energy, and fuel.

The processing operating cost estimates are the average cash costs applied to the mineral reserves mined throughout the LOM plan. These unit costs include both variable and fixed plant components.

The sole purpose of the presented figure is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance.

The overall operating cost estimate for the LOM is US$22,018M (Table 1-5).

Table 1-5: Operating costs and expenses

Area	Unit	Total LOM Plan
Mining Cost	U$ M	8,617
Processing Cost	U$ M	9,009
Logistics and Distribution Costs	U$ M	2,060
Royalties	U$ M	1,054
G&A and Corporate Overhead	U$ M	1,095
R&D and Other	U$ M	182
Total	***U$ M***	***22,018***

Note: Numbers have been rounded.

1.19 ECONOMIC ANALYSIS

1.19.1 INTRODUCTION

The aim of the economic evaluation presented in this chapter is to demonstrate the economic viability of the mineral reserve, therefore the production rates, operating efficiencies, costs and expenditures, taxes and other information presented can differ from other information Vale publishes and should not be considered as a guidance. Note that our planned production extraction may vary due to continuous mineral exploration and technical studies to add new mineral reserves.

1.19.2 METHODOLOGY AND ASSUMPTIONS

All inputs to the economic analysis are at a minimum of a pre-feasibility level of confidence. The economic analysis is based on a 36 Mt/a operation.

The financial model that supports the mineral reserve declaration is a standalone model that calculates annual cash flows based on scheduled ore production, assumed processing recoveries, metal sale prices and foreign exchange rate, projected operating and capital costs and estimated taxes.

The financial analysis is based on an after-tax discount rate of 7.5% following a mid year convention. All costs and prices are in unescalated “real” dollars. The currency used to document the cash flow is US$.

Revenue is calculated from the recoverable metal and the long-term forecast of metal prices and exchange rate.

The economic analysis is based on 100% equity financing and is reported on a 100% project ownership basis.

The statutory Federal corporate income tax rate is 34%, consisting of a 25% corporate income tax (IRPJ) and a 9% tax known as the for Social Contribution on Net Profit (CSLL). The actual IRPJ tax rate is 15%, plus a surcharge of 10% on taxable income exceeding USD $48,000 a year. The social contribution is levied on a taxable base similar to the Corporate Income Tax.

A Federal tax, CFEM, is levied on economic use of the produced good. Under this tax, 2% for “diamond and other mineral substances”, which includes copper ore.

The Social Contributions on Gross Revenues taxes (PIS and COFINS) are Federal social contribution taxes that must be paid by all entities in Brazil (i.e., not restricted to mining companies) and are calculated based on gross revenues. The applicable tax rate is 9.25% (1.65% PIS and 7.6% COFINS), not applicable to revenues from exports.

A Provincial tax, the Tax on Circulation of Goods and Services (ICMS), is an indirect tax similar to VAT. It is a State VAT tax and the rates vary according to where the product/good/mine is being sold, depending on the specific state legislation. In Para State, the tax is 17%, not applicable on exports.

The tax assessment assumes that the SUDAM benefit, an incentive designed to encourage investment in the Amazon area, which represents a 75% reduction in income tax rate (from 25% to 6.25%), will be applicable until 2023.

1.19.3 RESULTS OF ECONOMIC ANALYSIS

The post-tax $NPV_{7.5\%}$ is US$7,720 million. The financial analysis is based on an after-tax discount rate of 7.5% following a mid year convention and an exchange rate BR$/US$ 5.00. All costs and prices are in unescalated “real” dollars. The currency used to document the cash flow is US$.

As the cashflows are based on existing operations where all costs are considered sunk to 1 January 2022, considerations of payback and internal rate of return are not relevant.

The Wheaton Precious Metals streaming agreement is not included in the evaluation. Further details are discussed in Chapter 3.8.2.

1.19.4 SENSITIVITY ANALYSIS

Sensitivity analysis was performed on metal prices, metal recovered, capital costs and operating costs.

The sensitivity graph (*see 19.4*) shows the Salobo Operations are most sensitive to least sensitive, in order, to:

- Copper price;
- Copper recovered;
- Operating costs;
- Gold price;
- Gold recovered;
- Capital costs

1.20 CONCLUSIONS & RECOMMENDATIONS

Under the assumptions presented in this Report, the Qualified Persons conclude that the Salobo Operations have a positive cash flow, and mineral reserve estimates can be supported.

- Historical monthly, quarterly, and annual reconciliation evaluations indicate that tonnages and grades of the long-term model, and modifying factor assumptions including recovery and dilution, metallurgy and geotechnical are supported within acceptable limits.
- The permitting and environmental requirements to operate the Salobo Operations are well understood and can support mineral resource and mineral reserve estimation.
- The site developed mineral resource model follows industry practices and is a reasonable representation for the mineralization at Salobo.

Recommendations to de-risk, improve confidence in and add to the mineral resources and reserves include:

- Core drilling to support potential conversion of inferred mineral resources to higher confidence classifications.
- The Salobo mineralization remains open at depth under the current open pit outline. Continued exploration evaluation is warranted.
- Installation of metallurgical samplers at the plant feed, waste and concentrate lines, and installation of the automatic samplers in the conveyor belts.
- Upgrade of the flotation mechanical cells.
- Alignment on the commodity prices and foreign exchange used in the mine design and economic analysis to ensure appropriate pit optimisation and cut-off assumptions.

The reserve estimates are currently constrained to available tailings storage in the tailings storage facility. The storage capacity will need to be increased to convert any mineral resources to future mineral reserves. Studies are underway to address and mitigate any future gap.

2 INTRODUCTION

2.1 REGISTRANT

This technical report summary (the Report) was prepared for Vale SA (Vale) on the Salobo Operations in the Carajás Mining District, Pará State, Brazil. Figure 2-1 is a location plan for the operations. Vale uses its wholly-owned subsidiary, Salobo Metais S.A. (Salobo Metais), as operator of the Salobo Operations.

2.2 TERMS OF REFERENCE

2.2.1 REPORT PURPOSE

The Report was prepared to be attached as an exhibit to support mineral property disclosure, including mineral resource and mineral reserve estimates, for the Salobo Operations in Vale's Form 20-F for the year ending 31 December 2021.

Mineral resources and mineral reserves are reported for the Salobo deposit.

2.2.2 TERMS OF REFERENCE

The Salobo Operations consist of the Salobo open pit, and associated processing facilities that generate a copper–gold concentrate.

The term "Vale Base Metals" refers to the base metals division of Vale S.A. led by its wholly-owned subsidiary, Vale Canada Limited, comprised of nickel and copper mining, smelting and refining assets in Canada, Brazil, Indonesia, the United Kingdom and Japan, including the production and sale of cobalt, platinum group metals, and other precious metals as by-products of nickel and copper mining and processing operations.

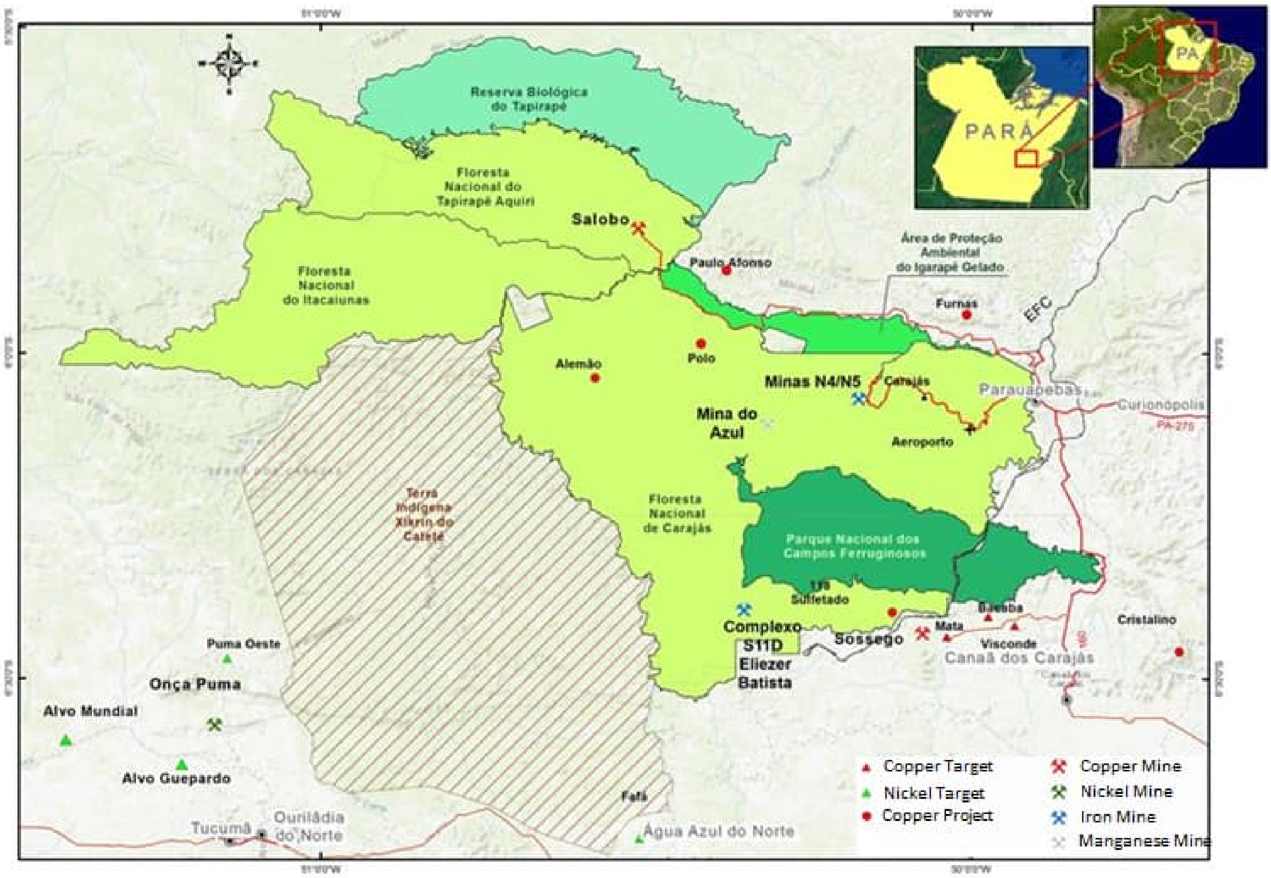
Vale Canada Limited is the corporate head for its base metals operations and assets globally. Vale Canada is also the ultimate holding company / parent company for all Base Metal assets save for Salobo Metais, Onca Puma and Sossego Operations which fall under Vale SA. Though the Salobo Operations are owned by Salobo Metais for local regulatory and tax efficiencies, responsibility resides with Vale Canada.

Unless otherwise indicated, all financial values are reported in US currency. The metric system is used in the Report unless otherwise noted.

Mineral resources and mineral reserves are reported using the definitions in Subpart 229.1300 – Disclosure by Registrants Engaged in Mining Operations in Regulation S-K 1300 (SK1300).

The Report uses Canadian English.

Figure 2-1: Salobo Operations Location Plan



Note: Figure prepared by Vale, 2021. Note in the context of the figure, target = prospect.

2.3 QUALIFIED PERSONS

The following Vale employees serve as Qualified Persons (QPs)

- Christy (Chris) Gauld, P.Geo., Manager Base Metals Resource Management;
  - Responsible for sections: 1, 2, 3, 4, 5, 6, 7.1, 7.2, 8, 9, 11, 20, 21, 22.1-22.8, 22.10, 22.20, 23, 24, and 25
- Nick A. Gardner, P.Eng., Base Metals Integrated Planning;
  - Responsible for sections: 1.1-1.2, 2.1-2.5, 12, 13, 15.1-15.4, 15.9 -15.11, 16, 17, 18, 19, 22.1, 22.11 - 22.12, 22.14 - 22.19, 22.20.1 - 22.21, 23, 24, and 25
- Alex Hossack MAusIMM (CP), Manager Base Metals, Mining;
  - Responsible for sections: 1.1-1.2, 1.21.1-1.21.2, 1.23, 2.1-2.4, 2.6, 7.3-7.4.3, 15.4, 22.1, 22.14, 22.20.1-22.20.2, 23-24.3, 25.1-25.7, 25.8.3
- Marcos Alvim, P.Geo., FAusIMM (CP), Long Term Planning Manager, Base Metals South Atlantic.
  - Responsible for sections: 1.1,1.2,2,10,14,22-25
- Greg Puro, P.Eng., Manager Base Metals, Dams.
  - Responsible for sections: 1, 2, 15, 22, 23, 24, and 25

2.4 SITE VISITS AND SCOPE OF PERSONAL INSPECTION

Chris Gauld most recently visited the Salobo Operations from October 22–24, 2019. During that visit he visited the mine, core facility and processing plant, discussed grade control, geological mapping, exploration and delineation drill practices, quality assurance and quality control (QA/QC) practices and findings, reconciliation, and mineral resource and mineral reserve estimation practices.

Nick Gardner visited the Salobo mining operations in 2019. His most recent site visit was from 4-8 August 2019. During the visits, he inspected the open-pit mining operations, toured the processing and maintenance facilities, viewed infrastructure, and discussed geology, exploration, mine planning, tailings dam and mining practices with site staff.

Alex Hossack has visited the Salobo mining operations from 24 – 26 November 2021. During this site visit, Hossack inspected the open pit mine and waste rock storage facilities, as well as reviewed the current geotechnical model, and assessed the effectiveness of geotechnical processes associated with design, planning, operation, monitoring and optimization with the operation, infrastructure, mine planning and geotechnical groups. Hossack also reviewed the progress of mining.

Greg Puro visited the Salobo mine site in November and December of 2019. He reviewed the physical condition of all the dams on site including the Mirim tailings dams. Also inspected were the reclaim water systems, saddle dykes and dam monitoring activities.

Marcos Alvim most recently visited Salobo operations in February of 2022. During the visit he visited and inspected the open pit me operations and waste rock facilities, core facilities, and toured the processing plant and tailings dam. He discussed grade control practices, near mine exploration, mining operations and infrastructure, metallurgical practices and geotechnical processes and controls with site staff and management group.

2.5 REPORT DATE

Information in this Report is current as at 31 December, 2021.

2.6 INFORMATION SOURCES

The reports and documents listed in Chapter 24 and Chapter 25 of this Report were used to support the preparation of the Report.

2.7 PREVIOUS TECHNICAL REPORT SUMMARIES

Vale has not previously filed a technical report summary on the Salobo Operations.

3 PROPERTY DESCRIPTION

3.1 PROPERTY LOCATION

The Salobo Operations are located approximately 90 km northwest of Carajás, Pará State, in northern Brazil. Geographic coordinates for the Salobo Operations are 5°47’27” S latitude and 50°32’5” W longitude.

3.2 PROPERTY AND TITLE IN BRAZIL

3.2.1 OVERVIEW

Under Brazilian laws, the Federal Government owns all mineral resources. Under Article 176 of the Brazilian Constitution, all mineral deposits (jazidas) belong to the Federal Government, whether or not the deposits are in active production. Mineral rights are distinct from surface rights.

Mining is ruled by Decree-Law 227, 1967 (Mining Code), regulated by Decree 9.406, 2018 (Regulation to the Mining Code), and other regulations issued by the National Mining Agency (ANM), formerly known as National Department of Mining Production (DNPM).

Brazil also has legislation and legal guarantees related to the exploitation and use of water rights.

3.2.2 MINERAL TITLE

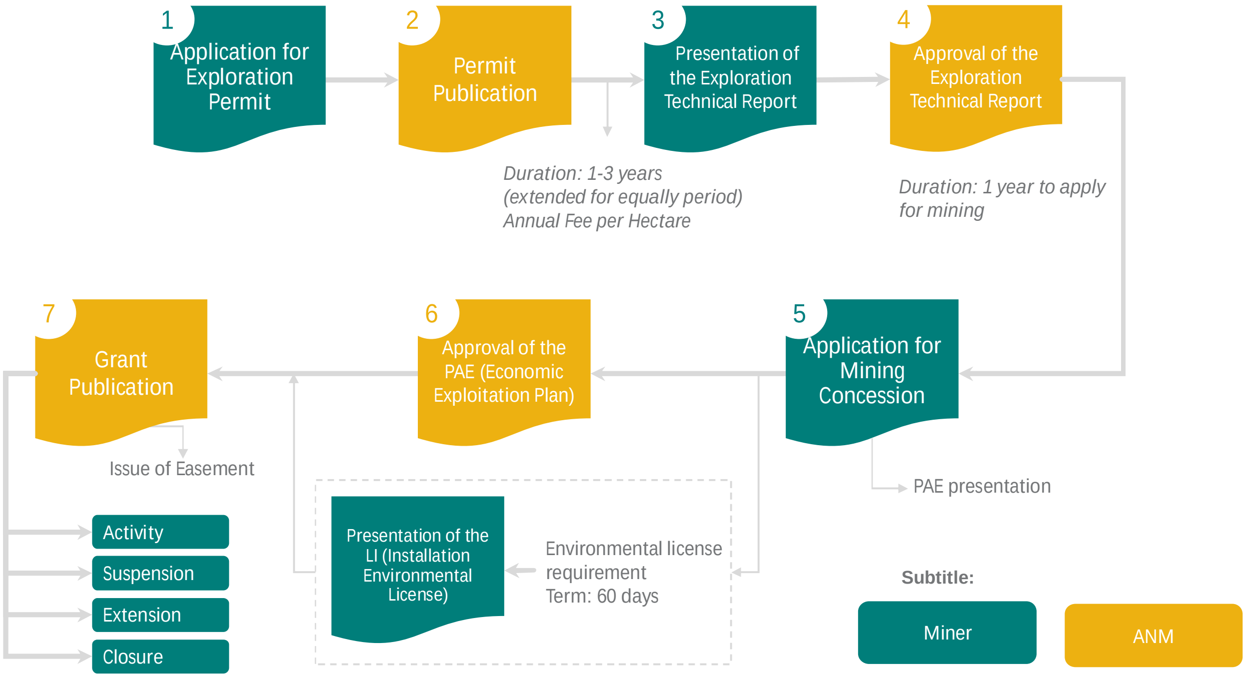
The application process for a mining concession is summarized in Figure 3-1.

The mineral title acquisition process begins with an Application for Exploration Permit. When the exploration permit (*Alvará de Pesquisa*) is granted, the grant is published in the Federal Gazette.

The permit has a 1–3 year and it may be extended equally, provided that it is requested within sixty days before the period of the current authorization expires. The permit allows the licence holder to conduct exploration activities. At the end of the permit term, the licence holder must provide an Exploration Technical Report (*Relatório Final de Pequisa*) to the ANM. The licence holder then has a year to apply for a mining concession over any discovered deposit. The application has to include an Economic Exploitation Plan (*Plano de Aproveitamento Econômico* or PAE), which must be prepared by a legally qualified professional. Once the PAE is presented and approved by ANM, the agency requires an installation licence (*Licença de Instalação* or LI) that is granted by an environmental licensing agency. The licence holder is responsible for updating ANM with the progress of the environmental licensing process, by providing reports every 180 days. Once the LI is granted, a mining concession is granted. the grant is published in the Federal Gazette. An environmental operation license (*Licença de Operação*) is also required.

Mining activities must start within six months of the publication of the mining concession grant, and annual production reports must be provided to the ANM. Assuming all other conditions are met, a mining concession remains valid until the deposit is depleted. Mining operations must be in accordance with the Economic Exploitation Plan approved by ANM. If additional minerals are discovered, ANM must be notified of the discovery, and the mining concession licence must be amended to include the new list of minerals before those minerals can be commercially produced and sold.

Figure 3-1: Mining Concession Grant Schematic



Note: Figure provided by Vale, 2021.

3.2.3 SURFACE RIGHTS

Surface rights in Brazil are separate from mineral rights. Under the mining law, mineral rights holders have the right to use and access areas that are planned for exploration or exploitation. Rights of way and easements can also be granted to mining rights holders over public and private lands.

Typically, the mining rights holder enters into an agreement with the affected surface rights holder in return for a compensation fee for the land use. Where disputes arise, a mining rights holder may apply for a local court order to allow a judge to establish the appropriate compensation fee to be paid to the surface rights holder.

3.2.4 WATER RIGHTS

All waters are in the public domain, and are separated into:

- Federal waters: lakes, rivers and any water courses on lands under Federal authority; those that flow through more than one State; those that serve as a frontier with another country, or flow into or originate in another other country; as well as marginal lands and riparian beaches
- State waters: Groundwater and rivers located entirely within the territory of a single State, unless otherwise classified as a Federal water.

Law 9,433 of 1997 established the National Water Resources Policy, created the National Water Resources Management System, and defined a catchment (river) basin as the unit for water resource planning. The law includes the principle of multiple water uses, thereby putting all user categories on an equal footing for access to water resources.

The organizational framework administering water includes the National Water Resources Council, State Water Resources Councils, River Basin Committees, State Water Resources Management Institutions, and Water Agencies.

In 2003, to facilitate the management of Brazilian water resources, the country was divided into 12 hydrographic regions; however, these do not coincide with the 27 state political divisions. The National Water Resources Council is responsible for resolving disputes over use of water for basins at the Federal level, and for establishing guidelines necessary to implement the institutional framework and instruments contained in the National Water Resources Policy. The State Water Resources Councils are responsible for basins at the State level. The State Water Resources Management Institutions are responsible for implementing the guidelines set by the State Water Resources Councils. The River Basin Committees and Water Agencies cover the actual water regions, which may be part of more than one State.

3.2.5 GOVERNMENT MINING TAXES, LEVIES OR ROYALTIES

The Financial Compensation for Mineral Exploitation (CFEM in the Brazilian acronym) was enacted by legislation in 1989 and varies depending on the mineral product:

- 2% for diamond and other unspecified mining substances, which includes copper ore

Several Brazilian states, including Minas Gerais, Pará and Mato Grosso do Sul, impose a tax on mineral production (Taxa de Fiscalização de Recursos Minerais - “TFRM”). By the time of Salobo reserve estimation, it was applied the rate of R$3.72 per metric ton of copper concentrate produced.

3.3 OWNERSHIP

The Salobo Operations are indirectly wholly-owned by Salobo Metais S.A, a wholly-owned subsidiary of Vale S.A

3.4 MINERAL TITLE

The Salobo Operations are located within one mining concession (Figure 3-2), ANM Mineral Right number 807.426/1974 granted for copper on 16 July, 1987 . The concession covers an area of 9,180.60 ha.

An annual report (RAL in the Brazilian acronym) is required to be lodged with the ANM, detailing the production for the year. This reporting obligation has been met for each year since concession grant.

3.5 PROPERTY AGREEMENTS

There are no property agreements relevant to the Salobo Operations.

3.6 SURFACE RIGHTS

Brazilian legislation separates surface ownership from sub-surface ownership. Salobo is located entirely within the National Forest of Tapirapé-Aquiri, which belongs to the Federal Government. There are no associated payments related to surface rights.

3.7 WATER RIGHTS

Four water permits are current:

- 1895/2017: Mamao and Finos II dams concessions, valid to 2052;
- 1896/2017: Surface water abstraction concession and effluent discharge, valid to 2027;
- 2024/2020: Effluent discharge concession, valid to 2030;
- 4443/2020: Groundwater abstraction for blasting, valid to 2030.

Salobo also has water usage permits for surface and groundwater, granted in 2020, that are valid for a 10-year period.

Water from the tailings storage facilities (TSFs) is permitted to be captured and re-used, and raw water capture from the Mamao dam is also permitted. These water sources provide all of the process water needs for the three process lines.

Renewal of all permits can be requested and renewed upon approval of the relevant regulatory authority.

There are sufficient water rights to support the LOM plan.

Figure 3-2: Mineral Tenure Location Plan

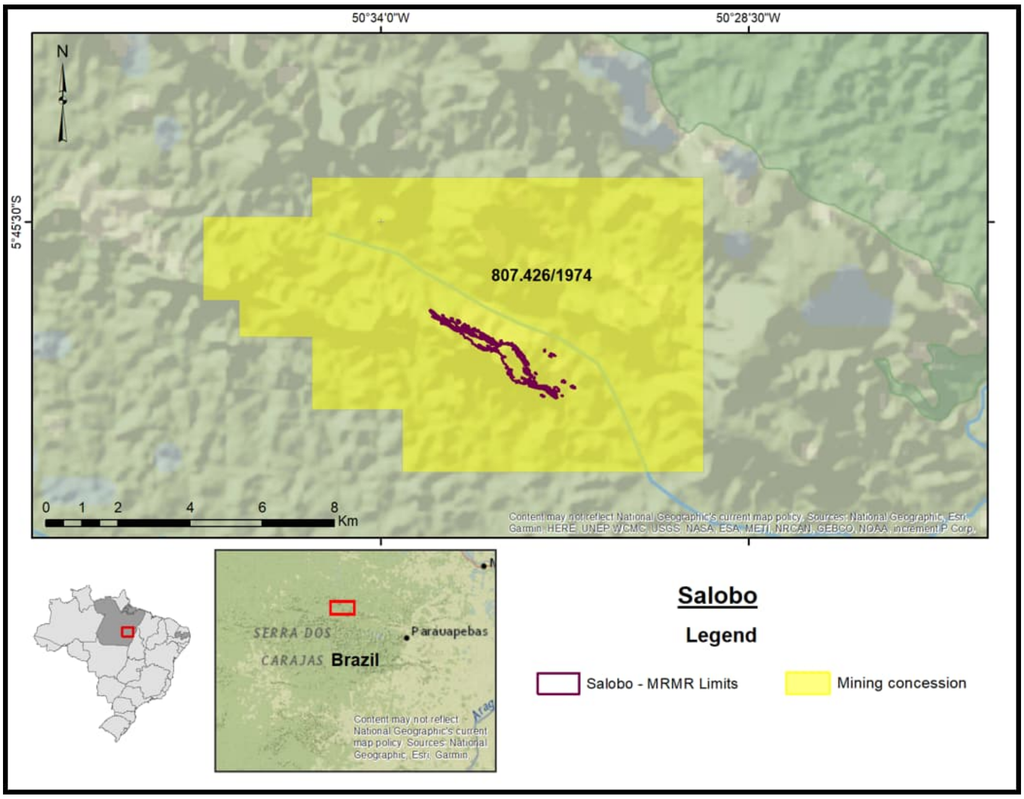


Figure prepared by Vale, 2019.

3.8 ROYALTIES & STREAMING

3.8.1 STATE AND FEDERAL ROYALTIES

The Project is subject to the CFEM (refer to discussion in Chapter 3.2.5). Vale must also pay the Pará State mineral production tax.

3.8.2 WHEATON PRECIOUS METALS STREAMING AGREEMENTS

Vale has a streaming agreement with Wheaton. The following are key highlights of the agreement. Since 2013, Wheaton Precious Metals has entered into the following three different life-of-mine (LOM) gold stream agreements on the Salobo Operations with Vale (through a wholly-owned subsidiary), each for 25%, for a total of 75%. In each of the agreements Wheaton Precious Metals agreed to ongoing payments of the lesser of $400/oz (subject to a 1% annual inflation adjustment that commenced in 2019 on the entire 75% stream) and the prevailing market price for each ounce of gold delivered under the agreement.

- February 2013: Vale entered into an agreement with Wheaton Precious Metals to sell 25% of the gold produced at the Salobo Operations for the LOM. In exchange, Vale received an initial cash payment of $1.33 billion and 10 million share purchase warrants exercisable at a strike price of $65 per common share;
- March 2015: Wheaton Precious Metals acquired an additional 25% of the gold production, increasing the gold stream to 50%. Under the amended 2015 streaming agreement, Wheaton paid Vale a cash consideration of $900 million for the new gold stream;
- August 2016: Wheaton Precious Metals agreed to acquire an additional 25% of the LOM gold production from the Salobo Operations. This acquisition was in addition to the 50% of the Salobo gold production that Wheaton Precious Metals was entitled to. Wheaton Precious Metals paid an upfront cash consideration of $800 million for the increased gold stream and

the 10 million Wheaton Precious Metals common share purchase warrants previously issued to a subsidiary of Vale were amended to reduce the strike price from US$65.00 to US$43.75 per common share.

- In October 2018, Vale announced the approval of the Salobo III mine expansion ("Salobo Expansion"), which if completed as proposed, would increase processing throughput capacity from 24 Mtpa to 36 Mtpa once fully ramped up. Wheaton will be required to make an additional payment to Vale, that is expected to range from $550 million to $670 million depending on certain contractual completion tests.

3.9 ENCUMBRANCES

There are no material encumbrances to the Salobo Operations known to the QP.

3.10 SIGNIFICANT FACTORS AND RISKS THAT MAY AFFECT ACCESS, TITLE OR WORK PROGRAMS

To the extent known to the QP, there are no other significant factors and risks that may affect access, title, or the right or ability to perform work on the Salobo Operations that are not discussed in this Report.

4 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE AND PHYSIOGRAPHY

4.1 PHYSIOGRAPHY

Salobo is in the northwest of the Carajás Region within the Tapirapé–Aquiri National forest. In the mine area the topography is steep, varying between 190–520 m in elevation.

The area is heavily forested and dominated by relative dense trees with substantial underbrush.

The two drainages on either side of the Salobo Ridge are the Cinzento and Salobo Rivers which flow into the Itacaiúnas River. The Itacaiúnas River flows into the Tocantins River close to Marabá City.

4.2 ACCESSIBILITY

The Salobo Operations are connected via an all-weather road network to the cities of Parauapebas (80 km), Marabá (240 km), and a commercial airport at Carajás (90 km). Infrastructure within the mining concession is accessed via gravel roads.

The Carajás airport is capable of accommodating large aircraft and is served by daily flights to Belém (Pará State major's city) and other major Brazilian cities.

The Carajás Railway (Estrada de Ferro Carajás) links Parauapebas with the Ponta da Madeira Maritime Terminal in São Luis, Maranhão State. Concentrate from Salobo is sent by truck to a storage terminal in Parauapebas and then transported on the Carajás Railway to the Ponta da Madeira Maritime Terminal, from which is transported to the Itaqui Port, in São Luis, Maranhão State.

4.3 CLIMATE

The operations are located in the Carajás mountain range in the eastern Amazon humid tropical rainforest. The area is characterized by distinct wet and dry seasons. The dry season extends from May to October and the wet season from November to April. Rainfall occurs all year, but approximately 80% falls during the six month-long wet season, and nearly 50% during January, February and March. Mean annual rainfall is 1.9 m. Temperatures range from 20.8–37.8°C with an average relative humidity of 80.5%.

Mining operations are conducted year-round.

4.4 INFRASTRUCTURE

Mining is the primary industry of the area. In addition to the Salobo Operations, Vale operates the Sossego copper mine; 136 km by road to the south, the Onça-Puma Nickel mine, 110 km air miles to the southwest, and the very large iron ore and manganese mines at Carajás about 60 km by road southeast.

Local housing is available for employees within the communities surrounding the mine. There are adequate schools, medical services and businesses to support the work force. The mine site has medical facilities to handle emergencies. In addition, medical facilities are available in Carajás to support the mine's needs.

Vale has invested significantly in infrastructure in Carajás, building a 130 km-long paved road to Parauapebas and a 20 km-long sewage system, together with a school, hospital, and day care center.

The Salobo Operations currently have all infrastructure in place to support the current mining and processing activities (see also discussions in Chapter 13, Chapter 14, and Chapter 15 of this Report). These Report chapters also discuss water sources, electricity, personnel, and supplies.

A process plant expansion, consisting of the addition of a third circuit, is underway. This is outlined in Chapter 14.

5 HISTORY

Docegeo, the exploration division of Companhia Vale do Rio Doce (CVRD; a predecessor company to Vale) discovered copper mineralization in the Igarapé Salobo region in 1974, and commenced detailed exploration in 1977. Work completed included stream sediment sampling, reconnaissance exploration, and ground induced polarization (IP) and magnetometer geophysical surveys. As a result, various targets were identified.

In 1978, the 1974 Salobo exploration targets were revisited and the presence of copper sulphides in an outcrop of magnetite schists at the Salobo 3 Alfa target was noted. Drilling of this target followed in conjunction with the development of two exploration adits. The Salobo 3 Alfa target is now referred to as Salobo. A pilot-scale study was carried out from 1985–1987 to further define the mineralization style and geometry. This included additional drilling and an additional 1 km of exploration adits.

The Carajás Copper Project team submitted an Exploitation Economical Plan for the Salobo deposit to the DNPM in June 1981. A pilot-scale study was completed between 1985 and 1987 to further define the mineralization style and geometry. The MME granted CVRD mining rights in 1987 through Ordinance No. 1121. A pre-feasibility study was completed by Bechtel in 1988 and a feasibility study was completed by Minorco in 1998. The feasibility study was revised and updated by Kvaerner in 2001.

Salobo Metais S.A. was incorporated on 29 June 1993 as a joint-venture vehicle between CVRD and Morro Velho Mining (a subsidiary of Anglo American Brasil Ltda., AABL). In June 2002, the Brazilian Council for Economic Defense approved the acquisition by CVRD of the 50% of Salobo Metais that was held by AABL. CVRD thus became the owner of Salobo Metais. CVRD changed its name to Vale in 2007.

The Salobo Operations commenced pre-stripping in 2009. Project ramp-up for Phase I of the Salobo Operations was completed three years later and the first concentrate was shipped in September 2012. The Salobo Phase I nameplate process plant capacity is 12 Mt/a. In 2014, the Salobo II process line, which doubled the nameplate capacity to 24 Mt/a, was completed. During 2019, construction began on Salobo III, which consists of a new beneficiation line with processing capacity of 12 Mt/a and supporting infrastructure. Salobo III is planned to be completed in 2022, and will take the overall plant throughput to 36 Mt/a.

6 GEOLOGICAL SETTING, MINERALIZATION, AND DEPOSIT

6.1 DEPOSIT TYPE

The Salobo deposit is an example of an iron oxide copper–gold (IOCG) deposit.

IOCG deposits as a group generally have the following characteristics: copper ± gold, as the main elements of economic interest; hydrothermal mineralization styles; strong structural controls; abundant magnetite ± hematite; iron oxides with the iron:titanium ratio greater than those found in most igneous rocks or the bulk crust; and no obvious spatial association with igneous intrusions, whereas porphyry and skarn deposits do show such associations.

The subset of IOCG deposits found in the Carajás District display the following: intense iron metasomatism leading to the formation of fayalite, grunerite, and/or iron oxides (magnetite and/or hematite); extensive carbonate alteration (mainly siderite), at least in the lower temperature deposits; iron-rich sedimentary rocks associated with quartzite and gneisses; amphibolite facies metamorphism; massive, foliated and banded rocks with predominant magnetite, fayalite, grunerite, almandine and subordinate biotite; hydrothermal alteration with areas affected by intense iron and potash metasomatism hosting most of the iron oxide copper–gold ore; sulphur-deficient nature of the sulphides (chalcopyrite, bornite, and primary chalcocite); quartz-deficient nature of the gangue; extremely low rare earth element (REE) enrichment; and enrichment in uranium and cobalt.

Genesis of the Carajás District deposits has been controversial, with a number of differing origins suggested, from porphyry copper styles to IOCG. The recent consensus within academia is that the deposits are best classified as examples of the IOCG style. The IOCG model is a valid model for exploration in the Salobo Operations area.

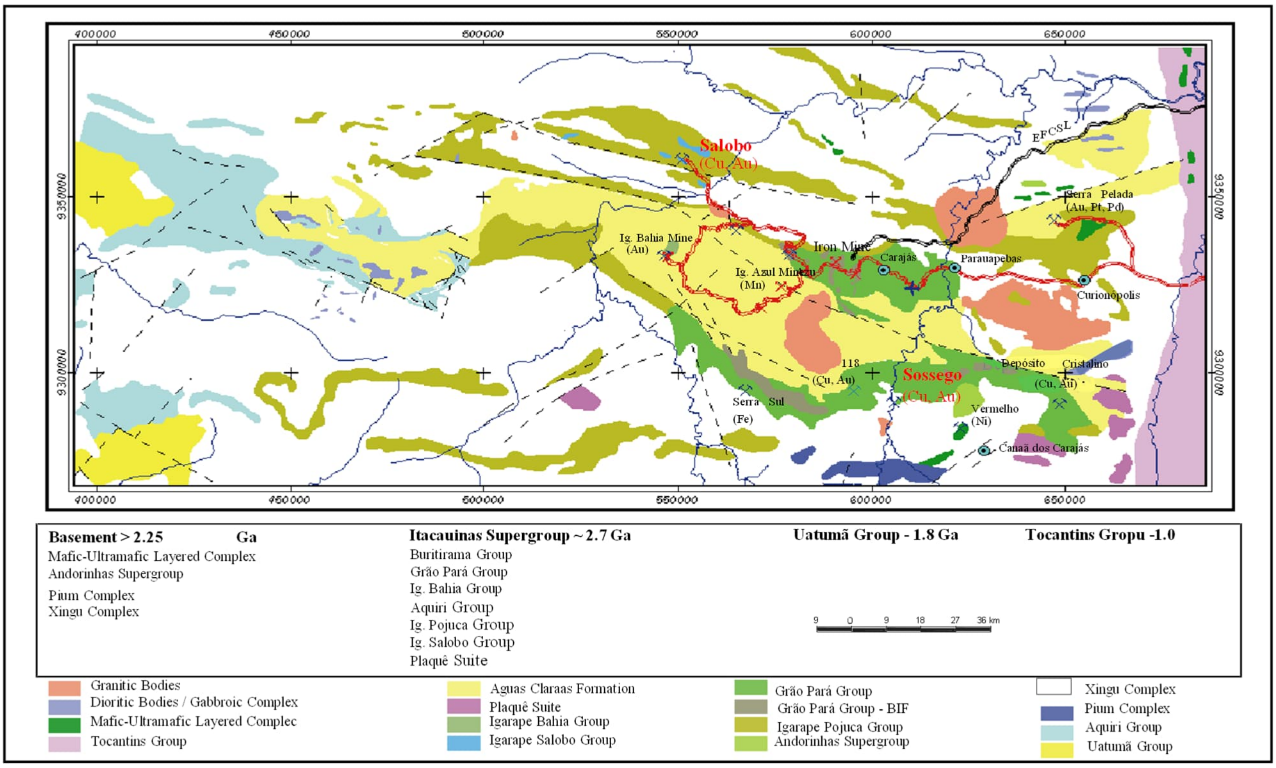
6.2 REGIONAL GEOLOGY

The Carajás Mining District, located in the southeast of Pará State, lies between the Xingu and Tocantins/Araguaia Rivers, and covers an area of about 300 km x 100 km. It is hosted in the Carajás Province, forming a sigmoidal-shaped, west–northwest–east–southeast-trending late Archean basin. Figure 6-1 shows a regional geology overview, and Figure 6-2 is a regional stratigraphic column.

The Archean basin contains a basement assemblage that is dominated by granite–tonalitic ortho-gneisses of the Pium Complex, and amphibolite, gneisses and migmatites of the Xingu Complex. The metamorphic rocks are cut by Archean-age intrusions, including the calc-alkaline Plaquê Suite, and the alkaline Salobo and Estrela granites.

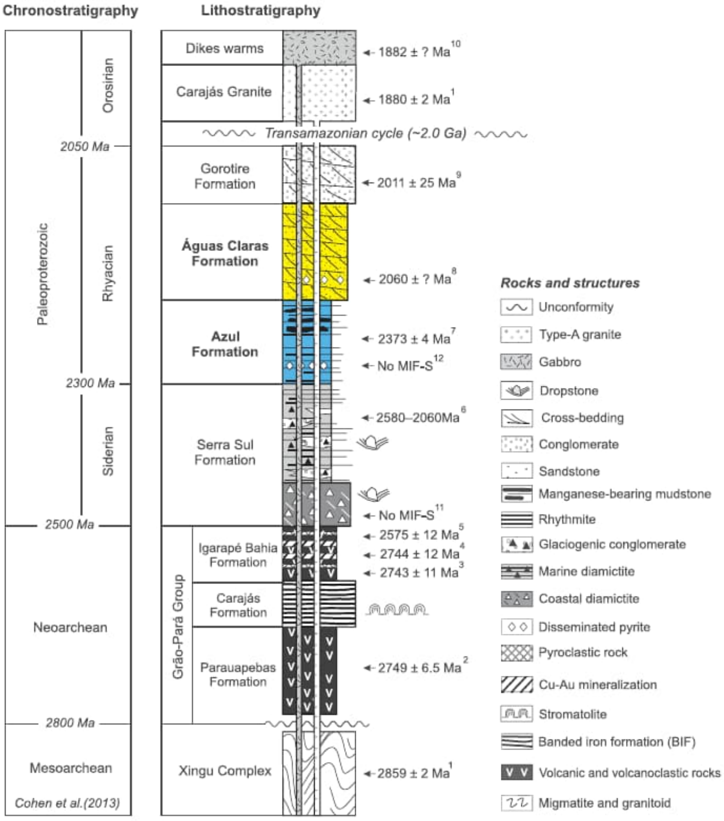
The basement rocks are overlain by volcanic and sedimentary rocks of the Itacaiúnas Supergroup, which in turn is overlain by an extensive succession of Archean marine to fluvial sandstones and siltstones known as the Rio Fresco Group or the Águas Claras Formation.

Figure 6-1: Regional Geology Plan



Note: Figure prepared by Vale, 2019. Deposits shown in red are held by Vale.

Figure 6-2 Regional Stratigraphic Column



Note: Figure from Araujo et al., 2020.

The non-deformed, Proterozoic Gorotire Formation, consisting of coarse arkoses and conglomerates with quartz, BIF, and basic rock clasts, overlies the older lithological units. A Proterozoic suite of anorogenic, alkaline granites, the Serra dos Carajás, the Cigano and the Pojuca granites, as well as several generations of younger mafic dykes, cross-cut the entire sequence.

6.3 LOCAL GEOLOGY

6.3.1 LITHOLOGIES

The Itacaiúnas Supergroup hosts all the Carajás IOCG deposits, including Salobo and Sossego (refer to Figure 6-1), and is interpreted to have been deposited in a marine rift environment. The metamorphism and deformation are attributed to the development of a sinistral strike-slip ductile shear zone (the Itacaiúnas Shear Zone) and to sinistral, ductile–brittle to brittle transcurrent fault systems (e.g., the Cinzento and Carajás Faults).

The Itacaiúnas Supergroup is sub-divided as follows (oldest to youngest): Igarapé Salobo Group; Igarapé Pojuca Group; Grão Pará Group: basal Parauapebas Formation and the Igarapé Bahia Group.

Mineralization at Salobo is hosted by the Igarapé Salobo Group which has undergone upper greenschist to lower amphibolite metamorphism. The group thickness varies from 300–600 m in the area of the Salobo Operations. Weathering in the area is to depths of 30–100 m. The rocks strike approximately N70°W and have a subvertical dip.

The major host units are biotite (BDX) and magnetite schists (XMT). Granitic intrusions (GR) occur adjacent to the north and southern sides of the BDX and XMT, and a series of much younger diabase dikes (DB) cross-cut the mineralization forming barren zones. Lithological descriptions of the major units are included in Table 6-1. A plan view of the geology is provided in Figure 6-3, and a cross-section in Figure 6-4.

6.3.2 STRUCTURE

The tectonic evolution of the Salobo area includes sinistral, transpressive, ductile deformation that developed under upper-amphibolite-facies conditions, followed by sinistral, transtensive, ductile–brittle-to-brittle shear deformation.

The Salobo deposit is situated within the Cinzento strike-slip system that reactivated older structures and formed a subparallel ductile–brittle shear zone in the northern part of the deposit and a brittle shear zone in the south. The brittle–ductile shear zone deformation resulted in lenticular-shaped mineralized shoots that show close associations between copper mineralization and magnetite content.

6.3.3 METAMORPHISM

Metamorphism consists of an initial high-temperature, low pressure phase followed by a retrograde greenschist phase. The initial phase included intense K-metasomatism and caused partial replacement of chalcopyrite by bornite and chalcocite. The retrograde phase is characterized by intense chloritization and partial replacement of bornite by chalcocite.

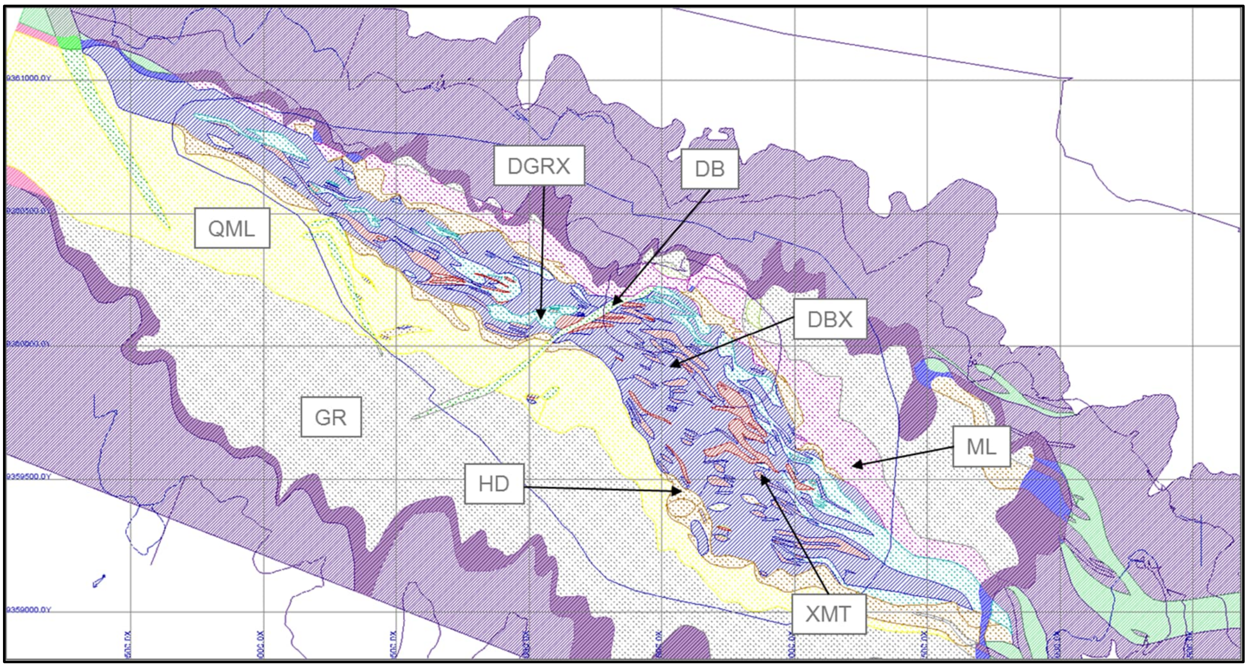
6.3.4 ALTERATION

The Salobo hydrothermal system has a core of massive magnetite that is surrounded by less intensely-altered rocks. Within the massive magnetite body there are small veins and irregular masses of secondary biotite. Garnet is completely replaced by magnetite, forming pseudomorphs. Away from the massive magnetite, the magnetite content gradually diminishes, giving way to biotite–garnet schist and/or garnet–grunerite schist. Alkali-metasomatism of the amphibolite facies rocks is expressed by weak sodium alteration with intense, superimposed potassium alteration (≤4.6 wt% of K_2O).

Table 6-1: Stratigraphic Table

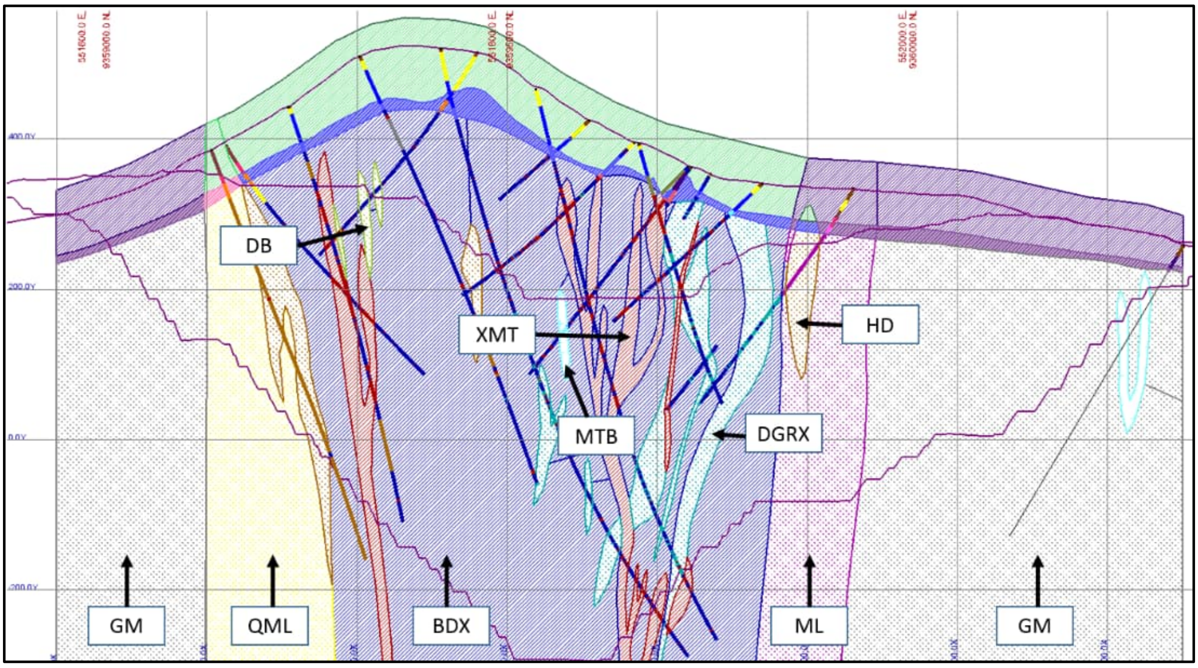
Unit	Description
Magnetite schists (XMT)	Massive, foliated and banded rocks, with predominant magnetite, fayalite, grunerite, almandine and secondary biotite. Presence of fayalite is marked by the replacement of grunerite and greenalite and transformation into magnetite and other sulphides. Iron–potassic alteration is common, creating schistosity in biotite units. The southeast portion of the deposit hosts hastingsite, replaced partially by actinolite, grunerite and sulphide minerals. Fluorite, apatite, graphite and uranium oxides are associated with this assemblage.
Biotite schist (BDX)	The most common lithology at Salobo. Consists of medium to coarse-grained material with anastomosed foliation. The mineral assembly is characterized by biotite (responsible for the foliation observed within the rocks), garnet, quartz, magnetite and chlorite. The assemblage with garnet, magnetite, grunerite and biotite is partially replaced by a second generation of biotite and magnetite with chlorite, K feldspar, quartz, hematite and sulphides. Tourmaline, apatite, allanite, graphite and fluorite generally occur throughout
Garnet–grunerite schist (DGRX)	Massive rocks with only local development of schistosity. The rocks with significant almandine and grunerite content have isotropic texture or very few schistosity structures. The predominant mineralogy is almandine and cummingtonite-grunerite, with magnetite, hematite, ilmenite, biotite, quartz, chlorite, tourmaline and subordinate allanite. Fluorite and uraninite generally occur in veinlets related to stilpnomelane, calcite and grunerite.
Feldspar–chlorite mylonite (ML)	Characterized by mylonitic foliation, produced by the orientation of rims of chloritized deformed biotite, hastingsite, elongated quartz and saussuritized plagioclase (K-feldspar, epidote and muscovite alteration). Garnet is partially to totally replaced by chlorite and epidote. Allanite and apatite generally occur throughout this lithology
Metavolcanic basic rock (MTB)	Massive coarse-grained rocks characterized by Fe-hastingsite and/or hornblende and plagioclase with chlorite alteration. It occurs irregularly in the system, but is concordant with other lithotypes in abrupt contacts, probably hydrothermally altered intrusive basic relicts within the package of volcanic rocks.
Quartz mylonites (QML)	Grey–white–green to red. Where present, Fe-oxides are medium to fine grained, foliated and composed predominantly of quartz, muscovite, sericite, sillimanite and chlorite. Accessory minerals, such as biotite, feldspar, magnetite, almandine, tourmaline, zircon and allanite are common. Two mylonite types are differentiated. (a) red quartz–feldspathic rocks formed by K-feldspar and quartz, which may be a product of shearing between the gneissic basement and the supracrustal rocks; and (b) chlorite schist, mainly composed of chlorite and quartz, which represent intense hydrothermal alteration. Chlorite schist occurs near the southern border of the deposits, close to major brittle shear zones that may have been conduits for hydrothermal fluids.
Old Salobo Granite (GR)	Colorless, pink to grey, coarse-grained and with mylonitization in some areas. Consists of K-feldspar (orthoclase-microcline), oligoclase, quartz, augite, hornblende, chlorite and, rarely, magnetite. Forms a stockwork.
Young Salobo Granite (GR)	Small northwest-trending sills. In some porphyritic portions, the matrix is aphanitic, containing a porphyry of red albite (Fe-oxide in microfractures) and chlorite pseudomorphed by biotite. Mineral assemblage comprises fine- to medium-grained, equigranular, grains of albite/oligoclase, orthoclase, quartz, chlorite, with minor epidote, zircon, fluorite, magnetite, chalcopyrite and pyrite.
Diabase (DB)	Set within shear/fault lateral geometries (N70°E) and frontal geometries (N20°W). Consists of augite, plagioclase, magnetite, ilmenite and quartz.
Rhyolite (RIO)	Grey–reddish in color, porphyritic in texture, within an aphanitic matrix. Consists of K-feldspars, plagioclase, quartz, amphibole in a matrix cut by quartz veinlets.

Figure 6-3: Geology Plan



Note: Figure prepared by Vale, 2019. Refer to Table 6-1 for abbreviation key.

Figure 6-4: Geological Cross-Section



Note: Figure prepared by Vale, 2019. Refer to Table 6-1 for abbreviation key.

K-feldspar, biotite and oligoclase are the main alteration minerals. Potassium alteration in amphibolite was marked by replacement of calcium-amphibole and by formation of biotite and magnetite.

The chemistry of the meta-greywackes at the deposit indicates that they also underwent significant iron and potassium alteration. Alteration assemblages are characterized by garnet, biotite and grunerite, with subordinate tourmaline and minor magnetite. The better-mineralized zones, located in the central part of the deposit, correspond to the most altered areas.

6.4 PROPERTY GEOLOGY

6.4.1 DEPOSIT DIMENSIONS

The Salobo deposit extends over an area of approximately 4 km along strike (west–northwest), is 100–600 m wide, and has been recognized to depths of 750 m below the surface.

6.4.2 LITHOLOGIES, STRUCTURE, ALTERATION

The deposit setting is outlined in Chapter 6.3.

6.4.3 MINERALIZATION

Mineral assemblages occur in a number of styles: disseminations, stringers, stockworks, massive accumulations, fracture fillings, or veins associated with local concentrations of magnetite and/or garnet filling the cleavages of amphiboles and platy minerals, and remobilized in shear zones. Textural relationships indicate that mineralization was developed initially as an oxide stage, with a second, subsequent, sulphide stage.

There is a positive relationship between copper minerals and magnetite. Copper content is typically >0.8% in XMT and BIF, but in gneisses and schists it is <0.8%. A positive correlation between copper and uranium exists.

Sulphide mineralization typically consists of magnetite–chalcopyrite–bornite and magnetite–bornite–chalcocite. Accessory minerals include hematite, molybdenite, ilmenite, uraninite, graphite, digenite, covellite, and sulphosalts.

Chalcopyrite, bornite, and chalcocite occur interstitially to silicate minerals. These sulphide minerals are commonly found filling cleavage planes of biotite and the amphibole grunerite. Hematite is rare, but in places it can reach as much as 4% by volume. It exhibits tabular textures (specularite), with bornite infill, and partial replacement by magnetite.

Native gold occurs as grains in cobaltite, safflorite ($(Co,Fe)As_2$), magnetite and copper sulphides, or interstitial to magnetite and chalcopyrite grains.

The gangue minerals are garnet, grunerite, and tourmaline, reflecting the intense iron-metasomatism. Minor amounts of fayalite and hastingsite are pseudomorphed by grunerite and magnetite. Ilmenite, uraninite, allanite, fluorite and apatite occur as accessory minerals.

Kinked biotite crystals are associated with potassic alteration, and spatially related to the copper–gold mineralization. Uraninite and zircon inclusions may be locally abundant in biotite.

Quartz is associated with biotite in better mineralized samples, and forms concordant veins within the host rocks.

7 EXPLORATION

7.1 EXPLORATION

7.1.1 INTRODUCTION

There is on going exploration activities, that are not within the scope of this document.

7.1.2 GRIDS AND SURVEYS

A topographic reference grid was established by ENGEVIX in 1978 and was corrected by ESTEIO in 2003. Salobo surveyors use a local datum, P3201, which has a planimetric difference with the more commonly used PSAD56 datum. The differences are: N: -9.7153 m; E: +2.8821. Local elevations have a +0.6442 m difference relative to the official Datum of Imbituba.

7.1.3 GEOLOGICAL MAPPING

Geological mapping at different scales was conducted over the concession area during the initial exploration campaigns, usually following survey traverses. However, due to the fact that nearly 80% of the rocks in the Carajás district are poorly exposed, most direct observations were made along access roads for drill sites and were complemented with additional information such as interpretation of air-photo images, geophysical and geochemical maps, and correlation on surface of core logging data. These data were used to vector into drill targets.

Pit mapping is conducted twice a month. A geologist loads the long-term geologic map over the updated topographic map on a global positioning system (GPS) instrument and establishes the actual position of the geological contacts where access is possible.

7.1.3.1 GEOCHEMICAL SAMPLING

Geochemical surveys were conducted by Docegeo and CVRD/GICOR during the initial exploration period (Salobo Metais/CVRDa, 2003). While, none of the consulted historical reports provide details of the geochemical methods, sampling or results, this was deemed as non-material to mineral resource and mineral reserve estimation.

7.1.4 GEOPHYSICS

Geophysical programs were conducted since initial exploration phases, and geophysical data are superceded in the open pit area by core drill data and pit wall exposures.

7.1.4.1 GROUND GEOPHYSICS

Ground magnetometer () and induced polarization (IP) surveys, using a 400 m x 40 m grid, were conducted by CVRD/GICOR in 1995. Various anomalies were identified at the Salobo and Mirim creeks and at the Planta Industrial sector. Gamma-spectrometry (GS) and GM surveys on a 200 m x 20 m grid confirmed the mineralized nature of the sources. Between July and December 2002, Fugro-Geomag S.A. (FugroG) conducted GS, GM, IP and ground transient electromagnetic (TEM) surveys in the mineral concession area.

The GM survey measured the total component of the magnetic field using two GSM-19 Overhauser (from GEM Systems) instruments, with 0.2 nT precision, 0.01 nT resolution, 20,000 nT to 120,000 nT dynamic range and over 10,000 nT/m tolerance. One magnetometer was used as a mobile instrument, with readings spaced at 20 m intervals along traverses. The second magnetometer was used as a base station at a fixed location, and readings were made every 5 s. In both cases, sensors were placed 2 m above ground level. In total, 413 km of lines were surveyed during the 2002–2003 campaign with this method.

The IP survey used a time-domain IP system built by Iris Ltd., consisting of a VIP 4000 transmitter and a 20-channel ELREC-6 receptor, on a dipole-dipole array with 80 m electrode spacing. The receptor measured six electrodes simultaneously on 20 programmable chargeability windows, as well as potential differences used for calculating the apparent resistivity. In total, 181 km of lines were surveyed during the 2002–2003 campaign with this method.

The GS survey used a GR-320 Envispec instrument with a 21 cubic-inch NaI sensor. Readings were always made 50 cm above ground level and with a 60 s integration time. Distance between reading points was 20 m. In total, 214.5 line km were surveyed with this method during the 2002–2003 campaign.

The ground TEM survey used a Geonics EM57 transmitter and a Geonics Protem receptor, with uniaxial coils for sequential readings of three components (X, Y and Z) on five frequencies: 0.3 Hz, 0.75 Hz, 3.0 Hz, 7.5 Hz and 30.0 Hz. In total, measurement on 750 loops were completed to cover the Project area.

Overall, mineralized bodies were characterized by low apparent resistivity and high chargeability values.

7.1.4.2 AIRBORNE GEOPHYSICS

A regional airborne gravity gradiometer survey was completed in 2012 over a portion of the Carajás Region, including the Salobo Operations area. It was designed to explore for new shallow copper–gold targets. The survey flight is typically at an altitude of 80 m or greater with a line spacing dependent on the target of investigation. The 2012 survey was flown on 100–200 m spaced lines.

There are a number of viable interpretations of the gravity data, one of which is that there could be a vertical extension of the Salobo mineralization below the current planned open pit, as the geological data have already indicated. In 2017, a deep drilling campaign explored this potential orebody extension and encountered mineralization at depth below the current open pit operations.

7.1.5 QUALIFIED PERSON’S INTERPRETATION OF THE EXPLORATION INFORMATION

The Salobo Operations area has been the subject of exploration and development activities since 1977, and a considerable information database developed as a result of both exploration and mining activities. Procedures are consistent with industry-standard practices at the time the work was performed.

7.1.6 EXPLORATION POTENTIAL

The potential for depth extensions of mineralization under the open pit has been the subject of exploration activity since 2017, and results of drilling to date remain encouraging.

7.2 DRILLING

7.2.1 OVERVIEW

Core drilling using diamond tools commenced in 1978 and was conducted through to 2003 in five different drilling campaigns. No exploration core drilling occurred between 2003 and 2009. In 2010, two infill holes were completed. Infill core drilling recommenced in 2017.

All drilling was completed by Vale. Most drill holes were vertical or oriented to the south–southwest, the latter with dips usually ranging from 60° to 70°. However, one campaign included holes with a north–northwest orientation and similar dips. Various holes were also drilled from an adit.

Drilling forms an irregular drill pattern, with drill holes spaced at 20–60 m in the core of the deposit and widening to 100–200 m on the deposit extremities.

The Salobo Operations perform geological logging and sampling and the collected data are reviewed and verified by Vale personnel.

7.2.1.1 DRILLING ON PROPERTY

There is a total of 577 core holes (206,768 m) completed for exploration purposes, and 14 core holes (8,042 m) were conducted for geotechnical purposes (Table 7-1). A drill collar location plan for the 1978–2021 drilling is provided in Figure 7-1. There was a drilling hiatus from 2010–2017. Drill collars for the drill holes completed since 2017 are shown in Figure 7-2.

7.2.1.1 DRILLING SUPPORTING MINERAL RESOURCE ESTIMATES

All drilling that has assay intercepts supports mineral resource estimation inside a mineral wireframe that was created using a reference cut-off of 0.2% Cu.

7.2.1.2 DRILLING EXCLUDED FOR ESTIMATION PURPOSES

The mineral wireframe is constructed using a 0.2% Cu cut-off. Data is excluded if the drill hole was not assayed, if the grade in the drill hole is <0.2% Cu and outside of the mineral wireframe, or if the purpose of the drill hole was condemnation or geotechnical drilling. All assays inside the mineral wireframe are included in the evaluation to account for waste.

7.2.2 DRILL METHODS

The surface drilling was initiated with HQ diameter core (63.5 mm) and usually continued with NQ diameter (47.6 mm). The minimum diameters were BX (42 mm) and BQ (36.4 mm). Underground drilling in the exploration adits used BX rods.

Drilling systems included conventional and wireline core methods.

Core makes up the majority sample type for geological modelling and mineral resource estimation at the Salobo Operations. Blastholes have been drilled since 2009; however, those are only used for short-term mine planning purposes.

7.2.3 LOGGING

During drilling campaigns from 1997 onward, core was collected in 1 m-long wooden boxes and photographed in sets of two boxes each after transportation to the core shack. Logging was completed prior to sampling, and consisted of describing each individual lithological package, as well as mineralogical variations, textures and structures, sulphide and other minerals (including a visual assessment of volume percentage), the presence of deleterious minerals (mainly fluorite), visible structures, and the foliation angle with respect to the core axis.

7.2.4 RECOVERY

Micon (2013) noted that core recoveries of 80% in weathered rock and 90% in fresh rock were achieved by the drilling companies during the campaigns. The average core recovery of the 2002 campaign (drill holes SAL-3ALF-FD 278 to 410) was 97.6%.

Amec Foster Wheeler (2016) reviewed the recovery data for holes where the information was recorded and supported Micon’s assessment of overall good recoveries.

Core recovery for the infill and deep drilling since 2017 has averaged 99%.

7.2.5 COLLAR SURVEYS

During the 1997 campaign, drill-hole collars were placed and resurveyed after completion using a WILD T1 theodolite.

During the 2002–2003 campaign, drill sites were placed and collar coordinates measured using total station equipment (before and after hole completion). The survey team oriented the drill rigs, and provided initial alignment and inclination to the drilling rods. Collar verification was completed by plotting drill hole locations on plan and in cross-section and comparing with the topographic surface.

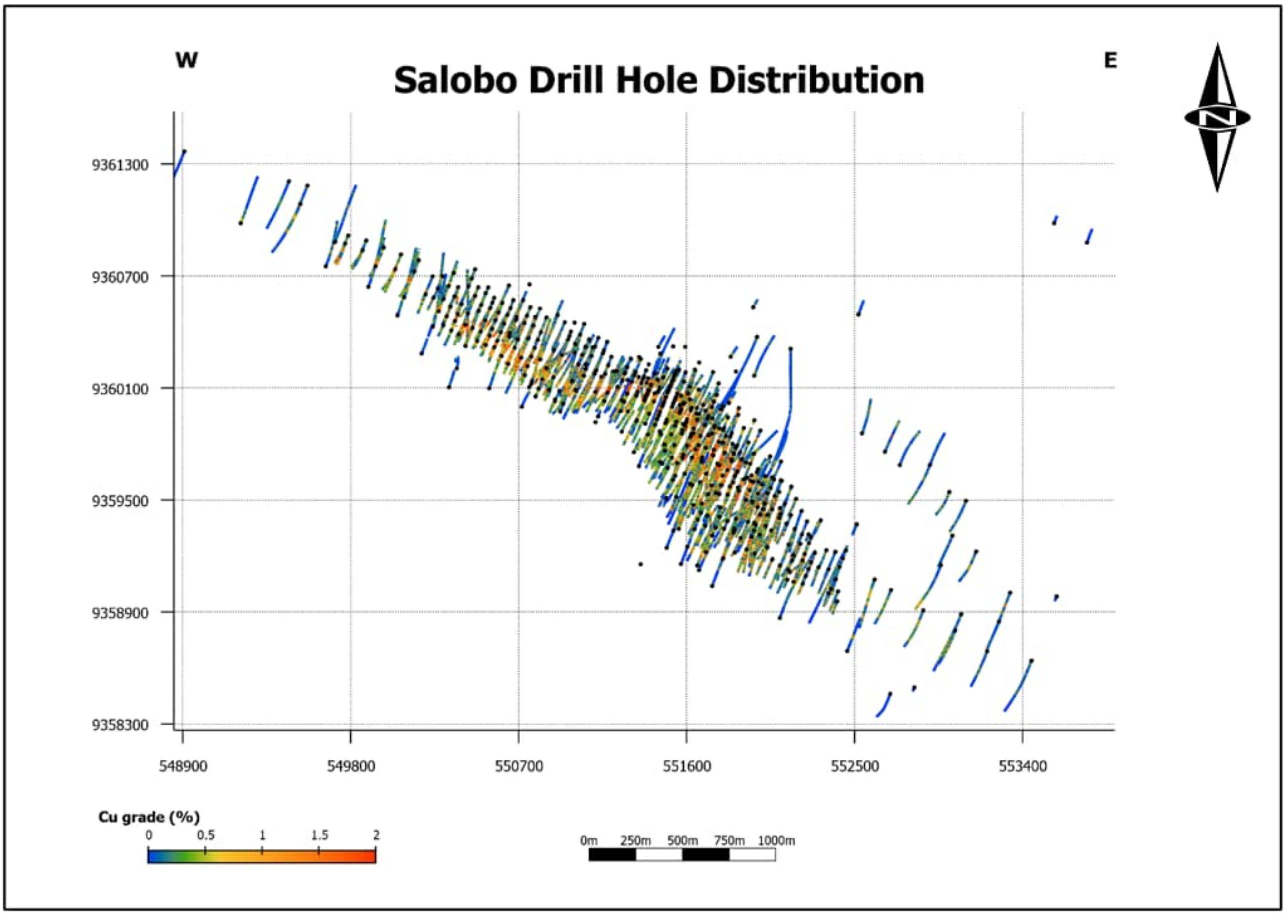
From 2010 onward, collar surveying was conducted by Vale surveyors using high-precision, differential GPS equipment.

Table 7-1: Salobo Operations Drill Summary Table

Campaign/Period	Purpose	Number of Drill Holes	Drill Hole ID	Total Meterage Drilled (m)
1978	Exploration	65	SAL-2ALF-FD001 to SAL-3ALF-FD 065	29,275
1986	Exploration	60	SAL-SALF-FD066 to SAL-3ALF-FD 125	9,051
1993	Exploration	64	SAL-3ALF-FD126 to SAL-3ALF-FD 189	14,585
1997	Exploration	88	SAL-3ALF-FD190 to SAL-3ALF-FD 277	25,491
2002	Exploration	143	SAL-3ALF-FD278 to SAL-3ALF-FD 420	69,908
2010	Infill	2	SAL-3ALF-FD421 to SAL-3ALF-FD 422	361
2017	Infill	42	S3A-FD00423 to S3A-FD00464	13,265
2017	Deep exploration	1	PSD-SALO-DH00001	1,566
2018	Infill	40	S3A-FD00465 to S3A-FD00504	12,322
2018	Deep exploration	3	PSD-SALO-DH00002, PSD-SALO-DH00002-1, PSD-SALO-DH00002-2	4,300
2019	Infill	29	S3A-FD00505 to S3A-FD533	10,510
2019	Deep exploration	2	PSD-SALO-DH00003, PSD-SALO-DH00003-1	2,723
2020	Infill	25	S3A-FD00534 to S3A-FD558	7,433
2020	Deep exploration	1	PSD-SALO-DH00003-2	1,269
2021	Infill	10	S3A-FD00559 to S3A-FD568	2,692
2021	Deep Exploration	2	PSD-SALO-DH00004 PSD-SALO-DH00004-1	2,016
Total exploration		577		206,768
1997	Geotechnical	7	SAL-3ALF-FG001 to SAL-3ALF-FG 007 *	3,847
2003	Geotechnical	7	SAL-3ALF-FG008 to SAL-3ALF-FG 014 *	4,194
Total geotechnical		14		8,042
Grand total		591		214,810

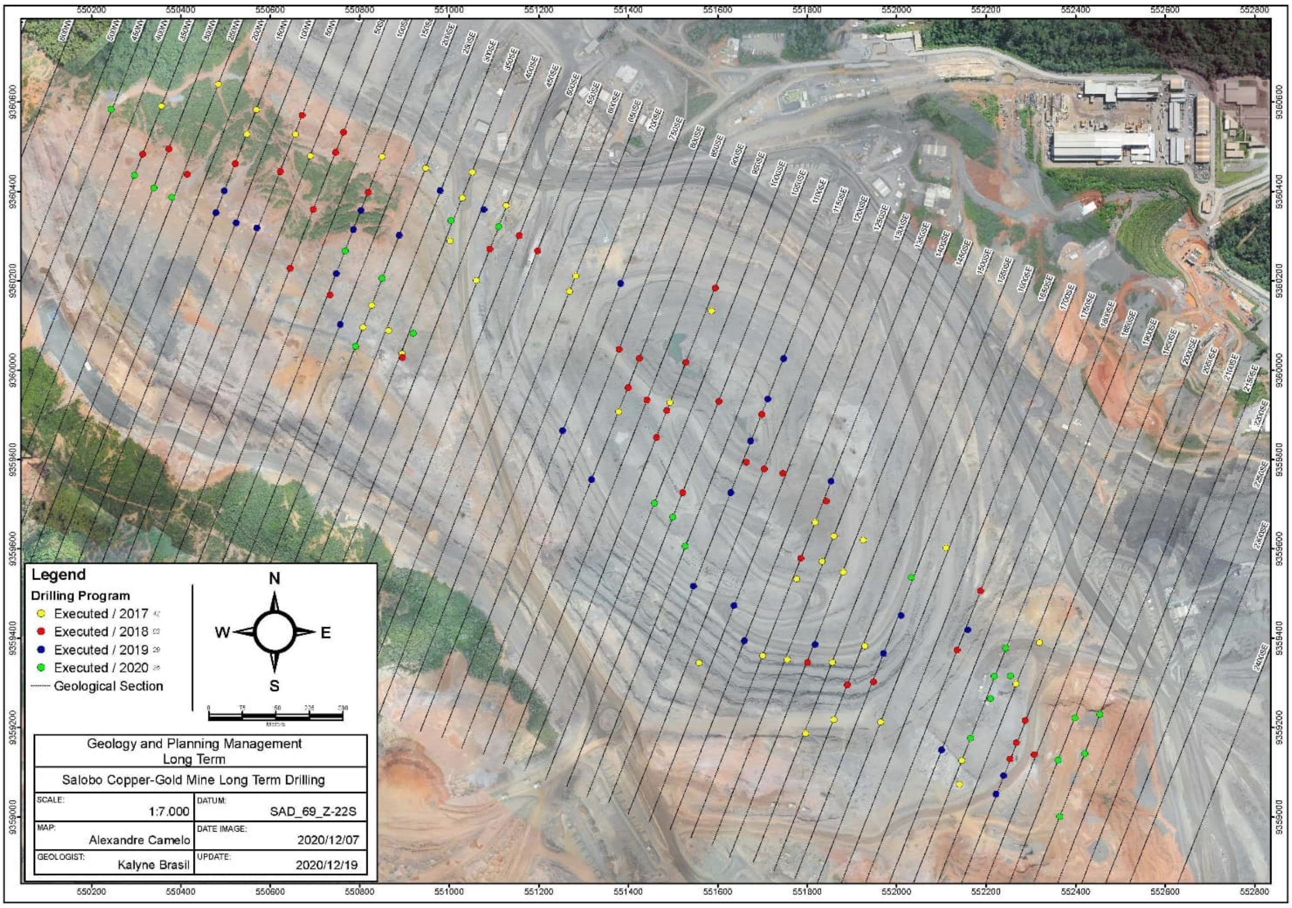
Note: * Geotechnical drill holes were typically not assayed.

Figure 7-1: Drill Collar Location Plan (1978–2021)



Note: Figure prepared by Vale, 2021.

Figure 7-2: Drill Collar Location Plan (2017–2020)



7.2.6 DOWN HOLE SURVEYS

During the 1997 campaign, downhole surveys were every 3 m down hole using the Reflex DDI (dip and direction pointer) and Maxibor units. These instruments were used to avoid errors in azimuth data due to the influence of magnetite in the host rocks.

During the 2002–2003 campaign, down-hole survey measurements were conducted every 3 m using Reflex Maxibor and gyroscopic instruments. Later drill campaigns used a Maxibor instrument.

Since 2017, the infill and deep drilling programs have used the Reflex Gyro tool for downhole surveys. Vale switched in 2019 to using a Reflex Gyro Sprint instrument.

7.2.7 COMMENT ON MATERIAL RESULTS AND INTERPRETATION

The Salobo Operations have been in production for nearly a decade. Drilling and surveying were conducted in accordance with industry standard practices at the time, and provide suitable coverage of the mineralization. The collar and downhole survey methods used provide reliable sample locations. Logging procedures provide consistency in descriptions.

These data are considered to be suitable for mineral resource and mineral reserve estimation. There are no drilling factors known to the QP that could materially impact the accuracy and reliability of the results.

7.3 HYDROGEOLOGY

7.3.1 INTRODUCTION

Information obtained during early-stage hydrological and hydrogeological evaluations is superseded by data obtained from over a decade of mining activities.

The aquifer system in the Salobo region is characterized by the absence of primary porosity. Groundwater flow is typically through discontinuities such as faults, joints and fractures. Fissured aquifers are usually characterized by low infiltration and storage capacities, limited flow rates, and high salinity.

7.3.2 SAMPLING METHODS AND LABORATORY DETERMINATIONS

The Salobo Operations have a water level monitoring network consisting of 24 piezometers, 15 monitoring wells and two pumping wells, in addition to monitoring the water levels in 78 boreholes.

The Salobo Operations hydrogeological model was reviewed in February 2019 by third-party consultants, MDGEO Hidrogeologia e Meio Ambiente (MDGEO). The original 2004 model was revised and updated to cover the open pit, stockpiles and TSF areas. The major water-bearing units were noted to be the alteration zone (20% of the annual recharge), and fractured granite gneisses (15%).

Following the hydrogeological model review, all instrumentation recommended in the monitoring plan was installed and is fully operational. The mine drainage and pumping plan was updated to mitigate erosion, fining and instability that can occur during the wet season.

A water balance assessment was performed in 2018 by third-party consultants, Walm Engenharia e Tecnologia Ambiental Ltda (Walm), to determine if the TSF could provide all of the process water requirements for the remaining LOM. Assuming that the TSF raises occur, as planned in two stages, in 2026, and 2042, Walm concluded that there will be sufficient water to support the operations such that Vale does not have to find additional water sources outside the TSF.

Surface water monitoring is conducted at set locations within the operations area. Samples collected are sent to SGS Geosol Laboratórios Ltda in Parauapebas, and analysed for a suite of parameters such as selected elements (e.g., lead, arsenic, cyanide), acidity, alkalinity, electrical conductivity, hardness and pH.

7.3.3 COMMENT ON RESULTS

A detailed water balance has been developed, and indicates that water for operations can be supplied by the TSF.

Surface samples are used to monitor compliance with local regulations and the impact of operations on local waters.

7.4 GEOTECHNICAL

7.4.1 INTRODUCTION

Information obtained during early-stage geotechnical evaluations is superseded by data obtained from mining activities.

7.4.2 SAMPLING METHODS AND LABORATORY DETERMINATIONS

Geotechnical logging of drill core was conducted by Vale geologists following guidance from geotechnical engineers. Logging included simple descriptions of the weathered zones and the weathering and fracturing degrees of the mineralized schists, as well as visual determination of the rock-quality designation (RQD) and rock resistance, and descriptions of the fracture types. Point-load tests (PLT) were conducted every 20 m. All testwork was performed by Vale personnel.

The Salobo Operations 3D geomechanical model was reviewed in June 2019 by third-party consultants, Walm and in September 2020 by an internal Vale team. Walm suggested that the operations perform additional bench cleaning due to rock spillage from blasting movements. Geotechnical inspections and monitoring are constantly undertaken for both short- and long-range mine plans and are checked against the existing models.

The Salobo pit has been subject to small seismic events. The first seismic event was reported in 2017. So far, no major damages or injuries have been reported. However, in October 2017, small wedge failure occurred on the south side of the pit. Because the seismicity appears to be related to geology rather than pit geometry, the seismic events are likely to continue. Unless there is associated pit wall instability or rock falls, the seismic events are not currently considered to be an operational issue.

There are three seismological stations installed the Salobo Operations area. Data are compiled monthly by third-party consultants USP, in conjunction with Vale geophysical personnel. Micro-seismic monitoring systems may be installed should seismicity increase beyond current levels.

7.4.3 COMMENT ON RESULTS

A combination of historical and current geotechnical data, together with mining experience, is used to establish slope design criteria and other geotechnical recommendations. These criteria and recommendations support the mine plan which is discussed in more detail in Chapter 13 of this Report.

Vale has constructed a structural model for the Salobo pit to support future pit design analyses for the deeper pit phases. Additional geotechnical data will be collected in support of final pit wall design. The potential influence of alteration on rock strength, and effects of pore pressures within structures that can affect pit wall stability are planned to be evaluated for the deeper pit phases.

8 SAMPLE PREPARATION, ANALYSES, AND SECURITY

8.1 SAMPLING METHODS

The Salobo Operations personnel perform geological logging, and sampling including the review and verification of the collected data.

8.1.1 DRILL CORE

The core sampling procedure was similar during the 1997 and 2002–2003 campaigns. Sample intervals averaged 1 m in mineralized zones, and varied from 2–4 m in barren zones. Sample lengths may vary depending on geological and lithological/structural criteria (such as geological boundaries, lithological/mineralogical changes, and the presence of structures such as faults and shear zones).

From 2017–2021, sample intervals averaged 1.05 m.

Core was cut in half using diamond saws. One half was bagged and submitted to the mine laboratory for analysis, and the remaining half core was retained as backup.

8.1.2 GRADE-CONTROL SAMPLING

Blastholes are drilled on varying grid patterns depending on the material to be sampled, the hole diameter, and the pit phase (see discussion in Chapter 13.5). All blastholes located in ore zones are sampled; however, as the blasthole reaches the barren zones, the proportion of sampled holes decreases (one in two or fewer), and the grade-control geologist determines which waste blastholes are sampled to check if the interpretation in the geological model matches with the observed mineralization.

The sampling pattern depends on the shape of the cone. If the cone is well formed, then four channels are cut across the cone at 90° using a small mattock, and the sample is collected using a jar from bottom to top of the inner channel wall. If the cone has been partially damaged, then three channels are cut; however, if it is seriously damaged then the cone is not sampled. The average sample weight is 2 kg.

Tags are currently inserted into the ore after blasting for tracking purposes to understand the differences between the estimated recovery of the samples, and the actual recovery in the processing plant. The tags are detected at specific points in the processing plant.

8.2 SAMPLE SECURITY METHODS

During the drill campaigns, the drill core was brought from the drill sites, at the end of shift, to a dedicated logging and storage facility, originally in Parauapebas, and later at the mine site.

All drill core was stored in wooden boxes with proper numbering to indicate the drill hole number and meterage. The core storage and logging facilities were kept locked when unoccupied. Unshipped samples were also stored in a secure facility at the same location.

Pulps are stored in paper envelopes grouped in plastic bags and the coarse rejects are stored in plastic bags. Both are organized in properly identified boxes.

At the Report date, a new core shed was under construction in Parauapebas and, when completed, all core is planned to be stored in that facility.

8.3 DENSITY DETERMINATIONS

During the 1997 campaign, bulk density determinations were made with the water-displacement method. Tests were conducted on 20–40-cm long saprolite and bedrock core samples within intervals of approximately 10 m length. Wet and dry bulk densities were determined on saprolite samples, which were weighed in air prior to and after drying (respectively), then coated with a thin plastic film, and submerged in water in a PVC container with a discharge opening. The sample volume was determined by measuring the water displaced through the discharge into a graduated cylinder. Core samples were assumed to be dried, so only dry density was determined. The bulk density (D) was determined as:

- D = P/V

where P is the dry (or wet) weight, and V is the volume of displaced water.

During the 2002–2003 campaign, the specific gravity (SG) was determined on representative fragments from all sampling intervals using a standard procedure. Hard-rock samples were cleaned and dried in air, and then weighed in air and in water. Saprolite samples were dried using an oven, then coated with paraffin prior to submerging the samples in water.

The infill and deep drilling programs conducted from 2017 onward use the same SG measurement methodology as the 2003 drilling campaign; however, saprolite core is wrapped in plastic instead of being wax-coated.

There are currently approximately 132,000 sample data points that were collected across the entire deposit. Values for weathered waste rock and fresh bedrock are separately determined, due to weathering related differences in permeability and porosity.

8.4 ANALYTICAL AND TEST LABORATORIES

The main laboratories, where known, which were used for sample preparation and analysis are included in Table 8-1.

8.5 SAMPLE PREPARATION

Where known, the sample preparation procedures have remained consistent between exploration and delineation core programs, and consist of crushing to 95% <4 mm or 95% <3.35 mm, followed by pulverizing to 95% passing 0.105 mm or 95% passing 0.106 mm.

Blasthole samples are crushed to >95% passing 3 mm size, and pulverized to >95% passing 0.105 mm.

Table 8-1: *Analytical and Test Laboratories*

Laboratory Name	Period Used	Function	Note	Independent
Docegeo, Belém, Pará (Docegeo), PA, Brazil	1978–1987	Sample preparation and primary analytical laboratory	Unknown accreditations	No
SUTEC, Santa Luzia, MG, Brazil	1978–1983	Primary analytical laboratory	Unknown accreditations	No
Pilot Plant Laboratory, PA, Brazil	1986-1987	Primary analytical laboratory	Unknown accreditations	No
Lakefield Geosol, Belo Horizonte, MG, Brazil	1986	Check assay laboratory (for copper and gold)	Unknown accreditations	Yes
Mineração Morro Velho laboratory, MG, Brazil	1993–1994, 1997	Sample preparation and primary analytical laboratory	Unknown accreditations	No
Nomos laboratory, Rio de Janeiro, Brazil	1993	Check assay laboratory (for gold)	Unknown accreditations	Yes
Fazenda Brasileiro, BA, Brazil	1993	Check assay laboratory	Unknown accreditations	No
Lakefield Geosol Belo Horizonte, MG, Brazil	2002–2003	Primary analytical laboratory	Routine analysis of copper, gold, and silver ISO 17025:1999 accredited	Yes
Acme, Vancouver, BC, Canada	2002–2003	Primary analytical laboratory	Routine analysis of molybdenum, uranium, fluorine, sulphur, and carbon. Unknown accreditation	Yes
Vale Gamik, Belo Horizonte, MG, Brazil	2002–2003	Check assay laboratory	Not accredited	No
Salobo Operations laboratory, PA, Brazil	2012 to date	Sample preparation (exploration core samples), sample preparation and analytical laboratory (blast hole samples)	ISO 9001:2015 certified	No
ALS Geochemistry, Lima, Peru	2017 to date	Primary analytical laboratory	ISO 17025:2017 accredited	Yes
ALS Geochemistry, Belo Horizonte, MG, Brazil	December 2018 to August 2021	Sample preparation	ISO 17025:2017 accredited	Yes
ALS Geochemistry, Parauapebas, PA, Brazil	September 2021 to date	Sample preparation	ISO 17025:2017 accredited	Yes
SGS Geosol, Belo Horizonte, MG, Brazil	March 2018 to date	Check assay laboratory	ISO 17025:2017 accredited	Yes

8.6 ANALYSIS

From 1978–1987, copper was assayed on 0.5g aliquots by multi-acid digestion and atomic absorption spectrometry (AAS). Iron, molybdenum, and silver were also determined using this method. Gold was assayed by aqua regia leaching, with solvent extraction (MIBX) and AAS determination.

Copper was determined in the 1993–1997 campaigns using multi-acid digestion and AAS reading on 0.5 g aliquots (0.002% detection limit), and gold was determined using the fire-assay (FA) method with gravimetric finish on 100 g aliquots (0.05 g/t detection limit). In addition, samples were assayed for sulphur and carbon by LECO, and fluorine by alkaline fusion with sodium carbonate and potassium nitrate, followed by ion-selective electrode determination.

In the 2002–2003 campaigns, chemical analysis was by AAS for copper and silver (on a 0.5 g aliquots and multi-acid digestion), while gold was assayed by FA with AAS finish on 20 g aliquots.

From 2017 to date, the copper analysis was reported using a four-acid digestion and a AAS reading (ALS method Cu-AA62). Gold was assayed by FA on a 50 g aliquot, using a two-step digestion with nitric and hydrochloric acids and reading by atomic absorption (ALS method Au-AA24). A multi-element suite (including main elements and traces, in addition to copper, silver, uranium and thorium) was determined after four-acid digest using inductively-coupled plasma (ICP) mass spectroscopy (MS) or atomic emission spectroscopy (AES) methods (ALS method ME-MS61). Chlorine was analyzed by lithium borate fusion and a wavelength dispersive X-ray fluorescence spectroscopy finish (ALS method XRF75V). Fluorine was assayed by potassium hydroxide fusion and specific ion electrode finish (ALS method ISE03A).

Blast hole samples were analyzed as summarized in Table 8-2.

8.7 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control (QA/QC) programs before 2002 mostly included seldom submission of external assay checks and, to lesser extent, standard reference material (standard) samples and coarse duplicates. A re-assay campaign was initiated to validate the available analytical data, thus a total of 51,768 of the original 75,577 samples drilled prior to 2002 were re-assayed to corroborate the original results.

A re-assay program was undertaken in 2002–2003 to validate the pre–2002 data, and following that program, the earlier data that were not re-assayed for lack of analytical material were accepted for use in estimation.

In the 2002–2003 drilling campaign, the QA/QC program consisted of the sample preparation blanks, SRM samples, pulp duplicates and external assay checks. The reliability of the 2002–2003 copper, gold, and silver assays was additionally verified by a re-assaying program that included two matrix-matched in-house standard samples.

The most recent QA/QC program, which was undertaken from 2017 to the Report date, included sample preparation blanks (2.5% frequency), standard samples (2.5%), twin or core duplicate samples (1%), coarse reject duplicates (2.5%), the same and different batch pulp duplicates (both at 2.5% frequency) and external assay checks (5%).

The QA/QC results were monitored regularly either by third-party consultants retained by Vale, or by Vale and predecessor company staff. No material issues from the QA/QC programs were noted, and the data were considered acceptable to support mineral resource estimates.

A QA/QC routine is in place, performed by the logging geologists, and checked by senior Vale personnel. An annual QA/QC report is prepared that summarizes the QA/QC for the drill programs that will be used in support of mineral reserve and mineral resource estimates.

Table 8-2: Salobo Operations Laboratory Blast Hole Sample Analytical Methods

Element	Aliquot (g)	Method
Cu (%)	0.25	ARD-AAS
Au (g/t)	50	FA-AAS
Ag (g/t)	10	MAD-AAS
Fe (%)	0.25	ARD-AAS
C (%)	0.25	LECO
S (%)	0.25	LECO
U (ppm)	1.0 / 10.0	MAD-ICP-AES or ICP-MS
F (ppm)	0.3	AF-ISE
Cl (ppm)	1.0	SAL-SNT
CuSol (%)	1.0	AcAL-AAS

Note: ARD: aqua-regia digestion; AAS: atomic absorption spectrometry; FA: fire assay; MAD: multi-acid digestion; AcAL: acetic acid leach; ICP-AES: inductively-coupled plasma atomic emission spectroscopy; ICP-MS: inductively-coupled plasma mass spectrometry; AF-ISE: boric-acid/sodium-carbonate fusion and ion-selective electrode determination; SAL-SNT: sulphuric acid leach and silver-nitrate titration; CuSol – acid soluble copper.

8.8 DATABASE

From August 2010, drilling and mine information were uploaded to a Geovia Gems SQL database. Several steps are employed to validate data and ensure the integrity of the database, the majority of which are performed by software data-checking routines. The database is subject to regular back-ups (see also discussion in Chapter 9.1).

8.9 QUALIFIED PERSON'S OPINION ON SAMPLE PREPARATION, SECURITY, AND ANALYTICAL PROCEDURES

Review of the analytical results for copper, gold, silver, uranium, thorium and fluorine indicate these are acceptable for mineral resource estimation.

The sample preparation, analysis, quality control, and security procedures used by the Salobo Operations have changed over time to meet evolving industry practices. Practices at the time the information was collected were industry-standard. The sample preparation, analysis, quality control, and security procedures used by the Salobo Operations are considered sufficient to provide sample results that are reliable to support estimation of mineral resources, mineral reserves, and can be used in mine planning.

9 DATA VERIFICATION

9.1 INTERNAL DATA VERIFICATION

9.1.1 DATA VALIDATION

The Salobo Operations used several steps of data validation. Most of these checks were performed by software data checking routines that rigorously verify data acceptance. All new assay data being added to the database were monitored daily and validated monthly for accuracy and consistency by comparing the data transferred to the database to the assay certificates received from the primary laboratories.

Vale staff also conducted regular logging, sampling, laboratory and database reviews. In addition to these internal checks Vale contracted independent consultants to perform laboratory, database and mine study reviews. The process of active database quality control and internal and external audits generally resulted in quality data.

Routine QA/QC reports are prepared on the drill hole database in support of the mineral resource estimation process. In addition, Vale's Resource Management Group conducts reviews of the available QC data and the reports, as well as carries out periodic sample preparation and analytical laboratory reviews and audits.

9.1.2 MINERAL RESOURCE AND MINERAL RESERVE ESTIMATES

A system of "layered responsibility" was established by Vale, embedded in Vale Corporate Guidelines and within the Vale's Base Metals Division for documenting the information supporting the mineral resource and mineral reserve estimates, describing the methods used, and ensuring the validity of the estimates. The concept of a system of "layered responsibility" is that individuals at each level within the organization assume responsibility, through a sign-off or certification process, for the work relating to preparation of mineral resource and mineral reserve estimates that they are most actively involved in.

Mineral reserve, mineral resource and exploration target estimates are prepared and certified by qualified persons at the mine site level, and are subsequently reviewed by qualified persons at the Vale Base Metals corporate level. Where there is more than one mine, the mine qualified persons prepare and sign on the estimates for their mine and provide them to the operations qualified persons, and then to the qualified persons at the Vale Base Metals corporate level.

Mineral reserves and mineral resources are estimated in accordance with the Vale Base Metals Guidelines and Standards for Mineral Resource Mineral Reserve Reporting protocols. Each year the corporate qualified persons update and revise these guidelines, which are then reviewed and approved annually by the Vale Base Metals Mineral Reserve and Mineral Resource Subcommittee. The guidelines may be subject to revisions as approved by the subcommittee any time throughout the year, based on certain circumstances such as external opinions, or amendments to external regulations.

Operations qualified persons have responsibility for ensuring that the mineral reserve, mineral resource, and exploration target estimates, technical documents and other scientific and technical information for their operation are consistent with the guidelines. These qualified persons also supervise the sample and analytical database manager; establish and maintain core drill hole and assay QA/QC programs for the operation; ensure that production reconciliation are tracked and reported quarterly; ensure that mining adherence results are tracked and reported monthly to the Corporate Technology and Engineering Group for compilation and reporting (if applicable) and ensure mitigation actions are in place to address deviations from tracked plans; and provide supporting documentation related to material additions or changes in estimates of mineral reserves, mineral resources, and exploration targets. Operations qualified persons are expected to co-ordinate with, and where applicable, assist mine qualified persons in co-ordinating with other subject matter experts to obtain all information necessary to support estimation. Other experts include individuals in marketing, legal, corporate affairs, finance (tax), strategic and business planning and sustainability (environment, social, governance). These experts are responsible for providing such information as may be required by the operation qualified persons to ensure that the reports supporting mineral resource and mineral reserve disclosure contain all pertinent information.

Mines qualified persons have similar responsibilities to those outlined for the operations qualified persons. Mines qualified persons are typically responsible for coordinating with other specialists to obtain all information necessary to prepare the estimates. Specialists are knowledgeable in areas such as geostatistics, block modelling, sampling and assaying procedures, core drilling, geotechnical, geomechanical, hydrogeology, hydrology, metallurgy, mineralogy, scheduling, cost estimation, lands administration, economic analysis, finance, law, and environment.

Corporate qualified persons are responsible for ensuring that the required governance is satisfied for the estimation, reporting, and disclosure of Vale Base Metals mineral resources and mineral reserves, including compliance with the internal guidelines. The corporate qualified persons are responsible for developing and maintaining mineral resource and mineral reserve estimation and reporting standards and ensuring that such standards and guidelines follow industry best practices, and meet Vale's corporate requirements as well as legal requirements.

Technical reviews of the mineral reserve and mineral resource estimates are performed by the Corporate Technology and Engineering Group annually (or as needed) for each operation and mine. The Corporate Technology and Engineering Group prepares and issues a technical review report to each mine and operation with risks identified and ranked. All identified risks require mitigation and addressing, consistent with the risk rating that has been assigned to them, to be consistent with the disclosure requirements of SK1300, and to be compliant with the Vale Base Metals corporate standards and guidelines for mineral resource and mineral reserve reporting, and the Vale Global Guidelines for Mineral Resources and Mineral Reserves Management.

9.1.3 STUDIES

Vale staff perform a number of audits, internal studies and reports in support of mineral resource and mineral reserve estimation. These include reconciliation studies, mineability and dilution evaluations, investigations of grade discrepancies between model assumptions and probe data, drill hole density evaluations, and long-range plan reviews. These studies support the assumptions of reasonable prospects of economic extraction used to estimate mineral resources, and the modifying factors used to convert mineral resources to mineral reserves.

9.1.4 RECONCILIATION

The Salobo Operations staff perform monthly, quarterly and annual reconciliation evaluations. Results indicate that the tonnages and grades of the long-term model are controlled within acceptable limits.

9.1.5 PEER REVIEW BY SUBJECT MATTER EXPERTS

The QPs requested that information, conclusions, and recommendations presented in the body of this Report be reviewed by Vale experts or experts retained by Vale in each discipline area as a further level of data verification.

Subject matter experts were requested to cross-check, where applicable, numerical data, flag any data omissions or errors they identified, review the manner in which the data were summarized and reported in the technical report summary, check the interpretations arising from the data as presented in the Report, and were asked to review that the QP's opinions stated as required in certain Report chapters were supported by the data and by Vale's future intentions and Project planning.

Feedback from the subject matter experts was incorporated into the Report as required.

9.2 EXTERNAL DATA VERIFICATION

Vale and its predecessor companies commissioned a number of audits and third-party reviews of block models, mineral resources and mineral reserves. A mineral resource and mineral reserve audit was performed during 2013 on behalf of Wheaton Precious Metals.

These external data verification programs are summarized in Table 9-1. Typically, the detailed external audits are performed approximately every five years, following the Vale Global Guidelines for Mineral Resources and Reserves Management.

9.3 DATA VERIFICATION BY QUALIFIED PERSON

As part of data verification, Chris Gauld performs reviews of core drill activities, core logging data collection and chain of custody reports, QA/QC, grade control, geological mapping and production reconciliation processes during site visits.

Gauld also reviews the following for the Salobo Operations: geological and resource estimation practices and peer review memos, QA/QC verification memos, currency of geological and structural support, core drill planning, production reconciliation results, budgeting and requirements for drill spacing for mineral classification, audits changes to mineral resource estimates, reviews the results of external and internal audits, and reviews the results of mineral resource and mineral reserve audits.

9.4 QUALIFIED PERSON'S OPINION ON DATA ADEQUACY

The QP is of the opinion that data that have been verified on upload to the database, and checked using applicable Vale protocols, are acceptable for use in mineral resource and mineral reserve estimation.

Table 9-1: External Data Verification

Company	Year	Verification Type
Bechtel	1988	Prefeasibility study
Minorco	1998	Feasibility study
MRDI	1997	Mineral resource estimate audit
Aker Kvaerner	2001	Updated feasibility study
AMEC	2002	Mineral resource estimate audit
Fluor JPS	2004	Final feasibility study
AMEC	2004	Mineral resource estimate audit
Pincock, Allen and Holt	2007	Mineral reserve estimate audit; due diligence audit
Pincock, Allen and Holt	2008	Mineral reserve estimate audit
Snowden	2009	Mineral resource estimate audit
Golder Associates	2010	Mineral resource and mineral reserve audit
Micon Consultants	2013	Mineral resource and mineral reserve audit
Amec Foster Wheeler	2015	Mineral resource and mineral reserve audit
SRK	2021	Mineral resource and mineral reserve audit

10 MINERAL PROCESSING AND METALLURGICAL TESTING

10.1 INTRODUCTION

The mineralogy and metallurgical performance of the Salobo deposit is well understood, based on a combination of the initial metallurgical testwork programs and a decade of production data.

10.2 TEST LABORATORIES

Metallurgical testing was primarily conducted at laboratories operated by, or affiliated with, Vale and its predecessor companies, and therefore these laboratories were not independent at the time the testwork was conducted. There is no international standard of accreditation provided for metallurgical testing laboratories or metallurgical testing techniques.

10.3 METALLURGICAL TESTWORK

Five distinct phases of testwork were completed in support of the current operations:

- CVRD from 1978–1981;
- CVRD and Anglo American from 1986–1987;
- Salobo Metais (Vale) from 1993–1998, including a pilot-plant campaign completed at the CVRD Research Centre (CRC);
- Locked-cycle flotation tests, flotation variability and grinding studies from 2003–2004;
- Trade-off study using high-pressure grinding rolls (HPGR) for tertiary crushing as an alternative to conventional semi-autogenous grinding (SAG), from 2005–2006.

10.3.1 VARIABILITY TESTWORK

U.I. Minerals (Uimin) reviewed 2003 testwork and consolidated plant trial and variability study results. Recovery projections were an average metallurgical recovery of 90.7% for Cu, and a mass recovery of 1.82%. A total of 177 samples were analyzed with grades above 0.4% Cu. Results showed 87.6% of the samples with a copper recovery >90%, 10.7% of samples had a recovery between 85–90%, and only 1.7% of samples were anomalous with recoveries<85%.

Rougher flotation tests were conducted on 251 drill core samples during a major 2004 variability test program on XMT (47%) and BDX (41%) lithology types. There was a direct correlation between the copper recovery and mass recovery for each lithology. The average gold recovery for the deposit was 67.4% with a standard deviation of 14.4%. Approximately 64% of samples with initial gold grades >0.4 g/t had gold recoveries up to 70%. A total of 59 locked cycle tests used 30 BDX samples and 16 XMT samples. A two-reagent system (A350, potassium amyl xanthate; and A3477, sodium di-isobutyl dithiophosphate) was adopted, which resulted in improved metallurgical recoveries and more stable flotation conditions.

Based on the consolidated results, equations predicting copper and gold recoveries were developed by Uimin for use in mine planning and production forecasts:

- Equation 1: Cu (%) = -0.023 / [%Cu in feed] + 0.9023
- Equation 2: Rec Au (%) = 0.0256 * [g/t Au in feed] + 0.6485

Unimin noted that Equation 1 was applicable mostly in the 0.6–1.5% Cu range.

These were the equations used in the project justification studies. The Geology and Mine Operations departments currently use them for projecting recoveries across all lithologies, even though the pre-production testwork data showed different responses for the XMT, BDX and DGRX lithologies.

10.3.2 HIGH PRESSURE GRIND ROLL STUDIES

The 2004 feasibility study incorporated a conventional primary crushing circuit, a standard semi-autogenous grind (SAG) mill/ball mill grinding circuit and a conventional copper flotation circuit. However, the presence of magnetite and significant variations in hardness and density of the mineralized lithologies led to the evaluation of an alternative. An extensive evaluation of an alternative comminution circuit was conducted that included primary crushing, secondary cone crushing and tertiary high-pressure grind roll (HPGR) crushing followed by conventional ball milling.

Two HPGR evaluations were completed, in 2005 and 2006. General observations from this testwork program were that there was a decline in specific throughput as the roll speed and the feed moisture content were increased.

For the first five-year sample, there was an 18% reduction in specific throughput when the feed moisture content was increased from 0.1% to 4.0%. Abrasion testing and specific wear rates on all samples indicate that Salobo ore had low abrasion characteristics.

Grindability tests were conducted on samples of HPGR product at <6 mm and conventionally crushed material at <6 mm of the pilot ore sample from the 2005 program. The results indicated a very similar Bond ball mill work index for both samples (19.4 kWh/t and 19.2 kWh/t, respectively), indicating no micro-fracturing of the rock and therefore no grindability advantage was attributed to HPGR. Various reviews and trade-off studies resulted in a decision by Vale in 2006 to implement the HPGR option based on the technical and economic benefits compared to conventional SAG.

10.3.3 MIXED ORE ZONE COPPER RECOVERY TESTWORK

A copper recovery study for the mixed ore stockpiled at the mine was commissioned in 2014. Improved metallurgical response resulted from increased addition rates of the collectors used in the rougher flotation, together with the inclusion of sodium silicate used as a dispersant (e.g., viscosity modifier).

A second study evaluated transition ore, to determine the amount of this material that could be added to fresh bedrock material without impacting the overall copper recovery in the plant. Results showed that a mixed ore component of up to 30% could be tolerated with limited impact on the results expected with fresh material only.

The equation underlying the recovery projection model is expressed as shown in Equation 3:

- Equation 3: $\text{Rec Cu} = 88.5 * (1 - \exp(-3.5 * [\text{Cu in feed}]))$,

where [Cu in feed] is the copper feed grade and the resulting projected recovery is based on a standardized concentrate grade target of 37.5% Cu.

The testwork program completed included modified reagent schemes, relative to the plant operations (changing the xanthate used from potassium amyl xanthate (PAX) to sodium isopropyl xanthate (SIPX), removing the sodium sulphide as modifier), as well as testing the addition of a desliming stage, with a cyclone, of the mixed stockpile material in an attempt to remove the most oxidized component and reduce reagent consumptions.

10.3.4 GEOMETALLURGICAL PROGRAM

Rougher, open cleaner and locked-cycle test (LCT) flotation assays were performed in 2019 by Vale's Mineral Development Centre (CDM in the Brazilian acronym) internal laboratory, located in Santa Luzia in Minas Gerais, on 12 global samples (24 sub-samples) from material planned to be mined in the 2019 plan and 20 global samples (41 sub-samples) from the 2020–2024 mining plan.

The LCT tests had higher copper and gold metallurgical recoveries than those defined in the original Salobo project (87% for Cu and 65% for Au). Copper and gold recoveries were respectively 90.8% and 67.0% from the 2019 samples and 89.2% and 64.9% from the 2020–2024 samples. However, the concentrates obtained in the LCT assays with the 2020–2024 samples had lower payable metal content (copper, gold, and silver) and higher deleterious contents (fluorine, chlorine, and uranium) compared to the chemical quality of the products obtained with the 2019 samples. The average fluorine, chlorine, and uranium grades in the concentrate obtained from the 2020–2024 samples were respectively 1,580 ppm, 1,008 ppm and 56 ppm, while the concentrate obtained from the 2019 samples had average grades of 1,160 ppm F, <615 ppm Cl and 46 ppm U.

The throughput and specific energy consumption values in HPGR and ball milling ranged from 2,890–3,500 t/hr (median: 3,125 t/hr), from 1.59–2.05 kWh/t (median: 1.87 kWh/t) and from 16.67–20.30 kWh/t (median: 18.74 kWh/t), respectively. The values obtained in the simulations showed variations consistent with those observed in the process plant, as shown by 2018 operational data.

An initial set of metallurgical samples from the material to be mined in Phases 5 and 6 of the Salobo pit were sent to CDM for mineralogical characterization, comminution and flotation studies, which are still underway. Provisional results indicate that recoveries in the rougher stage varied from 84–97%, with averaging around 92%. The Phase 5 samples appear to have higher soluble copper levels indicative of greater oxidation, and a higher percentage of chalcocite, when compared to the Phase 4 samples.

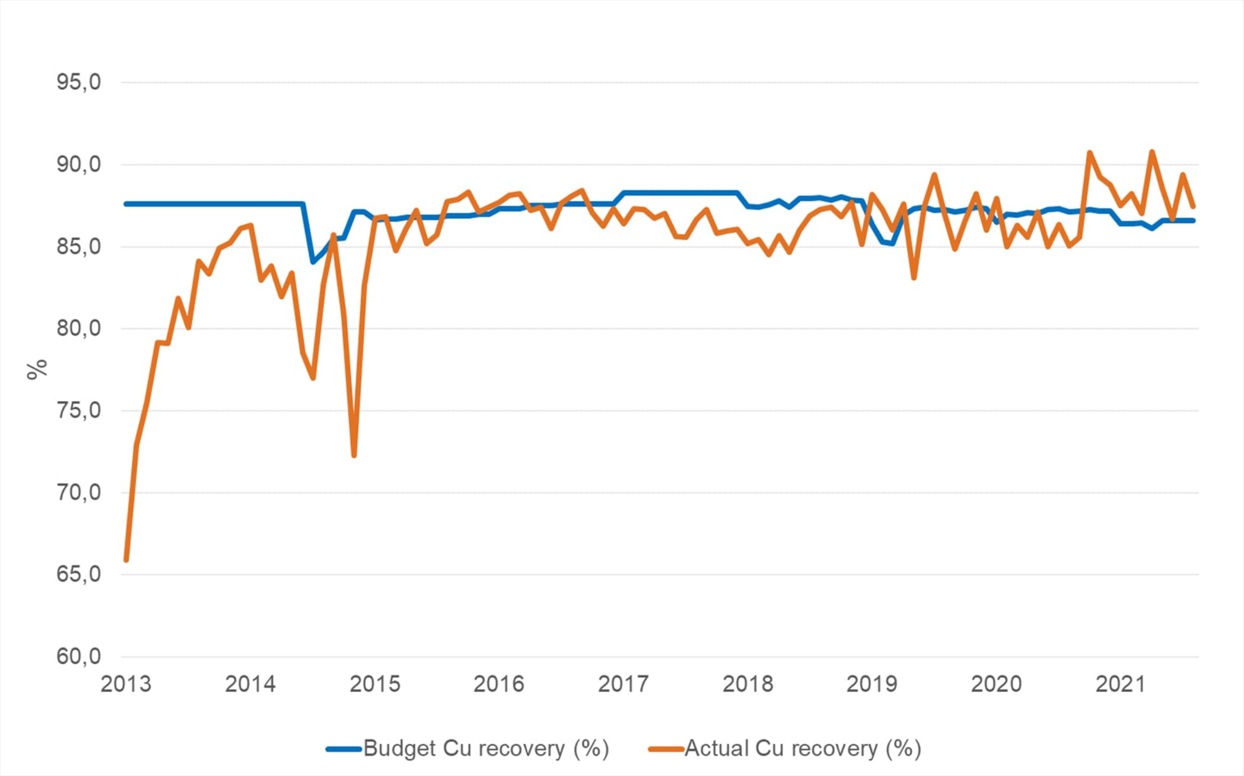
To date, there has been some variation in the mineralization from known ore characteristics, and historical metallurgical performance is reflected in current performance. The available information is considered acceptable for use in LOM planning. Where there have been some minor variations, the plant has been able to use on-site blending to control the variations.

10.4 RECOVERY ESTIMATES

Recovery projections for copper and gold are based on Equation 1 and 2, respectively. These underlie a fixed target copper grade in concentrate of 37.5% Cu. These equations are used to project metallurgical recoveries in the mineral reserve estimate, cut-off grade calculations, and the life-of-mine (LOM) financial model. Silver recovery was not tracked as diligently as copper and gold during the testwork phases.

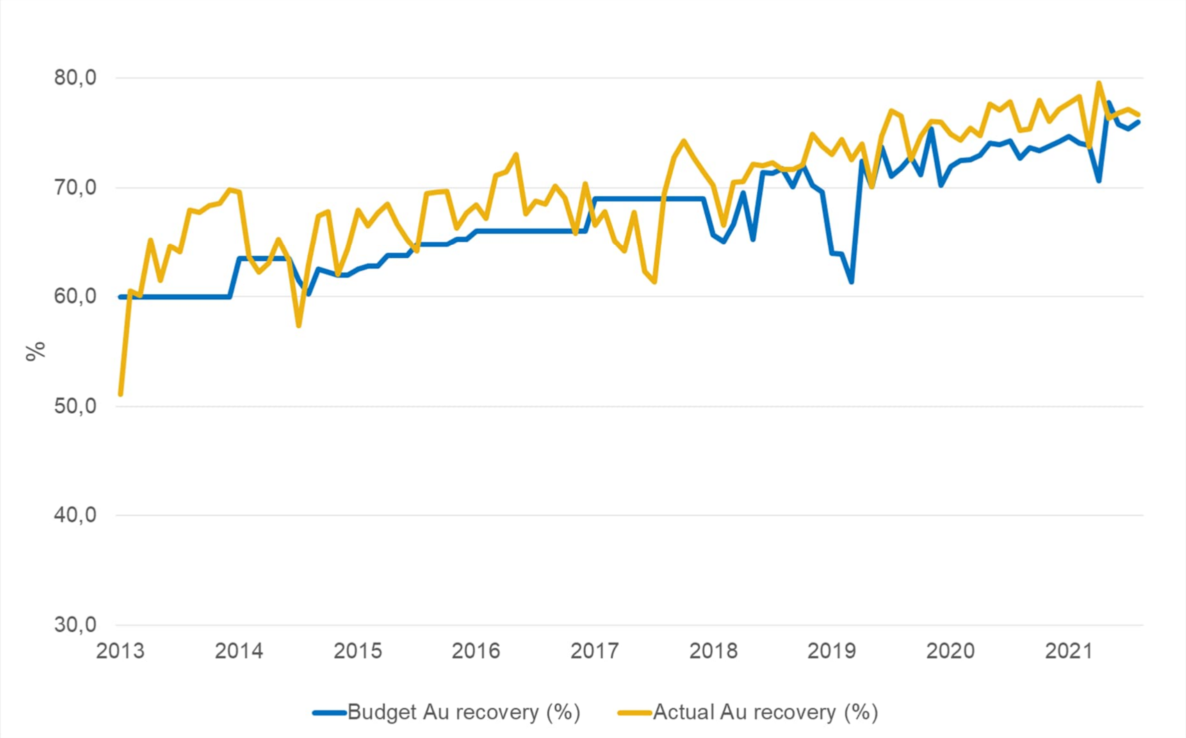
Figure 10-1 and Figure 10-2 show the recovery from the plant from 2013–August 2021 for copper and gold, respectively. The gold grade in the copper concentrate has been consistently between 19–24 g/t with variations being attributable to different Au:Cu ratios in the feed.

Figure 10-1: Actual versus Projected Monthly Plant Copper Recovery



Note: Figure prepared by Vale, 2021. 2021 data current as of August 2021.

Figure 10-2: Actual versus Projected Monthly Plant Gold Recovery



Note: Figure prepared by Vale, 2021. 2021 data current as of August 2021.

Pre-production testwork, especially the large variability testwork program of 2003–2004, provided indications that the copper metallurgical response was variable, not only in terms of feed grade but also by lithology. The adoption of a single equation to predict recovery, instead of drafting discrete equations for each lithology and using these to match the expected relative proportions provided in the mine plan as plant feed, is a simplification that may create daily discrepancies between expectations and actual results.

Metallurgical recovery forecasts are divided into short-term and long-term assumptions as shown in Table 10-1 and Table 10-2.

10.5 METALLURGICAL VARIABILITY

Tests were performed on samples considered to be representative of the mineralization that will be treated in the plant for the duration of the LOM plan.

Some variability in the metallurgical results can be expected as the mixture of lithologies found in the plant feed change. Over monthly periods, the resulting blend is more likely to approach the mineral reserves profile and thus mitigate the variability that may be detected on a daily basis, versus projections.

Introduction of mixed material above a proportion of 30% of plant feed leads to a degradation of the flotation results. This material requires blending.

10.6 DELETERIOUS ELEMENTS

There are four deleterious elements of potential concern in the Salobo copper concentrate, namely fluorine, chlorine, uranium and carbon. Of these, fluorine is the most significant. In general, smelters will tend to reject concentrates with high fluorine content due to problems that result in the smelter's sulphuric acid plants.

The determinations of the deleterious and payable element concentrations in concentrates are undertaken at the Salobo mine laboratory.

Vale secured contracts with smelters able to accept the copper concentrate with an average fluorine content of about 2,000 ppm, and a maximum content of 4,000 ppm. Penalties are charged above 300 ppm. These smelters placed the maximum acceptable chlorine content at 1,500 ppm, but with a penalty drawn at the 550–650 ppm level. Carbon is also an element of concern in the concentrate. The usual levels are between 2–4%. The specification limit is 4.5%.

Uranium is present in the copper concentrate. Current annual averages of uranium levels are between 40–60 ppm. In 2021, the specification limit ranged from 60–74 ppm depending on the end-user client. Operational procedures are being implemented to accurately forecast the uranium grade in the long-term and short-term planning models to enable blending of plant feed in the mine. Since concentrate lots are segregated by grade (low, medium and high grades) at the Parauapebas transfer storage house and at the port of Itaqui, blending of out-of-specification concentrate can be undertaken.

Table 10-1: Processing Recovery Assumptions (2022–2026)

Metal	Total Recovery to All Concentrates (%)
Copper	(-4,5679*(1/A) + 93,03) + 0,954825045064738
Gold	26,073*LN(B) + 91,424 + 0,751264079298551

Notes: Factors A = Feed Cu grade (%) and B = Feed Au grade (g/t).

Table 10-2: Processing Recovery Assumptions (2026–LOM)

Metal	Total Recovery to All Concentrates (%)
Copper	(-2.5362 * (1/% Cu in feed)) + 90.674)
Gold	(1.0173*Rec Cu) - 20.357

10.7 QUALIFIED PERSON’S OPINION ON DATA ADEQUACY

Industry-standard studies were performed as part of process development and initial mill design. Subsequent production experience and focused investigations have guided mill alterations and process changes. There are 10 years of production data to support the recovery assumptions and provide reasonable data on the deleterious element concentrations.

Testwork programs continue to be performed to support current operations and potential improvements. From time to time, this may lead to requirements to adjust cut-off grades, modify the process flowsheet, or change reagent additions and plant parameters to meet concentrate quality, production, and economic targets.

The plant will produce variations in recovery due to the day-to-day changes in ore type or combinations of ore type being processed. These variations are expected to trend to the forecast recovery value for monthly or longer reporting periods.

Based on these checks, the metallurgical test work and reconciliation and production data support the estimation of mineral resources and mineral reserves.

11 MINERAL RESOURCE ESTIMATES

11.1 INTRODUCTION

Vale has a set of protocols and guidelines in place to support the estimation process, which the estimators must follow. These include: comprehensive lithological and mineralization domain characterization; selection of all representative samples inside the domain(s); compositing of drill hole information on a consistent support size (length, density, recovery), validation through statistics on lengths and variables before and after compositing; comprehensive understanding of the statistical characters of the variables; in each estimation domain and at the contacts between domains; characterization of the spatial continuity of each variable to be modelled (variograms/correlograms); understanding of the influence of outliers and variables with highly skewed distributions and selection of an appropriate handling strategy (capping, restricted neighborhood); selection of an appropriate selective mining unit (SMU) size for the geometry of mineralization, spatial distribution of borehole and sample data, potential mining method and production rates under consideration; selection of an appropriate modelling technique and definition of proper parameters and options to be used (e.g., interpolation technique, interpolation or kriging plan, search strategy, variogram models to be used, post-processing methods, in particular for indicator estimation); validation of the estimates (visual inspection, checks for global and local bias, confirmation of the kriging plan, and a check on the degree of grade smoothing resulting from the interpolation); and confidence classification.

The mineral resource estimate is supported by core drilling. Software used in estimation included LeapFrog, Deswik and Isatis. The selective mining unit (SMU) size was 30 x 30 x 15 m and is considered appropriate for the mining equipment that would be used in operations.

11.2 EXPLORATORY DATA ANALYSIS

Bivariate and multivariate statistical and spatial data reviews were conducted on the deposit data. The reviews checked for elements such as outlier values that would require influence restrictions, and spatial geochemical trends. The copper co-efficients of variation (CVs) for the three major lithologies, BDX, DGRX and XMT, were <1.5. The gold CVs for the BDX and DGRX lithologies were >2, with the XMT lithology slightly over 1.5.

11.3 GEOLOGICAL MODELS

A thorough review of the drill holes and captured samples within the wireframes was completed to identify any drill holes with questionable data such as poor selection of the drill hole orientation, inconsistent geological interpretations, poorly-constrained drill trajectories, poor logging and analytical methodologies, and lost core intervals. All drill holes considered not relevant to the resource modeling were removed from the dataset, with the reasons recorded in the dataset. This included condemnation drilling (outside of the mineralization) and geotechnical drilling for structures.

Wireframes were verified to ensure there were no modelling construct issues such as merge, boundary or crossover strings.

The lithological and mineralization models were produced by Vale geologists using information on the deposit geological features, including structure, hydrothermal alteration minerals, lithologies and mineralization.

Two grade shells were constructed using cut-offs of 0.2% and 0.6% Cu, respectively, based on 20 m composites (Figure 11-1).

The deposit was divided in two sectors from west to east for spatial analysis evaluation to account for changes in the orientation and style of the mineralized zone along strike (Figure 11-2). The subdivision between the northwest and southeast sectors was based on differences in deformation, hydrothermal alteration, and dip. A N70°E striking diabase dyke defined the sector border. Polygonal shapes were used to create solids to code the other sectors, based on level-plan views of the mineralized zones. Little or minimal structural disturbance was observed within the Salobo deposit and for the purpose of mineral envelope modelling, structure was not considered.

Estimation domains (Table 11-1) were based on low-grade and high-grade shell units defined for total copper, resulting from a combination of sector and ore codes, and weathering variables (oxide, transition, sulphide).

Triangulated solid models were created for each of the waste rock types by implicit modelling and using generalized geological sections and level plans as interpretation basis. These waste lithological wireframes were used to estimate density values at the whole block-model.

A partial (percent) block model was generated in Deswik. Blocks were assigned percent volumes using the two domain wireframes.

Soft boundaries were used between the weathering domains for low-grade and high-grade during the estimation of all variables. For the low-grade and high-grade contacts, hard boundaries were used for copper, gold, silver, sulphur, and density. For uranium, fluorine, chlorine and carbon, soft boundaries were used between low-grade and high-grade domains after contact analysis studies indicated poor correlation. For the waste–ore contact, for all variables it was used hard-boundaries.

11.4 DENSITY ASSIGNMENT

Density values were assigned according to lithology for the blocks outside of the low- and high-grade domains. The average density for each lithology was based on the mean of the SG measurements for each specific lithology.

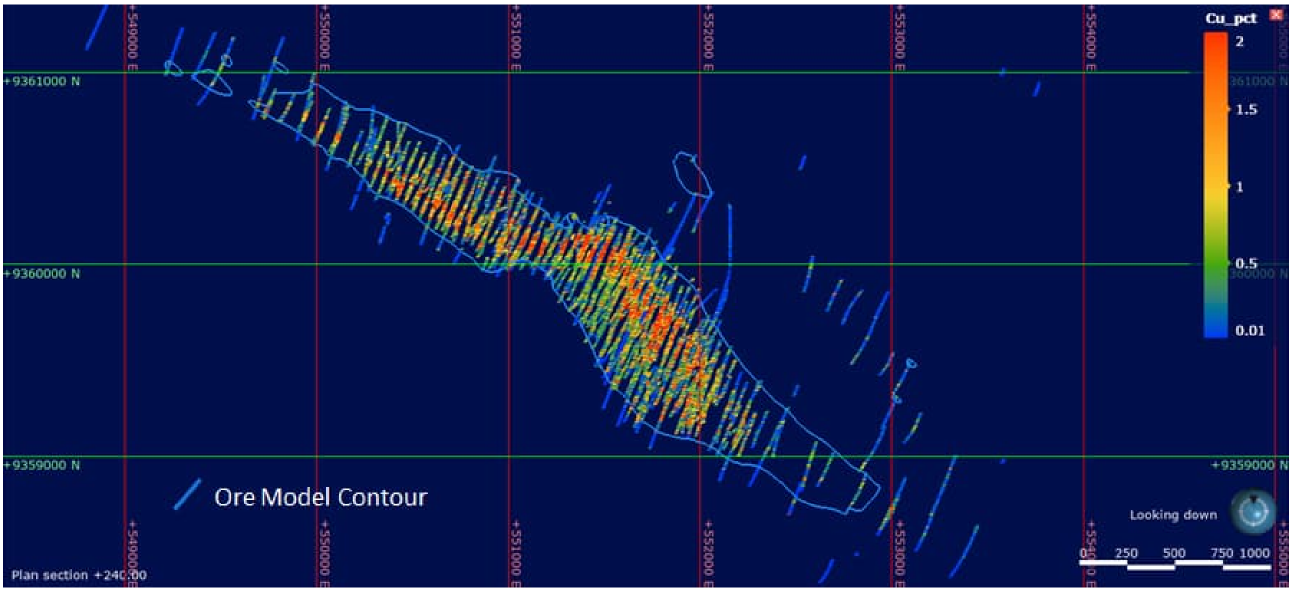
11.5 GRADE CAPPING/OUTLIER RESTRICTIONS

Outlier analysis of the original assays included a statistical review of the grade populations and a visual review of the location of outlier high-grade assays. A two-phase approach to restrictions was used. Grades were capped during before compositing, with copper grades capped at 11.5% Cu, and gold grades at 15 g/t Au, for both the low-grade and high-grade domains. Restrictions on the area of influence of an outlier assay were also imposed during estimation, with a 10 m window used for the three kriging passes, based on 1.6% Cu and 1.6 g/t Au capping values.

11.6 COMPOSITES

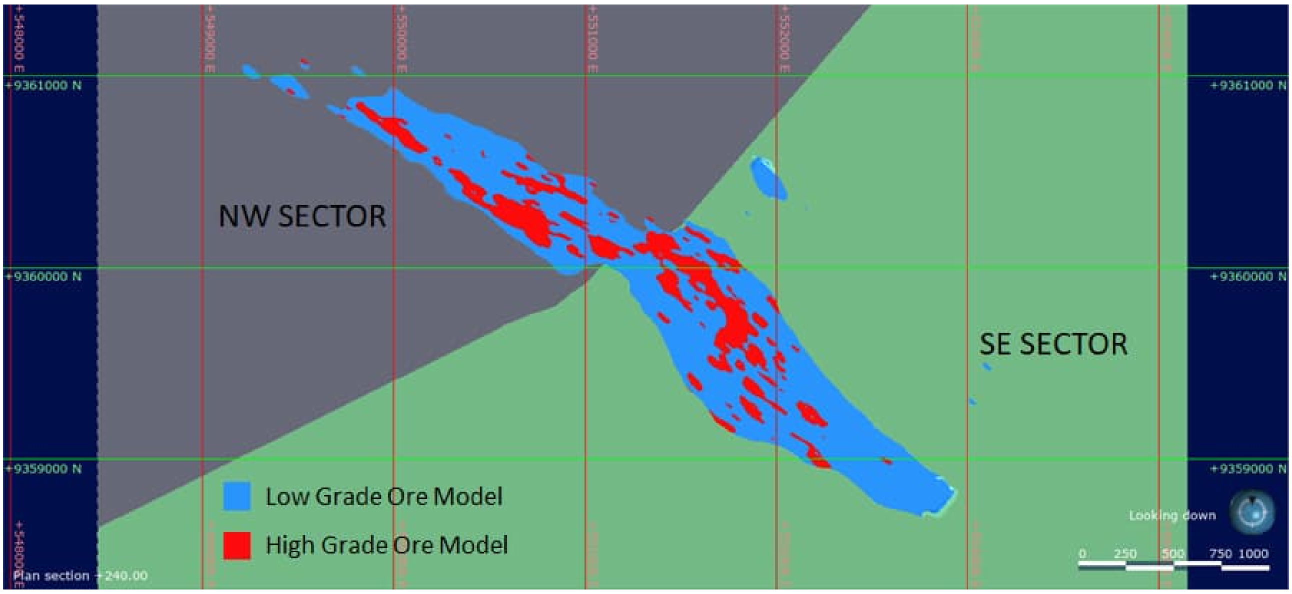
Sample intervals are generally 1.0 m and adhere to breaks such as geological contacts, faults and obvious changes in metal content. Two-metre down-hole composites were created for statistical and geostatistical analysis and block grade interpolation.

Figure 11-1: Example Cross-Section, Copper Grade Shell



Note: Figure prepared by Vale, 2021.

Figure 11-2: Schematic Showing Estimation Sectors



Note: Figure prepared by Vale, 2021. The blue wireframe is the low grade domain (>0.2% Cu), the red is the high grade domain (>0.6% Cu).

Table 11-1: Domain Codes

Sector	Oxide		Sulphide	
	Description	**Code**	**Description**	**Domain**
Southeast	Low-grade saprolite	1101	Low-grade fresh rock	1103
	Low-grade semi-weathered	1102		
	High-grade saprolite	1201	High-grade fresh rock	1203
	High-grade semi-weathered	1202		
Northwest	Low-grade saprolite	2101	Low-grade fresh rock	2103
	Low-grade semi-weathered	2102		
	High-grade saprolite	2201	High-grade fresh rock	2203
	High-grade semi-weathered	2202		

11.7 VARIOGRAPHY

Experimental grade correlograms were modelled from the composited drill hole data for copper, gold, specific gravity, silver, carbon, sulphur, fluorine, chlorine and uranium for the low- and high-grade domains and by sectors. The low- and high-grade domains were subsequently combined to produce larger datasets for analysis. The nugget effect was obtained using “down the hole” correlograms.

11.8 ESTIMATION/INTERPOLATION METHODS

Block grades and density were estimated using ordinary kriging (OK) in Isatis software. Blocks were estimated during three successive passes. Block estimation was completed on a 15 m x 15 m x 15 m block model with discretization set to 5 x 5 x 5 discretization points. The resulting block estimates were re-blocked to 30 m x 30 m x 15 m blocks and imported into Deswik.

11.9 VALIDATION

The following methods were used to validate the block grade estimates:

- Global mean comparison of mean composite, OK and nearest-neighbor (NN) block grade estimates. For both copper and gold, the OK block grades compare very well to the composites and NN block grades;
- Visual inspection of the composite and block model grades. Good correlation between the input data and output values was noted during inspection block and composite grades on plans and sections. No obvious discrepancies were noted;
- Swath plots of OK versus NN block grades on a series of sections and plans throughout the deposit. All domains showed good correspondence between the OK and NN block estimates for both copper and gold with the OK grades being somewhat smoother as expected from the effects of the kriging interpolation. Portions of the graphs where the block grades deviated were generally associated with areas of low data.

Copper and gold may be underestimated as a result of the restricted neighborhood strategy for high grades. Very low gold grades may be less well represented, particularly when a low-grade gold block is surrounded by high-grade gold blocks.

11.10 CONFIDENCE CLASSIFICATION OF MINERAL RESOURCE ESTIMATE

11.10.1 MINERAL RESOURCE CONFIDENCE CLASSIFICATION

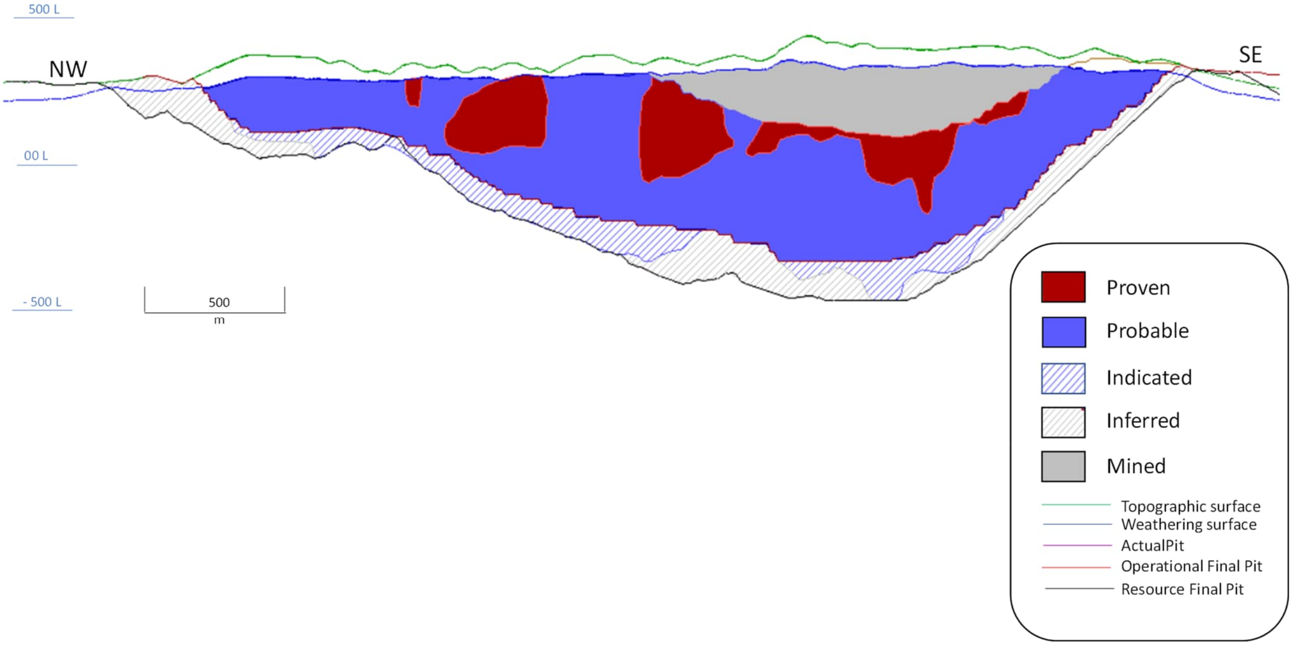
Classification of blocks was assigned by drill spacing:

- Measured required four drill holes within a 60 m radius window;

- Indicated required three drill holes within a 110 m radius window;
- Inferred required two drill holes within a 250 m radius window.

Subsequently, this classification was adjusted to recode any anomalous blocks of one confidence category otherwise situated in areas of a common category. Shown below, is a generalized cross-section showing the locations of the mineral resource estimate categories.

Figure 11-3: Schematic Cross-Section Showing Location of Mineral Reserves and Mineral Resources



Note: Figure prepared by Vale, 2021.

11.10.2 UNCERTAINTIES CONSIDERED DURING CONFIDENCE CLASSIFICATION

Uncertainties regarding sampling and drilling methods, data processing and handling, geological modelling, and estimation were incorporated into the classifications assigned. The areas with the most uncertainty were assigned to the inferred category, and the areas with fewest uncertainties were classified as measured.

11.11 REASONABLE PROSPECTS OF ECONOMIC EXTRACTION

11.11.1 INPUT ASSUMPTIONS

Mineral resources were confined within a conceptual pit shell that used the parameters outlined in Table 11-2. External mining dilution and mine loss were not applied. The resulting pit extents were considered for reasonableness, such as any potential impact on planned mine infrastructure (waste laydown areas, processing facilities), distribution of deleterious elements, and adequateness of the current waste rock storage facility (WRSF) capacities. Pit inter-ramp slope angles range from 27–61º.

11.11.2 COMMODITY PRICE

The commodity pricing forecasts in Table 11-2 have been established for purposes of pit optimization and mine design using a consensus approach based on long-term analyst and bank forecasts, supplemented with research by Vale's internal specialists. An explanation of the derivation of the commodity prices is provided in Chapter 16. These prices provide a reasonable basis for establishing the prospects of economic extraction for mineral resources.

11.11.3 CUT-OFF

The break-even cut-off grade calculation takes into account metal selling price, refining, market and/or sales cost, mining cost, processing cost, metal content or grade, plant (flotation when applicable) recovery and metallurgical recovery as inputs. Once the pit limit is defined, a mining block that is capable of covering the processing and refining, marketing, and/or sales costs is assumed to be sent to the processing streams; otherwise, is classified as waste and sent to the WRSFs.

A check is run on the selected break-even cut-off grade using Whittle software to determine what the marginal cut-off grade would be as a direct result of pit optimization process. If the absolute difference between cut-off calculation methods is ≤1%, the non-linear grade dependency is not considered critical and the marginal cut-off grade applied to equivalent copper grades can be used for ore/waste classification.

The copper equivalent (CuEq) grade is calculated using the formula:

- (CuEq)_%=(Cu)_%+(Au)_((g/t))*k

where "k" represents the equivalence between gold and copper net values, including flotation recoveries percentage and smelter returns percentage.

The mineral resource estimate for Salobo is reported above a 0.25% CuEq cut-off.

Table 11-2: Input Parameters

Parameter	Unit	Values
Copper sale price	$US/tonne	7,000
Gold sale price	$US/oz	1,300
Exchange rate	$BRL/$US	4.77
Mining method		Open pit
Cut-off	%CuEq.	0.25
Mineability	%	100%
Dilution	%	4% (2022) 3% (remaining LOM)
Mine production rate – ore	M tonnes/year	40
Mine production rate – waste	M tonnes/year	86
Mine full operating cost	$/tonne mined	3.47
Mine sustaining capital cost	$/tonne mined	0.57
Overall processing cost	$/tonne ore	7.79
Site G&A	M $US/year	15.0
Overall processing Cu recovery	%	(-2.5362*(1/Cu))+90.674
Overall processing Au recovery	%	(1.0173*RecCu)-20.357

Notes:

- Royalties are included in the selling costs.

- The differences between foreign exchange and commodity price assumptions for pit optimization and economic analysis are due to timing and do not have a material impact on the final results. Pit optimization was prepared in the beginning of 2021 and is based on certain foreign exchange and commodity price assumptions. As of December 31, 2021, the assumptions used for pit optimization continue to provide a reasonable basis for establishing the prospects of economic extraction for mineral resources.

11.11.4 QP STATEMENT

The QP is of the opinion that any issues that arise in relation to relevant technical and economic factors likely to influence the prospect of economic extraction can be resolved with further work. The mineral resource estimates are performed for deposits that are in a well-documented geological setting. Vale is very familiar with the economic parameters required for successful operations in the Salobo area; and Vale has a long history of being able to obtain and maintain permits, social licence and meet environmental standards. There is sufficient time in the 32-year timeframe considered for the commodity price forecast for Vale to address any issues that may arise, or perform appropriate additional drilling, testwork and engineering studies to mitigate identified issues with the estimates.

11.12 MINERAL RESOURCE STATEMENT

Mineral resources are reported using the definitions of mineral resources in SK1300. Mineral resources are reported on a 100% basis, as at 31 December, 2021. The reference point for the estimate is in situ. Mineral resources are reported exclusive of those mineral resources that were converted to mineral reserves. The Qualified Person for the estimate is Chris Gauld, P.Geo., a Vale employee.

A summary of the mineral resource estimates is provided in Table 11-3 for the measured and indicated mineral resources and in Table 11-4 for the inferred mineral resource estimate.

11.13 UNCERTAINTIES (FACTORS) THAT MAY AFFECT THE MINERAL RESOURCE ESTIMATE

Areas of uncertainty that may materially impact the mineral resource estimates include:

- Changes to long-term metal price and exchange rate assumptions;
- Changes in local interpretations of mineralisation geometry, structures, and continuity of mineralised zones;
- Changes to geological and grade shape and geological and grade continuity assumptions;
- Changes to metallurgical recovery assumptions;
- Changes to the input assumptions used to derive the conceptual open pit shell used to constrain the estimates;
- Changes to the forecast dilution and mining recovery assumptions;
- Changes to the CuEq cut-off applied to the estimates;
- Variations in geotechnical (including seismicity), hydrogeological and mining assumptions;
- Changes to environmental, permitting and social license assumptions.

The TSF capacity is matched to the mineral reserve estimate. Should additional mineral resources be considered for mineral reserve conversion, TSF capacities would need to be increased.

To the extent known to the QP, there are no other known environmental, permitting, legal, title related, taxation, socio-political or marketing issues that could materially affect the mineral resource estimate that are not discussed in this Report.

Table 11-3: Measured and Indicated Mineral Resource Statement

Classification	Tonnage (Mt)	Grade	
		Cu (%)	Au (g/t)
Measured	30.2	0.39	0.17
Indicated	439.4	0.49	0.25
Total measured + indicated	469.7	0.48	0.24

Table 11-4: Inferred Mineral Resource Statement

Classification	Tonnage (Mt)	Grade	
		Cu (%)	Au (g/t)
Inferred	268.9	0.5	0.3

Notes to accompany mineral resources tables:

Notes to accompany mineral resources tables:

1. Mineral resources are reported using the mineral resource definitions in S-K 1300. The reference point for the mineral resource estimate is in situ. The mineral resource estimate is current as at 31 December, 2021. The Qualified Person for the estimate is Chris Gauld, P.Geo., a Vale employee.
2. Mineral resources are not converted to mineral reserves as they have not demonstrated economic viability. Mineral resources that are reported, are those exclusive of those mineral resources converted to mineral reserves.
3. The estimate uses the following key input parameters: assumptions of open pit mining methods; copper sale price of US$7,000/t, gold sale price of US$1,300/oz; mining cost of US$3.47/t mined, process and general and administrative costs of US$9.07/t processed; the sustaining costs are included in the mining, process and G&A costs; variable metallurgical recoveries for copper based on (-2.5362*(1/Cu))+90.674 and for gold based on (1.0173*RecCu)-20.357; pit inter-ramp slope angles that vary from 27–61º. The estimate is reported above a copper equivalent cut-off grade of 0.25% CuEq.
4. Rounding as required by reporting guidelines may result in apparent summation differences.

12 MINERAL RESERVE ESTIMATES

12.1 INTRODUCTION

Mineral reserves were converted from measured and indicated mineral resources. Inferred mineral resources were set to waste. The mine plan assumes open pit mining using conventional mining methods and equipment.

The LOM planning process uses previous actual availabilities, utilizations and cost as a reference to initially develop a five-year plan that is subsequently updated and used as the basis for the pit optimization and overall LOM plan.

12.2 OPTIMIZATION

Mineral resources that are converted to mineral reserves are captured within an optimized pit shell that uses the parameters provided below.

Table 12-1: Summary of Key Assumptions and Parameters for Pit Optimization and Mine Design

Parameter	Unit	Value
Copper sale price	US$/tonne	7,000
Gold sale price	US$/oz.	1,300
Exchange rate	BRL/US	4.77
Mining method		Open pit
Cutoff	%CuEq.	0.25
Mineability	%	100
Dilution	%	4% (2022) 3% (LOM mine plan)
Average mine production rate – ore	M tonnes/year	40.0
Average mine production rate – waste	M tonnes/year	86.0
Mine full operating cost	US$/tonne mined	3.47
Overall processing cost	US$/tonne ore	7.79
Selling cost (Cu)	US$/lb	0.672
Corporate overhead	US$ M/year	14.0
Site G&A	US$ M/year	14.6
Overall processing copper recovery	%	(-2.5362*(1/Cu)) + 90.674
Overall processing gold recovery	%	(1.0173*RecCu) – 20.357

Notes:

- Royalties are included in the selling costs.
- The differences between foreign exchange and commodity price assumptions for pit optimization and economic analysis are due to timing and do not have a material impact on the final results. Pit optimization was prepared in the beginning of 2021 and is based on certain foreign exchange and commodity price assumptions. Evaluation to demonstrate the economic viability of the mineral reserve were made as of December 31, 2021, based on the assumptions described in Section 19.

Optimized pits were not constrained by surface infrastructure as all such infrastructure is located beyond the economic pit limit. A discount rate of 11% and an assumed mining decent rate of five benches per year were applied during the optimization process. Pit slope inter-ramp angles were variable, ranging from 27–61º. An unplanned dilution allocation of 3% was incorporated in the mine plan scheduling. Mining recovery of 100% was assumed during the pit optimization.

For pit optimization the base mining costs at the 250 bench is $3.65/t mined for fresh rock and $3.30/t mined for saprolite, with an average overall mining cost of $3.47/t. The mining unit costs were increased by $0.00736/t for each 15 m bench above the 250 bench and increased by $0.0382/t for every bench below the 250 bench. The process cost applied in pit optimization is a constant $7.79/t milled, including the processing sustaining costs. General and administrative operating costs were modeled at a constant rate of $1.28/t milled. The sustaining capital for the mine was assumed to be $0.57/t mined, the sustaining capital for the mill was $1.46/t milled, and $0.46/t milled for the G&A. The sustaining capital was added to the mining, processing, and G&A operating costs for the Whittle optimizations.

Metallurgical recoveries were variable, and based on the following equations:

- Copper recovery: 90.674%-(2.5362%)/(copper grade);
- Gold recovery: (1.0173 x copper recovery) – 20.357.

To calculate payable metal, average payable factors of 96.7% for copper and 93.94% for gold were applied to the recovered metal. Concentrate was modeled with a copper grade of 38%, 9.5% moisture, and a 0.5% loss in transportation. Refining costs inclusive of any penalties were modeled as a cost of US$0.672/lb Cu and US$0.520/oz Au. The total freight cost allocation was $0.115/lb Cu or US$92.9/wet tonne of concentrate.

The estimate was reported above a cut-off of 0.25% CuEq, using the criteria discussed in Chapter 11.11.1.3.

12.3 MINERAL RESERVE STATEMENT

Mineral reserves are reported using the mineral reserve definitions set out in SK1300. The reference point for the mineral reserve estimate is the point of delivery to the process plant. Mineral reserves are current as at 31 December, 2021.

Mineral reserves are reported in Table 12-2. The Qualified Person for the estimate is Nick A. Gardner, P.Eng., a Vale employee.

Table 12-2: Proven and Probable Mineral Reserve Statement

Pit/Operation	Classification	Tonnage (Mt)	Grade	
			Cu (%)	Au (g/t)
Salobo Pit	Proven	231.0	0.69	0.40
	Probable	696.4	0.66	0.38
	Subtotal proven + probable	927.3	0.66	0.39
Stockpiles	Proven	—	—	—
	Probable	206.1	0.42	0.20
	Subtotal proven + probable	206.1	0.42	0.20
Total	Proven	231.0	0.69	0.40
	Probable	902.4	0.60	0.34
	Total proven + probable	1,133.4	0.62	0.35

Notes to accompany mineral reserves table:

1. Mineral reserves are reported using the mineral reserve definitions set out in S-K 1300. The reference point for the mineral reserve estimate is the point of delivery to the process plant. The estimates are current as at December 31, 2021. The Qualified Person for the estimate is Nick A. Gardner, P.Eng., a Vale employee.

2. The pit optimization estimate uses the following key input parameters: open pit mining methods; copper sale price of US$7,000/t, gold sale price of US$1,300/oz (Revenue Factor = 1); mine operating costs of US$3.47/t mined, processing cost of US$7.79/t processed, selling cost of US$0.67/t processed, corporate overhead of US$0.43/t processed, general and administrative cost of US$0.39/t processed; variable metallurgical recoveries for copper based on the equation (-2.5362*(1/Cu)) + 90.674 and gold, based on the equation

(1.0173*RecCu) - 20.357; inter-ramp slope angles ranging from 27–61º; mining recovery of 100%, and a dilution average of 3% over the life-of-mine.

3. Inside the pit shell, the mineral reserves are restricted by the capacity of the tailings dam.

4. Rounding as required by reporting guidelines may result in apparent summation differences.

12.4 UNCERTAINTIES (FACTORS) THAT MAY AFFECT THE MINERAL RESERVE ESTIMATE

The following factors may affect the mineral reserve estimate:

- Copper and gold commodity prices;
- US dollar exchange rate;
- Brazilian inflation rate;
- Geotechnical (including seismicity) and hydrogeological assumptions;
- Changes to inputs to capital and operating cost estimates;
- Changes to operating cost assumptions used in the constraining pit shell;
- Changes to pit designs from those currently envisaged;
- Stockpiling assumptions;
- Ability of the mining operation to meet the annual production rate;
- Process plant recoveries and the ability to control deleterious element levels within LOM plan expectations;
- Assumptions that Salobo III will perform as predicted, based on the performances of Salobo I and II;
- Changes to the parameters used to determine TSF capacity and water management needs;
- Ability to meet and maintain permitting and environmental licences, and the ability to maintain social licence to operate.

The long-term storage of the medium- and low-grade material in a tropical environment may lead to some oxidation of contained sulphide minerals, which may in turn impact recovery of metals during eventual processing of the stockpiles.

The reserve estimates are currently constrained to available tailings storage in the TSF. The storage capacity will need to be increased to convert any mineral resources to future mineral reserves.

To the extent known to the QP, there are no other known environmental, permitting, legal, title related, taxation, socio-political or marketing issues that could materially affect the mineral reserve estimate that are not discussed in this Report.

13 MINING METHODS

13.1 INTRODUCTION

Conventional open pit mining methods are used, with the operations strategy based on Owner-operator mining equipment and labour. The ultimate pit was subdivided into eight phases; two of which have been mined out, and the remaining six phases form the basis of the LOM plan. Mining plans and engineering studies were completed for the mineral reserve estimates. All engineering studies were at a minimum prefeasibility-level studies.

The Salobo I mining operation started in 2012 with a plant feed production of 12 Mt/a and the Salobo II expansion started in 2014 with a plant feed production of 24 Mt/a and a total production of tonnes moved of 126 Mt/a (combined ore and waste). The base case mine production schedule discussed in this Report involves the movement of 130 Mt/a to feed 36.0 Mt/a of ore to the process plant from December 2022, by immediately processing a portion of the ore that would have been stockpiled in the previous 24 Mt/a production plan.

The open pit mine life is approximately 24 years, ending in 2045 (Reserve Only). The process plant will continue to operate by reclaiming stockpiled material until 2053.

13.2 GEOTECHNICAL CONSIDERATIONS

The overall wall slopes used in the pit optimization are provided in Table 13-1, based on the pit slope sectors in Figure 13-1. Figure 13-1 also identifies the major failure mechanisms that may occur in each sector that are the object of ongoing monitoring and mitigation.

An interferometric radar unit was installed to monitor pit slopes real time. This system delivers constant monitoring of surface rock displacement and rock fall, allowing effective geotechnical risk management when coupled with a Trigger Action Response Plan that defines triggers and associated actions to follow with the intent of protecting lives and equipment.

A procedure is in place that includes periodic slope inspections for the open pit, WRSFs, stockpiles, and TSF. The objectives of these inspections are to verify stability conditions, drain systems and ongoing workings. To minimize instability, there is a pit monitoring program whereby geotechnical staff evaluate the results of smooth blasting; and assess stability to prevent slope damage. These inspections are reported on a periodic basis.

13.3 HYDROGEOLOGICAL CONSIDERATIONS

Water inflow into the open pit is managed using a sump in the base of the open pit, which is connected, via pipelines, to the TSF. Water from the pit bottom sump is pumped to the TSF.

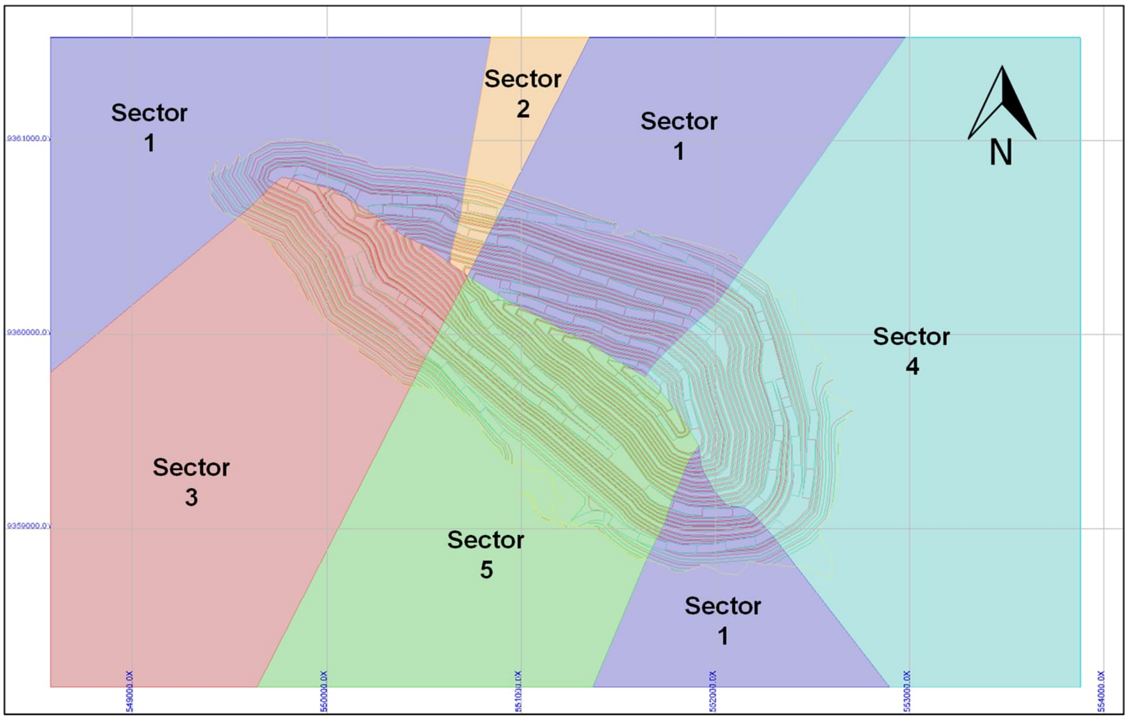
Table 13-1: Pit Slope Considerations

Sectors	Lithology	Class	Bench			Between Ramps "toe to toe"		Catch Berms (m)
			Height (m)	Berm Min. (m)	Batter Angle Max. (°)	Maximum Stacking Height (m)	Maximum Angle (º)	
1	Schist	I, II and III	30	11	70	150	54	20
	Mylonite							
	Gneiss							
	Saprolite (Gneiss)	V	15	12	40	45(2)	27	—
	Transition zone (Gneiss)	IV						
2	Biotite Garnet Schist	I, II and III	15	8	70	150	48	20
	Mylonite							
	Gneiss							
	Saprolite (Gneiss)	V		12	40	45(2)	27	—
	Transition zone (Gneiss)	IV						
3	Schist(1)	I, II and III	30	16	65(3)	150	45	20
	Mylonite							
	Gneiss							
	Saprolite (Gneiss/Schist/Quartz)	V	15	12	40	45(2)	27	—
	Transition zone (Gneiss/Schist/Quartzite)	IV						
4	Schist(1)	I, II and III	30	11	65	150	50	20
	Mylonite							
	Gneiss							
	Saprolite (Gneiss/Schist/Quartz)	V	15	12	45	45(2)	27	—
	Transition zone (Gneiss/Schist/Quartzite)	IV						
5	Schist(1)	I, II and	30	11	75	150	61	20

Sectors	Lithology	Class	Bench			Between Ramps “toe to toe”		Catch Berms (m)
			Height (m)	Berm Min. (m)	Batter Angle Max. (°)	Maximum Stacking Height (m)	Maximum Angle (º)	
	Quartzite	III						
	Gneiss							
	Saprolite (Gneiss/Schist)	V	15	12	40	45(2)	27	—

Notes: Lithologies that have the same schist geotechnical characteristics are classified with the schist lithology supergroup. For triple and quadruples benches consider a 15 m berm size. The berm width was designed to contain any material falling from sector 3, assuming a 65º bench angle.

Figure 13-1: Schematic, Pit Geotechnical Sectors



Note: Figure prepared by Vale, 2020

An upgrade to the pumping system, including a capacity increase, is planned for 2022–2023.

13.4 OPERATIONS

13.4.1 PIT PHASING AND STOCKPILING

The open pit plan was designed with eight phases (Figure 13-2). Phases 1 and 2 are mined out, Phases 3–6 are the current ore sources, and Phases 7 and 8 will be mined in the last years of open pit operations.

A stockpiling strategy is practiced, using different stockpiles for high-grade (>0.85% CuEq), medium-grade (0.60–0.85% CuEq) and low-grade (0.253–0.60% CuEq) material.

Phasing of the open pit development and application of a cut-off grade strategy allowed higher-grade ore (>0.90% Cu) to be processed in the initial years of the operation. From 2025 to 2039, the mining of progressively lower-grade material will occur. The copper grade increases during the final phases of pit development and then decreases as production ramps down. The primary mill feed material in the last years of the process life will be from stockpiles.

13.4.2 PIT DESIGN

The mine operates on a continuous schedule with three shifts per day of eight hours each. Approximately 10 days per year are planned as lost production delays due to poor weather conditions (i.e., rain and fog).

Mining uses standard open pit methods with drilling and blasting, loading and hauling, using 15 m benches in rock and 8 m loading benches in saprolites.

13.4.3 ROAD AND RAMP DESIGN CRITERIA

The mine design is based on cutback widths between 100–450 m as guided by Whittle analysis, with a minimum mining width of 80 m on all benches except the floor of the ultimate pit, where the widths will be 40 m. Nominal road and ramp widths of 35 m are used where the 240 t capacity trucks operate, and a ramp with of 42 m is used where truck fleets are mixed capacity, or the 360 t capacity trucks are in operation. The lowermost benches of phases are designed with single ramp access. The ramp gradient is designed up to 10%.

13.4.4 STOCKPILE AND WASTE ROCK STORAGE FACILITY DESIGN CRITERIA

Low- and medium-grade ore and waste rock from the mine are stored in three locations along the perimeter of the pit (refer to Figure 13-2). Some higher-grade ore stockpiles with limited capacity are situated close to the crusher, and serve as buffers in case of production disruption in the mine or the crusher. The piles also have a blending function.

Material is end-dumped in 15 m high lifts with 10 m berms between lifts. The bench face angles range from 32–35º. Storage capacity in the ore stockpiles is 354.3 Mt, and is 1,505 Mt for the WRSF. This is sufficient for LOM requirements.

13.5 PRODUCTION SCHEDULE

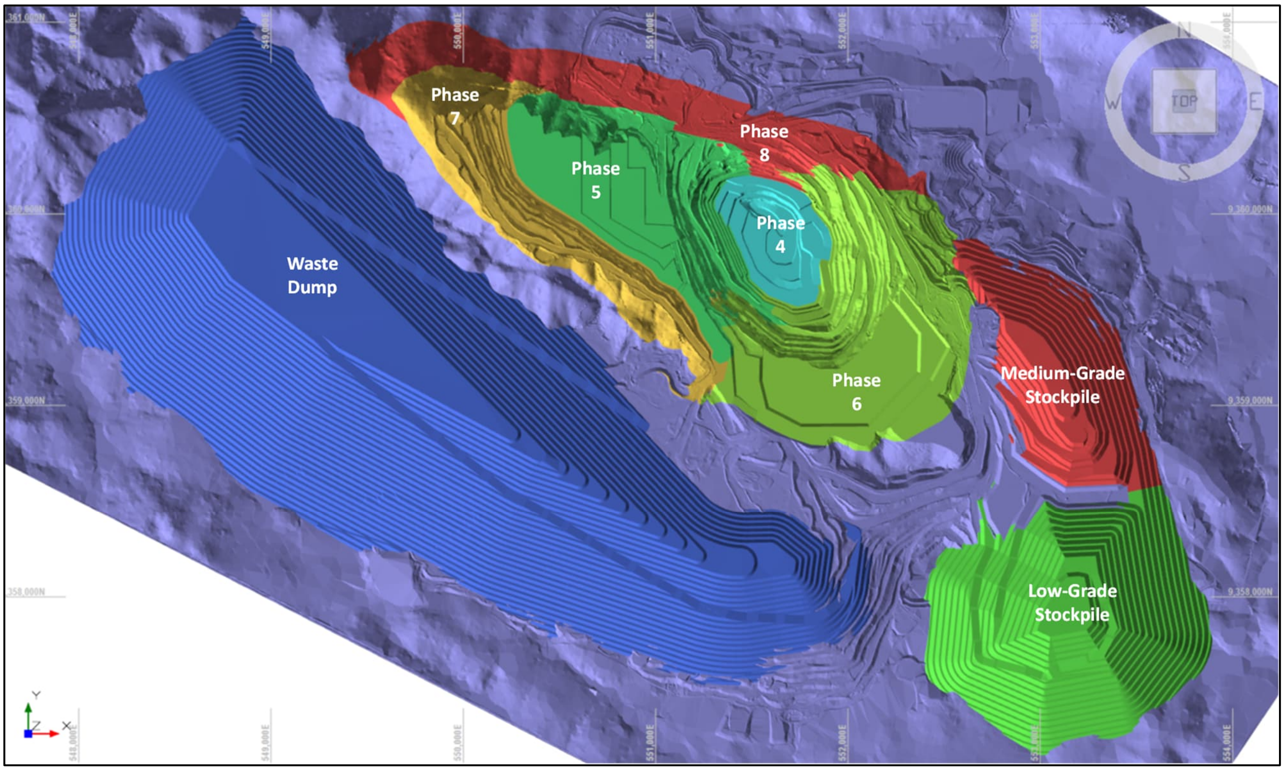
The open pit mine life is approximately 24 years, ending in 2045. The process plant will continue to operate by reclaiming stockpiled material until 2053.

13.6 GRADE CONTROL

Drilling is accomplished by a fleet of rotary blast-hole drills, both electric- and diesel-powered.

Grade control grids are dependent on the material type being evaluated (ore/waste), the drill hole diameter, and the pit phase. Grid sizes range from 5–13 m spacings. The blast-hole diameter ranges from 12¼–13¾ inches.

Figure 13-2: Pit Phase Schematic



Note: Figure prepared by Vale, 2021.

Grade control sampling uses drill cuttings collected from blastholes. All ore blastholes are sampled, and the grade control geologist determines which waste blastholes are sampled to ensure mineralization matches the interpretation in the geological model. Surveyors measure the drill hole collar locations using high-precision GPS equipment. Ore polygons are defined based on the assay results, and taking account of where the blasted material was thrown. This information is uploaded to the GPS units of the operating shovels and loaders to guide the mucking operations.

13.7 EQUIPMENT

The Salobo operations primarily use large electric (rope) shovels for ore and waste production. Hydraulic shovels are used for the oxide saprolite and transition material where a lower ground pressure is required. Wheel loaders are used for miscellaneous clean up jobs and for backup of the shovels when needed. A fleet of off-road haul trucks are used to transport material to the WRSF, the stockpiles, or the primary crusher stockpiles. Track dozers are assigned to maintain production areas, WRSFs and bench clean-up. Wheeled dozers, road graders and water trucks complete the remainder of the auxiliary equipment fleet.

The LOM plan average equipment fleet requirements are provided in Table 13-2.

13.8 PERSONNEL

A total of approximately 1,300 personnel currently support the mining operations.

Table 13-2: Equipment Fleet

Purpose	Fleet	Number
Loading	BE 495 HD (42 yd^3)	4
	BE 495 HR (63 yd^3)	1
	PC 5500 (38 yd^3)	4
	L 1850 (33 yd^3)	3
Hauling	Kom 830 (240 t)	14
	Kom 930 (320 t)	4
	CAT 793 (240 t)	12
	CAT 797 (360 t)	17
Drilling	Pit viper 351 (12 1/4")	6
	BE 49 HR (12 1/4")	6
	Komatsu 320XPC (12 1/4")	1
	ROC-L8 (6 3/4")	5
Support/auxiliary	Bulldozer- CAT D6	2
	Bulldozer- CAT D10	6
	Bulldozer- CAT D11	4
	Bulldozer- KOM 375A-5	1
	Bulldozer- KOM 475A-5	2
	Motor grader - CAT 16M	1
	Motor grader - CAT 24M	5
	Wheeldozer - CAT 854	3
	CAT 374D backhoe and retro tyre	1
	PC450-8 Backhoe	4
	Water truck Kom 785HD-7 and CAT 785D	4
	Tyre handler - CAT 988H and CAT 924K	2
	Scania P420 truck and surfboard	2
	Scania G440 truck	11
	Wheeldozer - Komatsu WD900	2
	CAT 349D, 390F and 320D backhoe	6

14 PROCESSING AND RECOVERY METHODS

14.1 PROCESS METHOD SELECTION

The process flowsheet is based on completed mining studies and knowledge gained from metallurgical testwork. The process plant was de-bottlenecked during operations where operating conditions deviated from design.

The existing processing plants, line 1 and line 2 (Salobo I and II), each have a nominal 12 Mt/a capacity. Vale is currently implementing the Salobo III project to provide a third line that is an identical nominal 12 Mt/a circuit, to increase the process capacity to a total of 36 Mt/a. Salobo III is forecast to start production following a ramp-up curve that will take 15 months to reach 100% capacity.

The process plant is designed to operate 365 days per year at 85% of operating availability with an average ore feed rate of 1,741 dmt/hr.

Salobo copper concentrates are sold to third parties, and shipped through the Itaqui Port in São Luís.city, Maranhão State.

14.2 FLOWSHEET

A simplified process flowsheet is provided in Figure 14-1. Each of lines 1, 2, and 3 (Salobo I, II and III) has the same flowsheet.

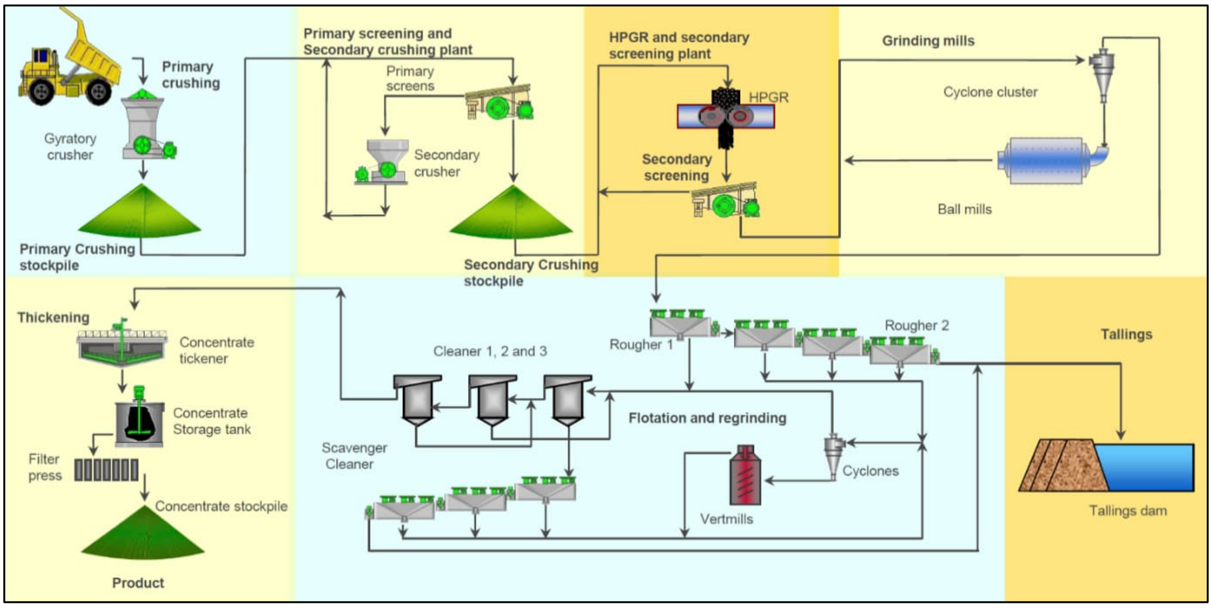
14.3 PLANT DESIGN

Run-of-mine ore is hauled to the ROM stockpile, and crushed in one of two primary gyratory crushers to a product size distribution with 80% passing 152 mm. Primary crushed ore is conveyed to a common crushed ore stockpile.

Four coarse ore stockpile reclaim feeders feed onto the primary screen feed conveyor that in turn feeds two operating double-deck vibrating screens. A third screen and crusher were added to the original two units with the Salobo II plant. These units are typically on stand-by.

Secondary-crushed product is conveyed by pipe conveyor running to a secondary crushed ore stockpile. Two parallel lines of four operating reclaim feeders feed crushed ore to the high-pressure grinding roll (HPGR) circuit.

Figure 14-1: Simplified Process Flowsheet



Note: Figure prepared by Vale, 2020. Flowsheet is the same for each of Salobo I, II and III.

The crushed HPGR product is discharged via the product collection conveyor and is then screened at 8 mm on the bottom deck of banana screens, with the top deck aperture set at 15 mm. There is a total of eight operating screens, with half dedicated to the HPGR of either Salobo I or Salobo II. The screen undersize, at 80% passing 6 mm, discharges directly into one dedicated ball mill discharge sump. The screen oversize is recirculated back via the screen oversize collection conveyor to the HPGR silos feed conveyor for further crushing. The circulating load is typically 110% around this circuit.

Slurry in the ball mill discharge sump is pumped to a battery of ten 660 mm hydrocyclones, of which seven are typically operating. Hydrocyclone underflow is fed by gravity to an overflow ball mill of 7.9 m diameter by 13.4 m long, equipped with a 17 MW gearless motor. There are four ball mills operating in locked circuit, each with a dedicated hydrocyclone cluster. Ball mill discharge feeds into the discharge sump for recirculation to the hydrocyclones. The design grinding circuit product is set at 80% passing 106 µm. Hydrocyclone overflow advances to the Rougher 1 flotation circuit at 45% solids by weight. The ball mills were designed to operate at a 30–35% ball charge using 76 mm diameter steel balls and with a circulating load of approximately 300%. These conditions were adjusted by the operations, now showing use of a 33% ball charge. Under these conditions, 16.5 MW are drawn from the mill motors. The circulating load is about 250%.

The flotation circuit is of conventional design, but the cleaning circuit consists of column flotation to improve rejection of gangue contaminant minerals carrying fluorine, chlorine and uranium. Lime is added at the front end of the circuit to raise the pH to about 11. The addition of thionocarbamate is done before the rougher line to collect gold particles, and thus increase the recovery of this by-product. Xanthate (PAX) and dithiophosphate are used as the primary and secondary collectors, respectively. Frothing is provided by propylene glycol and methyl isobutyl carbinol (MIBC).

Rougher flotation is carried out in four parallel lines (one for each ball mill) of seven cells each. The cells are mechanically agitated tank cells of 200 m^3 capacity, providing 59 minutes of design retention time. The rougher concentrate advances to the regrinding and posteriorly cleaning circuit. The rougher tailings advance to staged flotation reactors (SFRs). The concentrate from the SFRs reports to concentrate regrinding. SFR tailings gravitate to the TSF, which is located directly north of the processing plant.

The combined flotation circuit tailings (Rougher 2 and cleaner–scavenger tailings) flow by gravity from the plant to the TSF. Tailings are disposed from a single-point discharge and create a beach on the south side of the dam. Over the mine life, several phases of dam heightening with plant tailings will be required to provide the required storage volume. Vertical pumps installed at catchment points on the TSF pump recycled water back to the process plant, accounting for >95% of total process water requirements.

The cleaning circuit consists of three upgrading stages with flotation columns, and is closed by a cleaner–scavenger bank of conventional agitated cells. The arrangement of each upgrading stage is typical, where the concentrate of one stage advances to the next, and the tailings are recirculated back to the previous stage. The Cleaner 1 tailings proceed to the cleaner–scavenger and Cleaner 3 concentrate is the final copper concentrate.

The Cleaner 1 circuit consists of 16 column cells, each 6 m diameter x 14 m height, arranged in four lines of four cells each. Design residence time is 39 min. The Cleaner 1 columns are fitted with a Microcel sparging system, introducing flotation air to recirculated slurry pumped through static mixers. All of the other columns use more standard air spargers.

The concentrate from the Cleaner 1 circuit advances to the Cleaner 2 circuit, consisting of four lines of two columns each (4.3 m diameter x 14 m height,) for a design retention time of 34 min. Concentrate from the Cleaner 2 circuit advances to the Cleaner 3 circuit, consisting of four lines of one cell each (4.3 m diameter x 14 m height) for a design retention time of 39 min. The tailings from Cleaner 2 returns to Cleaner 1. The Salobo I circuit has a direct flotation reactor circuit installed to process this tailings material to concentrate, which resulted in a 0.3% overall recovery increase.

Tailings from Cleaner 1 are fed into the cleaner–scavenger section, made of four lines of five 200 m^3 agitated cells each. The tailings of this stage join the Rougher 2 tailings to form the complete plant tailings stream, directed by gravity to the TSF. The cleaner–scavenger concentrate is combined with the Rougher 2 concentrate and undergoes regrinding in one of three vertical mills fitted with 1.1 MW motors. These mills, filled with 20 mm diameter steel grinding media, are operated in locked-circuit with one dedicated cyclone cluster per mill, ensuring a regrinding circuit product at 80% passing 20 µm.

The final concentrate exiting Cleaner 3 is pumped to one of two 15 m diameter high-capacity thickeners, producing an underflow slurry at 65% solids. This slurry is transferred to a surge tank ahead of the filter presses.

The concentrate is further dewatered using four filter presses, each with a horizontal frame holding 50 plates of 1,500 mm x 1,500 mm. A typical filtration cycle lasts 20 minutes. The filtered concentrate has a residual moisture content of about 11%. It is stockpiled below the filter presses in a covered concentrate storage area holding 6,000 t.

The concentrate stockpile is reclaimed by a front-end loader and loaded into trucks at a nominal rate of 1,500 wmt/d. Trucks with about 27 wmt are weighed using a static scale and dispatched to a railroad terminal in Parauapebas city, about 94 km from the mine. The rail warehouse can hold 16 kt of concentrate, allowing for blending when required. The concentrate is reclaimed by a front-end loader and loaded into 80–90 wmt wagons for rail transport by trains with 100 wagons using the 892 km-long Carajás railroad (Estrada de Ferro Carajás/EFC) that links Carajás to the Vale port terminal at the Port of Itaqui. Concentrate is stored inside a 50 kt capacity warehouse at the port terminal. Concentrate can be ship-loaded at a rate of 1,100 wmt/hr. There is one ship-loading system at the port that is shared by Vale's Salobo and Sossego Operations.

14.4 EQUIPMENT SIZING

The key equipment list is provided in Table 14-1.

Table 14-1: Major Process Equipment

Salobo I	Salobo II	Salobo III
1 gyratory crusher: 60 x 89 in.	1 gyratory crusher: 60 x 89 in.	1 gyratory crusher: 60 x 89 in.
2 cone crushers	1 cone crusher	2 cone crushers
2 vibrating screens: 12 x 24 ft	1 vibrating screen: 12 x 24 ft	2 vibrating screens: 12 x 24 ft
1 overland pipe conveyor (78.7 in.); 6,000 hp; 1,700 m length; 4,600 t/hr capacity	Equipment shared with Salobo I	5 conventional conveyors, 2,286 t/hr capacity
2 high pressure grinding rolls: Ø 2.0 x 1.5 m	2 high pressure grinding rolls Ø 2.0 x 1.5 m	3 high pressure grinding rolls: Ø 2.0 x 1.5 m
2 ball mills: Ø 26 ft x 40 ft	2 ball mills: Ø 26 ft x 40 ft	2 ball mills: Ø 26 ft x 40 ft
24 flotation tank cells: 200 m^3	24 flotation tank cells: 200 m^3	24 flotation tank cells: 200 m^3
14 flotation columns: 14 m	14 flotation columns: 14 m	14 flotation columns: 14 m
2 flotation SFR: 60 m^3	2 Flotation SFR: 60 m^3	2 flotation SFR: 60 m^3
3 Vertimills: 1,500 hp	3 Vertimills: 1,500 hp	3 Vertimills: 1,500 hp
1 concentrate thickener: Ø 15 m	1 concentrate thickener: Ø 15 m	1 concentrate thickener: Ø 15 m
2 pressure filters: 2,000 x 2,000 / 36 chambers	2 pressure filters: 1,500 x 1,500 / 50 chambers	1 pressure filter: 1,500 x 1,500 / 50 chambers

Note: * One cone crusher and one vibrating screen are common for both Salobo I and II plants, as stand-by equipment; Ø = diameter.

14.5 POWER AND CONSUMABLES

The mill is provided with electricity from the plant substation (refer to discussion in Chapter 15.9). Step-down transformers provide the various voltages used by the equipment.

The bulk of the process water needs are covered by the recirculation from the TSF. The consumption of fresh water is limited to systems requiring better water quality, and is pumped from Mirim and Mamão Creeks.

Reagents include potassium amyl xanthate (PAX), dithiophosphate, propylene glycol, methyl isobutyl carbinol (MIBC), thionocarbamate, and lime.

14.6 PERSONNEL

A total of approximately 450 persons are currently employed in the process area.

15 INFRASTRUCTURE

15.1 INTRODUCTION

The majority of the infrastructure to support the LOM plan is in place. Major infrastructure includes:

- Operating open pit;
- Process plant with three process lines (Salobo I, II, and III);
- Waste rock storage facilities;
- Stockpiles;
- Tailings storage facilities;
- Pipelines and associated pumping facilities;
- Central administrative facilities: administrative offices, restaurant, change rooms, training centre and a medical clinic;
- Central maintenance facilities: a mine heavy equipment workshop including tyre-changing facility, a light vehicle maintenance shop, a plant maintenance shop for component overhaul and repair, a warehouse, and maintenance offices;
- Mine facilities: mine operations change rooms and mine operations offices;
- Mine heavy equipment fuelling facilities, located next to the primary crushers;
- Main substation;
- Small vehicle fueling station;
- Recycle centre;
- Security/ access control gate.

An infrastructure layout plan is provided in Figure 15-1.

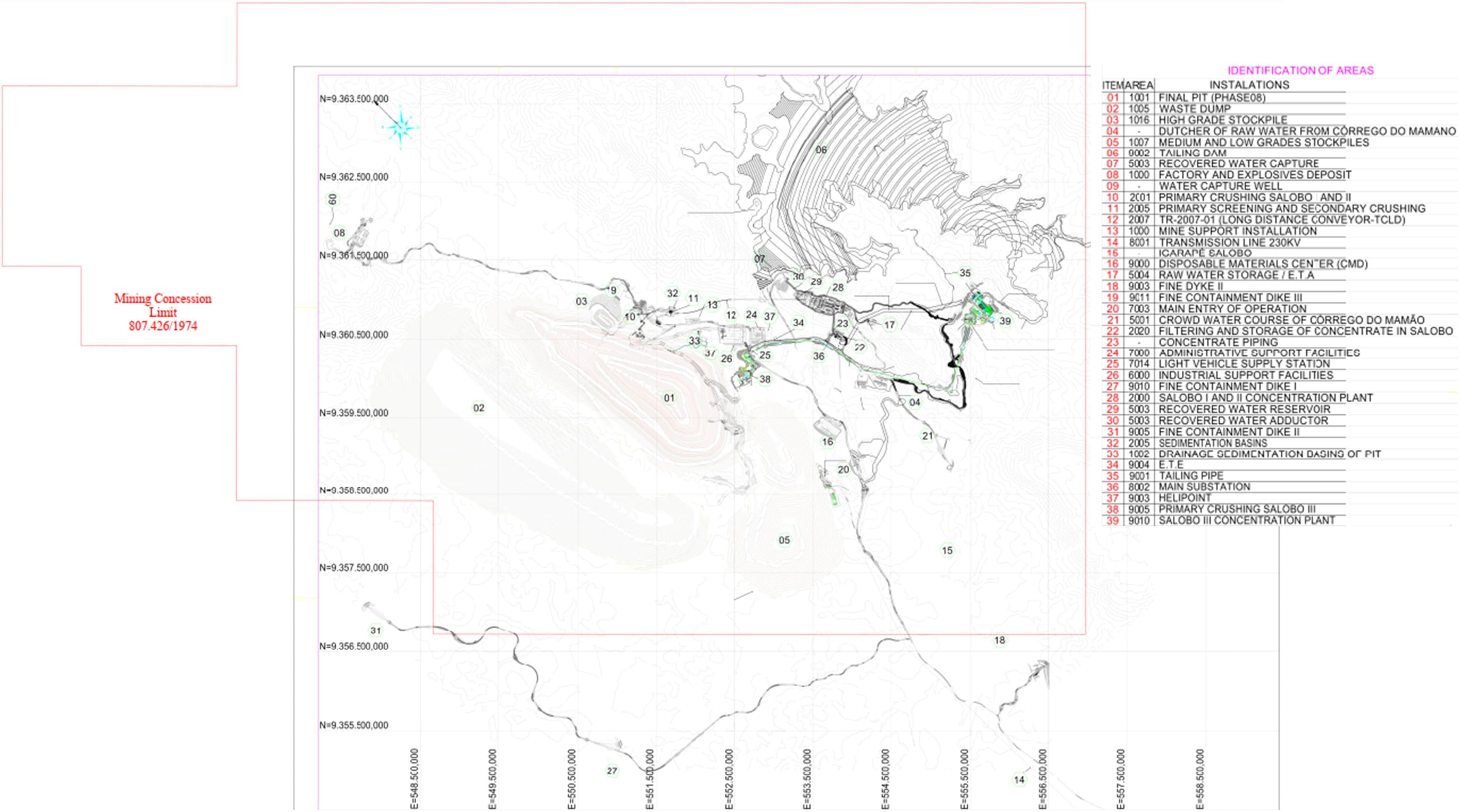
15.2 ROADS AND LOGISTICS

Road access and air services are discussed in Chapter 4.2.

Vale has a contract with a transportation company to transport employees and contractors from the Carajás and Parauapebas city areas to the Salobo mine site. Employees also use a fleet of company-owned vehicles for transportation.

Copper concentrate is shipped by truck from the Salobo Operations to a rail facility near the city of Parauapebas, 85 km from the mine. From there it is transported by rail to the Ponta da Madeira Marine Terminal at the port city of São Luís, a distance of approximately 870 km, for shipment.

Figure 15-1: Infrastructure Layout Plan



IDENTIFICATION OF AREAS

ITEM	AREA	INSTALATIONS
01	1001	FINAL PIT (PHASE08)
02	1005	WASTE DUMP
03	1016	HIGH GRADE STOCKPILE
04	-	DUTCHER OF RAW WATER FROM CÓRREGO DO MAMANO
05	1007	MEDIUM AND LOW GRADES STOCKPILES
06	9002	TAILING DAM
07	5003	RECOVERED WATER CAPTURE
08	1000	FACTORY AND EXPLOSIVES DEPOSIT
09	-	WATER CAPTURE WELL
10	2001	PRIMARY CRUSHING SALOBO I AND II
11	2005	PRIMARY SCREENING AND SECONDARY CRUSHING
12	2007	TR-2007-01 (LONG DISTANCE CONVEYOR-TCLD)
13	1000	MINE SUPPORT INSTALLATION
14	8001	TRANSMISSION LINE 230KV
15	-	ICARAPÉ SALOBO
16	9000	DISPOSABLE MATERIALS CENTER (CMD)
17	5004	RAW WATER STORAGE / E.T.A
18	9003	FINE DYKE II
19	9011	FINE CONTAINMENT DIKE III
20	7003	MAIN ENTRY OF OPERATION
21	5001	CROWD WATER COURSE OF CÓRREGO DO MAMÃO
22	2020	FILTERING AND STORAGE OF CONCENTRATE IN SALOBO
23	-	CONCENTRATE PIPING
24	7000	ADMINISTRATIVE SUPPORT FACILITIES
25	7014	LIGHT VEHICLE SUPPLY STATION
26	6000	INDUSTRIAL SUPPORT FACILITIES
27	9010	FINE CONTAINMENT DIKE I
28	2000	SALOBO I AND II CONCENTRATION PLANT
29	5003	RECOVERED WATER RESERVOIR
30	5003	RECOVERED WATER ADDUCTOR
31	9005	FINE CONTAINMENT DIKE II
32	2005	SEDIMENTATION BASINS
33	1002	DRAINAGE SEDIMENTATION BASINS OF PIT
34	9004	E.T.E
35	9001	TAILING PIPE
36	8002	MAIN SUBSTATION
37	9003	HELIPOINT
38	9005	PRIMARY CRUSHING SALOBO III
39	9010	SALOBO III CONCENTRATION PLANT

Figure prepared by Vale, 2021.

15.3 TAILINGS STORAGE FACILITIES

The TSF was constructed in Mirim Creek close to the confluence of the Salobo River, and approximately 650 m from the plant site. Tailings are deposited by gravity. The facility was designed for Vale by Brazilian engineering company BVP Engineering to withstand a one-in-10,000 year event. The current design was completed in July 2010.

The TSF is a cross-valley impoundment comprising a compacted earth and rock-fill embankment with internal drainage and transition zones, and a concrete lined spillway. The final dam raise is planned for 2025. Once the raise is completed, there will be sufficient capacity within the facility for LOM plan purposes. Should mineralization that is currently classified as indicated mineral resources be considered for mine plan purposes, additional TSF capacity, or a second TSF will be required.

Geotechnical inspections and monitoring of the TSF are conducted according to the governmental agency regulation (DNPM Act 70.389/17). The Mining Dam Emergency Action Plan (PABM), Periodic Safety Review of Dams (RPSB) and a Regular Safety Inspection (ISR) were completed. Instrumentation was installed on the 255 m elevation, and automated, with readings taken every four hours. A radar system was installed to monitor the TSF.

15.4 WATER MANAGEMENT

Under its granted water licences, Vale can capture water in the following water courses:

- Mamão Creek water dam: raw water captured and treated for human consumption;
- Tailings dam (Mirim Creek): water returned to process plant;
- Salobo Creek: water used for dust suppression.

Non-contact water is diverted around the mine, TSF, stockpiles, and WRSF where possible. Diversion channels, a 2.6 km tunnel, and dikes were constructed to transfer water from Salobo Creek to Mirim Creek, and then back to its original watercourse to prevent this water from being affected by the mine. Three sediment control ponds collect fine sediments from site runoff, stockpiles and the WRFs prior to discharge to downstream waters.

Process make-up water consists of runoff and direct precipitation within the tailings storage basin. This raw water is pumped to the plant together with return water from the TSF. If the plant requires additional makeup water, this can be extracted from Mamão Creek.

15.5 BUILT INFRASTRUCTURE

Infrastructure to support mining activities is in place. The process plant is undergoing expansion with the construction of the Salobo III line.

15.6 CAMPS AND ACCOMMODATION

There is no on-site accommodations camp. The workforce resides in Carajás, Parauapebas, and surrounding settlements.

15.7 POWER AND ELECTRICAL

The Salobo Operations are supplied by the Eletronorte division of Eletrobras, responsible for the northern region of Brazil, which operates and maintains the system on behalf of the National Operator of the Electrical System (NOS).

Electrical energy is supplied from Tucuruí, an 8,370 MW hydroelectric-generating station on the Tocantins River, 200 km north of Marabá, and 250 km due north of Parauapebas. The 180 MW of power required by the Salobo Operations (including Line III) is transmitted by an 87 km-long overhead 230 kV transmission line.

16 MARKET STUDIES

16.1 PRODUCTS

Salobo produces copper concentrate that is sold to third-party smelters, with a portion of gold sales included as a by-product in those copper concentrate sales. The majority share of Salobo gold production is sold under a multi-year streaming agreement.

16.2 MARKETS

16.2.1 COPPER

16.2.1.1 DEMAND

Copper consumption can be divided into product groups, such as copper wire rod, copper products and copper alloy products. In general, these products are consumed in broad sectors of the global economy, such as: civil and building construction, machinery, transportation, consumer and general products and utilities. Additionally, these copper products are vital to the rapidly growing green economy, such as renewable energy generation and storage.

Construction is the largest copper consuming sector, accounting for nearly 28% of total copper consumption. The main wire and cable and copper products consumed in the construction industry include building wire, power cable, copper plumbing and air conditioning tube, copper sheet and alloy products. Consumer and General and the Utility sector rank second and third, with both sectors accounting for just over 20% of copper demand.

Copper demand is diverse, which is why it is often describes as an “economic bellwether” for the global economy. Stable demand growth is expected from all the sectors described above. The long-term growth forecasts have been revised higher as global policy sets ambitious decarbonization targets, cost of renewable energy decreases and investments in the green economy increases. This acceleration will lead to a pivot towards more copper-intensive uses in renewable energy and transportation projects related to electric vehicles.

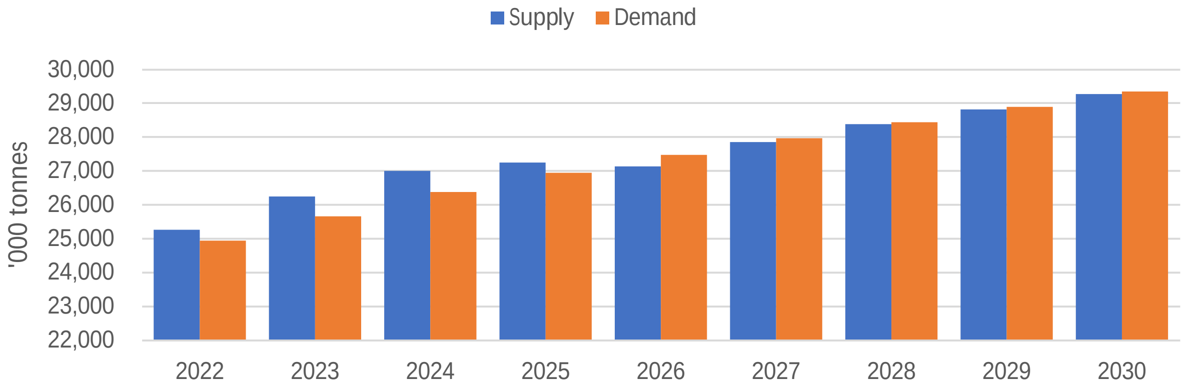
After significant impacts in 2020, due to the COVID-19 outbreak, copper demand is expected to grow at a compound annual growth rate (CAGR) of 2% between 2020 and 2030. Copper demand, net of recycled material, is predicted to grow from 23.5 Mt in 2020 to 29.3 Mt by 2030.

16.2.1.2 SUPPLY

Several mines were impacted during the initial COVID-19 outbreak in 2020, however, most were able to quickly reopen, and successfully manage the virus as time passed. In the short term, the overarching view is that there are enough quality assets being developed to meet demand. Longer term, growth is expected to struggle given declining ore grades and the lack of new major discoveries. More quality assets will be required in the medium to long term to replace existing operations ramping down or closing. Additionally, proposed increases to taxes and royalties in major producing regions could defer future investment, and risk longer-dated supply growth from key greenfield projects.

Refined copper supply is expected to increase at a CAGR of 2% between 2020 and 2030. Total refined supply is expected to reach 29.3 Mt by 2030, from 23.9 Mt in 2020. See Figure 16-1.

Figure 16-1: Copper Market Forecast, 2022–2030



Source: 3rd Party

16.2.1 GOLD

16.2.1.1 DEMAND

Gold is used in jewellery, as an investment instrument, in technology, and to manage central banks' reserves.

Gold jewelry is the largest demand sector, accounting for over 50% of total demand. Central bank demand has shifted since the financial crisis of 2008 with emerging markets increasing purchases and European banks halting sales of the metal, now accounting for roughly 6% of total market demand. Volatile markets sustain demand for gold in investment portfolios to protect purchasing power and minimize losses during market shocks, with this sector accounting for approximately 30% of total market demand. The unique properties of gold are driving technological uses in medicine, engineering and environmental management, with a total market share of approximately 10%.

The demand for gold has moved East in the past decade to the emerging economies of China and India. India is one of the largest consumers of gold and it plays a central role in the country's culture as a symbol of status.

16.2.1.2 SUPPLY

The geographical diversity of mined gold, mined on every continent except Antarctica, allows for stability in the market. Mine production of gold accounts for roughly 70% of total market supply annually with recycled material making up the balance.

16.2.2 COMMENTS ON MARKET STUDIES

There are no agency relationships relevant to the marketing strategies used by Vale Operations.

Product valuation is included in the economic analysis in Chapter 19 and is based on a combination of the metallurgical recovery, commodity pricing, consideration of processing charges, and allocations, where applicable for premiums paid on the products from the operations.

Since gold is a by-product of our operations, there is no technical specification for end-users to be saleable.

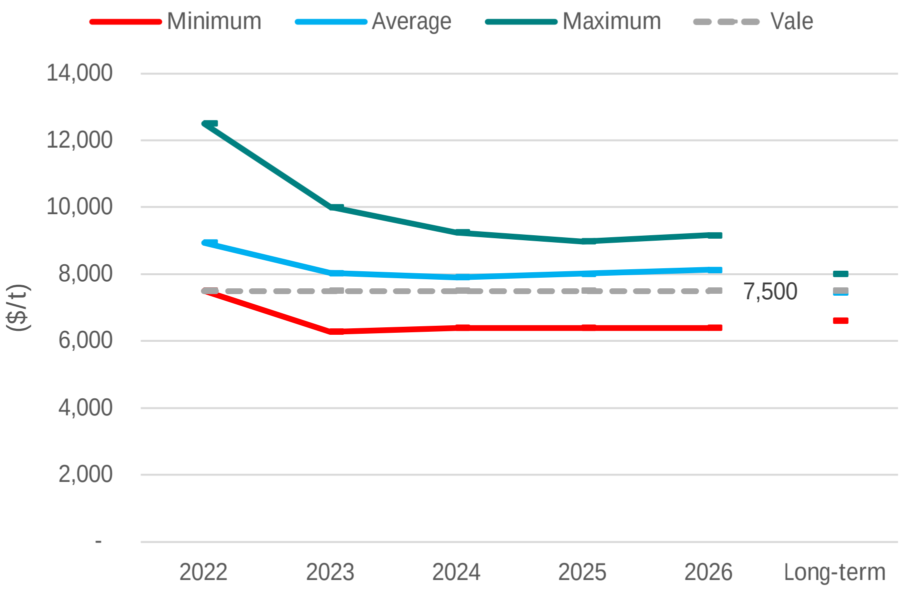
16.3 PRICE OUTLOOK

The intent is to demonstrate that the mineral reserves are economically viable, and the sensitivity analysis shows the potential upside or risks of the economics to factors such as price.

16.3.1 COPPER

The LOM pricing (US$7,500) forecast uses a consensus approach based on long-term analyst and bank forecasts, supplemented with research by Vale's internal specialists. The forecast uses annual predictions for the period 2021–2025, reverting to a long-term fixed forecast from 2026 for the remaining mine life (Figure 16-2).

Figure 16-2: LOM Copper Price Forecasts

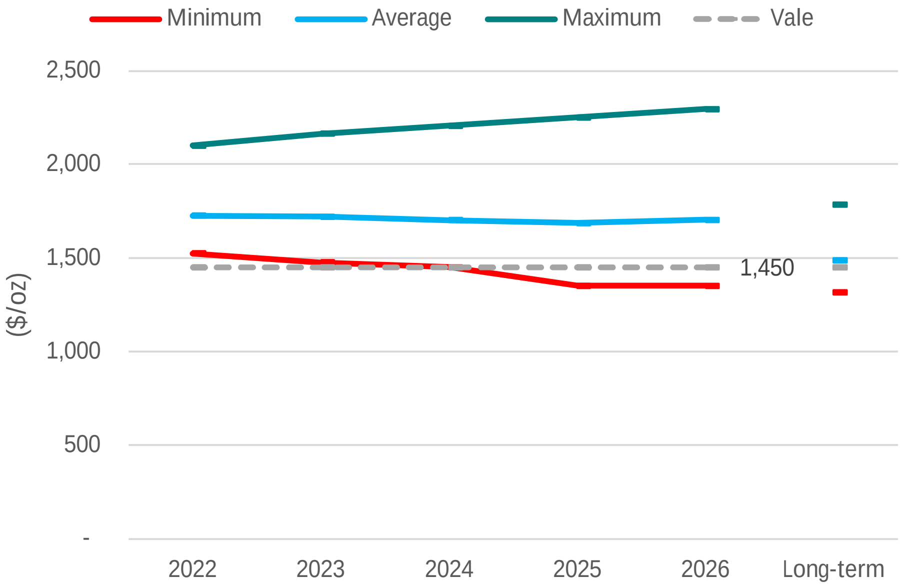


Source: Bank reports published from August 2021

16.3.1 GOLD

The LOM pricing (US$1,450) forecast uses a consensus approach based on long-term analyst and bank forecasts, supplemented with research by Vale's internal specialists. The forecast uses annual predictions for the period 2021–2025, reverting to a long-term fixed forecast from 2026 for the remaining mine life (Figure 16-3).

Figure 16-3: LOM Gold Price Forecasts



Source: Bank reports published from August 2021

16.4 CONTRACTS

Vale has agreements at typical copper concentrate industry benchmark terms for metal payables, treatment charges and refining charges for concentrates produced. Treatment costs and refining costs vary depending on the concentrate type and the destination smelter.

The terms contained within the concentrate sales contracts are typical and consistent with standard industry practice and are similar to contracts for the supply of copper concentrate throughout the world. Depending on the specific contract, the terms for the copper concentrate sale are either annually negotiated, benchmark-based treatment and refining charges, or in the case of spot agreements are based on fixed treatment and refining charges based on market terms negotiated at the time of sale. The differences between the individual contracts are generally in relative quantity of concentrates that are covered under annually negotiated treatment and refining charges.

As metals contained in copper products, the terms for gold are determined through a payable mechanism on metal content based on typical market terms. As typical for concentrates, the product is generally contracted under a medium-term contract.

Gold sands are typically sold using spot pricing terms with end-users based on prevailing market conditions. The majority share of Salobo gold production is sold under a multi-year streaming agreement (See Chapter 3.8.2)

Contracts may be entered into for goods and services required to operate underground mining operations. On occasions, mining contractors may be employed for specific mine development projects. The largest in-place contracts include transportation, purchase of fuel, reagents and other process consumables, ground support and mining equipment leases. The terms contained within the contracts are typical of, and consistent with, standard industry practices.

Intercompany agreements between Vale affiliates are negotiated at arm’s length based on market terms and rates that would be achieved had the contract been negotiated with an unaffiliated third party.

17 ENVIRONMENTAL STUDIES, PERMITTING, AND PLANS, NEGOTIATIONS, OR AGREEMENTS WITH LOCAL INDIVIDUALS OR GROUPS

17.1 BASELINE AND SUPPORTING STUDIES

Environmental and social baseline study areas were defined to characterize the conditions in the areas that would potentially be affected by mine components or activities.

The social and environmental management plans Vale has implemented represent best practice and comply with Brazilian legislation. Vale's aims to prevent as well as mitigate any potential impacts related to the Salobo operations, and ensure compliance with all relevant Brazilian legislation. The operations run environmental programs that mitigate and compensate for the previously-identified local impacts on fauna, and flora, and the physical and social environments.

17.2 ENVIRONMENTAL CONSIDERATIONS/MONITORING PROGRAMS

The site maintains a monitoring program for a number of different elements, including water monitoring of the Salobo Stream and Itacaiunas River (turbidity and elements of concern), total suspended particulates (TSPs), ongoing rehabilitation of degraded and disturbed areas, reforestation.

Vale has been notified of environmental issues related to contractor fleet vehicular accidents causing diesel spills, and has been advised of some environmental exceedances in certain elements that are above CONAMA limits. Vale is in discussion with the regulatory authorities in relation to the environmental exceedances.

Static acid base accounting and non-acid generating (NAG) test work concluded that all wastes were non-acid forming. Low-grade oxides are comingled with non-potentially acid-generating (PAG) waste rock within the centre of the WRSF as a preventive measure to neutralize potential acid generation for low-grade oxides.

17.3 CLOSURE AND RECLAMATION CONSIDERATIONS

The Salobo Closure Plan assumes that there will be partial recovery of infrastructure for use by educational activities, research and tourism. The closure plan is included in the Environmental Control Plan. The overall objective is to return the Project area to a natural condition to support the local vegetation and wildlife biodiversity of the Tapirapé–Aquiri National Forest.

There are no reclamation bonds required for the mine. Rehabilitation and re-vegetation work are ongoing during operations.

Closure costs are included in the mine site financial model as cash costs on an annual basis. The largest closure costs are associated with the process facility, WRSFs and stockpiles.

The current closure plan was developed by Sete Soluções e Tecnologia Ambiental Ltda in 2015 and was updated by Arcadis in March 2021. The escalated closure cost estimate for the Salobo Operations, as at year-end 2021, is US$211 million.

17.4 PERMITTING

The Operating License was renewed in October 19, 2018 and is valid for six years. The Salobo Operations have all necessary permits to support the current mining and processing activities. According to Brazilian environmental legislation, the operations license must be renewed within 120 days before the end of its validity. Therefore, the renewal request Salobo Operating License must be made by June 21, 2024.

The operations have a control and monitoring system to ensure that permits remain current, and to ensure that the requirements of each permit are monitored to comply with the relevant regulatory conditions imposed.

In addition to the Salobo Operating License, 12 environmental permits were issued for Salobo Operations:

- Five Installation Licenses (No 1046/2015, No 1157/2017, No 1209/2018, No 1383/2021 and 1395/2021);
- Four Vegetation Removal Licenses (No 1053.9.2021.38386, No 10539201917636, No 10539202020632 and No 10539202020631);
- Two Authorizations to Capture, Collect and Transport Biological Material (No 797/2017 and 85/2021).

Six environmental licenses were issued for the Salobo III expansion:

- One Installation Licence No. 1249/2018, valid until November 23, 2022;
- Two Vegetation Removal Licences No. 1339/2018 and No. 10539201914310/2019 (valid until December 12 and December 19, 2021, respectively);
- Three Authorizations to Capture, Collect and Transport Biological Material: No. 1017/2018; No. 1277/2020 and 1330/2020;

The Salobo III expansion was granted three water capture and discharge concessions: No. 3552/2019, No. 3188/2018 and No. 3795/2019.

Together, these licences are sufficient to support construction of Salobo III. The project schedule outlines the additional permits that must be obtained prior to operation of the third line. Permits on the critical path that are still to be obtained include incorporation of the Salobo III line in the Environmental Operation License, following completion of Salobo III installation.

17.5 SOCIAL CONSIDERATIONS, PLANS, NEGOTIATIONS AND AGREEMENTS

The Salobo Project is located in the Tapirapé Aquiri National Forest, Pará, whose indigenous lands Xikrin do Bacajá and Xikrin do Cateté, are 60 km and 25 km away, respectively, from the Project area.

The indigenous peoples from Xikrin do Cateté land traditionally move once a year to the same National Forest to collect Brazilian nuts, whose season goes from January until April. This activity is not shared by any other indigenous group, who does not use the Tapirapé Aquiri for any traditional practices.

As a result, Vale maintains a Communication Plan with the Xikrin do Cateté that includes a continued dialogue about health and safety during their stay. Vale also supports their camp with clean water, electricity, a specialist that speaks to the community on a daily basis, and provides first aid to any emergencies that may occur during the harvesting period. In addition, Vale's operational workers are fully trained in regards to the annual collecting practices, to avoid any ethnic or cultural conflicts.

That Social Inclusion intendeds to support a sustainable development by capitalizing the positive effects and minimizing any potential negative effects of the project. This plan is supported by a Social Communications program that facilitates information exchange and works to improve relations between the Salobo Operations and surrounding communities through an active community consultation program and a grievance registration process.

The closest non-traditional indigenous villages to the Salobo III Project are Paulo Fonteles and Sanção. The expected Project impact on these settlements is increased vehicle traffic using the Paulo Fonteles highway during Salobo III construction activities.

In July 2018, associations representing the indigenous communities of Xikrin do Cateté and Xikrin do Bacajá brought a class action lawsuit against Vale, IBAMA and FUNAI before a federal court in the city of Marabá seeking the suspension of the environmental permitting process and operation of Salobo mine. The associations contend that FUNAI and IBAMA have failed to conduct the appropriate studies regarding the affected indigenous communities during the environmental permitting process and contends that Vale operations would be contaminating the water of the Itacaiúnas River and consequently that the indigenous groups affected by this mine have not provided the required consent. The plaintiffs also requested a monthly payment for each association until the defendants conclude the studies. In July 2019, the court partially granted an injunction requested by the Indigenous Associations, ordering Vale and Salobo to prepare the Indigenous Component Study of the Salobo Mine project, but rejected all other requests filed by the plaintiff, including the request to shut down the project. A recent decision of the court determined the inclusion of the Indigenous community of Xikrin do Bacajá in the scope of the studies.

In December 2021, Vale and Xikrin communities signed an extrajudicial agreement for social and economic compensation to these communities. The out-of-court settlement was signed on January 17 and remains subject to approval by the Marabá Civil Court. Once approved by the Civil Court, this settlement is expected to end Salobo's litigation.

17.6 QUALIFIED PERSON’S OPINION ON ADEQUACY OF CURRENT PLANS TO ADDRESS ISSUES

The permitting and environmental requirements to operate the Salobo Operations are well understood and can support mineral resource and mineral reserve estimation.

No material issues with completed environmental studies, permitting, or closure assumptions were identified that would require significant mitigation plans to be developed.

18 CAPITAL AND OPERATING COSTS

18.1 INTRODUCTION

All capital and operating cost estimates are at a minimum at a pre-feasibility level of confidence, having an accuracy level of ±25% and a contingency range not exceeding 15%.

Costs are presented for a 36 Mt/a operation.

The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance

18.2 CAPITAL COST ESTIMATES

18.2.1 BASIS OF ESTIMATE

Capital costs are based on recent prices or operating data. Unit costs for in-house mine development are based on historical actual costs. Mobile equipment that is leased is included in operating costs. Lease periods typically range from two to five years. Lease costs are charged to capital while the equipment is doing capital work. Purchased equipment is allocated for in the capital plan. Mobile equipment and fixed asset costs are based on supplier quotations and/or current examples.

Sustaining capital cost forecasts are based on forecast mine development and construction needs, mobile equipment re-build/replacement schedules and fixed asset replacement and refurbishment schedules. Sustaining capital includes the following:

- Mine sustaining:
    - Mine mobile equipment acquisition, replacement, and rebuild;
    - Pre-stripping activities;
    - Mine infrastructure (e.g. electrical, dewatering, explosive storages, fuel storages, mobile garages);
    - Construction of waste disposal, dykes, haulage roads, and mine stockpile infrastructure.
- Processing sustaining:
    - Raising and maintenance of the TSF infrastructure;
    - Upgrades and automation of dam and processing plant monitoring technology;
    - Maintenance of plant infrastructure;
    - Purchase of plant components;
- Other sustaining:
    - G&A: Maintenance and construction of administrative buildings (offices, canteens, dry facilities);
    - IT/communications infrastructure;
    - Plant security;
    - Workforce logistics/transportation,
    - Training;
    - Legal and environmental projects.

18.2.2 CAPITAL COST ESTIMATE SUMMARY

The LOM plan estimated capital costs are summarized in Table 18-1, and total US$3,288 M.

The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance

18.3 OPERATING COST ESTIMATES

18.3.1 BASIS OF ESTIMATE

Operating costs are based on actual costs seen during operations and are projected through the LOM plan.

Historical costs are used as the basis for mine operating cost forecasts, which are estimated using a long-term cost model. This model accounts for the impact of varying production rates and labour complement. Operating cost forecasts are based on a combination of historical performance and calculations from first principles to take account of variation in production rates and expected process improvements. The cash mining costs include the direct operating costs, mine operating expenses and transportation to the mill. As the mine approaches the end of mine life, forecast mine overhead and distributed overhead costs are reduced in line with the projected lower production rates.

Mining operating costs are estimated in conjunction with the mobile equipment fleet selection process, using a cost model containing annually-reviewed production indicators in line with budget assumptions (five years and annual). In addition to the equipment direct operating costs, other key costs include maintenance, labour, salaries, energy, and fuel.

The processing operating cost estimates are the average cash costs applied to the mineral reserves mined throughout the LOM plan. These unit costs include both variable and fixed plant components.

18.3.2 OPERATING COST ESTIMATE SUMMARY

The LOM plan estimated operating costs are provided in Table 18-2. The overall operating cost estimate for the LOM is US$22,018million.

The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance

Table 18-1: Capital Cost Summary

Area	Allocation	Unit	Value
Mining	Sustaining	U$ M	1,435
Processing	Sustaining	U$ M	972
Other	Sustaining	U$ M	515
Salobo III	Project	U$ M	365
Total		***U$ M***	***3,288***

Note: Numbers have been rounded.

Table 18-2: Operating costs and expenses

Area	Unit	Total LOM Plan
Mining Cost	U$ M	8,617
Processing Cost	U$ M	9,009
Logistics and Distribution Costs	U$ M	2,060
Royalties	U$ M	1,054
G&A and Corporate Overhead	U$ M	1,095
R&D and Other	U$ M	182
Total	***U$ M***	***22,018***

Note: Numbers have been rounded. R&D = research and development.

19 ECONOMIC ANALYSIS

19.1 FORWARD-LOOKING INFORMATION CAUTION

The aim of the economic evaluation presented in this chapter is to demonstrate the economic viability of the mineral reserve, therefore the production rates, operating efficiencies, costs and expenditures, taxes and other information presented can differ from other information Vale publishes and should not be considered as a guidance. Note that our planned production extraction may vary due to continuous mineral exploration and technical studies to add new mineral reserves.

19.2 METHODOLOGY

The financial model that supports the mineral reserve declaration is a standalone model that calculates annual cash flows based on scheduled ore production, assumed processing recoveries, metal sale prices and BR$/US$ exchange rate, projected operating and capital costs and estimated taxes.

The financial analysis is based on an after-tax discount rate of 7.5% following a mid year convention and an exchange rate BR$/US$ 5.00. All costs and prices are in unescalated “real” dollars. The currency used to document the cash flow is US$.

All costs are based on the five-year plan approved budget. Post 2026, costs were estimated based on the 2022–2026 period.

Revenue is calculated from the recoverable metal and the long-term forecast of metal prices and exchange rate.

All inputs to the economic analysis are at a minimum of a pre-feasibility level of confidence.

19.3 INPUT PARAMETERS

The mineral reserves estimate was summarized in Chapter 12.3. The projected mine life was provided in Chapter 13.5. The metallurgical recovery forecast was provided in Chapter 10.4.

Revenue is calculated from the recoverable metal and the long-term forecast of metal prices and exchange rates. As well, revenue from the sale of a copper concentrate is included, based on the contained metal, accountability factors and the long-term forecast for metals prices and exchange rates.

Commodity prices were discussed in Chapter 16.3.

Capital costs were summarized in Chapter 18.2.2. Operating costs were summarized in chapter 18.3.2. Capital and operating costs were reported using Q4 2021 US$.

Royalties were summarized in Chapter 3.8.1.

Closure and reclamation costs were discussed in Chapter 17.3.

The economic analysis is based on 100% equity financing and is reported on a 100% project ownership basis.

19.4 TAXATION CONSIDERATIONS

The statutory Federal corporate income tax rate is 34%, consisting of a 25% corporate income tax (IRPJ) and a 9% tax known as the for Social Contribution on Net Profit (CSLL). The actual IRPJ tax rate is 15%, plus a surcharge of 10% on taxable income exceeding US $48,000 a year. The social contribution is levied on a taxable base similar to the Corporate Income Tax.

A Federal tax, CFEM, is levied on economic use of the produced good. Under this tax, 2% for “diamond and other mineral substances”, which includes copper ore.

The Social Contributions on Gross Revenues taxes (PIS and COFINS) are Federal social contribution taxes that must be paid by all entities in Brazil (i.e., not restricted to mining companies) and are calculated based on gross revenues. The applicable tax rate is 9.25% (1.65% PIS and 7.6% COFINS), not applicable to revenues from exports.

A Provincial tax, the Tax on Circulation of Goods and Services (ICMS), is an indirect tax similar to VAT. It is a State VAT tax and the rates vary according to where the product/good/mine is being sold, depending on the specific state legislation. In Para State, the tax is 17%, not applicable on exports.

The tax assessment assumes that the SUDAM benefit, an incentive designed to encourage investment in the Amazon area, which represents a 75% reduction in income tax rate (from 25% to 6.25%), will be applicable until 2023.

19.5 RESULTS OF ECONOMIC ANALYSIS

The mineral reserve only cashflow for Salobo operation is used to confirm economic viability. The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance

The annual cashflow is presented below, with the inputs as averages grouped for the first 2 years, followed by 3 years, and subsequently 5 year groups. For the end of the production period (LoMP) we have a specific group of 2 years. The cost related to the mine closure period are summarized as a 9 yr group (2054-2062).

The post-tax $NPV_{7.5\%}$ is US$7,720 million.

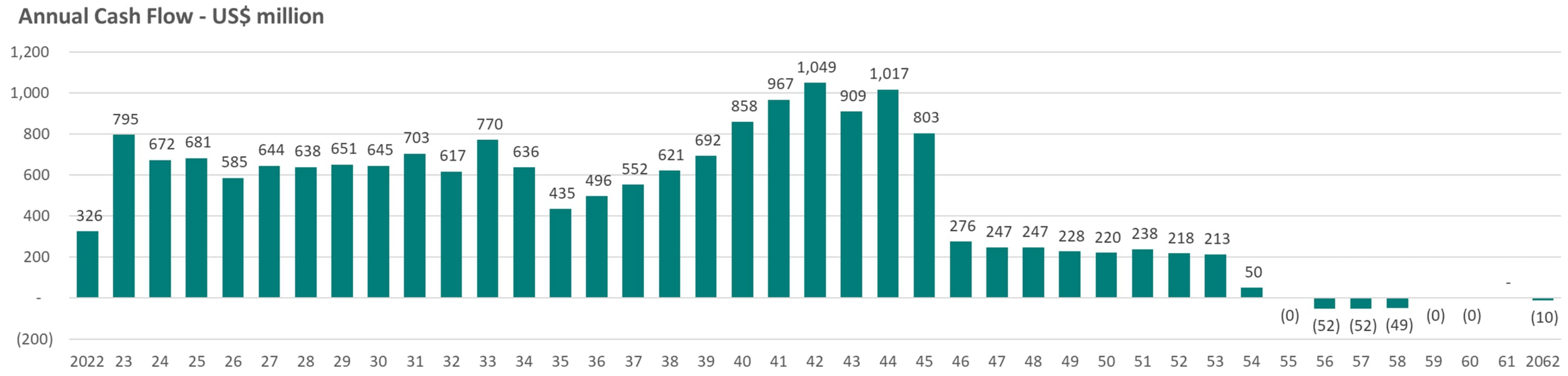
As the cashflows are based on existing operations where all costs are considered sunk to 1 January 2022, considerations of payback and internal rate of return are not relevant.

The cash payments and the forecasted contractual gold price conditions stated in the Wheaton streaming agreement are not reflected in the Cashflow evaluation. Further details on the terms of the Wheaton agreement are discussed in Chapter 3.8.2.

A cashflow is provided in Table 19-1.

Table 19-1: Cashflow[1],[2],[3] 2022- 2062

Cash Flow	Unit	2022-23	2024-26	2027-31	2032-36	2037-41	2042-46	2047-51	2052-53	2054-62
Ore Processed	Mt	28	35	36	36	36	36	36	36	-
Copper Recovered	kTonnes	204	221	208	203	234	207	102	102	-
Gold Recovered	kOz	315	313	311	284	331	328	111	111	-
Total Revenue	US$ million	1,796	1,912	1,812	1,743	2,012	1,829	829	829	-
Operating costs, expenses, royalties, and closure costs	US$ million	(762)	(834)	(784)	(785)	(800)	(607)	(453)	(448)	(18)
Income Tax and Working Capital Change	US$ million	(138)	(285)	(265)	(269)	(375)	(350)	(93)	(112)	6
Total CAPEX	US$ million	(335)	(147)	(108)	(98)	(99)	(61)	(47)	(54)	-



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[1] Sale price Copper US$7,500/tonne and Gold US$1,450/oz

[2] Figures shown do not deduct the stream amounts nor do they reflect our additional payment expected from Wheaton. For a description of our streaming arrangement with Wheaton, see Chapter 3.8.2

[3] The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve, therefore it can differ from other information Vale publishes and should not be considered as a guidance

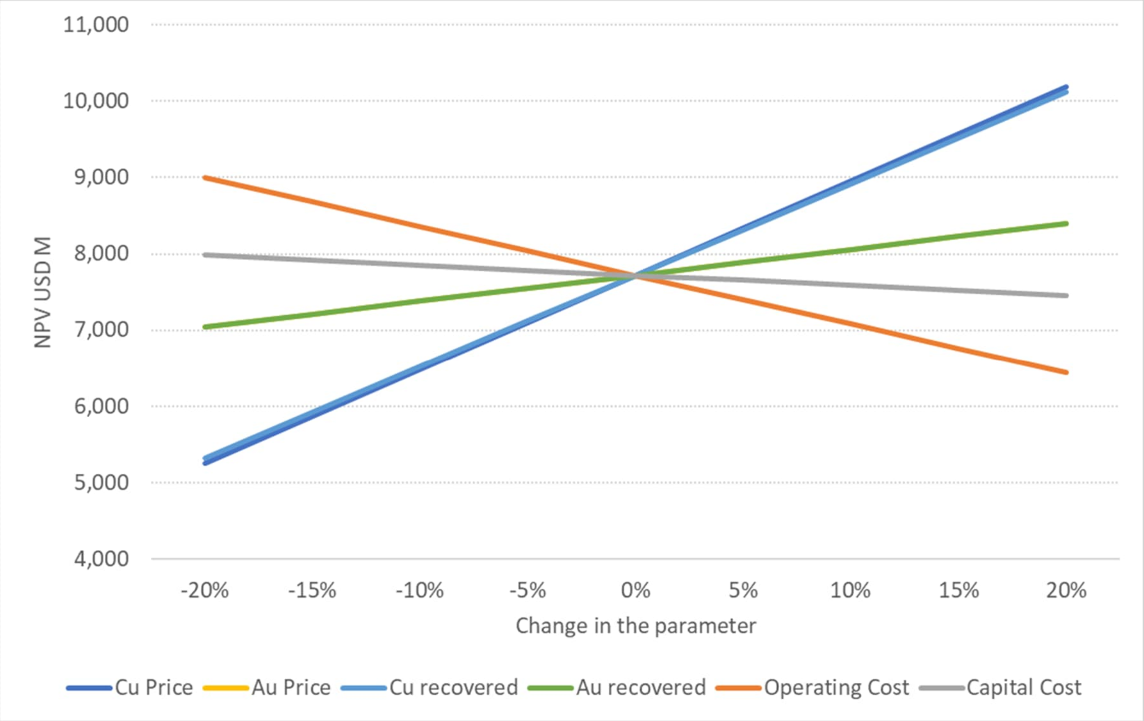
19.6 SENSITIVITY ANALYSIS

Sensitivity analysis was performed on metal prices, metal recovered, capital costs and operating costs.

Figure 19-1 shows the Salobo Operations are most sensitive to least sensitive, in order:

- Copper price
- Copper recovered
- Operating costs
- Gold price
- Gold recovered
- Capital costs

Figure 19-1: Sensitivity Analysis



20 ADJACENT PROPERTIES

This Chapter is not relevant to this Report.

21 OTHER RELEVANT DATA AND INFORMATION

This Chapter is not relevant to this Report.

22 INTERPRETATION AND CONCLUSIONS

22.1 INTRODUCTION

The QPs note the following interpretations and conclusions in their respective areas of expertise, based on the review of data available for this Report.

22.2 PROPERTY SETTING

The Salobo Operations are located in an area that has a long mining history. As a result, local and regional infrastructure and the supply of goods available to support mining operations is well-established. Personnel with experience in mining-related activities are available in the general district. There are excellent transportation routes that transect the Carajás area.

Although the mine is situated in an area of steep topography, there are no significant topographic or physiographic issues that would affect the Salobo Operations. The area surrounding the mining operations is heavily forested and dominated by relative dense trees with substantial underbrush.

Mining operations are conducted year-round.

22.3 OWNERSHIP

The Salobo Operations are indirectly wholly-owned by Vale.

22.4 MINERAL TENURE, SURFACE RIGHTS, WATER RIGHTS, ROYALTIES AND AGREEMENTS

Information obtained from Vale experts supports that the mineral tenure held is valid and is sufficient to support a declaration of mineral resources and mineral reserves.

There are no property agreements relevant to the Salobo Operations.

The Salobo Operations are located entirely within the National Forest of Tapirapé–Aquiri, therefore the surface rights belong to the Federal Government. There are no associated payments related to surface rights for the operations.

Vale holds sufficient water rights to support the current operations. Such rights can be renewed at the discretion of the relevant regulatory authority.

The CFEM royalty is payable to the Federal Government, and a mineral production tax is imposed by the state of Pará.

Since 2013, Wheaton Precious Metals has entered into three different LOM gold stream agreements on the Salobo Operations with Vale (through a wholly-owned subsidiary), each for 25%, for a total of 75%. . Wheaton will be required to make an additional payment to Vale, that is expected to range from $550 million to $670 million depending on certain contractual completion tests

22.5 GEOLOGY AND MINERALIZATION

The Salobo deposit is an example of an IOCG deposit.

The geological understanding of the settings, lithologies, and structural and alteration controls on mineralization in the different zones is sufficient to support estimation of mineral resources and mineral reserves. The geological knowledge of the area is also considered sufficiently acceptable to reliably inform mine planning.

The mineralization style and setting are well understood and can support declaration of mineral resources and mineral reserves.

Further work is required to determine what the exploration potential is at depth below the current open pit operations.

22.6 HISTORY

All exploration and development was conducted by Vale or predecessor companies.

A pre-feasibility study was completed by Bechtel in 1988 and a feasibility study was completed by Minorco in 1998. The feasibility study was revised and updated by Kvaerner in 2001. The Salobo Operations commenced pre-stripping in 2009. The first concentrate was shipped in September 2012.

22.7 EXPLORATION, DRILLING, AND SAMPLING

The exploration programs completed to date are appropriate for the deposit style.

Most drill holes are oriented to intersect mineralised zones at an angle, and the drill hole intercept widths reported for those drill holes are typically greater than the true widths of the mineralisation at the drill intercept point.

The quantity and quality of the lithological, geotechnical, collar and down-hole survey data collected during the exploration and delineation drilling programs are sufficient to support mineral resource and mineral reserve estimation. The collected sample data adequately reflect deposit dimensions, true widths of mineralization, and the deposit style.

Density is estimated based on measurements obtained using the water-displacement method. Density data are considered acceptable for use in mineral resource and mineral reserve estimation.

The sample preparation, analysis, quality control, and security procedures used by the Salobo Operations have changed over time to meet evolving industry practices. Practices at the time the information was collected were industry-standard. The sample preparation, analysis, quality control, and security procedures are sufficient to provide reliable data to support estimation of mineral resources and mineral reserves.

The QA/QC programs adequately address issues of precision, accuracy and contamination. Modern drilling programs typically included blanks, duplicates and standard samples. QA/QC submission rates meet industry-accepted standards. No material issues from the QA/QC programs were noted, and the data are considered acceptable to support estimation.

22.8 DATA VERIFICATION

Vale had data collection procedures in place that included several verification steps designed to ensure database integrity. Vale staff also conducted regular logging, sampling, laboratory and database reviews. In addition to these internal checks Vale contracted independent consultants to perform laboratory, database and mine study reviews. The process of active database quality control and internal and external audits generally resulted in quality data.

The data verification programs concluded that the data collected from the Salobo Operations area adequately support the geological interpretations and constitute a database of sufficient quality to support the use of the data in mineral resource and mineral reserve estimation.

Data that have been verified on upload to the database, and checked using the layered responsibility protocols, are acceptable for use in mineral resource and mineral reserve estimation.

22.9 METALLURGICAL TESTWORK

The mineralogy and metallurgical performance of the Salobo deposit is well understood, based on a combination of the initial metallurgical testwork programs and a decade of production data.

Industry-standard studies were performed as part of process development and initial mill design. Subsequent production experience and focused investigations guided mill alterations and process changes. Testwork programs, both internal and external, continue to be performed to support current operations and potential improvements. From time to time, this may lead to requirements to adjust cut-off grades, modify the process flowsheet, or change reagent additions and plant parameters to meet concentrate quality, production, and economic targets.

Samples selected for testing were representative of the various types and styles of mineralization. Samples were selected from a range of depths within the deposits. Sufficient samples were taken so that tests were performed on sufficient sample mass.

Recovery projections for copper and gold are based on formulae. These equations are used to project metallurgical recoveries in the mineral reserve estimate, cut-off grade calculations, and the LOM financial model. Silver recovery was not tracked as diligently as copper and gold during the testwork phases. The adoption of a single equation to predict copper recovery, instead of drafting discrete equations for each lithology and using these to match the expected relative proportions provided in the mine plan as plant feed, is a simplification that may create daily discrepancies between expectations and actual results.

Some variability in the metallurgical results can be expected as the mixture of lithologies found in the plant feed change. Over monthly periods, the resulting blend is more likely to approach the mineral reserves profile and thus mitigate the variability that may be detected on a daily basis, versus projections. Introduction of mixed material above a proportion of 30% of plant feed leads to a degradation of the flotation results. This material requires blending.

Recovery factors estimated are based on appropriate metallurgical testwork, and are appropriate to the mineralization types and the selected process route.

Three deleterious elements, fluorine, chlorine and uranium, report to the copper concentrate, of which fluorine is the most significant. Vale secured contracts with smelters able to accept the copper concentrate, with an average fluorine content of about 2,000 ppm, and a maximum content of 4,000 ppm. Penalties are charged starting below the actual content. These smelters placed the maximum acceptable chlorine content at 1,200 ppm, but with a penalty drawn at the 550–650 ppm level. Recent annual averages of uranium levels are between 35–50 ppm. The specification limit is 50 ppm. Operational procedures are being implemented to accurately forecast the uranium grade in the long-term and short-term planning models to enable blending of plant feed from the mine. Since concentrate lots are segregated by grade (lower, medium and high grades) at the Parauapebas transfer shed and at the port of Itaqui, blending of out-of-specification concentrate can be undertaken.

22.10 MINERAL RESOURCE ESTIMATES

Vale has a set of protocols, internal controls, and guidelines in place to support the estimation process, which the estimators must follow. Estimation was performed as a team effort involving several technical disciplines. The mineral resource estimate is supported by core drilling.

Mineral resources are reported using the mineral resource definitions set out in S–K1300 and are reported exclusive of those mineral resources converted to mineral reserves. The reference point for the estimate is in situ. Mineral resources are current as at 31 December 2021.

Areas of uncertainty that may materially impact the mineral resource estimates include: changes to long-term metal price and exchange rate assumptions; changes in local interpretations of mineralisation geometry, structures, and continuity of mineralised zones; changes to geological and grade shape and geological and grade continuity assumptions; changes to metallurgical recovery assumptions; changes to the input assumptions used to derive the conceptual open pit shell used to constrain the estimates; changes to the forecast dilution and mining recovery assumptions; changes to the CuEq cut-off applied to the estimates; variations in geotechnical (including seismicity), hydrogeological and mining assumptions; and changes to environmental, permitting and social license assumptions.

22.11 MINERAL RESERVE ESTIMATES

Mineral reserves are estimated using open pit mining assumptions and the use of conventional open pit mining equipment.

Mineral reserves were converted from measured and indicated mineral resources. Inferred mineral resources were set to waste. Economic cut-off grades were applied to the estimate based on a breakeven cut-off grade. Mining recovery (mineability) and external dilution factors were applied.

Mineral reserves were classified using the mineral reserve definitions set out in S–K1300. The reference point for the mineral reserve estimate is the point of delivery to the process plant. Mineral reserves are current as at 31 December 2021.

The following factors may affect the mineral reserve estimate: commodity prices; US dollar exchange rate; Brazilian inflation rate; geotechnical (including seismicity) and hydrogeological assumptions; changes to inputs to capital and operating cost estimates; changes to operating cost assumptions used in the constraining pit shell; changes to pit designs from those currently envisaged; stockpiling assumptions; ability of the mining operation to meet the annual production rate; process plant recoveries and the ability to control deleterious element levels within LOM plan expectations; assumptions that Salobo III will perform as predicted, based on the performances of Salobo I and II; ability to meet and maintain permitting and environmental licences, and the ability to maintain social licence to operate. The long-term storage of the medium- and low-grade material in a tropical environment may lead to some oxidation of contained sulphide minerals, which may in turn impact recovery of metals during eventual processing of the stockpiles.

22.12 MINING METHODS

Mining at the Salobo Operations uses conventional open pit mining methods and a conventional equipment fleet. The mine is Owner-operated.

The Salobo pit has been subject to small seismic events, interpreted to be related to a cross-cutting dyke in the pit. This resulted, in 2017, in a small wedge failure on the south side of the pit. Because the seismicity appears to be related to geology rather than pit geometry, the seismic events are likely to continue. Unless there is associated pit wall instability or rock falls, the seismic events are not currently considered to be an operational issue.

Pit water is pumped and sent to the TSF. There are no major known aquifers in the open pit area.

The open pit plan has eight phases. Phases 1 and 2 are mined out, Phases 3–6 are the current ore sources, and Phases 7 and 8 will be mined in the last years of open pit operations. A stockpiling strategy is practiced, and once active mining operations are completed, stockpiles will be fed to the plant.

The open pit mine life is approximately 24 years, ending in 2045. The process plant will continue to operate by reclaiming stockpiled material until 2053.

22.13 RECOVERY METHODS

The process flowsheet evolved based on the mining studies completed and knowledge gained from metallurgical testwork. The process design was de-bottlenecked during operations where operating conditions deviated from forecasts.

The existing processing plants, Salobo I and II, each have a nominal 12 Mt capacity. Vale is currently implementing the Salobo III Project to provide a third line that is an identical nominal 12 Mt circuit, to increase the process capacity to a total of 36 Mt/a.

The process methods and equipment used are conventional to the industry. The process facilities in use are appropriate to the mineralization styles. The plant will produce variations in recovery due to the day-to-day changes in ore type or combinations of ore type being processed. These variations are expected to trend to the forecast recovery value for monthly or longer reporting periods.

22.14 INFRASTRUCTURE

The majority of the infrastructure to support mining operations is in place. An expansion to the mill is underway and will add an additional 12 Mt/a capacity when the Salobo III line is completed in

2022. There is no on-site accommodations camp. The workforce resides in Carajás, Parauapebas, and surrounding settlements.

Copper concentrate is shipped by truck from the Salobo Operations to a rail facility near the city of Parauapebas, 85 km from the mine. From there it is transported by rail to the Ponta da Madeira Marine Terminal at São Luís, a distance of approximately 870 km, for shipment.

The TSF is a cross-valley impoundment comprising a compacted earth and rock-fill embankment with internal drainage and transition zones, and a concrete lined spillway. Tailings are deposited by gravity. There is sufficient capacity within the facility for LOM plan purposes. Geotechnical inspections and monitoring of the TSF are conducted according to the governmental agency regulation (DNPM Act 70.389/17).

Water can be captured from selected water courses under granted water licences. Non-contact water is diverted around the mine, TSF, stockpiles, and WRSF where possible. There are three sediment control ponds. Process make-up water primarily consists of runoff and direct precipitation within the tailings storage basin. The Salobo Operations monitor levels, flows and water balances on a regular basis.

Electrical energy is supplied from a hydroelectric-generating station on the Tocantins River. The 150 MW of power required by the Salobo Operations is transmitted 87 km by an overhead 230 kV transmission line. There is sufficient power availability to support the LOM plan.

22.15 MARKET STUDIES

Vale has an internal marketing department that is tasked with monitoring global commodities markets for the products from the Salobo Operations. The principal payable commodities within the concentrates are copper and gold. The marketing approach is consistent with what is publicly available on industry norms, and the information can be used in mine planning and financial analyses for the products from the Salobo Operations in the context of this Report.

The LOM pricing forecasts were established using a consensus approach based on long-term analyst and bank forecasts, supplemented with research by Vale's internal specialists. The forecast uses annual predictions for the period 2022–2026, reverting to a long-term fixed forecast from 2026 for the remaining mine life.

The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve; therefore, it can differ from other information Vale publishes and should not be considered as a guidance.

Contracts may be entered into for goods and services required for open pit mining operations. The largest in-place contracts include transportation, purchase of fuel, reagents and other process consumables, ground support and mining equipment leases. The terms contained within the contracts are typical of, and consistent with, standard industry practices.

22.16 ENVIRONMENTAL, PERMITTING AND SOCIAL CONSIDERATIONS

Baseline and supporting environmental studies were completed as part of mine development and are completed to assess both pre-existing and ongoing site environmental conditions, as well as to support decision-making processes, and if applicable, permit applications and permit renewals. Characterization studies were completed for all environmental media including soil, water, waste, air, noise and closure. Plans were developed and implemented to address waste management, spill prevention and contingency planning, water management and fugitive dust management.

The Salobo Closure Plan assumes that there will be partial recovery of infrastructure for use by educational activities, research and tourism. The closure plan is included in the Environmental Control Plan. There are no reclamation bonds required for the mine. Rehabilitation and re-vegetation work are ongoing during operations. Closure costs are included in the mine site financial model as cash costs on an annual basis. The largest closure costs are associated with the process facility, WRSFs and stockpiles. The current closure plan was developed by Sete Soluções e

Tecnologia Ambiental Ltda in 2015 and updated in 2021 by Arcadis. The escalated closure cost estimate for the Salobo Operations, as at year-end 2021, is US$211 million.

The Operating License was renewed in October 19, 2018 and is valid for six years. The Salobo Operations have all necessary permits to support the current mining and processing activities. Renewals have been requested as these fall due. In some instances, the Brazilian government does not have a date limit as to when a licence must be renewed by. In these instances, as the renewal was requested prior to licence expiry, the current licence remains valid. The operations have a control and monitoring system to ensure that permits remain current, and to ensure that the requirements of each permit are monitored to comply with the relevant regulatory conditions imposed.

The Salobo Operations are not located on Indigenous lands. The nearest Indigenous lands include the Xikrin do Bacajá and Xikrin do Cateté, all located 25 km or more from the Project area. The indigenous from Xikrin do Cateté land traditionally move once a year to the same National Forest where Salobo Operations is located to collect Brazilian nuts. Vale currently maintains a Communication Plan that commits to continued communication with the local Indigenous peoples to maintain community health and safety, cultural preservation, transparency of activities and harmony between mine workers and the Indigenous communities. There are a number of social management plans carried out by the Social Communications Department.

22.17 CAPITAL COST ESTIMATES

Capital cost estimates are at a minimum at a pre-feasibility level of confidence, having an accuracy level of ±25% and a contingency range not exceeding 15%. Costs are presented for a 36 Mt/a operation.

Capital costs are based on recent prices or operating data. Unit costs for in-house mine development are based on historical actual costs. Mobile equipment that is leased is included in operating costs. Lease periods typically range from two to five years. Lease costs are charged to capital while the equipment is doing capital work. Purchased equipment is allocated for in the capital plan. Mobile equipment and fixed asset costs are based on supplier quotations and/or current examples. Sustaining capital cost forecasts are based on forecast mine development and construction needs, mobile equipment re-build/replacement schedules and fixed asset replacement and refurbishment schedules.

The overall capital cost estimate for the LOM is US$3,288 million.

The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve; therefore, it can differ from other information Vale publishes and should not be considered as a guidance.

22.18 OPERATING COST ESTIMATES

Operating cost estimates are at a minimum at a pre-feasibility level of confidence, having an accuracy level of ±25% and a contingency range not exceeding 15%. Costs are presented for a 36 Mt/a operation.

Operating costs are based on actual costs seen during operations and are projected through the LOM plan. Historical costs are used as the basis for operating cost forecasts for supplies and services unless there are new contract terms for these items. Labour and energy costs are based on budgeted rates applied to headcounts and energy consumption estimates.

The long-term mine operating cost model accounts for the impact of varying production rates on the direct variable costs. As a mine approaches the end of mine life, the model reduces the indirect and distributed costs in line with the projected lower production rates. The processing operating cost estimates are the budget year cash costs applied to the mineral reserves mined throughout the LOM plan. These processing costs include both variable and fixed plant components.

Operating costs total US$22,018million over the LOM.

The sole purpose of the presented figures is to demonstrate the economic viability of the mineral reserve; therefore it can differ from other information Vale publishes and should not be considered as a guidance.

22.19 ECONOMIC ANALYSIS

The financial model that supports the mineral reserve declaration is a standalone model that calculates annual cash flows based on scheduled ore production, assumed processing recoveries, metal sale prices and BR$/US$ exchange rate, projected operating and capital costs and estimated taxes. The financial analysis is based on an after-tax discount rate of 7.5% following a mid year convention. All costs and prices are in unescalated “real” dollars. The currency used to document the cash flow is US$.

The post-tax $NPV_{7.5\%}$ is US$7,720 million, excluding the Wheaton Precious Metals streaming agreement. As the cashflows are based on existing operations where all costs are considered sunk to 1 January 2022, considerations of payback and internal rate of return are not relevant.

Sensitivity analysis was performed on metal prices, metal recovered, capital costs and operating costs. The Salobo Operations are most sensitive to least sensitive, in order, to copper price; copper recovered; operating costs; gold price; gold recovered and capital costs.

22.20 RISKS AND OPPORTUNITIES

22.20.1 RISKS

Factors that may affect the mineral resource and mineral reserve estimates were identified in Chapter 11.13 and Chapter 12.4 respectively.

Other risks noted include:

- Geotechnical and hydrological assumptions used in mine planning are based on historical performance, and to date historical performance has been a reasonable predictor of current conditions. As the pit trends deeper, however, additional geotechnical and hydrological data collection is warranted. Any changes to the geotechnical and hydrological assumptions could affect mine planning, affect capital cost estimates if any major rehabilitation is required due to a geotechnical or hydrological event, affect operating costs due to mitigation measures that may need to be imposed, and impact the economic analysis that supports the mineral reserve estimates;
- The Salobo pit has been subject to small seismic events. Because the seismicity appears to be related to geology rather than pit geometry, the seismic events are likely to continue. Unless there is associated pit wall instability or rock falls, the seismic events are not currently considered to be an operational issue. However, if this should change, there is a risk to the mine plan, and major seismicity could affect operating costs due to mitigation measures that may need to be imposed, and impact the economic analysis that supports the mineral reserve estimates;
- Areas of low-grade mineralization occur adjacent to waste zones and have been the source of unplanned dilution. Recent infill drilling programs have provided additional information to support modelling of these zones and have improved reconciliation between the short-range and long-range mine models. There is a minor risk of additional dilution if these zones are not appropriately captured in the long-range models, resulting in increased tonnage at a lower grade than forecast in the LOM plan being mined;
- The long-term storage of the medium- and low-grade material in stockpiles that are subject to a wet tropical environment may lead to some oxidation of contained sulphide minerals, which may in turn impact recovery of metals during eventual processing of the stockpiles. There is a risk that the recoveries forecast in the LOM plan for this stockpile material may not

be realized, which could affect the expected stockpile processing life, operating costs, and the economic analysis that supports the mineral reserve estimates;

- A third 12 Mt/a process line is being installed in the Salobo plant. While the line design is a mirror of the existing Salobo I and Salobo II lines, there is a risk that the line construction may not be completed by the 2022 forecast date. There is also a risk that the line may not operate as envisaged. This could cause a risk to the LOM plan, and to capital and operating costs if mitigation measured are required, and impact the economic analysis that supports the mineral reserve estimates;
- There have been a number of fuel spills along the Salobo access road as a result of contractor truck mishaps. There is a risk that fines levied on such spills could increase, resulting in an increase in contractor costs as reflected in mine operating costs, and may impact the economic analysis that supports the mineral reserve estimates and community perceptions of Vale.
- Environmental monitoring has indicated some instances of exceedances of elements above regulatory limits. There is a risk that if additional exceedances are noted, more fines will be levied. There is also a risk that the fines levied on such exceedances could increase. This will result in additional costs borne by the operation, and could impact the economic analysis that supports the mineral reserve estimates, and community perceptions of the Project;
- New amendments and regulations to the existing laws are expected in 2022, especially regarding to the safety of the mining dams and restrictions to operate in Self-Rescue Zones. As a result of new regulations, the licensing process for our operations may become longer and more uncertain, and Vale expect our monitoring and compliance costs to increase. These additional laws and regulations may impose further restrictions on our operations, require additional investments or modifications to our operations.
- A Public Civil Action claim has been lodged, claiming significant damages from Vale and certain Brazilian regulatory authorities. The claim alleges that there was an irregularity in the mine licensing process, in particular a failure to carry out an ECI study, and that the mining operations have caused damage to the Xikrin way of life. The claim requests damage payments and mine closure. While Vale has hired independent technicians to carry out the ECI, and has devised a work plan for ECI completion, this step cannot be concluded due to the Covid-19 pandemic. There is a risk to the capital cost estimates depending on whether any damages are found to be payable, and that could impact the economic analysis that supports the mineral reserve estimates. With the conclusion of the extrajudicial agreement, the risk of paralyzing operations at the Salobo mine dropped significantly.

22.20.2 OPPORTUNITIES

Opportunities include:

- The Salobo mineralization remains open at depth under the current open pit outline. Additional exploration evaluation is warranted;
- Pit slope angles in some areas of the pit are based on less detailed information than other areas. Review of the operational pit slope angles through geotechnical examination of the pit wall operation, design of pushbacks, and further geotechnical studies may provide support for the optimization of some of the pit walls and provide a mining upside as less waste material would need to be mined and sent to the WRSFs. This would have a positive effect on the operating cost estimates, and on the economic analysis that supports the mineral reserve estimates;
- Potential conversion of those measured and indicated mineral resources reported exclusive of mineral reserves, with supporting studies, to mineral reserves;
- Potential conversion of inferred mineral resources, with supporting studies, to higher confidence mineral resource classifications.

- The streaming agreement with Wheaton Precious Metals has provision for an additional payment, referred to as the “Additional Deposit” payment. The streaming agreement provides that the Additional Deposit payment, if determined to be payable and there is no dispute from Wheaton Precious Metals, must be paid by Wheaton Precious Metals. There is some upside potential if the Additional Deposit payment is agreed to be triggered on completion of the Salobo III expansion.

22.21 CONCLUSIONS

Under the assumptions presented in this Report, the Salobo Operations have a positive cash flow, and mineral reserve estimates can be supported.

23 RECOMMENDATIONS

Recommendations, totalling US$14.7 M, include:

- Core drilling to support potential conversion of inferred mineral resources to higher confidence classifications. A budget of $7.1 M is recommended.
- Installation of metallurgical samplers at the plant feed, waste and concentrate lines, and installation of the automatic samplers in the conveyor belts. A budget of $1.1 M is recommended;
- Upgrade of the flotation mechanical cells. A budget of $2.7 M is recommended;
- Construction of an integrated core shack for the base metals operations Parauapebas. A budget of $3.3 M is recommended.
- Alignment on the commodity prices and foreign exchange used in the mine design and economic analysis to ensure appropriate pit optimisation and cut-off assumptions.

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24.2 ABBREVIATIONS AND SYMBOLS

Abbreviation/Symbol	Term
AAS	atomic absorption spectrometry
ECI	Indigenous Component Study (Estudo de Componente Indígena)
G&A	general and administrative
GM	ground magnetometer
GPS	global positioning system
GS	gamma spectrometry
ICP	inductively coupled plasma
IP	induced polarization
LOM	life-of-mine
NI 43-101	Canadian National Instrument 43-101 “Standards of Disclosure for Mineral Projects”
NPV	net present value
OK	ordinary kriging
PAG	potentially acid-generating
QA/QC	quality assurance and quality control
QP	Qualified Person
PLT	point load test
R&D	research and development
RQD	rock quality description
SAG	semi-autogenous grind
SG	specific gravity
SME	Society for Mining, Metallurgy and Exploration

Abbreviation/Symbol	Term
TEM	transient electromagnetic
TSF	tailing storage facility
TSP	total suspended particulates
US	United States
WRSF	Waste rock storage facility
XRF	X-ray fluorescence

24.3 GLOSSARY OF TERMS

Term	Definition
amphibolite facies	One of the major divisions of the mineral-facies classification of metamorphic rocks, the rocks of which formed under conditions of moderate to high temperatures (500° C, or about 950° F, maximum) and pressures. Amphibole, diopside, epidote, plagioclase, almandine and grossular garnet, and wollastonite are minerals typically found in rocks of the amphibolite facies
aquifer	A geologic formation capable of transmitting significant quantities of groundwater under normal hydraulic gradients.
azimuth	The direction of one object from another, usually expressed as an angle in degrees relative to true north. Azimuths are usually measured in the clockwise direction, thus an azimuth of 90 degrees indicates that the second object is due east of the first.
ball mill	A piece of milling equipment used to grind ore into small particles. It is a cylindrical shaped steel container filled with steel balls into which crushed ore is fed. The ball mill is rotated causing the balls themselves to cascade, which in turn grinds the ore.
beneficiation	Physical treatment of crude ore to improve its quality for some specific purpose. Also called mineral processing.
Bond work index (BWi); Bond ball mill work index	A measure of the energy required to break an ore to a nominal product size, determined in laboratory testing, and used to calculate the required power in a grinding circuit design.
comminution/crushing/grinding	Crushing and/or grinding of ore by impact and abrasion. Usually, the word "crushing" is used for dry methods and "grinding" for wet methods. Also, "crushing" usually denotes reducing the size of coarse rock while "grinding" usually refers to the reduction of the fine sizes.
concentrate	The concentrate is the valuable product from mineral processing, as opposed to the tailing, which contains the waste minerals. The concentrate represents a smaller volume than the original ore
data verification	The process of confirming that data has been generated with proper procedures, has been accurately transcribed from the original source and is suitable to be used for mineral resource and mineral reserve estimation
density	The mass per unit volume of a substance, commonly expressed in grams/ cubic centimeter.
diabase	US terminology for an intrusive rock whose main components are labradorite and pyroxene, and characterized by an ophiolitic texture. Corresponds to a diorite.

Term	Definition
dilution	Waste of low-grade rock which is unavoidably removed along with the ore in the mining process.
discounted cash flow (DCF)	Concept of relating future cash inflows and outflows over the life of a project or operation to a common base value thereby allowing more validity to comparison of projects with different durations and rates of cash flow.
easement	Areas of land owned by the property owner, but in which other parties, such as utility companies, may have limited rights granted for a specific purpose.
encumbrance	An interest or partial right in real property which diminished the value of ownership, but does not prevent the transfer of ownership. Mortgages, taxes and judgements are encumbrances known as liens. Restrictions, easements, and reservations are also encumbrances, although not liens.
feasibility study	A feasibility study is a comprehensive technical and economic study of the selected development option for a mineral project, which includes detailed assessments of all applicable modifying factors, as defined by this section, together with any other relevant operational factors, and detailed financial analysis that are necessary to demonstrate, at the time of reporting, that extraction is economically viable. The results of the study may serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. A feasibility study is more comprehensive, and with a higher degree of accuracy, than a pre-feasibility study. It must contain mining, infrastructure, and process designs completed with sufficient rigor to serve as the basis for an investment decision or to support project financing.
flotation	Separation of minerals based on the interfacial chemistry of the mineral particles in solution. Reagents are added to the ore slurry to render the surface of selected minerals hydrophobic. Air bubbles are introduced to which the hydrophobic minerals attach. The selected minerals are levitated to the top of the flotation machine by their attachment to the bubbles and into a froth product, called the "flotation concentrate." If this froth carries more than one mineral as a designated main constituent, it is called a "bulk float". If it is selective to one constituent of the ore, where more than one will be floated, it is a "differential" float.
flowsheet	The sequence of operations, step by step, by which ore is treated in a milling, concentration, or smelting process.
gangue	The fraction of ore rejected as tailing in a separating process. It is usually the valueless portion, but may have some secondary commercial use
greenschist facies	one of the major divisions of the mineral facies classification of metamorphic rocks, the rocks of which formed under the lowest temperature and pressure conditions usually produced by regional metamorphism. Temperatures between 300 and 450 °C (570 and 840 °F) and pressures of 1 to 4 kilobars are typical. The more common minerals found in such rocks include quartz, orthoclase, muscovite, chlorite, serpentine, talc, and epidote
high pressure grinding rolls (HPGR)	A type of crushing machine consisting of two large studded rolls that rotate inwards and apply a high pressure compressive force to break rocks.
indicated mineral resource	An indicated mineral resource is that part of a mineral resource for which quantity and grade or quality are estimated on the basis of adequate geological evidence and sampling. The term adequate geological evidence means evidence that is sufficient to establish geological and grade or quality continuity with reasonable certainty. The level of geological certainty associated with an indicated mineral

Term	Definition
	resource is sufficient to allow a qualified person to apply modifying factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.
inferred mineral resource	An inferred mineral resource is that part of a mineral resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. The term limited geological evidence means evidence that is only sufficient to establish that geological and grade or quality continuity is more likely than not. The level of geological uncertainty associated with an inferred mineral resource is too high to apply relevant technical and economic factors likely to influence the prospects of economic extraction in a manner useful for evaluation of economic viability. A qualified person must have a reasonable expectation that the majority of inferred mineral resources could be upgraded to indicated or measured mineral resources with continued exploration; and should be able to defend the basis of this expectation before his or her peers.
initial assessment	An initial assessment is a preliminary technical and economic study of the economic potential of all or parts of mineralization to support the disclosure of mineral resources. The initial assessment must be prepared by a qualified person and must include appropriate assessments of reasonably assumed technical and economic factors, together with any other relevant operational factors, that are necessary to demonstrate at the time of reporting that there are reasonable prospects for economic extraction. An initial assessment is required for disclosure of mineral resources but cannot be used as the basis for disclosure of mineral reserves
internal rate of return (IRR)	The rate of return at which the Net Present Value of a project is zero; the rate at which the present value of cash inflows is equal to the present value of the cash outflows.
life of mine (LOM)	Number of years that the operation is planning to mine and treat ore, and is taken from the current mine plan based on the current evaluation of ore reserves.
locked cycle flotation test	A standard laboratory flotation test where certain intermediate streams are recycled into previous separation stages and the test is repeated across a number of cycles. This test provides a more realistic prediction of the overall recovery and concentrate grade that would be achieved in an actual flotation circuit, compared with a more simple batch flotation test.
measured mineral resource	A measured mineral resource is that part of a mineral resource for which quantity and grade or quality are estimated on the basis of conclusive geological evidence and sampling. The term conclusive geological evidence means evidence that is sufficient to test and confirm geological and grade or quality continuity. The level of geological certainty associated with a measured mineral resource is sufficient to allow a qualified person to apply modifying factors, as defined in this section, in sufficient detail to support detailed mine planning and final evaluation of the economic viability of the deposit.
mill	Includes any ore mill, sampling works, concentration, and any crushing, grinding, or screening plant used at, and in connection with, an excavation or mine.
mineral reserve	A mineral reserve is an estimate of tonnage and grade or quality of indicated and measured mineral resources that, in the opinion of the qualified person, can be the basis of an economically viable project. More specifically, it is the economically mineable part of a measured or indicated mineral resource, which includes diluting

Term	Definition
	materials and allowances for losses that may occur when the material is mined or extracted. The determination that part of a measured or indicated mineral resource is economically mineable must be based on a preliminary feasibility (pre-feasibility) or feasibility study, as defined by this section, conducted by a qualified person applying the modifying factors to indicated or measured mineral resources. Such study must demonstrate that, at the time of reporting, extraction of the mineral reserve is economically viable under reasonable investment and market assumptions. The study must establish a life of mine plan that is technically achievable and economically viable, which will be the basis of determining the mineral reserve. The term economically viable means that the qualified person has determined, using a discounted cash flow analysis, or has otherwise analytically determined, that extraction of the mineral reserve is economically viable under reasonable investment and market assumptions. The term investment and market assumptions includes all assumptions made about the prices, exchange rates, interest and discount rates, sales volumes, and costs that are necessary to determine the economic viability of the mineral reserves. The qualified person must use a price for each commodity that provides a reasonable basis for establishing that the project is economically viable.
mineral resource	A mineral resource is a concentration or occurrence of material of economic interest in or on the Earth's crust in such form, grade or quality, and quantity that there are reasonable prospects for economic extraction. The term material of economic interest includes mineralization, including dumps and tailings, mineral brines, and other resources extracted on or within the earth's crust. It does not include oil and gas resources, gases (e.g., helium and carbon dioxide), geothermal fields, and water. When determining the existence of a mineral resource, a qualified person, as defined by this section, must be able to estimate or interpret the location, quantity, grade or quality continuity, and other geological characteristics of the mineral resource from specific geological evidence and knowledge, including sampling; and conclude that there are reasonable prospects for economic extraction of the mineral resource based on an initial assessment, as defined in this section, that he or she conducts by qualitatively applying relevant technical and economic factors likely to influence the prospect of economic extraction.
net present value (NPV)	The present value of the difference between the future cash flows associated with a project and the investment required for acquiring the project. Aggregate of future net cash flows discounted back to a common base date, usually the present. NPV is an indicator of how much value an investment or project adds to a company.
open pit	A mine that is entirely on the surface. Also referred to as open-cut or open-cast mine.
plant	A group of buildings, and especially to their contained equipment, in which a process or function is carried out; on a mine it will include warehouses, hoisting equipment, compressors, repair shops, offices, mill or concentrator.
potassic alteration	A relatively high temperature type of alteration which results from potassium enrichment. Characterized by biotite, K-feldspar, adularia.
preliminary feasibility study, pre-feasibility study	A preliminary feasibility study (prefeasibility study) is a comprehensive study of a range of options for the technical and economic viability of a mineral project that has advanced to a stage where a qualified person has determined (in the case of

Term	Definition
	underground mining) a preferred mining method, or (in the case of surface mining) a pit configuration, and in all cases has determined an effective method of mineral processing and an effective plan to sell the product. A pre-feasibility study includes a financial analysis based on reasonable assumptions, based on appropriate testing, about the modifying factors and the evaluation of any other relevant factors that are sufficient for a qualified person to determine if all or part of the indicated and measured mineral resources may be converted to mineral reserves at the time of reporting. The financial analysis must have the level of detail necessary to demonstrate, at the time of reporting, that extraction is economically viable
probable mineral reserve	A probable mineral reserve is the economically mineable part of an indicated and, in some cases, a measured mineral resource. For a probable mineral reserve, the qualified person's confidence in the results obtained from the application of the modifying factors and in the estimates of tonnage and grade or quality is lower than what is sufficient for a classification as a proven mineral reserve, but is still sufficient to demonstrate that, at the time of reporting, extraction of the mineral reserve is economically viable under reasonable investment and market assumptions. The lower level of confidence is due to higher geologic uncertainty when the qualified person converts an indicated mineral resource to a probable reserve or higher risk in the results of the application of modifying factors at the time when the qualified person converts a measured mineral resource to a probable mineral reserve. A qualified person must classify a measured mineral resource as a probable mineral reserve when his or her confidence in the results obtained from the application of the modifying factors to the measured mineral resource is lower than what is sufficient for a proven mineral reserve.
proven mineral reserve	A proven mineral reserve is the economically mineable part of a measured mineral resource. For a proven mineral reserve, the qualified person has a high degree of confidence in the results obtained from the application of the modifying factors and in the estimates of tonnage and grade or quality. A proven mineral reserve can only result from conversion of a measured mineral resource.
qualified person	A qualified person is an individual who is a mineral industry professional with at least five years of relevant experience in the type of mineralization and type of deposit under consideration and in the specific type of activity that person is undertaking on behalf of the registrant; and an eligible member or licensee in good standing of a recognized professional organization at the time the technical report is prepared. For an organization to be a recognized professional organization, it must: (A) Be either: (1) An organization recognized within the mining industry as a reputable professional association, or (2) A board authorized by U.S. federal, state or foreign statute to regulate professionals in the mining, geoscience or related field; (B) Admit eligible members primarily on the basis of their academic qualifications and experience. (C) Establish and require compliance with professional standards of competence and ethics; (D) Require or encourage continuing professional development; (E) Have and apply disciplinary powers, including the power to suspend or expel a member regardless of where the member practices or resides; and;

Term	Definition
	(F) Provide a public list of members in good standing.
reclamation	The restoration of a site after mining or exploration activity is completed.
refining	A high temperature process in which impure metal is reacted with flux to reduce the impurities. The metal is collected in a molten layer and the impurities in a slag layer. Refining results in the production of a marketable material.
rock quality designation (RQD)	A measure of the competency of a rock, determined by the number of fractures in a given length of drill core. For example, a friable ore will have many fractures and a low RQD.
royalty	An amount of money paid at regular intervals by the lessee or operator of an exploration or mining property to the owner of the ground. Generally based on a specific amount per tonne or a percentage of the total production or profits. Also, the fee paid for the right to use a patented process.
run-of-mine	A term used to describe ore of average grade for the deposit.
semi-autogenous grinding (SAG)	A method of grinding rock into fine powder whereby the grinding media consists of larger chunks of rocks and steel balls.
specific gravity	The weight of a substance compared with the weight of an equal volume of pure water at 4°C.
strike length	The horizontal distance along the long axis of a structural surface, rock unit, mineral deposit or geochemical anomaly.
tailings	Material rejected from a mill after the recoverable valuable minerals have been extracted.

25 RELIANCE ON INFORMATION PROVIDED BY THE REGISTRANT

25.1 INTRODUCTION

The QPs fully relied on the registrant in the areas noted in the following sub-sections. As the operations have been in production for about 10 years, the registrant has considerable experience in this area.

The QPs took undertook checks to confirm that the information provided by the registrant was suitable to be used in the Report.

25.2 MACROECONOMIC TRENDS

Information relating to inflation, interest rates, discount rates, and taxes was obtained from the registrant.

This information is used in the economic analysis in Chapter 19. It supports the mineral resource estimate in Chapter 11, and the mineral reserve estimate in Chapter 12.

25.3 MARKETS

Information relating to market studies/markets for product, market entry strategies, marketing and sales contracts, product valuation, product specifications, refining and treatment charges, transportation costs, agency relationships, material contracts (e.g., mining, concentrating, smelting, refining, transportation, handling, hedging arrangements, and forward sales contracts), and contract status (in place, renewals), was obtained from the registrant.

This information is used when discussing the market, commodity price and contract information in Chapter 16, and in the economic analysis in Chapter 19. It supports the mineral resource estimate in Chapter 11, and the mineral reserve estimate in Chapter 12.

25.4 LEGAL MATTERS

Information relating to the corporate ownership interest, the mineral tenure (concessions, payments to retain, obligation to meet expenditure/reporting of work conducted), surface rights, water rights (water take allowances), royalties, encumbrances, easements and rights-of-way, violations and fines, permitting requirements, and the ability to maintain and renew permits was obtained from the registrant.

This information is used in support of the property ownership information in Chapter 3, the permitting and closure discussions in Chapter 17, and the economic analysis in Chapter 19. It supports the mineral resource estimate in Chapter 11, and the mineral reserve estimate in Chapter 12.

25.5 ENVIRONMENTAL MATTERS

Information relating to baseline and supporting studies for environmental permitting, environmental permitting and monitoring requirements, ability to maintain and renew permits, emissions controls, closure planning, closure and reclamation bonding and bonding requirements, sustainability accommodations, and monitoring for and compliance with requirements relating to protected areas and protected species was obtained from the registrant.

This information is used when discussing property ownership information in Chapter 3, the permitting and closure discussions in Chapter 17, and the economic analysis in Chapter 19. It supports the mineral resource estimate in Chapter 11, and the mineral reserve estimate in Chapter 12.

25.6 STAKEHOLDER ACCOMMODATIONS

Information relating to social and stakeholder baseline and supporting studies, hiring and training policies for workforce from local communities, partnerships with stakeholders (including national, regional, and state mining associations; trade organizations; fishing organizations; state and local chambers of commerce; economic development organizations; non-government organizations; and, state and federal governments), and the community relations plan was obtained from the registrant.

This information is used in the social and community discussions in Chapter 17, and the economic analysis in Chapter 19. It supports the mineral resource estimate in Chapter 11, and the mineral reserve estimate in Chapter 12.

25.7 GOVERNMENTAL FACTORS

Information relating to taxation and royalty considerations at the Project level, monitoring requirements and monitoring frequency, bonding requirements, and violations and fines was obtained from the registrant.

This information is used in the discussion on royalties and property encumbrances in Chapter 3, the monitoring, permitting and closure discussions in Chapter 17, and the economic analysis in Chapter 19. It supports the mineral resource estimate in Chapter 11, and the mineral reserve estimate in Chapter 12.