Vazante Polymetallic Operations
Minas Gerais State, Brazil
NI 43-101 Technical Report on Operations

Prepared by:
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Prepared for:
V.M. Holding S.A.

Report Effective Date:
24 July, 2017

Project Number:
Lima P00072

CERTIFICATE OF QUALIFIED PERSON

I, William (Bill) Bagnell, P.Eng., am employed as Manager Mining with Amec Foster Wheeler Americas Limited (Amec Foster Wheeler).

This certificate applies to the technical report titled "Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations" that has an effective date of 24 July, 2017 (the "technical report").

I am a Professional Engineer in the Provinces of Manitoba and Saskatchewan (#35339, and #12147 respectively). I graduated from the Technical University of Nova Scotia in 1996 with a Bachelor of Engineering, Mining Discipline.

I have practiced continuously in my profession for 21 years. I have been directly involved in pre-feasibility and feasibility level studies for underground projects in uranium, gold, potash and diamonds. I have been involved with mine operations in coal, potash, gold, and base metals.

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I visited the Vazante Operations from December 14–15, 2016.

I am responsible for Sections 1.3, 1.13, 1.14, 1.15.1, 1.15.2, 1.17, 1.20, 1.21, 1.24 to 1.26; Sections 2.2 to 2.6; Section 3; Section 15; Sections 16.1, 16.4 to 16.9; Sections 18.1 to 18.4, 18.7 to 18.12; Sections 20.4, 20.5; Sections 21.1.1 to 21.1.3, 21.1.5 to 21.1.9, 21.2.1, 21.2.2, 21.2.4 to 21.2.7, 21.3; Sections 24.1.4, 24.1.7; Sections 25.7, 25.8, 25.10, 25.13, 25.14, 25.16; Section 26.3.3 and Section 27 of the technical report.

I am independent of V.M. Holdings S.A. as independence is described by Section 1.5 of NI 43–101.

I have had no previous involvement with the Vazante Operations.

I have read NI 43–101 and the sections of the technical report for which I am responsible have been prepared in compliance with that Instrument.

As of the effective date of the technical report, to the best of my knowledge, information and belief, the sections of the technical report for which I am responsible contain all scientific and technical information that is required to be disclosed to make those sections of the technical report not misleading.

Dated: 19 September, 2017

"Signed and sealed"

Bill Bagnell, P.Eng.

CERTIFICATE OF QUALIFIED PERSON

I, Dr. Ted Eggleston, RM SME, am employed as a Principal Geologist with AMEC E&C Services Inc. (Amec Foster Wheeler).

This certificate applies to the technical report titled "Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations" that has an effective date of 24 July, 2017 (the "technical report").

I am a Registered Member of the Society for Mining, Metallurgy and Exploration (#4115851RM) and licensed as a Professional Geologist in the States of Wyoming (PG-1830) and Georgia (PG002016). I graduated from Western State University of Colorado with a BA degree in 1976 and from the New Mexico Institute of Mining and Technology with MSc and PhD degrees in Geology in 1982 and 1987 respectively.

I have practiced my profession for 40 years during which time I have been involved in the exploration for, and estimation of, mineral resources and mineral reserves, for various mineral exploration projects and operating mines. I have explored for, provided technical assistance for, or audited lead, zinc, silver and copper deposits including Arctic Camp (Alaska), Red Dog (Alaska), Touro (Spain), and Kidd Creek (Canada). I conducted regional exploration in Alaska, Arizona, Utah, Colorado, Wyoming, and Canada.

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I visited the Vazante Operations from 17 May to 19 May, 2017.

I am responsible for Sections 1.1, 1.3 to 1.9 1.24 to 1.26; Section 2; Section 3; Section 4; Section 5; Section 6; Section 7; Section 8; Section 9; Section 10; Section 11; Section 12; Section 23; Section 24.1.1; Sections 25.1 to 25.4, 25.16; Sections 26.1, 26.2; and Section 27 of the technical report.

I am independent of V.M. Holdings S.A. as independence is described by Section 1.5 of NI 43–101.

I have had no previous involvement with the Vazante Operations.

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Dated: 19 September, 2017

"Signed and stamped"

Ted Eggleston, RM SME

CERTIFICATE OF QUALIFIED PERSON

I, Douglas Reid, P.Eng., am employed as a Principal Geologist with Amec Foster Wheeler E&C Services Inc. (Amec Foster Wheeler).

This certificate applies to the technical report titled "Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations" that has an effective date of 24 July, 2017 (the "technical report").

I am a P.Eng. registered with the Association of Professional Engineers and Geoscientists of British Columbia (23347). I graduated with a Bachelor of Science in Geological (Geophysics) Engineering from the University of Saskatchewan in 1986.

I have practiced my profession for 30 years. I have been directly involved in the development and reviewing resource models and mineral resource estimation for mineral projects in North America and Africa since 1994.

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I visited the Vazante Operations from 17 May to 19 May, 2017.

I am responsible for Sections 1.11, 1.12, 1.24 to 1.26; Sections 2.2 to 2.6; Section 3; Section 14; Sections 25.6, 25.16; Section 26.3.2 and Section 27 of the technical report.

I am independent of V.M. Holdings S.A. as independence is described by Section 1.5 of NI 43–101.

I have had no previous involvement with the Vazante Operations.

I have read NI 43–101 and the sections of the technical report for which I am responsible have been prepared in compliance with that Instrument.

As of the effective date of the technical report, to the best of my knowledge, information and belief, the sections of the technical report for which I am responsible contain all scientific and technical information that is required to be disclosed to make those sections of the technical report not misleading.

Dated: 19 September, 2017

“Signed and sealed”

Douglas Reid, P.Eng.

CERTIFICATE OF QUALIFIED PERSON

I, Hendrik Cornelis Laurens (Laurie) Reemeyer, P.Eng., am employed as a Process Consultant with Amec Foster Wheeler Americas Limited (Amec Foster Wheeler).

This certificate applies to the technical report titled "Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations" that has an effective date of 24 July, 2017 (the "technical report").

I am a Member of the Association of Professional Engineers and Geoscientists of British Columbia, (#43997), and a Fellow of the Australasian Institute of Mining and Metallurgy, (#110005). I graduated from the University of Queensland in 1993 with a Bachelor of Engineering (Minerals Process) degree, and from the University of California at Berkeley in 2010 with a Masters of Business Administration degree.

I have practiced my profession for 23 years. I have been directly involved in managing a major lead-zinc-silver concentrator at Century, Queensland, Australia, and metallurgical and financial assessment of several polymetallic mines and projects including Greens Creek, in Alaska, USA, Izok in Nunavut, Canada, and, in Australia, Rosebery in Tasmania and Dugald River in Queensland.

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I have not visited the Vazante Operations.

I am responsible for Sections 1.2, 1.10, 1.16, 1.17 1.19 to 1.26; Section 2.3, 2.6; Section 3; Section 13; Section 17; Section 18.7; Section 19; Sections 21.1.1, 21.1.2, 21.1.4, 21.1.6 to 21.1.9, 21.2.1, 21.2.3 to 21.2.7, 21.3, Section 22; Section 24.1.5; Section 24.1.9, Sections 25.5, 25.9; 25.12 to 25.16; and Section 27 of the technical report.

I am independent of V.M. Holdings S.A. as independence is described by Section 1.5 of NI 43–101.

I have had no previous involvement with the Vazante Operations.

I have read NI 43–101 and the sections of the technical report for which I am responsible have been prepared in compliance with that Instrument.

As of the effective date of the technical report, to the best of my knowledge, information and belief, the sections of the technical report for which I am responsible contain all scientific and technical information that is required to be disclosed to make those sections of the technical report not misleading.

Dated: 19 September, 2017

“Signed and sealed”

Laurie Reemeyer, P.Eng.

CERTIFICATE OF QUALIFIED PERSON

I, Dr Martin Shepley, am employed as an Associate Hydrogeologist with Amec Foster Wheeler Environment and Infrastructure, a Division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler).

This certificate applies to the technical report titled “Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations” that has an effective date of 24 July, 2017 (the “technical report”).

I am a Professional Geoscientist of the Association of Professional Geoscientists of Ontario, membership number 1878. I am also a Chartered Geologist of the Geological Society of London, UK. I graduated from the University of Edinburgh with a BSc in geology in 1987. I graduated from the University of Oxford with a DPhil in structural geology in 1993. I graduated from University College London with an MSc hydrogeology in 1994.

I have practiced my profession for 22 years. I have been directly involved in mining and mining projects since 2000 including in the UK (East Midlands coalfield, historic Derbyshire lead mines), Ontario (Detour Gold, Rainy River, Goliath), Newfoundland (Carol Lake, Voisey’s Bay), Mexico (Media Luna), Guyana (Omai) and Germany (Spremberg Kupferschliefer). I have published peer-reviewed papers on hydrogeological aspects of underground mining in the UK.

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I visited the Vazante Operations from 17 May to 19 May, 2017.

I am responsible for Sections 1.15.4, 1.24; 1.26; Sections 2.3, 2.4, 2.6; Section 3; Section 16.3; Section 24.1.3; Section 25.16; Section 26.3.1; and Section 27 of the technical report.

I am independent of V.M. Holdings S.A. as independence is described by Section 1.5 of NI 43–101.

I have had no previous involvement with the Vazante Operations.

I have read NI 43–101 and the sections of the technical report for which I am responsible have been prepared in compliance with that Instrument.

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Dated: 19 September, 2017

"Signed and sealed"

Dr Martin Shepley, P.Geo.

CERTIFICATE OF QUALIFIED PERSON

I, Peter Cepuritis, MAusIMM (CP), am employed as a Technical Director Geomechanics with Amec Foster Wheeler Perú S.A. (Amec Foster Wheeler).

This certificate applies to the technical report titled "Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations" that has an effective date of 24 July, 2017 (the "technical report").

I am a Chartered Professional (CP) and Member of The Australasian Institute of Mining and Metallurgy (MAusIMM) (#109802). I graduated from the Royal Melbourne Institute of Technology with a Bachelor of Applied Science in Applied Geology (1990), a Master of Engineering Science in Mining Geomechanics (1997) and a Doctor of Philosophy in Rock Mechanics (2010) from Curtin University.

I have practiced my profession for *27* years of practical and consulting experience in geological and mining engineering since graduation and I have been directly involved in mine geotechnical engineering components of NI 43-101 and JORC reviews, due diligence, feasibility and mine design studies and reporting since 1992*.*

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I visited the Vazante Operations from 14–16 December, 2016.

I am responsible for Sections 1.15.3; 1.24; Sections 2.3, 2.4, 2.6; Section 3; Section 16.2; Section 24.1.2; Section 25.16; and Section 27 of the technical report.

I am independent of V.M. Holdings S.A. as independence is described by Section 1.5 of NI 43–101.

I have had no previous involvement with the Vazante Operations.

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Dated: 19 September, 2017

“Signed”

Dr Peter Cepuritis, MAusIMM (CP)

CERTIFICATE OF QUALIFIED PERSON

I, Juleen Brown, MAusIMM (CP) am employed as a Manager, Environment with Amec Foster Wheeler Australia Pty Ltd (Amec Foster Wheeler).

This certificate applies to the technical report titled "Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations" that has an effective date of 24 July, 2017 (the "technical report").

I am a Chartered Professional (CP) and Member of the Australasian Institute of Mining and Metallurgy (MAusIMM) (#201809). I graduated from the University of Queensland in 1999 with a Bachelor of Engineering (Mining) degree, and from the University of Queensland in 2006 with a Masters of Environmental Management degree.

I have practiced my profession for 17 years. I have been directly involved in environmental management of mining operations, environmental input and planning into feasibility studies for mining projects, environmental and social due diligence of mining operations and projects, mine closure input and reviews, and managing large multidisciplinary Environmental and Social Impact Assessments to IFC standards. My experience includes coal and metalliferous mines in Australia, Asia-Pacific, and Ecuador.

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I have not visited the Vazante Operations.

I am responsible for Sections 1.18.1, 1.18.4 to 1.18.6, 1.24 to 1.26; Sections 2.3, 2.6; Section 3; Sections 20.1 to 20.3; Section 20.8 to 20.11, Section 24.1.8; Sections 25.11.1, 25.11.4 to 25.11.6, 25.16, Section 26.3.4 and Section 27 of the technical report.

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Dated: 19 September, 2017

"Signed"

Juleen Brown, MAusIMM (CP).

CERTIFICATE OF QUALIFIED PERSON

I, Bing Wang, Ph.D., P.Eng., am employed as a Senior Associate, Technical Advisor with Amec Foster Wheeler Environment & Infrastructure, a division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler).

This certificate applies to the technical report titled “Vazante Polymetallic Operations, Minas Gerais State, Brazil, NI 43-101 Technical Report on Operations” that has an effective date of 24 July, 2017 (the “technical report”).

I am a member of Professional Engineers Ontario (Licence No.: 90293754). I graduated from McGill University, Montreal, Canada, with Master of Engineering and Doctor of Philosophy degrees in 1984 and 1990, respectively.

I have practiced my profession for 30 years since graduation. I have been directly involved in field of geo-environmental engineering with site investigations, scoping, prefeasibility and feasibility studies, detailed design and construction for tailings and water management facilities, including geotechnical assessments and implementations for mining projects in Canada and worldwide.

As a result of my experience and qualifications, I am a Qualified Person as defined in National Instrument 43–101 *Standards of Disclosure for Mineral Projects* (NI 43–101).

I have not visited the Vazante Operations.

I am responsible for 1.18.2, 1.18.3, 1.24 to 1.26; Section 2.3, Section 2.6; Section 3; Sections 18.5, 18.6; Sections 20.6, 20.7; Section 24.1.6; Sections 25.16, 25.11.2, 25.11.3; Section 25.16 and Section 27 of the technical report.

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As of the effective date of the technical report, to the best of my knowledge, information and belief, the sections of the technical report for which I am responsible contain all scientific and technical information that is required to be disclosed to make those sections of the technical report not misleading.

Dated: 19 September, 2017

"Signed and sealed"

Dr Bing Wang, P.Eng.

IMPORTANT NOTICE

This report was prepared as National Instrument 43-101 Technical Report for V.M. Holding S.A. (Votorantim) by Amec Foster Wheeler Perú S.A. (Amec Foster Wheeler). The quality of information, conclusions, and estimates contained herein is consistent with the level of effort involved in Amec Foster Wheeler's services, based on i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this report. This report is intended for use by Votorantim subject to terms and conditions of its contract with Amec Foster Wheeler. Except for the purposed legislated under Canadian provincial and territorial securities law, any other uses of this report by any third party is at that party's sole risk.

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1.0 SUMMARY

1.1 Introduction

V.M. Holding S.A. (Votorantim) requested that Amec Foster Wheeler Perú S.A. (Amec Foster Wheeler) prepare an independent technical report (the Report) in compliance with the requirements of National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101) and Form 43–101F1 Technical Report for Votorantim on the Vazante Operations (Vazante Operations or the Project), located in Minas Gerais State in Brazil. The Vazante Operations comprise the Vazante underground zinc–lead–silver mine (the Vazante Mine) and the Extremo Norte underground zinc–lead–silver mine (the Extremo Norte Mine).

The corporate entity that conducts the mining operations is Votorantim Metais Zinco SA, an indirectly wholly-owned subsidiary of Votorantim. For the purposes of this Report, unless otherwise noted, Votorantim and Votorantim Metais Zinco SA will be referred to interchangeably as Votorantim.

1.2 Principal Outcomes

Table 1-1 summarizes the principal outcomes of the financial analysis.

Table 1-1: Principal Outcomes

Mine life (date from–to)	2018–2027	
Net revenue (US$ million over life-of-mine)	Zinc concentrate	2,468
	Lead concentrate	47
Capital cost (US$ million over life-of-mine)	195	
Operating cost estimate (life-of-mine average US$/t)	Mining	14.78
	Process	17.62
	Maintenance	13.19
	G & A	5.14
	Total	50.72
NPV@9% (US$ million)	681	

1.3 Terms of Reference

The Report was prepared to support scientific and technical disclosure on the Vazante Operations in the initial public offering by V.M. Holding S.A.

1.4 Project Setting

The Vazante Operations are located about 7 km from the municipality of Vazante, in Minas Gerais State. Access from Brasilia is via federal highway BR-040 toward

Paracatu, thence south to the city of Guarda Mor on MG-188, and to the mine site using highway LMG-706. Concentrates are trucked about 250 km to the Tres Marias smelter. The closest commercial airport is in Brasilia. The Vazante municipal airport for light aircraft is adjacent the mine site.

1.5 Mineral Tenure, Surface Rights, Water Rights, Royalties, and Agreements

Amec Foster Wheeler was provided with legal opinion that supports that Project ownership is in the name of Votorantim Metais Zinco S.A.

For the purposes of this Report, the mineral concessions have been divided into the core tenements, where the known mineral deposits are located and mining operations are occurring, and the surrounding exploration concessions. The total Project area is about 40 km long, approaches 20 km wide at the widest extent, and covers a significant strike extent of the lithologies that host mineralization at the Vazante and Extremo Norte Mines.

Votorantim holds eight mining concessions in the core area that have a total area of approximately 2,091 ha. These host the active mining operations.

Votorantim also holds 12 exploration applications (about 2,756 ha), 22 exploration authorizations (11,948 ha), one mining concession application (190 ha) and one granted mining concession (53 ha) that surround the core tenements. These total approximately 14,947 ha in addition to the core tenements.

Votorantim holds, or has acquired through negotiation, surface rights sufficient to support the current operations. Some surface rights agreements require annual payments to the owners. Three easements have been granted in support of mining activities. There are no indigenous group stakeholders that may be affected by the Vazante Operations. Where access is required for regional exploration or drilling programs, negotiations are typically conducted on an individual basis with the affected landowner. If required, judicial action can be invoked to allow surface access.

Votorantim holds seven licences for water usage for the operations, one of which is currently inactive. Votorantim confirmed that renewal applications have been lodged, where applicable, for the water licences in use.

1.6 History

Exploration conducted in the Project area to date has included geological mapping, rock, pan concentrate, stream sediment and soil sampling, airborne and ground magnetic surveys, auger drilling, and core drilling.

Mineralization was initially exploited by artisanal miners during the 1950s. Mechanized open pit mining commenced in 1969, and underground mining in 1983. The current primary ore types mined are hydrothermal zinc silicates, largely willemite (Zn_2SiO_4).

Initial mining operations exploited supergene calamine ores (a mixture of the zinc secondary minerals hemimorphite ($Zn_4(Si_2O_7)(OH)_2 \cdot H_2O$) and smithsonite ($ZnCO_3$) derived from the weathering of primary silicate ores.

1.7 Geology and Mineralization

The Vazante and Extremo Norte deposits are classified as examples of epigenetic zinc silicate deposit types.

Mineralization is hosted within a sequence of pelitic carbonate rocks belonging to the Serra do Poço Verde Formation of the Vazante Group. The major structural control is the Vazante Fault. The currently-known mineralization extends over about 12 km of strike.

Zinc silicate mineralization of the Vazante deposit is hosted in a tectonic–hydrothermal breccia zone found near the contact between the Lower Pamplona and Upper Morro do Pinheiro Members of the Serra do Poço Verde Formation. The Vazante orebody is about 7 km long, has a variable thickness, and is currently known to extend to at least 400 m depth below surface. Willemite can form as pods, veinlets, and metre-wide veins within the hydrothermal breccia and is locally fault-controlled. Mineralization typically contains willemite, dolomite, siderite, quartz, hematite, zinc-rich chlorite, barite, franklinite, and zincite, with subordinate concentrations of magnetite and apatite.

The Extremo Norte deposit is primarily hosted in the Lower Pamplona Member, or along the contact between the Lower Pamplona and Upper Morro do Pinheiro Members. Ore zones form discontinuous lenses that may be tens of metres in length and width, within tectonic–hydrothermal breccias. Breccias may range from a few, to nearly 100 m in thickness, and typically gently plunge to the south. Mineralization consists of willemite, specular hematite, and minor franklinite.

The geological setting and understanding of the mineralization setting are adequately known to support Mineral Resource estimation and mine planning.

Regional exploration potential remains in a number of areas, including the Pasto, Lages Lagoa Feia Sul, Lagoa Feia Norte, Cercado, and Olhos D'agua trends and the Boi Branco deposit.

Within the Vazante and Extremo Norte Mine areas, ongoing exploration tests for extensions to known mineralization, infilling areas where no data are currently available, and using mining knowledge and structural interpretations to identify areas where mineralization may be present both within the mine areas, and in brownfields locations close to the mines.

1.8 Drilling and Sampling

Regional core drilling on record totals 87 drill holes (about 27,135 m); there is currently no information on any regional drilling prior to 1976. There are also an additional 70 auger drill holes (691 m).

Drilling in the operations area is divided into two groups: surface drilling, also called long-term drilling; and underground drilling, also called short-term drilling. A total of 5,918 drill holes for 962,883 m have been completed at the Vazante Mine. In addition to drilling at Vazante, 130 channel samples for a total of 745.08 m were collected from underground workings. Drilling at the Extremo Norte Mine totals 884 drill holes for 199,059 m.

Exploration and production drilling operations have been performed by company personnel over the Project history, using a variety of drilling machines. Core sizes have included HQ (96 mm), NQ (75 mm) and BQ (36 mm) core diameters.

Geological logs have been completed on all core holes. Geotechnical and hydrogeological descriptions are also completed and stored in the geological database. All core is currently photographed.

The overall average core recovery for the period 2009–2016 is 93.4%.

Underground and most surface drill collar surveying has been done with total station instruments using the SAD69 datum or the Córrego Alegre Zone 23S datum. Some surface collar surveying was done with differential global positioning system (GPS) instruments. There are currently two instruments to measure downhole deviations at the mine: one Reflex Maxibor II™ and one Reflex Gyro™. Prior to that, a number instruments were used. All were considered to be industry standard instruments at the time they were used.

In some cases, drill intercepts, and thus sample lengths, are perpendicular to the mineralized bodies and the sample length will be equal to the true thickness. In most cases, however, the true thickness is less than the sample thickness because the drill holes intersect the mineralized bodies at oblique angles.

Core samples have a preferred length of 1 m but length may vary from a minimum of 0.50 m and a maximum of 1.50 m, depending on the location of lithological, alteration, mineralization, or other natural boundaries or contacts. Votorantim personnel sample 3 m above and 3 m below mineralized intervals. Sample collection and core handling are in accordance with industry standard practices. Procedures to limit potential sample losses and sampling biases are in place. Sample intervals are consistent with the type of mineralization.

Underground channel samples range from 0.5–1.5 m long, and respect lithological, alteration, mineralization, and other natural boundaries. Samples are collected with a hammer and chisel or battery-powered hammer drill, about 1.2 m above the floor of the mine working.

Prior to 2014, mine and exploration samples were analyzed at the Vazante mine laboratory on the mine site. Samples were prepared using the mine laboratory machinery. This laboratory was not accredited. ALS, an independent laboratory, has been the primary laboratory for preparation of exploration and production samples since 2014. Samples are prepared and analyzed at either of the ALS laboratories located in Vespasiano, Minas Gerais and Goiânia, Goiás. Both laboratories are ISO 9001:2008 certified, and independent of Votorantim. ALS Lima performs the sample analytical step. This laboratory is independent of Votorantim, and holds ISO 9001:2008 and ISO 17025 accreditation.

Sample preparation at the mine laboratory included weighing, drying at 100°C, and jaw crushing to a minimum of 70% minus 5 mesh, splitting the sample through a riffle splitter, pulverizing a split using a ring and puck system to 100% passing 100 mesh, then a second pulverization to 100% passing 200 mesh. Sample preparation procedures at ALS Lima consist of drying, crushing to 70% passing a 2-mm screen, secondary crushing and pulverizing to 85% passing a 75 µm screen. Sample preparation procedures at the mine laboratory and at ALS are consistent with typical industry practices and are adequate to support Mineral Resource estimation.

Prior to 2014, chemical analyses at the mine laboratory were performed using an X-ray fluorescence (XRF) technique and an atomic absorption spectroscopy (AAS) procedure for selected elements. Sample with zinc contents >6% were re-assayed with the AAS procedure.

The transition from XRF to inductively-coupled plasma (ICP) and AAS began in 2014 when analyses began to be performed at the ALS laboratory in Lima. Selected elements were analyzed via AAS, while the same elements, and others, were analyzed with ICP-atomic emission spectroscopy (AES). High-grade zinc was analyzed specifically using the volumetric method for better results. From 2015 onward, all analyses have been performed at ALS, Lima.

Sample analysis at the mine laboratory and ALS Lima is performed using standard procedures that are widely used in the industry. In both cases, analytical procedures are adequate to support Mineral Resource estimation and mine planning.

Company-wide QA/QC protocols were implemented in 2009, and have improved over time. The current program includes submission of twin, coarse and pulp duplicates, certified reference materials (CRMs), external controls, and coarse blank samples.

QC results from 2009–2013 were considered to be adequate at the time of the analyses, but a number of questions could not be satisfactorily answered so in 2014, approximately 25,000 samples were reanalyzed with proper QC procedures. The QC results are all well within normal limits. Results from 2015 and 2016 are similarly within limits. Amec Foster Wheeler considers the data to be adequately accurate and precise to support Mineral Resource estimation and mine planning.

Prior to 2015, the density was measured through the displaced volume method for all samples collected. From the second half of 2015 onwards, there was a transition to the Joly method and, due to the large number of data available, analyses were performed only on a few drill holes. The Joly method was implemented in the second half of 2015 and every 20th sample is checked by the displaced volume method. Variations of both methods are widely used in the mineral industry, and the procedures are adequate to support Mineral Resource estimation and mine planning.

Mine data are stored in a Fusion™ database. Primary original documents and logs, down-hole surveys, core photographs, and assay certificates are stored network drives. Digital copies of the database network drives are routinely backed-up.

Core boxes are transported to the core shed by personnel from the drilling company. Samples are transported by company or laboratory personnel using corporately owned vehicles. Core boxes and samples are stored in safe, controlled areas.

Chain-of-custody procedures are followed whenever samples are moved between locations, to and from the laboratory, by filling out sample submittal forms.

1.9 Data Verification

All data that are stored in the Project database are verified by Votorantim staff via software verification before final entry into the database. These routines are aimed at preventing entry of extraneous data such as incorrect lithology codes or overlapping assay intervals into the database. They are largely successful; however, these checks are not perfect and additional internal checks are made to assure that information used for Mineral Resource estimation and mine planning is as nearly correct as possible. Such checks include reviews of sample length problems, maximum and minimum grade values, negative values, detection limits and null values, drill hole surveys, sample size, gaps, overlaps, drill hole collars versus topography, co-ordinate datum, verification of mining permissions, and laboratory analysis certificates.

Three audits have been performed by independent third-parties on the Mineral Resource estimates since 2010, including SRK during 2010, Snowden during 2012, and RPA during 2014. Votorantim advised that recommendations from these external audits were taken into consideration and applied to improve the resource estimation process. Amec Foster Wheeler conducted a gap analysis in preparation for this Report. A number of recommendations in support of operational improvements were made. Votorantim advised that these recommendations were taken into consideration. As part of his 2017 site visit, the QP performed high-level reviews of the database and procedures were performed. These included reviews of sampling procedures, geological logging procedures, core drilling and core handling procedures, and QA/QC procedures.

The inspected data were considered acceptable to support Mineral Resource and Mineral Reserve estimates. Sample data collected adequately reflect the deposit dimensions, true widths of mineralization, and the style of the deposits.

1.10 Metallurgical Testwork

Metallurgical studies have been completed since plant operations began in 1969. Studies incorporated mineralogy, grinding characteristics, and flotation separation testing. Much of the testwork has been completed in the Votorantim laboratory at the Vazante Operations. Studies have been supported by universities including the Federal University of Minas Gerais (UFMG) and the University of Sao Paulo. Most studies have focused on factors affecting zinc recovery.

For all the deposits at the Vazante Operations, willemite is the predominant zinc mineral, with other zinc minerals in minor or trace quantities. The Vazante Operations produce a zinc concentrate that is elevated in silica and lower in sulphur compared with most zinc concentrates globally, as willemite contains approximately 59% Zn and 27% SiO_2. Dolomite is the dominant gangue mineral in all Vazante Mine ore types; however, the Extremo Norte Mine contains significantly higher quantities of hematite than other Vazante Operations ores.

Poor zinc recovery in some anomalous ores has been linked to the presence of other oxide zinc minerals such as franklinite and gahnite. Vazante Operations has a geometallurgical test program in place to identify such ores before processing.

Vazante Operations has also completed laboratory flotation testwork on a range of Vazante and Extremo Norte ores, focusing on the relationship between hardness, grind size, and zinc recovery. It has been established that controlling grind size below p80 150 µm is critical to maintain zinc recovery at target levels, and that recovery can be improved by reducing p80 to 100 µm.

The presence of willemite in Vazante Operations ore results in zinc concentrates that are unusually high in silica for feed to an electrolytic zinc smelter. However, the Tres Marias smelter has been configured to manage this.

Deleterious elements that need particular management in the concentrate are magnesium oxide (MgO) and fluorine.

1.11 Mineral Resource Estimation

The close-out date for the Vazante (including Sucuri Norte) and Extremo Norte databases is 27 December, 2016. A total of 631 channel samples were used for estimation with the drill hole samples.

The stratigraphy of the metasedimentary domains was used to construct a preliminary lithological model using the "stratigraphic interpolant" function within Leapfrog. A model of the hydrothermal breccia (BXD) unit was created using a combination of lithology codes and zinc grades. Mineralized envelopes, based on a 5% zinc cut-off, were constructed using Leapfrog's "vein interpolant" function. A low-grade (Zn <5%) domain or buffer zone was created proximal to the mineralized domain; however, the buffer zone was not used for estimation.

Linear regression equations were used to make a correlation between the sum of zinc plus lead plus iron grades, compared to measured density values. The regression formula was applied to the resource model blocks based on estimated grades to determine a density value for each block.

One metre composites were created for both deposits, based on the most common sampling interval. Separate variograms for zinc, lead, iron, and silver were constructed for the Vazante and Extremo Norte domains. Metal grades were capped prior to estimation. Capping levels were based on examination of probability plots..

Ordinary kriging (OK) was selected to estimate the zinc, lead, iron, and silver grades within the block model, and the step was conducted separately for the Vazante and Extremo Norte deposits. Multi-pass kriging strategies were used in three passes, together with octants and sample constraints. A minimum of 10 and maximum of 80 samples were allowed for estimation purposes, based on a quantitative kriging neighbourhood analysis. In both Vazante and Extremo Norte, a discretization of 4 x 4 x 4 was employed.

Model validation checks included a global bias check where the OK estimate was compared to the nearest-neighbour (NN) grades at a zero cutoff, local bias checks using swath plots, change of support checks using Herco plots, and visual data inspection.

Confidence categories were assigned to blocks by Votorantim using a combination of some or all of the following: the number of available samples, drill spacing, data quality (QA/QC, density, and topography), and whether the data were supported by underground openings that had been sampled and/or mapped. The final limits for the Measured, Indicated and Inferred classifications were manually refined to remove isolated blocks of one confidence category in areas where most of the blocks were classified using another category. Kriging variance was used as reference in this post-processing to help define the limits.

Amec Foster Wheeler reviewed the classification using a confidence limits approach. Blocks were classified based on Amec Foster Wheeler's drill spacing criteria and tabulated. The resulting tabulation compared well to Votorantim's classification, thus Amec Foster Wheeler accepted the classification of Mineral Resources as determined by Votorantim. The initial Votorantim estimate was refined to remove the following blocks: mineralized pillars that must be retained for mine stability, areas of geotechnical concern, mined-out areas, and areas where information is insufficient to support block confidence classification (non-classified blocks).

To meet reasonable prospects of eventual economic extraction assumptions, only the blocks within the mineralized domain are included in the Mineral Resources. Within this domain, a NSR cut-off of US$52.12/t was applied. Other considerations included zinc price is US$2,767.00/t (US$1.26/lb), lead price is US$2,235/t (US$1.01/lb), silver price is US$18.94/oz; zinc metallurgical recovery is 86%, lead metallurgical recovery is 21%, silver metallurgical recovery is 36%; mining cost of US$14.00/t, plant cost of US$18.25/t, maintenance and other costs of US$19.87/t.

1.12 Mineral Resource Statement

Mineral Resources were initially classified using the 2012 JORC Code, and reconciled to the definitions in the 2014 Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Definition Standards for Mineral Resources and Mineral Reserves (the 2014 CIM Definition Standards).

The Qualified Person responsible for the estimate is Mr Douglas Reid, P.Eng., an Amec Foster Wheeler employee.

Mineral Resources in Table 1-2 have an effective date of 31 December, 2016 and are reported exclusive of the Mineral Resources converted to Mineral Reserves.

Factors that may affect the estimate include: additional infill and step out drilling; changes in local interpretations of mineralization geometry and continuity of mineralization zones; density and domain assignments; changes to design parameter assumptions that pertain to stope design; dilution from internal and contact sources; changes to geotechnical, hydrogeological, and metallurgical recovery assumptions; and changes to the assumptions used to generate the NSR value including long-term commodity prices and exchange rates.

Table 1-2: Mineral Resource Statement

	Tonnage (Mt)	Zn Grade (%)	Pb Grade (%)	Ag Grade (g/t)
Measured	1.8	17.81	0.43	28.82
Indicated	1.2	15.54	0.38	20.82
Total Measured + Indicated	***3.1***	***16.90***	***0.41***	***25.60***
Inferred	2.9	16.34	0.35	22.35

Notes to accompany Mineral Resource Table:

1. Mineral Resources have an effective date of 31 December 2016. Douglas Reid, P. Eng, an Amec Foster Wheeler employee, is the Qualified Person responsible for the Mineral Resource estimate.
2. Mineral Resources are reported exclusive of the Mineral Resources converted to Mineral Reserves. Mineral Resources that are not Mineral Reserves do not have demonstrated economic viability.
3. Mineral Resources are reported within a 5% Zn envelope with a US$52.12 NSR cut-off applied. The NSR is calculated as follows: if Zn(%) ≥ 2.6, NSR = 19.0653 x Zn(%); if Pb(%) ≥ 0.25, NSR = 1.8743 x Pb(%); Ag(g/t), NSR = 5.88 x Ag(g/t)/31.1035. The NSR calculations include an allocation of US$234.72/t for the zinc premium paid by the Tres Marias smelter. Zinc price used is US$2,767.00/t (US$1.26/lb), lead price is US$2,235/t (US$1.01/lb), silver price is US$18.94/oz. Zinc metallurgical recovery is 86%, lead metallurgical recovery is 21%, silver metallurgical recovery is 36%. Cost assumptions include mining cost of US$14.00/t, plant cost of US$18.25/t, maintenance and other costs of US$19.87/t.
4. Mineral Resources are stated as in situ with no consideration for planned or unplanned external mining dilution. Mineral Resources are reported on a 100% basis.
5. Rounding as required by reporting guidelines may result in apparent summation differences. Totals may not sum due to rounding

1.13 Mineral Reserve Estimation

The stope shapes developed for Mineral Reserve planning at Vazante include any internal waste material and this is included at zero grade. The stope shapes also include any Inferred Mineral Resource material at zero grade. These stope shapes are the Mineral Resource stope shapes and have not had modifying factors applied.

For the life-of-mine (LOM) reserve case, recovery is estimated at 98% of the broken ore for sub-level open stoping (SLOS) and vertical retreat (VRM) mining. Recovery of the rib pillars is estimated at 60% for mine planning purposes.

For the cut-and-fill (C&F) mining areas planned for later in the mine life, the recovery factor is also 98%. Dilution in the C&F areas is assumed to be 12%. The C&F dilution figure is based upon the historical development overbreak factor used in waste and ore development headings.

For purposes of mine planning the deposits are assumed to perform similarly in the process plant and not have adverse effects on the recovery process. Blending is not undertaken for metallurgical purposes.

The general assumption is the mine will operate at an average of 4,098 t/d for 365 days per year. This gives a nominal average production rate of 1.5 Mt/a over the

LOM (ranging from1.38–1.60 Mt). The economic cut-off value used is a net smelter return (NSR) value that is populated in the block model, and is based on a linear regression equation. For mine planning purposes, the NSR can be considered the break-even cut-off grade.

1.14 Mineral Reserve Statement

The Mineral Reserve estimates prepared by Votorantim staff, and included in Table 1-3 use the 2014 CIM Definition Standards. The QP for the Mineral Reserves estimate is William Bagnell, P.Eng., an Amec Foster Wheeler employee. Mineral Reserves are reported using a net smelter return (NSR) cut-off.

Factors that may affect the ability of the Vazante Operations to extract the Mineral Reserves safely and economically include: commodity prices and exchange rate assumptions, global markets, internal operating costs, government actions including changes to environmental, permitting, taxation and royalty regulations and laws, social licence to operate, geological unknowns, availability of skilled labor, and variations in metallurgical performance. Votorantim may also have site-specific issues due to the underground operations. including deterioration of ground conditions due to geological changes, mining-induced seismic events limiting access to mining areas, and higher than predicted groundwater or surface water inflow events.

1.15 Mining Methods

1.15.1 Mining Operations

The Vazante underground mine has been in operation since 1983, and is a fully mechanized mine using rubber tired diesel equipment for development and production activities. Access is through two portals for Vazante and one portal for Extremo Norte. As development progresses at Extremo Norte a connecting drift will be established from Vazante to Extremo Norte.

The mine has a current depth of 350 m below surface and currently is producing from six levels. Future expansion is planned below the current Level 326 horizon to expose additional mineralization for extraction. The expansion requires completion and commissioning of the EB140 pump room before extending mine workings below the existing EB297 pump room.

Two primary mining methods are employed at Vazante for extraction:

- SLOS; used where there is no continuity of the mineralization between levels
- VRM; used where the mineralization is continuous between levels.

Backfill is used in conjunction with VRM; with SLOS, the stopes are left open after mining.

Table 1-3: Mineral Reserves Statement

Classification	Tonnage (Mt)	Zn Grade (%)	Pb Grade (%)	Ag Grade (g/t)
Proven	8.68	11.11	0.30	17.52
Probable	6.34	9.61	0.28	13.73
Total Proven and Probable	***15.02***	***10.48***	***0.29***	***15.92***

Notes to accompany Mineral Reserves table:

1. Mineral Reserves have an effective date of 30 June, 2017. The Qualified Person responsible for the estimate is William Bagnell, P.Eng., an Amec Foster Wheeler employee.
2. Mineral Reserves are reported within engineered stope outlines on a 100% basis assuming three mining methods: sub-level open stoping (SLOS), vertical retreat mining (VRM) with rock backfill, and mechanized-cut-and fill (C&F) with rock backfill. Typical stope dimensions are 30 m high x 60 m long x 8 m deep. A minimum mining width of 4 m is applied to all stopes. Typical C&F rooms are 4 m x 4 m. Mineral Reserves incorporate dilution and mining recovery factors.
3. All Mineral Reserves are reported at a net smelter return (NSR) cut-off value independent of the mining method. SLOS/VRM and C&F are reported with an NSR cutoff of $52.12/t. The NSR calculations are based on head grade mill recoveries of 85.8% Zn, 20.6% Pb and 36.3% Ag. Metal prices used for the NSR calculation are: Zn: US$1.09/lb; Pb: US$0.88/lb; and Ag: US$18.94/oz. NSR calculations are based on polynomial equations for each of the concentrate elements, and incorporate considerations of sliding smelter payments that vary depending on the grade of the concentrate.
4. Totals may not sum due to rounding.

Waste from lateral and ramp development is used as backfill in the VRM stopes. Waste rock is dumped into the stopes from the overcut drifts to provide support to the hanging wall and reduce dilution of subsequent mining lifts. Between stopes, a 10 m rib pillar is left to prevent backfill dilution of adjacent stopes, and sill pillars are left every 60 m of mining height to prevent backfill dilution from mining blocks extracted from higher mine levels.

Grade control in accomplished using the block model, stope reserve grade developed by the short-range planners, face calls, and production sampling.

Ore is hauled to surface with 28 t haul trucks via ramps, and is stored in surface stockpiles at the portals for later re-handle. Ore is delivered to the concentrator with a surface haul truck fleet.

Vazante is a trackless operation utilizing a diesel-powered mobile equipment fleet. The selected equipment is sized to meet the mine production targets for material movement with the calculated cycles and productivities. The current mine haulage fleet, and stope mucking and development waste mucking equipment are split between the Vazante and Extremo Norte Mines. The fleets are not restricted to the currently-assigned mines and can be moved between sites as operational requirements dictate. An opportunity exists to reduce the fleet through better utilization of existing equipment. Votorantim is currently undertaking a study to address the equipment usage.

1.15.2 Ventilation

Mine ventilation at Vazante is designed to comply with Brazilian National Regulation 22, and uses a push-pull system. Fresh air is obtained for the Vazante Mine via two ramps and a shaft; for Extremo Norte, fresh air is obtained through a ramp. Exhaust air at both mines is vented through raises.

The Vazante Mine ventilation infrastructure will be expanded starting in 2018 to support additional mining faces. Ventilation infrastructure for Extremo Norte Mine will begin expansion in 2020 to support additional mining faces.

1.15.3 Geotechnical Considerations

The methodology for developing stope design parameters, such as level intervals, stope strike spans, pillar widths, etc. is based on empirical methods. Significant unplanned dilution (up to 150%) has occurred as a result of the combination of the vertical retreat and long hole stoping methods, and is a major economic factor for the mine.

1.15.4 Hydrogeological Considerations

There is a well-documented conceptual model of the hydrogeological system where the geological strata have been classified according to their water-bearing capacity. This comprises the identification of the highly water-transmissive karstic dolomitic aquifers and formations with limited ability to transmit water (aquitards/aquicludes). The conceptual model has provided the basis for the development of a groundwater flow model of the Vazante mine site.

The Vazante Mine has a large historical data set of hydrometric data that covers mine development, and supports the development and improvement of the present hydrogeological conceptual model, and is used to calibrate the FEFLOW groundwater model. Presently the FEFLOW groundwater model is well calibrated to flows, with the 2016 calibration simulating 10,800 m^3/hr total average mine water pumping compared to a 2016 measured average of about 10,600 m^3/hr (2% difference).

The present pumping system for the Vazante Mine has a reported pumping capacity of 15,650 m^3/hr (375,600 m^3/day) comprising two pumping stations located at the lowest elevation of the present mine. Mine water is collected through galleries within the mine and pumped to surface from the mine sump elevation. A new underground pumping station, due to be operational in 2019, is currently being constructed. This station will increase the pumping capacity to a total of approximately 19,000 m^3/hr (456,000 m^3/d). Pumping from the Extremo Norte Mine started in November 2016 and has averaged 160 m^3/hr since then, with a maximum daily average pumping rate of 220 m^3/hr based on Votorantim data up to the end of April, 2017.

Votorantim has recorded pumped mine water quantities and rainfall in detail during operation of the mine. Infiltration rates of rainfall on karstic aquifers are high, and consequently there is a seasonality in mine water pumping, with very high pumping rates during and immediately after peak rainfall events. The recent long-term average pumping rate (July 2013–June 2016) is approximately 10,500 m^3/hr; however, recently recorded maxima of the daily average pumping rate have exceeded this by up to almost 50%. There is a degree of uncertainty associated with relying on historic records to predict frequency and magnitude of severe rainfall events and associated peak mine water pumping.

There is a well-documented history of doline/sinkhole development with water table drawdown as the mine has developed. Up to April 2017, Votorantim had recorded over 2,000 such features.

1.16 Recovery Methods

Vazante is the largest zinc mine in Brazil, processing about 1.5 Mt of ore annually grading an average of about 11.3 wt% Zn to produce about 135,000 t of zinc metal contained in willemite and bulk sulphide concentrates.

Processing is conducted in two adjacent plants (C and W) based on crushing, grinding and flotation with some interconnected concentrate handling systems. The main differences between the flowsheets for the plants is that Plant W incorporates a sulphide flotation stage for recovery of a lead–silver concentrate. Both plant flowsheets include crushing, grinding and willemite flotation. Willemite concentrate is filtered for transport to the smelter, and combined Plant W and Plant C tailings are thickened prior to disposal in the tailings storage facility (TSF). The production plan excludes treatment of calamine mineralization.

Plant W is a modern plant and processes about 80% of the total tonnage of higher-grade willemite ore produced by the mine through an initial bulk sulphide flotation circuit and willemite flotation circuits. The sulphide circuit produces a lead–silver sulphide concentrate that is elevated in zinc. Zinc production in the sulphide circuit accounts for <1% of total zinc production. Zinc provides the primary revenue, while lead, silver and zinc recovered in the bulk sulphide concentrate provide a minor by-product credit. Plant W was commissioned in 2003, and the sulphide circuit was added in 2012.

Plant C is an older plant that was historically used for the treatment of calamine ore, and was subsequently converted to treat willemite ore. It has, until recently, treated about 20% of the total Vazante processed tonnage. The feed in 2016 consisted of a mix of lower-grade willemite ore and a low-grade zinc oxide/willemite stockpile generated by a previous historical mining and processing operation as a dense medium float discard material (float material). Processing of the float material was suspended in January 2017, and is not included in the life-of-mine mill production plan.

Prior to 2012, there were no process facilities to recover a separate lead–silver concentrate, and these metals were discarded in tailings. After completion of the sulphide flotation circuit in late 2012, Plant W ground ore was processed for lead and silver recovery. Currently, the sulphide circuit is not operated continuously, rather in campaigns determined when an economic and saleable lead–silver concentrate can be produced. In 2016, the sulphide circuit operated with approximately 70% availability, compared with an overall 96% availability for Plant W. The Plant W lead recovery while the sulphide circuit was operating was 37%. Lead and silver in the feed to Plant C are not recovered into the lead–silver concentrate. Therefore, the overall combined lead recovery with respect to combined Vazante mill feed was 21% in 2016.

To support incremental mine production increases, it is planned to install a Vertimill, which is due to be commissioned in late 2019. This will increase Plant W capacity to 153 t/h while reducing grind size from p80 140 µm to 100 µm. The finer grind size would potentially increase zinc recovery; however, it is possible that there will be some bottlenecks and inefficiencies in the Plant W zinc flotation circuit due to increased volumetric flow. Therefore, current zinc recovery estimates of 85.9% are assumed to continue after Vertimill installation. If the scoping and subsequent studies of zinc flotation capacity improvements are successful, Votorantim may be able to improve zinc recovery in the future.

Votorantim reported that the combined Vazante Operations milling facilities drew approximately 43 kWh/t milled, or 7.2 MW in 2016. Power consumption will increase by 2020 in conjunction with the commissioning of the Vertimill and tailings filtration circuits.

The main reagents consumed include grinding media for ball mills, sulphide collector, sulphide dispersant, frother, willemite activator, pH modifier, willemite dispersant, willemite amine collector, and flocculant.

Zinc concentrates are trucked in bulk approximately 250 km to Votorantim's Tres Marias smelter. Lead–silver concentrates are trucked approximately 900 km to the Port of Itaguai, and sold to the Mitsui Hachinohe smelter in Japan.

1.17 Project Infrastructure

All infrastructure required for the current mining and processing operations has been constructed and is operational. This includes the underground mines, access roads, powerlines, water pipelines, offices and warehouses, process plant/concentrator, conveyor systems, waste rock facilities, temporary ore stockpiles, paste-fill plants, and tailings storage facilities.

The incremental mill expansion planned will require installation of a Vertimill and a new pack of hydrocyclones in the process plant.

Electrical power for the mine site is supplied from the state grid. Two independent 138 kV transmission lines feed the site which can provide up to 55 MW. An additional 60 MW power transmission line is currently under development and will be completed by 2020. Two diesel generators can provide backup power in case of power failure.

The mines are situated about 7 km from the municipality of Vazante, and accessed via paved roads. Internal roadways connect the various mine-site components.

1.18 Environmental, Permitting and Social Considerations

1.18.1 Environmental Considerations

Compilation of the results from monitoring programs, research studies, and public data was completed in 2017 for climate, air quality, noise, hydrology, groundwater, water quality, seismicity, biology, and social setting.

Environmental licensure requires a number of on-going monitoring programs. Votorantim provided documentation that supported that the required 2016 monitoring and reporting was completed, and the reports sent to the relevant regulatory authorities.

1.18.2 Tailings Storage Facility

The Vazante Operations currently dispose tailings produced by the process plant in the Aroeira Tailings Storage Facility (TSF). The TSF has the dual purpose of capturing water for use in the process plant. The estimated life of the TSF is forecast until the end of 2020, at which point the operation is planning to filter and stack tailings in the Pilha Garrote dry stack facility that will be constructed to the west of the TSF. The Aroeira dam will remain in operation after this time as the water storage dam for water supply to the process plant.

Embankment construction for the Aroeira TSF commenced in 1999. The dam has undergone eight raises, the first three using compacted earth fill and the remaining carried out with compacted cyclone underflow tailings. The final embankment elevation of 626 m was reached in 2014.

Monitoring of instrumentation installed in the dam is carried out by Votorantim personnel and an external consultant (Geoconsultoria) and cross-checked by Ausenco Peru.

Other structures present at the Vazante Operations include the “Old Dam” (Antiga) and Reservoir modules I, II and III. Of these structures, module III is currently the only one in operation, and is used as a sedimentation dam and reservoir for water supply when the Aroeira TSF undergoes maintenance.

The Pilha Garrote dry stack facility is projected to commence construction in July 2018, be operational by about 2020–2021, and continue to 2026. The tailings plant will consist of cyclones, screens, thickening and filtering. Dewatered tailings will consist of a blend of screened cyclone underflow and filtered cyclone overflow. Water recovered at the filter plant and from the thickener overflow will be piped to the Aroeira TSF. A monitoring plan for the life of the Pilha Garrote dry stack facility has been developed. The tailings deposit will undergo progressive reclamation, with the potential to commence reclamation early in the facility lifecycle.

1.18.3 Water Management

Water is primarily derived from four areas: surface water, groundwater, recirculated water, and rainfall. The main water source (by annual volume for 2016) for industrial purposes is the underground mine. The Santa Catarina River is the only source for domestic purposes.

Hydraulic infrastructure such as diversion channels have been implemented to ensure hydrological stability for the mine facilities, and to divert water around the operations to natural watercourses.

1.18.4 Closure and Reclamation Planning

Four conceptual Closure Plans are approved for the Vazante Operations: Vazante Mine decommissioning plan (2008, updated in 2013), waste rock facility and decommissioning plan (2011), Extremo Norte Mine decommissioning plan (2012), and the former process plant decommissioning plan (2013).

The Closure Plans have been designed to address remediation of the operational areas, and to meet Brazilian engineering requirements for such plans at a conceptual phase. Typically, the plans assume most facilities will be dismantled, and equipment removed from the site. Underground openings will be blocked, and groundwater levels allowed to stabilize. The host lithologies and mineralization style are not expected to result in metals leaching. The plans assume revegetation and surface drainage control measures will be conducted. Post-closure monitoring will be implemented for about five years after closure and will include the following: fauna; revegetation; geotechnical and water quality.

Associated costs are reported in the dollar values at the time the estimate was completed:

- Vazante Mine decommissioning plan: The total closure costs are estimated to be approximately US$23.3 million, to be expended in or about 2026

- Waste rock facility rehabilitation plan: Rehabilitation was assumed, in 2011, to require a budget of about US$230,000
- Extremo Norte Mine decommissioning plan: The total closure costs are estimated to be approximately US$15.1 million, to be expended in or about 2024
- Former process plant decommissioning plan: The total closure costs are estimated to be approximately US$1.7 million, to be expended in or about 2021.

1.18.5 Permitting Considerations

Operations must adhere to specific federal, state, and local regulations and requirements. The mine holds a number of current permits in support of the current operations. Compliance with permitting is monitored via semi-annual evaluations carried out by consulting companies, and annual audits.

1.18.6 Social Considerations

Votorantim developed a Socioeconomic Characterization Plan that outlines the social commitments and responsibilities that Votorantim will undertake toward the municipality of Vazante. From 2011 to 2016, Votorantim has expended US$91 million in social projects, ranging from community cinema initiatives to improvements in public education. The largest program, the “network for sustainable development” or ReDes, aims to support local businesses and develop new business initiatives.

1.19 Markets and Contracts

Vazante and Extremo Norte are operating mines with concentrate sales contracts in place. As a result, market studies are not relevant to the operation. All zinc concentrates produced by the Vazante Operations process plant are transported to, and treated through Votorantim’s Tres Marias smelter. The concentrate from the Vazante Operations makes up approximately 70% of the feed to the smelter, with an additional 13% sulphide concentrates from Votorantim’s Morro Agudo Mine, and 17% imported sulphide concentrates.

The Tres Marias smelter has a long history of treating zinc carbonate and silicate concentrates from the Vazante Operations. Due to the low zinc and high silica grades of the zinc concentrate, the terms for selling onto world custom concentrate markets would be much less favourable than for typical zinc sulphide concentrates. This highlights the importance of Tres Marias as the customer of Vazante Operations concentrate.

Lead-–silver concentrates are sold to the Mitsui Hachinohe smelter in Japan, which has a contract in place with Votorantim. The smelter uses the Imperial Smelting Furnace (ISF) process, which allows it to recover and pay for a portion of zinc in the concentrate. Treatment charges for lead–silver concentrates reflect recent forecasts from Wood Mackenzie. Over the last 15 years, there has been significant closures of smelters using ISF technologies, which could limit alternative marketing of the lead concentrate should the Hachinohe smelter close.

1.20 Capital Cost Estimates

Votorantim has prepared a major projects capital schedule including expansion and modernization projects; safety, health, and environment; and sustaining capital projects from 2017 to 2022. A cost summary of the major projects capital is provided in Table 1-4.

There is an allocation for sustaining capital post 2022 of US$27.5 million (2023–2027).

1.21 Operating Cost Estimates

Operating costs were developed in Brazilian Real, and separated into variable and fixed components. A cost summary is provided in Table 1-5.

1.22 Economic Analysis

The results of the economic analyses discussed in this section represent forward-looking information as defined under Canadian securities law. The results depend on inputs that are subject to a number of known and unknown risks, uncertainties and other factors that may cause actual results to differ materially from those presented here. Information that is forward-looking includes:

- Mineral Resource and Mineral Reserve estimates
- Assumed commodity prices and exchange rates
- The proposed mine production plan
- Projected mining and process recovery rates
- Sustaining costs and proposed operating costs
- Assumptions as to closure costs and closure requirements
- Assumptions as to environmental, permitting and social risks.

Additional risks to the forward-looking information include:

- Changes to costs of production from what is assumed
- Unrecognized environmental risks
- Unanticipated reclamation expenses

Table 1-4: Major Projects Capital Cost Summary (US$ million)

Year	2018	2019	2020	2021	2022
Expansion and modernization	60.1	33.2	17.1	4.2	1.5
Safety, health and environment	15.6	5.7	0.0	0.0	0.0
Sustaining capital	5.1	1.9	7.9	7.9	7.9
Total capital	***80.8***	***40.8***	***25.0***	***12.0***	***9.3***

Table 1-5: Operating Cost Summary (US$ million)

Cost category	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Total variable- mine and mill	30.6	31.8	37.1	39.0	39.5	40.4	40.8	41.3	39.8	24.4	365
Total fixed - mine and mill	32.6	33.0	33.6	33.5	33.5	33.5	33.5	33.5	33.5	19.0	319
Total fixed - G & A	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	44
Total Costs	***67.6***	***69.2***	***75.1***	***76.9***	***77.3***	***78.2***	***78.6***	***79.1***	***77.7***	***47.8***	***728***

- Unexpected variations in quantity of mineralised material, grade, or recovery rates
- Geotechnical and hydrogeological considerations during mining being different from what was assumed
- Failure of plant, equipment, or processes to operate as anticipated
- Accidents, labour disputes and other risks of the mining industry.

The financial model that supports the Mineral Reserve declaration is a stand-alone model on a 100% basis which calculates annual cash flows based on scheduled ore production, assumed processing recoveries, metal sale prices, projected operating and capital costs, and estimated taxes.

The gross LOM revenue for Vazante Operations is US$ 3,272 million, of which zinc contributes a gross LOM revenue of US$3,213 million. The net LOM revenue is US$2,515 million. Zinc concentrate makes up over 98% of the net revenue for the Vazante Operations. Mill production, which results in 1.28 Mt of recovered zinc of concentrate delivered to the smelter. Vazante Operations generates an NPV at 9% of US$680 million over the LOM. Substantial free cash flow is generated in every year of mine life.

Given that the mine is generating an immediate positive cash flow, payback period and IRR calculations are not relevant. Over the LOM, the Vazante Operations is assumed to pay US$13 million of CFEM (Brazilian royalty payment), and US$516 million of income tax.

1.23 Sensitivity Analysis

The sensitivity of NPV was determined against metal prices (all metals), head grade (all metals), site operating costs, offsite costs (conversion, treatment and refining charges, transport costs), and capital costs.

NPV is most sensitive to changes in metal prices, then head grade. NPV is relatively insensitive to capital costs, as remaining capital requirements are comparatively low.

If the Tres Marias smelter was unable to transfer the zinc metal premium to the mine, and assuming all other parameters remained unchanged, NPV would drop to US$557 million, similar to the effect of a 10% reduction in metal prices.

1.24 Risks and Opportunities

A summary of the key opportunities and risks identified by the QPs is provided in Table 1-6.

1.25 Interpretation and Conclusions

Under the assumptions in this Report, the Vazante Operations show a positive cash flow over the life-of-mine and support Mineral Reserves. The mine plan is achievable under the set of assumptions and parameters presented.

1.26 Recommendations

Recommendations have been broken into two phases. The Phase 1 recommendations are made in relation to exploration activities. Recommendations proposed in Phase 2 are suggestions for improvements in current operating procedures, and the program is not contingent on the results of Phase 1 work.

The Phase 1 recommendations are made in relation to exploration activities, and include drilling, geological mapping, and geochemical and geophysical surveys. The total cost for the Phase 1 work is about US$25 million, of which about US$3.8 M/a will be spent on mine area exploration, and about US$2.5 M/a would be expended on regional exploration.

Phase 2 is estimated at US$2.8 million to US$3 million. Work suggested includes: formalizing annual updates of the FEFLOW groundwater model; assess groundwater rebound on mine closure and impact on surface water; review of the hydrometric monitoring network; commission independent third-party reviews of the FEFLOW groundwater model; implement a formal, documented, reconciliation process; study how best to reduce mining dilution rates; review findings from the 2016 environmental and permitting audit; update closure planning and closure cost estimates.

Table 1-6: Risk and Opportunity Summary

Discipline	Opportunity	Risks
Geology and exploration	Continued exploration activities in the mine area, such as infilling areas where no data are currently available, and using mining knowledge and structural interpretations to identify areas where mineralization may be present, has the potential discover additional mineralization that may support Mineral Resource estimation. There are a number of regional exploration targets, that with further work, represent upside opportunity to potentially add to the resource base.	
Geotechnical	A reconciliation process to incorporate production tonnages from haulage data and post mining cavity monitor surveys has not been established that links the block model through to the stope; this should be undertaken to improve the understanding of mechanisms and sources of unplanned dilution in the dilution control plan. To reduce dilution, it is suggested that development in the hanging wall ore drives should incorporate the hanging wall contact and a partial shanty design. This allows for fan patterns of cable bolting into the hanging wall to provide additional stope support thereby reducing unplanned overbreak	The mining method combines vertical retreat and long hole stoping method (with up and down holes). Some stopes have incurred significant unplanned dilution and this is a major economic factor for the mine. It is understood that the mine is establishing a dilution control plan to manage this aspect.
Hydrogeological		Interception during mining of major structural and/or karstic features may cause sudden increases in mine water inflows, and potentially, mine flooding. Flooding from the Santa Caterina River may temporarily result in increased water flows to the mine, increased pumping requirements, and potentially, mine flooding. Estimations of pumping rates for mine planning purposes rely on calibration of the FEFLOW groundwater model to historical data. Given climate change, there is presently more uncertainty associated with relying on historic records to predict frequency and magnitude of severe rainfall events and associated peak mine water pumping. Amec Foster Wheeler considers that the risk of mine flooding during an extreme rainfall event, including any associated flooding of the Santa Catarina River, likely represents the greatest risk to mine operations from a water management perspective. There is a well-documented history of doline/sinkhole development with water table drawdown as the mine has developed. Unexpected doline development has the potential to impact surface infrastructure. The FEFLOW groundwater model may under-predict future mine water inflows, particularly during peak climatic events when inflows are likely to be much higher than the average mine water inflows presently predicted. Therefore, current and planned pumping

Discipline	Opportunity	Risks
		assumptions may not match eventual requirements. No studies have been undertaken to assess issues with groundwater rebound on cessation of pumping and mine closure. Due to changes in the groundwater heads and aquifers as a result of mining, there is potential for localized flooding to occur in the Santa Caterina River valley post-cessation of mining,
Mine plan	The mobile equipment fleet outlined in the report is the actual equipment meeting production targets at the Vazante Operations. An opportunity exists to reduce the fleet through better utilization of existing equipment. Votorantim is currently undertaking a study to address the equipment usage. If dilution can be better controlled in some of the underground stopes, there is an opportunity maximize mill recoveries from higher-grade material.	Extraction of the Mineral Reserves below the EB326 horizon is dependent upon successful development and commissioning of the EB140 pump station. Should the water inflows exceed the design pumping capacity of the pump station, these Mineral Reserves would be at risk.
Process	Zinc recovery is sensitive to grind size, and there is significant potential to improve zinc recovery by reducing grind size to approximately p80 of 100 µm. This should be achieved with the installation of the Vertimill in 2019. Following the planned capacity increases, there is an opportunity after about 2025 for the plant to be able to treat more mill feed material, should additional Mineral Resources that can support conversion to Mineral Reserves be identified. Votorantim has tested ore-sorting technologies. If successful, ore-sorting could allow mining of material that is below the current cut-off grade, which could subsequently be upgraded to feed the process plant. The benefits could include lower combined mining and process costs, and additional mill feed material and resulting metal production	Lead recovery falls at low head grades, and in general the lead recovery from Extremo Norte ores is poor. This may limit the ability to consistently produce a lead–silver concentrate. The Plant C ball mill shell has recently experienced excessive wear, which could lead to a prolonged outage and loss of approximately 20% of the total processing capacity. Vazante Operations has taken steps to complete repairs. In the event that Tres Marias was unable to process concentrates from the Vazante Operations, mine economics would be affected due to the significantly higher transport and treatment charges that would apply to an alternative customer. In addition, due to the low zinc and high silica grades of the zinc concentrate, the terms for selling onto world custom concentrate markets would be much less favourable than for typical zinc sulphide concentrates. If Tres Marias is unable to keep the current balance of different feed supplies to control chemistry and costs, then there is a risk that the zinc premium currently paid could be reduced, thereby reducing profitability of the operation.
Tailings storage facility	The planned shift of the tailings storage methodology to dry stack may be able to reduce risks in the existing wet storage facility, by reducing the amount of stored water, and proceeding to earlier closure and rehabilitation. There are also opportunities with the dry stack facility to better control the overall water balance.	
Infrastructure	The current upgrading of the site electrical power, and associated infrastructure redundancies present a future opportunity for mill feed expansion should additional Mineral Resources that can support conversion to Mineral Reserves be identified through exploration success	Decreases in rainfall may cause reservoir and river levels to decrease, impacting the ability of the hydroelectric stations to provide sufficient power to meet the mine's needs.

Discipline	Opportunity	Risks
Environmental, permitting and social		There is a risk that the final closure costs are underestimated because elements that will require closure and rehabilitation do not appear to be fully addressed in the four plans prepared to date. Sending general waste to an unlicenced facility carries a potential liability risk if pollution and seepage occur from the waste facility. Authorization from the competent environmental authorities is required prior to work being conducted that may affect Permanent Preservation Areas (APPs). There is a risk that future approvals to impact APPs may not be granted for mineral concessions where the approval process has not been completed, and this may affect planned work programs such as exploration and drilling activities.
Financial model	It is possible that Votorantim has been conservative in its forecast of plant electricity loads, and that overall site electricity use and hence costs will come in at lower levels than included in the life-of-mine plan. This could result in a modest increase in profitability.	The contingency allocation may be underestimated for the major capital projects, in particular the Vertimill and the dry stack tailings facility. Creation of new taxes, fees, and/or royalties or significant changes to the assumptions as to these in the Report will affect the cashflow estimates. Hedging is not considered in the financial evaluation, which is performed at the mine level. Votorantim has corporate hedging arrangements in place. Should a future decision be made to implement hedging at the mine level, the cashflow estimates could be affected.

2.0 INTRODUCTION

2.1 Introduction

V.M. Holding S.A. (Votorantim) requested that Amec Foster Wheeler Perú S.A. (Amec Foster Wheeler) prepare an independent technical report (the Report) in compliance with the requirements of National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101) and Form 43–101F1 Technical Report for Votorantim on the Vazante Operations (Vazante Operations or the Project), located in Minas Gerais State in Brazil. The Vazante Operations comprise the Vazante underground zinc–lead–silver mine (the Vazante Mine) and the Extremo Norte underground zinc–lead–silver mine (the Extremo Norte Mine). The Extremo Norte Mine portal is situated about 7 km north of the Vazante Mine portals.

The corporate entity that conducts the mining operations is Votorantim Metais Zinco SA, an indirectly wholly-owned subsidiary of Votorantim. For the purposes of this Report, unless otherwise noted, Votorantim and Votorantim Metais Zinco SA will be referred to interchangeably as Votorantim.

The Project location is shown in Figure 2-1. An overview of the operations is provided in Figure 2-2.

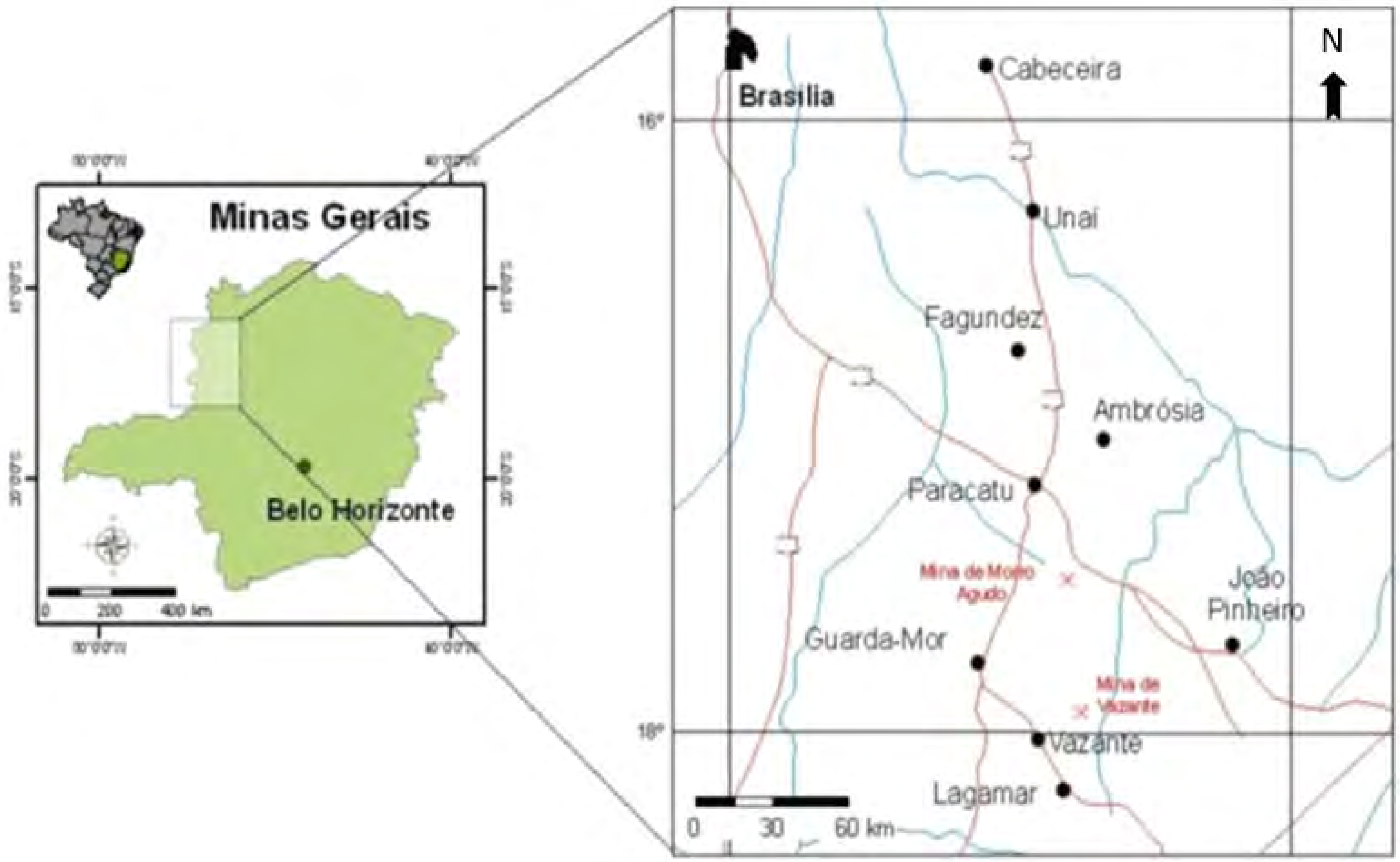
2.2 Terms of Reference

The Report was prepared to support scientific and technical disclosure on the Vazante Operations in the initial public offering by V.M. Holding S.A.

Mineral Resources and Mineral Reserves are reported in accordance with the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Definition Standards for Mineral Resources and Mineral Reserves (May 2014; the 2014 CIM Definition Standards) and the CIM Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines (November 2003; 2003 CIM Best Practice Guidelines).

All measurement units used in this Report are metric units and currency is expressed in US dollars (US$), unless stated otherwise. The Brazilian currency is the Real (BR$). The Report uses Canadian English.

Figure 2-1: Project Location Map



Note: Figure courtesy Votorantim, 2017.

Figure 2-2 General Overview, Vazante Operations Area

Note: Figure uses Google Earth backdrop. Modified by Amec Foster Wheeler, 2017

2.3 Qualified Persons

The following Amec Foster Wheeler staff serve as Qualified Persons (QPs) as defined in NI 43-101:

- Mr William (Bill) Bagnell, P.Eng., Manager Mining
- Dr Ted Eggleston, RM SME, Principal Geologist
- Mr Douglas Reid, P.Eng., Principal Geologist
- Mr Laurie Reemeyer, P.Eng., Process Consultant
- Dr Martin Shepley, P.Geo., Associate Hydrogeologist
- Dr Peter Cepuritis, MAusIMM, CP, Technical Director Geomechanics
- Ms Juleen Brown, MAusIMM, CP., Manager, Environment
- Dr Bing Wang, P.Eng., Senior Associate Engineer, Geotechnical

2.4 Site Visits and Scope of Personal Inspection

The following Amec Foster Wheeler staff performed a site visit from 17 May to 19 May, 2017:

- Dr Ted Eggleston reviewed data collection, database integrity, and geological model construction. Discussions on geology and mineralization were held with Vazante Mine personnel, and field site inspections were performed. Dr. Eggleston visited active mining operations to review the geology of the deposits and visit operating drill machines, inspected the main mine laboratory and reviewed procedures. He worked with site geological personnel reviewing aspects of data storage (database) and analytical quality control
- Mr Douglas Reid physically reviewed examples of underground channel samples and infill drill stations. Discussions were held on geology, controls on mineralization, and modeling methodology that incorporate geology into digital format with Vazante Mine geology staff. Mr. Reid conducted visual reviews of the block model in cross sections and plans, covering geology, mineralization, and high-grade zinc domain, block grades for zinc, lead, and silver, and Mineral Resource classification
- Dr Martin Shepley visited the underground mine dewatering operations and the area of the mine site, including a subset of the groundwater monitoring installations and doline/sinkhole features. He held discussions with the Vazante Mine hydrogeologist on aspects of the site hydrogeology, groundwater data collection and processing, groundwater modelling, groundwater risk management procedures and reviewed the hydrogeological logging of drill cores.

Mr Bill Bagnell visited site from December 14–15, 2016. During the visit, he toured underground workings, including production stopes, backfill placement, the crushing and conveying system, and development areas. He also met with Vazante Mine technical staff and management personnel to collect mining data, answer questions, and clarify issues.

Dr Peter Cepuritis visited site from 14–16 December, 2016. During that visit, he held discussions with mine planning, geological, hydrogeological, and geotechnical staff regarding the process of developing geotechnical factors for mine design and Mineral Reserve estimations. This involved data collection, data analysis model construction, and geotechnical analyses. He also visited underground operations to inspect first hand general rock mass conditions and mining methods and practices

2.5 Effective Dates

There are a number of effective dates, as follows:

- Date of the Mineral Resource estimate: 31 December, 2016
- Date of the Mineral Reserve estimate: 30 June, 2017
- Date of supply of the last information on mineral tenure and permitting: 14 June, 2017
- Date of letter regarding taxation considerations that supports the financial analysis: 14 July, 2017
- Date of financial analysis: 24 July, 2017.

The overall effective date of the Report is taken to be the date of the financial analysis, and is 24 July 2017.

2.6 Information Sources and References

Mr Ken Brisebois, P.Eng., an Amec Foster Wheeler employee, visited the site from 14–15 December, 2016. Mr Brisebois reviewed data collection and database integrity and discussed geology and mineralization with Votorantim personnel, reviewed geological and block model construction, and reviewed Mineral Resource estimation procedures and some of the corporate protocols supporting the estimates. Mr Brisebois provided specialist information on aspects of Mineral Resource estimation to Mr Reid.

Mr William Colquhoun, FSAIMM, visited site from 14–15 December, 2016. During that visit he inspected the process plant, and held discussions on plant operating practices with Votorantim staff. Mr Colquhoun provided specialist information on aspects of the metallurgical testwork programs, plant design, and plant operation to Mr Reemeyer.

Mr Felipe Riquelme, an Amec Foster Wheeler employee, visited the Votorantim corporate offices in Sao Paulo on Friday, 26 May, 2017, to discuss aspects of the environmental, permitting and social operations with Votorantim staff. Mr Riquelme provided specialist input on aspects of water management and environmental, permitting, and social considerations to Ms Brown.

The key information sources for the Report include the reports and documents listed in Section 3.0 (Reliance on Other Experts) and Section 27.0 (References) of this Report, and were used to support the preparation of the Report. Additional information was sought from Votorantim and Amec Foster Wheeler personnel where required.

2.7 Previous Technical Reports

No previous technical report under NI 43-101 has been filed on the Project.

3.0 RELIANCE ON OTHER EXPERTS

3.1 Introduction

The QPs have relied upon the following other expert reports, which provided information regarding mineral rights, surface rights, property agreements, royalties, taxation, and marketing sections of this Report.

3.2 Mineral Tenure, Surface Rights, and Royalties

The QPs have not independently reviewed ownership of the Project area and any underlying property agreements, mineral tenure, surface rights, or royalties. The QPs have fully relied upon, and disclaim responsibility for, information derived from Votorantim and legal experts retained by Votorantim for this information through the following documents:

- Azevedo Sette Advogados, 2017: Projects Ambrosia, Morro Agudo and Vazante: legal opinion, 14 June, 2017.

This information is used in Section 4 of the Report. The information is also used in support of the Mineral Resource estimate in Section 14, the Mineral Reserve estimate in Section 15, and the financial analysis in Section 22.

3.3 Environmental, Permitting and Social and Community Impacts

Amec Foster Wheeler has fully relied upon, and disclaim responsibility for, information supplied by Votorantim staff and experts retained by Votorantim for information related to environmental (including tailings, waste rock storage, water management) permitting and social and community impacts as follows

- Padron, A.O.S., 2017: Section 20 Content for the Vazante Technical Report: document prepared by Votorantim for Amec Foster Wheeler, 31 July, 2017.

This information is used in Section 20 of the Report. This information is also used in support of the Mineral Resource estimate in Section 14, the Mineral Reserve estimate in Section 15, and the financial analysis in Section 22.

3.4 Taxation

The QPs have fully relied upon, and disclaim responsibility for, information supplied by Votorantim staff and experts retained by Votorantim for information related to taxation as applied to the financial model as follows:

- Bertoncini, M.A., 2017: Taxation Assumptions for the Financial Model of Vazante: letter prepared by Votorantim for Amec Foster Wheeler, 14 July, 2017.

This information is used in support of the Mineral Reserve estimation in Section 15, and the financial analysis in Section 22.

3.5 Markets

Amec Foster Wheeler has have not independently reviewed the marketing, smelter terms, or metal price forecast information. Amec Foster Wheeler has fully relied upon, and disclaims responsibility for, information derived from Votorantim experts for this information through the following documents:

- Marinho, F.J.T., 2017: Market Assumptions for Vazante Technical Report: document prepared by Votorantim for Amec Foster Wheeler, 31 July, 2017.
- Da Silva, R.C.R, 2017: Smelter Terms for Vazante Technical Report: document prepared by Votorantim for Amec Foster Wheeler, 31 July, 2017.
- Dario, B.F., 2017: Metal Price Assumptions for the Vazante and Morro Agudo Technical Reports: document prepared by Votorantim for Amec Foster Wheeler, 28 July, 2017

This information is used in Section 19, and in support of the Mineral Reserves estimate in Section 15, and the financial analysis in Section 22.

Metals marketing, global concentrate market terms and conditions, and metals forecasting are specialized businesses requiring knowledge of supply and demand, economic activity and other factors that are highly specialized and requires an extensive database that is outside of the purview of a QP. The QPs consider it reasonable to rely upon Votorantim for such information as the company is a well-known supplier of zinc and lead concentrates to the market, and maintains a specialist marketing and contracts department that tracks these concentrate markets.

4.0 PROPERTY DESCRIPTION AND LOCATION

4.1 Introduction

The mines within the Vazante Operations are located as follows, using the WGS 84 datum, zone 23K:

- Vazante Mine: easting: 303120; northing: 8012410; elevation: 712 masl
- Extremo Norte Mine: easting: 307640 east, northing: 8018580; elevation: 658 masl

4.2 Property and Title in Brazil

This section provides a general overview of mineral-related law and title in Minas Gerais State, Brazil, sourced from public domain documentation, including Castro et al., (2012), Lagodourado.com (2015), and PwC, (2013) and has not been independently verified by the QPs.

4.2.1 Introduction

Under Brazilian laws, the Federal Government owns all mineral resources.

Mining is regulated by Decree-Law 227, 1967 (the Mining Code), and Decree No. 62,934, 1968, together with rulings made by the National Department of Mineral Production (DNPM). The DNPM is part of the Ministry of Mines and Energy of Brazil (MME), and is responsible for: the administration of all mineral rights; planning and development of mineral exploitation; management of mineral resources; and control of mining activities throughout Brazil.

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

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

4.2.2 Mineral Tenure

There are two levels of mineral tenure:

- Exploration authorizations (*autorização de pesquisa*)
- Mining concessions (*concessão de lavra*).

Exploration Authorizations

Exploration authorization applications must be accompanied by information on which minerals are to be explored for, the area and location of the area applied for, a “Exploration Work Plan” documenting the work that is intended to be performed, and an accompanying budget and work schedule.

Exploration authorizations can be granted for a minimum one year period, and a maximum three-year period, depending on the Exploration Work Plan proposed and DNPM approval. The authorization can be renewed once. Work must commence within 60 days of grant of the authorization.

A final report on the work completed must be provided to the DNPM, and be formally approved. On completion of a final report on the work conducted (termed a Final Exploration Report), the exploration authorization holder can apply for a mining concession.

Exploration authorization fees are set on a per hectare basis, and are payable annually.

Mining Concessions

The holder of an exploration authorization with an approved final report has a 12-month exclusion period in which to apply for a mining concession. After that date, any other party may apply for the ground. Depending on the minerals applied for, and the location, exploration authorizations can range in size from 50–10,000 ha.

Applications for a mining concession require documentary support, including the minerals are to be explored for, a description and location of the area applied for, a map showing the area, any easements, an “Economic Development Plan”, and evidence of sufficient funds to complete the plan. Mining concessions are considered granted when an ordinance (*portaria*) is published in the Official Gazette.

Within 90 days of the publication of the portaria, the holder must apply for possession (*imissão na posse*) of the surface area that is required to enact the Economic Development Plan. The DNPM will then draft an “Access Term” that must be signed by all stakeholders. The owner of the surface area is entitled to royalties that are equivalent to 50% of the amount paid as CFEM.

Work must commence within six months of the mining concession grant. Annual production reports must be filed. Assuming all other conditions are met, mining concessions remain valid until the deposit is depleted.

The holder can conduct mining activities only in the area covered under the lease agreement, and only after the agreement has been registered before the DNPM, and the appropriate operation license (*licença de operação*) has been issued. If additional minerals are discovered, the mining concession must be amended to include the new list of minerals.

Mining activities are regulated by the MME.

Mining Charges

Royalties (mining charges) in the form of a Compensation for the Exploitation of Mineral Resources (*Compensação Financeira pela Exploração de Recursos Minerais* or CFEM) are levied (see also discussion in Section 22.3.8).

4.2.3 Surface Rights

Surface rights in Brazil are separate from mineral rights. Under the mining law, mining 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.

4.2.4 Environmental Licencing

Mining activities are subject to mandatory environmental licensing by the Federal or State Environmental Agency, depending on the potential environmental impact. Environmental licenses are granted prior to mine construction, installation, expansion, or operation.

Generally, the environmental licensing is a three-stage process:

- A Preliminary License (LP) must be obtained during planning stage evaluation. An Environment Impact Assessment (EIA) and a closure and remediation plan must be prepared during the LP stage. Public hearings are usually called to present the EIA to the communities and authorities. The LP usually imposes conditions that must be complied with by the mining company. The environmental authority will also set the amount of the environmental compensation, which is a minimum of 0.5% of the projected development investment
- An Installation Licence (LI) is required prior to construction. The holder must present an Environmental Control Plan (PCA) for approval. Once the PCA is approved, the LI is granted and usually has conditions attached specific to the operation. A mining concession can only be granted by the Minister of Mines once the holder has obtained the LI

- An Operations Licence (LO) is granted once construction is complete and inspection by the environmental authorities confirms that the conditions imposed in the LI and the commitments made in the PCA have been kept.

Although the Brazilian legal system provides for two types of titles, one for exploration and one for mining, it does grant security that the holder of an exploration licence can mine any deposit that is discovered within the granted title. The government is required to grant a mining concession to an entity that has explored for, identified a Mineral Resource, obtained DNPM approval of the exploration report, filed applications for a mining concession in a timely manner, and obtained an LI.

Reasons for not granting a mining concession would be on the grounds of public interest, or if the Federal Government considers that it could have a negative effect on certain interests which are more important than mineral exploitation. In the latter instance, in those cases where a final exploration report has already been approved, a mining concession applicant is entitled to be indemnified by the Federal Government for any expenses incurred relating to the completed exploration work.

Brazil has a concept that is termed "environmental conservation units", which can be created by either the Federal Government, States, or Municipalities, and can be either total protection conservation units, where industrial activities such as mining cannot take place; or sustainable use conservation units, where some industrial activities (including mining) may be carried out as long as they comply with regulatory requirements. Every environmental conservation unit in Brazil must have its own management plan that sets out the regulations for the administration and occupation of the unit. The plan includes regulations applicable to the zone that surrounds the unit.

4.2.5 Social Licence

Areas reserved for indigenous populations are designated as "restricted access" or "prohibited" access for mining. The Brazilian Constitution requires that any mining activities in indigenous areas requires prior approval of the Brazilian National Congress. Indigenous communities have the right to receive royalties from any mining in their areas.

In addition to the indigenous communities, there are other communities (*Quilombolas*) that have Constitutional rights to own and occupy specific lands. Mining is permitted in these areas; however, the communities are entitled to compensation, and if the community needs to be relocated for mining purposes, the community must be relocated to land that has similar characteristics to the area that was previously occupied, or be fairly compensated.

4.2.6 Water Rights

All waters are considered to be 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 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 (NWRP), created the National Water Resources Management System (NWRMS), 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 (NWRC), State Water Resources Councils (SWRCs), River Basin Committees (RBCs), State Water Resources Management Institutions (SWRIs) and Water Agencies (WAs).

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 NWRC 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 NWRP. The SWRCs are responsible for basins at the State level. The SWRIs are responsible for implementing the guidelines set by the SWRCs. The RBCs and WAs cover the actual water regions, which may be part of more than one State.

4.2.7 Fraser Institute Survey

Amec Foster Wheeler has used the Investment Attractiveness Index from the 2016 Fraser Institute Annual Survey of Mining Companies report (the Fraser Institute survey) as a credible source for the assessment of the overall political risk facing an exploration or mining project in Brazil.

Amec Foster Wheeler has relied on the Fraser Institute survey because it is globally regarded as an independent report-card style assessment to governments on how attractive their policies are from the point of view of an exploration manager or mining company, and forms a proxy for the assessment by industry of political risk in Brazil from the mining perspective.

The Fraser Institute annual survey is an attempt to assess how mineral endowments and public policy factors such as taxation and regulatory uncertainty affect exploration investment.

Overall, Brazil ranked 61 out of the 104 jurisdictions in the survey in 2016.

4.3 Project Ownership

Amec Foster Wheeler was provided with legal opinion that supports that Project ownership is in the name of Votorantim Metais Zinco S.A., an indirectly held Votorantim subsidiary. An organogram of the Votorantim ownership interest is provided in Figure 4-1.

4.4 Mineral Tenure

For the purposes of this Report, the mineral concessions have been divided into the core tenements, where the known mineral deposits are located and mining operations are occurring, and the surrounding exploration concessions. Figure 4-2 shows the tenement layout for the Project area. The total project area is about 40 km long, approaches 20 km wide at the widest extent, and covers a significant strike extent of the lithologies that host mineralization at the Vazante and Extremo Norte Mines. Figure 4-3 is a legend explaining the lithologies that form the backdrop to Figure 4-2.

4.4.1 Core Tenements

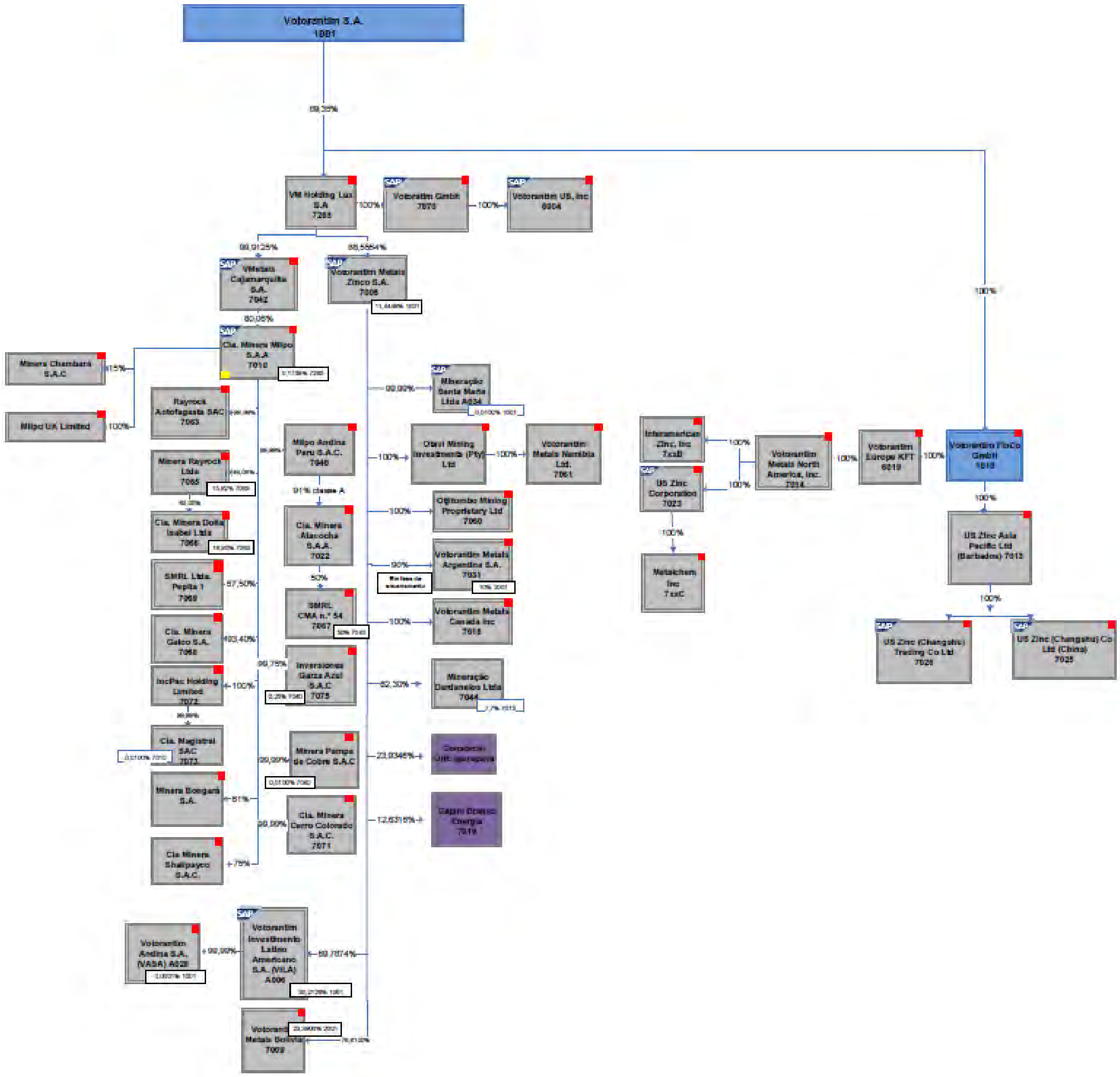
Votorantim holds eight mining concessions (see Table 4-1 and Figure 4-4) that have a total area of approximately 2,091 ha. These host the active mining operations.

There is an existing mining reporting grouping, 802.185/1971, which covers mining concessions 001.032/1955, 001.034/1955, 002.664/1956, 001.035/1955, 001.036/1955, and 014.840/1967 and was granted in 1972, for regulatory reporting purposes. As part of the regulatory assessment in support of the grouping, the Mineral Reserves for those concessions were re-evaluated on 11 June, 2006.

An application is currently pending to group those concessions, with the addition of mineral concessions 001.973/1962 and 805.141/1976 into a single mining group for regulatory reporting purposes.

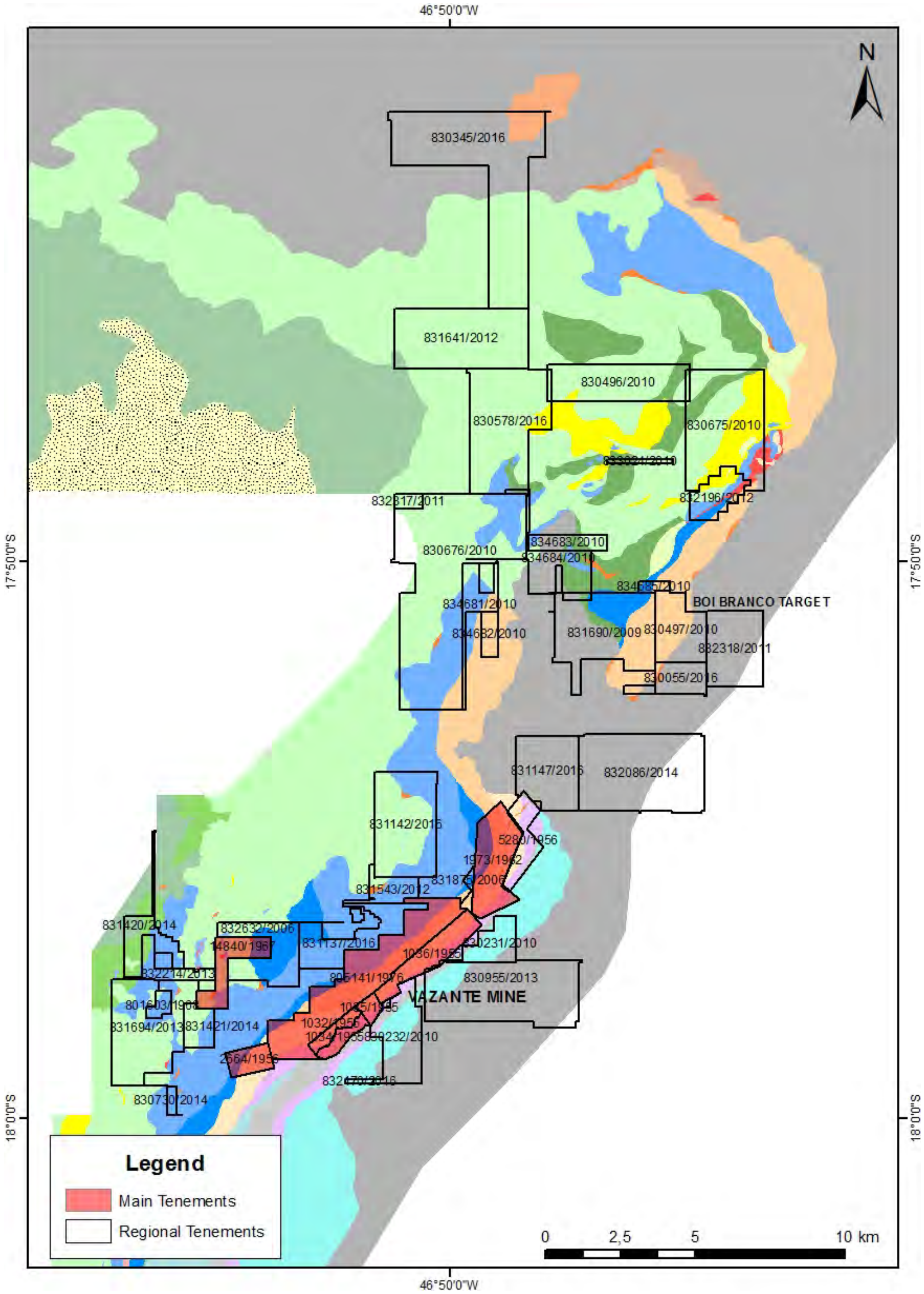
As per mining regulation requirements, some of the concessions have undergone formal re-evaluations of the Mineral Reserves, or have had modifications made to the existing economic extraction plan. In some instances, additional minerals that can be mined have been added to the concession conditions.

Figure 4-1: Ownership Organogram



Note: Figure courtesy Votorantim, 2017.

Figure 4-2: Vazante Project Mineral Tenure



Note: Figure courtesy Votorantim, 2017.

Figure 4-3: Lithology Key for Figure 4-1

Legend

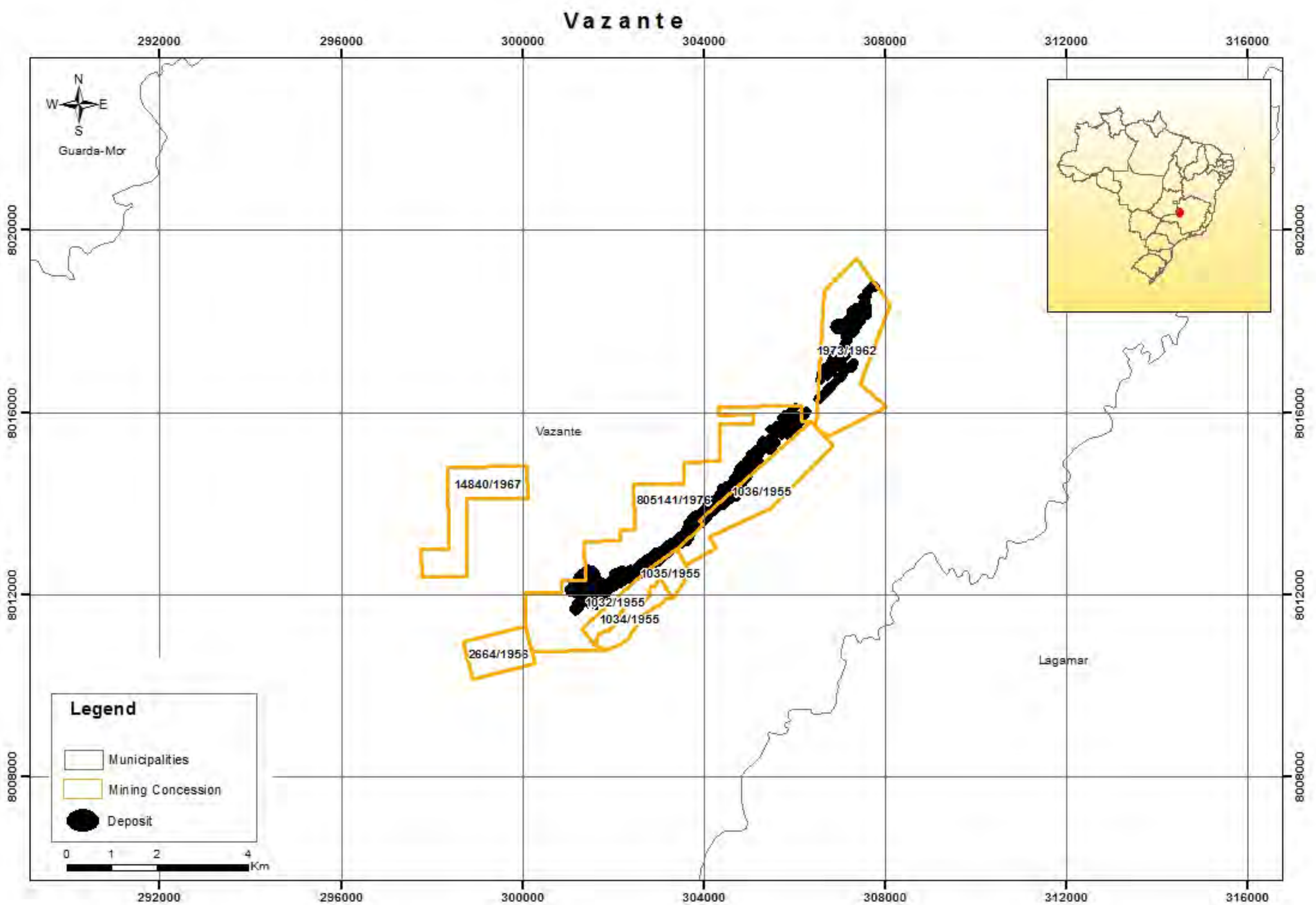
- Sulphide hydrothermal breccia, Zinc and Lead
- Dolarenite
- Soil
- Silexitic breccia
- Hematite breccia
- Marls
- Laminated dolomite with levels of dolarenite and dolorudite
- Dolorudite with stromolytic levels. Interbeded with dololutite
- Formação Paracatu (Mb. Serra das Antas) - Fine foliated gray to ocher phyllites locally layered and sericitic
- Formação Paracatu, Mb Morro do Au. Predominance of arenophilite metarithmite, intercalations of phyllite, sometimes with laminated carbonate and dolomite.
- Formação Serra do Landim - Greenish marl, rich in chlorite
- Formação Serra da Lapa - Dark gray dolomite, fine (carbonate mud), placoid with marls intercalations
- Formação Serra da Lapa - Carbonous phyllite lenses
- Formação Morro do Calcáreo - Light gray recrystallized dolomite, laminated
- Formação Morro do Calcáreo - Intraclastic breccia (dolorudites) with medium to fine matrix, with angular to subarrounded clasts of dolomite and dolarenite
- Formação Morro do Calcáreo - Dolorudites with fine matrix and giant clasts up to 1m, sub-rounded
- Formação Morro do Calcário - Columnar stromatolytic dolomite, locally with marl intercalations.
- Formação Serra do Poço Verde - Clayey dolomite, fine, dark gray, placoid
- Formação Serra Poço Verde - Pink/gray dolomite locally with laminated metamarls intercalations and presence of intraformational breccias
- Formação Serra Poço Verde - Undifferentiated dolomite with strong pelitic contribution, silicified pink dolomite and with algal laminations on top
- Formação Serra Poço Verde - Clayey Phyllites/Carbonous phyllites/Meta-ritimites, gray to ocher, with intercalations of light gray to dark dolomites, with algal laminations
- Formação Serra Poço Verde - Dark gray dolomite, fine, with algal laminations, locally bird's eyes and stromatolites
- Formação Serra do Garrote - Pink and red metapelites, with carbonaceous phyllites and quartzite lenses intercalations
- Formação Lagamar - Light gray dolomites/dololutites, recrystallized locally with algal lamination
- Formação Lagamar - dolomite/dolarenites locally with stromatolites

Note: Figure courtesy Votorantim, 2017.

Table 4-1: Mineral Concessions Summary Table

Tenure ID	Holder	Title Type	Minerals	Area (ha)	Date Granted	Expiry Date	Comments
001.032/1955	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb, Cu, dolomite	73.19	14 November, 1957	Mining concessions remain valid until the deposit is depleted	The DNPM approved a re-evaluation of Mineral Reserves on 23 January, 1978.
001.034/1955	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb, Cu, dolomite	76.71	14 November, 1957		The DNPM approved a re-evaluation of Mineral Reserves on 23 January, 1978. An approval to add dolomite extraction to the approved minerals list was granted 8 October, 1982.
002.664/1956	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb, Cu	119	14 November, 1957		The DNPM approved a re-evaluation of Mineral Reserves on 23 January, 1978.
001.035/1955	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb, Cu, dolomite	47.89	14 November, 1957		The DNPM approved a re-evaluation of Mineral Reserves on 23 January, 1978. The DNPM approved a new extraction plan on 9 July, 1986.
001.036/1955	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb, Cu, dolomite	276.25	14 November, 1957		The DNPM approved a re-evaluation of Mineral Reserves on 23 January, 1978. The DNPM approved a new extraction plan on 9 July, 1986.
001.973/1962	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb	412.39	13 January, 1962		The DNPM approved a re-evaluation of Mineral Reserves on 30 March, 2009. The DNPM approved a new extraction plan on 10 July, 1986. Two easements were granted on 22 August, 2006 and 30 March, 2009. An approval to add lead extraction to the approved minerals list was granted 10 July, 2015.
014.840/1967	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb, Cu, barite	226.5	20 March, 1973		
805.141/1976	Votorantim Metais Zinco S.A.	Mining Concession	Zn, Pb, dolomite	859.17	22 September, 1994		The DNPM approved a re-evaluation of Mineral Reserves on 15 August, 2014.
				2,091.1			

Figure 4-4: Core Tenements Mineral Concessions Plan



Note: Figure courtesy Votorantim, 2017.

4.4.2 Exploration Tenure

Votorantim also holds 12 exploration applications (about 2,756 ha), 22 exploration authorizations (11,948 ha), one mining concession application (190 ha) and one granted mining concession (53 ha) that surround the core tenements. These total approximately 14,947 ha in addition to the core tenements. The locations were included in Figure 4-1, and the tenure details are provided in Table 4-2.

4.5 Surface Rights

Votorantim holds, or has acquired through negotiation, surface rights sufficient to support the current operations:

- Concession 805.141/1976: agreements with 11 surface rights holders
- Concession 802.185/1971: agreements with four surface rights holders
- Concession 001.973/1962: agreements with one surface rights holder

Some surface rights agreements require annual payments to the owners. These payments are half of the CFEM (see discussion in Section 22.3.9), and are paid when mining activities occur on the landowner's property. Such royalty payments are included in the financial model in Section 22, and are assumed to extend over the life of the mine.

Three easements have been granted in support of mining activities in mining concession 001.973/1962, on 22 August, 2006 and 30 March, 2009. The easements cover 14.05 ha, 49.44 ha, and 192.91 ha.

There are no indigenous group stakeholders that may be affected by the Vazante Operations.

Where access is required for regional exploration or drilling programs, negotiations are typically conducted on an individual basis with the affected landowner. If required, judicial action can be invoked to allow surface access.

4.6 Water Rights

Votorantim holds seven licences for water usage for the operations, one of which is currently inactive (Table 4-3). Votorantim confirmed that renewal applications have been lodged, where applicable, for the water licences in use.

Table 4-2: Exploration Tenure Table

Tenure ID	Holder	Title Type	Area (ha)	Minerals	Date Granted	Expiry Date	Comments
5280/1956	Votorantim Metais Zinco S A	Mining Application	189.98	Pb, Cu, Zn			
801603/1968	Votorantim Metais Zinco S A	Mining Concession	52.50	Pb, Zn			Operation not initiated
830055/2016	Votorantim Metais Zinco S A	Exploration Authorization	168.88	Zn	January 5, 2017	January 5, 2020	
830231/2010	Votorantim Metais Zinco S A	Exploration Application	201.16	Zn			Replaced by 830460/2017
830232/2010	Votorantim Metais Zinco S A	Exploration Authorization	42.10	Zn	May 10, 2017	May 10, 2020	
830345/2016	Votorantim Metais Zinco S A	Exploration Authorization	1473.04	Zn	November 29, 2016	November 29, 2019	
830496/2010	Votorantim Metais Zinco S A	Exploration Application	542.43	Zn			
830497/2010	Votorantim Metais Zinco S A	Exploration Authorization	337.70	Zn	April 8, 2016	April 7, 2019	
830578/2016	Votorantim Metais Zinco S A	Exploration Authorization	914.28	Pb, Zn	July 26, 2016	July 26, 2019	
830675/2010	Votorantim Metais Zinco S A	Exploration Application	918.48	Pb, Zn			
830676/2010	Votorantim Metais Zinco S A	Exploration Authorization	1835.06	Zn	May 11, 2016	May 11, 2019	
830730/2014	Votorantim Metais Zinco S A	Exploration Authorization	30.15	Zn	October 26, 2015	October 26, 2018	
830955/2013	Votorantim Metais Zinco S A	Exploration Authorization	896.45	Limestone	April 15, 2015	April 15, 2018	
831137/2016	Votorantim Metais Zinco S A	Exploration Authorization	377.72	Zn	June 28, 2016	June 28, 2019	
831142/2016	Votorantim Metais Zinco S A	Exploration Authorization	689.36	Zn	June 28, 2016	June 28, 2019	
831147/2016	Votorantim Metais Zinco S A	Exploration Authorization	462.65	Zn	July 26, 2016	July 26, 2019	
831420/2014	Votorantim Metais Zinco S A	Exploration Application	223.88	Zn			
831421/2014	Votorantim Metais Zinco S A	Exploration Application	130.44	Zn			

831543/2012	Votorantim Metais Zinco S A	Exploration Authorization	143.25	Zn	March 24, 2014		waiting for renewal
831641/2012	Votorantim Metais Zinco S A	Exploration Authorization	857.81	Zn	March 24, 2014		waiting for renewal
831690/2009	Votorantim Metais Zinco S A	Exploration Authorization	782.02	Zn	May 31, 2016	May 31, 2019	
831694/2013	Votorantim Metais Zinco S A	Exploration Authorization	707.79	Zn	May 22, 2014	May 22, 2017	Replaced by 830868/2017
831875/2006	Votorantim Metais Zinco S A	Exploration Authorization	29.70	Zn	May 7, 2012	May 7, 2013	Final Report approved
832086/2014	Votorantim Metais Zinco S A	Exploration Authorization	1020.70	Zn	February 19, 2016	February 19, 2019	
832170/2016	Votorantim Metais Zinco S A	Exploration Application	10.31	Zn			
832196/2012	Votorantim Metais Zinco S A	Exploration Authorization	206.37	Zn	November 7, 2014	November 7, 2017	
832214/2013	Votorantim Metais Zinco S A	Exploration Authorization	133.98	Zn	March 24, 2014		waiting for renewal
832317/2011	Mineracao Soledade Ltda	Exploration Authorization	44.40	Zn	July 18, 2011		waiting for renewal
832318/2011	Votorantim Metais Zinco S A	Exploration Authorization	450.47	Zn	July 18, 2011	March 31, 2019	
832632/2006	Votorantim Metais Zinco S A	Exploration Authorization	344.52	Zn, Dolomite	March 7, 2012	March 7, 2013	Final Report approved
833024/2010	Votorantim Metais Zinco S A	Exploration Application	25.56	Pb, Zn			
834681/2010	Votorantim Metais Zinco S A	Exploration Application	166.72	Zn			
834682/2010	Votorantim Metais Zinco S A	Exploration Application	75.82	Zn			
834683/2010	Votorantim Metais Zinco S A	Exploration Application	131.55	Zn			
834684/2010	Votorantim Metais Zinco S A	Exploration Application	293.89	Zn			
834685/2010	Votorantim Metais Zinco S A	Exploration Application	35.49	Zn			

Table 4-3: Water Rights

Agency	Purpose	File Number	Issue Date	Expiration Date	Status
SUPRAM-NOR	Underground pumping for Vazante Mine	1672 / 2013-2019	8/1/2013	7/18/2019	Active
SUPRAM-NOR	Santa Caterina River water catchment	201 / 2014-2016	2/11/2014	6/26/2016	Inactive
SUPRAM-NOR	Palmital stream diversion	00218 / 2013-2016	2/4/2013	6/26/2016 renewal application 21394/2016	Active
SUPRAM-NOR	Aroeira TSF dam	01805 / 2008-2013	10/6/2008	10/6/2013 renewal application 10107/2013	Active
SUPRAM-NOR	Underground pumping for Extremo Norte Mine	01887 / 2011-2016	6/29/2011	6/29/2016 renewal application 21392/2016	Active
IGAM	Barrel stream remediation	02986 / 2009-2014	11/18/2009	11/18/2014 renewal application 17988/2014	Active
SEMAD	Santa Caterina River water catchment	2282/2016	11/17/2016	3/31/2020	Active

4.7 Royalties and Encumbrances

The Project is not subject to any royalties other than the CFEM and the payments of half of the CFEM to surface rights holders if mining activity occurs in their property (see also Section 4.5 and Section 22.3.9).

4.8 Property Agreements

Other than the surface rights agreements discussed in Section 4.5, there are no other agreements currently in effect.

4.9 Permitting Considerations

Project permitting is discussed in Section 20.

4.10 Environmental Considerations

The environmental considerations relevant to the Project are discussed in Section 20.

4.11 Social License Considerations

The social considerations relevant to the Project are discussed in Section 20.

4.12 Comments on Section 4

The legal opinion and information from Votorantim experts supports the following:

- Votorantim Metais Zinco S A has been duly incorporated, and is a valid corporate entity under the laws of Brazil. The company may conduct business in Brazil and has the requisite power and authority to own property and assets in Brazil
- Votorantim has the rights to acquire, hold, and transfer title in the listed mining concessions, and has the rights to carry out exploration, development, and production with respect to the listed mining concessions
- Mining concessions and mineral claims held in the name of Votorantim Metais Zinco S A are appropriately registered, valid, and are in good standing. The mineral concessions are not subject to outstanding liens or encumbrances, and are not pledged in any way
- Votorantim holds sufficient surface rights for the mining operations
- Sufficient water rights are held to support operations

Votorantim advised that to the extent known, there are no other significant factors and risks that may affect access, title or right or ability to perform work on the Project.

5.0 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE, AND PHYSIOGRAPHY

5.1 Accessibility

The mine site is about 7 km from the municipality of Vazante (Figure 5-1):

- From Brasilia, access is via federal highway BR-040 toward Paracatu, thence south to the city of Guarda Mor on MG-188, and to the mine site using highway LMG-706.
- From Belo Horizonte, access is via state highway MG-050 toward the city of Patos de Minas, then via MG-354 and LMG-706 to the mine site.

Concentrates are trucked about 250 km to the Tres Marias smelter.

The closest commercial airport is in Brasilia. The Vazante municipal airport for light aircraft is adjacent the mine site.

Additional information on accessibility is included in Section 18 of this Report.

5.2 Climate

The climate in the Project area is classed as humid sub-tropical, with average maximum temperatures of about 30º, and average minimum temperatures of about 13ºC. The hottest months are generally September and October; typically, June and July are the coolest.

The wet season occurs from October to April, with dry months from May to September.

The predominant wind directions are generally northeast to southwest.

Underground mining operations are conducted on a year-round basis.

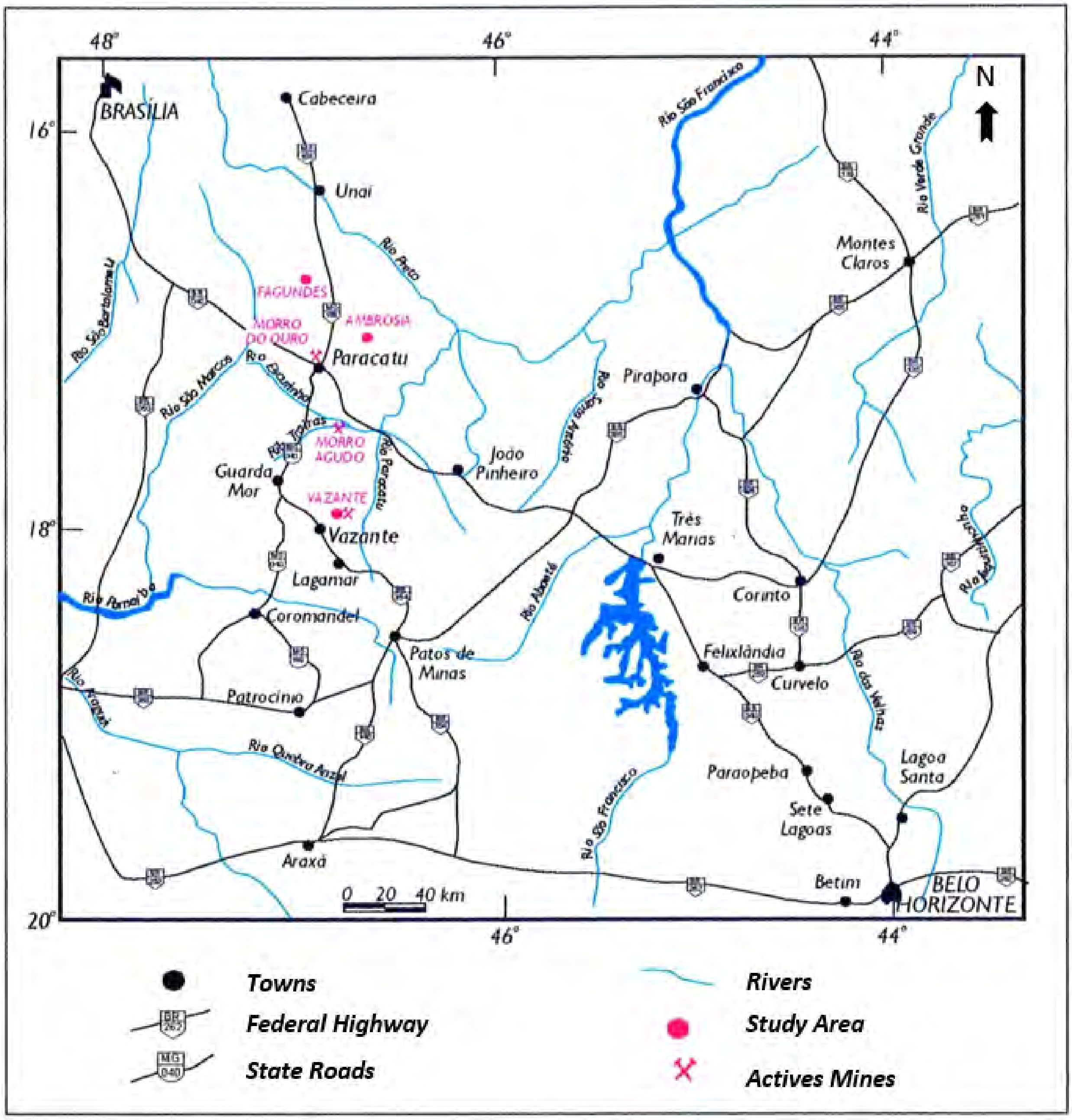
5.3 Local Resources and Infrastructure

The closest settlement is the municipality of Vazante, population approximately 20,000. Most mine workers reside in the town, and commute to the mine site.

Goods and services in support of mining operations are generally sourced from Belo Horizonte.

Additional information on infrastructure is provided in Section 18 and Section 20.

Figure 5-1: Project Access Plan



Note: Figure courtesy Votorantim, 2017.

5.4 Physiography

The Project area has elevations ranging from about 690 to 970 masl.

Remnant vegetation typically consists of open savannah (*cerrado*) with gallery-type forest cover in the riparian areas. *Cerrado* is a protected environment, where it occurs.

The majority of the region is farmed or used for pasture. The primary food items are rice, beans, soybean, and manioc.

The main water systems are tributaries of the Paracatu River, part of the Sao Francisco River basin. The Santa Catarina River cuts through the southern part of the Project area.

5.5 Seismicity

The mining operations are not located in a known active area.

5.6 Comments on Section 5

There is sufficient suitable land available within the mineral tenure held by Votorantim for tailings disposal, mine waste disposal, and installations such as the process plant and related mine infrastructure. All necessary primary infrastructure has been built on site and is sufficient for the projected life-of-mine (LOM) plan (LOMP); (see also comments on ventilation and paste fill in Section 16).

A review of the existing power and water sources, manpower availability, and transport options (see Sections 18 and 20), indicates that there are reasonable expectations that sufficient labor and infrastructure will continue to be available to support declaration of Mineral Resources, Mineral Reserves, and the proposed LOMP.

6.0 HISTORY

6.1 Exploration History

The history of the Vazante Operations is summarized in Table 6-1.

Mineralization was initially exploited by artisanal miners during the 1950s. Mechanized open pit mining commenced in 1969. Initial mining operations exploited supergene calamine ores (a mixture of the zinc secondary minerals hemimorphite ($Zn_4(Si_2O_7)(OH)_2 \cdot H_2O$) and smithsonite ($ZnCO_3$) derived from the weathering of primary silicate ores. A location plan showing the mined-out open pits is included as Figure 6-1. As pit names have been modified over time, Table 6-2 summarizes the nomenclature used in the closure plans discussed in Section 20.8 against the current naming.

Underground mining, which is ongoing, commenced in 1983. The current primary ore types mined are hydrothermal zinc silicates, largely willemite (Zn_2SiO_4).

6.2 Production

No information is available that describes the artisanal workings in the early Project history.

Table 6-3 provides, where known, the historical calamine and willemite production in tonnes, for the period 1969 to 1999.

Table 6-4 summarizes the zinc production history from 2000 to 2016 from the current underground operations, and includes the forecast production for 2017. Table 6-5 provides the lead–silver production for the period 2013–2017. Lead and silver were only recovered from the zinc concentrate after 2012.

6.3 Prior Estimates

Votorantim received exemptive relief from the second part of the definition of “historical estimates” under NI 43-101 in order to disclose a summary of the prior Mineral Resource and Ore Reserve estimates from 2011 to 2015 for the Vazante Operations as historical estimates.

Section 1.1 of NI 43-101 defines “*historical estimate*” as follows: “*means an estimate of the quantity, grade, or metal or mineral content of a deposit that an issuer has not verified as a current mineral resource or mineral reserve, and which was prepared before the issuer acquiring, or entering into an agreement to acquire, an interest in the property that contains the deposit*”.

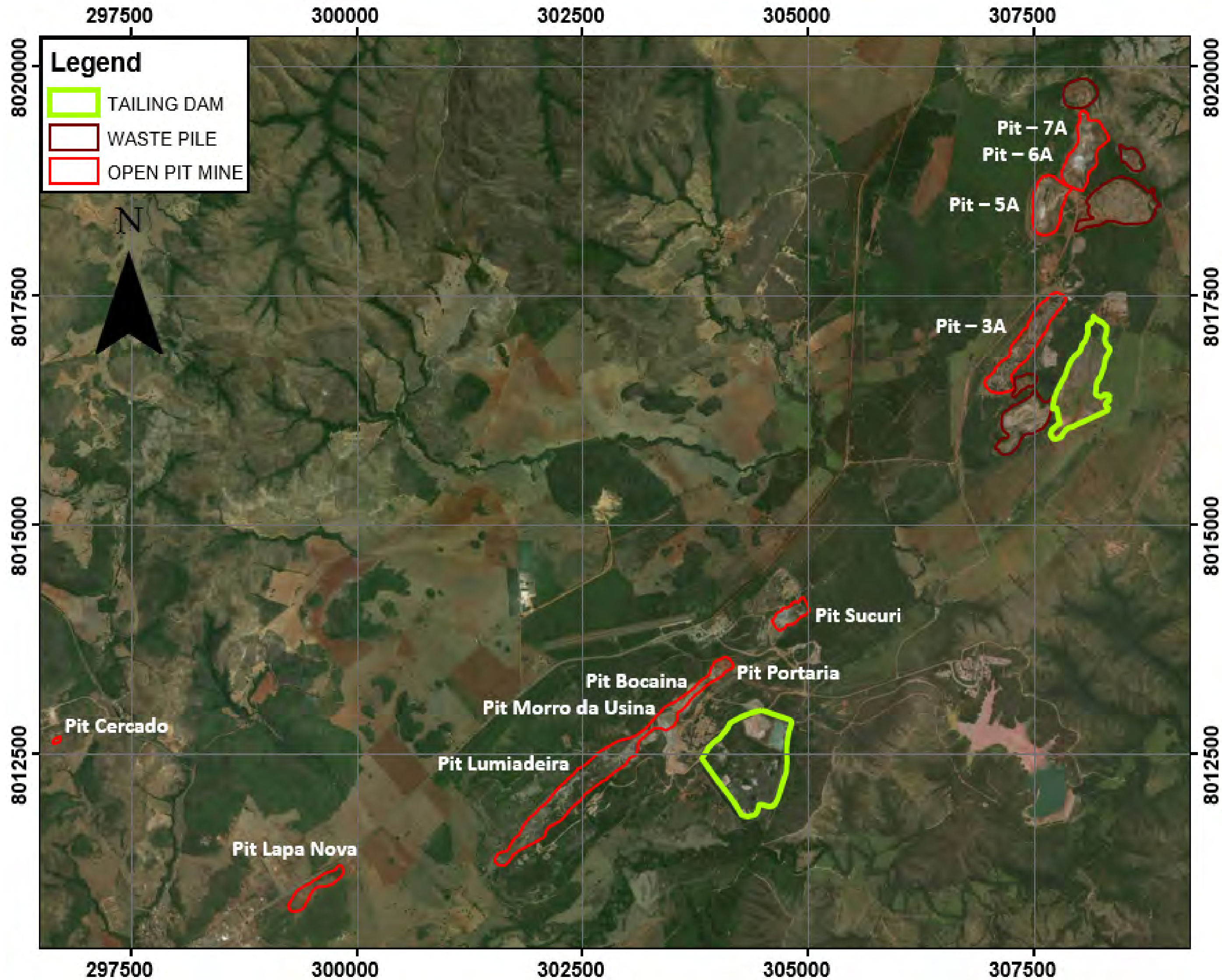
Table 6-1: Project History

Year	Operator	Purpose	Work Completed	Comment
1933	Angelo Solis			Zinc discovery in the Vazante region
1956	Companhia Miniera de Metais (CMM)			Company established
1969	U.S. Steel	Surface exploration	Geological mapping	Regional geological mapping - Cia Meridional First ore transport from Vazante open pit mining phase to Tres Marias
1972	DOCEGEO	Surface exploration	Geological mapping	Regional map of Vazante belt
1974–1978	ENJEX/DOCEGEO/CMM (Votorantim)/DNPM	Drilling	Exploratory drilling and mineral potential definition	Agua Doce and Pasto prospects.
1980–1989	CMM/BSHELL	Drilling	Exploratory drilling and mineral potential definition	Agua Doce and Pasto prospects.
1990	CMM (Votorantim)	Drilling	Exploratory drilling	Agua Doce prospect
2000	CMM (Votorantim)	Surface exploration	Stream sediment sampling	Sampling of the Garrote Formation along the Lagoa Feia trend, and around the Lages, Cercado, and Partecal targets.
2001	COMIG	Geophysics	Aerial MAG-GAMA survey	Vazante Belt
2004–2006	Votorantim	Surface Exploration Drilling	Regional mapping Exploratory drilling and resource classification. Exploratory auger drilling	Drilling at Olho D'Água target In 2004, CMM became Votorantim Metais
2007	Votorantim	Surface exploration	Regional scale geological mapping (1:10,0000), and local scale mapping (1:20,000), rock sampling	Define potential areas and better understanding of the stratigraphic and metallogenetic context around Vazante Mine targets.
		Drilling	Mineral potential definition	Olho D'Água prospect
2008	Votorantim	Surface exploration	Regional and local-scale mapping (1:100,000 and 1:20,000), rock sampling.	Potential areas definition through initial exploratory field-work and mineral target definition with geological mapping, rock and geochemical sampling at Cercado and Olho D'Água prospects
2009	Votorantim	Surface exploration	Regional and local-scale mapping (1:100,000 and 1:20,000), rock, soil, and stream sediment sampling	Potential areas definition with regional surface exploration and infill geological detail in exploratory targets such as Cercado, Olhos D'agua, and the Lagoa Feia trend
		Geophysics	Ground magnetic survey	Ground magnetic survey at Agua Doce, Extremo Norte Mine, Vazante Mine and Lagoa Feia trend

Year	Operator	Purpose	Work Completed	Comment
2010	Votorantim	Surface exploration	Regional and local-scale mapping (1:100,000 and 1:20,000), soil, rock, and stream sediment sampling	Large geological mapping campaign to assess mineral potential definition in the Vazante South belt, soil sampling over prospective targets such as Olho D'Água trend, Vazante Mine area, and Cercado trend
		Drilling	Exploratory drilling and mineral potential definition	Focus on drilling over the Cercado trend
2011	Votorantim	Surface Exploration	Regional and detail-scale mapping (1:100,000 and 1:5,000), rock, soil, pan concentrate, and stream sediment sampling	Large geological mapping campaign to assess mineral potential definition in the Vazante South belt, soil sampling over prospective targets such as Olho D'Água trend, Vazante Mine area, and Cercado trend
		Drilling	Exploratory drilling and mineral potential definition	Vazante mine, Olho D'Água, Boi Branco
		Geophysics	FALCON airborne MAG-GRAV acquisition	Regional airborne survey
2012	Votorantim	Surface exploration	Regional scale mapping (1:100,000), rock, pan concentrate and stream sediment sampling	Potential areas definition. Detailed work over the Olho D'Água, Lagoa Feia, Partecal trend and Boi Branco prospect.
		Drilling	Exploratory drilling and mineral potential definition	Olho D'Agua trend
2013	Votorantim	Surface exploration	Regional, local and detail-scale mapping (1:100,000, 1:20,000 and 1:5,000), rock and pan concentrate sampling	Cercado trend and Boi Branco prospect
		Drilling	Exploratory drilling and resource definition drilling	Potential Vazante Mine parallel structure and Agua Doce prospect
2014	Votorantim	Surface Exploration	Regional, local and detail-scale mapping (1:100,000, 1:20,000 and 1:5,000), rock, pan concentrate, and soil sampling	Potential area definition in parallel structure to the Vazante Mine
		Drilling	Exploratory drilling	Olhos D'agua trend, Vazante Mine parallel structures trend
		Geophysics	Electroresistivity data	Undertaken to delineate weathering zone and fracture zones at Vazante Mine limits
2015	Votorantim	Surface exploration	Regional and local-scale mapping (1:100,000 and 1:20,000), rock, soil, stream sediment and pan concentrate sampling	Boi Branco, Lages, Partecal, Olhos D'agua trend
		Drilling	Exploratory drilling, mineral potential and resource definition	Vazante Mine parallel structures

Year	Operator	Purpose	Work Completed	Comment
2016	Votorantim	Surface exploration	Detail-scale mapping (1:10000) rock and soil sampling)	Detail-scale geological mapping at Lages and Lagoa Feia.
		Drilling	Exploratory drilling, mineral potential and resource definition	Vazante mine drilling (Lumiadeira Sul, gaps at Extremo Norte) and Lages
		Geophysics	IP survey	Spectral IP at Lages, Extremo Norte target and Boi Branco trend
2017	Votorantim	Surface exploration	Detail-scale mapping (1:10,000) rock and soil sampling.	Lages and Lagoa Feia targets
		Drilling	Exploratory drilling, mineral potential and resource definition	Drilling Vazante (Lumiadeira Sul, gaps at Extremo Norte and Lages). Beginning of drilling program to assess calamine potential in Vazante Mine
		Geophysics	IP survey	Spectral IP survey over Vazante, Lages, and Lagoa Feia target

Figure 6-1: Historic Open Pits and Waste Rock Storage Facilities



Note: Figure courtesy Votorantim, 2017.

Table 6-2: Open Pit Nomenclature

Closure Plan Name	Current Name
Bocaina Portaria Sucuri Morro da Usina	Sucuri (Serra do Sucuri)
Lumiadeira	Lumiadeira (Serra do Lumiadeira)
3A	3A
5A	5A
6A	6A 7A
Cercado	Cercado
	Lapa Nova

Table 6-3: Historical Calamine and Willemite Production (1969 to 1989)

	Units	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Open Pit Calamine	t	6,000	13,000	24,000	32,000	48,000	74,000	73,000	110,000	121,000	151,000	232,000	280,000
Open Pit Willemite	t	2,700	5,720	10,512	13,600	21,120	31,450	31,390	46,200	50,215	57,380	69,600	72,800
Vazante Willemite	t	—	—	—	—	—	—	—	—	—	—	—	—

	Units	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Open Pit Calamine	t	316,000	501,000	584,000	156,054	116,157	209,221	182,146	267,139	247,350	129,799	173,268	78,470
Open Pit Willemite	t	—	—	—	419,967	384,293	400,785	315,635	538,475	500,553	609,522	550,354	595,242
Vazante Willemite	t	—	—	—	657	20,342	4,621	13,942	5,965	—	2,050	21,999	42,174

	Units	1993	1994	1995	1996	1997	1998	1999
Open Pit Calamine	t	279,727	185,777	137,538	111,138	205,322	181,070	188,601
Open Pit Willemite	t	629,893	553,879	376,879	187,200	296,322	163,806	85,499
Vazante Willemite	t	31,410	115,797	143,504	226,996	227,927	309,946	416,583

Table 6-4: Zinc Production History, 2000–2017

		2000	2001	2002	2003	2004	2005	2006	2007
Tonnage	kt	441.90	531.61	590.50	680.25	708.39	815.82	868.73	1,026.79
Zn Grade	%	14.58	14.97	15.14	15.04	15.10	14.43	15.67	15.33
		2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Tonnage	kt	986.45	1,096.66	1,301.53	1,323.74	1,401.28	1,389.52	1,389.57	1,355.2
Zn Grade	%	14.61	15.12	15.37	13.03	10.61	10.5	10.68	11.32
		2016	**2017 ***						
Tonnage	kt	1,298.55	1,311.94						
Zn Grade	%	11.34	11.45						

Note: 2017 production figures are forecasts

Table 6-5: Lead and Silver Production History, 2013–2017

	Zinc Concentrate tonnage (t)	Pb Grade (%)	Ag Grade (g/t)
2013	1,389.52	0.31	18.6
2014	1,389.57	0.28	16.9
2015	1,355.2	0.28	15.1
2016	1,298.55	0.34	14.5
2017 *	1,311.94	0.39	21.5

Note: 2017 production figures are forecasts.

The relief granted by the Canadian Securities Administrators to Votorantim allows the prior estimates to disclosed as “*historical estimates*” even though Votorantim was the owner of the Vazante Operations at the time of the estimates.

These prior estimates are considered by Votorantim to be useful for the purpose of illustrating Votorantim’s ability to replenish Mineral Resources and Ore Reserves during mining activities. Votorantim does not intend to update or verify the prior estimates as current. A portion of the material in the estimates has been mined out.

Table 6-6, Table 6-7, and the accompanying table footnotes summarize the Mineral Resource and Ore Reserve estimates for 2011–2015, and provide, where known, the key parameters, assumptions, and methods that were used by Votorantim staff in preparing the estimates.

Table 6-6: Prior Mineral Resource Estimates

Confidence Classification	Units	2011	2012	2013	2014	2015
Measured	Tonnage (Mt)	—	—	—	1.11	1.20
	Grade Zn (%)	—	—	—	12.05	22.85
Indicated	Tonnage (Mt)	0.52	2.24	2.09	1.75	0.47
	Grade Zn (%)	29.24	13.38	16.87	16.15	26.72
Total Measured and Indicated	***Tonnage (Mt)***	***0.52***	***2.24***	***2.09***	***2.86***	***1.68***
	Grade Zn (%)	***29.24***	***13.38***	***16.87***	***14.56***	***23.94***
Inferred	Tonnage (Mt)	10.81	7.82	8.03	5.52	3.74
	Grade Zn (%)	16.95	16.00	16.12	15.63	17.20

Notes to accompany prior Mineral Resource estimate table:

1. Mineral Resource estimates for the Vazante Operations have an effective date of 31 December of the previous year, such that the 2011 estimate was prepared as of 31 December, 2010, the 2012 estimate was prepared as of 31 December, 2011, the 2013 estimate as of 31 December 2012, the 2014 estimate as of 31 December 2013, and the 2015 estimate as of 31 December, 2014.
2. Mr Jose A. Lopes, MAusIMM (CP), employed as the Manager of Mineral Resources and Exploration with Votorantim, was the Competent Person responsible for each Mineral Resource estimate, and supervised the Votorantim personnel who prepared the estimates.
3. Mineral Resources were reported exclusive of the Mineral Resources converted to Ore Reserves.
4. Mineral Resources are not Ore Reserves, and do not have demonstrated economic viability.
5. The Mineral Resources were assumed to be extracted using vertical retreat mining (VRM) methods.
6. The estimates were reported using a cut-off grade of 5% Zn. The cut-off grade covered mining, processing, and other costs. No lead estimates were performed.
7. Zinc metal prices used were variable: 2011, US$2,033/t; 2012, US$2,407/t; 2013, US$2,260/t; 2014, US$2,376/t; 2015, US$2,376/t.
8. Operating cost assumptions varied by year: 2011: mining cost of US$13.50/t, process cost of US$13.10/t, other costs of US$13.00/t; 2012: mining cost of US$12.90/t, process cost of US$13.50/t, other costs of US$14.00/t; 2013: mining cost of US$13.30/t, process cost of US$14.10/t, other costs of US$12.00/t; 2014: mining cost of US$15.40/t, process cost of US$14.00/t, other costs of US$13.00/t; 2015: mining cost of US$12.70/t, process cost of US$15.10/t, other costs of US$15.00/t.
9. The zinc metallurgical recovery assumption was 85% for each estimate.
10. Mineral Resources were stated as in situ with no consideration for planned or unplanned external mining dilution.
11. Rounding may result in apparent summation differences.

Table 6-7: Prior Ore Reserve Estimates

Confidence Category	Unit	2011	2012	2013	2014	2015
Proved	Tonnage (Mt)	2.37	2.19	4.02	6.53	7.57
	Grade Zn (%)	10.19	11.52	11.53	11.34	11.38
Probable	Tonnage (Mt)	6.17	5.88	4.05	5.01	4.95
	Grade Zn (%)	11.11	11.19	10.61	9.49	9.63
Total Proven and Probable	***Tonnage (Mt)***	***8.54***	***8.07***	***8.07***	***11.54***	***12.52***
	Grade Zn (%)	***10.85***	***11.28***	***11.07***	***10.54***	***10.69***

Notes to accompany prior Ore Reserve estimate table:

1. Ore Reserves have an effective date of 31 December of the same year, such that the 2011 estimate was prepared as of 31 December, 2011, the 2012 estimate was prepared as of 31 December, 2011, the 2013 estimate as of 31 December, 2013, the 2014 estimate as of 31 December, 2014. The estimation dates changed in 2015 to the previous year, such that the 2015 estimate has an effective date of 31 December, 2014.
2. Mr Thiago Nantes, employed as a Long-Term Planning Manager with Votorantim, was responsible for each Ore Reserve estimate, and supervised the Votorantim personnel who prepared the estimates.
3. The estimates were reported using a 5% Zn cut-off, which covered mining, processing and other costs, and was considered to be the operating cost cut-off for each year. No lead estimates were performed.
4. Zinc metal prices used were variable: 2011, US$2,033/t; 2012, US$2,407/t; 2013, US$2,260/t; 2014, US$2,376/t; 2015, US$2,376/t.
5. Operating cost assumptions varied by year: 2011: mining cost of US$13.50/t, process cost of US$13.10/t, other costs of US$13.00/t; 2012: mining cost of US$12.90/t, process cost of US$13.50/t, other costs of US$14.00/t; 2013: mining cost of US$13.30/t, process cost of US$14.10/t, other costs of US$12.00/t; 2014: mining cost of US$15.40/t, process cost of US$14.00/t, other costs of US$13.00/t; 2015: mining cost of US$12.70/t, process cost of US$15.10/t, other costs of US$15.00/t.
6. Metallurgical recovery assumptions were 85% for zinc.
7. In all instances, the mining method was vertical retreat mining, assuming typical stope dimensions of 30 x 30 x 5 m. The dilution assumptions used in the estimate varied by stope, based on orebody thickness, and on the minimum operational criteria used. Planned mining dilution averaged 34%. On average, operational mining dilution averaged about 14% in the VRM areas, and about 35% in remnant areas. Mining recovery assumptions included 98% recovery for VRM stopes, and 60% for rib pillars.
8. Rounding may result in apparent summation differences.

The QP has not done sufficient work to classify the prior estimates as current Mineral Resources or Mineral Reserves. Votorantim is not treating the prior estimates as current estimates; the current Mineral Resource estimates are provided in Section 14 of this Report and the current Mineral Reserves in Section 15.

Mineral Resource and Ore Reserve estimates were prepared by Votorantim staff, using the guidance and confidence classifications set out in the 2004 edition of the Joint Ore Reserves Committee (JORC) Code (2004 JORC Code). There is no assurance that the prior estimates are in accordance with the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Definition Standards for Mineral Resources and Mineral Reserves (May 2014; the 2014 CIM Definition Standards) or the CIM

Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines (November 2003; 2003 CIM Best Practice Guidelines), and the prior estimates should not be regarded as consistent with those standards in all aspects.

The prior estimates are supported by internal documentation, but have not been previously disclosed in a technical report under NI 43-101. Votorantim staff performed checks on the supporting data and estimation processes used in the prior estimates as per corporate standards and protocols, which are set out in internal procedures documents. The 2011 Mineral Resource and Ore Reserve estimate was subject to an audit by Snowden Associates, an independent third-party consultant, in 2012. RPA, an independent third-party consultant, reviewed the 2013 Mineral Resource and Ore Reserve estimate in 2014.

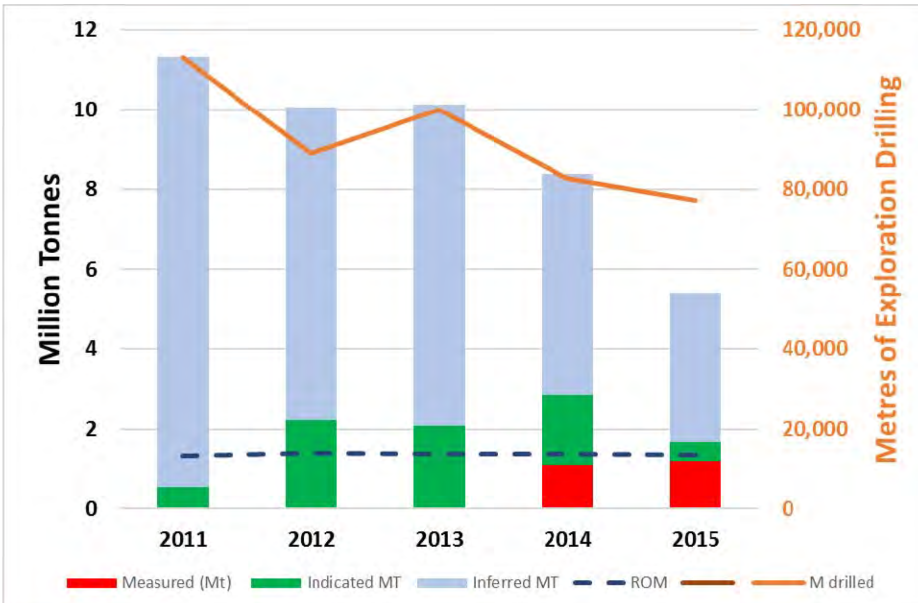
Mineral Resources were prepared under the supervision of a Competent Person. Software used in the Mineral Resource estimation process included LeapFrog Geo™, Datamine™, and ISATIS™. Block models were updated annually, and typically used a 6 m x 6 m x 1 m block size, assuming underground mining using room-and-pillar mining. Estimation was performed using ordinary kriging (OK). Confidence classifications assigned were based on an assessment of drill hole spacing, kriging variance, and data quality sourced from quality assurance and quality control (QA/QC) programs. Cut-off criteria and metallurgical recovery assumptions were based on historical data from the Vazante Operations.

Ore Reserves were prepared under the supervision of an appropriately experienced mining professional who did not have Competent Person status at the time of the estimates. Software used in the Ore Reserve estimation process included Mine 2-4D™ and Deswik™. The stope designs assumed an average size of 30 m x 30 m x 5 m. The block model was adjusted for operational dilution; dilution assumptions used in the estimate varied by stope, based on orebody thickness, and on the minimum operational criteria used. The mine plans supporting the Ore Reserves assumed a combination of mining of primary stopes, and recovery of rib pillar materials. A portion of the Ore Reserves were supported by mine plans and mining assumptions that included Mineral Resources; this was allowed under the 2004 JORC Code. On average, planned dilution averaged 34%, and operational mining dilution averaged about 14%. Mining recovery assumptions included 98% recovery for VRM stopes, and 60% for rib pillars.

Ore Reserves also considered other Modifying Factors, including infrastructure, economic, marketing, legal, environmental, social, and governmental factors.

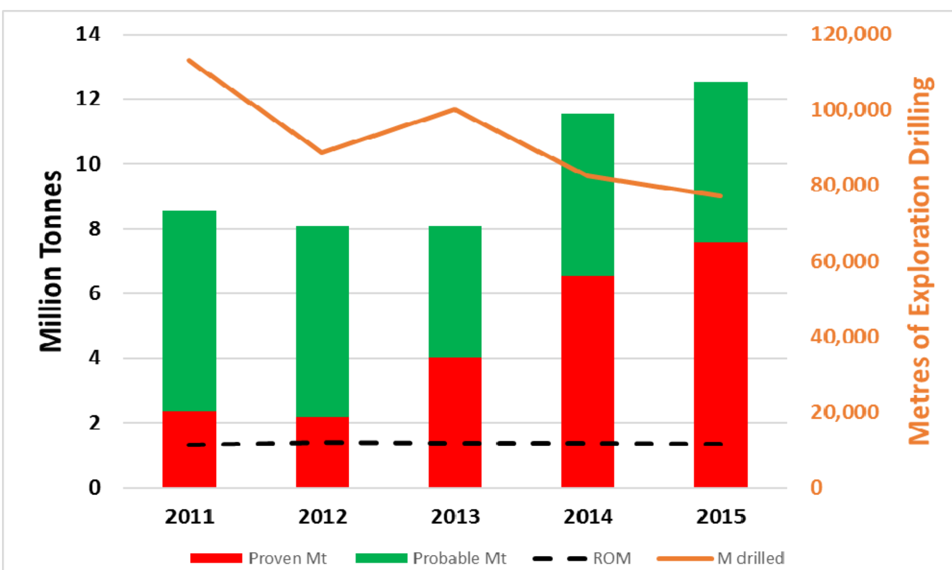
Figure 6-1 is a graphic of the prior estimates that shows the Mineral Resources, drilling completed each year, and the run-of-mine (ROM) production data for each year from 2011 to 2015. Figure 6-2 shows the Ore Reserves against the same drilling and ROM production data.

Figure 6-2: Mineral Resource Prior Estimates, Annual Drilled Metres, and Run-of-Mine Production by Year



Note: Figure prepared by Amec Foster Wheeler, 2017.

Figure 6-3: Ore Reserve Prior Estimates, Annual Drilled Metres, and Run-of-Mine Production by Year



Note: Figure prepared by Amec Foster Wheeler, 2017.

7.0 GEOLOGICAL SETTING AND MINERALIZATION

7.1 Regional Geology

The Vazante and Extremo Norte Mines are situated within the Tocantins Province (Almeida et al., 1977), an orogenic system located between Sao Francisco Craton, Amazon Craton, and a potential covered third cratonic block in the Paraná watershed. The province is bordered by three orogenic mountain ranges: the Paraguay and Araguaia ranges that border the Amazon Craton, and the Brasília range, which borders Sao Francisco Craton. The regional geology is shown in Figure 7-1.

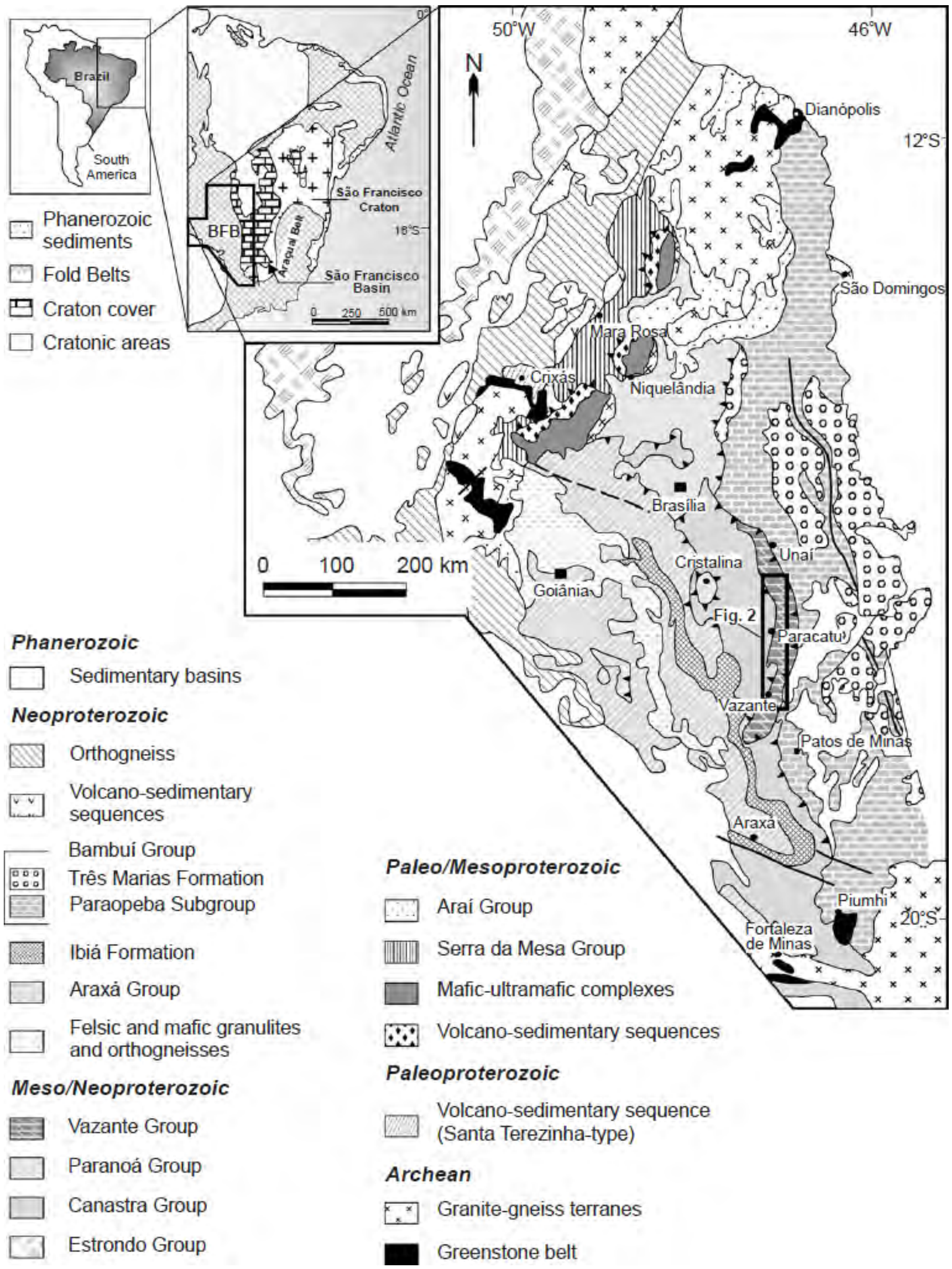
A regional and local geological map is included as Figure 7-2. All known mineralization is hosted by the Meso-Neoproterozoic Vazante Group. Stratigraphy of the Vazante Group is shown in Figure 7-3 (Dardenne, 2000). This stratigraphy is regional in extent and the nomenclature is based on work by Companhia Mineira de Metais (CMM) in the Paracatu and Unaí region in 1987.

The Vazante Formation was first proposed by Dardenne (1979) to designate a set of pelitic-carbonate units traditionally attributed to the Bambuí Group. The Vazante Formation was split in three sections: basal, intermediate, and top. Later, Dardenne et al. (1998) redefined the Vazante Formation as the Vazante Group which included the Retiro, Lagamar, Serra do Garrote, Serra do Poço Verde, Morro do Calcário, and Serra da Lapa Formations.

A schematic cross section of the region, showing the contacts between the Vazante, Canastra and Bambuí Groups, is shown on Figure 7-4.

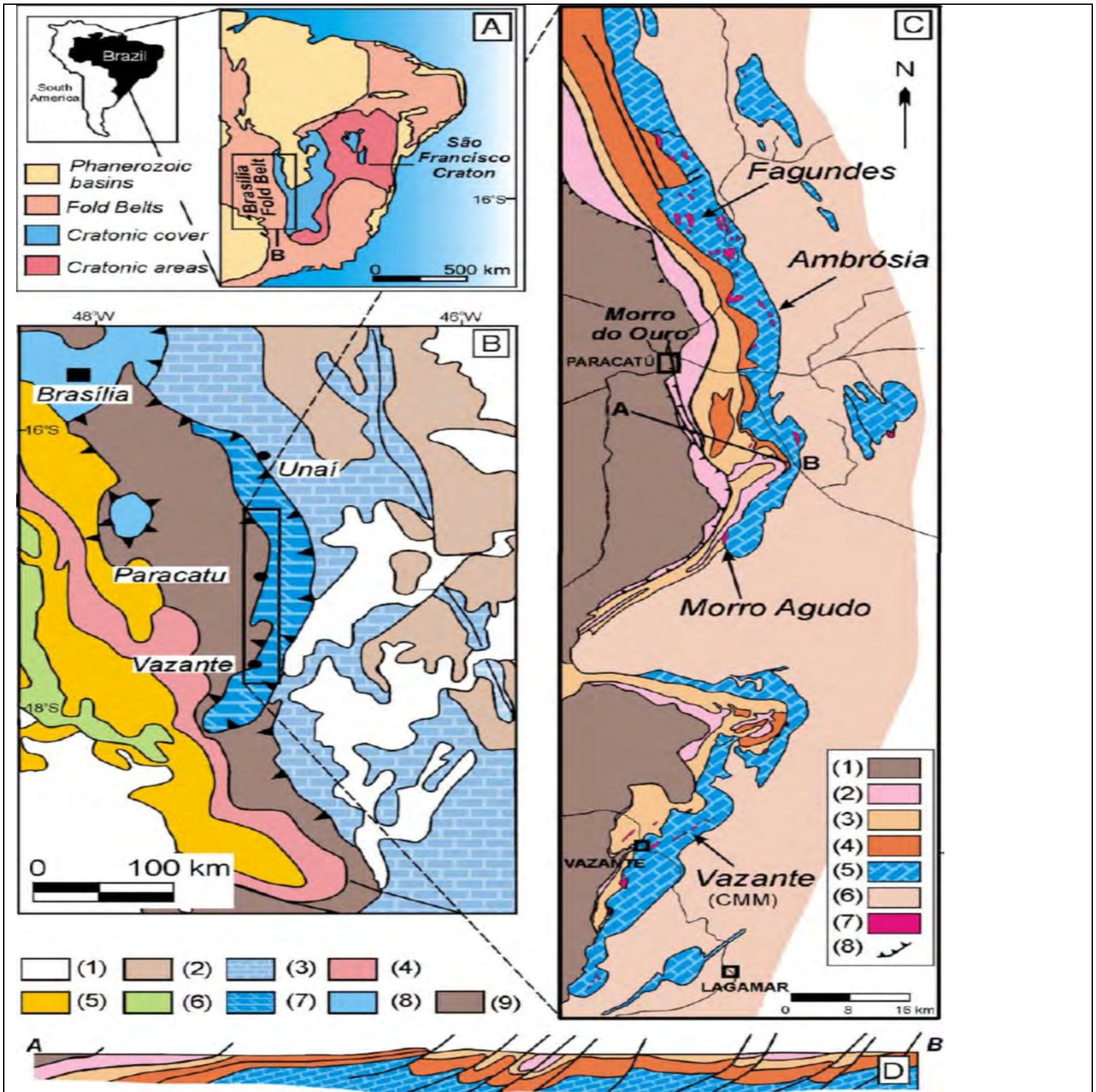
Zinc–lead deposits found in pelitic-carbonate rocks of Sao Francisco Craton are considered to be genetically connected to regional compression that forced basinal brines outward and upward along regional structures (Guimarães, 1962; Beurlen, 1974; Iyer et al. 1992; Iyer, 1984). Zinc-lead deposits were deposited along those structures. Major zinc and lead deposits hosted by Vazante Group occur as two major types. The first type is represented by the Vazante zinc silicate deposit, and the second by the Morro Agudo zinc sulphide deposit. These deposit types have distinct lithostratigraphic controls as well as significant differences in terms of hydrothermal (Vazante) and syn-diagenetic (Morro Agudo) origins.

Figure 7-1: Regional Geological Map of the Brasília Fold Belt



Note: Figure from Dardenne, 2000.

Figure 7-2: Geological Map of the Brasilia Fold Belt and Sao Francisco Craton



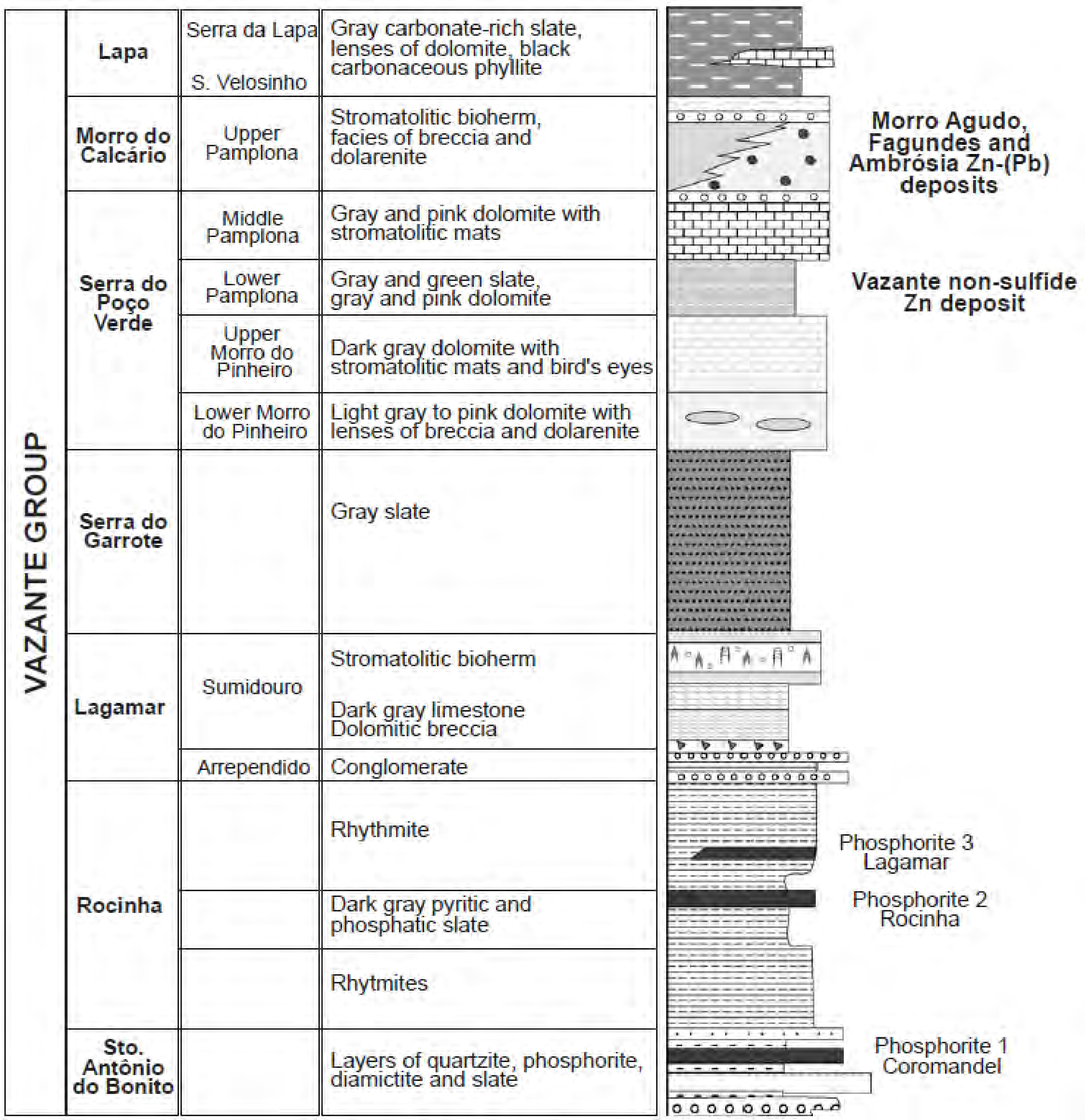
Key:

B) 1) Phanerozoic Basins; 2) Bambuí Group, Tres Marias Formation; 3) Bambuí Group, Paraopeba Subgroup; 4) Ibiá Formation; 5) Araxá Group; 6) Felsic and mafic granulite and orthogneiss; 7) Vazante Group; 8) Paranoá Group; 9) Canastra Group

C) 1) Canastra Group, Paracatu Formation; 2) Canastra Group, Serra do Landim Formation; 3) Vazante Group, Serra Da Lapa Member; 4) Vazante Group, Serra do Velosinho Member, Lapa Formation; 5) Vazante Group, Morro do Calcário and Serra do Poço Verde Formations; 6) Vazante Group, Serra Do Garrote Formation; 7) Pb Anomalies.

Note: Figure after Dardenne, 2000; Monteiro et al., 2007.

Figure 7-3: Stratigraphic Column



Note: Figure after Dardenne, 2000.

Figure 7-4: Schematic Profile of Vazante Group showing Location of Major Mineral Occurrences

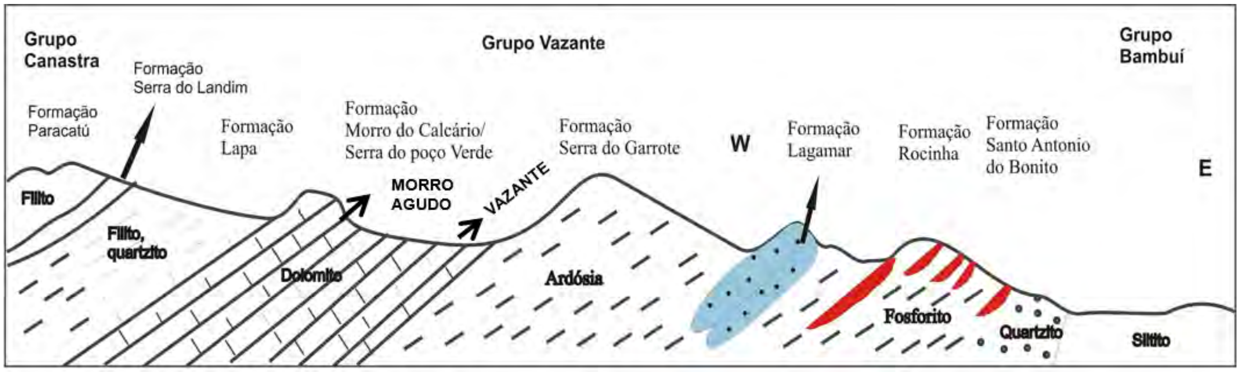


Figure adapted from Dardenne et al., 1998. In this figure, Grupo = Group, Formação = Formation., Filito = phyllite, quartzite = quartzite, ardósia = slate, fosforito = phosphorite, siltito = siltstone.

7.2 Project Geology

The geology of the area consists of a sequence of pelitic carbonate rocks belonging to the Serra de Garrote and Serra do Poço Verde formations of the Vazante Group (Figure 7-5). The currently-known mineralization extends over about 12 km of strike from south of the Vazante Mine to north of the Extremo Norte Mine.

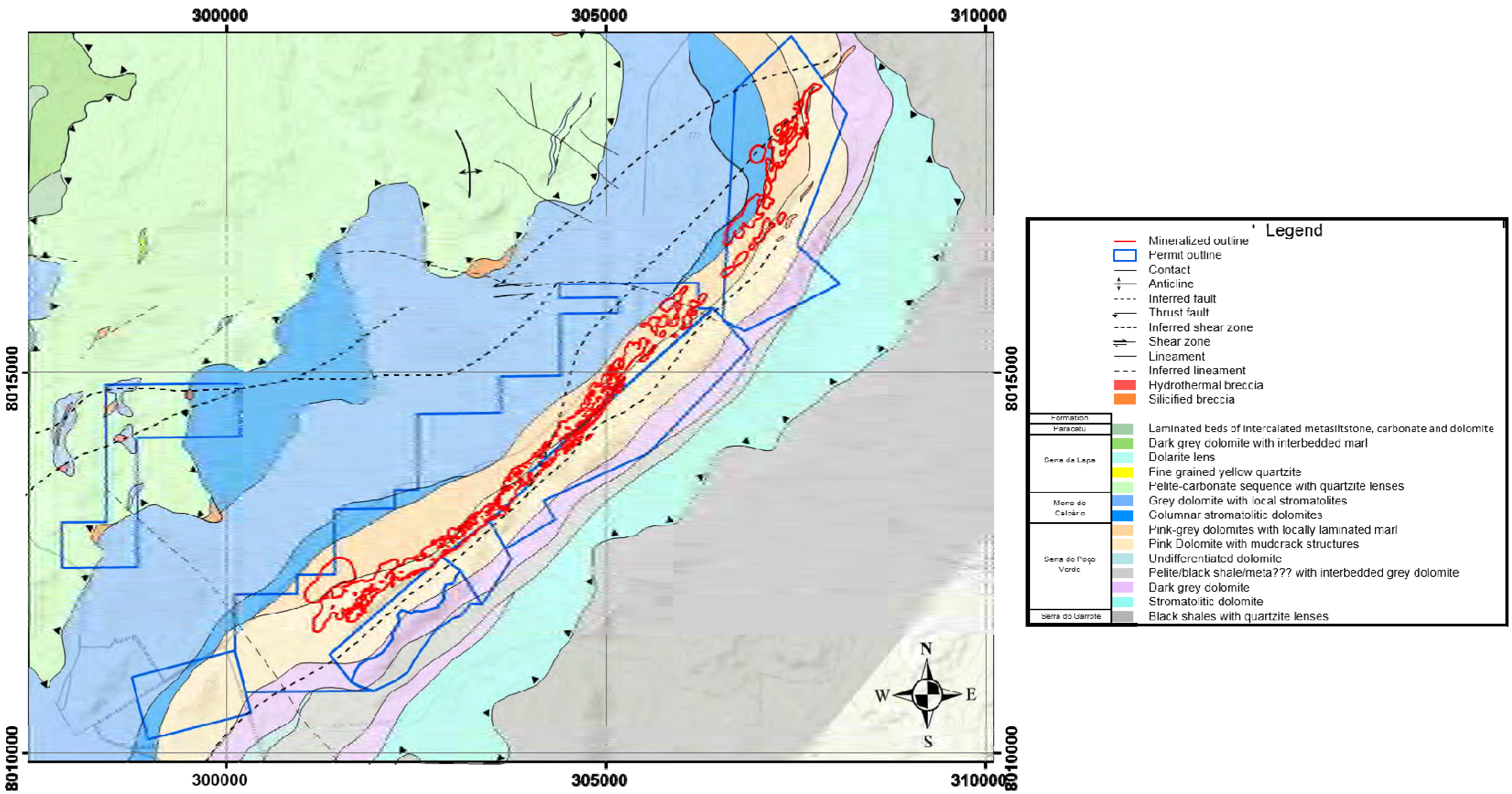
7.2.1 Serra do Garrote Formation

The Serra do Garrote Formation consists of carbon-rich phyllites containing ferruginous breccias and hematite blocks. Ferruginous breccias are likely due to superficial weathering processes. The hematite blocks are possibly due to hydrothermal fluid flows. The phyllites are carbon-rich, black to dark gray when fresh, and quite homogeneous. Outcrops are abundant, taking the form of flat outcrops such as stream bottoms and cliffs, carved on hill slopes, road-cuts, and ravines.

In the field, these phyllites appear as laminated rocks, alternating beds with different colours and particle sizes (Figure 7-6). Bedding thickness ranges from millimetres to centimetres. Sedimentary bedding is typically parallel to subparallel to cleavage (S1). The rock is also affected by late phase kinks (D1), and crenulation cleavage.

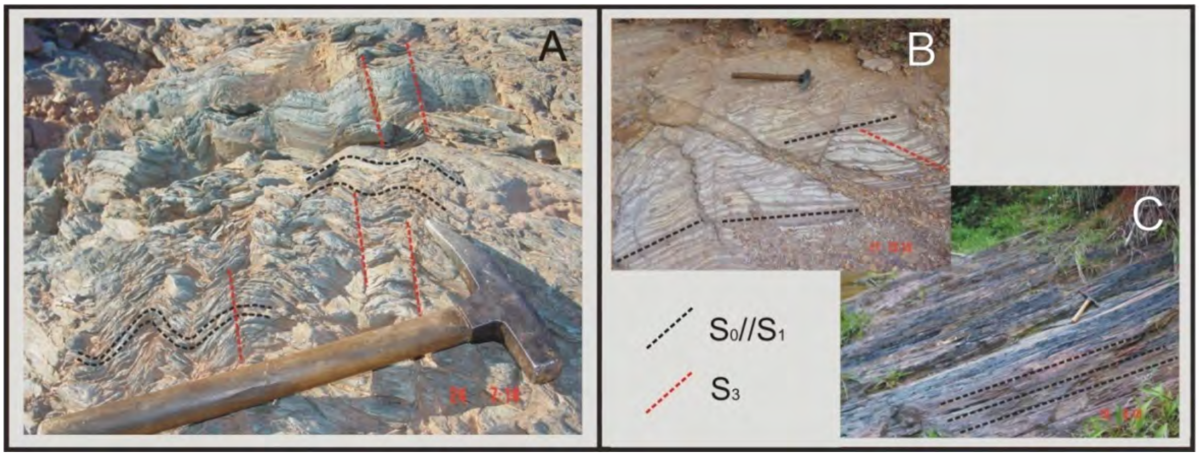
Those phyllites consist primarily of sericite, chlorite, and quartz with minor amounts of detrital crystals of feldspars, tourmaline and stilpnomelane. Iron hydroxide and oxide pseudomorphs after pyrite are interstitial to irregular sericite blades and quartz crystals.

Figure 7-5: Local Geology Plan, Vazante to Extremo Norte Mines



Note: Figure courtesy Votorantim, 2017.

Figure 7-6: Phyllites of the Serra do Garrote Formation



Note: Images courtesy Votorantim, 2017.

7.2.2 Serra do Poço Verde Formation

In the Extremo Norte Mine area, the Serra do Poço Verde Formation is represented from the base to the top by Lower Morro do Pinheiro, Upper Morro do Pinheiro and Lower Pamplona members. The Lower and Upper Morro do Pinheiro members occur to the east of Vazante Fault at the contact between the footwall and the hydrothermal dolomite breccia, and the Lower Pamplona member occurs west of the Vazante fault, at the contact between the cover and the breccia.

Lower Morro do Pinheiro Member

Proposed by Dardenne (1978), the Lower Morro do Pinheiro Member occurs at the base of the dolomitic sequence of the Serra do Poço Verde Formation in the Extremo Norte Mine area. It consists of gray and sometimes pinkish, dolomites, with algal mat features. Occasional bird's eye features, consisting of lens-shaped intergranular spaces filled with sedimentary material, also occur.

This unit features dolomitic conglomerates (dolorudites) characterized by angular to sub-rounded clasts of different sizes, arranged in a limey mud (micritic) matrix. It consists almost exclusively of dolomite and some rare opaque crystals and quartz. The unit is locally silicified and can contain iron-rich dolomite, quartz, and dolomite crenulations.

The almost monomineralic composition is probably related to diagenetic processes that favored complete dolomitization. The presence of dissolution structures and cavity filling such as stromatactis (which consist of cavities filled by well-developed crystals of dolomite with quartz at the middle) are considered to be related to the diagenetic dolomitization process. Much of the unit near the mine is interpreted to be a diagenetic collapse breccia (Figure 7-7).

Upper Morro do Pinheiro Member

The Upper Morro do Pinheiro Member was initially defined by Dardenne (1978). This member features thinly-bedded dolomite, with clay- to silt-sized mineral grains and a massive to slightly laminated structure. This member displays only minor evidence of hydrothermal alteration, and has maintained a light and/or dark gray colour. Primary structures including bird's eyes and algal mats are preserved (Figure 7-8).

The dolomite contains local intraclast breccia lenses with angular clasts of various sizes (0.2–10 cm) surrounded by a dolomite matrix. Gray to greenish metapelite layers with average thicknesses of around 2 to 3 m occur in this member. It is possible to clearly define two metamorphic foliations in the metapelites, a continuous one that features a slaty cleavage, and a discontinuous one that locally generates a crenulation (Figure 7-9).

Lower Pamplona Member

The Lower Pamplona Member was defined by Dardenne (1978). It is located west of the Vazante Fault, in a down-dropped block.

It consists of a metadolomite that is pinkish, fine-grained, and marked by the presence of algal mats that define a sedimentary bedding. It contains several marly intervals that range from purple to greenish in colour. Two metamorphic foliations are recognized in the marls (Figure 7-10).

The unit has been extensively altered by hydrothermal fluids that have commonly produced siderite and ankerite veinlets, and locally, some brecciation. The metadolomite is sometimes totally silicified.

Brecciated Dolomites (Hydrothermal Breccia)

Brecciated dolomites are exposed in a north-south strip associated with the Vazante Fault. They cut the Extremo Norte Mine area where they thicken near the contact with the Serra de Garrote Formation and are characterized by intense strain (D3) that allowed the brecciated structure to develop (Figure 7-11).

The rock type is generally pink to reddish, and few primary structures that evidence the initial sedimentary bedding are preserved. The unit is highly veined, with thick siderite, ankerite and dolomite veins. Clasts are round to sub-rounded, due to the partial assimilation that took place during the flow of hydrothermal fluids. The clasts are chaotically disposed in a totally recrystallized dolomite matrix that has a comb structure.

Figure 7-7: Intraclast Breccias with Subangular Clasts in Dolomite Matrix, with Stromatactis Filled with Dolomite

Note: Images courtesy Votorantim, 2017.

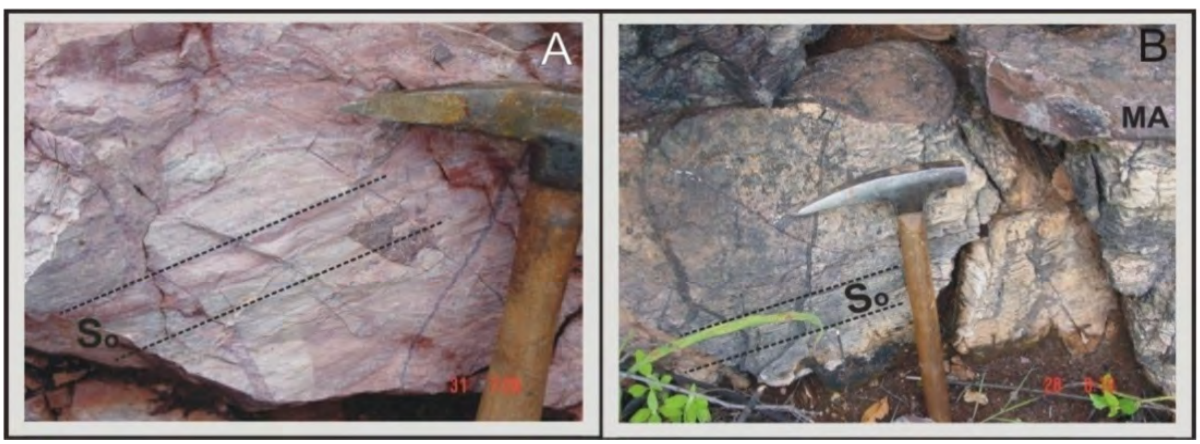
Figure 7-8: (A) Gray, Massive Dolomite with Bird's Eyes and (B) Bird's Eyes Structures

Note: Images courtesy Votorantim, 2017.

Figure 7-9: Metapelite Featuring Two Metamorphic Foliations Oblique to Each Other

Note: Image courtesy Votorantim, 2017.

Figure 7-10: Pink Dolomite with Algal Mats. (A) A Highlight on SO Bedding. (B) Meta-Marl Intercalations (MA).



Note: Images courtesy Votorantim, 2017.

Figure 7-11: Hydrothermal Dolomite Breccia with Intense Veinlet Development

Note: Image courtesy Votorantim, 2017.

7.3 Hydrothermal Alteration

Regionally, hydrothermal alteration is primarily controlled by brecciation and structures relating to brecciation. The most common alteration minerals are siderite, ankerite, quartz and hematite, which can occur as both veins, and matrix infill around breccia clasts. Gahnite was noted in some veinlets close to ore-grade mineralization (Monteiro et al., 1999).

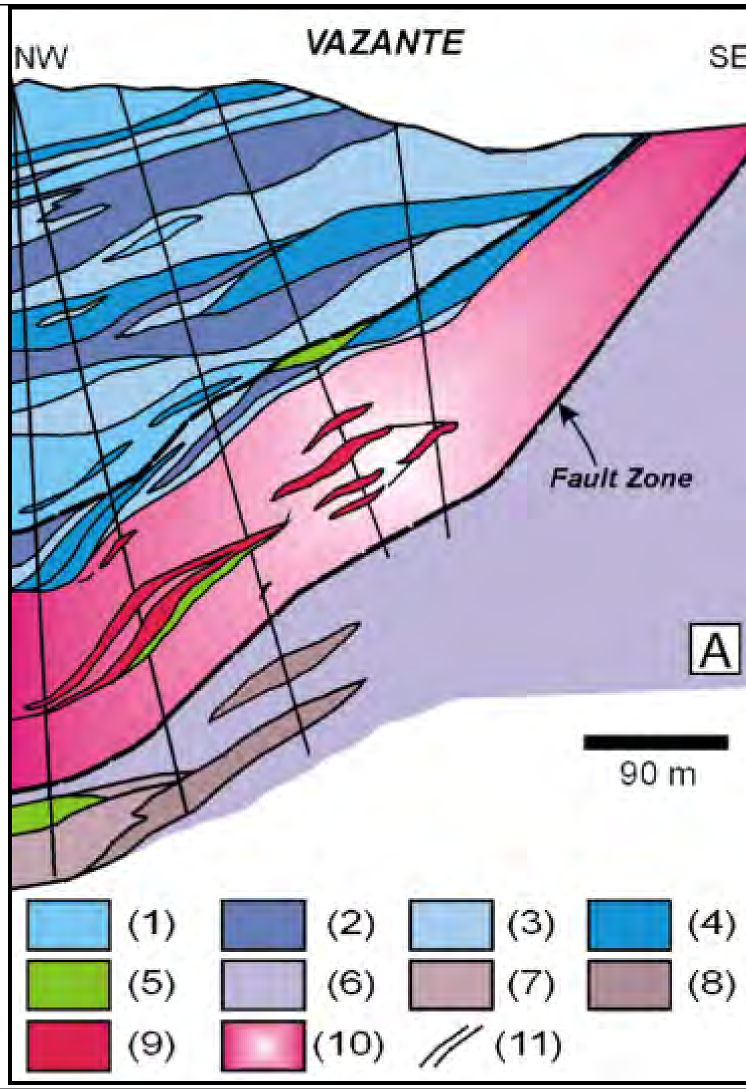
Pervasive hematite alteration may cause a colour change in the gray dolostones to pink. Silicification within the dolostones is also common (Slezak, 2012).

Hydrothermal alteration is well developed in and around the mineralized zones, manifested as ferroan dolomite, ankerite, siderite, and replacement silica that persist for about 100 to 150 m into the hanging wall and 50 m into the footwall of the fault zone (Hitzman et al., 2003). Within the Vazante Fault zone, silica–hematite veins cut ferroan dolomite, particularly along the upper and lower edges of the fault zone.

7.4 Mineralization

Mineralization is hosted in the Vazante Shear Zone, which is approximately 12 km long, strikes N50E, and dips 60NW (Figure 7-12).

Figure 7-12: Vazante Schematic Cross Section



Key

1) Serra do Poço Verde Formation, Lower Pamplona Member, Gray dolostone
2) Serra do Poço Verde Formation, Lower Pamplona Member, Sericitic phyllite, slate, marl
3) Serra do Poço Verde Formation, Lower Pamplona Member, Pink dolostone
4) Serra do Poço Verde Formation, Lower Pamplona Member, Light gray dolostone, quartz sericite phyllite
5) Metabasite
6) Upper Morro do Pinheiro Member, dark gray dolostone
7) Upper Morro do Pinheiro Member, pyrite-bearing black phyllite
8) Upper Morro do Pinheiro Member, pyrite-rich metamarl
9) Nonsulphide zinc mineralization
10) Breccia
11) Limit of Vazante Fault (shear) zone

Note: Figure after Monteiro et al., 2007

Mineralization at Vazante and Extremo Norte is hypogene and composed mainly of willemite (Zn_2SiO_4) hosted by sphalerite-rich carbonate. Mineralization typically contains willemite (50% to 70%), dolomite (10% to 30%), siderite (10% to 20%), quartz (10% to 15%), hematite (5% to 10%), zinc-rich chlorite (5% to 10%), barite (<5%), franklinite (<5%), and zincite (<5%), with subordinate concentrations of magnetite and apatite (Monteiro et al., 2006).

7.5 Deposit Descriptions

7.5.1 Vazante

The zinc silicate mineralization of the Vazante deposit is hosted in a tectonic-hydrothermal breccia zone found near the contact between the Lower Pamplona and Upper Morro do Pinheiro Members.

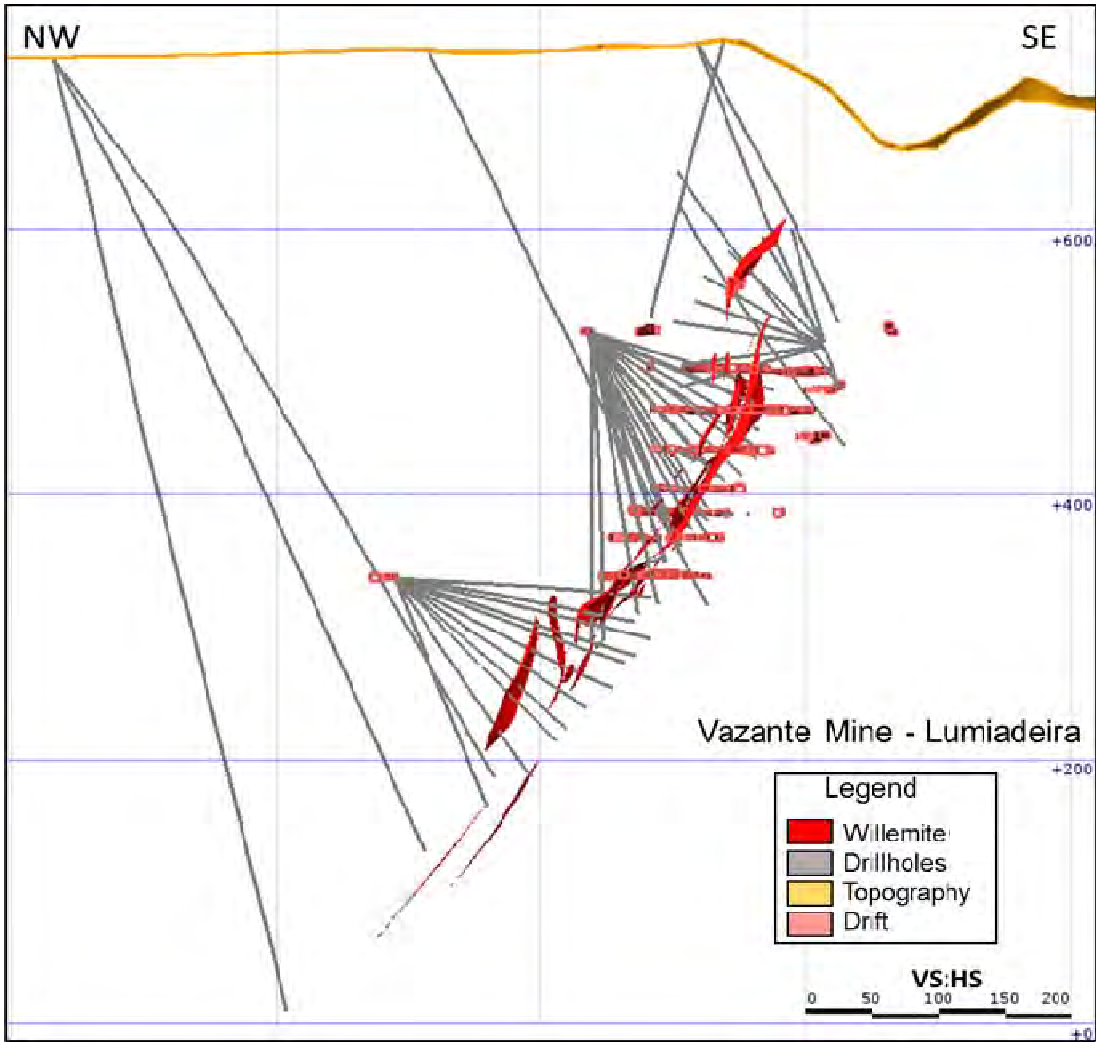
Metamorphosed dikes are tectonically imbricated with the carbonates and hydrothermal breccias in the main orebody.

The Vazante orebody is about 7 km long, has a variable thickness, and is currently known to extend to at least 400 m depth below surface. Willemite can form as pods, veinlets, and metre-wide veins within the hydrothermal breccia and is locally controlled by antithetic faults in the deposit. The willemite composition, according to electron micro-probe (EMP) studies conducted by Monteiro et al. (2006), contains minor amounts of FeO (to 0.3 wt %) and CaO (to 0.13 wt %).

Willemitic mineralization is tectonically imbricated with small sulphide orebodies, metabasites, and brecciated metadolomites. The sulphide orebodies are offset by normal and reverse faults, and cut by late hydrothermal veins. This can cause a complex relationship between orebodies and host rocks. The sulphide bodies consist of iron-poor sphalerite with round inclusions of galena, and occasional inclusions of hematite, quartz, and dolomite. The relationship between sphalerite and willemite is not well understood. They may have co-precipitated from the same solution (e.g. Monteiro et al., 1999; Hitzman et al., 2003), or the willemite may be an alteration or metamorphic product after sphalerite (e.g. Appold and Monteiro, 2009).

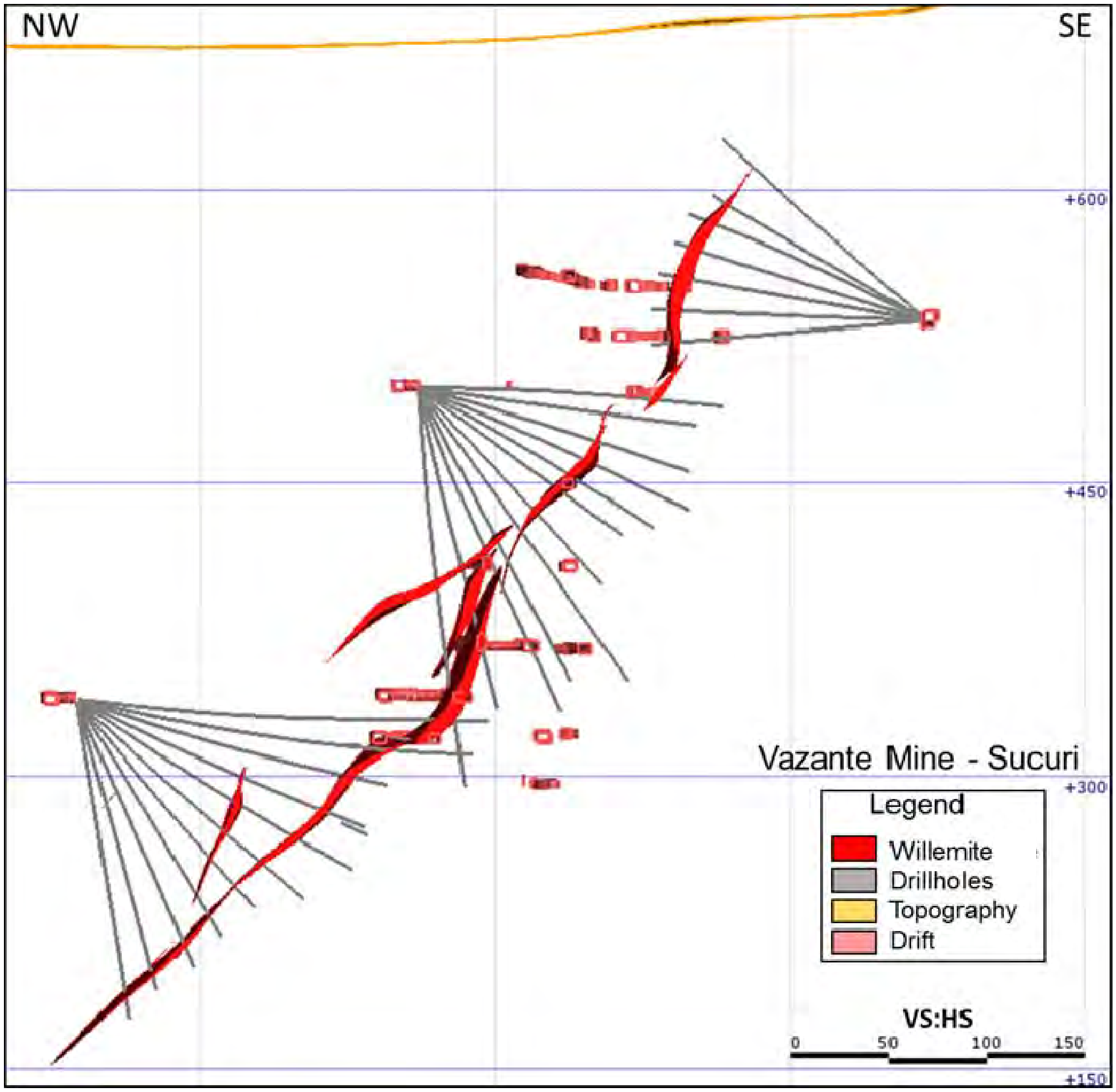
A cross section through the Lumiadeira area of the Vazante Mine is provided in Figure 7-13. Figure 7-14 is a cross section through the Sucuri area.

Figure 7-13: Cross Section, Vazante Mine, Lumiadeira Area



Note: Figure courtesy Votorantim, 2017.

Figure 7-14: Cross Section, Vazante Mine, Sucuri Area



Note: Figure courtesy Votorantim, 2017.

7.5.2 Extremo Norte

The Extremo Norte mineralization is associated with the Vazante Fault Zone, and primarily hosted in the Lower Pamplona Member, or along the contact between the Lower Pamplona and Upper Morro do Pinheiro Members.

Mineralization consists of willemite (variable percentages, but may reach as much as 40%), specular hematite (1–50%), and minor franklinite ($ZnFe_2O_4$). Mineralized zones form discontinuous lenses that may be tens of metres in length and width, within tectonic–hydrothermal breccias. Breccias may range from a few, to nearly 100 m in thickness, and typically gently plunge to the south (Slezak, 2012).

A section through the Extremo Norte Mine is included as Figure 7-15.

The Vazante Mine mineralization occurs at a greater depth, has more sulphide associated with the silicate ore, and has experienced more ductile deformation than the Extremo Norte mineralization. Metamorphosed and hydrothermally-altered basic dykes are tectonically imbricated with the carbonates and hydrothermal breccias in the Vazante Mine (Babinski et al., 2005), but have not been observed at Extremo Norte (McGladrey, 2014).

7.6 Prospects/Exploration Targets

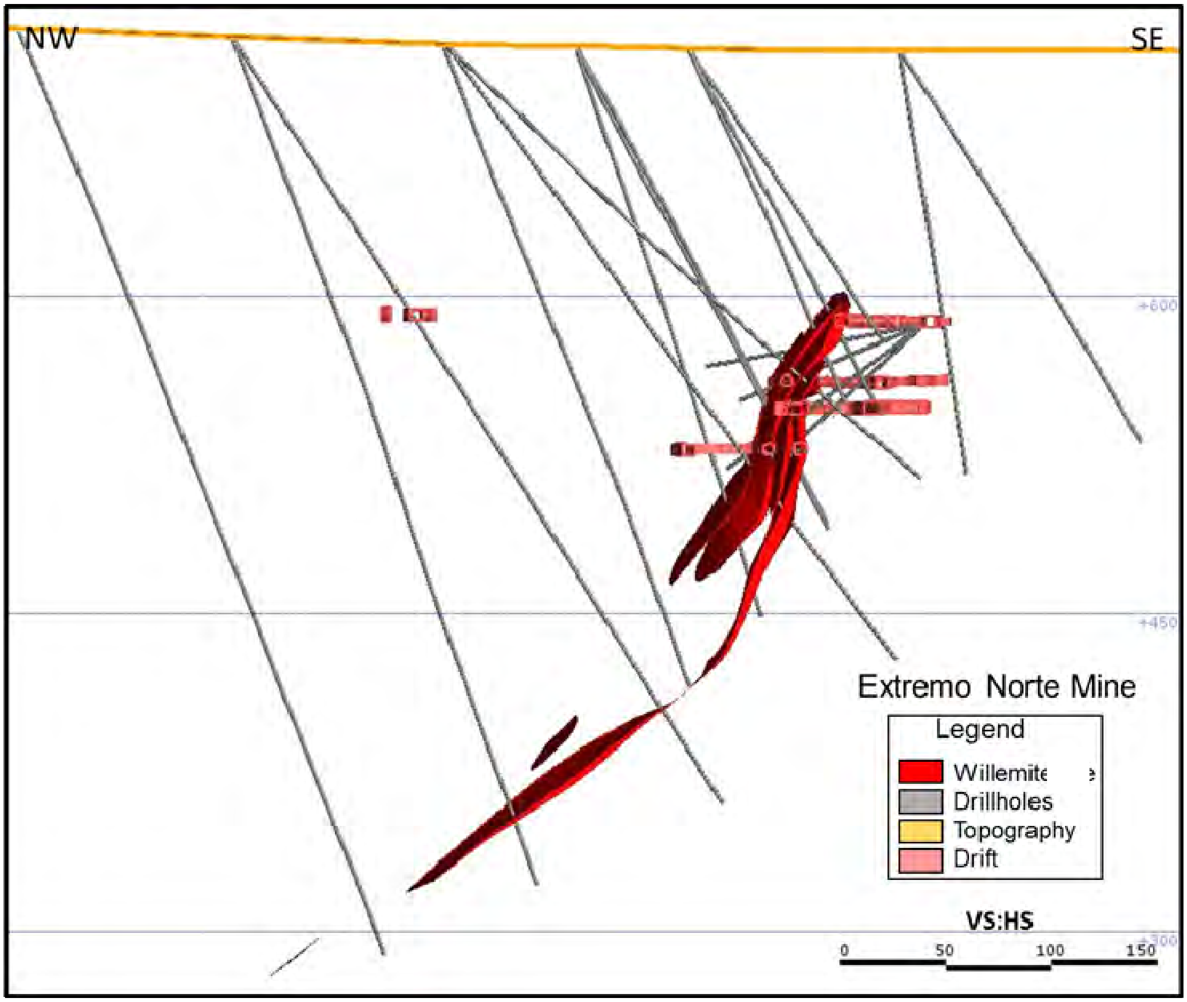
Exploration potential is discussed in Section 9.7.

7.7 Comments on Section 7

The geological setting is adequately known to support Mineral Resource estimation and mine planning.

Understanding of the mineralization is adequate to support Mineral Resource estimation and mine planning.

Figure 7-15: Cross Section, Extremo Norte Mine



Note: Figure courtesy Votorantim, 2017.

8.0 DEPOSIT TYPES

8.1.1 Deposit Model

Vazante Operations zinc deposits are an unusual epigenetic zinc silicate deposit type, and are one of the largest deposits of that type worldwide. Similar deposits occur at Franklin and Sterling Hill (New Jersey, USA), Beltana (South Australia) and Kabwe, in Zambia (Hitzman, et al., 2003).

Two types of non-sulphide zinc deposits are known, supergene deposits and hypogene deposits (Hitzman, et al., 2003). Hypogene deposits are further subdivided as being either structurally-controlled or stratiform.

Typical features of structurally-controlled non-sulphide zinc (or zinc silicate) deposits include:

- Occur in Neoproterozoic to Cambrian sedimentary basins that have been metamorphosed to at least sub-greenschist facies
- Hosted in carbonate rocks associated with major structures, such as district-scale faults and folds
- Associated with brecciation, which may be the result of either karstification, or the result of tectonism and hydrothermal fluid flow
- Dominant economic mineral is willemite. May include zinc oxides such as zincite, franklinite, or zinc carbonates, such as smithsonite
- Alteration minerals can include ferroan dolomite, hematite, and quartz.

8.1.2 Discussion

The mineralization at the Vazante Operations is linked to the development of the shear zone associated with the Vazante Fault, which has been interpreted to be a transpressional transcurrent fault that later reactivated as a normal fault (Monteiro et al., 2007; Pinho, 1990).

The current primary ore consists of hydrothermal zinc silicates, largely willemite. Supergene calamine ores were formerly mined.

Primary mineralization has two strong controls: lithostratigraphic, and structural. The deposit is clearly confined to a clay–dolomite interval near the contact between the Lower Pamplona Member and Lower Morro do Pinheiro Member, and the mineralization is restricted to the breccia area in a fault zone with a long history of reactivation (Monteiro, 2002). This primary ore resulted from deposition of metals from hydrothermal fluids in the shear zone associated with the Vazante Fault.

The morphology of the Vazante deposit consists of veins and anastomosed podiform bodies that are fault-limited.

- Geochemical controls on deposition of mineralization are not well understood and the metal source is not known. The deposit genesis is thus debated. It may have originally represented a sulphide deposit that was silicified, or may have consisted of silicates that were later re-concentrated into the Vazante Fault Zone.
- Monteiro et al. (1999, 2006, 2007) suggest that the willemite can form by reacting sphalerite and quartz through the reaction:

  $2ZnS + 2SiO_2 + 2O_2 = 2ZnSiO_4 + S_2$

This reaction would presumably occur during a low-grade metamorphic event.

Brugger et al. (2003) investigated the origin of these deposits and suggested that the willemite could form by direct precipitation from hydrothermal fluids under high pH and high oxygen fugacity (f_{O2}/f_{S2}) conditions.

Hitzman et al. (2003) concluded that the fluids responsible for transporting zinc to the Vazante-type zinc deposits appear to be geochemically similar to solutions produced in many continental sedimentary basins. Because non-sulphide zinc deposits appear to form from the mixing of highly oxidized, sulphur-poor solutions with zinc-bearing solutions, they could be found in the same districts as sphalerite-rich Mississippi Valley-type or Irish-type deposits formed by fluid mixing. Such appears to be the case in the Bambuí Group in Brazil.

The Irish-type Morro Agudo zinc–lead deposit, approximately 100 km north of Vazante, occurs in rocks stratigraphically above the level of mineralization at Vazante. Morro Agudo, like other Irish-type deposits (Hitzman and Beaty, 1996), formed by the mixing of a metal-rich, sulphur-poor reduced hydrothermal fluid with a sulphur-rich fluid. Vazante may have formed through the mixing of a similar metal-rich, reduced hydrothermal fluid with a highly oxidized, sulphur-poor fluid (Hitzman et al., 2003).

This deposit style is currently the main zinc deposit type being explored for in Brazil.

8.2 Comments on Section 8

The Vazante zinc deposit is an usual epigenetic zinc silicate deposit, and is one of the largest deposits of its type worldwide. Somewhat similar deposits are known from elsewhere in the world. Primary mineralization is strongly controlled by lithology and structure. The deposit is clearly confined to a clay–dolomite interval that is stratigraphically well-defined, and the mineralization is restricted to the breccia area along a fault zone with a long history of reactivation. The geochemical controls on mineralization are not well understood and the deposit genesis remains controversial. Additional research is required to better understand the origin of these deposits.

The structural and stratigraphic controls are sufficiently well understood to provide useful guides to exploration, Mineral Resource estimation, and mine planning. The QP considers that an epigenetic zinc silicate deposit model is appropriate to support exploration vectoring.

9.0 EXPLORATION

9.1 Introduction

Zinc was first discovered at Vazante in 1951 when gossan and calamine were discovered in surface outcrops. Since then, exploration has largely consisted of geological mapping and geophysical surveying with minor geochemical sampling. Geochemical sampling is useful only for discovery of near-surface deposits and many of the known deposits are not located near the surface. Geophysical surveys are useful to identify structure and Zn silicate deposits. In the Vazante Operations area, exploration has supported all the mine extensions and continues with possible deepening of the mine. In the Vazante and Extremo Norte Mine areas, geochemistry and geophysics have been superseded by drilling as the primary exploration tool.

9.2 Grids and Surveys

The grid system used for regional exploration survey data is UTM SAD69 Zone 23S. For exploration in the Vazante Mine area, the grid used is UTM Córrego Alegre Zone 23S.

The regional topographic surface used to reconcile exploration acquisition information and 3D software (Leapfrog) is the shuttle radar topography mission (SRTM). Contour lines every 5 m were created using GEOSOFT software.

9.3 Geological Mapping

Mapping programs have been conducted by US Steel (1969), Rio Doce Geologia e Mineração S/A (1970s), Serviço Geológico Do Brasil (1986, 2013, 2015), and Votorantim (2004–date).

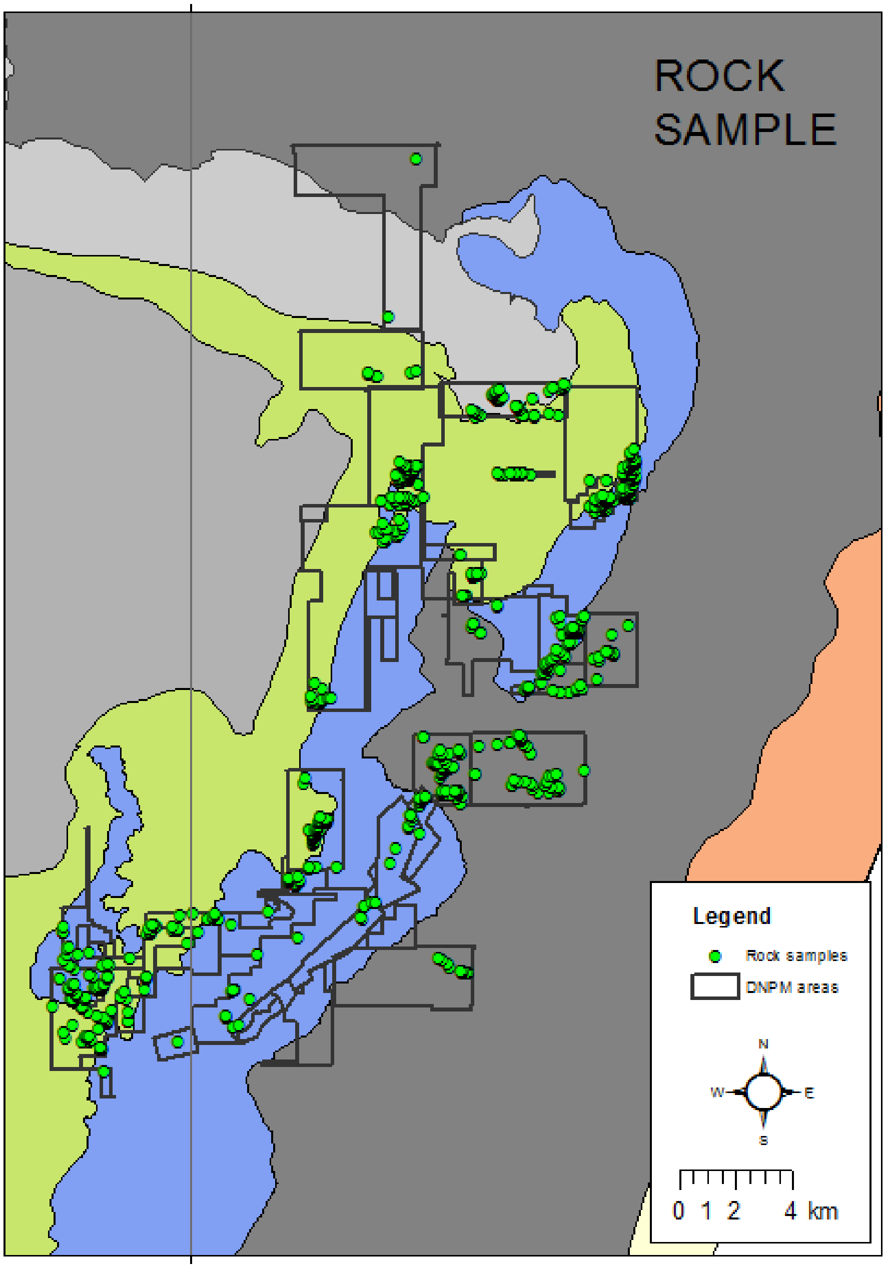
Mapping scales have ranged from regional (1:100,000, 1:75,000, 1:50,000) to more local (1:10,000), as exploration vectored into targets that warranted the additional level of detailed mapping. Geological mapping has collected information such as lithology types, gossan and sulphide zinc exposures, alteration zones, and faults and structural data.

The acquired information is used to guide exploration programs and drill targeting.

9.4 Geochemical Sampling

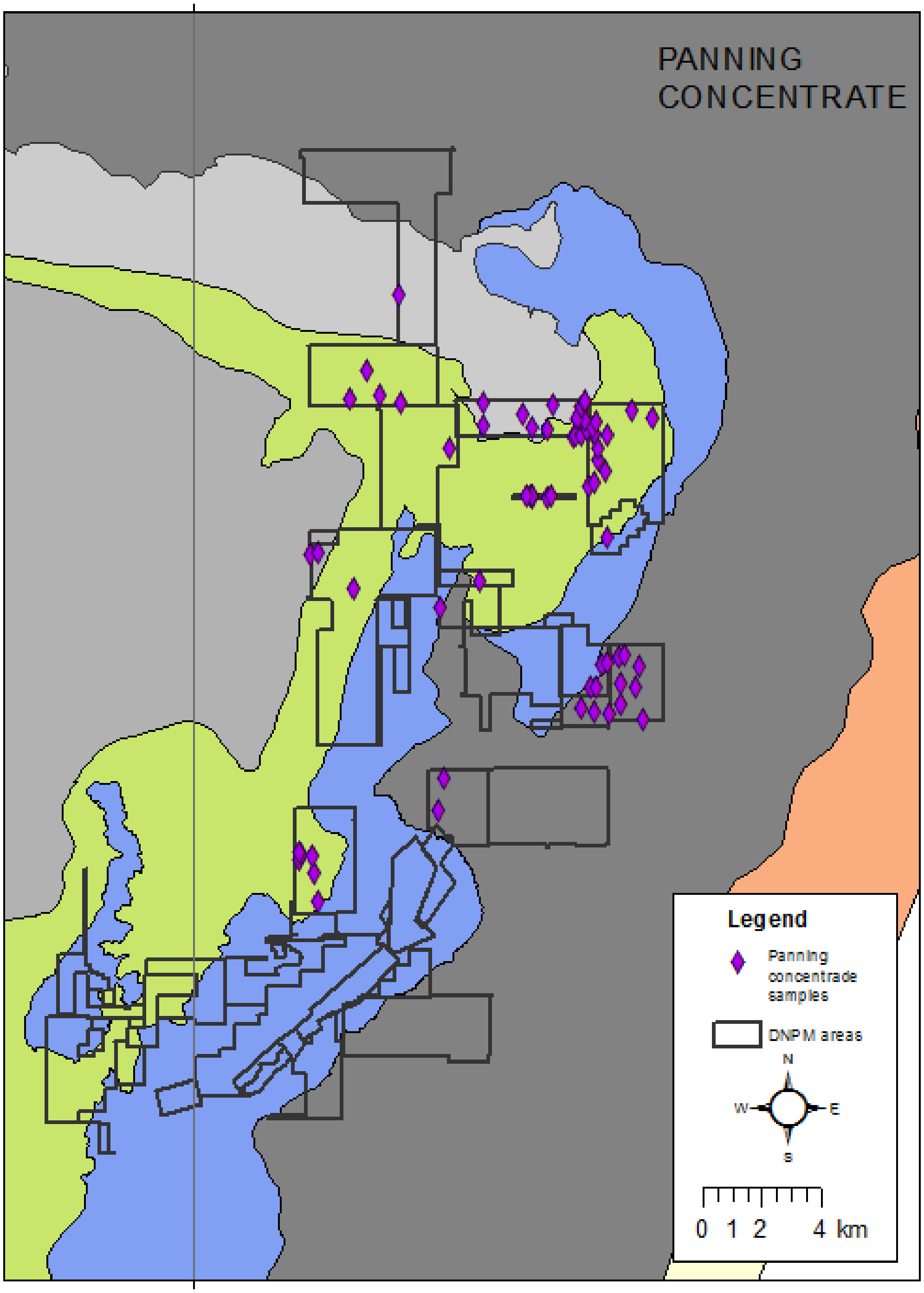
Geochemical exploration activities have included collection of 1,073 rock chip (Figure 9--1), 71 pan concentrate (Figure 9-2), 332 stream sediment (Figure 9-3) and 2,080 soil samples (Figure 9-4). Figure 9-5 is a lithology key for the backdrop used for the figures.

Figure 9-1: Location Plan, Rock Chip Sampling



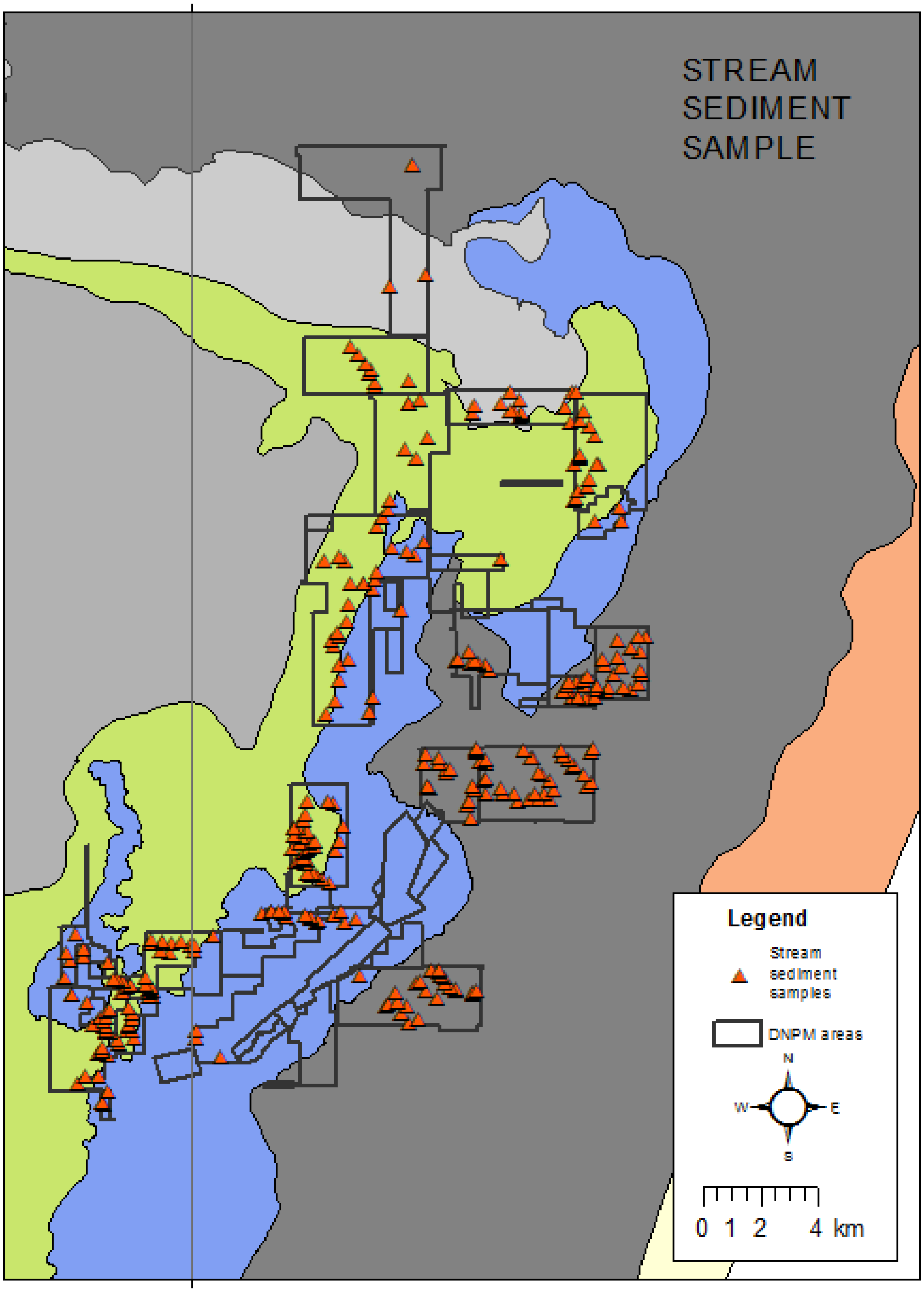
Note: Figure courtesy Votorantim, 2017

Figure 9-2: Location Plan, Pan Concentrate Samples



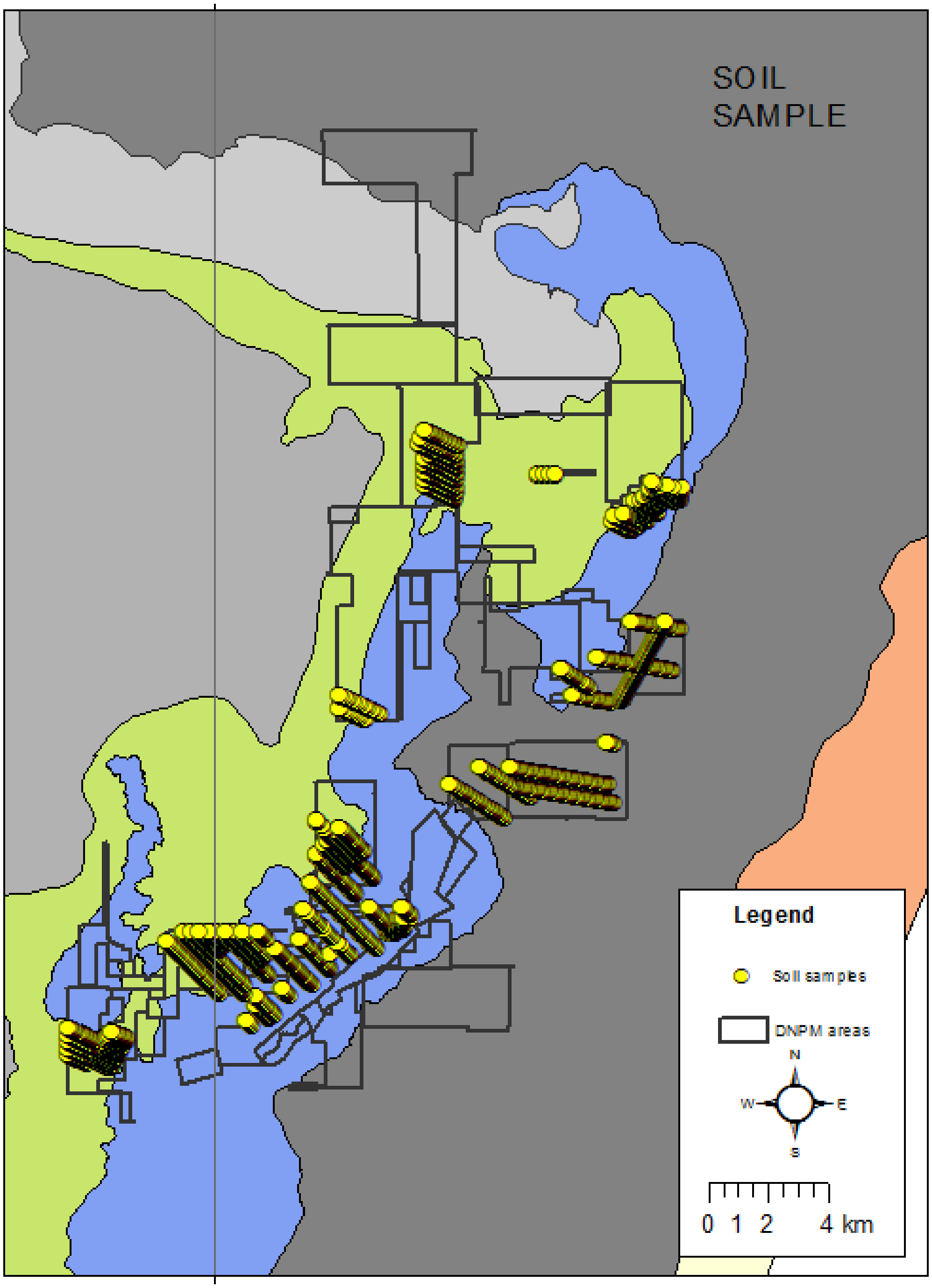
Note: Figure courtesy Votorantim, 2017

Figure 9-3: Location Plan, Stream Sediment Samples



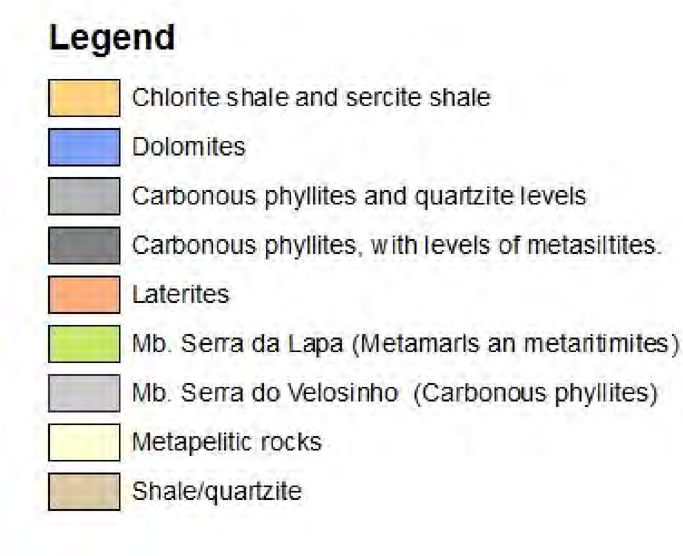
Note: Figure courtesy Votorantim, 2017

Figure 9-4: Location Plan, Soil Samples



Note: Figure courtesy Votorantim, 2017.

Figure 9-5: Legend Key for Figure 9-1 to Figure 9-4



Note: Figure courtesy Votorantim, 2017.

Rock chip sampling mainly focused on outcrops within the Morro do Calcário Formation. Stream sediment sampling was used where stream conditions warranted. Soil sampling, like rock chip sampling, was primarily over areas considered to be underlain by the Morro do Calcário Formation. Results were used to generate drill targets.

9.5 Geophysics

9.5.1 Airborne Surveys

An airborne survey was completed by Lasa, a geophysical contractor, on behalf of Companhia Mineradora de Minas Gerais (COMIG) in 2000–2001. The survey used a fixed wing Islander BN2-A aircraft. The sensor was a magnetic system with caesium vapour, Scintrex CS-3 model, with 10 Hz frequency and a sampling interval of 6 m. Control lines were spaced at 2,500 m, with flight lines at 250 m, and an average flight height of about 100 m. The survey covered about 85,155 linear km.

An airborne geophysical survey was flown by Lasa on behalf of Votorantim in 2010, covering an approximate area of 346.2 km². The aircraft used was a Caravan C208 (PR-FAK) with flight lines spaced of 150 m and control lines spaced at 1,500 m. The average flight height was 100 m. The magnetic survey used a Scintrex cesium vapor sensor, model CS-3, with a resolution of 0.001 nT. Gravity data were acquired using the FALCON ™ AGG system.

A segment of the survey images over the Vazante Operations area is provided in Figure 9-6 (magnetics) and Figure 9-7 (gamma spectroscopy).

Magnetic survey information was used to delineate fault structures and lineaments that could play a role in localizing mineralized fluids. Gravity data were used in an attempt to differentiate areas of zinc mineralization, as there is a marked gravity difference between the host rocks, and zones of zinc sulphide/willemite mineralization.

9.5.2 Ground Surveys

Ground magnetic surveys were completed in 2009 over the Vazante Mine area (144.6 line km), Extremo Norte Mine area (24.9 line km), Agua Doce prospect (14.3 line km) and the Lagoa Feia prospect (136.6 km). The surveys targeted areas of late faulting, and areas where franklinite, which is weakly magnetic, and associated with mineralized iron–carbonate, could occur. Figure 9-8 shows the areas where the surveys were conducted.

During 2016, an induced polarization (IP) survey was completed at the Extremo Norte Mine (1.3 line km) and the Lages prospect (7.45 line km). Additional IP surveys were performed in 2017 at Lages (3.7 line km), Lagoa Feia (10.8 line km) and Boi Branco (3 line km). Figure 9-9 shows the areas where the surveys were conducted. The survey targeted areas of low resistivity and high chargeability that could represent pyrite mineralization that could be associated with sphalerite and galena. Good results were achieved over the Lages prospect.

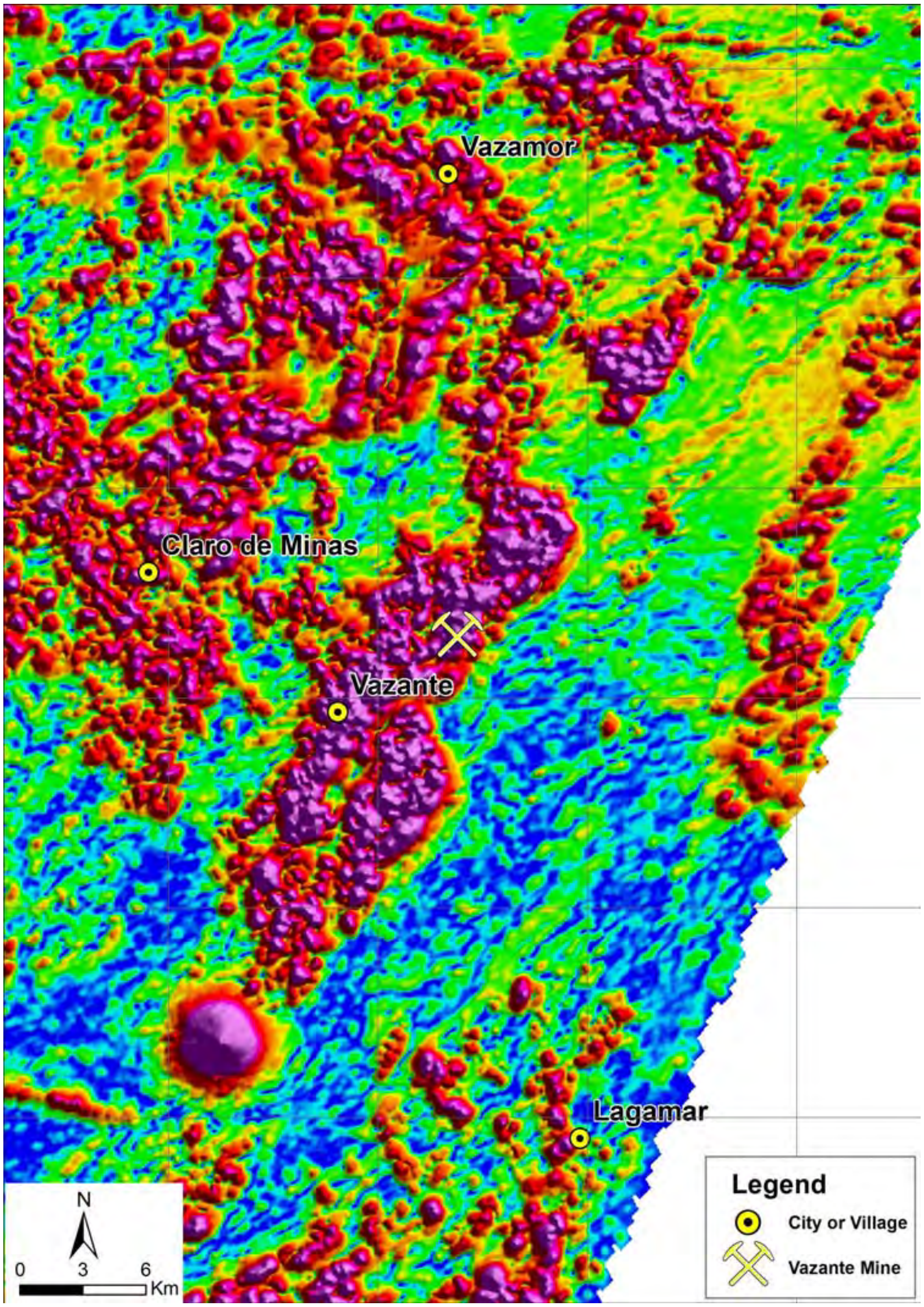
An orientation IP line was run over the Extremo Norte Mine area to see if the known willemite mineralization had a detectable geophysical signature (see also discussion in Section 9.7.1).

Northwest-trending late-stage faults appear to preferentially host significant water flows, resulting in the development of karst features that are very difficult to drill through. Based on limited data, these areas may be able to be identified on the basis of resistivity values. If, so, these data may have a significant impact on the collar placement and orientation of future drill holes.

9.6 Geotechnical and Hydrological Studies

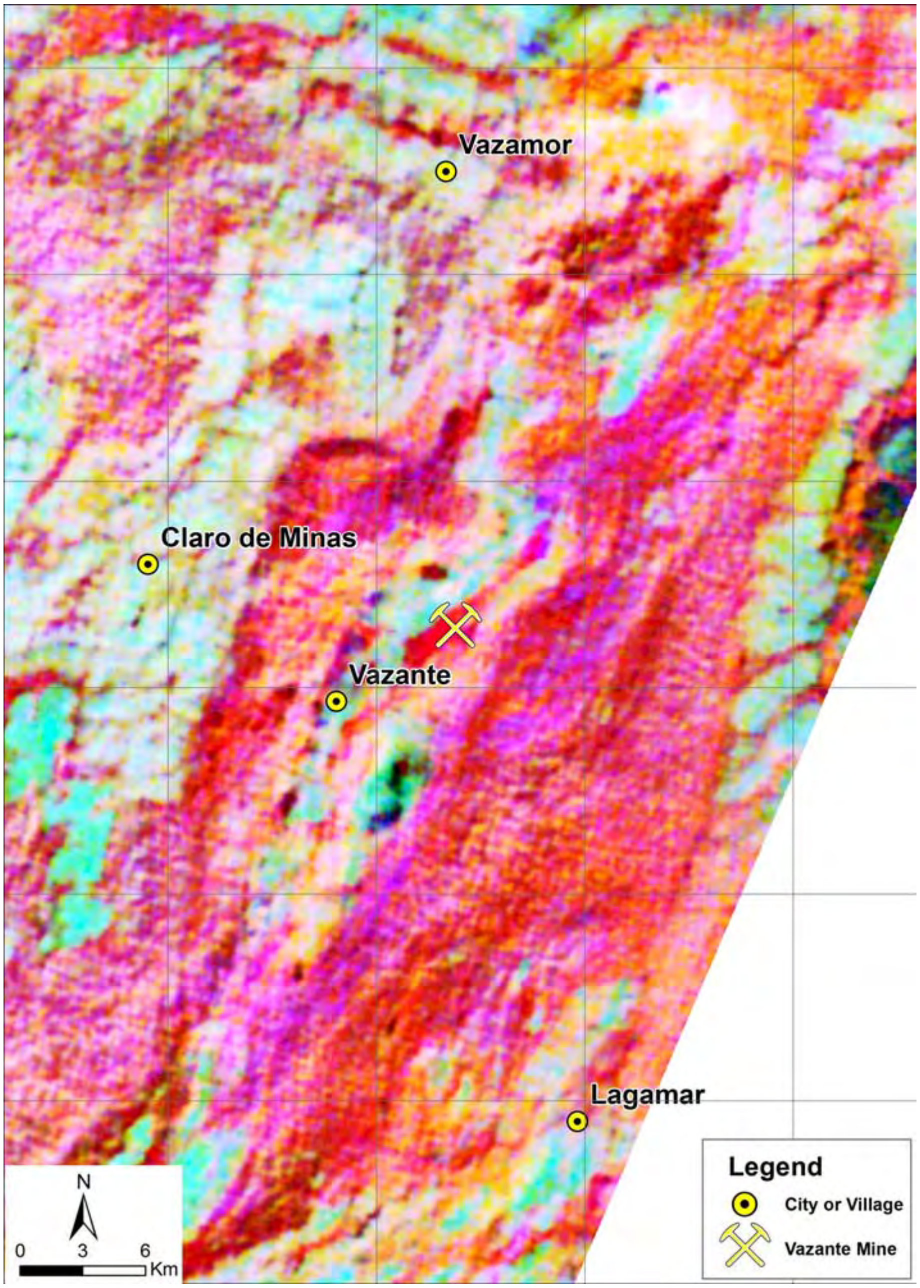
The main lithological units have been well described (dolomitic breccia, grey or pink dolomites, and black phyllites) and modelled with sufficient detail to support geotechnical characterization and evaluation of geotechnical risks related to mining activities. Given the mining methods employed, rock mass conditions and mining depths, it is considered that the rock reinforcement and support types are suitable.

Figure 9-6: Regional Gamma Spectroscopy Image



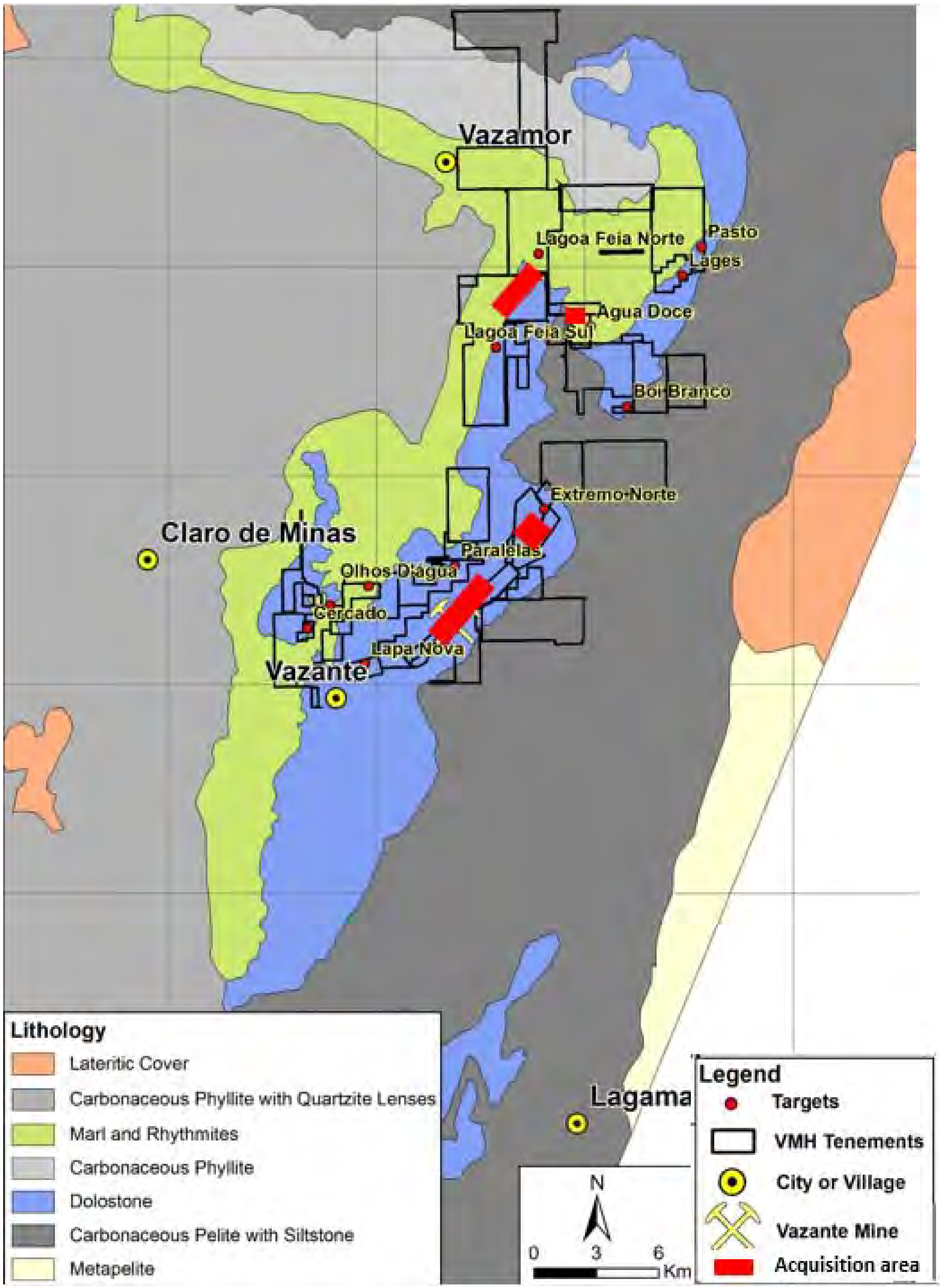
Note: Figure courtesy Votorantim, 2017, sourced from Brazilian Geological Survey data.

Figure 9-7: Regional Magnetometry Image



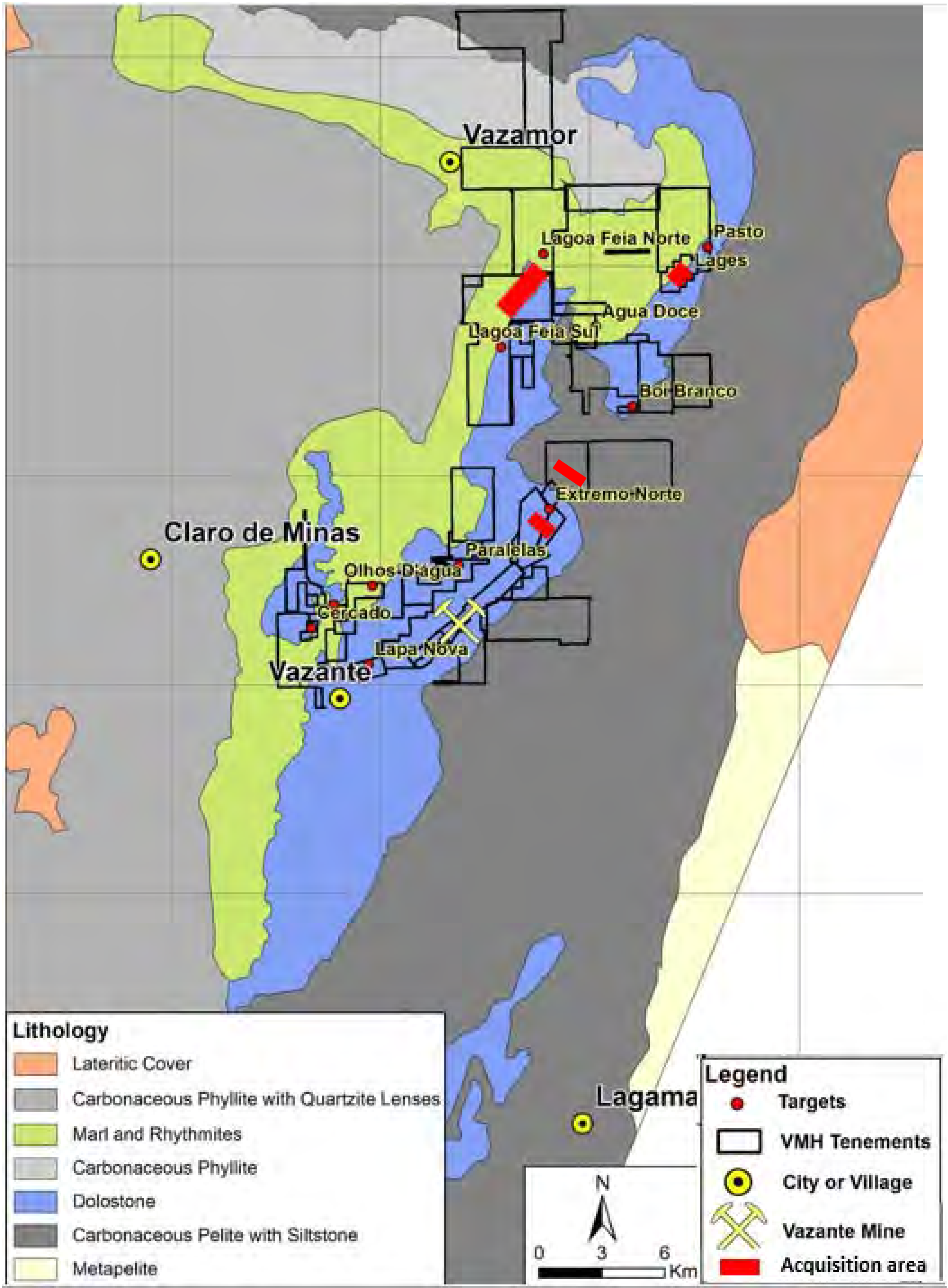
Note: Figure courtesy Votorantim, 2017, sourced from Brazilian Geological Survey data.

Figure 9-8: Location Extent, Ground Magnetic Surveys



Note: Figure courtesy Votorantim, 2017.

Figure 9-9: Location Extent, IP Surveys



Note: Figure courtesy Votorantim, 2017.

The geotechnical mapping and data analysis protocols do not include industry-standard practices such as detailed descriptions of the various structural domains and their characteristics. No geomechanics laboratory tests were provided, therefore it is difficult to ascertain whether data are of sufficient quantity, quality, and distribution to adequately characterize the various rock mass domains. A summary of averages and ranges for intact rock strengths have been made in various reports. Geotechnical characterization must be a continuous proactive process as new mining areas are accessed.

9.7 Exploration Potential

The exploration team have both near-mine and regional exploration targets that are actively being investigated.

9.7.1 Mine Area Targets

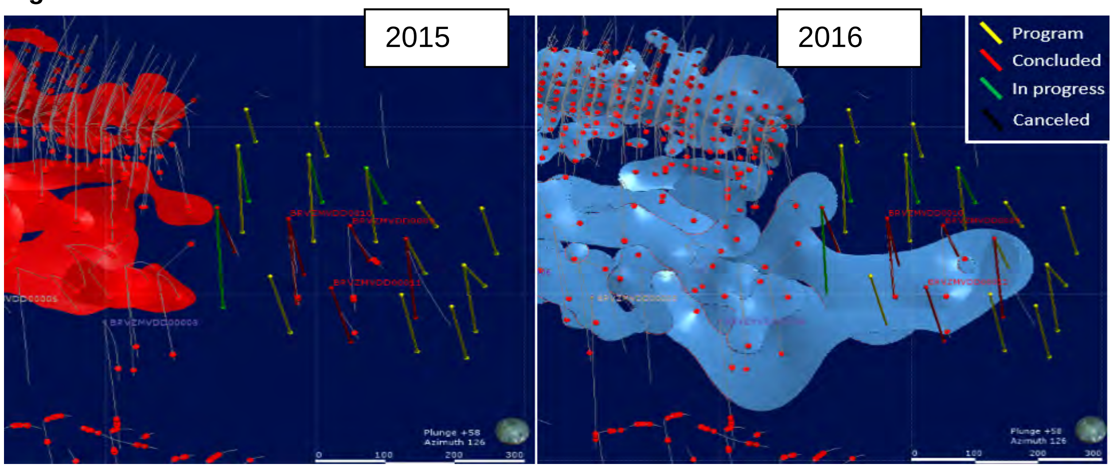
Areas of Data Gaps

Ongoing exploration tests for extensions to known mineralization, infilling areas where no data are currently available, and using mining knowledge and structural interpretations to identify areas where mineralization may be present. Examples of exploration successes using these methods include Lumiadeira (Figure 9-10), Ramp 29 (Figure 9-11), and Deep Exploration (Figure 9-12), within the Vazante Mine area. The figures show the information known as at the end of 2015 (left images), and the additional mineralization inferred from drilling completed during 2016 (right images).

Extremo Norte

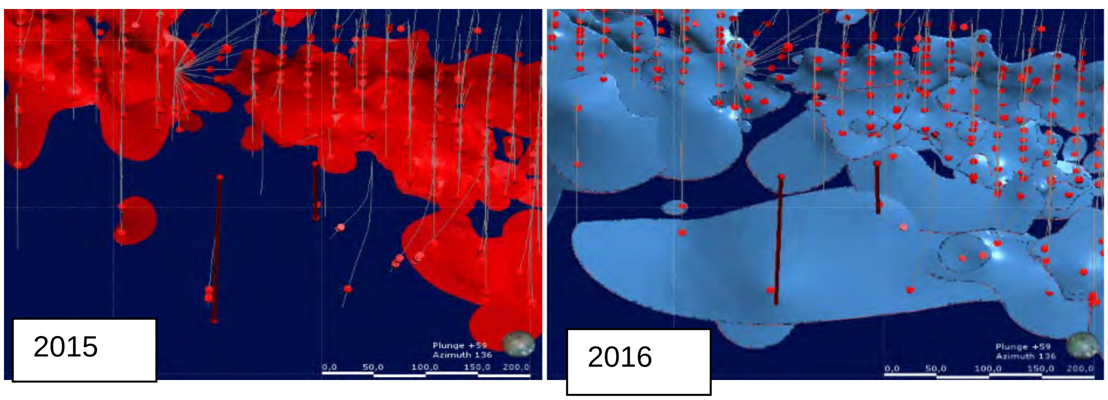
Mineralization is affected by post-mineralization faults. These low-angle faults usually have dip of about 5°, are associated with late regional thrusts, and are reasonably readily mappable at the mine scale. The faults have locally caused thickening and enrichment of the mineralization (Figure 9-13). Such zones are actively sought by mine exploration, using a combination of ACT-oriented drilling, and 3D software modelling.

Figure 9-10: Lumiadeira



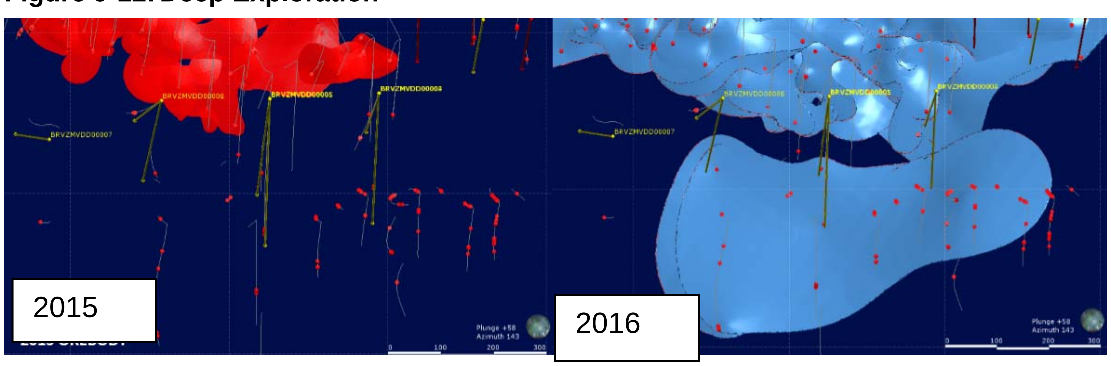
Note: Figure courtesy Votorantim, 2017.

Figure 9-11: Ramp 29



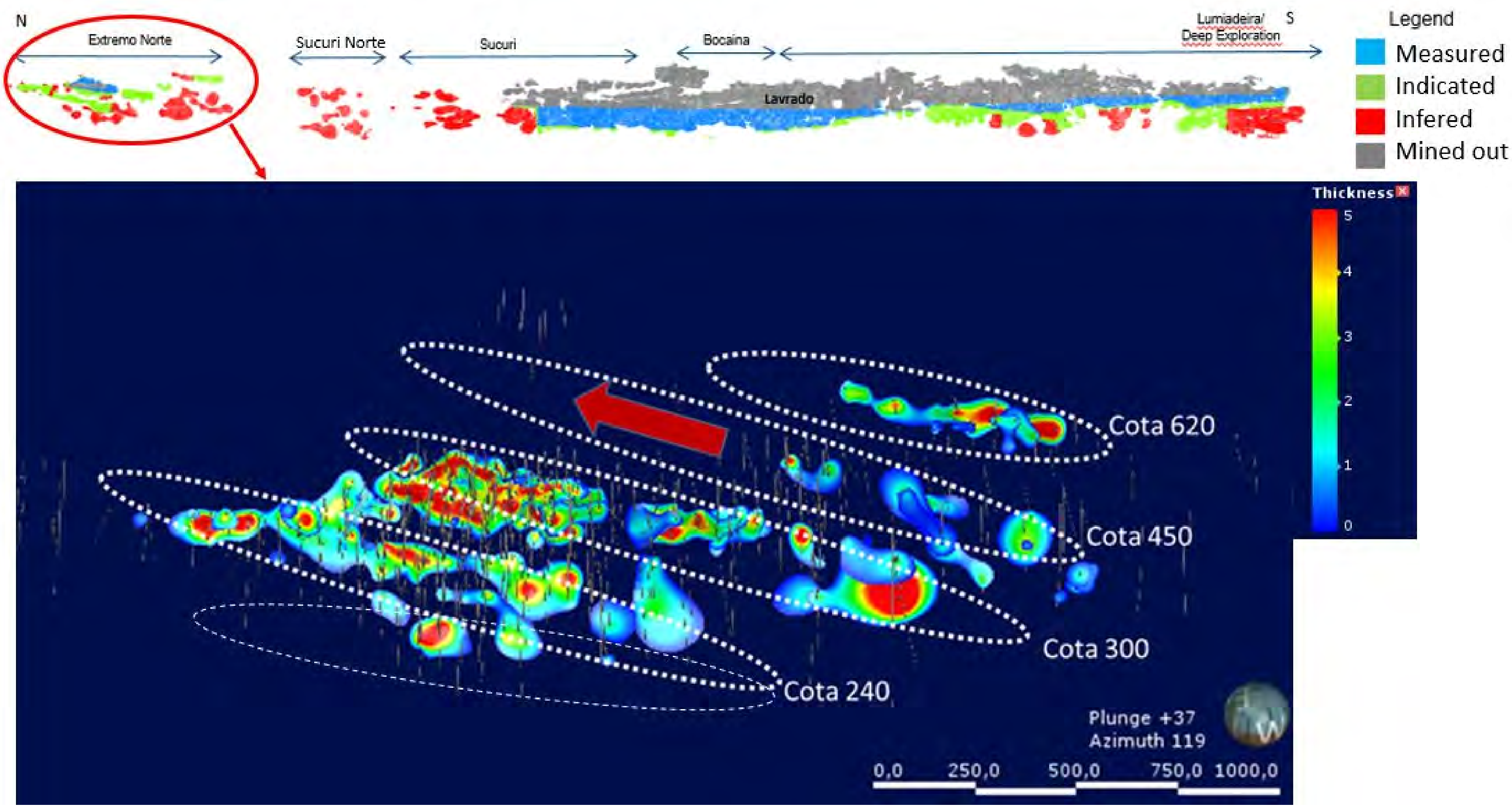
Note: Figure courtesy Votorantim, 2017.

Figure 9-12: Deep Exploration



Note: Figure courtesy Votorantim, 2017.

Figure 9-13: Section Showing Zones of Thickening and Zinc Grade Enhancement



Note: Figure courtesy Votorantim, 2017. Cota = mine level.

Calamine

As noted in Section 9.5.2, northwest-oriented late-stage faults are often significant water-bearing structures. Long-term water interaction with zinc sulphide mineralization can result in oxidation of the sulphides into secondary mineral assemblages; this calamine mineralization was the target of the early open pit mining campaigns.

The current interpretation of the formation of the calamine bodies is that the mineralization is controlled by late-stage, brittle, northwest-trending structures that cross the Vazante Fault and are related to the development of karst topography (known locally as bocaina). Weathering of sphalerite or willemite in these areas can result in significantly supergene-enriched zinc zones that are attractive exploration targets.

Geological interpretations will be tested by a combination of soil sampling, two-dimensional resistivity tomography surveys, and potentially, where results support, drilling. Figure 9-14 shows an interpretation using existing data that could be refined during exploration targeting. This figure relates the existing low resistivity data to an image of the geomorphology of the bocaina area.

Brownfields Exploration

Figure 9-15 shows three brownfields targets in the immediate vicinity of Vazante and Extremo Norte.

Target 1 is a possible along-strike extension of known zinc mineralization. A few holes drilled in the area have encouraging zinc intercepts (see example drill holes BRVZMVDD00001, BRVZMVDD00005, BRVZMVDD00022, and BRVZMVDD00030 in Section 10.9).

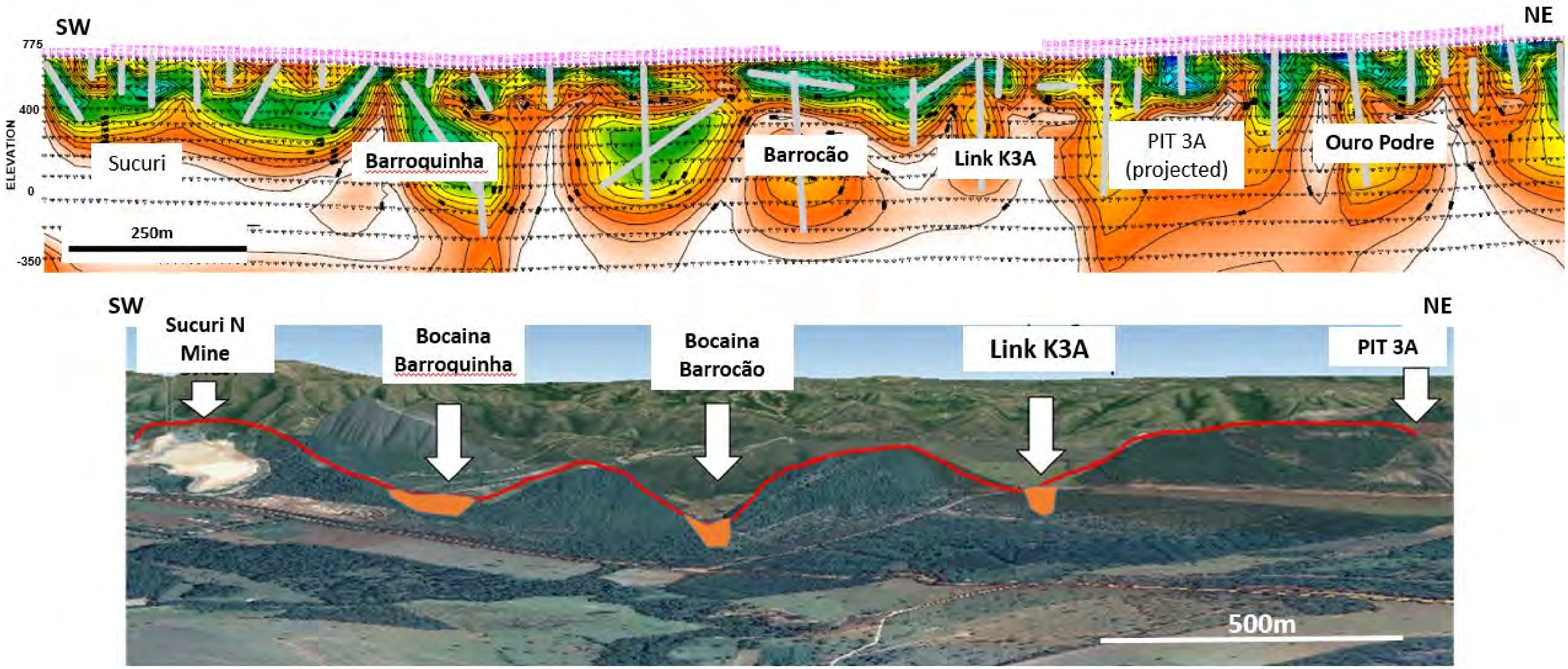
Targets 2 and 3 are calamine targets with possible sulphide targets below the calamine. Target 2 has no recent drilling.

Several holes in Target 3 have returned encouraging zinc intercepts (refer to example drill holes BRMVZCLD00001, BRMVZCLD00007, BRMVZCLD00011, BRMVZCLD00015, BRMVZCLD00023, BRMVZCLD00029, and BRMVZCLD00034 in Section 10.9).

9.7.2 Regional Targets

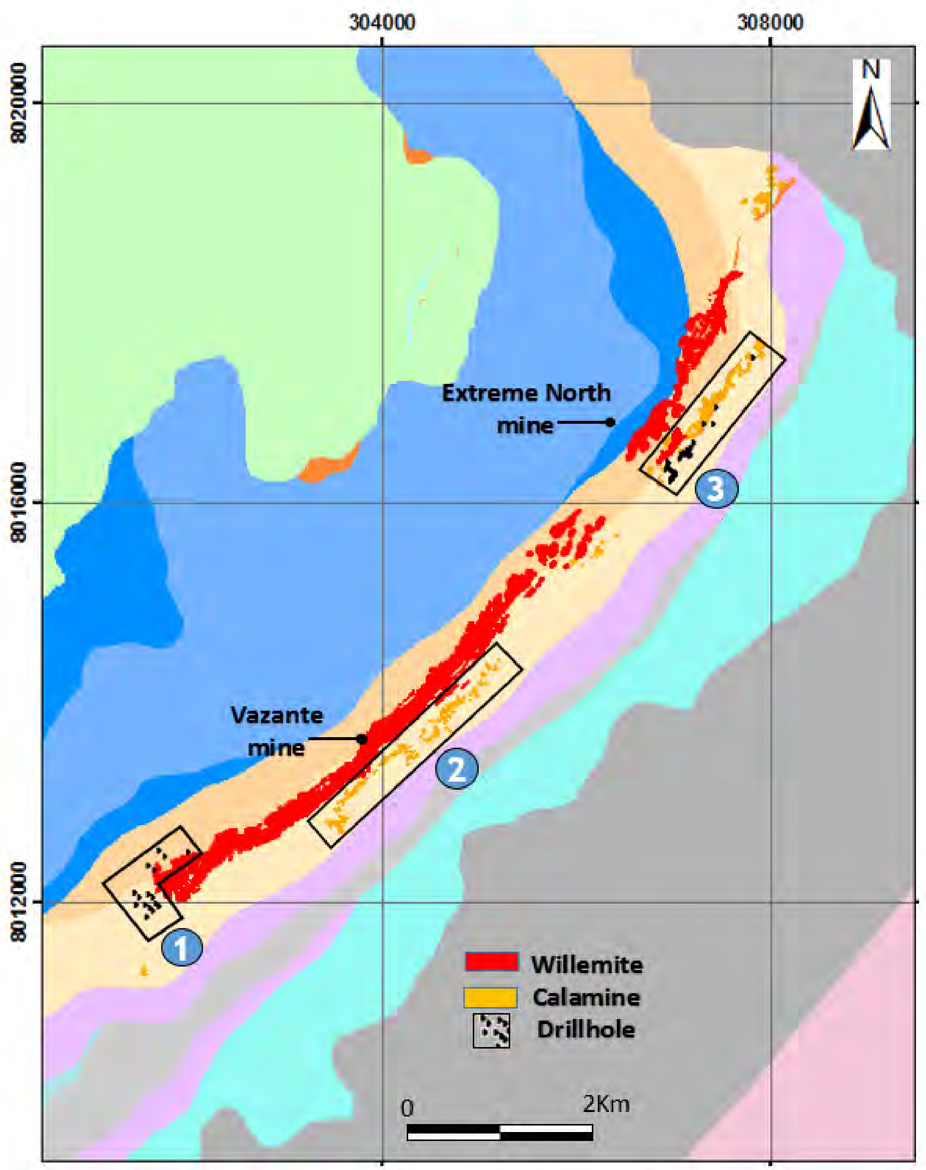
Regional exploration has identified a number of areas that warrant additional work (Figure 9-16).

Figure 9-14: Bocaina Area Prospectivity Map



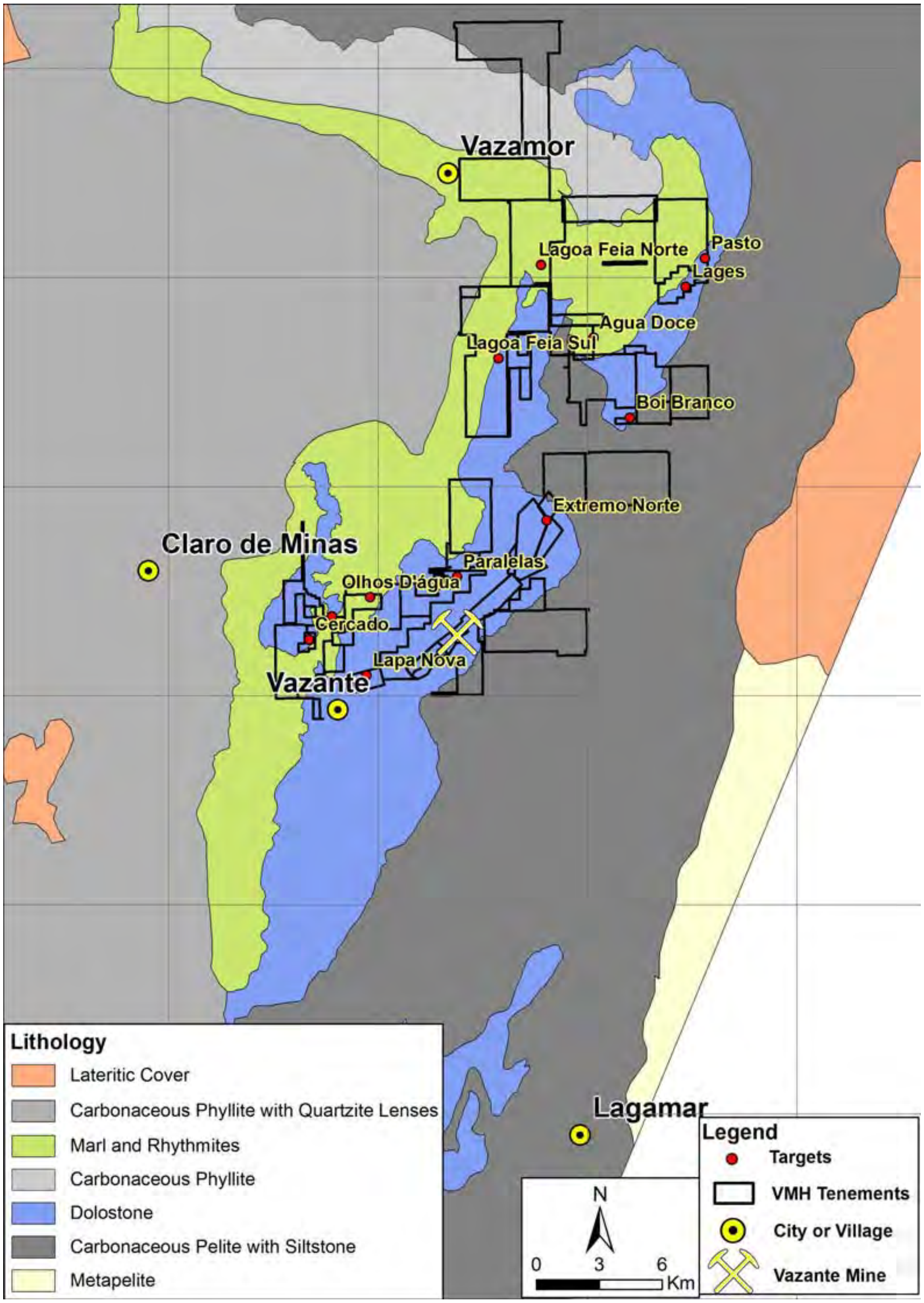
Note: Figure courtesy Votorantim, 2017. Resistivity scale in ohms. Colour scale: green–blue colour range about 100–400 ohm, orange–red colour range about 750–950 ohm.

Figure 9-15: Brownfields Exploration Targets



Note: Figure courtesy Votorantim, 2017.

Figure 9-16: Regional Exploration Targets



Note: Figure courtesy Votorantim, 2017.

Pasto and Lages Trend

Following collation of all available data from historical drilling campaigns, and soil and rock sampling, the conceptual model for the area was reinterpreted. This led to completion of ground magnetic and IP surveys, and a 1:10,000 scale geological mapping program.

The prospect consists of a well-developed, 60 m long tabular hydrothermal breccia that has pervasively altered a grey dolostone of the Morro do Calcário Formation. Alteration includes silicification, dolomitization and iron–carbonate minerals, which have changed the rock colour to an intense red. The alteration style is similar to known alteration at the Vazante Mine, and the 45ºNW dip of the breccia is similar to the known dips of breccias at Vazante (N40E/30NW). Post-breccia sulphide veining, comprising dolomite, galena and sphalerite has preferentially developed along the contact between the breccia and the dolostone. This contact may have acted as a fluid trap, and is considered a major exploration target in the region.

The regional mapping program identified a series of northwest faults that segment the sedimentary package. A carbonaceous phyllite horizon forms a regional marker, and will be used to determine fault kinematics. Geophysical data indicate that the hydrothermal breccia has a high resistivity/low chargeability response, whereas the carbonaceous phyllite displays low resistivity/high chargeability. These characteristics will be used in support of detailed exploration targeting, in conjunction with more detailed geological mapping and geochemical sampling.

Lagoa Feia Sul and Lagoa Feia Norte Trend

All available data from early geochemical and drilling programs was re-evaluated and a 1:10,000 geological mapping program was completed. This program identified a gossan in the area, which is located over a geophysical anomaly that has been interpreted as a deep structure.

Review of historical drill data refined the stratigraphic interpretation such that the area is considered to be a structural window comprising carbonates and phyllites of the Serra da Lapa Formation.

Zinc and lead anomalies in soils extends over 6 km of strike. Geophysical surveys, including magnetics and IP, are planned and will target northwesterly-trending fault zones that may act as fluid traps for mineralized fluids.

Boi Branco

This prospect occurs at the geological contact between the Serra do Garrote and Morro do Calcário Formations, and is along strike from the Vazante Mine. The exploration target is sediment-hosted base metal mineralization that may have developed in black shales and fine-grained sandstone units.

Work completed to date has included soil and rock geochemical surveys, which identified hydrothermal haematite alteration along the trace of the Vazante Fault. Some sphalerite mineralization was noted in drill holes completed along the fault trace. Additional drilling is planned.

Cercado and Olhos D’agua Trend

Silicate ore hosted in dolostone along a splay of the Vazante Fault was mined in the Cercado area in the 2000s. Olhos D’agua is a zinc silicate prospect along strike from Cercado. In addition to these willemite occurrences, gossans after sulphides, and haematitic breccias have been mapped and sampled.

Previously-acquired regional airborne geophysical data were subject to new inversion procedures, and reinterpreted to help construct better regional geophysical models. The intent is to be able to better relate structures in the geophysical data to known zinc soil anomalies and gossan outcrops. Preliminary results are encouraging, and additional exploration is proposed.

Franklinite was identified in a mineralization study on material from the Cercado prospect. As franklinite appears to occur in association with haematite alteration, ground magnetic surveys may prove a useful locator of the low magnetic signature of the mineral.

9.8 Comments on Section 9

Local and regional exploration is ongoing with reasonable annual budgets and has discovered not only extensions to the Vazante mineralization but possible new mineralization that may potentially add to the resource base. Surface geological mapping, geochemical sampling, and geophysical surveying are the primary exploration tools all of which are quickly superseded by drilling once a prospective area is discovered.

The QP considers the type and amount of exploration to be appropriate for the type of deposit.

10.0 DRILLING

10.1 Introduction

Figure 10-1 provides a regional overview of the drilling completed in the Vazante Operations area, including regional drilling. Regional core drilling on record totals 87 drill holes (about 27,135 m; see Table 10-1); there is currently no information on any regional drilling prior to 1976. There are also an additional 70 auger drill holes (691 m).

Drilling is divided into two types: surface drilling, also called long-term drilling; and underground drilling, also called short-term or production drilling.

Table 10-2 summarizes all drilling production since 2002 at the Vazante Mine. A total of 5,918 drill holes for 962,883 m have been completed. In addition to drilling at Vazante, 130 channel samples for a total of 745.08 m were collected from underground workings.

Table 10-3 summarizes drilling at the Extremo Norte Mine by year since 2005. Drilling totals 884 drill holes for 199,059 m.

Figure 10-2 shows the drilling and channel sampling completed in the Vazante Mine area. Figure 10-3 shows the drilling and channel sampling completed in the Extremo Norte Mine area. Figure 10-4 provides the drilling breakout for underground and surface for the period 2009–2016.

10.2 Drill Methods

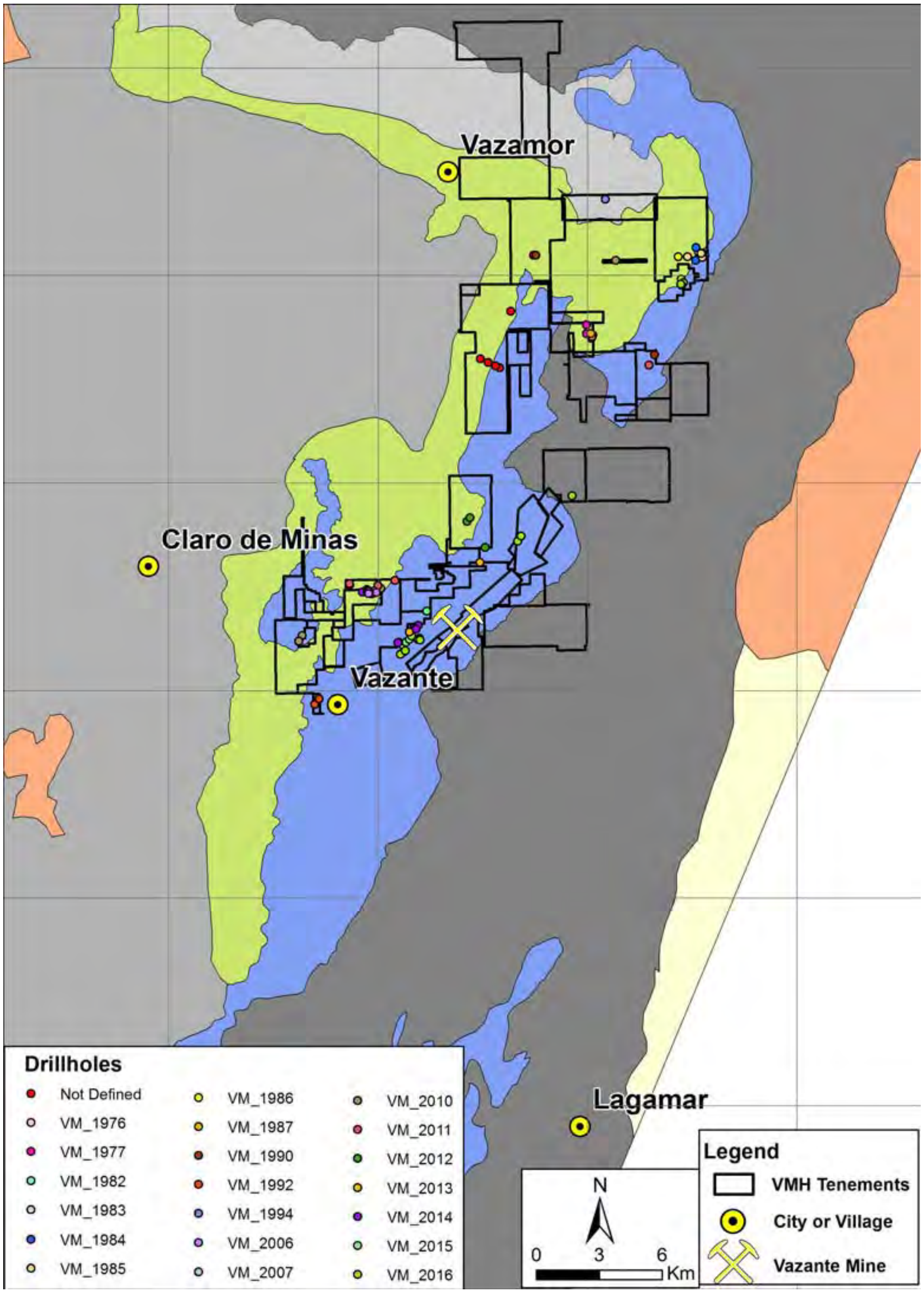
Drilling operations are performed by company personnel using internal corporate standards (standard numbers PO-VM-ZINCO-VZ-SOND-016 and PO-VM-ZINCO-VZ-SOND-012). The Vazante Operations are certified by BSI for ISO9001 and ISO14001 standards (certificates FM504361 and EMS86481 respectively).

Drilling of the 6,831 core holes at Vazante and Extremo Norte has been completed with a number of different drill machines, the types of which are not recorded.

The current drilling fleet consists of two surface drills; an Atlas drill model CS14 and Boart Longyear drill model LF90-D. The underground fleet includes five Boart Longyear model LM 75 drill rigs, and two Atlas U6 MCR model drill rigs.

Surface drilling starts with a diameter that is HQ (96 mm) or larger to better accommodate difficult surface drilling. When the rock mass improves, drill holes are reduced to NQ (75 mm) diameter. In many instances, drilling conditions dictate that the hole diameter be reduced further, to BQ (36 mm).

Figure 10-1: Regional Drill Hole Location Plan



Note: Figure courtesy Votorantim, 2017.

Table 10-1: Regional Drilling Summary

Year	Drill Type	Number of Drill Holes	Metres Drilled
1976		2	283.87
1977		4	889.69
1982		2	623.5
1983		2	695.9
1984		8	1,201.6
1985		4	505.05
1986		1	485.4
1987		2	430.75
1990		1	254.8
1997		1	613.75
1990		1	217.05
1992	Core	2	213.7
2006		2	760.3
2007		1	244.4
2010		5	1,273.55
2011		5	1,285.9
2012		3	926.1
2013		2	715.7
2014		8	2,457.6
2015		7	4,147.25
2016		18	7,387.5
Undated		6	1,521.55
Total		***87***	***27,134.91***
2006	Auger	70	691.3

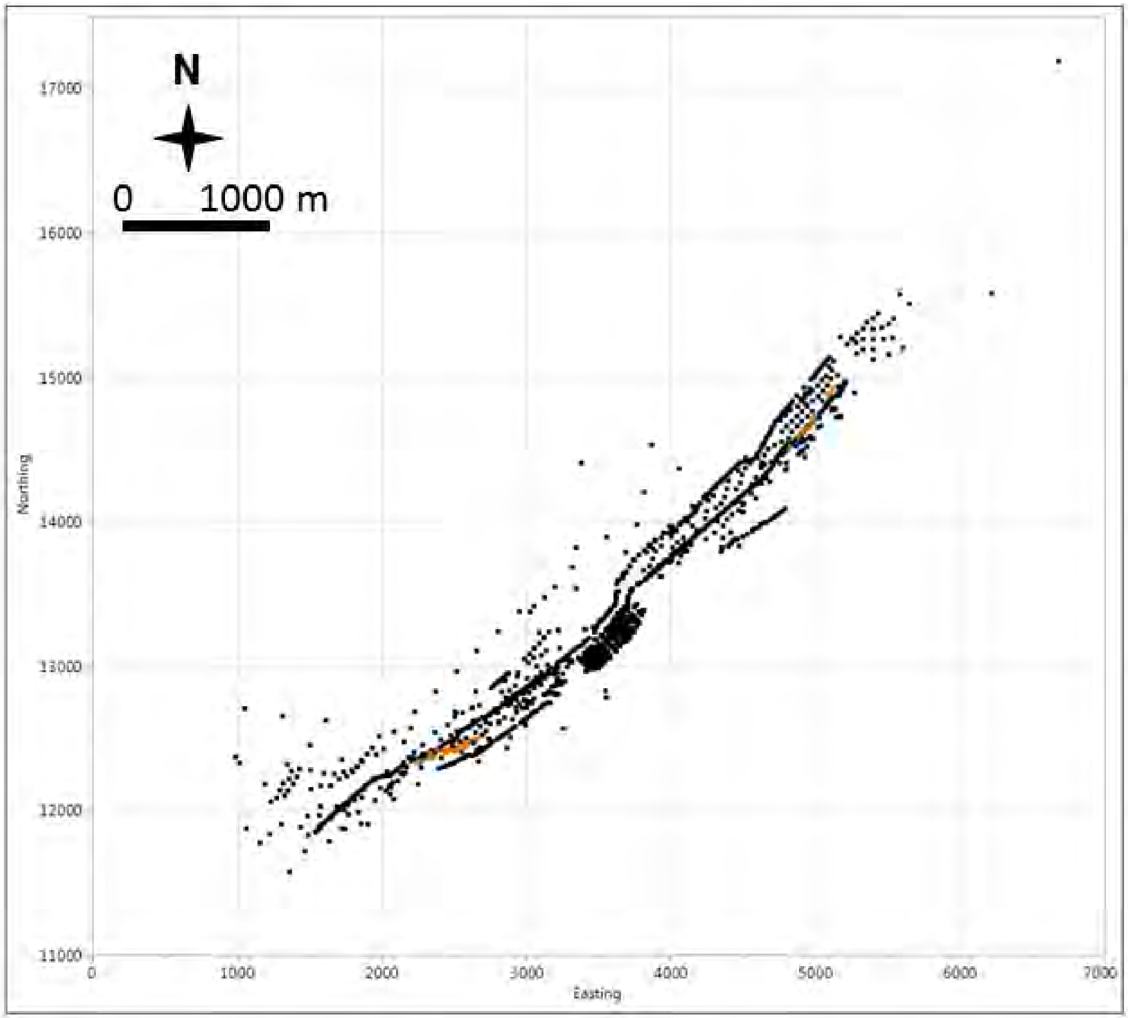
Table 10-2: Summary of Drilling at Vazante by Year

Year	Number of Holes	Total Depth(m)
2002	288	99,518.15
2003	10	3,956.70
2004	164	36,454.40
2005	412	96,087.95
2006	396	77,234.55
2007	234	40,224.35
2008	191	34,263.70
2009	289	40,736.15
2010	1,124	176,012.19
2011	1,233	111,279.10
2012	242	22,865.45
2013	467	67,435.45
2014	368	60,076.00
2015	291	51,032.35
2016	209	45,706.42
Total	***5,918***	***962,882.91***

Table 10-3: Summary of Drilling at Extremo Norte by Year

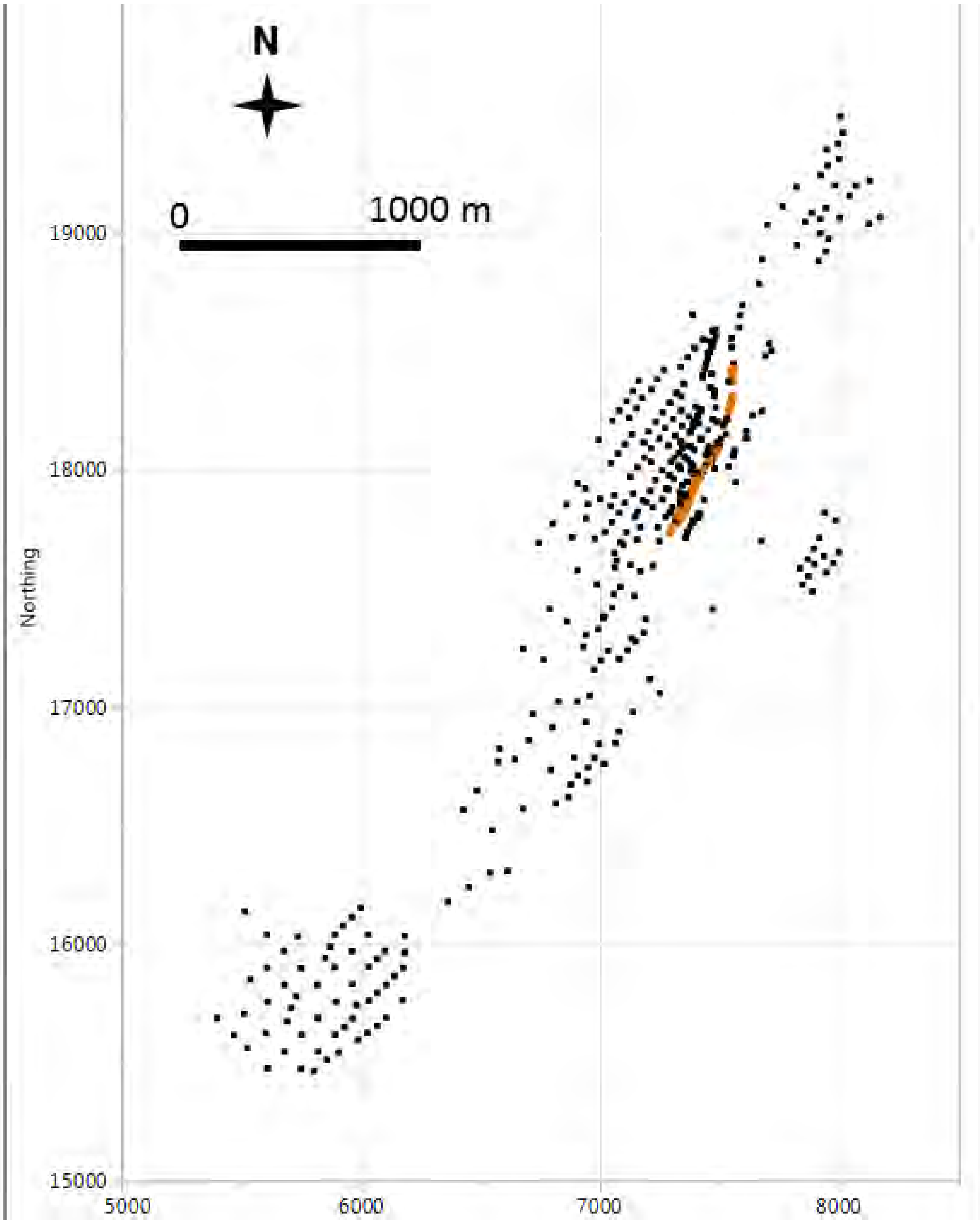
Year	Number of Holes	Total Depth (m)
2005	67	21,164.20
2006	72	26,648.80
2007	40	5,265.65
2008	71	23,821.00
2009	56	15,052.40
2010	44	11,406.45
2011	12	4,343.65
2012	35	5,306.90
2013	111	18,459.75
2014	72	16,931.70
2015	104	16,061.60
2016	200	34,596.70
Total	***884***	***199,058.80***

Figure 10-2: Vazante Mine Area Drill Hole and Channel Sample Location Map



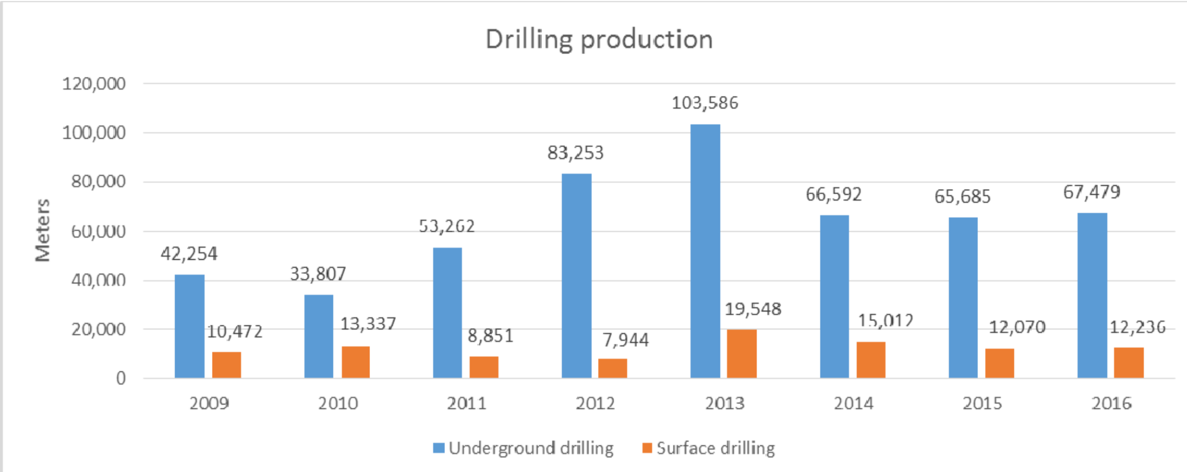
Note: Figure prepared by Amec Foster Wheeler, 2017. Black circles are drill holes, orange circles are channel samples.

Figure 10-3: Extremo Norte Mine Area Drill Hole and Channel Sample Location Map



Note: Figure prepared by Amec Foster Wheeler, 2017. Black circles are drill holes, orange circles are channel samples.

Figure 10-4: Production Drilling, 2009–2016



Note: figure prepared by Amec Foster Wheeler, 2017.

Geological conditions for underground drilling are typically much better than surface conditions, because the drill holes start in fresh rock and thus, they typically employ BQ diameter tools throughout.

10.3 Logging Procedures

Core description and sampling processes are set out in internal corporate standards documents (standard numbers PG-VM-ZINCO-VZ-GEO-002 for quality assurance and quality control (QA/QC), PG-VM-ZINCO-VZ-GEO-003 for geological logging, PO-VM-ZINCO-VZ-GEO-006 for core sampling, and PO-VM-ZINCO-VZ-GEO-007 for core shed operations).

Core boxes are checked by the drilling support team, who review core size and recovery data, and verify the location of core blocks. If irregularities are discovered, they are resolved before the core is released to the core shack. All core is photographed. Drill holes are then transferred to the core workbench where the core is described by a team of geologists and technicians. The principal items logged include lithology, colour, texture, weathering, structure, and fracture density.

Geotechnical and hydrogeological descriptions are also completed and stored in the geological database.

Core is marked up to show sample intervals and the locations of control samples.

Once the description of the core is complete, the boxes to be sampled are identified and the remaining boxes are stored.

10.4 Recovery

Table 10-4 summarizes average core recovery by year from 2009 to 2016. The overall average recovery is 93.4%.

10.5 Collar Surveys

Underground and most surface drill collar surveying has been done with total station instruments using the in UTM Zone 23 South, Corrego Alegre datum. Some surface collar surveying was done with differential global positioning system (GPS) instruments.

10.6 Downhole Surveys

Information as to survey methods pre-2002 is not available. A Tropari instrument was used until 2005, and a Reflex Maxibor I was used from 2002–2008.

There are currently two instruments to measure downhole deviations at the mine: one Reflex Maxibor II™ and one Reflex Gyro™. Those are operated under standard operating procedures PO-VM-ZINCO-VZ-SOND-003 (2017), PO-VM-ZINCO-VZ-SOND-018 (2017), and PO-VM-ZINCO-VZ-GEO-020 (2017).

10.7 Geotechnical and Hydrological Drilling

The principal source of geotechnical characterization data is the geotechnical drill core logging. The geotechnical logging is performed by the site geotechnical department and recorded in the geological database. An established classification procedure and logging format characterizes the mine-scale rock mass based on grade of alteration, degree of fracturing, presence of structure/voids/cavities, and patterns of lithological structural.

A geotechnical model has been developed for Lumiadeira (650 mRL to 350 mRL), Sucuri Deeps and Extremo Norte using Leapfrog Geo software.

10.8 Sample Length/True Thickness

Figure 10-5 shows a typical cross section across the mineralization (red outlines). In some cases, drill intercepts, and thus sample lengths, are perpendicular to the mineralized bodies and the sample length will be equal to the true thickness. In most cases, however, the true thickness is less than the sample thickness because the drill holes intersect the mineralized bodies at oblique angles.

Table 10-4: Example Average Drill Recoveries (2009–2016)

Year	Drilled (m)	Recovery (m)	Recovery %
2009	38,458	34,933	92.09%
2010	49,271	44,873	92.10%
2011	113,131	106,919	94.93%
2012	88,824	83,239	94.85%
2013	100,052	92,546	93.56%
2014	82,602	80,884	92.92%
2015	77,205	73,323	94.97%
2016	79,714	75,609	94.80%

Figure 10-5: Vazante Cross Section Showing Drilling Oblique to Mineralization

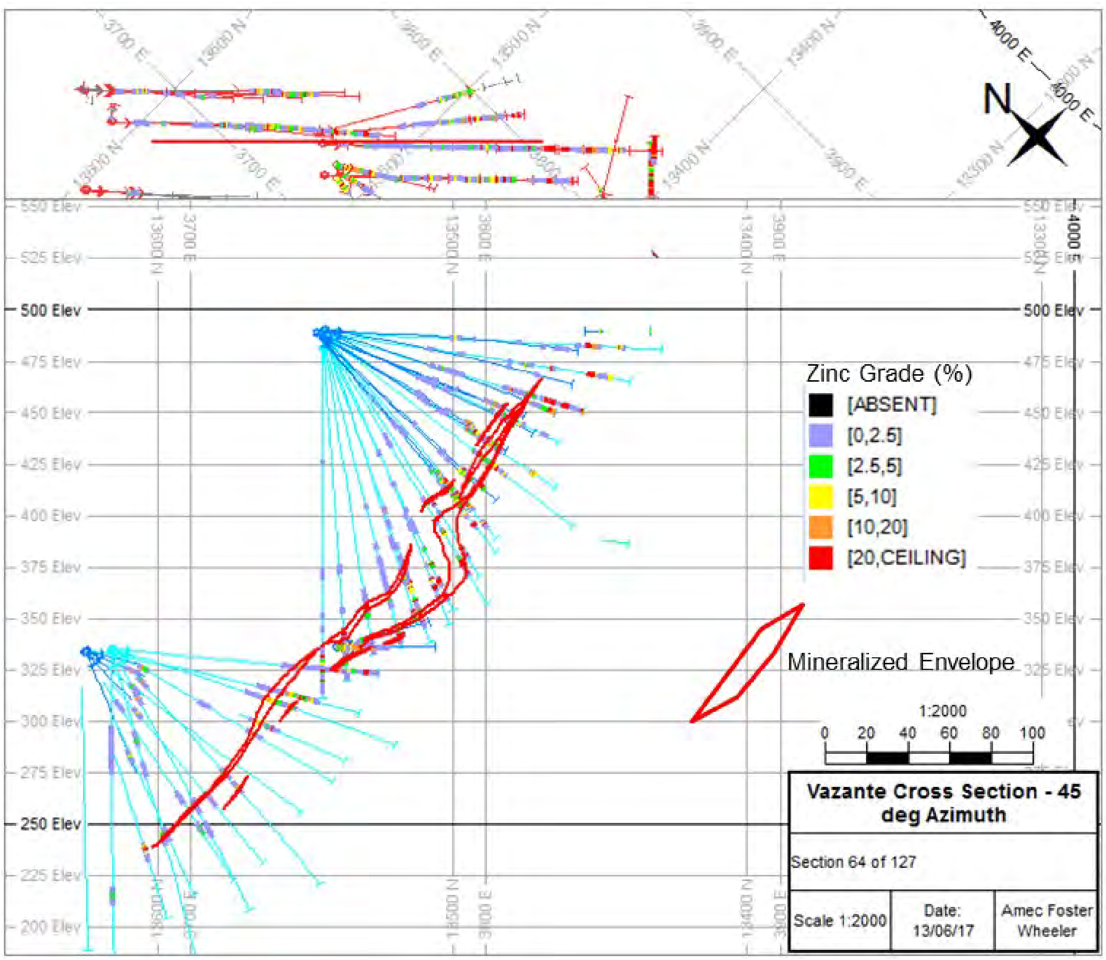


Figure prepared by Amec Foster Wheeler, 2017.

10.9 Summary of Drill Intercepts

The Project database contains 7,678 core holes and channels, most of which contain at least one mineralized intercept, and many holes have multiple intercepts. Table 10-5 provides a selected list that is illustrative of the grades and thicknesses that have been encountered in the drill programs completed in the mine area.

Table 10-6 provides a selected list of the drill holes completed as part of the Lumiadiera and Vazante Deeps exploration programs to illustrate the grades and thicknesses that have been encountered to date.

Table 10-7 provides a selected list of the drill holes completed as part of the calamine exploration program to illustrate the grades and thicknesses that have been encountered to date.

10.10 Comments on Section 10

Drilling equipment and procedures are consistent with industry standards and are adequate to support Mineral Resource estimation and mine planning.

Underground and most surface drill collar surveying has been done with total station instruments. Some surface collar surveying was done with differential GPS.

Currently, two instruments, a REFLEX Maxibor II™ and a REFLEX Gyro™ are in use at Vazante. These instruments are commonly used in the industry and are adequate to support Mineral Resource estimation and mine planning.

Geological logging of core is performed using procedures that are typical in the industry. The principal items described are: lithology, colour, texture, weathering, structure, and fracture density as well as appropriate geotechnical and hydrogeological items. The QP considers geological logging to be adequate to support Mineral Resource estimation and mine planning.

Average core recovery is 93.4% which is adequate to support Mineral Resource estimation and mine planning.

In some cases, drill intercepts, and thus sample lengths, are perpendicular to the mineralized bodies and the sample length will be equal to the true thickness. In most cases, however, the true thickness is less than the sample thickness because the drill holes intersect the mineralized bodies at oblique angles.

Table 10-5: Example Drill Intercepts, Mine Area

BHID	Easting	Northing	Elevation	Total Depth (m)	Azimuth (º)	Inclination (º)	From (m)	To (m)	Drilled Thickness (m)	Zn Grade (%)	Pb Grade (%)	Fe Grade (%)	Ag Grade (g/t)
1009	2214.31	12365.10	704.04	295.00	121.9	69	242.35	251.30	8.95	28.24	0.00	16.40	0
1014	2280.96	12381.67	704.89	336.50	121.9	73	226.85	234.70	7.85	28.98	0.00	16.36	0
1023	2400.75	12433.27	703.53	285.20	123.5	61	257.00	263.30	6.30	19.39	0.00	14.68	0
1024	2400.75	12433.27	703.52	280.00	123.5	72	190.20	197.50	7.30	40.39	0.00	9.87	0
1024	2400.75	12433.27	703.52	280.00	123.5	72	228.4	251	22.6	40.86	0.00	12.60	0.00
1667	4944.53	14728.25	660.95	373.90	134.5	85	351.15	354.95	3.80	40.32	0.76	6.38	78.74
388TR13090SF02	4977.70	14573.15	412.88	30.70	310.2	-44.4	14.45	23.9	9.45	23.03	0.00	4.46	0.00
500SW300F05	3472.75	13113.72	502.46	41.45	136.2	75	23.80	26.1	2.30	16.72	0.00	9.84	0.00
500SW75F03	3641.22	13262.98	500.47	24.35	136.2	40	7.50	18.25	10.75	18.99	0.00	8.91	0.00
570NW1F12	3663.66	13201.57	570.94	43.70	316.19	-70	9.70	14.45	4.75	18.10	0.00	6.17	0.00
570SE1F05	3611.82	13113.57	574.71	63.25	316.19	-73	12.05	26.05	14.00	13.82	0.00	12.18	0.00
570SE1F05	3611.82	13113.57	574.71	63.25	316.19	-73	37.65	44.15	6.50	22.89	0.00	30.26	0.00
920	2680.72	12580.45	718.69	332.35	127.63	67.45	229.75	244.2	14.45	5.44	0.00	3.31	0.00
BI500F05	3663.03	13325.18	500.40	66.40	136.19	40	35.00	45.45	10.45	43.76	0.00	11.05	0.00
GP484P11662SF09	3877.01	13651.39	490.95	109.30	136.17	27	93.90	99.3	5.40	23.05	0.00	3.04	0.00
GP484P11687SF02	3895.71	13667.95	489.86	106.00	136.2	51	91.00	96.45	5.45	18.71	0.00	7.40	0.00
GP484P11875SF13	4046.17	13785.48	492.76	134.90	136.19	76	117.30	125.3	8.00	11.76	0.00	11.86	0.00
GP484P11950SF12	4095.52	13835.04	494.00	233.90	0	90	190.00	202.4	12.40	18.75	0.62	6.07	6.34
GP484P12062SF07	4176.01	13916.03	494.75	178.10	134.48	80	157.90	170	12.10	20.96	0.52	8.16	58.45
GP484P12125SF06	4229.19	13951.05	495.43	183.00	136.25	87	164.00	168.10	4.10	30.48	0.44	15.73	16.65
GP484P12125SF07	4229.72	13950.41	495.29	212.70	0	90	178.20	192.85	14.65	18.91	0.65	5.15	33.78
GP484P12225SF12	4305.14	14016.02	496.33	230.70	0	90	147.70	155.60	7.90	15.76	1.30	11.64	60.84
GP484P12400SF09	4436.33	14129.83	496.92	152.10	136.29	71	102.30	147.00	44.70	23.56	0.01	10.13	0.36
GP484P13050SF12	4892.71	14594.16	500.14	172.20	136.96	85.41	145.30	151.50	6.20	37.73	0.26	3.30	8.66
GP507P10100SF12	2663.53	12623.46	522.92	260.50	135.2	79.8	239.30	245.3	6.00	23.43	0.53	14.25	8.10
GP507P10100SF13	2663.49	12623.48	522.92	293.80	135.2	84.7	266.60	281	14.40	21.39	0.25	8.84	19.53

BHID	Easting	Northing	Elevation	Total Depth (m)	Azimuth (º)	Inclination (º)	From (m)	To (m)	Drilled Thickness (m)	Zn Grade (%)	Pb Grade (%)	Fe Grade (%)	Ag Grade (g/t)
GP507P10150SF13	2663.49	12623.48	522.92	293.80	0	90	188.40	199.6	11.20	25.46	0.41	16.23	26.72
GP507P10350SF14	2884.64	12759.42	519.69	204.40	135.59	78	175.80	183.9	8.10	24.09	0.15	5.72	12.31
GP507P10375SF12	2908.08	12772.76	520.10	228.50	136.58	75	144.90	171.8	26.90	8.74	0.34	3.72	22.80
GP507P9050SF08	1757.27	12051.75	533.69	191.90	136.35	54.64	175.90	182.8	6.90	25.86	1.03	28.16	151.49
GP507P9300SF12	1944.94	12221.91	532.72	220.80	136	80.3	186.80	211	24.20	11.93	0.62	9.09	32.98
GP507P9400SF11	2057.72	12240.77	531.71	175.00	135.6	80.8	132.90	149.1	16.20	17.21	0.30	6.05	14.06
GP507P9750SF13	2379.49	12419.50	526.92	193.50	136.4	84.5	164.90	172	7.10	33.40	0.57	11.07	118.81
GPSH345P13200SF04	4901.80	14841.91	375.48	167.10	146.25	28.08	150.90	155.5	4.60	32.28	1.16	11.30	48.27
GPSH345P13250SF07	4923.56	14855.58	375.20	144.70	135.46	53.6	71.80	78.2	6.40	28.51	0.25	9.58	38.33
RIXGV12F05	3221.07	13022.94	498.54	140.00	133.21	50	121.90	127.2	5.30	24.84	0.00	17.77	0.00

Table 10-6: Example Drill Intercepts, Lumiadiera and Deep Exploration

BHID	Easting	Northing	Elevation	Total Depth (m)	Azimuth (º)	Inclination (º)	From (m)	To (m)	Drilled Thickness (m)	Zn Grade (%)	Pb Grade (%)	Fe Grade (%)	Ag Grade (g/t)
BRVZMVDD00001	301349	8012318	663	614.6	134	-75	508	510	1.95	6.32			
BRVZMVDD00005	301348	8012319	663	602.6	133	-86	545	560	13.45	5.52	0.21	2.54	4.9
BRVZMVDD00009	301159	8011775	646	136	68	395.6	339	347	8.43	15.36			
BRVZMVDD00010	301224	8011836	643	136	80	407.1	361	375	14.35	17.72			
BRVZMVDD00011	301066	8011874	652	136	71	442.7	395	396	0.60	15.55			
BRVZMVDD00015	301224	8011836	641	133	71	414.7	353	357	4.20	17.59			
BRVZMVDD00022	301320	8011730	637	352.8	132	-72	287	290	3.5	27.54			
BRVZMVDD00026	301249	8011688	638	143	60	356.5	283	286	2.48	12.49			
BRVZMVDD00028	301185	8011634	641	136	79	327.2	259	268	9.35	30.78			
BRVZMVDD00029	301021	8011793	652	136	67	442.6	385	388	2.14	8.06			
BRVZMVDD00030	301319	8011731	637	352.4	136	-71	315	323	7.1	11.85			

Table 10-7: Example Drill Intercepts, Calamine Exploration Area

BHID	Easting	Northing	Elevation	Total Depth (m)	Azimuth (º)	Inclination (º)	From (m)	To (m)	Drilled Thickness (m)	Zn Grade (%)
BRMVZCLD00001	307078.6	8016534.2	665	91.7	128	-50	0	0.85	0.85	13.6
							26.45	27.30	0.85	49.68
BRMVZCLD00003	307,367	8,017,108	696	132.00	-50.00	158	102.65	111.00	8.35	16.08
BRMVZCLD00004	307,961	8,017,810	719	130.00	-45.00	121.2	NS	NS	NS	NS
BRMVZCLD00005	307171.1	8016739.5	658	132.00	-60.00	36	8.15	11.15	3.00	18.51
BRMVZCLD00007	307,171	8,016,740	658	64.6	132	-80	8	20.95	12.95	32.89
BRMVZCLD00011	307,086	8,016,528	666	67.3	190	-60	23.35	24.40	1.05	35.23
							56.75	63.25	6.5	4.03
BRMVZCLD00012	307,180	8,016,746	658	230.00	-45.00	45.7	10.50	26.70	16.20	30.91
BRMVZCLD00013	307,086	8,016,528	666	190.00	-45.00	95.7	71.50	79.35	7.85	20.58
BRMVZCLD00015	307014.6	8016591.4	677	84.3	220	-50	39.15	42.7	3.55	9.49
BRMVZCLD00019	307,290	8,016,855	669	43.00	-45.00	16	51.00	62.20	11.20	22.21
BRMVZCLD00020	307,290	8,016,855	669	43.00	-70.00	88.4	NS	NS	NS	NS
BRMVZCLD00023	307,050	8,016,445	680	90.4	10	-65	5.6	28.55	22.95	18.16
BRMVZCLD00029	307,009	8,016,648	688	88.4	132	-80	0	6.1	6.1	10.58
BRMVZCLD00030	307,230	8,016,786	659	0.00	-90.00	101.75	45.00	51.50	6.50	10.26
BRMVZCLD00031	307,266	8,016,722	653	55.00	-70.00	72.45	6.75	11.40	4.65	10.50
BRMVZCLD00032	307,051	8,016,444	682	0.00	-90.00	80.4	0.00	14.40	14.40	13.32
BRMVZCLD00033	307,136	8,016,673	667	225.00	-45.00	45.7	NS	NS	NS	NS
BRMVZCLD00034	307,558	8,017,263	659	49.7	225	-45	18.15	25	6.85	9.35

Note: NS = not sampled

11.0 SAMPLE PREPARATION, ANALYSES, AND SECURITY

11.1 Sampling Methods

11.1.1 Core Samples

Votorantim staff collect samples according to internal corporate standards (standard numbers PG-VM-ZINCO-VZ-GEO-003 and PO-VM-ZINCO-VZ-GEO-007).

Core samples have a preferred length of 1 m but length may vary from a minimum of 0.50 m and a maximum of 1.50 m, depending on the location of lithological, alteration, mineralization, or other natural boundaries or contacts. If core recovery is less than 100%, the length of the sample is equivalent to the anticipated length. Votorantim personnel sample 3 m above and 3 m below mineralized intervals.

After sampling and sample description are completed and entered into the database, a sampling plan is prepared. That plan identifies assay and QC sample locations and sample numbers. QC samples are inserted and photographed prior to shipment as an aid to identification of those samples when problems occur.

Samples from underground drill holes are not split; that is, they are forwarded to the laboratory as whole core (typically BQ). Surface drill holes are split using a dedicated core saw. One-half is forwarded to the laboratory, and the other half is placed into boxes and archived in the core shack. The material that comes back from the laboratory (coarse rejects and pulps) is placed into identified boxes and stored into the core shack.

11.1.2 Channel Samples

Underground channel samples are collected according to internal corporate standards (standard number PO-VM-ZINCO-VZ-GEO-019). Channel samples range from 0.5–1.5 m long, and respect lithological, alteration, mineralization, and other natural boundaries. Samples are collected with a hammer and chisel or battery-powered hammer drill, about 1.2 m above the floor of the mine working.

11.2 Density Determinations

Prior to 2015, the density was determined through the displaced volume method for all samples collected at the Vazante Operations. From the second half of 2015 on, there was a transition to the Joly method and, due to the large number of data available, analyses were performed only on a few drill holes.

Currently, density is determined for selected holes using the Joly Method which is checked with the displaced volume method (internal corporate standard number PO-VM-ZINCO-GEO-018) procedure. The database has approximately 117,281 data for the Vazante Mine and 15,725 data at Extremo Norte Mine, for a total of more than 133,000 density data. A few suspect data have found their way into the database; however, the number is small, on the order of 400 results that are probably not reliable.

The Joly method was implemented in the second half of 2015 and every 20th sample is checked by the displaced volume method. The Joly method relies on the fact that porosity of the samples is very low. For each determination, an entire sample is weighed in air in a plastic mesh bag, and then weighted while the sample is suspended in water in the mesh bag. This allows for very accurate determination of density of the entire sample rather than a small piece of the sample. The displaced volume method requires that the sample be placed in a large container of water and allowed to overflow into another container. The overflow is then weighed. The weight of water is essentially equivalent to the volume in cm^3 of the sample. Recent results have shown a good correlation and no systematic bias among the measurements via displaced volume and the Joly method (Figure 11-1).

11.3 Analytical and Test Laboratories

Analytical laboratory usage is summarized in Table 11-1.

Prior to 2014, mine and exploration samples were analyzed at the Vazante Operations mine laboratory on the mine site. Samples were prepared using the mine laboratory equipment. This laboratory was not accredited, and not independent of Votorantim.

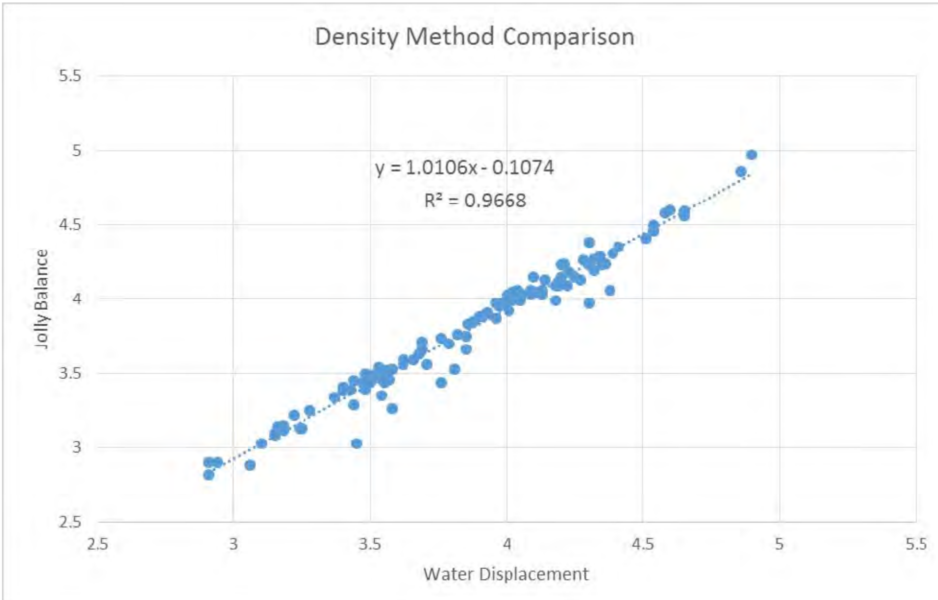
All operational samples continue to be analysed onsite by the mine laboratory.

ALS, an independent laboratory, has been the primary laboratory for preparation of exploration samples since 2014. Samples are prepared and analyzed at either of the ALS laboratories located in Vespasiano, Minas Gerais and Goiânia, Goiás. Both laboratories are ISO 9001:2008 certified (#FS571108).

ALS Lima, which is also independent of Votorantim, has been the primary analytical laboratory for exploration samples since 2014. The ALS analytical laboratory in Lima is ISO 9001:2008 and 17025:2005 accredited.

The mine site laboratory is not independent, and is not accredited.

Figure 11-1: Joly versus Displaced Water Volume Comparison



Note: Figure courtesy Votorantim, 2017.

Table 11-1: Analytical and Sample Preparation Laboratories

Assay Laboratory	Use	Timeframe	Independent of Votorantim	Certification
Mine laboratory	Exploration samples	Pre-2014	No	None
ALS Vespasiano, Minas Gerais	Exploration samples	2014 to date	Yes	ISO 9001:2008
ALS Goiânia, Goiás	Exploration samples	2014 to date	Yes	ISO 9001:2008
ALS Lima	Exploration samples	2014 to date	Yes	ISO 9001:2008 ISO17025 for selected analytical techniques

11.4 Sample Preparation

11.4.1 Mine Laboratory

Samples were delivered to the mine laboratory in labelled plastic bags. At the laboratory, samples were verified and entered into the database system.

Sample preparation included weighing, drying at 100°C, and jaw crushing to a minimum of 70% minus 5 mesh (4 mm), splitting the sample through a riffle splitter, and pulverizing a split using a ring and puck system to 100% passing 100 mesh.

A sample of 20 g was prepared and a binder solution was added. The sample with the binder solution was transferred to a ring and puck pulveriser again to a 100% passing 200 mesh. Pressed powder disks of 37 mm in diameter were then created using a hydraulic press.

11.4.2 ALS

All exploration samples are currently prepared at ALS.

After samples are split at the core shed, they are sent to ALS, where they undergo preparation using the flowchart in Figure 11-2. The procedure is as follows:

- As samples are received at the laboratory, any differences between the number of samples indicated on the Analytical Request (RA) letter that accompanies the samples and what has effectively been received are reported, as well as any other existing anomalies
- Samples are weighed after they are checked against the RA letter
- Samples are dried in a kiln for 8–12 hours, with maximum controlled temperature of 120ºC.
- The sample is crushed to 70% passing a 2-mm screen (9 mesh Tyler)
- Samples are homogenized and split through a Jones-type rifle splitter. Approximately 250 g is split for the analytical sample. The remaining fraction is stored as coarse reject
- Samples are pulverized until 85% of the particles pass a 75 µm (-200 mesh) screen.

The pulverized sample is bagged in kraft paper bags and sent to the laboratory for analysis.

Channel samples are prepared in the same manner as the drill core samples.

11.5 Analytical Methods

Prior to mid-2014, chemical analyses at the mine laboratory were performed using an X-ray fluorescence (XRF) technique and an atomic absorption spectroscopy (AAS) procedure for selected elements. Sample with zinc contents >6% were re-assayed with the AAS procedure.

Figure 11-2: Flowchart Used for Sample Preparation at ALS

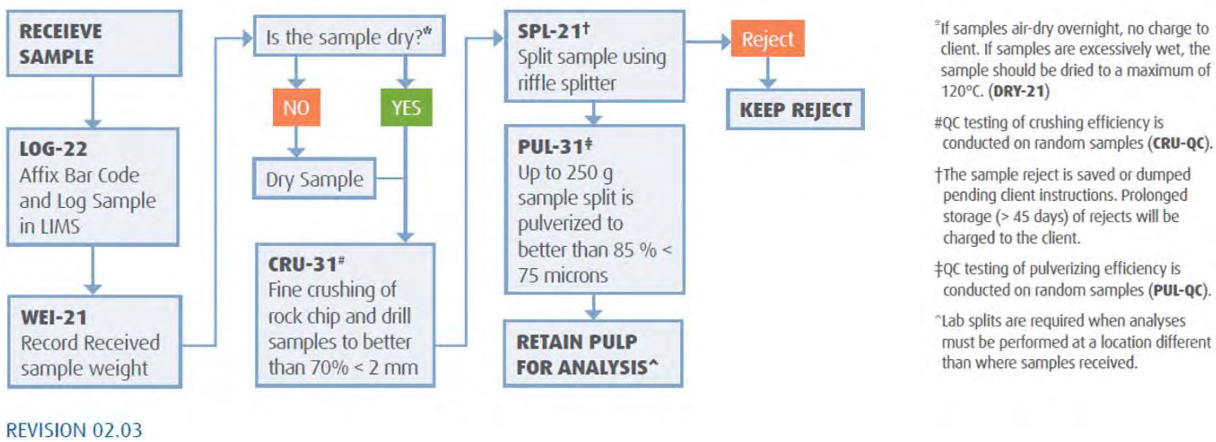


Figure courtesy Votorantim, 2017. Both the Vespasiano, Minas Gerais and Goiânia, Goiás laboratories use this preparation flowsheet.

The procedures consisted of:

- Lead–silver by aqua regia digestion followed by AAS finish (currently an Agilent Technologies GTA120 Graphite Tube AA, Mod 240 FS)
- Zinc and iron by XRF on 25 g pressed pellets. The current instrument is a Philips MagiXPro.
- Carbon and sulphur were completed on a LECO instrument
- A GBC 908 AA is available as a backup.

The transition from XRF to inductively-coupled plasma (ICP) and AAS began in 2014 when analyses began to be performed at the ALS laboratory in Lima. Selected elements were analyzed via AAS, while the same elements, and others, were analyzed with ICP-atomic emission spectroscopy (AES). High-grade zinc was analyzed specifically using a volumetric method for better results. From 2015 onward, all analyses have been performed at ALS, Lima.

At ALS Lima, core and channel samples are dissolved using a four-acid digestion (HNO_3–HCl-H_2SO_4-HF). The solutions are then finished on either an ICP-AES or AAS method. Both finishes are appropriate for the elements of potential economic interest as well as deleterious elements. Table 11-2 summarizes the elements available by AAS and their lower and upper limits of detection. In the case of zinc, a volumetric method, which has an upper detection limit of 100%, is used for samples with 30% or more zinc. Table 11-3 summarizes the elements available by ICP-AES with their lower and upper limits of detection.

Table 11-2: Elements Available for Analysis by the AAS Method with Lower and Upper Limits of Detection

Element	Symbol	Units	Lower Detection Limit	Upper Detection Limit	Default Over Limit Method
Silver	Ag	ppm	1	1000	Ag-GRA21
Arsenic	As	%	0.01	30	
Cadmium	Cd	%	0.0001	10	
Cobalt	Co	%	0.001	30	
Copper	Cu	%	0.001	50	
Iron*	Fe	%	0.01	100	
Manganese*	Mn	%	0.01	50	
Molybdenum	Mo	%	0.001	10	
Nickel	Ni	%	0.001	50	
Lead	Pb	%	0.001	30	
Antimony	Sb	%	0.01	20	
Strontium	Sr	%	0.01	20	
Vanadium	V	%	0.01	30	
Zinc	Zn	%	0.001	30	

Note: * Elements normally reported as oxides

Table 11-3: Elements Analyzed with the ICP-AES Method with Lower and Upper Limits of Detection

Element	Symbol	Units	Lower Detection Limit	Upper Detection Limit	Default Over Limit Method
Aluminum	Al	%	0.01	50	
Antimony	Sb	ppm	5	10000	
Arsenic	As	ppm	5	100000	
Barium	Ba	ppm	10	10000	
Beryllium	Be	ppm	0.5	1000	
Bismuth	Bi	ppm	2	10000	
Cadmium	Cd	ppm	0.5	5000	
Calcium	Ca	%	0.01	50	
Chromium	Cr	ppm	1	10000	
Cobalt	Co	ppm	1	10000	Co-OG62
Copper	Cu	ppm	1	10000	Cu-OG62
Gallium	Ga	ppm	10	10000	
Iron	Fe	%	0.01	50	
Lanthanum	La	ppm	10	10000	
Lead	Pb	ppm	2	10000	Pb-OG62

Element	Symbol	Units	Lower Detection Limit	Upper Detection Limit	Default Over Limit Method
Lithium	Li	ppm	10	10000	
Magnesium	Mg	%	0.01	50	
Manganese	Mn	ppm	5	100000	
Molybdenum	Mo	ppm	1	10000	Mo-OG62
Nickel	Ni	ppm	1	10000	Ni-OG62
Niobium	Nb	ppm	5	2000	
Phosphorus	P	ppm	10	10000	
Potassium	K	%	0.01	10	
Rubidium	Rb	ppm	10	10000	
Scandium	Sc	ppm	1	10000	
Selenium	Se	ppm	10	1000	
Silver	Ag	ppm	0.5	100	Ag-OG62
Sodium	Na	%	0.01	10	
Strontium	Sr	ppm	1	10000	
Sulfur	S	%	0.01	10	
Tantalum	Ta	ppm	10	10000	
Tellurium	Te	ppm	10	10000	
Thallium	Tl	ppm	10	10000	
Thorium	Th	ppm	20	10000	
Tin	Sn	ppm	10	10000	
Titanium	Ti	%	0.01	10	
Tungsten	W	ppm	10	10000	
Uranium	U	ppm	10	10000	
Vanadium	V	ppm	1	10000	
Yttrium	y	ppm	5	10000	
Zinc	Zn	ppm	2	10000	Zn-OG62
Zircon	Zr	ppm	5	500	

11.6 Quality Assurance and Quality Control

Company-wide QA/QC protocols were implemented in 2009, are based on internal corporate standards (standard numbers PG-VM-EXPMIN-001, PG-VM-EXPMIN-002 and PG-VM-EXPMIN-003), and have improved over time.

The current program includes submission of twin, coarse and pulp duplicates, certified reference materials (CRMs), external controls, and coarse blank samples (Table 11-4).

Table 11-4: QC Sample Types

Sample Type	Code	Insertion Rate (%)	Insertion Ratio	Purpose
CRM (Standard)	PD	5	1:20	Accuracy
Coarse Blank	BR	2	1:50	Contamination detection in sample preparation
Field Duplicate/Replicate	RP	1	1:100	Quality of sampling
Coarse Reject Duplicate	RG	1	1:50	Quality of sample preparation
Pulp Duplicate	DP	2	1:50	Precision
Interlaboratory Check	DC	2	1:50	Bias between laboratories - accuracy.

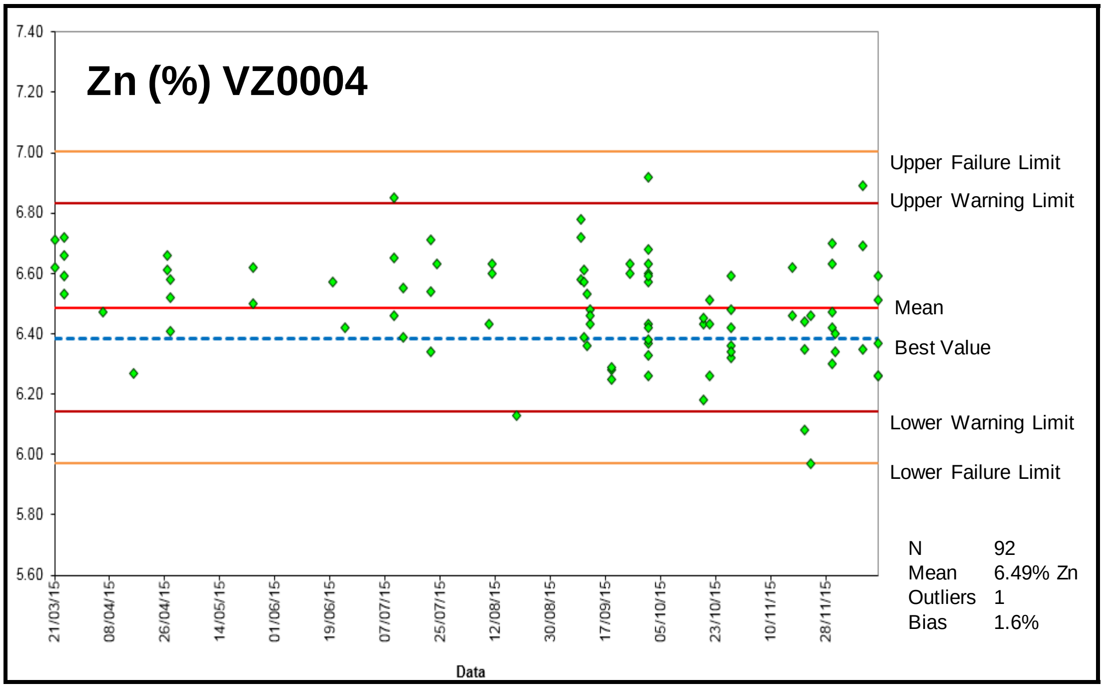
Review of reports from 2009–2013 indicates that the data generated by the mine laboratory were adequate, but that there were minor problems with those data, largely due to "growing pains", while the laboratory and exploration personnel learned the system. The 2013 data demonstrate that the mine laboratory was operating reasonably. In early 2014, the mine laboratory began having problems with zinc standards and the analytical work was sent to ALS. The ALS data from 2014 onward show well-controlled laboratories.

11.6.1 Certified Reference Materials

Certified reference materials (CRMs or standards) are used to monitor accuracy of the analytical laboratory and precision of the analyses generated by the laboratory. Three CRMs (VZ0004, VZ0005 and VZ0007) were analyzed at ALS from January, 2015 to December, 2015. Control charts for each CRM and each element have the best value (BV; also known as the certified value or sought value) and analytical acceptance limits. Figure 11-3 is an example control chart.

Analytical acceptance (control) limits are used to determine whether, or not, the analysis is acceptable based on the standard deviation (s) of the analyses at the laboratory. Such limits are normally set at ±2 standard deviations for a warning line which indicates possible problems, and a ±3 standard deviation limit which indicates failure of the result. Comparison of the mean to the BV is the bias of the sample relative to the BV. In this case, the mean is 1.6% higher than the BV which is acceptable. One result is slightly outside the lower failure limit (-3s) and five results are within the upper and lower warning areas. These are typical results of a well-run laboratory. Table 11-5 summarizes CRM results since 2009.

Figure 11-3: Zn Control Chart for CRM VZ0004



Note: Figure courtesy Votorantim, 2017.

Table 11-5: CRM Summary Results

2009	Zn		Fe		Pb		Ag	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**
VZ001	-11.7	—	-2.1	—	-6.1	—	—	—
VZ002	-9.4	—	-1.3	—	-13.6	—	—	—
VZ003	-7.0	—	4.2	—	3.5	—	—	—
2010	**Zn**		**Fe**		**Pb**		**Ag**	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**
VZ001	-7.1	—	-0.6	—	-3.1	—	—	—
VZ002	-1.0	—	-1.5	—	-2.5	—	—	—
VZ003	1.6	—	5.2	—	6.4	—	—	—
2011	**Zn**		**Fe**		**Pb**		**Ag**	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**
VZ001	-6.9	—	-2.7	—	-10.8	—	—	—
VZ002	-1.0	—	-4.8	—	-11.1	—	—	—
VZ003	1.3	—	2.2	—	-5.3	—	—	—
2012	**Zn**		**Fe**		**Pb**		**Ag**	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**

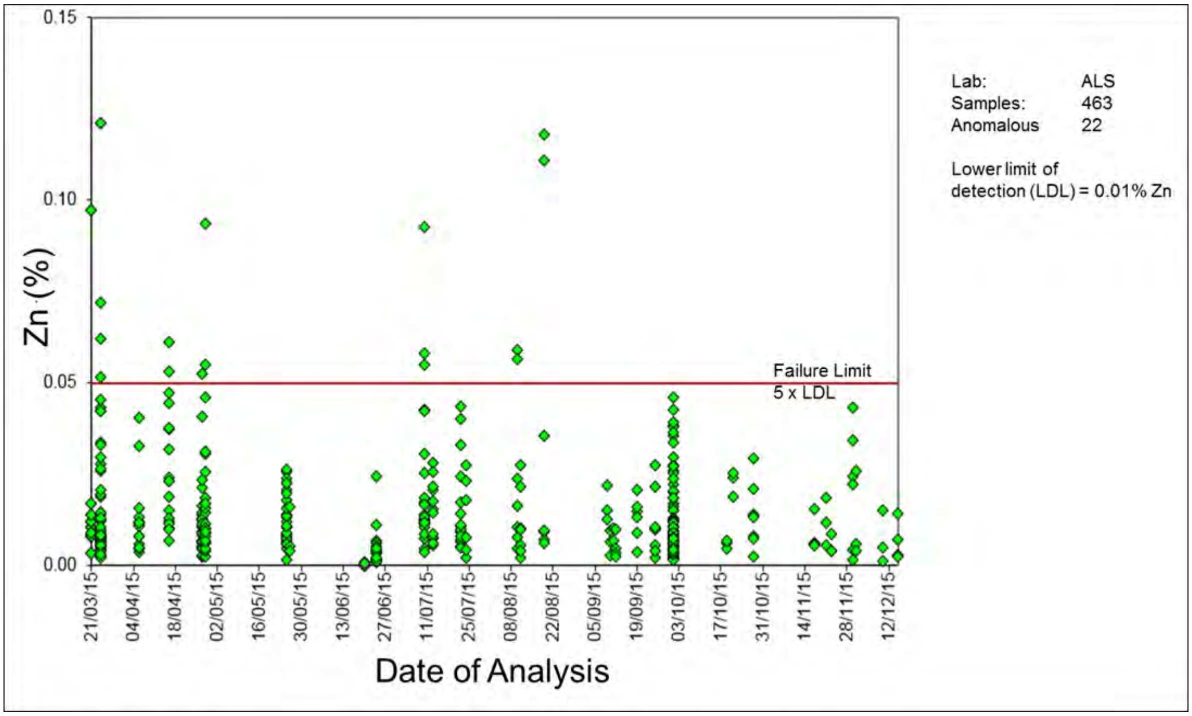
VZ001	-8.6	—	-4.8	—	—	—	—	—
VZ002	-2.2	—	-3.5	—	—	—	—	—
VZ003	-0.8	—	8.4	—	—	—	—	—
2013	**Zn**		**Fe**		**Pb**		**Ag**	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**
VZ001	-7.9	—	-4.4	—	—	—	—	—
VZ002	-0.8	—	1.6	—	—	—	—	—
VZ003	1.7	—	7.9	—	—	—	—	—
2014	**Zn**		**Fe**		**Pb**		**Ag**	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**
CTRS90915	0.0	—	—	—	-3.9	—	—	—
VMMA-03	-0.4	—	-1	—	-4.9	—	—	—
MA003	0.0	—	-	—	1.1	—	—	—
VZ003	2.0	—	4	—	-1.5	—	—	—
2015	**Zn**		**Fe**		**Pb**		**Ag**	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**
VZ0004	1.6	2	-0.8	1	0.3	1	-1.8	2
VZ0005	1.3	0	-2.0	2	-0.2	2	1.2	0
VZ0007	0.8	1	-1.8	3	-0.9	0	3.8	0
2016	**Zn**		**Fe**		**Pb**		**Ag**	
CRM	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**	**Bias (%)**	**Failures**
VZ0004	2.5	1	-0.2	1	0.3	1	-0.7	1
VZ0005	2.0	1	-1.0	1	-0.8	3	2.1	0
VZ0007	0.6	3	-2.8	2	-1.7	1	2.7	2

11.6.2 Blank Samples

Blank samples are defined as samples of material that contain zero or negligible concentration of the elements of interest and are used to detect contamination introduced during sample preparation and analysis.

A control graph for blank samples is used as a tool to analyze blank performance (Figure 11-4). The acceptance limit of samples is five times the lower detection limit, except for Fe, which is 10 times the lower detection limit. No significant contamination was noted in any of the analytical work.

Figure 11-4: Example Blank Control Chart for Zn



Note: Figure courtesy Votorantim, 2017.

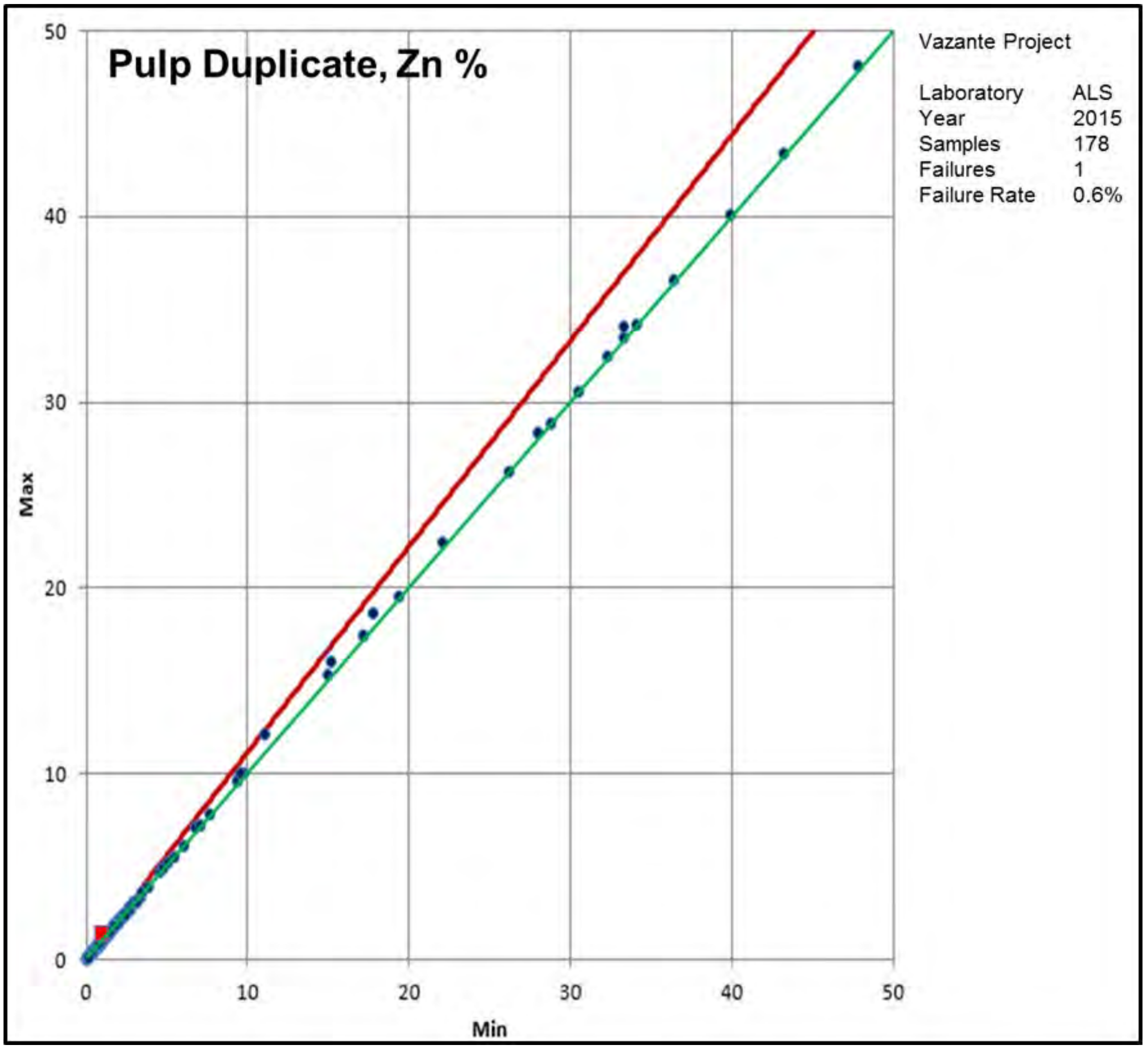
11.6.3 Duplicate Samples

Duplicate samples are utilized to monitor laboratory precision. Three types of duplicate samples are typically used:

- Replicates (core): These are typically half-core versus half-core comparisons where both halves of a core sample are prepared and analyzed to evaluate geological variance
- Crusher duplicates: These are typically collected after the last crusher step, typically at the 2-mm stage to evaluate crusher performance,
- Pulp duplicates: These are collected from the pulverized material produced during the last sample preparation comminution step. These samples are used to monitor analytical precision and provide a baseline for evaluation of the other duplicate sample types.

The evaluation of the results was carried out through graphic verification. The max-min dispersion graph (Figure 11-5) was used and failure limits are determined using a hyperbolic equation ($y^2 = m^2x^2 + b^2$; Simon, 2005). Parameters for construction of the hyperbola for each type of sample are shown in Table 11-6.

Figure 11-5: Exampled Min-Max Control Chart for Zn in 2015 Pulp Duplicates



Note: Figure courtesy Votorantim, 2017.

Table 11-6: Parameters for Construction of the Control Charts for Duplicates

Type of Duplicate	b	m	Limit m
Replicate (RP)	10	1.35	30%
Coarse Duplicate (RG)	5	1.22	20%
Pulp duplicate (DP)	3	1.11	10%

The error limit, an estimate of precision, is also in Table 11-6. In all cases, samples outside the limits are considered to be failures. Votorantim considers the data adequate if less than 10% of the data are outside the limits. Table 11-7 summarizes duplicate failure rates.

11.6.4 Survey QA/QC

QC data for total station surveys consist of closed loops for all surveys, both surface and underground. DGPS surveys rely on duplicate surveys as well as repeated surveys of known points at the beginning and end of each survey day.

Downhole survey QC data consist of duplicate surveys for all holes.

11.7 Databases

Fusion™, a database management software package sold and supported by Datamine™ is used for database management at the Vazante Operations. Fusion™ provides reliability and traceability assurance as well as an easy interface with Datamine™ modeling and mine planning software. Login is password protected by individual personnel and all personnel have the permission necessary to complete their jobs. Three people in the company have unlimited access to the database. Data cannot be entered or changed in the database without the appropriate permission. There is an expert in charge of the database full time to make certain that data are reliable and to provide data extraction and editing services.

Primary data entered by the site geologists into the tablet devices are imported directly into Fusion™. Analytical data are provided digitally by the assay laboratories.

Primary original documents and logs, down-hole surveys, core photographs, and assay certificates are stored network drives. Digital copies of the database network drives are routinely backed-up daily, weekly, and monthly.

11.8 Sample Storage

All mineralized core from underground drilling is sent for assay. Non-mineralized core is discarded.

Core from surface drilling is halved, and half-core is retained for the permanent record. There is a dedicated core storage facility, which, in 2017, accommodated approximately 19,000 boxes of core.

Table 11-7: Summary of Duplicate Failure Results

2009	Zn (%)	Pb (%)	Fe (%)	Ag (%)
Replicate (RP)	27.3	11.4	23.1	—
Crusher Duplicate (RG)	41.5	21.6	46.6	—
Pulp Duplicate (DP)	—	—	—	—
2010	**Zn (%)**	**Pb (%)**	**Fe (%)**	**Ag (%)**
Replicate (RP)	8.2	5.5	14.8	—
Crusher Duplicate (RG)	41.4	21.8	44.3	—
Pulp Duplicate (DP)	—	—	—	—
2011	**Zn (%)**	**Pb (%)**	**Fe (%)**	**Ag (%)**
Replicate (RP)	16.5	3.8	17.0	—
Crusher Duplicate (RG)	31.5	41.9	29.0	—
Pulp Duplicate (DP)	—	—	—	—
2012	**Zn (%)**	**Pb (%)**	**Fe (%)**	**Ag (%)**
Replicate (RP)	20.5	5.3	16.4	—
Crusher Duplicate (RG)	34.1	47.1	29.2	—
Pulp Duplicate (DP)	—	—	—	—
2013	**Zn (%)**	**Pb (%)**	**Fe (%)**	**Ag (%)**
Replicate (RP)	14	5.3	22.0	11.9
Crusher Duplicate (RG)	15	47.1	20.0	26.5
Pulp Duplicate (DP)	16	42.0	34.0	57.0
2014	**Zn (%)**	**Pb (%)**	**Fe (%)**	**Ag (%)**
Replicate (RP)	—	—	—	—
Crusher Duplicate (RG)	3.3	3.96	6.7	3.9
Pulp Duplicate (DP)	1	0.1	0.1	0.1
2015	**Zn (%)**	**Pb (%)**	**Fe (%)**	**Ag (%)**
Replicate (RP)	2.7	2.7	11.1	5.4
Crusher Duplicate (RG)	2.4	0.8	1.6	2.8
Pulp Duplicate (DP)	0.6	0.0	0.0	1.7
2016	**Zn (%)**	**Pb (%)**	**Fe (%)**	**Ag (%)**
Replicate (RP)	27.3	0	13.6	13.6
Crusher Duplicate (RG)	3.3	0	1.7	0.0
Pulp Duplicate (DP)	1.7	0.9	0.0	2.6

11.9 Sample Security

Core boxes are transported every day to the core shed by personnel from the drilling company. Analytical samples are transported by company or laboratory personnel using corporately owned vehicles. Core boxes and samples are stored in safe, controlled areas.

Chain-of-custody procedures are followed whenever samples are moved between locations, to and from the laboratory, by filling out sample submittal forms.

11.10 Comments on Section 11

Sampling methods for core and channel samples are consistent with industry practices and adequate to support Mineral Resource estimation and mine planning.

Prior to 2014, exploration samples were analyzed at the mine laboratory on the mine site. The mine laboratory is not accredited and is not independent.

External independent laboratories belonging to ALS Global have been used for preparation (Vespasiano, Minas Gerais and Goiânia, Goiás) and chemical analyses (Lima, Peru) since 2014. Both ALS sample preparation laboratories in Brazil are ISO 9001:2008 certified (#FS571108). The analytical laboratory in Lima is ISO 9001:2008 and 17025 accredited.

Sample preparation procedures at the mine laboratory and at ALS are consistent with typical industry practices and are adequate to support Mineral Resource estimation. Sample analysis at the mine laboratory and ALS is performed using standard procedures that are widely used in the industry. In both cases, analytical procedures are adequate to support Mineral Resource estimation and mine planning.

Fusion™, a database management software package sold and supported by Datamine™ is used for database management at Vazante. Fusion™ is specifically designed to accommodate geological and mining data with an easy interface with Datamine™ estimation and mine planning software. Database construction and management meet or exceed current industry standards and are adequate to support Mineral Resource estimation and mine planning.

QC results from 2009–2013 were considered to be adequate at the time of the analyses, but a number of questions could not be satisfactorily answered so in 2014, approximately 25,000 samples were reanalyzed with proper QC procedures. The QC results are all well within normal limits. Results from 2015 and 2016 are similarly within limits. Amec Foster Wheeler considers the data to be adequately accurate and precise to support Mineral Resource estimation and mine planning.

Survey QC is exemplary and well ahead of most mining/exploration companies and adequate to support Mineral Resource Estimation and mine planning.

Prior to 2015, the density was measured through the displaced volume method for all samples collected at the Vazante Operations. From the second half of 2015 on, there was a transition to the Joly method and, due to the large number of data available, analyses were performed only on a few drill holes. The Joly method and every 20th sample is checked by the displaced volume method. Variations of both methods are widely used in the mineral industry, and the procedures are adequate to support Mineral Resource estimation and mine planning.

12.0 DATA VERIFICATION

12.1 Internal Data Verification

All data stored in the Project database are verified via software verification before final entry into the database. These automatic routines are aimed at preventing entry of extraneous data such as incorrect lithology codes or overlapping assay intervals into the database. They are largely successful; however, these checks are not perfect and additional internal checks are made to ensure that information used for Mineral Resource estimation and mine planning is as nearly correct as possible. Votorantim's internal corporate standard operating procedure PO-VM-GRM-001, requires additional checking of the following items:

- Sample length problems
- Maximum and minimum grade values
- Negative values
- Detection limits and null values;
- Drill hole surveys
- Sample size
- Gaps
- Overlaps
- Drill hole collars versus topography
- Coordinate datum
- Verification of mining permissions
- Laboratory analysis certificates.

Each of these items are checked and if discrepancies are discovered, verified and corrected if necessary.

12.2 External Data Verification

Three audits have been performed by independent third-parties on the Mineral Resource estimates since 2010:

- SRK in 2010
- Snowden in 2012

- RPA in 2014.

Votorantim advised that recommendations from these external audits were taken into consideration and applied to improve the resource estimation process.

The last audit (RPA, 2014) concluded that the Vazante data at the time were acceptable and that procedures used in estimation were consistent with industry standards. No critical issues were identified regarding the Mineral Resource evaluation process. Votorantim notes that recommendations for possible improvements to the QA/QC program have been implemented.

A gap analysis was undertaken by Amec Foster Wheeler in preparation for this Report and was completed in early 2017. A number of recommendations in support of operational improvements were made. Votorantim advised that these recommendations are being taken into consideration and that they are in the process of implementing the recommendations.

As part of his 2017 site visit, the QP performed high-level reviews of the database and procedures. These included reviews of sampling procedures, geological logging procedures, core drilling and core handling procedures, and QA/QC procedures.

12.3 Comments on Section 12

Amec Foster Wheeler has reviewed the appropriate data and reports and is of the opinion that the data verification programs undertaken on the data collected in previous campaigns adequately support the geological interpretations, and the analytical and database quality.

The QP considers the analytical data to be sufficiently accurate and precise to support Mineral Resource estimation and mine planning and the project database to be sufficiently error free to support Mineral Resource estimation and mine planning.

13.0 MINERAL PROCESSING AND METALLURGICAL TESTING

13.1 Introduction

Vazante is a major carbonate-hosted zinc deposit with unusual mineralogy in that zinc is predominantly present as silicate (willemite) rather than as sulphide. Zinc is the main economic metal, and minor quantities of lead and silver are also present. A flowsheet has been developed that includes crushing, grinding, and sulphide flotation to produce a lead–silver concentrate, and zinc silicate flotation. The reagent scheme at Vazante uses MIBC frother, sodium sulphide activator and potassium amyl xanthate collector in the sulphide circuit, and sodium sulphide activator and amine collector in the willemite flotation circuit. Sodium sulphide also contributes to controlling pH to desired levels in flotation. Before 2017, sodium silicate dispersant was also used in the sulphide circuit.

Ore comes from the Vazante and Extremo Norte Mines.

13.2 Metallurgical Testwork

Metallurgical studies have been completed since plant operations began in 1969. Studies incorporated mineralogy, grinding characteristics and flotation separation testing. Table 13-1 summarizes the metallurgical studies completed on the Vazante Operation willemite ores. Test programs on calamine ores that were mined historically are not included in this list.

Much of the testwork has been completed in the Votorantim laboratory at the Vazante Operations. Studies have been supported by universities including the Federal University of Minas Gerais (UFMG) and the University of Sao Paulo. Most studies have focused on factors affecting zinc recovery. These were found to be:

- Spatial ore location (Vazante Mine ore zones vs. Extremo Norte Mine ore zones)
- Zinc head grade
- Mineralogy, including zinc minerals and gangue minerals deportment and liberation
- Grind size, including relationship to ore hardness and liberation
- Testwork to determine ultimate flotation recovery at extended flotation times
- Flotation testwork to develop reagent schemes.

The test program has followed geometallurgy principles.

Table 13-1: Metallurgical Testwork Summary Table

Document	Facility	Description
Mineralogy applied to Zn recovery optimization (Votorantim, 2016)	Votorantim Tecnologia	Mineralogical evaluation of standard vs. anomalous ore blocks from the Vazante and Extremo Norte Mines, including valuable mineral and gangue mineral abundance and liberation.
Vazante Ore 2016 – Geometallurgy (Votorantim, 2015)	Votorantim Tecnologia	Mineralogical evaluation of standard vs. anomalous ore blocks from the Vazante and Extremo Norte Mines, including liberation, mineral association. Rougher and scavenger flotation tests on various ore types.
Determination of the Ideal Granulometry for Floating Zinc in the Vazante Mill (Bechir et al, 2015)	Votorantim Tecnologia, Universidad de Sao Paulo	Flotation testing at different grind sizes to determine effect on zinc recovery
Standard jar mill test (Metso, 2014)	Metso York Test Facility, PA, USA	Standard jar mill test to support the sizing and specification of a vertically stirred grinding mill for the Vazante Plant W mill. Tested samples of Vazante and Vazante/Extremo Norte blend.
Comminution circuit survey, Bond Mill Work Index (BMWi) and Abrasion Index (Ai) tests to support expansion project	Votorantim Tecnologia, HDA	Comprehensive survey of the Plant W crushing and grinding circuit to generate data for circuit simulations to evaluate alternative equipment and circuit configurations for plant expansion. Supported by laboratory BMWi and Ai testing on selected ore samples from Vazante and Extremo Norte.
Geology, Mineralogy, and Geochemistry of the Vazante Northern Extension Zinc Silicate Deposit, Minas Gerais, Brazil (Slezak, 2012)	Queens University	Mineralogy of Extremo Norte deposit, including descriptive mineralogy and electron microprobe measurements of dolomite, willemite and sphalerite.

13.2.1 Mineralogy Studies

Votorantim has completed mineralogy testwork using a mineral liberation analyzer (MLA) to understand ore characteristics and determine how mineralogy affects metallurgical performance. Table 13-2 shows the minerals that have been identified, grouped by zinc minerals, lead–silver minerals and gangue minerals (Votorantim, 2015; Slezak, 2012).

For all the deposits at the Vazante Operations, willemite is the predominant zinc mineral, with others in minor or trace quantities. Therefore, the Vazante Operations produce a zinc concentrate that is elevated in silica and lower in sulphur compared with most zinc concentrates globally. Pure willemite contains approximately 59% Zn and 27% SiO_2. Minor galena is present, along with associated trace quantities of silver minerals. The low modal abundance of galena results in difficulties in producing high-grade lead concentrates. Sphalerite reports to lead concentrate.

Table 13-2: Major Mineral Species

Zinc Minerals	Lead–Silver Minerals	Gangue Minerals
Willemite, Zn_2SiO_4	Galena, PbS	Dolomite, $CaCO_3.MgCO_3$
Sphalerite, ZnS	Cerrusite, $PbCO_3$	Hematite, Fe_2O_3
Franklinite, $ZnFe_2O_4$	Jalpaite, Ag_3CuS_2	Quartz, SiO_2
Gahnite, $ZnAl_2O$	Duhamelite, $PbCu(As,V)O_4$	Mica
Zincite, ZnO	Anglesite, $PbSO_4$	Barite, $BaSO_4$
		Chlorite
		Siderite, $FeCO_3$
		Pyrite, FeS_2

Dolomite is the dominant gangue mineral in all Vazante Mine ore types; however, the Extremo Norte Mine contains significantly higher quantities of hematite than other Vazante Operations ores. The typical modal abundance of minerals is shown in Table 13-3.

The presence of carbonate gangue results in elevated calcium, magnesium, and carbonate levels in the zinc concentrate.

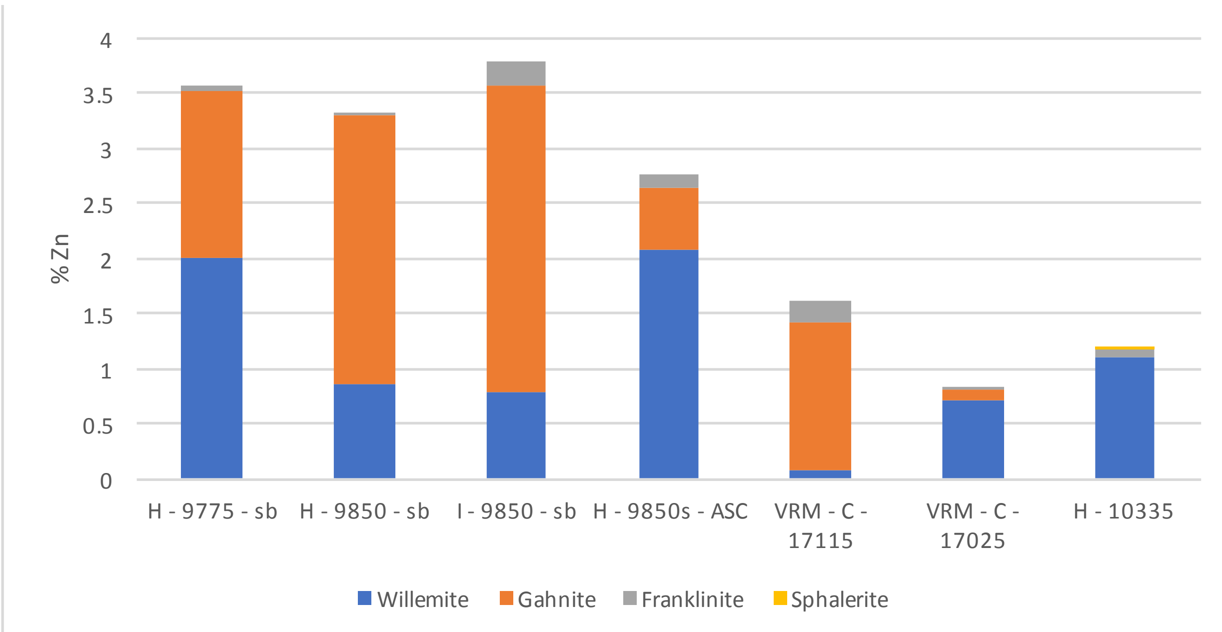
Studies have been conducted to understand how the zinc deportment in different minerals relates to zinc recovery. Different tailings streams were analyzed in 2016. Figure 13-1 shows that higher zinc tailings grades were observed for samples containing significant levels of gahnite. This suggests that future ores with elevated gahnite levels may show lower than typical zinc recovery.

In a study on mineralization from the Extremo Norte deposit by Slezak (2012), dolomite content was analyzed by electron microprobe (EMP). Dolomite from one mineralization type (type 4 breccia as defined by Slezak, 2012) was found to contain elevated ZnO content (2–4%), compared with other mineralization types (0–0.8%). If type 4 breccia mineralization was treated in the concentrator, zinc losses could be higher than normal, as dolomite is rejected as gangue to achieve target zinc concentrate quality. Dissolved zinc losses in dolomite would, in that case, contribute a significant amount to overall zinc losses in tailings.

Table 13-3: Mineral Modal Abundance

Mineral	Modal Abundance Range (%)
Willemite	15–30
Sphalerite	1–5
Galena	0.5–2
Dolomite	55–75
Hematite	5–20
Mica	1–10
Quartz	1–5
Barite	1–5

Figure 13-1: Vazante Tailings Zn Deportment by Mineral for Selected Ore Types



Note: Figure courtesy Votorantim, 2016.

13.2.2 Liberation and the Effect of Grind Size

In addition to assessing zinc deportment by mineral, Votorantim has also completed liberation and mineral association measurements, in conjunction with flotation tests at different grind sizes. In 2015, samples of ore were ground to five different size targets passing 150 µm: 76%, 82%, 88%, 94% and 99%. Liberation measurements were performed on the 82%, 88% and 94% passing 150 µm samples. For reference, the

88% passing 150 µm (p80 125 µm) is similar to the target grind size in the Vazante Operations mill in 2017. From 2012 to 2015, the grind size was coarser at 82.9% passing 150 µm (VMH, 2017), close to the 82% passing 150 µm case. The proportion of willemite in particles containing at least 85% willemite was used as an indicator of the potential quality of separation that could be achieved. This proportion is shown for the different grind sizes in Table 13-4.

The increased liberation levels at the finer grinds gives an indication of the potential to improve zinc recovery at finer grind sizes. Rougher flotation tests were completed to confirm the potential to improve zinc recovery. A standard reagent scheme was applied, at a pH of 10.5 and with reagent dosages as shown in Table 13-5.

The flotation tests used a two-minute roughing step. The metallurgical performance of the different grind sizes is shown in Table 13-6.

Results showed significant increases in zinc recovery, especially as the grind size was reduced from p80 of 176 µm to 124 µm. At the very fine 69 µm p80 grind, zinc recovery continued to increase, but concentrate grade deteriorated below target. This was attributed to difficulties in separating fine gangue particles entrapped with the fine concentrate froth. The study concluded that the current grind size used in the Vazante plant (p80 of 140 µm) was not optimized for zinc recovery, and that a finer grind, around 100 µm should be used.

Willemite liberation was also measured in different particle size fractions (Votorantim, 2016). The proportion of liberated (>85%) willemite in coarse particle fractions, + 150 µm (100#) was 48%, compared with 80% for fine fractions, - 37 µm (400#). This observation is consistent with the observed high zinc losses in coarser tailings fractions, as less liberated coarse particles are more likely to report to tailings.

The understanding of liberation was applied to selected ore blocks treated in 2015 and 2016. The proportion of willemite in the >85% liberation class was measured for two ore blocks with normal-good metallurgical performance, and three blocks with anomalous bad metallurgical performance. Results are shown in Table 13-7.

Willemite in tails for the anomalous blocks were found to be much more associated with dolomite than for normal blocks (37.9% vs 15.2%).

Table 13-4: Measured Willemite Liberation at > 85% Particle Class for Different Grind Sizes

% Passing 150 µm	p80 (µm)	% of Willemite in Particles with >85% Abundance
82%	145	77.8
88%	124	81.6
94%	102	82.2

Table 13-5: Standard Reagent Scheme

Reagent	Dosage (g/t)
Sodium sulphide (activator)	1,250
AGLP (dispersant)	320
Amine (collector)	70
MIBC (frother)	28

Table 13-6: Flotation Performance at Different Grind Sizes

% passing 150 µm	p80 µm	Head grade % Zn	Concentrate % Zn	Recovery % Zn
76%	176	11.9	37.5	64
82%	145	11.9	38.3	69.6
88%	124	11.9	37.9	78.7
94%	102	12	38.1	80.4
99%	69	12.1	34.7	84.4

Table 13-7: Willemite Liberation in Normal and Anomalous Ore Blocks

Sample	% Willemite in >85% Liberation Class
E10600 (normal)	69.3
I 10270 (normal)	87.2
I9850sB (anomalous)	47.5
H9850sB (anomalous)	58.8
H9775sB (anomalous)	19.0

13.2.3 Ore Hardness and Relation to Grind Size and Zinc Recovery

Ore Hardness

Testwork by Votorantim has confirmed that zinc losses to tailings increase at coarser grind sizes, and that grind sizes increase when harder ores, such as some of the material from Extremo Norte, are treated (Votorantim Metais Zinco Tecnologia, 2015, Minério de Vazante 2016 – Geometalurgia). Therefore, in 2014, Votorantim started investigating options to reduce grind size by installing additional comminution equipment in Plant W.

A consultant, HDA, was engaged to study alternative technologies and comminution circuit configurations. The study was based on a major plant survey in December 2013. In conjunction with this study, BMWi and Ai tests were completed on several Vazante and Extremo Norte ore samples. All samples were found to be hard from the work index perspective. Abrasion index was more variable, with the high-iron Extremo Norte Mine sample significantly more abrasive than Vazante Mine willemite or low-iron Extremo Norte Mine samples. Results are shown in Table 13-8.

Votorantim developed a test procedure to classify ores into different hardness categories, using a parameter, K, that represents the coarseness of grind that would be achieved on that ore for a given energy input. The parameter is determined from the weight % of ore retained on a 100# (150 µm) screen, for a laboratory mill feed and product. Ore is ground for a standard time (37 minutes) resulting in a standard energy input. The K value is then derived from the following equation:

- $K = 1/13.2 * \ln(F/P)$

Where 13.2 is the standard energy input, F is % retained on 100# screen in laboratory mill feed, and P is % retained on 100# screen in laboratory mill product.

A higher K value indicates a softer ore, and lower value, a harder ore, and typical Vazante ore has a K value of >0.158. Ores were compared from the Lumiadeira area within the Vazante Mine and the Extremo Norte Mine (Table 13-9).

This demonstrates that Extremo Norte ores have a higher proportion of harder ores than Vazante–Lumiadeira, and are therefore more susceptible to a drop in zinc recovery as grind size increases due to higher hardness.

Recovery by Size

The breakdown of zinc losses in tailings were measured in 2014 by assaying the zinc grade in different size classes. It was determined that zinc grades were highest in coarser size fractions (> 150 µm), and that these fractions contained a significant proportion of overall zinc losses in tailings. Figure 13-2 shows the zinc grade in final tailings particle size classes from samples in 2014. Much higher zinc grades were observed in the coarser factions (retained on 100# or 150 µm and 65# or 212 µm) compared with intermediate and finer sizes (retained on 150# or 105 µm, 270# or 53 µm, 400# or 37µm, and passing 400#). This is a clear indicator of higher zinc losses in the coarser size classes, that is low zinc recovery in those size classes.

13.2.4 Effect of Head Grades on Metallurgical Performance

Zinc rougher-scavenger flotation tests were completed using six minutes of flotation time, and results were reported by different zinc feed grade bins. A strong positive correlation was found between zinc head grade and zinc recovery (Table 13-10).

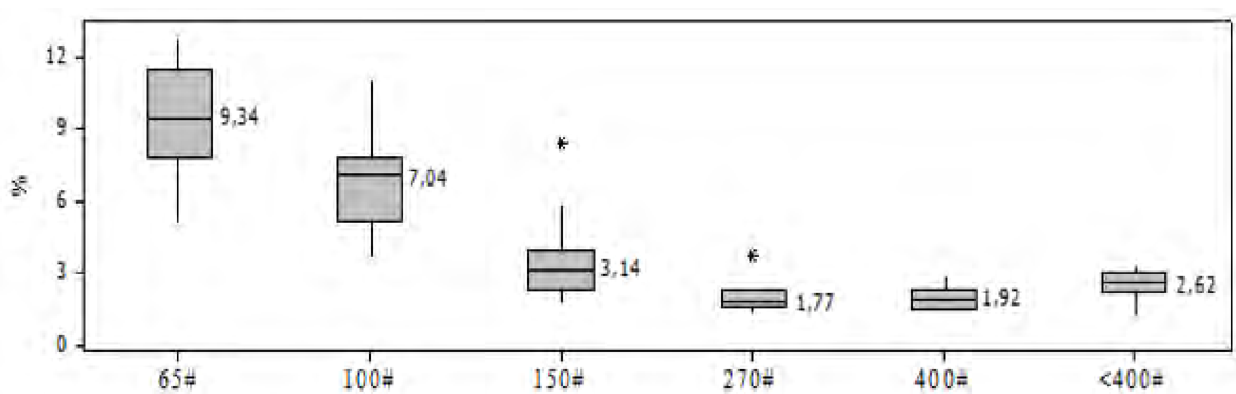
Table 13-8: Bond Mill Work Index and Abrasion Index Test Results

Sample	Bond Mill Work Index (kWh/t)	Abrasion Index
Vazante willemite	19.8	0.272
Extremo Norte low Fe (13 - 20%)	20.0	0.363
Extremo Norte high Fe (20 to 27%)	20.5	0.506
50:50 Vazante: high Fe Extremo Norte	19.6	
50:50 Vazante: high Fe Extremo Norte check	21.1	

Table 13-9: Distribution of Vazante and Extremo Norte Ore by Hardness Classes

Class	K value (range)	Vazante Lumiadeira	Extremo Norte	Forecast 2018–2028
A (soft)	K >0.24	31%	21%	6%
B	0.24 > K > 0.195	23%	29%	47%
C	0.195 > K > 0.158	38%	21%	22%
D (hard)	0.158 > K	8%	29%	25%

Figure 13-2: Zinc grade in Final Tailings by Particle Class for 2014 Samples



Note: Figure prepared by Votorantim, 2014.

Table 13-10: Comparison, Zinc Head Grade and Zinc Recovery

Zinc Head Grade Class	Zinc Recovery 2013–2015 Samples (%)	Zinc Recovery 2016 Samples (%)
% Zn <7.3	81.6	80.4
7.3 < % Zn < 10.9	86.2	84.3
10.9 < % Zn < 14.3	89.1	88.9
14.3 < % Zn	92.7	90.9

Zinc flotation tests were completed on Extremo Norte samples by breaking samples into different iron feed grade bins. No correlation was found between zinc recovery and iron grade in feed.

Lead rougher–scavenger flotation tests were also performed on Vazante and Extremo Norte samples. Samples were grouped into lead head grade bins (Table 13-11). Results indicated that it was challenging to produce an adequate lead concentrate grade at low lead head grades, but that the performance on 2016 samples was substantially worse than for 2015. Low rougher-scavenger concentrate grades are an indication that the lead circuit would fail to produce a saleable concentrate.

In rougher laboratory flotation tests completed in 2015 (Table 13-12), lead flotation performance was found to be much worse for Extremo Norte Mine samples than for Vazante Mine samples, for the same feed grade bin of 0.22% < % Pb < 0.39% (Votorantim, 2016). While these results may not correlate exactly with plant performance, they indicate that relative lead recovery performance of Extremo Norte may be worse than Vazante ores.

The reasons for poor lead metallurgy were not fully determined, and may relate to differences in deportment of lead in other minerals that have not been fully studied. The metallurgical results give an indication that lead recovery forecasts should be reduced for low grade and Extremo Norte ores. The geometallurgical program has provided Votorantim with information about mining blocks that should not be treated through the sulphide flotation process due to poor metallurgical performance.

13.3 Recovery Estimates

In 2016, Vazante predicted regressions for zinc recovery:

- Using zinc head grade alone
- Using a combination of mineralogy and zinc head grade

The head grade using only zinc head grade gave the following regression with R2 of 0.514:

- Zn recovery = 75.88 + 0.9771 * % Zn head grade

Including mineralogy, the regression with R2 of 0.731 was:

- Zn recovery = 92.7 + 0.179 * % willemite – 0.179 * % dolomite – 0.553 * % quartz – 0.141 * % hematite – 2.95 * % franklinite + 0.568 * % Zn head grade

Of the coefficients, franklinite, zinc, and quartz had the highest significance. The stronger regression incorporating mineralogy confirms the importance of mineral abundance on predicting zinc recovery.

Average recoveries for the LOMP are 85.8% Zn, 20.6% Pb, and 36.3% Ag.

Table 13-11: Lead Head Grade Bins

Lead Head Grade Class	Lead Concentrate Grade 2015	Lead Concentrate Grade 2016
% Pb <0.23	0.59	0.24
0.23 < % Pb < 0.30	1.07	0.52
0.30 < % Pb < 0.49	3.58	1.37
0.49 < % Pb	7.15	17.3

Table 13-12: Lead Rougher Flotation Test Results for Vazante Mine vs. Extremo Norte Mine Samples

	Vazante Mine	Extremo Norte Mine
Lead recovery (%)	16.8	6.7
Lead concentrate grade (% Pb)	1.09	0.95

13.4 Metallurgical Variability

Testwork for mineralogy, grinding and flotation has included samples from a range of Vazante and Extremo Norte ore zones. The geometallurgy program established by the Vazante Operations identifies and samples ore representative of each stope that is planned for the following year's production schedule. Quarterly mine plans are also reviewed by the geometallurgy team to ensure that all representative material is included in the test programs. Testwork appears to include material representative of the short to medium term variability of the deposit (2018–2020).

Laboratory grinding and flotation tests are competed, to determine the expected zinc recovery and concentrate grade. Mineralogical testing is also completed on the feed, concentrate and tailings from the laboratory tests using the mineralization liberation analyser (MLA) at UFMG. This program ensures that the metallurgical variability of different mine stopes is understood, and helps to predict the metallurgical performance of the process plant.

13.5 Deleterious Elements

13.5.1 Zinc Concentrates

The presence of willemite in Vazante Operations ore results in zinc concentrates that are unusually high in silica for feed to an electrolytic zinc smelter. However, the Tres Marias smelter has been configured to manage this.

Deleterious elements that need particular management in the concentrate are magnesium oxide (MgO) and fluorine.

The MgO specification is <4.0%, and the mine typically operates near the limit of this specification. Magnesium oxide is mainly present in dolomite, and control of it relates to the effectiveness of the willemite and dolomite separation. Magnesium oxide has increased from approximately 3.1% in 2010 and 2011, when target zinc concentrate was also higher (approximately 42%). Tres Marias quality specifications for zinc, MgO, carbonate and iron have been subsequently relaxed, and concentrate quality has consequently changed.

The fluorine specification in zinc concentrate is less than 250 ppm. The produced concentrates from 2014 to mid-2017 indicate a range from 220 to 245 ppm F for a range of Vazante and Extremo Norte Mine ore blends. Average fluorine content in concentrate has increased significantly from approximately 155 ppm F in 2010 and 2011.

Table 13-13 shows the annual zinc concentrate composition.

13.5.2 Lead Concentrates

Votorantim advised that there are no deleterious elements in the lead concentrates,

The Hachinohe smelter invokes a silica penalty at levels above 10%; however, to date, no lead concentrate has had silica levels high enough to incur the penalty.

There is no evidence to suggest that future concentrate production will have any other deleterious elements.

13.6 Comments on Section 13

Mineralogy has a significant influence on the concentrate grades and metal recoveries that can be achieved. Votorantim has developed a zinc recovery regression using head grades and mineral abundance. The presence of certain non-willemite zinc minerals such as franklinite can result in higher losses.

Zinc recovery is sensitive to grind size, and there is significant potential to improve zinc recovery by reducing grind size to approximately p80 of 100 µm.

Lead recovery falls at low head grades, and in general the lead recovery from Extremo Norte ores is poor. This may limit the ability to consistently produce a lead–silver concentrate.

Votorantim has developed robust laboratory grinding, flotation, and mineralogy test procedures as part of the geometallurgy program, which can be used to assess the metallurgical performance of future mill feed material.

Table 13-13: Annual Zinc Concentrate Composition

Year	Zn (%)	CO_3 (%)	MgO (%)	CaO (%)	Fe (%)	F (ppm)
2010	42.0	10.0	3.1	4.1	6.3	158
2011	41.7	9.1	3.1	4.5	5.5	153
2012	40.1	10.2	3.7	4.7	4.8	184
2013	40.3	10.2	3.8	4.8	4.7	215
2014	40.9	11.4	3.7	4.6	4.5	223
2015	39.7	10.4	4.0	4.7	5.8	230
2016	38.9	12.8	4.2	5.3	6.8	231
2017 (Jan to Apr)	39.1	12.2	3.7	4.7	6.3	241

14.0 MINERAL RESOURCE ESTIMATES

14.1 Introduction

The close-out date for the Vazante (including Sucuri Norte) and Extremo Norte databases is 27 December, 2016. A total of 631 channel samples were used for estimation with the drill hole samples.

14.2 Geological Models

The Vazante and Extremo Norte mine models were prepared using commercially-available Leapfrog software.

The stratigraphy of the metasedimentary domains was used to construct a preliminary lithological model using the "stratigraphic interpolant" function within Leapfrog (Figure 14-1). A model of the hydrothermal breccia (BXD) unit was created using a combination of lithology codes and zinc grades (Figure 14-2).

The mineralized envelopes, based on a 5% zinc cut-off that is a natural break displayed in probability plots, were constructed using Leapfrog's "vein interpolant" function. A low-grade (Zn <5%) domain or buffer zone was created proximal to the mineralized domain. This domain extended approximately 3 m from the mineralized contact. The buffer domain was not included in the Mineral Resource tabulations.

A block size of 8 m x 8 m x 4 m (x, y, z) was used. Sub-cells were constructed to better respect the geological volume, with a minimum size of 1 m x 1 m x 1 m.

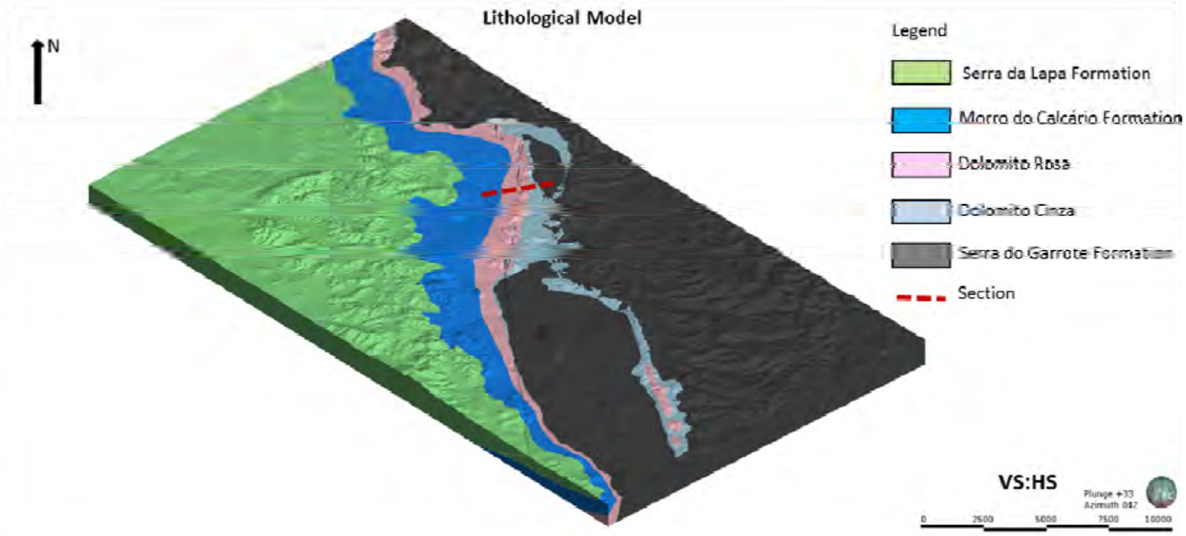
14.3 Exploratory Data Analysis

14.3.1 Channel Samples

The channel samples underwent the same analysis and QA/QC procedures as the drill hole samples. These data were merged only after analysis confirmed the absence of significant bias. Data were obtained from sample pairs within 5 m of each other. The mean zinc grade typically agreed within 1%.

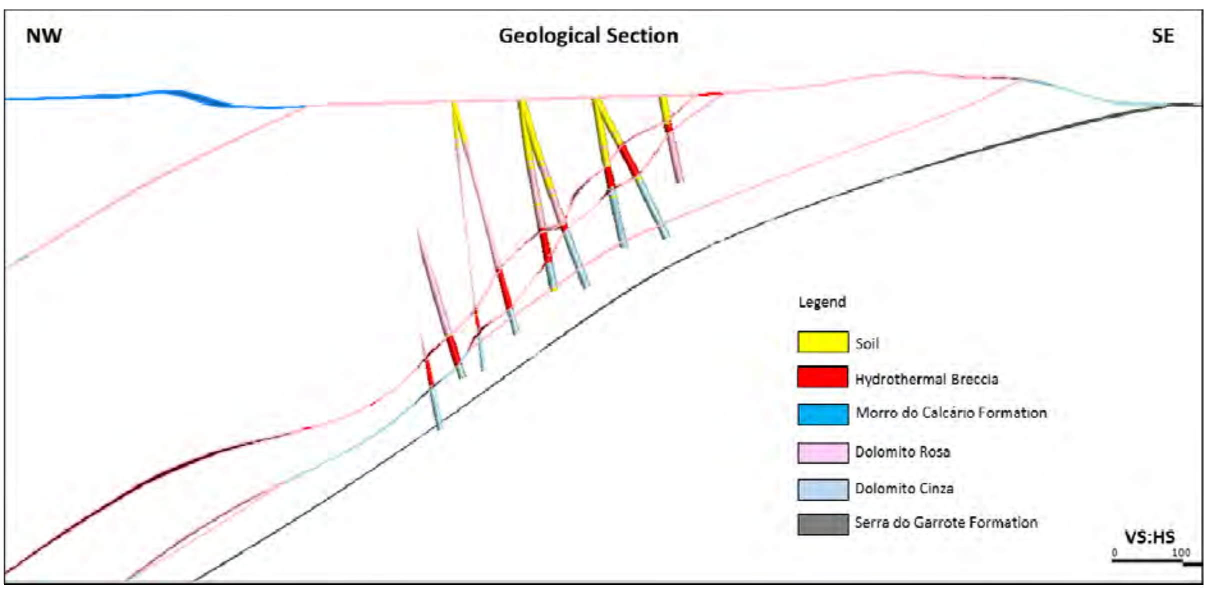
The following sub-sections report the results of the exploratory data analysis completed on the combined channel and drill hole datasets.

Figure 14-1: Lithology Interpretation



Note: Figure courtesy Votorantim, 2017. Dolomito Rosa = pink dolomite; Dolomito Cinza = grey dolomite.

Figure 14-2: Vazante Mine Section Showing Hydrothermal Breccia Interpretation



Note: Figure courtesy Votorantim, 2017. Dolomito Rosa = pink dolomite; Dolomito Cinza = grey dolomite

14.3.2 Declustering Analysis

A cell de-clustering analysis was conducted to check the influence of clustered or closely spaced samples in the data. A cluster of high-grade data was noted, and a cell size of 50 x 50 x 50 m was used to obtain declustered statistics.

14.3.3 Bivariate Analysis

Bivariate analysis was undertaken using scatterplots. The linear correlation coefficients indicate a low correlation between the variables reviewed. The highest correlation noted, at 0.416, was between lead and silver.

14.3.4 Data Evaluation

A histogram evaluation and an examination of the basic statistics of the main deposit variables, zinc, lead, iron, and silver, was performed after grade capping and declustering.

14.3.5 Contact Plots

Contact plots were constructed to assess the nature of the mineralization at the contacts between the (≥ 5% Zn) and low-grade domain (<5% Zn) for both deposits. This indicated that the contact should be treated as “hard”, with no sharing of composites between the two domains.

14.4 Density Assignment

Linear regression equations were used to make a correlation between the sum of zinc plus lead plus iron grades, compared to measured density values. The density database has in excess of 127,000 data points. The regression formula was applied to the resource model blocks based on estimated grades to determine a density value for each block.

The final density equation used for both deposits was:

$$Density = 0.022657 \times (Zn + Pb + Fe) + 2.785876$$

14.5 Grade Capping/Outlier Restrictions

Grade caps were established using probability plots. The capping values were defined separately in the mineralized domain (≥ 5% Zn) and low-grade domain (<5% Zn), see Table 14-1.

Table 14-1: Grade Caps

Capping Values		Zn (%)	Pb (%)	Ag (g/t)	Fe (%)
Vazante	Mineralized (≥ 5% Zn)	54	6	550	50
	Low-grade (<5% Zn)	40	2.5	200	45
Extremo Norte	Mineralized (≥ 5% Zn)	48	3	130	47
	Low-grade (<5% Zn)	24	1	25	50

14.6 Composites

One metre composites were created for both deposits, based on the most common sampling interval.

14.7 Variography

Votorantim constructed separate variograms for zinc, lead, iron, and silver for the Vazante and Extremo Norte domains, using GSLIB. The variogram models were oriented to conform to the main directions of the mineralized body.

Downhole variograms were constructed to determine the nugget effect for each variable. An experimental unit sill (variogram variance was standardized to 1) was calculated for each element. The models were built using nested spherical models.

14.8 Estimation/Interpolation Methods

Ordinary kriging (OK) was selected to estimate the zinc, lead, iron, and silver grades within the block model, and the step was conducted separately for the Vazante and Extremo Norte deposits.

Multi-pass kriging strategies were used in three passes, together with octants and sample constraints (Table 14-2 and Table 14-3). The second and third passes consists of respectively, two and three times the variogram ranges.

A minimum of 10 and maximum of 80 samples were allowed for estimation purposes, based on a quantitative kriging neighbourhood analysis. In both Vazante and Extremo Norte, a discretization of 4 x 4 x 4 was employed.

Table 14-2: Search Parameters, Vazante Mine

Element	Search Range			Rotation			Min Octants	Min Samples Per Octant	Max Samples Per Octant	Min Number of Samples	Max Number of Samples	Max Samples Per Drill Hole
	X	Y	Z	Z	Y	X						
Zn	100	190	35	48	0	57	2	1	40	10	80	—
Pb	40	110	7	48	0	57	2	1	40	10	80	—
Ag	45	50	7	48	0	57	2	1	40	10	80	—

Table 14-3: Search Parameters, Extremo Norte

Element	Search Range			Rotation			Min Octants	Min Samples Per Octant	Max Samples Per Octant	Min Number of Samples	Max Number of Samples	Max Samples Per Drill Hole
	X	Y	Z	Z	Y	X						
Zn	100	190	8	30	0	48	2	1	40	10	80	—
Pb	60	80	7	30	0	48	2	1	40	10	80	—
Ag	45	75	8	30	0	48	2	1	40	10	80	—

14.9 Block Model Validation

After the entire estimation process, the resulting resource model must honour the local geology, mineralization domains, and sample data. To ensure that the result of the estimate was unbiased, Votorantim staff followed internal validation procedures, which include Inferred Mineral Resources in the validations. However, Amec Foster Wheeler included only Measured and Indicated Mineral Resources in validations performed in support of this Report.

The kriged block estimates were checked for global bias by comparing the average grade (with no cut-off) from the estimated model with that obtained from nearest-neighbour (NN) estimates. The global biases were within the recommended Amec Foster Wheeler guidelines of ±5% (relative) for zinc, lead, and silver within the mineralized envelope for Measured and Indicated Mineral Resources.

Amec Foster Wheeler completed change of support checks using Herco (based on Hermetian correction (Herco) for change of support calculations as described in Journel and Huijbregts, 1978) comparisons within Measured and Indicated blocks contained in the mineralized envelopes. A selective mining unit (SMU) size of 20 m x 10 m x 4 m was used. These checks showed that estimated grades for zinc were acceptable near the economic cut-off grades of 5% Zn, with the contained metal agreeing within approximately 2% to the Herco-adjusted contained metal.

Checks for local biases for zinc, lead, iron, and silver were performed within the mineralized envelopes by creating and analyzing local trends in the grade estimates using swath plots. Swath plots for Measured and Indicated zinc blocks showed good agreement, especially in areas supported by large numbers of blocks (Figure 14-3 and

Figure 14-4). The results of the swath plots for the other elements are also considered acceptable.

Visual validations were also carried out by comparing the composites grades and the estimated block grades.

14.10 Classification of Mineral Resources

Mineral Resource classification assigned by Vazante, based on the 2012 JORC Code. Table 14-4 summarizes the considerations used in the classification.

The final limits for the Measured, Indicated and Inferred classifications were manually refined to remove isolated blocks of one confidence category in areas where most of the blocks were classified using another category. Kriging variance was used as reference in this post-processing to help define the limits.

A drill hole spacing study was conducted which suggests for both deposits that a drill spacing of 30 m is required to support Measured Mineral Resources, 75 m is required to support Indicated Mineral Resources and 110 m for Inferred Mineral Resources.

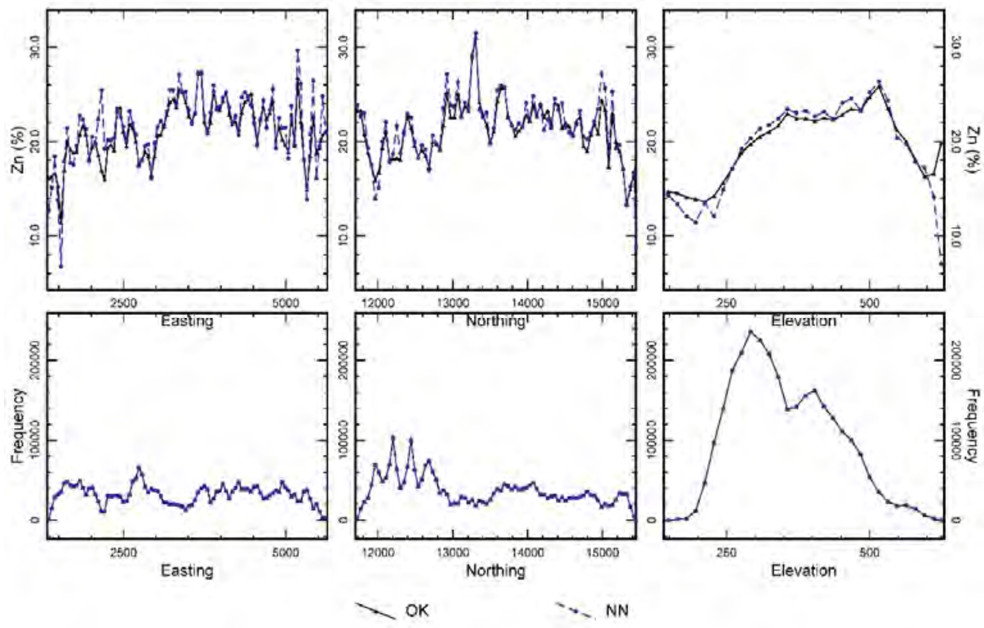
For a block to be classified as Measured Mineral Resources, one drill hole must be within 25 m and two drill holes within 35 m. Indicated Resources required two drill holes within the 80 m and an additional drill hole with 60 m. Inferred Mineral Resources required a single hole within 110 m of the block.

Blocks were classified based on Amec Foster Wheeler’s drill spacing criteria and tabulated. The resulting tabulation compared well to Votorantim’s classification, thus Amec Foster Wheeler accepted the classification of Mineral Resources as determined by Votorantim.

The initial Votorantim estimate was refined to remove the following blocks: mineralized pillars that must be retained for mine stability, areas of geotechnical concern, mined-out areas, and areas where information is insufficient to support block confidence classification (non-classified blocks).

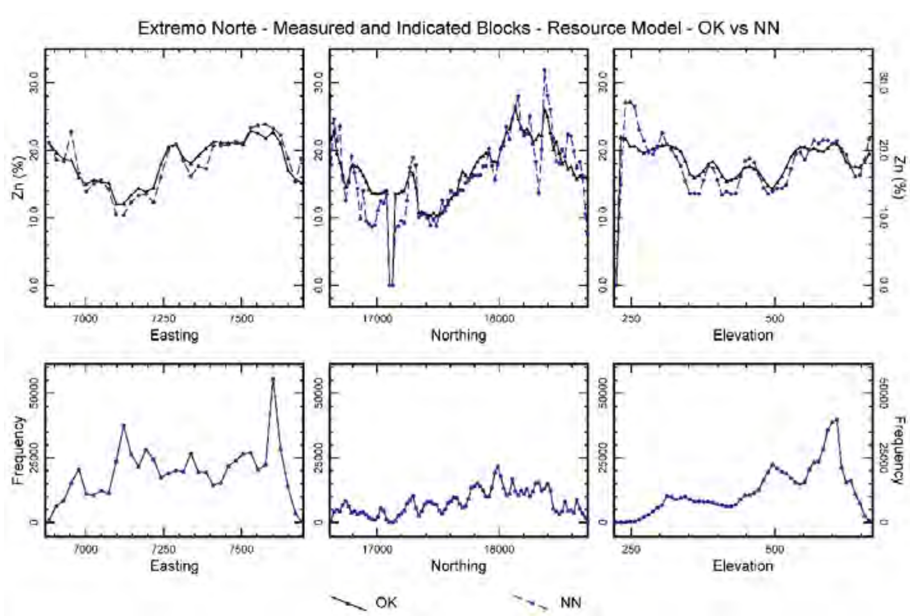
Figure 14-5 illustrates the confidence categories assigned by Votorantim to the Vazante deposit, and Figure 14-6 shows the areas that were downgraded. Figure 14-7 shows the classifications for the Extremo Norte deposit.

Figure 14-3: Swath Plot Comparisons of OK vs NN, Vazante Measured and Indicated



Note: Figure courtesy Votorantim, 2017.

Figure 14-4: Swath Plot Comparisons of OK vs NN, Extremo Norte Measured and Indicated

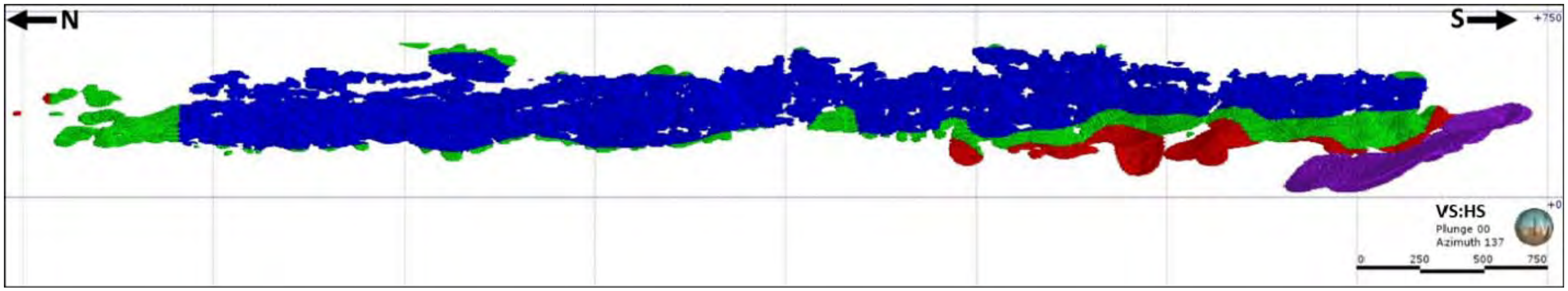


Note: Figure courtesy Votorantim, 2017.

Table 14-4: Initial Resource Classification Criteria

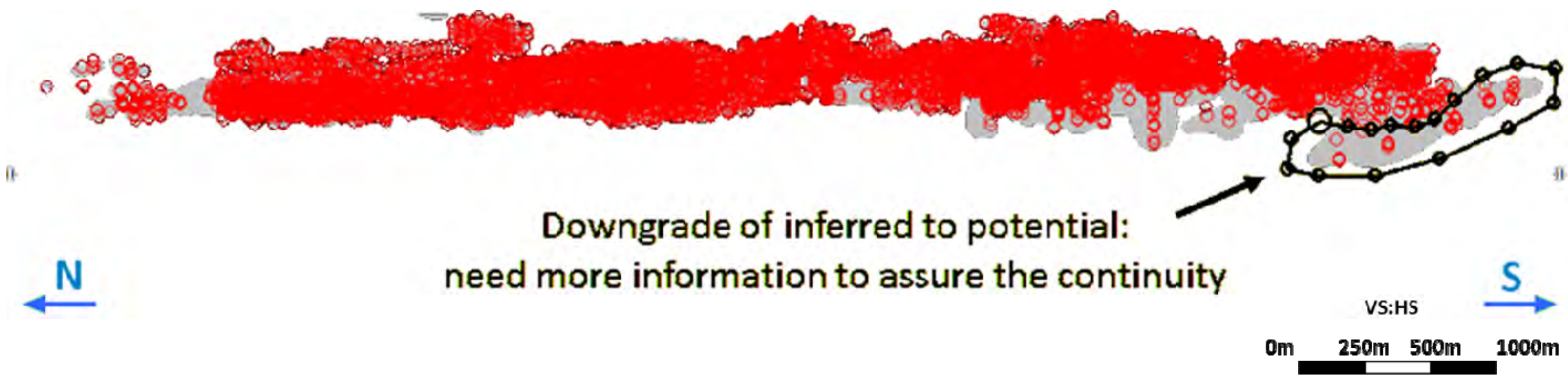
Classification	Number of Samples And/or Drill Spacing	Quality of Information: QA/QC, Density and Topography	Opened Level, Sampled and Mapped	Final Classification
Measured	First search volume, minimum of 3 mineralized intercepts (25 x 15 m)	Acceptable QA/QC results	Opened level mapped	Final definition using a refined wireframe
Indicated	Second search volume, minimum of 3 mineralized intercepts (50 x 30 m)	Acceptable QA/QC results	Opened level mapped	Final definition using a refined wireframe
Inferred	Third search volume, minimum of 3 mineralized intercepts (100 x 100 m)	Remaining	Remaining	Remaining

Figure 14-5: Confidence Classifications, Vazante



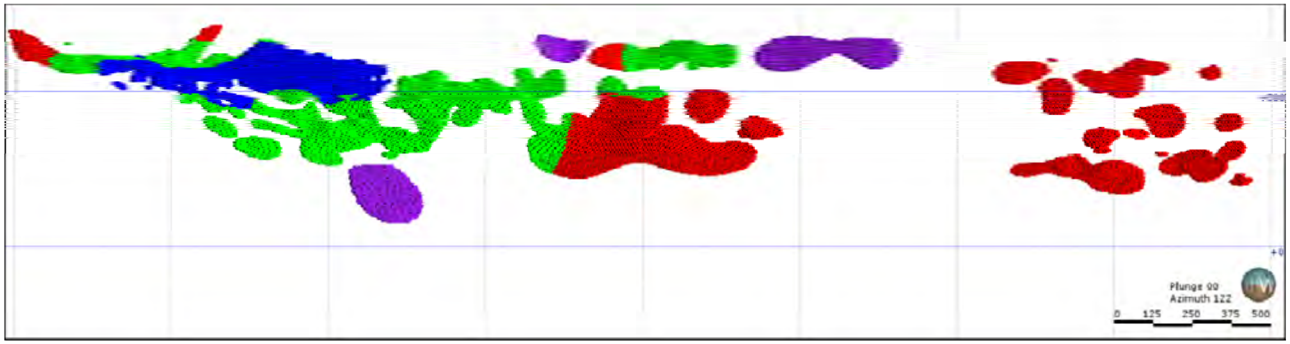
Note: Figure courtesy Votorantim, 2017. Blue = Measured; green = Indicated in green, red = Inferred; magenta = unclassified.

Figure 14-6: Confidence Classifications Showing Areas of Downgrade



Note: Figure courtesy Votorantim, 2017.

Figure 14-7: Confidence Classifications, Extremo Norte



Note: Figure courtesy Votorantim, 2017. Blue = Measured; green = Indicated in green, red = Inferred; magenta = unclassified.

14.11 Reasonable Prospects of Eventual Economic Extraction

The Mineral Resource was defined based on SMU (stopes). No cut-off was applied to the Mineral Resource because the Mineral Reserve study demonstrated that all of the modeled Mineral Resource blocks had reasonable prospects of eventual economic extraction.

For the material available in the Measured and Indicated categories at Vazante and Extremo Norte, reasonable prospects for eventual economic extraction of the resource base are established at Vazante and Extremo Norte using the breakeven net smelter return (NSR) cut-off criteria applied during the process of designing and blocking out conceptual sub-level open stope (SLOS) and vertical retreat (VR) stope volumes. Conceptual stope volumes and portions of these volumes that are not scheduled (and converted to Mineral Reserves) remain in the Measured and Indicated Mineral Resource categories.

The Inferred material is reported at the breakeven NSR cut-off in-situ within the interpreted mineralized envelope.

To meet reasonable prospects of eventual economic extraction assumptions, only the blocks within the mineralized domain are included in the Mineral Resources. Within this domain, a NSR cut-off of US$52.12/t was applied. This cut-off is the all-in cost and is based on an assumed average price of zinc and lead for the next 10 years (see Section 19.2) with a 15% uplift applied to those prices for the purposes of Mineral Resource estimation.

The NSR is calculated as follows:

- If Zn(%) ≥ 2.6, NSR = 19.0653 x Zn(%)
- If Pb(%) ≥ 0.25, NSR = 1.8743 x Pb(%)
- Ag(g/t), NSR = 5.88 x Ag(g/t)/31.1035.

The NSR calculations include an allocation in US$/t for the zinc premium that is paid by the Tres Marias smelter, which is the average of the 2017–2026 assumed payable premiums. The average value is US$234.72/t.

Areas that have been mined have been removed from the Mineral Resource estimate.

Other assumptions include:

- Zinc price used is US$2,767.00/t (US$1.26/lb), lead price is US$2,235/t (US$1.01/lb), silver price is US$18.94/oz
- Zinc metallurgical recovery is 86%, lead metallurgical recovery is 21%, silver metallurgical recovery is 36%

- Mining cost of US$14.00/t, plant cost of US$18.25/t, maintenance and other costs of US$19.87/t.

14.12 Mineral Resource Statement

Mineral Resources were initially classified to the 2012 JORC Code, and reconciled to the definitions in the 2014 CIM Definition Standards. Votorantim staff prepared the estimates. The QP responsible for the estimate is Mr Douglas Reid, P.Eng., an Amec Foster Wheeler employee.

Mineral Resources have an effective date of 31 December, 2016, and are reported exclusive of Mineral Reserves.

The aggregated Mineral Resources for the Vazante Operations are included as Table 14-5. Mineral Resources for the Vazante deposit are provided in Table 14-6. Mineral Resources for the Extremo Norte deposit are included as Table 14-7.

14.13 Factors That May Affect the Mineral Resource Estimate

Factors that may affect the Mineral Resource estimates include:

- Additional infill and step out drilling
- Changes in local interpretations of mineralization geometry and continuity of mineralization zones
- Density and domain assignments
- Changes to design parameter assumptions that pertain to stope design
- Dilution from internal and contact sources
- Changes to geotechnical, hydrogeological, and metallurgical recovery assumptions
- Changes to the assumptions used to generate the NSR value including long-term commodity prices and exchange rates

14.14 Comments on Section 14

Mineral Resources are reported in accordance with the 2014 CIM Definition Standards.

Table 14-5: Mineral Resource Statement

	Tonnage (Mt)	Zn Grade (%)	Pb Grade (%)	Ag Grade (g/t)
Measured	1.8	17.81	0.43	28.82
Indicated	1.2	15.54	0.38	20.82
Total Measured + Indicated	***3.1***	***16.90***	***0.41***	***25.60***
Inferred	2.9	16.34	0.35	22.35

Notes to accompany Mineral Resource Table:

1. Mineral Resources have an effective date of 31 December 2016. Douglas Reid, P. Eng, an Amec Foster Wheeler employee, is the Qualified Person responsible for the Mineral Resource estimate.
2. Mineral Resources are reported exclusive of the Mineral Resources converted to Mineral Reserves. Mineral Resources that are not Mineral Reserves do not have demonstrated economic viability.
3. Mineral Resources are reported within a 5% Zn envelope with a US$52.12 NSR cut-off applied. The NSR is calculated as follows: if Zn(%) ≥ 2.6, NSR = 19.0653 x Zn(%); if Pb(%) ≥ 0.25, NSR = 1.8743 x Pb(%); Ag(g/t) NSR = 5.88 x Ag(g/t)/31.1035. The NSR calculations include an allocation of US$234.72/t for the zinc premium paid by the Tres Marias smelter. Zinc price used is US$2,767.00/t (US$1.26/lb), lead price is US$2,235/t (US$1.01/lb), silver price is US$18.94/oz. Zinc metallurgical recovery is 86%, lead metallurgical recovery is 21%, silver metallurgical recovery is 36%. Cost assumptions include mining cost of US$14.00/t, plant cost of US$18.25/t, maintenance and other costs of US$19.87/t.
4. Mineral Resources are stated as in situ with no consideration for planned or unplanned external mining dilution. Mineral Resources are reported on a 100% basis.
5. Rounding as required by reporting guidelines may result in apparent summation differences.
6. Mineral Resources in Table 14-6 and Table 14-7 are not additive to the Mineral Resources in this table.

Table 14-6: Mineral Resource Statement for the Vazante Mine

	Tonnage (Mt)	Zn Grade (%)	Pb Grade (%)	Ag Grade (g/t)
Measured	1.7	17.69	0.44	30.29
Indicated	0.7	16.12	0.43	28.35
Total Measured + Indicated	***2.4***	***17.21***	***0.43***	***29.69***
Inferred	1.1	16.32	0.46	34.89

Notes to accompany Mineral Resource Table:

1. Mineral Resources have an effective date of 31 December 2016. Douglas Reid, P. Eng, an Amec Foster Wheeler employee, is the Qualified Person responsible for the Mineral Resource estimate.
2. Mineral Resources are reported exclusive of the Mineral Resources converted to Mineral Reserves. Mineral Resources that are not Mineral Reserves do not have demonstrated economic viability.
3. Mineral Resources are reported within a 5% Zn envelope with a US$52.12 NSR cut-off applied. The NSR is calculated as follows: if Zn(%) ≥ 2.6, NSR = 19.0653 x Zn(%); if Pb(%) ≥ 0.25, NSR = 1.8743 x Pb(%); Ag(g/t) NSR = 5.88 x Ag(g/t)/31.1035. The NSR calculations include an allocation of US$234.72/t for the zinc premium paid by the Tres Marias smelter. Zinc price used is US$2,767.00/t (US$1.26/lb), lead price is US$2,235/t (US$1.01/lb), silver price is US$18.94/oz. Zinc metallurgical recovery is 86%, lead metallurgical recovery is 21%, silver metallurgical recovery is 36%. Cost assumptions include mining cost of US$14.00/t, plant cost of US$18.25/t, maintenance and other costs of US$19.87/t.
4. Mineral Resources are stated as in situ with no consideration for planned or unplanned external mining dilution. Mineral Resources are reported on a 100% basis.
5. Rounding as required by reporting guidelines may result in apparent summation differences.
6. Mineral Resources in Table 14-5 are not additive to the Mineral Resources in this table.

Table 14-7: Mineral Resource Statement for the Extremo Norte Mine

	Tonnage (Mt)	Zn Grade (%)	Pb Grade (%)	Ag Grade (g/t)
Measured	0.2	18.99	0.31	13.60
Indicated	0.5	14.66	0.31	9.29
Total Measured + Indicated	***0.7***	***15.74***	***0.31***	***10.36***
Inferred	1.8	16.35	0.28	14.89

Notes to accompany Mineral Resource Tables:

1. Mineral Resources have an effective date of 31 December 2016. Douglas Reid, P. Eng, an Amec Foster Wheeler employee, is the Qualified Person responsible for the Mineral Resource estimate.
2. Mineral Resources are reported exclusive of the Mineral Resources converted to Mineral Reserves. Mineral Resources that are not Mineral Reserves do not have demonstrated economic viability.
3. Mineral Resources are reported within a 5% Zn envelope with a US$52.12 NSR cut-off applied. The NSR is calculated as follows: if Zn(%) ≥ 2.6, NSR = 19.0653 x Zn(%); if Pb(%) ≥ 0.25, NSR = 1.8743 x Pb(%); Ag(g/t) NSR = 5.88 x Ag(g/t)/31.1035. The NSR calculations include an allocation of US$234.72/t for the zinc premium paid by the Tres Marias smelter. Zinc price used is US$2,767.00/t (US$1.26/lb), lead price is US$2,235/t (US$1.01/lb), silver price is US$18.94/oz. Zinc metallurgical recovery is 86%, lead metallurgical recovery is 21%, silver metallurgical recovery is 36%. Cost assumptions include mining cost of US$14.00/t, plant cost of US$18.25/t, maintenance and other costs of US$19.87/t.
4. Mineral Resources are stated as in situ with no consideration for planned or unplanned external mining dilution. Mineral Resource are reported on a 100% basis.
5. Rounding as required by reporting guidelines may result in apparent summation differences.
6. Mineral Resources in Table 14-5 are not additive to the Mineral Resources in this table.

15.0 MINERAL RESERVE ESTIMATES

15.1 Introduction

The Mineral Reserves have been established based on actual costs and modifying factors from the Vazante Operations, and on operational level mine planning and budgeting.

15.2 Mineral Reserves Statement

Mineral Reserves in Table 15-1 use the 2014 CIM Definition Standards. The QP responsible for the Mineral Reserves estimate is William Bagnell, P.Eng., an Amec Foster Wheeler employee. Mineral Reserves are reported using a net smelter return (NSR) cut-off.

15.3 Factors that May Affect the Mineral Reserves

The Vazante underground mine has been in operation since 1983. The annual mine production will average approximately 1.5 Mt/a (ranging from 1.38–1.60 Mt/a) over the remaining LOM.

Factors that may affect the ability of the Vazante Operations to extract the Mineral Reserves safely and economically include:

- Commodity prices and exchange rate assumptions
- Global markets
- Internal operating costs
- Government actions including changes to environmental, permitting, taxation and royalty regulations and laws
- Social licence to operate
- Geological unknowns
- Availability of skilled labour
- Variations in metallurgical performance.

Votorantim may also have site-specific issues due to the underground mining method, including deterioration of ground conditions due to geological or hydrogeological changes, mining-induced seismic events limiting access to mining areas, and higher than predicted ground water or surface water inflow events.

Table 15-1: Mineral Reserves Statement

Classification	Tonnage (Mt)	Zn Grade (%)	Pb Grade (%)	Ag Grade (g/t)
Proven	8.68	11.11	0.30	17.52
Probable	6.34	9.61	0.28	13.73
Total Proven and Probable	***15.02***	***10.48***	***0.29***	***15.92***

Notes to accompany Mineral Reserves table:

1. Mineral Reserves have an effective date of 30 June, 2017. The Qualified Person responsible for the estimate is William Bagnell, P.Eng., an Amec Foster Wheeler employee.
2. Mineral Reserves are reported within engineered stope outlines on a 100% basis assuming three mining methods: sub-level open stoping (SLOS), vertical retreat mining (VRM) with rock backfill, and mechanized cut-and-fill (C&F) with rock backfill. Typical stope dimensions are 30 m high x 60 m long x 8 m deep. A minimum mining width of 4 m is applied to all stopes. Typical C&F rooms are 4 m x 4 m. Mineral Reserves incorporate dilution and mining recovery factors.
3. All Mineral Reserves are reported at a net smelter return (NSR) cut-off value independent of the mining method. SLOS/VRM and C&F are reported with an NSR cutoff of $52.12/t. The NSR calculations are based on head grade mill recoveries of 85.8% Zn, 20.6% Pb and 36.3% Ag. Metal prices used for the NSR calculation are: Zn: US$1.09/lb; Pb: US$0.88/lb; and Ag: US$18.94/oz. NSR calculations are based on polynomial equations for each of the concentrate elements, and incorporate considerations of sliding smelter payments that vary depending on the grade of the concentrate.
4. Totals may not sum due to rounding.

15.4 Underground Estimates

15.4.1 Throughput Rate and Supporting Assumptions

Life of mine planning is based upon a phased expansion of mine throughput between 2020 and 2024 which will see a 13% percent increase in the annual production rate from 1.38 Mt/a to 1.60 Mt/a (approximate LOM average rate of 1.5 Mt/a). This is an incremental change to the production rate and the necessary capital investments have been made to support this increase. The major capital items to support the throughput rate increase are:

- Increases in the underground haul truck fleet numbers from the current 15 units to 18 units by 2021
- Installation of a Vertimill in the process plant to support the higher tonnage rate from Extremo Norte, which has slightly harder ore than Vazante.

15.4.2 Stopes

Two types of stoping are employed at Vazante:

- Sub-level open stoping (SLOS)
- Vertical retreat mining (VRM).

Both stoping types employ a retreat sequence along strike and are broken into panels to minimize the open hanging wall area during extraction. The stoping method is consistent with the thickness and orientation of the deposits at Vazante.

Sub-level open stoping is only applied to the recovery of remnants that do not have continuity between levels. The stopes are drilled with upholes only to the extent of the mineralization envelope and ring blasted to recover the available ore.

Vertical retreat mining is applied to mineralized areas that have continuity between levels. Drilling of downholes between levels from the overcut or a combination of upholes from the undercut and downholes are employed where the deposit has sufficient undulation to require a change of drilling orientation.

Backfilling of VRM stopes is done with uncemented development waste rock dumped from the overcut horizon. Sub-level open stopes are not backfilled due to the lack of access for backfilling from the level above.

15.4.3 Dilution and Mine Losses

The stope shapes developed for Mineral Reserve planning at Vazante include any internal waste material at zero grade. The stope shapes also include any Inferred Mineral Resource material at zero grade. These stope shapes are the Mineral Resource stope shapes and have not had modifying factors applied.

The assumptions for dilution in the SLOS and the VRM areas are shown in Table 15-2, and vary depending upon the width of the stope across strike.

Mine recovery is estimated based upon the mining method planned for the area and the historical values reported for that method in previous years’ production. Historic dilution is based upon cavity monitor surveys to map the final opening of the stope. This is then compared back to the planned extraction shape. Final dilution includes both planned dilution within the mining envelope and additional waste rock (if any) within the final stope shape.

For the life-of-mine (LOM) reserve case, recovery is estimated at 98% of the broken ore for SLOS and VRM mining. Recovery of the rib pillars is estimated at 60% for mine planning purposes.

For the cut-and-fill (C&F) mining areas planned for later in the mine life, the recovery factor is also 98%. Dilution in the C&F areas is assumed to be 12%. The C&F dilution figure is based upon the historical development overbreak factor used in waste and ore development headings.

Table 15-2: Vazante Stoping Dilution Factors

Mining Method	Ore Width Across Strike (m)	Dilution Factor (%)	Mining Recovery (%)
Stoping	<6	23	98
	>6 but <10	18	98
	>10	12	98
Cut-and-fill	5	12	100

15.4.4 Cut-off Criteria

The various deposits at Vazante are polymetallic and contain zinc, lead and silver as the primary metals. For purposes of mine planning the deposits are assumed to perform similarly in the process plant and not have adverse effects on the recovery process. Blending is not undertaken for metallurgical purposes.

Historically Vazante has employed an equivalent zinc (ZnEq) cut-off grade for mine planning purposes. The ZnEq converts all metals in the deposit to an equivalent zinc value using agreed upon metal prices and process plant recoveries for the individual metals present in the run-of-mine ore. Vazante moved away from ZnEq to NSR with the Milpo acquisition in Peru to have consistent break-even cut off cost calculations between operations.

The economic cut-off value used is a net smelter return (NSR) value that is populated in the block model, and is based upon a linear regression of the following factors:

- The contained metal within the mining block or stope
- The metal price input of zinc, lead and silver
- The recovery of the various metals from the process plant
- The costs associated with the mining, processing and refining the of process concentrate
- Various other factors such as taxes and royalties.

Commodity prices used for the development of the NSR calculation are shown in Table 15-3.

The current NSR calculation is shown in Equation 1.

Table 15-3: NSR Calculation Commodity Prices

Metal	Units	Price)	Units	Reserve
Zinc	US$/t	2,406	$/lb	1.09
Lead	US$/t	1,943	$/lb	0.88
Silver	US$/oz	18.94	$/oz	18.94

Note: * based upon Votorantim price assumptions as communicated 09 May 2017

Equation 1: Vazante NSR Calculation

- $NSR = 1{,}607.49 \times Zn_{HG} + 185.64 \times Pb_{HG} + 7.41 \times Ag_{HG}$

Where Zn and Pb are in %, Ag is in oz/t, and HG = head grade.

Costs associated with sustaining capital and capital recovery factors are not included in the NSR calculation. For mine planning purposes the NSR can be considered the break-even cut-off grade.

Breakeven operating costs for the sub-level open stoping and vertical retreat mining methods are shown in Table 15-4. The break-even mine operating cost component of the NSR for Vazante is US$52.12/t.

15.5 Comments on Section 15

Mineral Reserves are reported in accordance with the 2014 CIM Definition Standards.

Table 15-4: Break Even Site Operating Costs

Costs	Unit	Value
Mine Cost	US$/t	14.00
Plant Costs	US$/t	18.25
Maintenance Costs	US$/t	9.64
Other Costs	US$/t	10.23
AIC	**US$/t**	52.12
Sustaining	US$/t	—
AISC	**US$/t**	52.12

Note: AIC = all-in cost, AISC = all-in sustaining cost

16.0 MINING METHODS

16.1 Overview

The underground Vazante Operations have been in operation since 1983, and are fully mechanized, using rubber-tired diesel equipment for development and production activities. Access is through two portals for Vazante and one portal for Extremo Norte. As development progresses at Extremo Norte a connecting drift will be established from Vazante to Extremo Norte.

Underground mining consists of three distinct mining areas (Figure 16-1):

- Sucuri (north and south)
- Extremo Norte
- Lumiadeira (north and south).

The mine has a current depth of 350 m below surface and is producing from six levels. Future expansion is planned below the current Level 326 horizon to expose additional mineralization for extraction. The expansion requires completion and commissioning of the EB140 pump room before extending mine workings below the existing EB297 pump room.

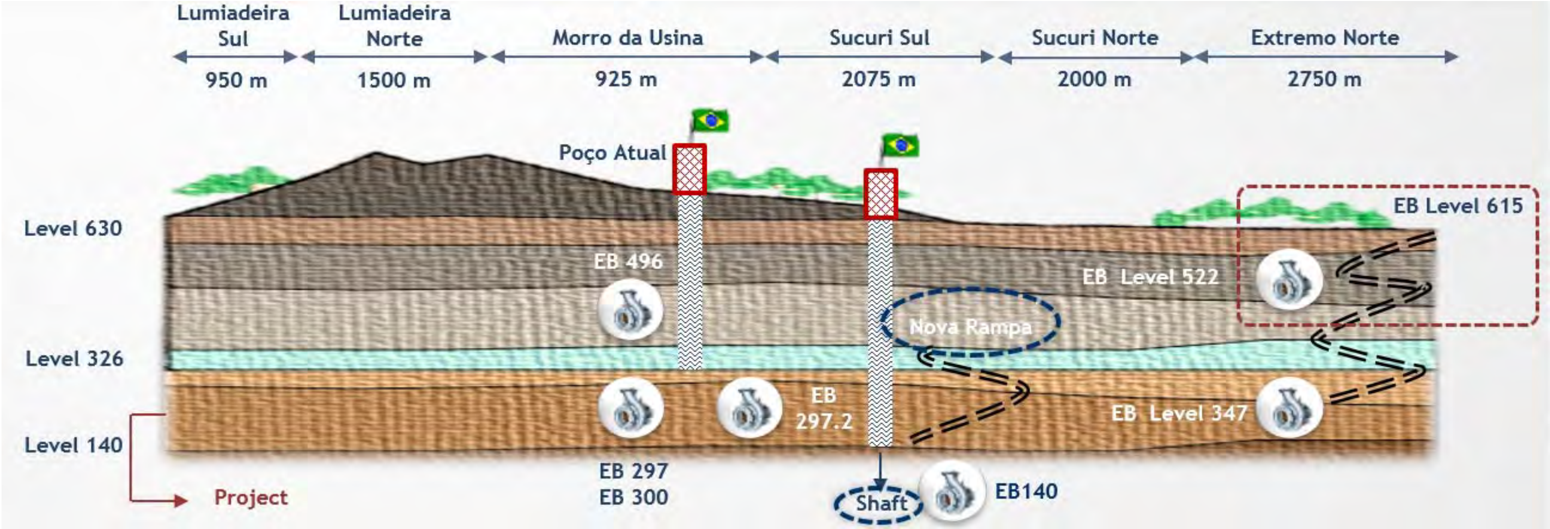
Ore is hauled to surface with 28 t haul trucks via ramps, and is stored in surface stockpiles at the portals for later re-handle. Ore is delivered to the concentrator with a surface haul truck fleet.

The current active mining levels and their uses in the Vazante mine are shown in Table 16-1.

16.2 Geotechnical Considerations

During the site visit by Amec Foster Wheeler in December 2016, a formal methodology for the analysis and design of major production excavations (i.e. stopes) was presented by Votorantim in the document "Sizing of Horizontal Sill Pillars for the VRM Mining Method". This document describes the process for development of geotechnical design parameters to support mine planning and Mineral Reserve estimates. The methodology for developing stope design parameters, such as level intervals, stope strike spans, pillar widths, etc. is based on empirical methods. No major flaws were identified with these processes. Vazante is a mature operation, and staff have a well-developed understanding of the hydrogeology, geology, and mining methods required to safely extract the mineralization.

Figure 16-1: Mine General Arrangement Schematic Showing Mining Areas



Note: Figure courtesy Votorantim, 2016. Poço Atual = current shaft; nova rampa = new ramp. The second shaft and new ramp will be constructed to support the Deepening project.

Table 16-1: Vazante Mine Levels and Type

Mine	Level Type	Level Number
Vazante	Exploration Drift	509
		484
	Production	484
		455
		420
		388
		345
		326
	Pump Station	297
Extremo Norte	Exploration Drift	585
		555
		522

The main types of rock reinforcement and support consist of, but is not limited to: resin grouted rebar, weld wire mesh, and cable bolting. When warranted by the presence of poorer ground conditions, shotcrete is applied to increase the surface support capacity. Swellex rock bolts have been used occasionally where resin grouted rebar has not been effective.

Upon completion of the stoping, backfill is placed to improve the local/regional stability to optimise ore recovery.

A formal stope design process exists, and incorporates the existing geological resource model as the source for grade and tonnage data. Dilution and recovery factors are added to the stope tonnes and grade to produce the Mineral Reserves grade for mine planning. Cavity monitoring surveys (CMS) are routinely used to identify and characterize dilution geometry and this data is incorporated into the stope design process.

Given the mining methods employed, rock mass conditions and mining depths, Amec Foster Wheeler considers the rock reinforcement and support types to be suitable. In some situations, the presence of ground water has required modifications to the ground support regimes.

The mining method combines VRM and SLOS methods. Due to the nature of these mining methods there is the potential for significant unplanned dilution; however, this is not a common occurrence. Obtaining reliable estimates of unplanned dilution is critical for the estimation of Mineral Reserves at both Vazante and Extremo Norte. There appears to be an intention to reduce the planned and unplanned dilution and the tonnage of waste rock hauled to the process as part of routine mining operations by changing the drill hole diameter from 4.5” to 3.5” and parallel drilling along the hanging wall contact.

A reconciliation process to incorporate production tonnages from haulage data and post mining cavity monitor surveys has not been established that links the block model through to the stope; this should be undertaken.

Currently, cable bolting is undertaken in the ore drives with fans being drilled across the contact and into the hanging wall. (rib-roc reinforcement). A benefit of placing the ore drives along the hanging wall contact is that they can be used for stope cable bolting where required. Drilling cable fans into the hanging wall will provide a more effective scheme with greater coverage and load distribution. The rock mass model should be used to guide placement.

It is suggested that development in the hanging wall ore drives should incorporate the hanging wall contact and a partial shanty design to reduce encroaching into the hanging wall. This allows for fan patterns of cable bolting into the hanging wall to provide additional stope support thereby reducing unplanned overbreak.

How intact rock and rock mass strength vary across the mine is currently being evaluated. Field index strength estimates (as a minimum) should be included in the geomechanical core logging and mapping, with regular point load tests of drill core and block samples undertaken in development mapping.

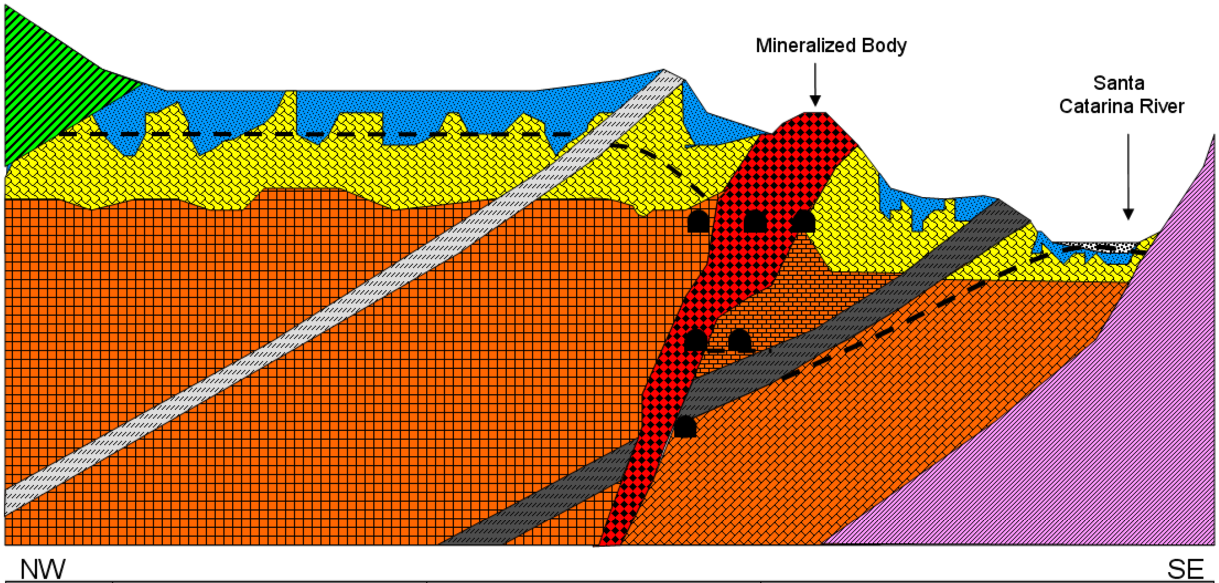
No systematic geotechnical instrumentation system is installed at either Vazante or Extremo Norte. Occasional convergence or closure monitoring is undertaken, along with displacement monitoring along identified structures. Instrumentation should be installed in selected areas of the mine to gather geotechnical data on the performance of ground support.

16.3 Hydrogeological Considerations

16.3.1 Hydrogeological Conceptual Model

There is a well-documented conceptual model of the hydrogeological system (Hidrovia, 2012) where the geological strata have been classified according to their water-bearing capacity as shown in Figure 16-2.

Figure 16-2: Schematic showing Vazante Mine Hydrogeological Conceptualization



Legend	Hydrogeological System	Kind of aquifer	Litology
	Serra do Garrote Formation	Aquiclude	Phyllite
	Lapa Formation	Aquiclude	Marlstone
	Black phyllite	Aquitard	Black phyllite
	Hangwall	Karstic/Fissured	Pink metadolomite
	Upper Footwall	Karstic/Fissured	Gray metadolomite with intecalation of marlstone.
	Lower Footwall	Karstic/Fissured	Gray marl metadolomite
	Breccia	Fissured Aquitard	Mineralized and breccied pink metadolomite.
	Epikarst	Karstic	Karstic surface metadolomite
	Alluvium	Intergranular Aquifer	Silt and sand
	Colluvium	Aquiclude	Mudstone and siltstone
	Water Level	Tunnel	

Note: Figure from Bittencourt et al., 2008.

This comprises the identification of the highly water-transmissive karstic dolomitic aquifers and formations with limited ability to transmit water (aquitards/aquicludes). The following aspects of the conceptual model are recognized as being of importance with respect to mine water inflows:

- The interception of major structural and/or karstic features causes sudden increases in mine water inflows. An example is the interception of a fault in December 2009, which created an increase in pumped mine water of approximately 1,000 m^3/hr (SWS, 2011)

- The interaction of the Vazante Mine with the Santa Catarina River and its associated floodplain. An example is the surface flooding of the Santa Catarina River that occurred in January 2007, and was followed by an abrupt and sustained increase in mine water pumping from January 2007 to March 2007 (SWS, 2011).

The interaction of the mine with the Santa Catarina River was subject to a large-scale dye tracing study undertaken by DHI in 2013, which has since provided more detailed data on the hydraulic connection between the Santa Catarina River and the Vazante Mine.

The conceptual model has provided the basis for the development of a groundwater flow model for the Vazante Operations and surrounding areas.

16.3.2 Groundwater and Surface Water Monitoring

The Vazante Mine has a large historical data set of hydrometric data that covers the full mine development. The groundwater monitoring network presently comprises 155 monitoring wells and subsurface piezometers, with weekly to bi-weekly monitoring occurring at 115 of these sites, and with pressure transducers reading daily water pressure at an additional 31 of these sites. From examining a small subset of this groundwater monitoring network, it appears to be well maintained. Wells are solidly constructed and protection of headworks is in place.

The surface water monitoring network comprises 13 gauging stations, eight on the Santa Catarina River, three of which are monitored continuously with the remainder monitored on a bi-weekly basis.

The detailed historical record of hydrometric measurements and mine water pumping are very important data sets that are critical for the development and improvement of the present hydrogeological conceptual model as the mine is developed. They are also a key input for the calibration of the groundwater model. In addition to the pumping data, hydrometric data from the present network provides adequate data to calibrate the FEFLOW groundwater model.

16.3.3 Groundwater Flow Model

A FEFLOW groundwater model of the Vazante Operations and adjacent areas was constructed by Schlumberger Water Services (SWS) in 2011 (SWS, 2011). Since 2011, the FEFLOW groundwater model has been operated, and further developed and refined, by Votorantim staff.

The current FEFLOW groundwater model is based on the present Leapfrog geological model (Eufrasio de Araújo et al., 2016) and calibrated to both mine water pumping and measurements of groundwater heads from the hydrometric network (Eufrasio de Araújo et al., 2016).

The FEFLOW groundwater model is the key tool for planning future mine water pumping requirements. It is therefore important to recognize the uncertainties associated with the groundwater model. FEFLOW is a well-known finite-element computer code for simulating Darcian groundwater flow through porous media. By applying the equivalent porous media (EPM) concept, this type of model is widely used to predict flows in karstic aquifers where non-Darcian (turbulent) flow occurs (e.g. Scanlon et al., 2003). However, there can be a compromise with the calibration of the model as it is not possible to calibrate fully to groundwater heads and flows as the Darcian principle of linear proportionality of head loss and flow does not fully apply to a karstic aquifer. In addition, heterogeneity and parameter uncertainties (e.g. hydraulic conductivity) add uncertainty to modelling predictions (Anderson et al., 2015), particularly at smaller scales. It is therefore imperative that the FEFLOW groundwater model is continually updated and checked against measured mine water inflows as the mine is expanded.

Presently the FEFLOW groundwater model is well calibrated to flows, with the 2016 calibration simulating 10,800 m^3/hr total average mine water pumping compared to a 2016 measured average of about 10,600 m^3/hr (2% difference).

16.3.4 Pumping System

The present pumping system has a reported pumping capacity of 15,650 m^3/hr (375,600 m^3/day) comprising two pumping stations located at the lowest elevation of the present mine. Mine water is collected through galleries within the mine and pumped to surface from the mine sump elevation.

The main pumping station consists of nine pumps, each with a capacity of 1,350 m^3/hr (32,400 m^3/day), giving a total capacity of 12,150 m^3/hr (291,600 m^3/day). The pumping station is located at an elevation of 297 masl, approximately 320 m below ground surface, and the water is pumped directly to surface from this station.

An additional adjacent pumping station is located at 300 masl with a capacity of 3,500 m^3/hr. This is pumped to surface in two stages (190 + 130 m).

A new pumping station, due to be operational in 2019, is currently being constructed underground at an elevation of 142 masl. This station will increase the pumping capacity to a total of approximately 19,000 m^3/hr (456,000 m^3/d). The station will pump to the current main pumping station at elevation 297 masl, from where water will be pumped to surface.

16.3.5 Predicted Pumping Requirements versus Current and Future Pumping Capacity

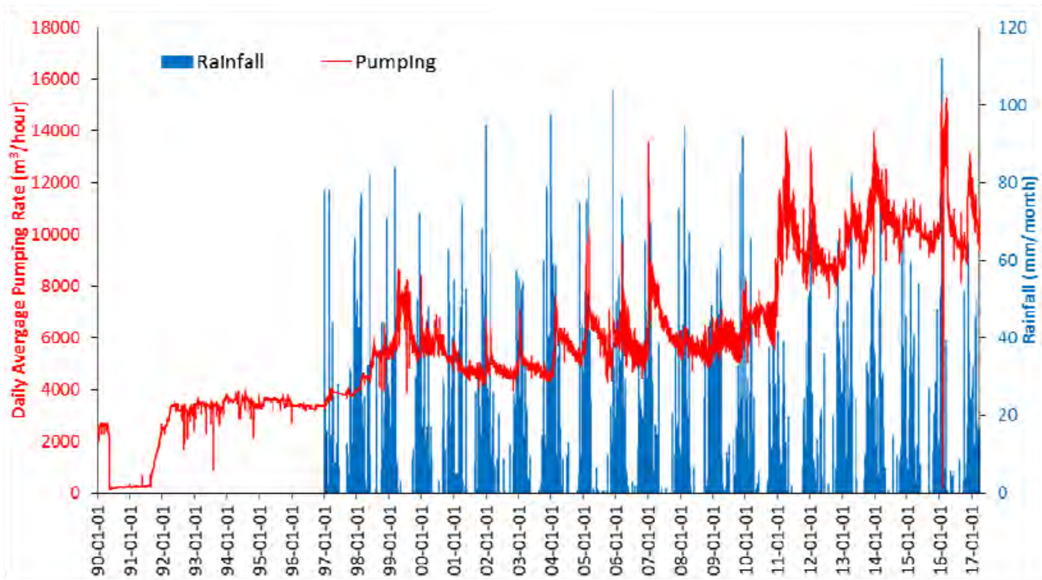
Votorantim has recorded pumped mine water quantities and rainfall in detail during operation of the mine. Figure 16-3 shows a graph of historically pumped mine water from the Vazante Mine up to March 2017, together with monthly rainfall figures from the Vazante Mine. The average rainfall is 1,470 mm/a (Bittencourt et al., 2008). However, rainfall is seasonal with 90% falling within the months of October and March (Bittencourt et al., 2008) as shown by Figure 16-3. Infiltration rates of rainfall on karstic aquifers are high, and consequently there is a seasonality in mine water pumping, with very high pumping rates during and immediately after peak rainfall events (refer to Figure 16-3).

The recent long-term average pumping rate (July 2013–June 2016) is approximately 10,500 m^3/hr; however, recently recorded maxima of the daily average pumping rate have exceeded this by up to almost 50% (Table 16-2). Given climate change, there is presently more uncertainty associated with relying on historic records to predict frequency and magnitude of severe rainfall events, and associated peak mine water pumping.

Figure 16-3 and Table 16-2 do not include water pumped from Extreme Norte. Pumping from this part of the mine started in November 2016 and has averaged 160 m^3/hr since then, with a maximum daily average pumping rate of 220 m^3/hr based on Votorantim data up to the end of April, 2017.

Currently, the 2016 FEFLOW groundwater model predicts approximately a maximum *average* mine water pumping rate of 13,500 m^3/hr, of which 1,200 m^3/hr is from the Extreme Norte. The maximum average pumping rate is predicted to occur in 2024, and remaining stable thereafter until the completion of the ultimate underground mine in 2028. Almost 12,000 m^3/hr mine water inflow is predicted below 297 masl for the ultimate underground mine, the present elevation of the main pumping station. The seasonal variation in pumping is not predicted currently by the FEFLOW groundwater model. Given an historic seasonal variation of mine water pumping that can be 50% higher than average, seasonal peak daily inflows could exceed 19,000 m^3/hr (greater than present planned capacity) for short periods after about 2020, based on the 2016 FEFLOW groundwater model predictions.

Figure 16-3: Vazante Mine Monthly Rainfall (mm/month) and Daily Average Pumping (m^3/hr)



Note: Figure prepared by Amec Foster Wheeler, 2017.

Table 16-2: Recent Maxima of Mine Water Daily Average Pumping Rate Compared to Recent Mine Water Long-term Average Pumping Rate

Peak Pumping Day[1]	Maxima of Daily Average Pumping Rate[2] (m^3/hr)	% Above Recent Long-term Average Pumping Rate[3] (%)
March 23, 2016	15,300	46
April 13, 2011	14,000	33
December 20, 2013	14,000	33
January 14, 2012	13,300	27
December 12, 2016	13,100	25

Notes:

1. Five highest occurrences since 2011 for data up to April 2017
2. Rounded to the nearest hundred, based on data provided by Votorantim
3. Calculated as [(daily average) - (long-term average)] / (long-term average) using the July 2013–June 2016 recent long-term average pumping rate of 10,500 m^3/hr

16.3.6 Dolines and Sinkholes

There is a well-documented history of doline/sinkhole development with water table drawdown as the mine has developed. Up to April 2017, Votorantim had recorded over 2,000 such features. The recorded incidences from the year 2000 to end 2016 are shown according to year in Figure 16-4.

Based on historical knowledge of doline/sinkhole development, the rate of development is increased substantially by sudden groundwater level drawdown (Bittencourt et al., 2008). An example is a 1999 event when interception of a karstified fault increased mine water inflows by 2,200 m^3/hr resulting in rapid groundwater level drawdown, and a very high rate of doline/sinkhole incidence (14.6/month). Presently, the doline/sinkhole incidence is much lower (Bittencourt et al., 2008).

16.3.7 Risks and Current Mitigation

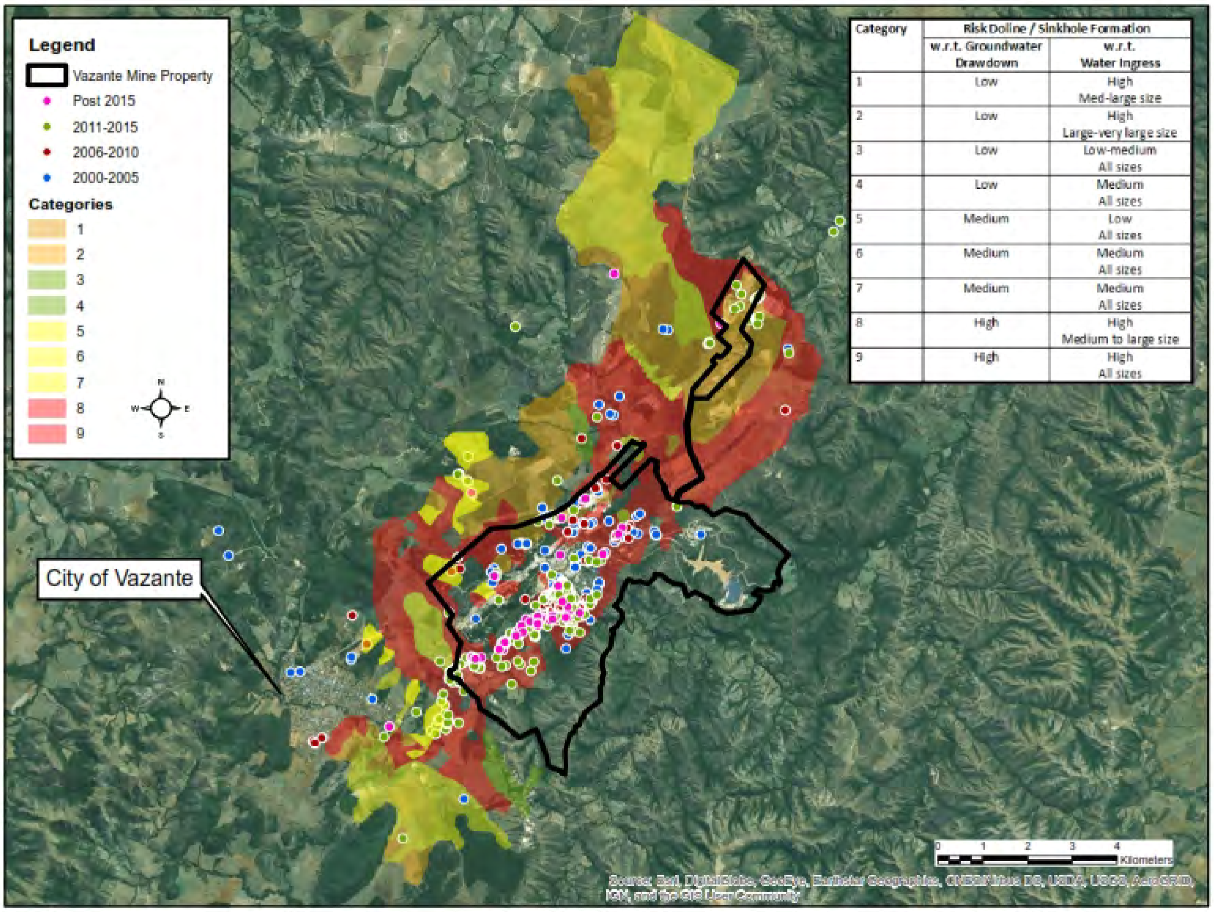
Votorantim has recognized the principal groundwater risks for operating the Vazante Mine, which are documented in their Dolomite Risk Management Plan (PG-VM-ZINCO-HIDRO-005, Rev. 3.1)

These risks include:

- Mine flooding due to interception of very water-transmissive fracture/karst feature that leads to a sudden in rush of groundwater
- Temporary mine flooding due to enhanced infiltration caused by the Santa Catarina River overflowing its banks and filling its floodplain
- Mine flooding due to high intensity rainfall events
- Subsidence or collapse of mine property or infrastructure from doline formation
- Subsidence or collapse of third party property or infrastructure from doline formation
- Enhance of infiltration, particularly in the Santa Catarina River floodplain causing greater and more prolonged peak mine water pumping events during and immediately after surface flooding of this river.

These risks are managed through operational procedures. A formal procedure of investigation (PG-VM-ZINCO-HIDRO-003, Rev. 2.1) has been adopted to progressively map the water-transmissive fracture and/or karst features with the ultimate aim of putting measures in place to limit rapid groundwater drawdown and inflows as the mine is advanced.

Figure 16-4: Doline/Sinkhole Incidence 2000 Onwards and Risk Map



Category	Risk Doline / Sinkhole Formation	
	w.r.t. Groundwater Drawdown	w.r.t. Water Ingress
1	Low	High Med-large size
2	Low	High Large-very large size
3	Low	Low-medium All sizes
4	Low	Medium All sizes
5	Medium	Low All sizes
6	Medium	Medium All sizes
7	Medium	Medium All sizes
8	High	High Medium to large size
9	High	High All sizes

Note: Figure prepared by Amec Foster Wheeler, 2017.

This comprises a hierarchy of long-term surveys (geophysical methods such as gravity and resistivity surveys), medium-term surveys (drilling and characterization of hydrogeological features; PG-VM-ZINCO-HIDRO-006, Rev. 1), to short-term measures used when the mine is being advanced (advanced drilling and flow testing). Mitigation measures may also include grouting or avoidance of transmissive features.

Support is provided by external consultants for specialized advice for risk management, such as the development of doline/sinkhole risk maps using the method defined by Buttrick et al. (2001) undertaken by VGI Consult (2001) and adopted by Votorantim.

Based on reviews in support of this Report, Amec Foster Wheeler adds the following risks:

- The FEFLOW groundwater model likely under-predicts future mine water inflows, particularly during peak climatic events. Present mitigation measures include the update of the model on an annual basis and comparison of predicted to pumped mine water inflows and update of predictions. Continued calibration to flows increases confidence in present predictions and is a recognized method for reducing uncertainty (Anderson et al., 2015)
- Surface flooding on mine closure. It has been noted that presently no studies have been undertaken to assess issues with groundwater rebound on cessation of pumping and mine closure. The Vazante Mine, including the Extremo Norte, are located within the watershed of the Santa Catarina River, with groundwater flow restricted to the east and west by the low-permeability Serra do Garrote and Lapa Formations respectively. It may thus be expected that groundwater flow will discharge to the Santa Catarina River at the lowest point in the drainage basin where it crosses the Serra do Garrote Formation. However, as the mine will have greatly changed the groundwater heads and aquifer conditions from natural pre-mining, localized flooding may be caused.
- Amec Foster Wheeler considers that the risk of mine flooding during an extreme rainfall event, including any associated temporary flooding of the Santa Catarina River, likely represents the greatest risk to mine operations from a water management perspective. This risk will need to be continually managed throughout the mine life, even after the pumping capacity is increased in 2019.

16.4 Underground

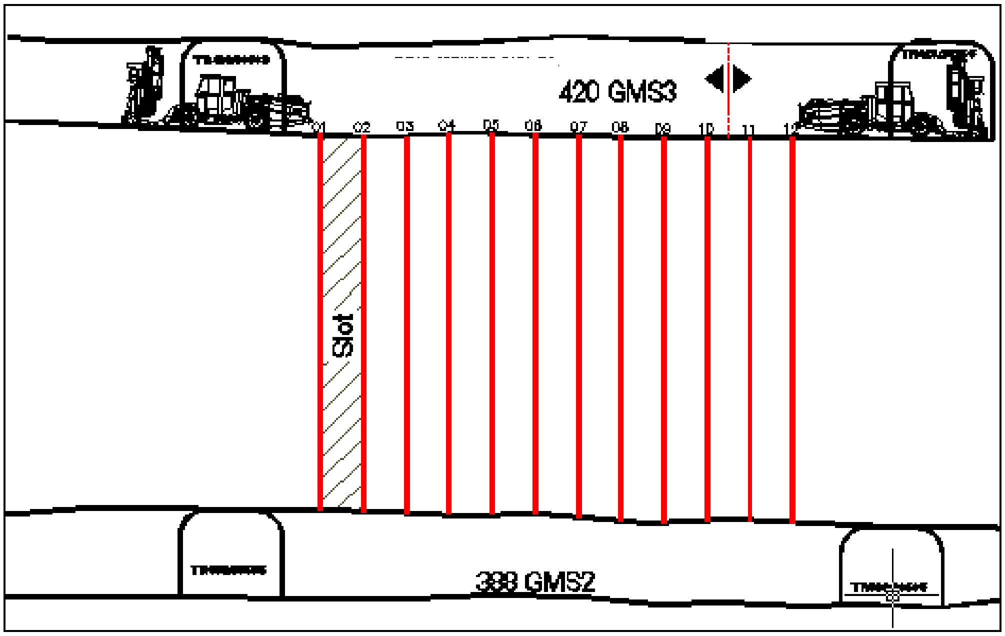
16.4.1 Mining Method Selection

Backfill is used in conjunction with VRM; however, with SLOS the stopes are generally left open after mining.

Sublevels are developed at 30 m level intervals with stopes being 60 m along strike. Support pillars 10 m wide are left between stopes. Haulage drifts are developed offset 30 m from the footwall contact of the deposit. Access cross-cuts are developed 70 m on centre in the support pillars. Stopes range in thickness from a minimum mining width of 4 m to greater than 10 m in some areas.

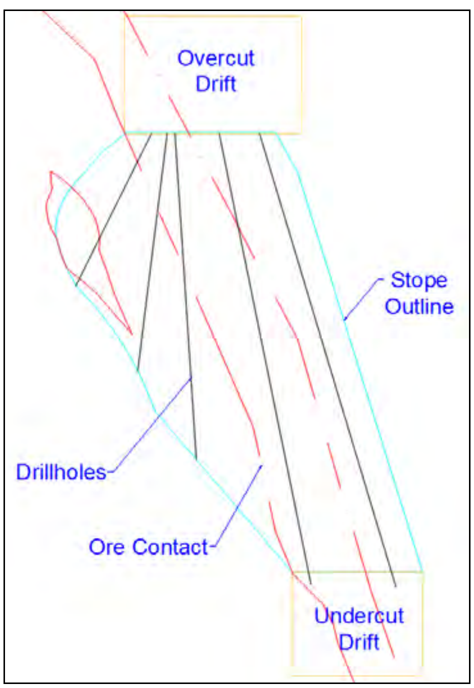
Vertical retreat mining is used where the mineralization is continuous between levels. Stopes are accessed on the overcut and undercut horizons and drilling is either with downholes from the overcut or a combination of upholes from the undercut and downholes, depending on the variation in the ore contacts between levels (Figure 16-5 and Figure 16-6).

Figure 16-5: Schematic Longitudinal Section of VRM Drilling with Holes between Levels



Note: Figure courtesy Votorantim, 2017.

Figure 16-6: Schematic of VRM Downhole Arrangement in Section



Note: Figure courtesy Votorantim, 2017.

The 60 m long stopes are divided into 15 m panels for drilling and blasting. Completed stopes are then backfilled with uncemented waste rock before proceeding to the next stope.

Sub-level open stoping has similar design parameters to VRM, but is limited to uphole drilling only. Sub-level open stoping is employed where there is no continuity of the mineralization between levels. Holes are drilled to the extents of the deposit envelope and blasted in a retreat fashion. The resulting open void after extraction is not backfilled and left as-is after mining. Figure 16-7 shows a longitudinal section of the upholes used for SLOS. Figure 16-8 shows the general arrangement of the SLOS drilling pattern in a stope. Typically, holes are drilled with a top hammer drill and stopes are left open after mining.

16.4.2 Design Assumptions and Design Criteria

The general assumptions and design criteria set out in Table 16-3 are used for the planning and layout of underground development and infrastructure.

It is assumed that the mine will operate at an average of 4,098 t/d for 365 days per year. This gives a nominal average production rate of 1.5 Mt/a (ranging from 1.38–1.6 Mt/a).

16.4.3 Backfill

Waste from lateral and ramp development is used as backfill in the VRM stopes. The waste is not sized prior to placement nor is binder used to provide additional support. Waste rock is dumped into the stopes from the overcut drifts to provide support to the hanging wall and reduce dilution of subsequent mining lifts.

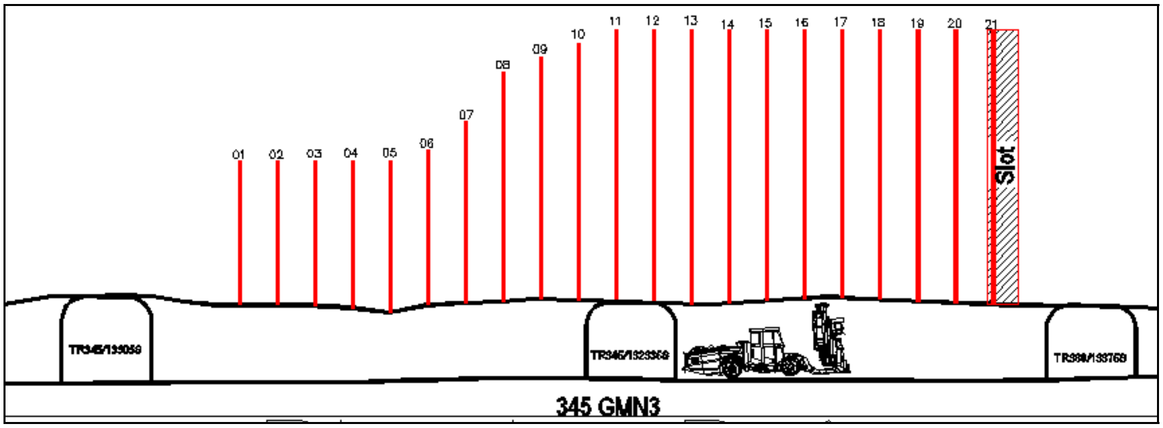
Between stopes, a 10 m rib pillar is left to prevent backfill dilution of adjacent stopes, and sill pillars are left every 60 m of mining height to prevent backfill dilution from mining blocks extracted from higher mine levels. Backfill quantities for the life of mine plan are shown in Table 16-4.

16.4.4 Ventilation

Mine ventilation at Vazante is designed in to comply with Brazilian NR 22 and is based upon whichever is the largest of the following criteria:

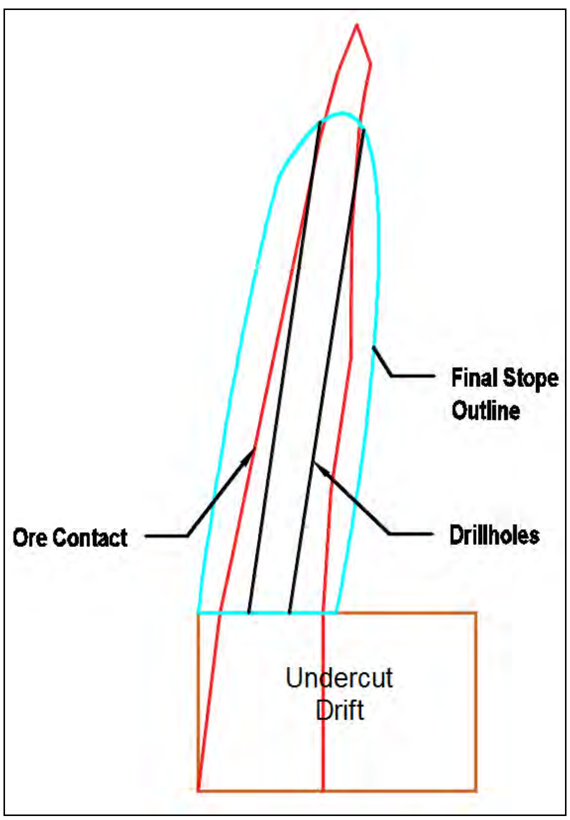
- Maximum number of equipment with diesel engines
- Explosives consumption in the mine
- Monthly production tonnages
- Number of mining fronts in operation.

Figure 16-7: Schematic SLOS Drilling Arrangement Showing Holes Going to Extents



Note: Figure courtesy Votorantim, 2017.

Figure 16-8: Schematic Cross-section of SLOS Drilling Arrangement



Note: Figure courtesy Votorantim, 2017.

Table 16-3: Vazante Underground Mine Design Criteria

Category	Design Item	Criteria
Operations	Days Operating	365 d/a
	Days Operating	7 days/week
	Hours Operating	8 hours/shift
	Shifts per Day	3 shifts/day
Production Rate	Steady State Production	4098 t/d average
Ramp	Dimension	6.0 m wide (W) x 5.0 m high (H)
	Gradient	± 14% nominal
Haulage	Dimension	5.0 mW x 5.5 mH
	Gradient	± 3%
Drainage	Dimension	4 mW x 4 mH
	Gradient	± 3%
Cross-cuts	Dimension	4.5 mW x 4.5 mH
	Gradient	± 3%
Ore Drives	Dimension	4.5 mW x 5.0 mH
	Gradient	± 3%

Table 16-4: Backfill Quantities Life of Mine by Mining Area ('000's tonnes))

	2017	2018	2019	2020	2021	2022	2013	2024	2025	2026	2027	*Totals*
Total Backfill	188	522	459	531	497	456	506	399	474	441	182	***4,655***
Mine Area												
Lumiadeira	166	309	99	27	0	0	108	300	250	337	98	***1,694***
Sucuri	0	171	330	447	251	231	257	76	168	100	16	***2,048***
Extremo Norte	22	41	31	56	246	224	141	24	56	3	69	***914***

Table 16-5: Existing Mine Ventilation Quantities by Area

Area	Type	Name	Volume (m^3/s)	Area (m^2)	Velocity (m/s)
Vazante	Fresh Air	Ramp VII	140	30	5
		Ramp X	111	30	4
		Shaft	111	19.6	6
	Return Air	LUMI Raise	140	4.5	31
		SUCU I Raise	92	4.5	20
		SUCU II Raise	130	7.5	17
Extremo Norte	Fresh Air	Ramp I	150	30	5
	Return Air	Raise III	150	12.6	12

The ventilation infrastructure to support operations underground at the Vazante and Extremo Norte Mines is listed in Table 16-5.

The Vazante Mine ventilation infrastructure will be expanded starting in 2018 to support additional mining faces. Ventilation infrastructure for Extremo Norte Mine will begin expansion in 2020 to support additional mining faces. Table 16-6 presents the projected mine ventilation quantities for the LOM. Table 16-7 shows the ventilation infrastructure expansion required for underground operations support.

16.4.5 Underground Infrastructure Facilities

Accesses

The Vazante Mine has three main accesses:

- Ramp VII
- Ramp X
- Shaft.

Ramp VII and Ramp V are inclines driven from surface and are nominally 6.0 m wide x 5.0 m high. The ramps serve as the primary access points to the mine for personnel and mobile equipment.

An additional ramp access is planned as part of the ventilation system expansion. Ramp 509 is planned to be commissioned in January 2018 to provide additional flow volume to the Lumiadeira area of the mine for personnel and equipment.

The current shaft is a 5.0 m diameter circular shaft that provides access to the EB297 pump room for infrastructure access for mine dewatering pumping and as an egress in mine emergency situations. The shaft is equipped with a hoist and has a cage for personnel movement.

A second shaft to the EB140 level is being developed with a raise bore to provide dewatering infrastructure access, and also egress in the event of an emergency.

The Extremo Norte Mine has independent access through a 6.0 m wide x 5.0 m high decline ramp (Rampa 1) from surface. There is also a 4.0 m diameter circular ventilation shaft that can also be used for emergency egress.

Table 16-6: Mine Ventilation Quantities over Life of Mine

Area	Unit	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Vazante	(m^3/s)	362	614	595	560	387	424	552	684	629	495	188
Extremo Norte	(m^3/s)	150	125	96	197	407	306	191	85	70	49	296

Table 16-7: Mine Ventilation Infrastructure Expansion by Area and Year

Location	Name	Type	Year
Vazante	Sucuri III	Return Air	2018
	Raise Sucuri Norte	Fresh Air	2025
	Ramp 509	Return Air	2018
Extremo Norte	Raise IV	Return Air	2020

Dewatering

The Vazante mine generates approximately 11,000 m^3/hr on average of ground water. The ground water is managed through a series of drifts and ramps that use gravity to move the water to the EB297 pumproom.

The pumproom is equipped with nine 1,350 m^3/hr (32,400 m^3/day) pumps, eight active and one in reserve, giving a total capacity of 12,150 m^3/hr (291,600 m^3/day). Inflow to this pump station is pumped directly to the surface for discharge.

A second pumproom is located on EB300, and has a capacity of 3,500 m^3/hr. Inflow to this pump station is lifted in two stages to the EB190 and EB130 levels before discharge on surface.

The combined current pumping capacity of the system is 15,650 m^3/hr (375,600 m^3/day).

An expansion of the dewatering system is planned for commissioning in 2019 to permit an increase to 19,000 m^3/hr. The EB297 pumproom will be expanded to meet the higher pumping capacity, and a second pumping facility is being developed on the EB140 level to allow development of the mine below EB326. This second pumproom will also have a 19,000 m^3/hr capacity. The two pumprooms will be joined in series, with the EB297 acting as a booster station for the EB140 pumproom.

Electrical Power Distribution

Electrical power is distributed throughout the mine via substations. Maximum working distance from substations is 300 m. Each substation is equipped with a 1000 kVA transformer that can provide power for up to 12 electrical panels to support development equipment, ventilation fans and dewatering pumps.

16.5 Production Schedule

The current LOM production plan for the Vazante Operations forecasts an average production rate of 1.43 Mt/a between 2018 and 2027. Peak production during that time will be 1.60 Mt/a. Production will average approximately 3,920 t/d during this period with an average zinc grade of 10.48%, an average lead grade of 0.29%, and an average silver grade of 15.92 g/t between 2017 and 2027.

16.5.1 Production Schedule

Production at Vazante over the LOM will be from three primary mining methods

- SLOS
- VRM
- C&F.

Additionally, stope access development will produce the balance of mill feed through the LOMP. Currently the C&F mining tonnes account for approximately 4% of the overall tonnes planned for the last three years of the current LOMP.

Production will be split between the mining areas of Sucuri, Lumiadeira and Extremo Norte. Production from the Lumiadeira zone will temporarily cease between 2021–2022. Mining will re-commence in this area in 2023. Lumiadeira has limited development areas available on the current mining horizon above the EB326 level. Commissioning of the EB140 pump station is required before development can proceed below the current EB326 area and open significant areas of Lumiadeira for production.

The production forecast is provided in Table 16-8 by mine zone. Table 16-9 provides the breakdown by mining method. Figure 16-9 shows the production by mine zone, and Figure 16-10 production by mining method.

16.5.2 Mining Sequence

Stope mining is undertaken on a primary–primary basis along the longitudinal axis of the deposit. Stopes are extracted on retreat basis from the panels and then backfilled. After the panel has been backfilled, the next lift of retreat stopes is mined. The ultimate panel height is 60 m for VRM mining. Sub-level open stoping is used in areas where the mineralization extends above the VRM mining stope height. The final panel height in those areas is geologically controlled, and will vary.

Table 16-8: Life of Mine Production Plan by Zone for Vazante Operations

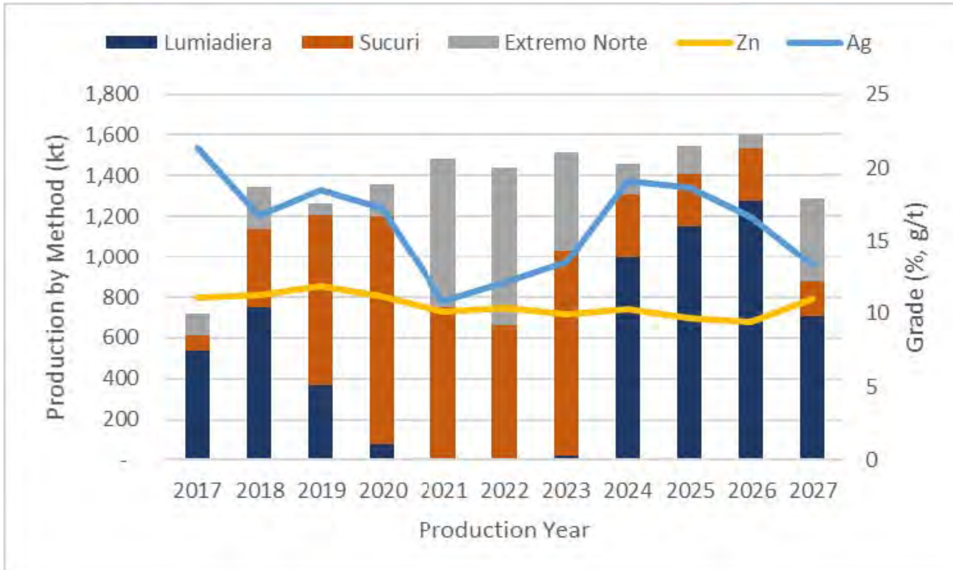
Zone	Unit	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Lumiadeira	kt	537	748	370	78	—	—	23	998	1,152	1,278	704
	% Zn	10.66	10.03	10.79	9.19	0.00	0.00	11.41	9.86	9.88	9.21	10.29
	% Pb	0.40	0.26	0.25	0.17	0.00	0.00	0.41	0.30	0.31	0.29	0.22
	Ag - g/t	23.59	15.89	16.99	17.31	0.00	0.00	30.91	20.80	21.76	17.33	14.88
Sucuri	kt	75	394	838	1,126	751	662	1,007	312	259	256	174
	% Zn	15.80	13.41	12.37	11.31	10	10.58	10.44	12.38	7.63	10.13	11.78
	% Pb	0.39	0.33	0.32	0.33	0.34	0.31	0.34	0.41	0.27	0.30	0.38
	Ag - g/t	25.33	23.13	19.68	18.44	15.46	17.10	16.87	20.79	11.89	16.65	23.02
Extremo Norte	kt	110	205	59	153	731	780	485	149	137	66	409
	% Zn	9.68	11.37	11.27	10.78	10.04	10.27	8.72	8.78	12.24	9.92	11.77
	% Pb	0.25	0.23	0.27	0.23	0.22	0.22	0.25	0.17	0.17	0.19	0.24
	Ag - g/t	7.74	7.48	10.76	8.08	6.10	7.88	5.69	4.33	4.79	4.21	6.56
Total mine production	***kt***	***721***	***1,346***	***1,267***	***1,356***	***1,482***	***1,442***	***1,515***	***1,459***	***1,547***	***1,600***	***1,287***
	% Zn	***11.05***	***11.22***	***11.86***	***11.13***	***10.15***	***10.41***	***9.90***	***10.29***	***9.71***	***9.39***	***10.96***
	% Pb	***0.37***	***0.28***	***0.30***	***0.31***	***0.28***	***0.26***	***0.31***	***0.31***	***0.29***	***0.29***	***0.25***
	Ag - g/t	***21.36***	***16.73***	***18.48***	***17.21***	***10.84***	***12.11***	***13.51***	***19.11***	***18.61***	***16.68***	***13.34***
% Extremo Norte in ROM	%	15.2	15.2	4.6	11.3	49.3	54.1	32.0	10.2	8.8	4.1	31.8

Table 16-9: Vazante Life-of-Mine Production by Mining Method

Period	Unit	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Total - Mine Production													
Vertical Crater Retreat													
Ore Tonnes	kt	317	817	734	826	878	564	859	703	697	775	454	**7,625**
Zn	%	9.93	11.22	11.59	10.65	9.83	10.22	10.42	8.82	9.45	9.00	13.16	**10.32**
Pb	%	0.30	0.23	0.25	0.25	0.23	0.21	0.30	0.26	0.25	0.27	0.13	**0.24**
Ag	g/t	21.95	18.71	17.35	17.62	11.17	12.80	15.78	19.71	17.43	17.38	12.28	**16.42**
Cut & Fill													
Ore Tonnes	kt	—	—	—	—	—	—	—	—	6	42	93	**141**
Zn	%	—	—	—	—	—	—	—	—	7.31	7.08	8.30	**7.90**
Pb	%	—	—	—	—	—	—	—	—	0.17	0.21	0.27	**0.25**
Ag	g/t	—	—	—	—	—	—	—	—	7.36	9.84	13.00	**11.84**
Sub Level Open Stoping													
Ore Tonnes	kt	194	290	313	315	379	612	435	455	633	621	631	**4,880**
Zn	%	11.14	10.76	10.81	10.54	9.77	9.69	9.14	9.72	9.77	9.87	8.53	**9.78**
Pb	%	0.36	0.22	0.21	0.25	0.23	0.20	0.24	0.25	0.23	0.18	0.21	**0.22**
Ag	g/t	21.52	12.90	14.24	15.05	11.33	10.64	12.50	19.03	18.14	13.28	10.67	**14.04**
Development Ore													
Ore Tonnes	kt	211	239	219	215	225	265	220	302	211	162	108	**2,377**
Zn	%	10.11	9.85	10.77	8.96	7.65	7.03	7.53	6.51	6.68	6.10	6.98	**8.05**
Pb	%	0.26	0.21	0.24	0.24	0.16	0.22	0.25	0.22	0.21	0.20	0.14	**0.22**
Ag	g/t	17.58	15.70	16.47	11.81	7.02	11.70	15.69	15.92	15.73	11.94	8.29	**13.76**

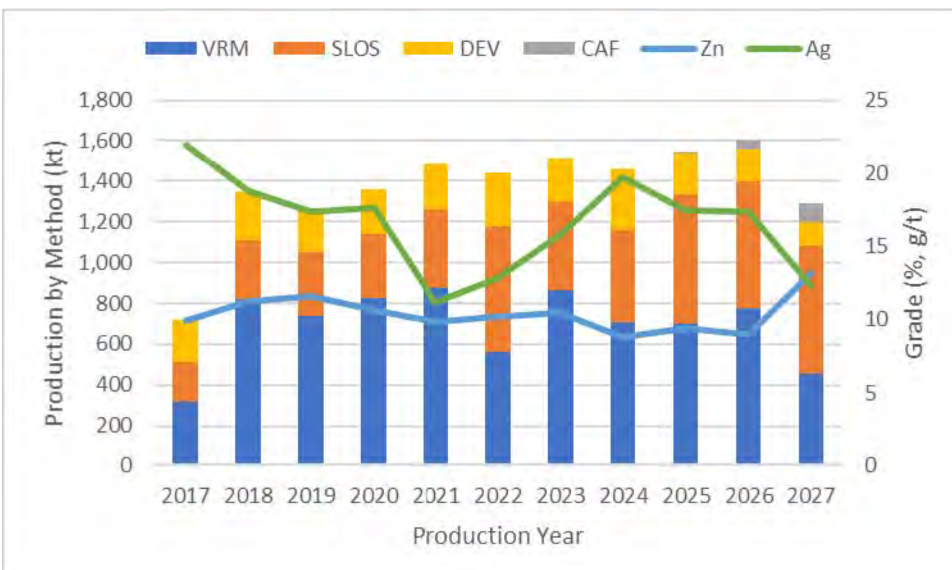
Note: Totals may not sum due to rounding

Figure 16-9: Vazante Operations Production Plan by Zone



Note: Figure prepared by Amec Foster Wheeler, 2017.

Figure 16-10: Production Forecast by Mining Method



Note: Figure prepared by Amec Foster Wheeler, 2017.

16.6 Blasting and Explosives

Explosives and blasting accessories are contractor-supplied. All explosives used underground are emulsion explosives due to the requirement for high water resistance. ANFO-based explosives are not practical due to the low water resistance of those blasting agents.

Conventional pyrotechnic detonators are used for both the development and production blast initiations. The explosives loading units are contractor supplied and the units are capable of loading upholes or downholes as required by the stope parameters.

16.7 Grade Control

Grade control in accomplished using the block model, stope reserve grade developed by the short-range planners, face calls, and production sampling.

Stopes are scheduled where possible to provide a uniform head grade to the mill. This may not always be possible as stope sequencing for production and ground control override the head grade requirement.

Stopes are planned by the short-range planning team to maximize recovery and reduce external dilution where possible.

Grade calls are made by geology on a daily basis based upon visual assessment of stope material in load–haul–dump (LHD) buckets.

16.8 Mining Equipment

Vazante is a trackless operation utilizing a diesel-powered mobile equipment fleet. The selected equipment is sized to meet the mine production targets for material movement with the calculated cycles and productivities.

The mine haulage fleet is composed of 28 t nominal load, articulated road trucks modified for underground usage. The current fleet is split between the Vazante and Extremo Norte Mines, with 11 trucks allocated to the Vazante Mine, and four trucks allocated to the Extremo Norte Mine.

Stope mucking and development waste mucking is undertaken by a fleet of 5.7m^3 LHD units. These units have a nominal tramming capacity of 12.5 t for truck loading. Currently the fleet split is eight units at the Vazante Mine, and one unit at the Extremo Norte Mine. The fleets are not restricted to the currently-assigned mines and can be moved between sites as operational requirements dictate.

Table 16-10 provides a summary of the production equipment fleet. The primary mining equipment list is shown in Table 16-11. Table 16-12 provides the auxiliary fleet list.

16.9 Comments on Section 16

Extraction of the Mineral Reserves below the EB326 horizon is dependent upon successful development and commissioning of the EB140 pump station. Should the water inflows exceed the design pumping capacity of the pump station, these Mineral Reserves would be at risk.

The current life-of-mine plan is based upon achievable targets and is developed with site best practices.

Inferred Mineral Resources have been excluded from the mine plan.

The mining methods employed are suitable for a steeply-dipping, regularly-structured deposit.

The mobile equipment fleet outlined in the report is the actual equipment meeting production targets at the Vazante Operations. An opportunity exists to reduce the fleet through better utilization of existing equipment. Votorantim is currently undertaking a study to address the equipment usage.

Table 16-10: Production Equipment Fleet

		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Truck	Fleet Size	15	16	17	18	18	18	18	18	16	16
	Spare Equipment	0	1	1	1	0	0	0	0	-2	0
	Replacement	0	6	2	2	1	3	2	2	2	1
	Purchased	**0**	7	3	3	1	3	2	2	0	1
LHD	Fleet Size	8	8	8	8	8	8	8	8	8	8
	Spare Equipment	0	0	0	0	0	0	0	0	0	0
	Replacement	2	2	1	2	2	0	0	0	1	0
	Purchased	**2**	2	1	2	2	0	0	0	1	0
Bolter	Fleet Size	4	4	4	4	3	3	3	3	2	2
	Spare Equipment	0	0	0	0	-1	0	0	0	-1	0
	Replacement	0	1	1	2	0	0	0	0	0	0
	Purchased	**0**	1	1	2	0	0	0	0	1	0
Cable Bolter	Number	1	1	1	1	1	1	1	1	1	1
	Spare Equipment	0	0	0	0	0	0	0	0	0	0
	Replacement	1	0	0	0	0	0	1	0	0	0
	Purchased	**1**	0	0	0	0	0	1	0	0	0
Jumbo	Fleet Size	6	6	6	6	5	5	5	5	4	4
	Spare Equipment	0	0	0	0	-1	0	0	0	-1	0
	Replacement	1	0	0	1	0	0	0	1	0	0
	Purchased	**1**	0	0	1	0	0	0	1	0	0
Scaler	Fleet Size	7	7	7	7	7	7	7	6	4	4
	Spare Equipment	0	0	0	0	0	0	0	-1	-2	0
	Replacement	1	1	0	0	1	1	1	0	0	0
	Purchased	**1**	1	0	0	1	1	1	0	0	0
Fandrill	Fleet Size	4	4	4	4	4	4	4	4	4	4
	Spare Equipment	0	0	0	0	0	0	0	0	0	0
	Replacement	0	0	1	1	0	0	0	2	0	0
	Purchased	**0**	0	1	1	0	0	0	2	0	0

Table 16-11: Primary Production Equipment List

Equipment	Equipment Supplier	Equipment Model	Quantity
Anfoloader	DUX		3
Boltec	Atlas Copco	235 S	1
Robolt	Sandvik	DS 311 C	1
Boltec	Atlas Copco	MC	1
Cabolt	Sandvik	7.5	1
Truck	Volvo	A30F	14
Truck	Volvo	A30F/G	4
LHD	Caterpillar	1600G	1
LHD	Caterpillar	950 H	1
LHD	Caterpillar	R1700G	8
LHD	Sandvik	LH 410	1
LHD	Volvo	L110 F	1
Jumbo	Atlas Copco	282	1
Jumbo	Atlas Copco	282 S	4
Jumbo	Atlas Copco	M2C	2
Scaler	BTI	DS 20	1
Scaler	BTI	25DS	1
Scaler	BTI	DS 25 II	1
Scaler	BTI	HFS 25	5
Scaler	Normet	SCAMEC 2000S	1
Simba	Atlas Copco	H1257 S	1
Simba	Atlas Copco	M6C ITH	2
Simba	Atlas Copco	S7 D	1
Solo	Sandvik	DL 321	1
Totals			**58**

Table 16-12 Auxiliary and Support Equipment Fleet List

Equipment	Equipment Supplier	Equipment Model	Quantity
Truck	Scania	PRANCHA	1
Ambulance	Mercedes Benz	SPRINTER	1
Ambulance	Mitsubishi	L200 GL	1
Ambulance	Toyota	HILUX	2
Truck	Ford	Comboio F14000	1
Truck	Ford	Plataforma F14000	1
Truck	Mercedes Benz	ATEGO 1719 MUNCK	1
Truck	Mercedes Benz	ATEGO 1726	1
Truck	Mercedes Benz	ATRON 2729	1
Truck	Mercedes Benz	ATRON 2729 PIPA	1
Truck	Mercedes Benz	MUNK 1720	1
Truck	Scania	Comboio P270	1
Truck	Volkswagen	8150	1
Truck	Chevrolet	S10	1
Truck	Ford	F 350	1
Truck	Ford	F 4000	5
Truck	Mitsubishi	L200 GL	6
Truck	Mitsubishi	L200 OUTDOOR	3
Truck	Mitsubishi	L200 TRITON	23
Bus	Mercedes Benz	TATUZÃO	1
Pick Up	Volkswagen	SAVEIRO	2
Motorgrader	Caterpillar	120 K	2
Utilift	Normet	MF 540	1
Utilift	Normet	XCR 430	2
Spraymec	Normet	6050 WPC	3
Raisebore	Redpath		1
Retroexcavator	Caterpillar	416 E	1
Retroexcavator	Volvo	BL 70	3
Dux	Utilift	SL 5000 N	2
Totals			***71***

17.0 RECOVERY METHODS

17.1 Introduction

Vazante is the largest zinc mine in Brazil, processing about 1.5 Mt of ore annually grading an average of about 11.3 wt% Zn to produce about 135 kt of zinc metal contained in willemite and bulk sulphide concentrates. Concentrates are sent to Votorantim's Tres Marias zinc smelter, located about 250 km from the operations.

17.2 Process Flow Sheet

Processing is conducted in two adjacent plants (C and W) based on crushing, grinding and flotation with some interconnected concentrate handling systems. The main differences between the flowsheets for the plants is that Plant W incorporates a sulphide flotation stage for recovery of a lead–silver concentrate. Both plant flowsheets include crushing, grinding and willemite flotation. Willemite concentrate is filtered for transport to the smelter, and combined Plant W and Plant C tailings are thickened prior to disposal in the tailings storage facility (TSF). Figure 17-1 shows a simplified flowsheet for the current plants. No calamine mineralization is included in the current process plan.

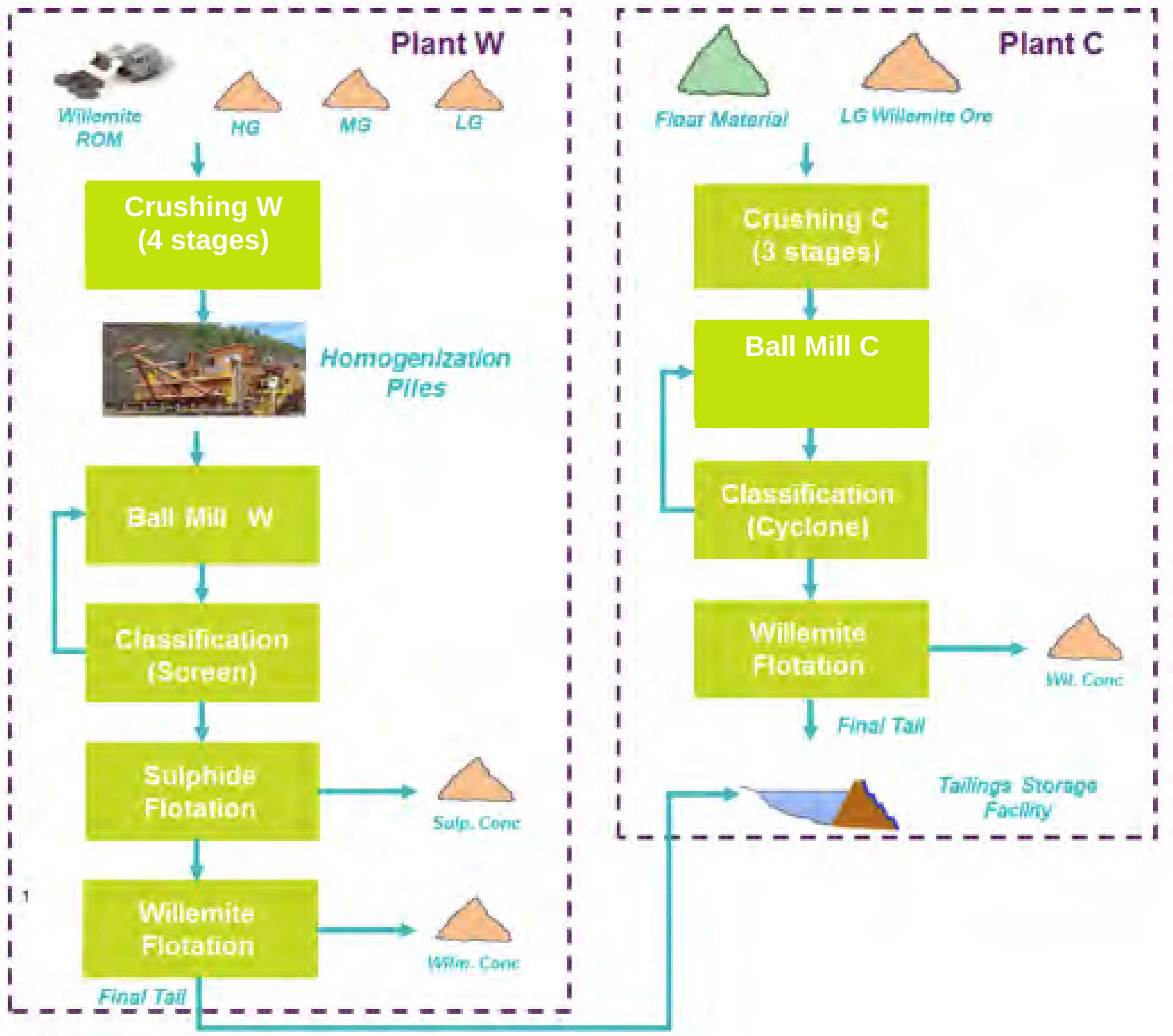
17.3 Plant Design

17.3.1 Introduction

Plant W is a modern plant and processes about 80% of the total tonnage of higher-grade willemite ore produced by the mine through an initial bulk sulphide flotation circuit and willemite flotation circuits. The sulphide circuit produces a lead–silver sulphide concentrate that is elevated in zinc. Zinc production in the sulphide circuit accounts for <1% of total zinc production. Zinc provides the primary revenue, while lead, silver and zinc recovered in the bulk sulphide concentrate provide a minor by-product credit. Plant W was commissioned in 2003, and the sulphide circuit was added in 2012.

Plant C is an older plant that was historically used for the treatment of calamine ore, and was subsequently converted to treat willemite ore. It has, until recently, treated about 20% of the total Vazante processed tonnage. The feed in 2016 consisted of a mix of lower-grade willemite ore and a low-grade zinc oxide/willemite stockpile generated by a previous historical mining and processing operation as a dense medium float discard material (float material). Processing of the float material was suspended in January 2017, and is not included in the life-of-mine mill production plan.

Figure 17-1: Simplified Flowsheet of the Current Vazante Processing Facilities



Note: Figure courtesy Votorantim, 2017.

Table 17-1 presents the mill feed types by plant for 2016.

The capacities of sections of the Vazante processing facilities by unit operations are shown in Table 17-2. The capacities of the grinding lines depend on the target grind sizes.

Table 17-1: Vazante Mill Feed Types by Plant in 2016 (t)

Feed Type	Plant W	Plant C	Total
Vazante willemite ore	722,000	104,000	825,000
Extremo Norte	396,000	47,000	443,000
Historical float material	0	102,000	102,000
Total	***1,117,000***	***253,000***	***1,371,000***

Table 17-2: Plant and Unit Operations Capacity for Vazante Processing Facilities

Plant	Unit Operation	Capacity (t/h)
Plant W	Crushing	180
	Grinding	140
	Sulphide flotation (Pb/Zn)	170
	Lead filtration	0.5
	Willemite flotation	132
Plant C	Crushing	45
	Grinding	35
	Willemite flotation	38
Combined Zn concentrate handling	Filtration	45
	Concentrate loading	60
Tailings handling	Thickening	130

Note: at grinding product size of 83% passing 149 µm

Prior to 2012, there were no process facilities to recover a separate lead-silver concentrate, and these metals were discarded in tailings. After completion of the sulphide flotation circuit in late 2012, Plant W ground ore was processed for lead and silver recovery. Currently, the sulphide circuit is not operated continuously, rather in campaigns determined when an economic and saleable lead–silver concentrate can be produced. In 2016, the sulphide circuit operated with approximately 70% availability, compared with an overall 96% availability for Plant W. The lead recovery while the sulphide circuit was operating was 37%. Lead and silver in the feed to Plant C are not recovered into the lead–silver concentrate. Therefore, the overall combined lead recovery with respect to combined Vazante mill feed was 21%.

17.3.2 Plant W

High, medium, and low-grade run-of-mine ore is crushed in a four-stage crushing circuit in closed circuit with screens to 98% passing 9.5 mm. Crushed ore is homogenized on a chevron-style stacker, then fed to the Plant W milling circuit. This consists of a ball mill in closed circuit with a fine vibrating screen deck. The screen undersize is approximately 88% passing 150 µm (p80 of 125 µm), and is directed to conditioning tanks prior to feeding the Plant W lead–silver flotation circuit.

The sulphide (lead–silver) flotation circuit uses MIBC frother, sodium sulphide activator and potassium amyl xanthate collector. The circuit includes lead roughing and scavenging using three and two 70 m^3 FLSmidth tank cells respectively. Scavenger concentrate is recycled to rougher feed, while lead scavenger tail reports to the Plant W zinc flotation circuit. Rougher concentrate is treated in the first cleaner stage, which consists of two 10 m^3 FLSmidth tank cells. First cleaner tail reports to the lead first cleaner–scavenger, with the lead first cleaner–scavenger concentrate returning to the lead first cleaner, and lead first cleaner–scavenger tailings returning to lead rougher feed.

The lead first cleaner is followed by a second cleaner stage, which consists of one 5 m^3 FLSmidth tank cell in closed circuit with the first cleaner. There are two additional cleaning stages in closed circuit with each other, the third and fourth cleaners, which each consist on one 0.5 m^3 FLSmidth tank cell. Third cleaner tailings report to a two-stage lead third cleaner–scavenger consisting of six 0.5 m^3 FLSmidth tank cells. The first two cells produce a third cleaner–scavenger concentrate that returns to the third cleaner feed, while the last four cells recirculate their concentrate to the first two cells. The tailings from the third cleaner–scavenger return to the lead first cleaner.

The fourth cleaner produces the final lead concentrate, which is dewatered using a pressure filter to produce a filter cake with approximately 10% moisture. Concentrate is loaded onto trucks for delivery to customers.

The lead cleaner circuit also included a small lead regrind mill, however this mill was shut down in 2016.

The Plant W zinc circuit recovers a willemite concentrate from the lead scavenger tailings, or the grinding circuit screen undersize during periods when the lead circuit is bypassed. The zinc flotation feed is conditioned with sodium sulphide activator, AGPL dispersant and amine collector. The first stage of flotation is the zinc roughers, which consist of nine 14.2 m^3 forced air flotation cells. Rougher concentrate combines with Plant C zinc rougher concentrate to form the final zinc concentrate. Rougher tailings are pumped to the zinc first scavenger circuit, which has five 14.2 m^3 forced air flotation cells. The first scavenger concentrate is recirculated to zinc rougher feed. The zinc first scavengers are followed by the zinc second scavengers, consisting of an additional four 14.2 m^3 cells. Second scavenger concentrate is cycloned, with the fine overflow fraction stored in a low-grade zinc concentrate pond, and coarser fraction reporting to Plant C flotation feed. Zinc second scavenger tailings are pumped to the tailings thickener for dewatering and disposal.

17.3.3 Plant C

Low grade run-of-mine ore and, on occasions, reclaimed historical dense medium plant rejects material (floats) are crushed in a three-stage crushing circuit in closed circuit with screens to 98% passing 9.5 mm. Run-of-mine ore is dumped into a silo, then fed to the primary jaw crusher, which then discharges onto a primary double-deck vibrating screen. The top deck has a 38 mm aperture screen, and the bottom deck is a 16 x 14 mm screen. Material retained on the top deck reports to two secondary jaw crushers, while material retained on the bottom deck feeds the tertiary Omnicone cone crusher. The product of both secondary jaw crushers returns to the primary vibrating screen. The primary vibrating screen bottom deck undersize are combined with tertiary crusher discharge and form the overall product from the Plant C crushing plant. This crushed ore is stored in a conical pile, of up to 4,000 t capacity, then fed by loader to the Plant C milling circuit.

The Plant C milling circuit consists of a 2.4 m diameter x 11 m effective length ball mill in closed circuit with three hydrocyclones. The target grind size is approximately 88% passing 150 µm. Grinding circuit product is pumped to two conditioning tanks in series, where sodium sulphide activator, AGPL dispersant and amine collector are added to prepare willemite for flotation. The conditioned pump is then treated in the zinc rougher circuit, which consists of four 8.5 m^3 forced air flotation cells. Rougher concentrate is combined with Plant W rougher concentrate. Rougher tail is directed to the zinc first scavengers, which have four 8.5 m^3 cells. The first scavenger concentrate recirculates to the rougher feed. The first scavenger tailings reports to the second scavenger circuit, which has four 8.5 m^3 cells. The second scavenger concentrate is recirculated to the first scavenger feed, to allow another opportunity for ultimate recovery into the zinc rougher concentrate. Second scavenger tails are pumped to the tailings thickener, in conjunction with Plant W scavenger tails.

17.3.4 Combined Zinc Concentrate Treatment and Dewatering

The zinc rougher concentrates from Plant W and Plant C are combined, stored in stocktanks. The combined rougher concentrates may be fed to a single G cell. The G cell, when operational, floats carbonate from the zinc rougher concentrates. This produces a low-grade zinc-bearing carbonate concentrate, which can sometimes be treated separately at the Tres Marias smelter. When produced, this low-grade concentrate is stored and dewatered in a low-grade G cell pond. Therefore, the final zinc concentrate is the combined Plant W and Plant C rougher concentrates when the G cell is bypassed, or the G cell tailings when the G cell is operational. The G cell was suspended from operation in early 2017, and is not assumed to operate in the LOM mill production plan.

Final zinc concentrate is thickened in a 16 m diameter Dorr Oliver-Eimco concentrate thickener. Thickener overflow is recycled to process water. Thickener underflow is pumped to hydrocyclones. The coarser underflow is dewatered in three vacuum drum filters, while the finer overflow is dewatered in one Andritz plate and frame pressure filter. The combined cake produced is approximately 13% moisture.

17.3.5 Tailings Dewatering

Combined Plant W and Plant C scavenger tailings are dewatered in a 28 m diameter conventional tailings thickener to approximately 45% solids. Water recovered from the tailings thickener overflow is directed to the water pond within the TSF, and is then recycled in the grinding and flotation plants. Thickened tailings are pumped then deposited via four spigots into the TSF.

17.3.6 Plant Design and Equipment Summary for Current Plants

The overall zinc and lead concentrate tonnages, grades and recoveries for Plant W and Plant C for 2016 are shown in Table 17-3. These results exclude approximately 6,000 tonnes of low-grade zinc carbonate concentrate produced by the G cell, which operated for much of 2016. The G cell is assumed not to operate during the LOMP.

The zinc recovery in Plant C was significantly lower than Plant W. This may be attributed to the lower zinc head grade, the inclusion of historical dense medium float material in the feed, and differences in the performance of the grinding and classification circuit in this plant.

Table 17-4 summarizes the additional process and equipment criteria for the existing process plants.

17.3.7 Process Plant Upgrade to Support Mine Expansion

Vertimill

In the 2014 HDA study of comminution expansion options, simulations of the circuit were completed using JKSimmet. A total of 22 circuit configurations were modelled, investigating alternative technologies including high-pressure grinding rolls (HPGR), an additional ball mill, and a vertically-stirred mill (Vertimill).

HPGR technology was not well suited to the Vazante application, because of materials handling concerns. The ball mill option was also not favourable, as the space in the mill was limited. HDA recommended a VTM1500 (1,137 kW) Vertimill.

Table 17-3: Plant C and Plant W Production Data Summary, 2016

Parameter	Production Tonnage (t)	Grade			Recovery (%)		
		% Pb	% Zn	g/t Ag	Pb	Zn	Ag
Plant W ore	1,117,380	0.31	11.9	14.0			
Pb concentrate Plant W	3,074	28.7		2,270	25.2		44.5
Zn concentrate Plant W	298,015		38.8			87.1	
Plant C ore	253,139	0.31	9.0	14.0			
Pb concentrate Plant C	0	0.0		0	0.0		0.0
Zn concentrate Plant C	45,740		38.8			78.2	
Combined C + W ore	1,370,518	0.31	11.3	14.0			
Combined Pb concentrate	3,074	28.7		2,270	20.6		36.3
Combined Zn concentrate	343,755		38.8			85.8	

Table 17-4: Plant Parameters and Major Equipment List

Parameter	Unit	Value
Annual Throughput	t/y	1420000
Daily Throughput	t/d	3900
Plant C throughput	t/d	700
Plant W throughput	t/d	3200
Operating days per year	d/y	365
Crushing plant availability	%	79%
Overall concentrator availability	%	96%
Nominal design feed grade	% Zn	14%
Plant C		
Primary crusher type		Jaw, Atlas 9060
Primary crusher power	kW	93
Secondary crushers (2) type		Jaw, Atlas 9025
Secondary crushers (2) power (each)	kW	30
Secondary screen type		Vibrating sieve
Secondary screen dimensions	m	2.4 x 6.0
Secondary screen aperture - top deck	mm	12
Secondary screen aperture - bottom deck	mm	10
Tertiary crusher type		Cone, Metso OMNICONE
Tertiary crusher power	kW	75
Ball mill diameter	m	2.4
Ball mill length	m	11

Parameter	Unit	Value
Ball mill power	kW	697.51
Ball mill hydrocyclone diameter	mm	TBC
Grinding circuit product size, p80	um	140
Zinc rougher-scavenger cells	m3	18 x 8.5
Plant W		
Primary crusher type		Jaw, Metso C100
Primary crusher power	kW	112
Ore homogenizing (blending) stockpile capacity	t	TBC
Secondary screen type		Inclined vibrating, Metso
Secondary screen dimensions	m	2.1 x 4.9
Secondary screen aperture - top deck	mm	50
Secondary screen aperture - bottom deck	mm	25
Secondary crusher type		Cone, Metso OMNICONE
Secondary crusher power	kW	149
Tertiary crusher type		Cone, Metso
Tertiary crusher power	kW	298
Quaternary crusher type		Cone, Barmac
Quaternary crusher power	kW	187
Tertiary screen type		Vibrating sieve
Tertiary screen dimensions	m	2.4 x 6.1
Tertiary screen aperture - top deck	mm	12
Tertiary screen aperture - bottom deck	mm	10
Ball mill diameter	m	4.4
Ball mill length	m	5.9
Ball mill power	kW	1828
Ball mill classification screen type		Derrick, high frequency 5 deck
Ball mill classification screen aperture	um	TBC
Grinding circuit product size, p80	um	140
Bulk flotation rougher-scavengers	m3	5 x 70
Bulk flotation 1st cleaners	m3	4 x 10
Bulk flotation 2nd cleaner	m3	1 x 5
Bulk flotation 3rd and 4th cleaners	m3	8 x 0.5
Zinc rougher-scavenger cells	m3	18 x 14.2
Tailings and concentrate dewatering		
Tailings thickener diameter	m	28
Tailings thickener underflow density	% solids	45
Zinc concentrate thickener diameter	m	16

Parameter	Unit	Value
Zinc concentrate filter type 1 (3)		Eimco drum
Zinc concentrate filter type 2		Andritz pressure

During 2016, Vazante investigated an increase in Plant W throughput rate to 153 t/h in conjunction with a reduction in grind size to p80 100 µm. The evaluation of the comminution circuit upgrade was updated. A trade-off study determined that a VTM1500 mill would not provide sufficient power to achieve these goals. Therefore, a VTM3000 (2237 kW) mill was selected to meet the updated grinding circuit design criteria. The mill is due to be commissioned in late 2019.

The current grinding screen undersize will feed a new pack of hydrocylones. Cyclone underflow will report the Vertimill, and mill discharge will be in closed circuit with the cyclones. Cyclone overflow will be the new feed stream to the sulphide flotation circuit.

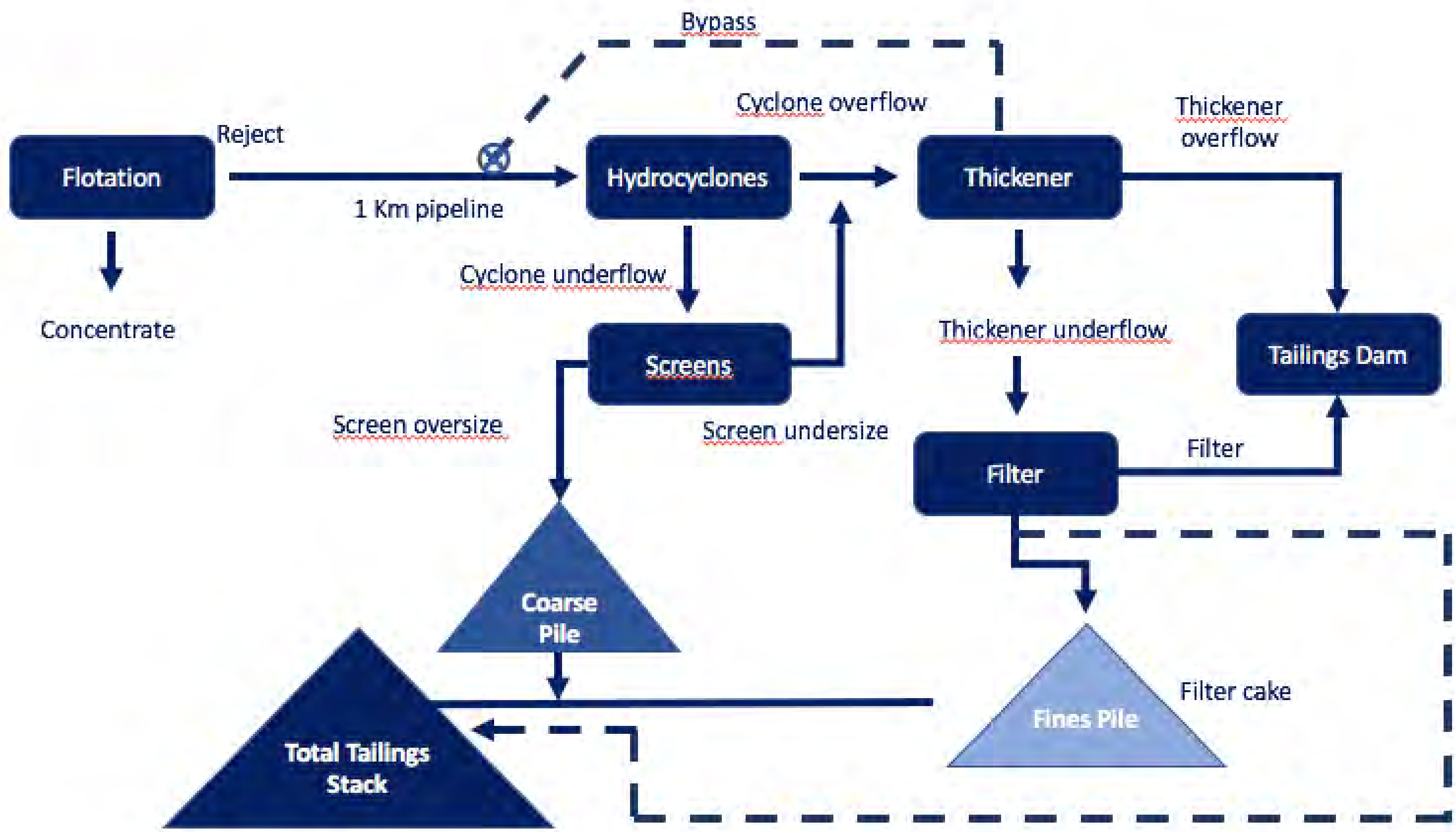
The plant upgrade does not include other modifications to the flotation circuits. After the increase to 153 t/h, it is possible that there will be some bottlenecks and inefficiencies in the Plant W zinc flotation circuit due to increased volumetric flow. The finer grind from the Vertimill would be expected to allow an increase in zinc recovery, if completed in conjunction with other capacity improvements in the flotation circuit. However, as Votorantim is still studying such improvements at a scoping level, no capital for such flotation improvements have yet been allocated, and no improvement in zinc recovery has been assumed after the installation of the Vertimill. This assumption seems reasonable. If the scoping and subsequent studies of zinc flotation capacity improvements are successful, Votorantim may be able to improve future zinc recovery beyond current forecasts.

Tailings Classification and Filtration for Dry Stack Tailings

Votorantim has studied changes in tailings classification and dewatering in conjunction with changing from slurry tailings to dry stack tailings disposal. This will ensure continuity of operations, as the current tailings storage facility (TSF) is nearing capacity. The dry stack project evaluation has been completed to a pre-feasibility level of study.

Currently, Votorantim is studying options to either filter all of the combined Plant W and Plant C tailings, or splitting off some of the coarser tailings fractions using hydrocyclones and vibrating screens. The modified flowsheet that would incorporate the new facility is shown in Figure 17-2, for the option that includes hydrocyclones and screens. In this option, cyclone underflow will report to vibrating screens, and screen undersize will combine with cyclone overflow to feed the tailings thickener.

Figure 17-2: Tailings Filtration Schematic



Note: Figure modified by Amec Foster Wheeler, original provided by Votorantim, 2017.

Thickener underflow will be filtered in one of two Andritz plate and frame pressure filters. A third filter will be available as a standby. Filters will have 65 plates, each of 2.0 x 2.0 m dimensions. The filter cake will combine with tailings screen oversize to form the dewatered tailings cake. This cake will be trucked to the new tailings dry stack. The filter capacity has been estimated assuming the option that all tailings will be thickened and filtered.

The tailings thickener overflow and tailings filter filtrate will be pumped to the existing Aroeira tailings dam.

Other

No bottlenecks are anticipated in the concentrate handling circuit as the Vazante plant has previously operated with substantially higher zinc head grades and hence zinc concentrate productions than in the LOM forecast.

17.4 Product/Materials Handling

Filtered concentrates are held in a small concentrate stockpile at the process plant, then loaded onto trucks for transport to customers.

Thickened tailings are currently sent to the Aroeira TSF. After the transition to dry-stack operations (see Section 20.6.10), tailings will be pumped approximately 1 km to the new tailings classification and filtration plant, Pilha Garrote. Filtered tailings combined with tailing screen oversize will be trucked to Pilha Garrote.

17.5 Smelter

Zinc concentrates are trucked in bulk approximately 250 km to Tres Marias. The smelter circuit leaches concentrates from the Vazante Operations through an autoclave with recycled leach solutions to dissolve carbonates. This is primarily to remove MgO, which can affect electrolysis efficiency. Zinc silicate is then leached with sulphuric acid to zinc sulphate, with chemistry controlled to precipitate silica. The zinc-bearing solution is then purified and zinc recovered by electrolysis. Fluorine levels in leach solutions must be controlled to avoid quality problems with stripping zinc cathodes in the electrolysis stage.

The smelter relies on a treating a balance of sulphide concentrates that, when roasted, generate the sulphuric acid that is used to leach the Vazante concentrates.

Overall zinc recovery from the Vazante Operations concentrate at Tres Marias is 94.9%. The conversion costs of Vazante Operations concentrates are projected at US$553/t recovered zinc in 2018. Votorantim expects these costs to fall in 2021 to US$509/t Zn due to improvements at the smelter.

Lead concentrate is loaded into bulk bags at Vazante Operations, and is transported approximately 900 km to the Port of Itaguai for shipment. Concentrate is sold in 200 t to 600 t shipments, depending on production from the operations. The existing contract with the Mitsui Hachinohe smelter in Japan includes shipment to Hachinohe Port. Use of bulk bags should allow proper containment of lead concentrate and alleviate any occupational health and hygiene concerns in shipping and handling.

17.6 Energy, Water, and Process Materials Requirements

The combined Vazante milling facilities drew approximately 43 kWh/t milled, or 7.2 MW in 2016. Power consumption will increase by 2020 in conjunction with the commissioning of the Vertimill and tailings filtration circuits. This results from both a higher specific power input due to the finer grind size and production of tailings filter cake, and the increase in overall plant throughput.

Table 17-5 shows the major process consumables on a g/t basis for 2016 consumption rates. Until early 2017, 416 g/t of sodium silicate dispersant was used in the process plant. This reagent is no longer expected to be used in future.

After the commissioning of the Vertimill in late 2019, Plant W will consume approximately 500 g/t of 19 mm steel balls for grinding media.

17.7 Comments on Section 17

The Vazante Operations use a conventional crushing, grinding, flotation, and concentrate dewatering flowsheet to recover lead-silver and zinc concentrates.

The process plant consists of the newer, larger Plant W, and the older Plant C. Plant C has no circuit for lead–silver recovery, and achieves lower zinc recovery performance than Plant W. Overall, the throughput and metal recoveries are achievable from the combination of plants.

Votorantim has extensively studied a stirred grinding mill to reduce flotation feed size and maintain recovery in conjunction with increased throughput. The Vertimill selected for Plant W appears of sufficient size, and is appropriate technology, and is planned to be operational by late 2019, in time for throughput expansion.

Votorantim has designed a tailings classification and filtration flowsheet that uses appropriate technology for dry-stacking. The flowsheet and equipment sizing are appropriate for changing tailings handling practices during 2019, in time to transition before the existing Aroeira slurry tailings dam reaches capacity.

Table 17-5: Major Process Consumables – 2016 Rates

Item	Description	Requirement (g/t)
Forged balls 50/60/70/90 mm	Grinding media for ball mills	439
Potassium amyl xanthate	Sulphide collector	26
MIBC	Frother	36
Sodium sulphide	Willemite activator	2,219
Sodium carbonate	pH modifier	483
AGLP 250	Dispersant	459
M100-4F Pietsch	Willemite amine collector	69
SNF Floeger 9026	Flocculant	26

18.0 PROJECT INFRASTRUCTURE

18.1 Introduction

A site infrastructure layout plan is presented in Figure 18-1.

18.2 Road and Logistics

The mine is situated 8 km from Vazante town, which is located north of Patos de Minas at the BR 354 highway, connecting with Belo Horizonte (496 km). The road to the mine is paved.

Concentrate is trucked from the mine by paved road to highway BR040 (75 km) and onward to the Tres Marias smelter (175 km) for a total distance of 250 km.

The closest commercial airport is in Brasilia, 340 km, or a four-and-a-half-hour drive from the mine on paved roads.

The main supplies for the mine are sourced from Belo Horizonte.

Internal roadways connect the various mine-site components including:

- Underground mine access portals
- Concentrator plant
- Waste storage
- Tailings
- Main offices, administration, and camp.

18.3 Stockpiles

Stockpiles are discussed in Section 20.4.

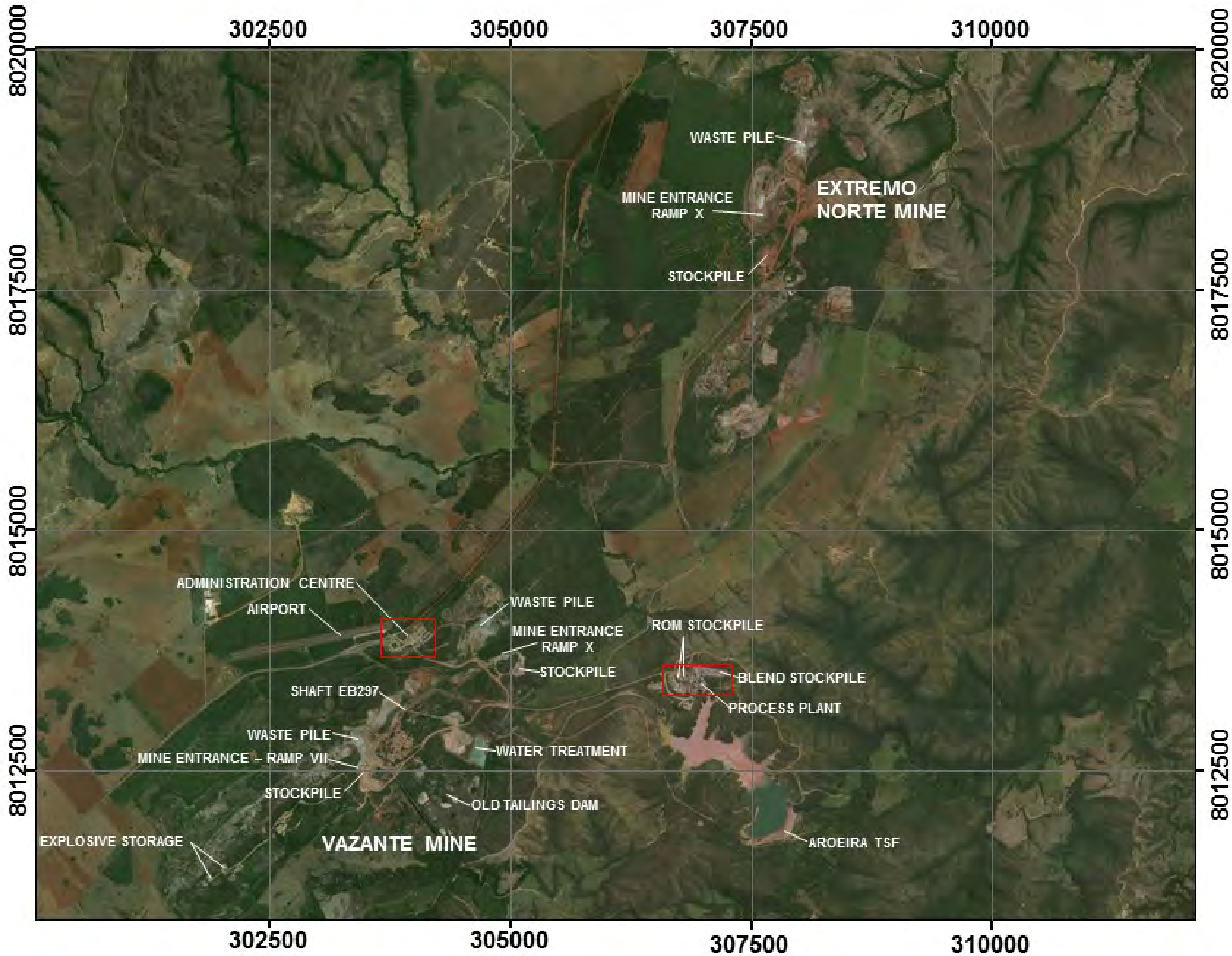
18.4 Waste Rock Storage Facilities

Waste rock storage facilities are discussed in Section 20.5.

18.5 Tailings Storage Facilities

Tailings storage facilities are discussed in Section 20.6.

Figure 18-1: Site Layout Plan



Note: Figure courtesy Votorantim, 2017. Grid north is to top of image. Red rectangles are inset plans included as Figure 18-2 and Figure 18-3.

Figure 18-2: Inset Details of Administrative Areas

Note: Figure courtesy Votorantim, 2017. Grid north is to top of image.

Figure 18-3: Inset Details of Process Plant Area

Note: Figure courtesy Votorantim, 2017. Grid north is to top of image.

18.6 Water Management

Water management in relation to mining activities is provided in Section 16.3.

Surface water management is discussed in Section 20.7.

18.7 Built Infrastructure

All infrastructure required for the current mining and processing operations has been constructed and is operational. This includes the underground mines, access roads, powerlines, water pipelines, offices and warehouses, process plant/concentrator, conveyor systems, waste rock facilities, temporary ore stockpiles, paste-fill plants, and tailings storage facilities.

The incremental mill expansion planned will require installation of a Vertimill and a new pack of hydrocyclones in the process plant.

The Vazante Deepening project will require additional underground access and electrical infrastructure and construction of a new shaft.

18.8 Camps and Accommodation

No accommodation camps are used in support of mining activities. Mine personnel commute from the municipality of Vazante to the operations.

18.9 Power and Electrical

Electricity supply is generated by hydroelectric power stations managed by Votorantim Energia, including Campos Novos, Capim Branco 1 and 2, Picada and Igarapava.

The power supply for the mine and processing facilities is provided entirely via the CEMIG-owned transmission network that serves the Vazante Operations. CEMIG is a large regional energy provider throughout Minas Gerais.

Two independent 138 kV transmission lines feed the site which can provide up to 55 MW. In 2016, the actual demand was 27.4 MW. The breakdown of this demand was:

- Mine: 2.8 MW
- Underground mine water pumping: 15.5 MW
- Mill: 9.1 MW
- General administration: 0.1 MW.

There are two 23/40 MVA transformers in a substation at the mine site to adjust the voltage to 13.8 kV. Power is then distributed to the plant and different levels in the mine.

In the mine, mobile substations lower voltage from 13.8 kV to 440 V for power use by the main fixed and mobile mine equipment. The mine has 30 mobile substations covering the whole production area. Each mobile substation is used for the development of approximately 300 m of galleries; once this development metreage has been reached, a new gallery is excavated, and the substation is transferred to the new area.

Overall power demand at the site is anticipated to increase by approximately 30% by 2021 due to a combination of higher mine dewatering requirements, power requirements for the Vazante Deepening mine extension, and additional process plant equipment (2.6 MW for Vertimill, and tailings filtration). By 2026, the total electricity demand is expected to reach 46 MW as the dewatering demand continues to grow.

An additional 60 MW power transmission line that will be operated by CEMIG is currently under development, and will be completed by 2020. An additional 40 MVA transformer will be mounted in the existing substation by April 2018. These changes will increase capacity and operational stability of the power supply, and have been allocated for in the capital plan.

The substations have fire-fighting systems and high reliability relays for circuit protection. These features protect the electricity supply system from major outages.

Two emergency 700 kVA diesel generators provide onsite power backup in case of state grid power failures.

18.10 Fuel

All underground equipment is fueled by fuel service trucks at the mine headings.

Underground equipment that regularly travels to the surface, such as haul trucks and supply trucks, can also be fueled on surface.

18.11 Communications

Communications throughout the mine are by radio and telephone. There is a central control room for the underground mine that serves as a command centre in the event of an emergency.

18.12 Comments on Section 18

Mining operations are active at Vazante and Extremo Norte, and supporting infrastructure is built. Some additional infrastructure, including a new shaft, will be built to support the Vazante Deepening project.

The incremental mill expansion planned will require installation of a Vertimill and a new pack of hydrocyclones in the process plant.

19.0 MARKET STUDIES AND CONTRACTS

19.1 Market Studies

Vazante and Extremo Norte are operating mines with concentrate sales contracts in place. As a result, market studies are not relevant to the operation.

All zinc concentrates produced by the Vazante Operations process plant are transported to, and treated through Votorantim's Tres Marias smelter. The concentrate from the Vazante Operations makes up approximately 70% of the feed to the smelter, with an additional 13% sulphide concentrates from Votorantim's Morro Agudo Mine, and 17% imported sulphide concentrates.

The smelter has a long history of treating zinc carbonate and silicate concentrates from the Vazante Operations, with electrolytic zinc production from Vazante Operations concentrates commencing in 1969.

Due to the low zinc and high silica grades of the zinc concentrate, the terms for selling onto world custom concentrate markets would be much less favourable than for typical zinc sulphide concentrates. This highlights the importance of Tres Marias as the primary customer for the Vazante Operations concentrate. In the event that Tres Marias was unable to process concentrates from the Vazante Operations, mine economics could be affected due to the significantly higher transport and treatment charges (TC) that would apply to an alternative customer.

Lead–silver concentrates are sold to the Mitsui Hachinohe smelter in Japan, which has a contract in place with Votorantim. This smelter uses the Imperial Smelting Furnace (ISF) process, which allows it to recover and pay for a portion of zinc in the concentrate (45% of zinc after deducting first 10%). Lead and silver payment terms are typical within the industry (Pb pay 95% minimum deduction 3%; Ag pay 90% deducting first 2 oz/t). Treatment charges are forecast at $196/dmt in 2018, rising to $215/dmt in 2019, based on Wood Mackenzie forecasts. There are no known penalties in the lead concentrates.

19.2 Commodity Price Projections

Votorantim provided Amec Foster Wheeler with the metal price projections for use in the Report. Votorantim established the pricing using a consensus approach based on long-term analyst and bank forecasts prepared during 2015 and 2016.

Amec Foster Wheeler reviewed the key input information, and considers that the data reflect a range of analyst predictions that are consistent with those in use by Amec Foster Wheeler and industry peers. Based on these sources, Amec Foster Wheeler agrees that Votorantim's price projections are acceptable as long-term consensus prices for use in mine planning and financial analyses for the Vazante Operations in the context of this Report.

The long-term price forecasts that are applicable to the Vazante Operations are summarized in Table 19-1.

Votorantim has also provided Amec Foster Wheeler with corporate projections for exchange rates for the LOM. These are summarized in Table 19-2, and are based on an industry-consensus view.

19.3 Contracts

19.3.1 Concentrates

Zinc Concentrates

The Tres Marias smelter has communicated specifications for zinc concentrate as follows:

- Zn > 39%
- Carbonate < 11.4%
- MgO < 4%
- CaO < 5%
- Fe < 7.7%
- F < 250 ppm
- Moisture < 13%
- % passing 37 µm > 35%.

Deleterious elements that need particular management in the Vazante Operations zinc concentrate are MgO and fluorine. The fluorine levels have increased towards specification limit in 2016, and it may be necessary to increase zinc concentrate grade to offset this effect. Other parameters were found to be at, or within, specification limits.

Table 19-1: Long-term Consensus Commodity Price Projections

Commodity	Unit	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Mineral Reserves	Mineral Resources
Zn	$/t	2,650	2,723	2,564	2,408	2,338	2,338	2,338	2,338	2,338	2,338	2,338	2,406.03	2,766.93
Pb	$/t	2,067	1,955	1,989	1,956	1,933	1,933	1,933	1,933	1,933	1,933	1,933	1,943.16	2,234.64
Ag	$/oz	17.51	18.46	18.75	19.31	19.45	18.91	18.91	18.91	18.91	18.91	18.91	18.94	21.78

Table 19-2: Long-term Consensus Exchange Rate Projections

Period	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
BR$:US$	3.35	3.33	3.36	3.38	3.38	3.38	3.38	3.38	3.38	3.38

Lead Concentrate

While a current contract is in place for the lead–silver concentrate, it should be noted that the Vazante Operations concentrate grade is unusually low, and may be difficult to market if the Hachinohe smelter suspends operations. Over the last 15 years, there has been significant closures of smelters using ISF technologies, which may limit alternative marketing of the lead concentrate.

19.3.2 Operations

Contracts to 46 firms have been let for provision of goods and services for the Vazante Operations, including the mine, mill and maintenance departments plus a number of support functions. Details on contractor services and numbers are provided in Section 21.2.5.

19.4 Comments on Section 19

Vazante and Extremo Norte are operating mines with concentrate sales contracts in place.

An explanation of the integration of the Vazante Operations, Morro Agudo Project, and the Tres Marias Smelter was provided to support assumptions for zinc payment, treatment costs and assigning the zinc metal premium.

The QPs have reviewed the information provided by Votorantim on marketing, contracts, metal price projections and exchange rate forecasts, and note that the information provided is consistent with the source documents used, and that the information is consistent with what is publicly available on industry norms. The information can be used in mine planning and financial analyses for the Vazante Operations in the context of this Report.

Long-term metal price assumptions used in the Report are based on a consensus of price forecasts for those metals estimated by numerous analysts and major banks. The analyst and bank forecasts are based on many factors that include historical experience, current spot prices, expectations of future market supply, and perceived demand. Over a number of years, the actual metal prices can change, either positively or negatively from what was earlier predicted. If the assumed long-term metal prices are not realized, this could have a negative impact on the operation’s financial outcome. At the same time, higher than predicted metal prices could have a positive impact.

20.0 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT

20.1 Introduction

Information regarding the environmental and social considerations for the Vazante Operations are summarized from the approved environmental assessments which include the Environmental Impact Assessment (EIA) for the Willemita underground mine (Brandt, 2001); the EIA for the Pilha Garrote Tailings Disposal Project (Ecolab, 2016); the EIA for the proposed process plant expansion (Ecolab, 2017); the closure plan for the Willemita underground mine expansion (AECOM, 2012); the closure plan for the Vazante unit (AECOM, 2013); the closure plan for the former process plant (SETE, 2013); the rehabilitation plan for waste rock storage facilities (Golder 2011); and the water balance and other relevant environmental information.

The main information source for baseline information is the Environmental Impact Assessment for the Pilha Garrote Tailings Disposal Project (Ecolab, 2017).

20.2 Baseline Studies

20.2.1 Climate

The region is classified as warm (calid) sub-humid ((IBGE, 2005), with 4–5 dry months annually. In the region where the mine is situated, the average temperature varies between 13ºC and 27ºC in the winter and between 18ºC and 30ºC in the summer.

The historical average rainfall is 1,441.5 mm, with more than 80% of this total occurring during the rainy season, which runs from October to March.

The predominant wind directions are northeast to southwest.

20.2.2 Air Quality and Noise Levels

Air quality monitoring between January 2014 and August 2016 included measurements of total suspended particles, inhalable particles, sulphur dioxide (SO_2) and nitrogen oxide (NO_2) at five sampling points. Results included:

- Total suspended particles and inhalable particles: Concentrations were below the maximum permitted values established by CONAMA for all monitoring points during the 2015 sampling program. For 2014, exceedances were registered for both parameters during the dry season in the monitoring station near the roads. No evidence of mitigating measures was noted to be in place. For the Extremo Norte monitoring point one value (July 2014) was found to be above the limit. CONAMA Resolution No. 03/1990 allows one exceedance for each parameter for each year, therefore the readings were not considered to be out of compliance

- SO_2: concentrations were below the maximum permitted values for 2014 and 2015 in all monitoring stations, except one value
- NO_2: results were below the maximum permitted values.

20.2.3 Water Quality

Water sampling points were established in the Santa Catarina River to assess water quality and contamination. In addition, the Instituto Minero de Gestão das Aguas 16-1(IGAM) monitored water quality in the State of Minas Gerais using two monitoring stations in the Santa Catarina River, over a 34-quarter period, running from March 2008 to June 2016. According to the monitoring results in 2014 and 2015, in the Santa Catarina River the parameters that exceeded the maximum limit values (COPAM/CERH-MG n° 01/2008) were suspended solids, turbidity, cadmium, and lead.

The EIA for the New Process Plant (SETE, 2000) indicates acceptable dissolved oxygen levels in the Santa Catarina River. In addition, total solids and turbidity were below the maximum limit, and had a very low concentration compared to the maximum limit established by COPAM 010/86. Cadmium and lead were found to be below the laboratory analytical detection limits.

The IGAM results found also bacteriological contamination of water was identified at both sampling points, consisting of thermotolerant coliforms, and *E. coli.*

20.2.4 Hydrology

The Vazante Operations are located on the Santa Catarina River sub-basin, which is a tributary of the Paracatu River, which is located in the Sao Francisco river basin. The Santa Catarina River has a drainage area of 1,182 km^2. Its main tributaries are the Carrapato creek, and the Carranca, Indaiazinho, and Arrependido streams.

The Santa Catarina River has a dendritic drainage pattern. Near the municipality of Vazante, the river runs through carbonate lithologies and a flattened topography.

20.2.5 Groundwater

Groundwater monitoring commenced in 1989, based on a piezometer network. The numbers of piezometers in the network has steadily increased, from an initial 28 to more than 155 currently.

Pumping by the mine has lowered water levels in some of the aquifers. Some local groundwater users have been affected by the pumping activity, and Votorantim supplies these users from alternate water sources.

20.2.6 Biological Considerations

From the primary data obtained for the EIA (Ecolab, 2017), protected species according to the IUCN and CITES list were identified within the influence area of the Vazante Operations:

- Three bird species (2015–2016) within the direct influence area were classified as near-threatened according to IUCN
- Five mammal species (2015–2016) within the direct and indirect influence area were listed in Appendix I and II of CITES.

A threatened species management plan is in place, developed by Ecolab in 2016.

20.2.7 Social and Heritage Considerations

The 2010 Census documented about 211,560 persons living in the micro-region of Paracatu. The municipality of Vazante is the third-largest in the region, with a population of approximately 19,700, or about 9% of the micro-region. Population emigration into the area is about 4% to the municipality, and approximately 5% overall to the micro-region of Paracatu.

The municipality of Vazante has public, state, and private schooling available, although no tertiary institutions exist to date. The illiteracy rate for those over 18 is lower than the average for the state of Minas Gerais as a whole.

About 40 medical facilities/centres are contained within the Vazante municipality.

20.3 Environmental Considerations/Monitoring Programs

Environmental licensure requires a number of on-going monitoring programs (Table 20-1).

Votorantim provided documentation that supported that the required 2016 monitoring reporting was completed and sent to the relevant regulatory authorities for 2016.

A LOM Environmental Monitoring Plan that evaluates air and water quality on an ongoing basis is also a cornerstone of community involvement (see Section 20.10). Results of the monitoring activities are used to update environmental management practices.

20.4 Stockpiles

Stockpiles and bins are mainly provided for short-term operational ore control and emergency ore handling purposes, and are not intended to provide longer-term storage capacity. Consequently, no oxidation/recovery issues are reported or expected.

Table 20-1: Key Monitoring Requirements

N°	Monitoring/Reporting Description	Reporting Frequency
1.	***Operating License No. 10/2012, COPAM 104/1988/049/2011***	
1.1	*Condition 1*	
	Water and Effluent Quality Monitoring Report 3rd quarter 2015, filed on 10/16/2015, under number 0703.03.00253 / 15 4th quarter 2015, prepared by VMH_VZ in July 2016 and filed on 01/29/2016, under number 0703.03.00017/16 1st quarter of 2016, filed on 04/26/2016, under number 3.03.00121/16 2nd quarter of 2016, filed on 07/18/2016, under number 3.03.00181/16 3rd quarter of 2016 Protocol PRTEFLAG-0703.03.00270/2016 4th quarter of 2016 Protocol PRTEFLAG-0703.03.00015/2017	Quarterly
	Groundwater quality monitoring Air quality	monthly
	Ecotoxicity monitoring Noise	Yearly
1.2	*Condition 6*	
	Compliance Report (groundwater), prepared by VM_VZ in April 2016 and filed on 04/18/2016, under nº 3.03.00111 / 16	Yearly
	Report of the Environmental Education Program Protocol COPAM nº R0365945/2016	Yearly
2.	***Operating License No. 028/2013 COPAM 104/1988/053/2012***	
2.1	*Condition 1*	
	Water and Effluent Quality Monitoring Report 1st quarter of 2016 Protocol PRTEFLAG-0703.03.00120/2016 2nd quarter of 2016 Protocol PRTEFLAG-0703.03.00180/2016 3rd quarter of 2016 Protocol PRTEFLAG-0703.03.00269/2016 4th quarter of 2016 Protocol PRTEFLAG-0703.03.00014/2017	Quarterly
2.2	*Condition 10*	
	Report of the Environmental Education Program Protocol COPAM nº R0365950/2016	Yearly
3.	***Operating License No. 15/2012***	
3.1	*Condition 4*	
	Report of the Environmental Education Program Protocol COPAM nº R0365936/2016	Yearly

N°	Monitoring/Reporting Description	Reporting Frequency
4.	***Operating License No. 05/2016***	
4.1	*Condition 1*	
	Report of the Environmental Education Program Protocol COPAM nº R0365928/2016	Yearly
5.	***Joint Regulatory Decision CERH / IGAM No. 1/2008***	
	Evidence of the Pollution Load Declaration Report - Base year: 2015; Filed on 03/16/2016 under No. CP0121302016	Yearly
6.	***COPAM Normative Resolution 110/2007***	
	Environmental Education Program Letter CO - VM_VZ - VZ - GSMA - 139/2014, protocol R0356128 / 2014. The updated program was filed on 12/17/15	Yearly
	Report of the Environmental Education Program developed under protocols	
7.	***Others***	
	Annual Work Report – RAL; Last RAL was presented on 2016 with No.0703.0300096/16, of 01/04/2016.	First report due after 60 days, afterwards annually.
	Letter CO-VM-VZ-GSMA-034/2016; No. 0703.03.00111/1; Consolidated, discussed and conclusive report confirming the execution of all mitigation programs and measures listed in this single opinion and in the PCA	Every six months
	Letter CO-VM-VZ-GSMA-034/2016; No. 0703.03.00111/16; Compliance with mitigation measures	Every 6 months
	Letter No. 0703.03.00090/16; Inventory of industrial solid waste	Yearly
	Piezometer and water flow reports: 0703.03.00249/16–16/09/2016; 0703.03.00220/16–18/08/2016; 0703.03.00182/16–18/07/2016; 0703.03.00147/16–17/06/2016; 0703.03.00131/16–18/05/2016; 0703.03.00109/16–18/04/2016; 0703.03.00076/16–17/04/2016; 0703.03.00042/16–16/02/2016; 0703.03.00006/16–18/01/2016.	Monthly
	Consolidated reports on pumping flow monitoring data, updating of the dewatering fronts, drainage systems and flow chart of the underground water paths; 0703.03.00184/16, on 07/18/2016, referring to the first half of 2016.	Every 6 months

20.5 Waste Rock Storage Facilities

A number of waste rock facilities are present on the site as a result of historical open pit mining activities (refer to Figure 6-1).

Currently, waste is only brought to surface for storage if one of the following arises in the underground operations:

- Production or development activities occur in close proximity to a stope or mined block, such that backfilling is not possible
- No stopes or mined blocks are available close to the area where waste is being mined.

This waste is currently used to backfill the mined-out Morro da Usina and Sucuri open pits. The Bocaina pit could also be used for waste storage in the future, if required.

20.6 Tailings Storage Facility

20.6.1 Introduction

The Vazante Operations currently disposes tailings produced by the process plant in the Aroeira TSF. The Aroeira TSF has the dual purpose of capturing and storing water for use in the process plant. The estimated life of the Aroeira TSF is forecast until approximately the end of 2020 or early 2021, at which point the operation is planning to filter and dry stack tailings in the Pilha Garrote dry stack facility. This facility will be constructed to the west of the Aroeira TSF. Construction is forecast to start in July 2018, ready for operations in or about December 2020/January 2021. The Aroeira dam will remain in operation after 2020 as a water supply source for the process plant.

A summary of key design characteristics of the Aroeira TSF is displayed in Table 20-2.

20.6.2 Tailings Storage Facility Design Considerations

Site Characterization

As part of site characterization studies, numerous drilling and test pitting campaigns were undertaken at the embankment foundations, borrow source areas and reservoir as part of design studies by Geoconsultoria (CM01-RT-04, Nova Barragem de Rejeitos Obras Iniciais Projeto Executivo July 2000), a Brazilian geotechnical engineering consultant. These investigations were complemented by laboratory testing and analyses on selected samples.

Tailings Geochemical Characterisation

Tailings characterization carried out by Hidrogeo (Classification of tailings from flotation of Vazante, (RT-01-01-GE-17-16-F, pgs. 20-21, September 2016) included laboratory testing and was in accordance with the Brazilian Norm (ABNT-NBR 10.004).

The report concluded that the tailings should be classified as Class II-A, non-dangerous and inert, in accordance with the norm. Tailings are non-acid forming.

Table 20-2: Aroeira TSF Dam Key Design Characteristics

Item	Value
Tailings embankment crest elevation	626 m
Maximum water level	625 m; controlled by a constantly operating spillway
Current reservoir volume	11.2 Mm^3
Final reservoir volume capacity (estimated at El. 626m)	13.5 Mm^3
TSF estimated storage life	3.5 years
Location	N8011867 E307846
Maximum embankment height	44 m
Crest width	5 m (average)
Crest length	690 m
Spillway type	Shaft
Spillway invert elevation	620.5 m
Embankment construction	Staged downstream method – compacted earth fill and cycloned tailings
Final embankment elevation	626 m
Tailings dry density	1.25 t/m^3
Start of construction and final raise	1999, 2014
Design engineer	Geoconsultoria Ltda

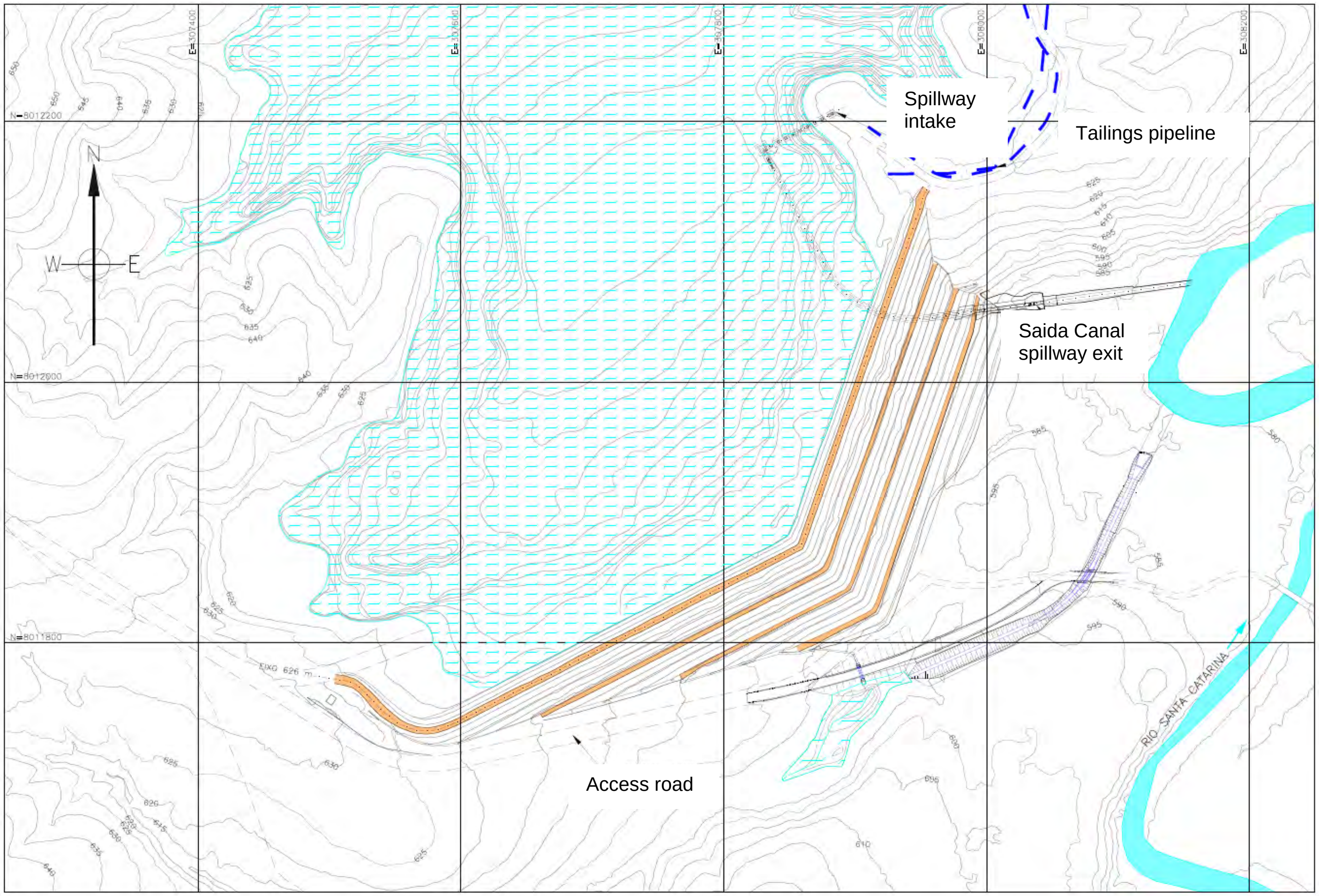
Embankment Design

The original dam design concept was to construct a starter dam and then discharge the underflow from cycloned flotation tailings in a centreline-raise type construction. The starter dam consisted of a compacted earth fill embankment with internal drainage including a chimney drain and downstream blanket. The dam has undergone eight raises, the first three using compacted earth fill and the remaining carried out with compacted cyclone underflow tailings. The final embankment elevation of 626 m was reached in 2014. Amec Foster Wheeler was not provided with documentation that this raise was fully permitted.

The embankment design, carried out by Geoconsultoria, considered local geological and geotechnical conditions, materials available for construction and economics of the project.

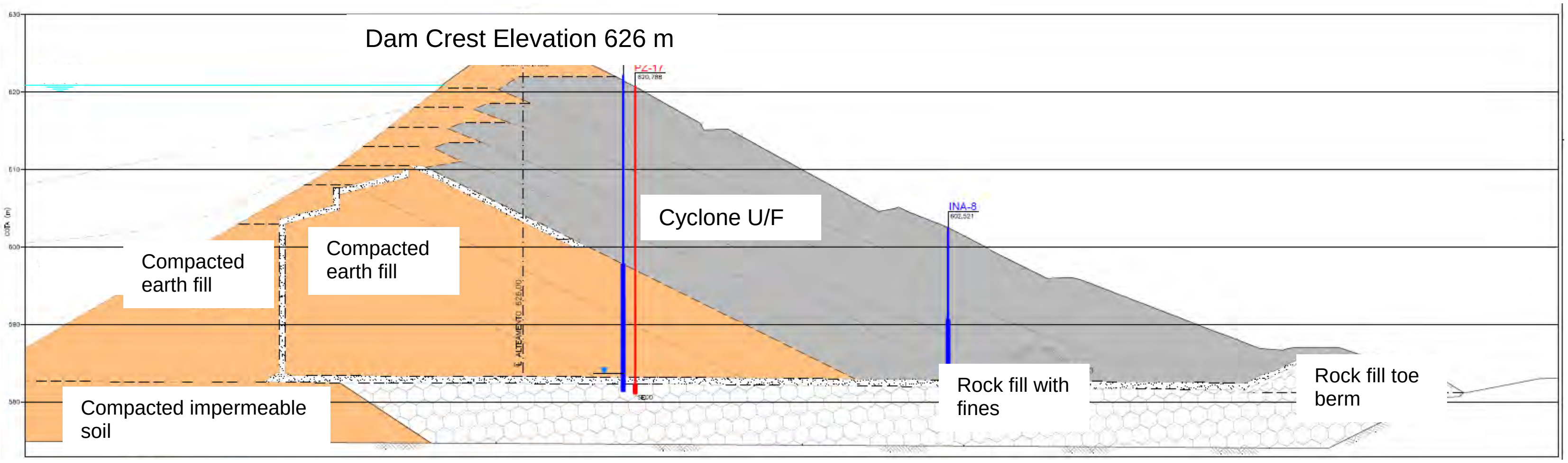
Figure 20-1 shows a general layout of the Aroeira TSF embankment and spillway, with the Santa Catarina River to the east. Figure 20-2 displays a typical cross section of the Aroeira embankment with vertical and horizontal drains and compacted cyclone underflow (grey) used for construction of the downstream embankment raises. A 4 m to 5 m wide section of compacted earth fill is used to cap the crest of the dam.

Figure 20-1: General Layout of the Aroeira Embankment and Spillway Plan



Note: Figure courtesy Votorantim, 2017. Grid squares are 200 m x 200 m. Rio Santa Caterina = Santa Caterina River

Figure 20-2: Typical Section of the Aroeira Embankment



Note: Figure courtesy Votorantim, 2017. Red and blue lines indicate instrumentation locations.

Foundation preparation included the compaction of soil beneath the upstream area of the starter dam, and placement of a rockfill blanket drain from the downstream area of the starter dam, continuing to the toe of the final dam.

20.6.3 Tailings Containment Structure Stability

The following criteria were adopted in dam design: NBR nº 13.028, the Brazilian norm for "Elaboration and Presentation of Tailings Dam Projects, Sedimentation Dams and Water Reservoirs".

Upstream and downstream embankment slopes were defined based on the following factor of safety (FS) values:

- FS>1.5: Long-term condition
- FS>1.3: End of construction
- FS>1.2: Seismic loading.

Geoconsultoria completed stability analyses and concluded that these were satisfactory values for all phases of embankment construction and operation.

20.6.4 Tailings Deposition

Currently, tailings are spigoted in the reservoir area as well as from the crest of the embankment on the upstream face of the dam. The objective of depositing from the crest is to build a tailings beach which will force the pond further from the embankment, reduce the hydraulic gradient on the upstream face, and the quantity of seepage flow.

It is understood Votorantim are in the process of developing a tailings thickening circuit to gain further capacity in the dam. Amec Foster Wheeler has not sighted studies and engineering designs to support this strategy.

20.6.5 TSF Water Management

Spillway Design

The shaft spillway was constructed in the initial phase for the life of the facility, and consists of an inlet structure on the left shoulder of the dam which passes into a drop shaft and through a pipeline under the embankment (with energy dissipaters) and exits at the downstream toe of the embankment. The exit is into a reinforced, open concrete channel that passes into a rockfill-lined section and then into the Santa Catarina River.

A monthly monitoring program is in place, checking water quality from a sampling point at the spillway outlet. Samples collected are analyzed for physical, chemical, and biological parameters by an independent third-party laboratory. To date, all results have been within regulatory limits.

Water Reclaim

The water reclaim system includes facilities to recover water from the tailings impoundment to be pumped to the process plant. The structure consists of pumps mounted on a floating platform with a design capacity of 12,000 m^3/hr with a solids content of 2,000 ppm. The platform is located to the north of the embankment on the eastern side of the reservoir.

20.6.6 TSF Construction, Operation and Monitoring

Embankment construction commenced in 1999 and was completed to the final elevation of 626 m in 2014. Construction comprised an earth-fill starter dam with vertical and horizontal drainage, and two separate downstream raises to 608 m and 610.5 m respectively of compacted earthfill. Following these raises, the embankment was raised using compacted cycloned tailings underflow using the downstream construction method.

Monitoring of instrumentation installed in the dam is carried out by Votorantim personnel and external consultants. Further details of these inspections are provided in Section 20.6.8. A summary of instruments installed in and around the dam is provided in Table 20-3.

Amec Foster Wheeler was provided with an internal presentation that contemplated a further dam embankment raise to 630 m. However, no design or documentation was provided in support of such a plan.

20.6.7 Old Dam and Reservoir Modules I, II and III

Other structures present at the Vazante Operations include the Old Dam (Antiga) and reservoir modules I, II and III. Of these structures, module III is currently the only one in operation. Figure 20-3 shows the location of the Old Dam and modules to the west of the process plant site.

Module III serves as a sedimentation dam and reservoir for water supply when the Aroeira TSF undergoes maintenance. The dam is geomembrane lined. Key design characteristics are provided in Table 20-4.

Table 20-3: Instrumentation Installed in and Around the Aroeira TSF

Item	Number
Piezometers	10
Water Level Indicator	14
Flow Meters	2
Survey Monuments	11
Reservoir Level Indicator	1
Rain Gauge	1

Figure 20-3: Google Image of Old Dam and Modules at the Vazante Operation

Note: Figure capture from Google Earth, captions prepared by Amec Foster Wheeler, 2017.

Table 20-4: Module III Dam Key Design Characteristics

Item	Value
Type of construction	Homogeneous earth fill
Dam crest elevation	600 m
Dam dimensions	300 m x 160 m
Dam height	8 m
Dam crest width	4 to 8 m
Reservoir capacity	400,000 m^3
Spillway type	Surface
Liner	Geomembrane
Construction of initial phase	1984

20.6.8 TSF Dam Safety

Aroeira TSF Dam Classification

The Aroeira TSF dam has been classified by Geoconsultoria according to the Brazilian Legislation (Artigo 2º da DN COPAM nº 62/2002) as a Class III Dam. The norm defines a Class III dam as one which has a "High Potential for Environmental Damage". The classification assigned determines the frequency of dam inspections and dam monitoring requirements.

TSF Safety Audits

Dam safety inspections are carried out by Votorantim professionals on a monthly basis and by Geoconsultoria every six months. The latest review by Geoconsultoria that was sighted by Amec Foster Wheeler was dated 30 August, 2016 (Relatório Técnico CM18-RT46 Rev.0, pgs 5, 12). In this report Geoconsultoria states the dam safety condition is "satisfactory".

In addition to the Geoconsultoria report, a "Cross Check" study was carried out by Ausenco Peru (Report 101862-03RPT-001, February 2017, pgs 11–13), in which it was concluded that:

- The Aroeira TSF dam is in "good condition", the seepage collection system functioning adequately and seepage water is of good quality
- There were no settlements or cracking noted on the crest
- The quantity of instrumentation in the dam is considered adequate and information derived from the instrumentation indicates the dam is in a stable condition
- The plan for accidents and emergencies includes the necessary information

- The dam break study should be updated.

20.6.9 Future Planning

The Aroeira TSF was constructed to its maximum elevation in 2014 and is forecast to reach its maximum limit at or about the end of 2020/early 2021. Votorantim conducted a trade-off study of various alternatives for tailings deposition and, as a result, will proceed with construction of a dry stack facility. Construction will start in about July 2018, and the facility will be operational in about December 2020/January 2021. The filter stack will receive tailings until 2026, at which stage the Mineral Reserves are expected to be depleted.

The area nominated for deposition of filtered tailings is known as the Pilha Garrote, and a general plan showing the disposal area location to the west of the Aroeira TSF is displayed in Figure 20-4. The EIA for the dry stack facility has been submitted to the relevant regulatory authorities. Votorantim advised that the preliminary LI and LP permits were expected to be granted sometime between August and December, 2017.

Votorantim has indicated that the mined-out 3A pit at Extremo Norte may also be available for tailings backfill storage, if needed. Permits for this usage would have to be obtained.

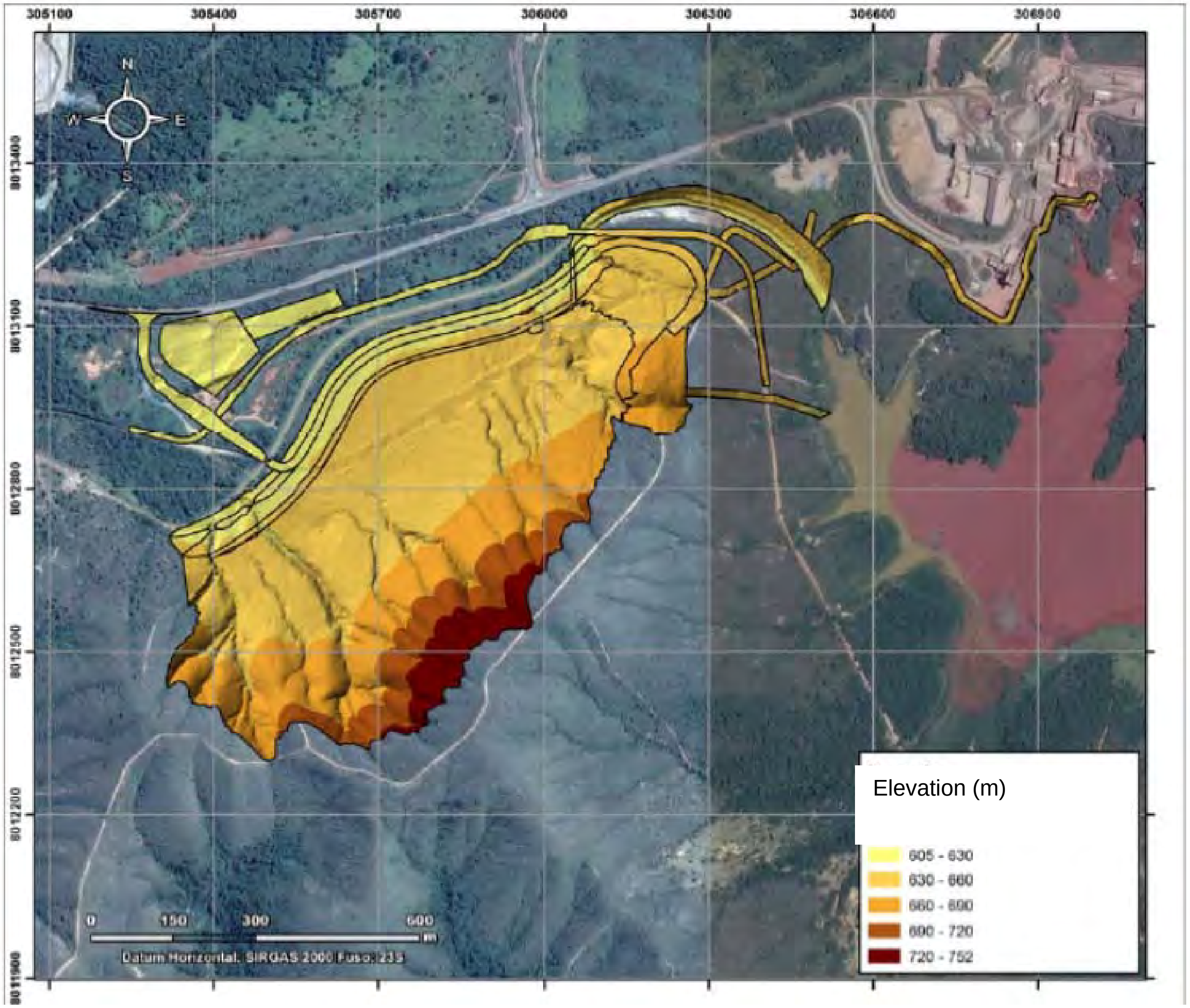
Filtered Tailings Process

The tailings plant will be composed of cyclones, thickening and filtering. Water reclaimed in the process will be discarded directly in the Aroeira TSF. Total tailings will be pumped from the plant by pipeline to the cyclone station from where the underflow will be transported by truck to the Pilha Garrote, where it will be spread and compacted. The overflow from cycloning will be thickened in the thickener. From the underflow of the thickener, the tailings will be sent to the filter plant from where the filter cake will be transported by truck to the Pilha Garrote. Water recovered at the filter plant and from the thickener overflow will be piped to the Aroeira TSF. Figure 17-2 displayed the proposed process flow diagram for filtered tailings production at the Vazante Operations.

Pilha Garrote Design Considerations

The basic design of the Pilha Garrote dry stack facility was carried out in 2016 by Walm (MD-I721015037-0902CIV0100-R3), a Brazilian consulting engineering company, and the environmental impact assessment was performed by Ecolab, a Brazilian environmental consultancy. General design characteristics of the Pilha Garrote are provided in Table 20-5 and a general layout plan is provided as Figure 20-5. Run-off water will be captured at the base of the stack as displayed in a schematic cross section in Figure 20-6.

Figure 20-4: General Layout Plan of Proposed Garrote Dry Stack Tailings Disposal Area



Note: Figure courtesy Votorantim, 2017. Grid squares are 300 m x 300 m.

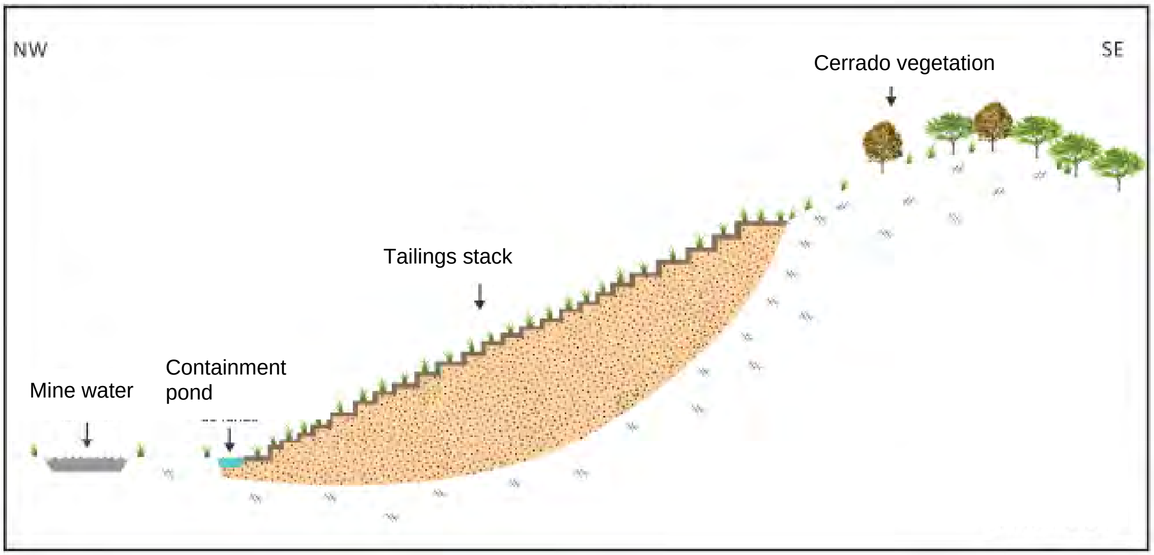
Table 20-5: Pilha Garrote Filtered Tailings Stack Characteristics

Item	Value
Area of footprint	378,678m^2
Estimated volume	8.6 Mm^3
Maximum height	120.00 m
Slope geometry	1V:2H
Berm height	5.0 m
Berm width	5.0 m
Estimated life span of deposit	10.7 years

Figure 20-5: General Layout of Pilha Garrote Tailings Stack

Note: Figure courtesy Votorantim, 2015. Grid squares are 150 m x 150 m.

Figure 20-6: Schematic Section Through the Pilha Garrote (from the northwest to southeast)



Note: Figure courtesy Votorantim, 2017.

Monitoring and Closure

The geotechnical monitoring program proposed for the Pilha Garrote is planned to include the following components:

- Periodic field inspections to inspect for slope slippage, presence of surface erosive processes
- Condition of drainage and revegetation conditions
- Analysis of readings taken of water monitoring instruments (water level indicators, surface displacement frames, groundwater wells and flow meters)
- Systematic follow-up and analysis of the global slope stability of the stack and the protective dike embankment.

The tailings deposit will undergo progressive reclamation, with the potential to commence early in the facility lifecycle.

20.7 Water Management

The primary purpose of water management is to ensure that the quality and quantity of water sources in the vicinity of the Vazante Operations are not impacted by mining activities.

The information for this section was obtained from the water balance provided by Votorantim Metais (2017), the EIA for the Modification and Expansion of the Process Plant (Ecolab, 2017), and the Pilha Garrote Dry Tailings Disposal Project (Ecolab, 2016).

20.7.1 Infrastructure

Hydraulic infrastructure such as diversion channels have been implemented to ensure hydrological stability for the mine facilities, and to divert water around the operations to natural watercourses. Channels divert not only runoff water, but also divert groundwater pumped from underground to a sedimentation pond, prior to release to the Santa Catarina River. This pond has a storage capacity of 11.2 Mm^3, and a surface area of 82 ha. The dam crest will be about 300 m long, and have a maximum height of 1.7 m.

The planned Pilha Garrote dry stack facility will be constructed to include sub-drainage, to ensure groundwater infiltration is adequately captured for stability purposes.

20.7.2 Water Supply

Water is primarily derived from four areas: surface water, groundwater, recirculated water, and rainfall.

The main water source for industrial purposes (by annual volume for 2016) is the underground mine which provides about 93,071 ML to the Aroeira tailings dam, of the annual total in the dam of approximately 107,117 ML. The total outflow from the Aroeira tailings dam is around 97,306 ML, which is used by the processing plant and ancillary facilities.

The EIA for the modification and expansion of the process plant (Ecolab, 2017) states that the actual water consumption reaches 766.3 m^3/hr; however, after the process plant expansion total water consumption will be approximately 1,174 m^3/hr, which is 407.7 m^3/hr higher. Using the 2016 data, about 9,922 ML (approx. 1,132 m^3/hr) is sent to the process plant, which covers current consumption. The expansion scenario will require an update of the water balance to cover the planned production increase, and therefore the increase in water that will be required to be recycled through the plant.

The majority of the water volume from the underground mine and from the Aroeira TSF is discharged to the Santa Catarina River. According to IGAM Ordinance 49/2010 and CERH Normative Decree 26/2008, the discharge of waste water into natural water bodies is subject to permitting. However, at present, only areas within a specific set of municipalities within the Mata River basin require a discharge permit. All other river basin areas are temporarily exempt from permit requirements. In accordance with CERH Normative Resolution 47/2014, the water management regulatory authorities are in the process of formalizing discharge permits; however, this formalization is not yet in place for the Sao Francisco basin.

Water captured at the Pilha Garrote dry stack facility will be directed back to the Aroeira TSF.

20.7.3 Water Treatment

Waste waters are sent to the Aroeira TSF (Ecolab, 2017), where water is recycled and sent firstly to the waste water plant, and then to the processing plant. With the processing plant expansion, the waste water discharges are estimated to be 453 m^3/hr. The mine life of the Aroeira TSF was projected to December 2017; however, improvements made to the tailings spigoting system should allow the facility to be used until at least the end of 2020.

20.7.4 Water Balance

The water outflow from the Aroeira TSF is 97,306 ML. Of this total, 86,645 ML is discharged to the Santa Catarina River, about 550 ML is lost to evaporation, and approximately 10,111 ML is available for use as industrial water. The process plant water requirements are 9,922 ML, and the remaining 189 ML is used in other mining activities. The overall water balance provided by Votorantim indicates that the water utilization efficiency is around 9%.

Recycled water from the Aroeira TSF is captured by a pumping system which consists of two pumps that have a capacity of 1,000 m^3/hr each. Water is conveyed about 2 km to the water treatment plant. From here, water is distributed to the process plant, mining areas, the administrative building, and is also used for irrigation purposes.

The Santa Catarina River is the only water source for domestic purposes, providing a total volume of 28 ML that is pumped to the potable water treatment plant.

20.7.5 Water Monitoring

The approved monitoring plan requires hydrogeological, surface, effluents and groundwater quality monitoring as stated in the four operating licenses.

Hydrogeological Monitoring

Monitoring programs are undertaken as required under operating licence conditions and regulations.

The execution and maintenance of the hydrogeological monitoring program is periodically verified through reports on environmental conditions to Regional Superintendence of the Environment and Sustainable Development of the Northwest of the state of Minas Gerais (*Superintendência Regional de Meio Ambiente e*

Desenvolvimento Sustentável do Noroeste de Minas or SUPRAMNOR). Recently submitted annual reports include:

- CO-VM-VZ-GSMA 060.2016, protocol PRTEFLAG-0703.03.00186/16 of 18/07/2016, in compliance with Condition No. 02 of Operation License No. 005/2016
- CO-VM-VZ-GSMA 061.2016, protocol PRTEFLAG-0703.03.00187 / 16 of July 18th, 2016, in compliance with Condition 04 of Operating License No. 028/2013.

Half-yearly reports are also submitted, for example:

- CO-VM-VZ-GSMA-012/2017, protocol PRTEFLAG-0703.03.00017/17 of January 18th, 2017, in compliance with Condition No. 12 Operation License No. 005/2016
- CO-VM-VZ-GSMA-013/2017, protocol PRTEFLAG-0703.03.00018/17 of January 18th, 2017 in compliance with condition No. 07 of Operating License No. 028/2013
- CO-VM-VZ-GSMA-014/2017, protocol PRTEFLAG-0703.03.00019/17 of 01/18/2017 in compliance with condition 12 of Permit 1672/2013.

Surface Water Monitoring

Environmental monitoring of the surface water and effluent quality have daily and monthly monitoring frequencies and quarterly report submission.

The purpose of the monitoring is to characterize the quality of the river upstream and downstream of the effluent discharge of the Vazante Operations, and meet the conditions of two different licensing processes:

- Condition 1 of LO 010/2012 of the COPAM Process 104/1988/049/2011
- Condition 1 of LO 28/2013 of the COPAM Process 104/1988/053/2012.

The water quality and effluent monitoring reports are sent to SUPRAMNOR on a quarterly basis to comply with conditions 1 of LO 010/2012 and LO 28/2013. The reporting was completed for 2016, as indicated below:

- Condition 1 of LO 010/2012 (COPAM 104/1988/049/2011):
  - Protocolo PRTEFLAG-0703.03.00121/2016 - Relatório de Monitoramento da Qualidade da Água e efluentes – 1º Trimestre de 2016
  - Protocolo PRTEFLAG-0703.03.00181/2016 - Relatório de Monitoramento da Qualidade da Água e efluentes – 2º Trimestre de 2016
  - Protocolo PRTEFLAG-0703.03.00270/2016 - Relatório de Monitoramento da Qualidade da Água e efluentes – 3º Trimestre de 2016
  - Protocolo PRTEFLAG-0703.03.00015/2017 - Relatório de Monitoramento da Qualidade da Água e efluentes – 4º Trimestre de 2016.

- Condition 1 of LO 028/2013 (COPAM 104/1988/053/2012):
  - Protocolo PRTEFLAG-0703.03.00120/2016 - Relatório de Monitoramento da Qualidade da Água e efluentes – 1º Trimestre de 2016.
  - Protocolo PRTEFLAG-0703.03.00180/2016 - Relatório de Monitoramento da Qualidade da Água e efluentes – 2º Trimestre de 2016.
  - Protocolo PRTEFLAG-0703.03.00269/2016 - Relatório de Monitoramento da Qualidade da Água e efluentes – 3º Trimestre de 2016.
  - Protocolo PRTEFLAG-0703.03.00014/2017 - Relatório de Monitoramento da Qualidade da Água e efluentes – 4º Trimestre de 2016.

Although some sampling indicated minor deviations from allowed limits, there were no significant issues noted in the 2016 reports.

Groundwater Quality Monitoring

The monthly monitoring of groundwater is carried out in compliance with condition 01 of LO 10/2012 and reports are required to be submitted every six months. Toxicity parameters are also monitored at four stations and submitted annually.

There are currently 155 piezometers where Votorantim monitors water levels, although Amec Foster Wheeler has no evidence for which piezometers also monitor groundwater quality.

No documentation was provided by Votorantim that supported that the required reports had been submitted to SUPRAMNOR for 2016.

20.8 Closure Plan

The following closure plans are approved for the Vazante Operations:

- Vazante Mine decommissioning plan: conceptual phase (2008, updated by AECOM in 2013).
- Waste rock facility and open pit rehabilitation plan (Golder Associates, Brazil, 2011)
- Extremo Norte Mine decommissioning plan: conceptual phase (AECOM, 2012)
- Former process plant decommissioning plan: executive phase (SETE, 2013).

20.8.1 Vazante Mine

The conceptual Vazante Mine Closure Plan update prepared by AECOM in 2013 covers the following:

- Underground mine

- Open pits: Bocaina, Sucuri Central, Morro da Usina, Sucuri South, Portaria, and Cercado
- Waste rock facilities: Depósito N°1 and Cercado
- Tailing storage facilities: Antiga (Old Dam) and Aroeira (current TSF dam)
- Processing plants for willemite and calamine (plants W and C)
- Ancillary infrastructure: administrative and operational support facilities.

The Closure Plan assumes most facilities will be dismantled, and equipment removed from the site. Structures made of limestone will likely remain, as they will not affect groundwater quality. Underground openings will be blocked off, and the water table allowed to re-establish. The Closure Plan assumes that host lithologies and mineralization style will not result in metals leaching (Closure Plan of Vazante Mine, AECOM, pg. 145, 2013). Although lithology and mineralogical compositions within the mining areas do not have the potential for acid generation, geochemical characterization of the tailings and waste rock is recommended.

The Closure Plan has been designed to address remediation of the operational areas, and to meet Brazilian engineering requirements for such plans at a conceptual phase. Based on the 2013 assumptions, progressive closure would commence during 2013 and would continue to 2025. Final mine closure would be implemented over a two-year period (conceptually 2026 and 2027 in the Closure Plan).

Post-closure monitoring would be undertaken over a five-year period (conceptually 2028–2032), and would include monitoring of the following key areas: fauna, revegetation, geotechnical, and water quality.

The total closure costs were estimated at the time to be approximately US$23.3 million, to be expended in or about 2026. The margin of error in the accuracy estimate was stated to be ±30% (Closure Plan Vazante Unit, AECOM 2013, pg. 168 Section 11 Cost Estimates and Physical and Financial Schedule).

20.8.2 Extremo Norte Mine

The conceptual Extremo Norte Mine Closure Plan prepared in 2012 by Golder Associates, Brazil, covers the following:

- Additional underground mining infrastructure (including installation and construction)
- 3A, 5A and 6A open pits. These are mined-out open pits from historical mining activities, which have existing rehabilitation plans (PRAD) that have been approved by the Brazilian authorities
- Ancillary infrastructure (power distribution, roads, administrative facilities).

At Votorantim’s request, the Closure Plan was scheduled to start in 2011, as Votorantim had already commenced rehabilitation activities at pit 5A.

As with the Vazante Mine, the current conceptual Closure Plan for the Extremo Norte Mine assumes most facilities will be dismantled, and equipment removed from the site. Structures made of limestone will likely remain, as they will not affect groundwater quality. Underground openings will be blocked off, and the water table allowed to re-establish. The host lithologies and mineralization style are not expected result in metals leaching. The plan assumes revegetation and surface drainage control measures will be conducted.

The Closure Plan has been designed to address remediation of the operational areas, and to meet Brazilian engineering requirements for such plans at a conceptual phase. The 2011 scenario assumes that 11 years will be required for progressive closure (2011–2022), and one year for final closure (2023).

Post-closure monitoring would require five years (conceptually from 2024–2028), and would incorporate considerations as to fauna, revegetation, geotechnical, and water quality.

The total closure costs at the time were estimated to be approximately US$15.1 million, to be expended in or about 2024. The margin of error in the accuracy estimate was stated to be ±30% (Closure Plan, AECOM 2012, pg. 201 Section 11 Cost Estimates and Physical and Financial Schedule).

20.8.3 Former Process Plant

The executive closure plan (SETE, 2013) includes the former process plant (Planta Antiga), replaced by plants W and C, and closed in 2003. Closure planning is considered straightforward, and will consist of removal of buildings and structures, implementation of drainage systems and re-vegetation. Zinc concentrations in the soil are naturally high, and the levels in the plant area reflect the natural concentrations. As a result, no topsoil replacement is likely to be required. No remedial recontouring is expected, as the site is flat, can be readily re-vegetated, and no significant water management issues are expected.

Post-closure monitoring, as described in the conceptual closure plan, will include erosion and flora monitoring, and is expected to be conducted over a five-year period. The total closure costs at the time were estimated to be approximately US$1.7 million, to be expended in or about 2021 (Closure Plan, SETE 2013, pg. 58, Section 5 Costs of Executive Project for Planta Antiga).

20.8.4 Waste Rock Storage Facilities

A rehabilitation plan was developed by Golder Associates in 2011 for the LCA-01 to LCA-05 waste rock storage facilities, and the Lumiadeira open pit. The plan addressed erosion control and stability. The conceptual and basic level plans that Golder Associates developed included surface drainage controls, revegetation activities, and land contouring. SUPRAMNOR recommended against the proposed measures.

As a result, Votorantim requested that Golder Associates prepare a rehabilitation plan for the Lumiadeira open pit and the waste rock facilities that identified the areas that needed rehabilitation, and identified what rehabilitation activities were required. A revegetation and erosion control plan was developed. The work program was assumed, in 2011, to require a budget of about US$230,000 to implement for 17 months. The margin of error in the accuracy estimate was stated to be ±25% (Rehabilitation Plan, Golder Associates, pg. 22).

An additional cost would be the maintenance of retaining walls and vegetation; the provisional budget allocation, in annual terms, was equivalent to 10% of the total value.

20.9 Permitting

The Brazilian legal framework for environmental protection consists of federal, state, and local environmental laws and regulations (see also Section 4.2.4):

- Environmental licensing was made mandatory after the Environmental National Policy Law No. 6938 was enacted in 1981, which promulgated three types of license schemes (refer to Section 4.2).
- Law No. 6938 was amended by laws 11.284/06, 11.941/09, 12.651/12 and Complementary Law 140/11. In addition, in 1986, the National Council for the Environment (CONAMA) passed Resolution No 1/86 which enforced the presentation of a previous Environmental Impact Study (EIS).
- The environmental licensing process is normally conducted at the state level by the relevant state environmental agency. When a project may impact on more than one state, the licensure is conducted at the federal level by the Brazilian Environmental Agency (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis*) (IBAMA).

The environmental framework includes:

- Federal Law No. 6938/1981, which established the National Environmental Policy
- Federal Constitution 1988, which provides the main framework and provisions for environmental protection in Brazil (*Article 225*)
- Federal Law No. 7735/1989, which created the federal environmental protection agency IBAMA

- Federal Law No. 9605/1998 (Environmental Crimes Act), which addresses criminal and administrative breaches
- Federal Law No. 9985/2000, which established the National System for Conservation Units
- Federal Law No. 11516/2007, which created the federal agency responsible for the management of federal conservation units (*Instituto Chico Mendes de Conservação da Biodiversidade*) (ICMBio)
- Federal Decree No. 6514/2008, which contains the implementing regulations for the Environmental Crimes Act, and specifically, administrative penalties
- Federal Law No. 12,305/2010, which establishes the National Policy for Solid Waste
- Federal Complementary Law No. 140/2011, which co-ordinates the constitutional jurisdiction for protecting the environment and natural resources
- Federal Law No. 12,651/2012, which established the new Forest Code
- The National Policy on Water Resources, Federal Law No. 9,433/1997

Where there is non-compliance with requirements and conditions set out in environmental licences, Federal Law No. 9605 (1998) imposes criminal and administrative sanctions on individuals and companies whose conduct and activities cause harm to the environment. The mere demonstration of the damages caused and the existence of causal connection to the polluter's activity is sufficient for polluter liability.

In addition to general rules, Minas Gerais state has enacted laws and regulations regarding environmental management of contaminated areas (Minas Gerais, Deliberative Resolution No. 116/2008) that protect soil quality and provide for management of contaminated areas.

In summary, the key permits derived from the above regulatory requirements for the Vazante Operations are listed in Table 20-6.

Environmental licences are valid for a set period. Votorantim must request renewal of the LO 120 days before its expiration date, so that the licence remains valid until the new and renewed licence is issued (Article 13(4) Complementary Law No. 140/2011). According to the Report of Compliance of Condition 06 (Relatório de Atendimento À Condicionante 06, Votorantim, 2017), four active operating license renewals (LO 10/2012; LO 15/2012; LO 28/2013 and LO 005) were granted to Votorantim on 19 April, 2017 by No. 104/1988/059/2016.

Table 20-6: Key Permits

Regulatory Authority	Permit Number	Title	Short Description	Grant Date	Duration (validity)	Condition
Agricultural, Fisheries and Supplies Ministry - MAPA	Register No. MG00112/2016-2021	Provision of concentrated zinc ore to manufacture fertilizer	Register of Establishment	11/02/2016	03/02/2021	Active
Environmental Company of Sao Paulo State - CETESB	Authorization No. 26004346/2015-2017	Disposal of Batteries	Environmental authorization	05/05/2015	05/05/2017	Not active
Government Counsel of Environmental Policy - COPAM	Operation License No. 010 / 2012-2017 COPAM Process nº 104/1988/049/2011	Operating License	Open pits, process plant, tailings dam, waste damp, roads for mineral and waste transport, drainage channels, energy substations and gas station.	19/04/2012	19/04/2017	In the process of renewal through COPAM No. 104/1988/059/2016
	Operation License No. 015 / 2012-2017 COPAM Process nº 104/1988/052/2012	Operating License	Lead and Silver recovery project	26/06/2012	26/06/2017	Active. No evidence of the process of renewal.
	Operation License No. 028 / 2013-2019 COPAM Process nº 104/1988/053/2012	Operating License	Underground mining and emulsion tank	18/07/2013	18/07/2019	Active
	Operation License No. 005 / 2016-2020 COPAM Process nº 104/1988/056/2014	Operating License	Extremo Norte Project	31/03/2016	31/03/2020	Active
	Installation License No. 025 / 2012-2018	Installation License	Extremo Norte Project	16/08/2012	16/08/2018	Not active
	Operation License No. 264 / 2012-2017 COPAM nº 104/1988/033/2006	Operating License	Mining and processing of zinc ore	17/09/2007	17/09/2012	Not active
Public Ministry of Minas Gerais - MPMG	TC MPMG 2012	Terms of Agreement	Terms of agreement relevant to the licensing of the Extremo Norte Project	02/03/2012	02/03/2017	Active

Regulatory Authority	Permit Number	Title	Short Description	Grant Date	Duration (validity)	Condition
National Commission of Nuclear Energy - CNEN	Authorization No. 6740/2015 - CGMI/CNEN	Authorization for operation.	Authorization for nuclear meter use	09/09/2015	01/08/2019	Active
Mining Institute of Water Management - IGAM	Permit No. 02986 / 2009-2014	Water permit	Permit for clean-up of the Barroquinha stream	18/11/2009	18/11/2014	In process of renewal by Process No. 17988/2014 (18/11/2009). IGAM have not responded yet.
	Permit No. 2282/2016	Water permit	Water intake from Santa Catarina river	17/11/2016	31/03/2020	Active
Environmental and Sustainability Development Government Secretariat - SEMAD	Permit No. 304295/2013	Permit	Open pit or underground mining in karstic areas with or without treatment. Storage of chemical products, including explosives	26/06/2013	26/06/2019	Active
	License No. 1672 / 2013-2019	Underground Water Permit	Lowering of water level of the underground Vazante mine. Flow rate granted: 19 823 (m^3/h)	31/07/2013	18/07/2019	Active
Regional Superintendence of Environmental Regularization - SUPRAM-NOR	License No. 201 / 2014-2016	Superficial Water Permit	Water intake from Santa Catarina river for industrial purposes. Flow rate granted: 55,6 (L/s)	10/02/2014	26/06/2016	In process of renewal by Process No. 21393/2016 (22/06/2016)
	Certificate No. 0119705 / 2013-2017	Waiver certificate	Exemption from licensing for the construction of 129 drill platforms.	15/02/2013	15/02/2017	Not active

Regulatory Authority	Permit Number	Title	Short Description	Grant Date	Duration (validity)	Condition
	Certificate of Exoneration No. 0562130 / 2015-2019	Waiver certificate	Tailings discharge with spigots from Aroeira Tailings Dam	12/06/2015	12/06/2019	Active
	Environmental Impact Assessment Department (DAIA) No. 0028192-D / 2014-2016	Authorization for environmental Intervention	Removal of vegetation to build 129 exploration drilling platforms	15/05/2014	15/05/2016	Not active
	DAIA No. 0030083-D / 2015-2017	Authorization for environmental Intervention	Removal of vegetation to build Pit II	20/08/2015	20/08/2017	Not active
	DAIA No. 0030638-D / 2015-2017	Authorization for environmental Intervention	Removal of vegetation t tailings discharge with spigots for Tailings Dam Aroeira	19/11/2015	19/11/2017	Not active
	Permit No. 00218 / 2013-2016	Water permit	Diversion of the Palmito stream to build the Aroeira Dam (there is no flow granted).	04/02/2013	26/06/2016	Active. The application for renewal was filed on 06/22/2016 under No. 0710338/2016 (Case 21394/2016).
	Permit No. 01805 / 2008-2013	Water permit	Construction of a dam on Santa Catarina tributary; waste disposal and recovery of water for industrial use (no flow granted)	06/10/2008	06/10/2013	In process of renewal. The application for renewal was filed on 05/24/2013, under number 0910318/2013 (Case 10107/2013
	Permit No. 01887 / 2011-2016	Water permit	Lowering of water level of the Extremo Norte mine. Flow granted: 2000 m³/h.	29/06/2011	29/06/2016	In process of renewal by Process No. 21392/2016 (22/06/2016)
	Plan for Degraded Areas – PRAD No. R175835			2011	2029	Approved

Regulatory Authority	Permit Number	Title	Short Description	Grant Date	Duration (validity)	Condition
Others	Approval No. 100815/2015; in compliance with Articles 3 and 5 of the National Council for the Environment (*Conselho Nacional do Meio Ambiente* or CONAMA) Resolution No. 273/2000;	Certification	Certifies the absence of equipment leaks (tank, pumps and distribution lines are sealed).	2015	2 years	Active
	Protocol no. 0703 03.00075/16; Protocol nº 0703. 03.00219/16;	Certificate	Certificates of oil waste disposal	2016	6 months	Active
	Certificate No. 0703.03.00115/2016.	Certificate	Absence of acid drainage	2016	Yearly	Active
	Certificate No. 0703.03.00015/16	Certificate	Annual Report on Rainwater Drainage Systems	2016	Yearly	Active
	Certificate No. 0703.03.00114/16;	Certificate	Training certificate for workers at supply station	2016	2 years	Active
	Certificate No. 0703.03.00110 / 16	Certificate	No evidence of leakage or pollution on the area of the dam.	2016	2 years	Active

The EIA for the process plant expansion was filed with the appropriate regulatory authorities for the LO certification in January 2017. The EIA included an increase in the mining rate of 470,000 t/a, to bring the allowed annual production rate to 1.87 Mt/a. The expansion application was filed to update the permits to match the actual mine production rate from the Vazante Mine of 1.4 Mt/a (LO 028/2013) and mine production from the Extremo Norte Mine of 470,000 t/a (LO 005/2016).

Compliance with permitting is monitored as follows:

- Monthly legal monitoring of new legislation is undertaken by a third-party. Votorantim's legal team verifies if new permits/licenses are required and generates a compliance action plan
- Annual audits conducted by a third-party to verify compliance with legal requirements, licensing, and any licence conditions.

Based on an audit document provided by Votorantim (Correa and Fideles, 2016), the final disposal of solid wastes generated at the Vazante Operations is in compliance with State Law No. 18.031/2009. Although sanitary and common residues are being sent to the Municipality of Vazante landfill, which is unlicensed, the PCA approved by the environmental agency acknowledged this destination. Correa and Fideles (2016) indicate that Votorantim is in the process of licencing a landfill for the Vazante Operations.

Correa and Fideles (2016) noted a number instances of minor non-compliance or omissions and gaps with the information reviewed, including:

- Certificates of calibration for certain flow monitoring meters from the National Institute of Metrology, Quality and Technology (*Instituto Nacional de Metrologia, Qualidade e Tecnologia* or INMETRO) or Metrology Network of Minas Gerais (*Rede Metrológica de Minas Gerais* or RMMG) should be confirmed to have been obtained
- If water is being used for purposes that are not specified in the relevant water licence, an application should be made to amend the licence to include the new usage

A groundwater data review should be completed to check monitoring results not only against SUPRAMNOR requirements, but also against the maximum allowable values listed in CONAMA Resolution No. 420/2009 or Normative Resolution COPAM/CERH 02/2010. Some groundwater monitoring points appear to be recording elevated lead, iron, manganese, and zinc levels. These may be a reflection of naturally-elevated concentrations in the soil, but could also be reflective of an issue that requires mitigation.

Reviews should continue to be conducted to ensure proper compliance and effective monitoring, and to ensure that the requirements of each permit are reported to the relevant national authority to meet with regulatory and legal requirements.

20.10 Considerations of Social and Community Impacts

Votorantim has developed a Social Communication and Information Plan (PCIS) for the Vazante Operations based on the communication and social responsibility guidelines set out in the approved EIAs. The plan outlines the social commitments and responsibilities that Votorantim will undertake toward the municipality of Vazante.

Votorantim has also developed a Socioeconomic Characterization Plan that outlines the social commitments and responsibilities that Votorantim will undertake toward the municipality of Vazante. From 2011 to 2016, Votorantim expended about US$91 million in social projects, ranging from community cinema initiatives to improvements in public education. The largest program, the “network for sustainable development” (ReDes), aims to support local businesses and develop new business initiatives.

In partnership with the appropriate internal and external resources, Votorantim staff develop and implement Community Engagement Relations Plans by determining the potentially-impacted communities and probable partner stakeholders that could be potentially impacted; defining issues that are important to stakeholders; and establishing objectives consistent with what Votorantim and the affected communities wish to accomplish initially by 2025 and subsequently by 2030.

Through these consultation methods, stakeholder partnerships are created and result in developing an annual budget, and a portfolio of social initiatives sufficient to support the Community Engagement Relations Plans, agreements, and negotiation processes. These plans are included in the business strategic planning and determine and implement methods for measuring the effectiveness of the Community Engagement Relations Plans.

20.11 Comments on Section 20

Amec Foster Wheeler recommends that the 2016 audit document be reviewed to identify any areas where there may be gaps or inconsistencies in permitting, and rectify these. If flow meters and other measuring devices require certification, this should be completed.

The existing closure plans, which assumed closure of the Extremo Norte Mine area would commence in 2011, and the Vazante Mine area in 2013, should be updated. The waste rock facilities are covered by a rehabilitation plan; however, a check should be made with the regulatory authorities to determine if an executive-level closure plan is required in addition. It would be useful to refine the closure plan cost estimate analyses further from the current 25–30% accuracies.

Specific areas that may require careful management or follow-up activities include:

- The Legal Audit states that Votorantim is in the process of licensing their own landfill. It is recommended that this continue to be advanced so the operations can cease sending general waste to an unlicensed landfill
- The conceptual plan for the Vazante Mine and the Extremo Norte mine stated that progressive closure would commence during 2013 and 2011 respectively. The plans should be updated, and it is recommended that the estimate margin be better defined from the current ± 30% accuracy
- Confirmation should be sought from SUPRAM as to whether an executive-level closure plan is required for the waste rock storage facilities that currently hold only a rehabilitation plan
- The status of the non-compliances found during the internal audit should be reviewed

21.0 CAPITAL AND OPERATING COSTS

21.1 Capital Cost Estimates

21.1.1 Basis of Estimate

Votorantim has prepared a capital schedule including expansion and modernization projects; safety, health, and environment; and sustaining capital projects from 2017 to 2022. Nominal sustaining capital allowances were included from 2023 to 2027.

21.1.2 Contingency

Limited contingency has been allocated for major capital projects (Vazante Deepening, Vertimill, and dry stack tailings).

21.1.3 Mine Capital Costs

The mine capital costs are primarily related to the Vazante Deepening project (Table 21-1).

21.1.4 Process Capital Costs

There are two main capital projects planned in the process plant:

- Vertimill (VTM3000)
- Tailings classification and filtration circuit for dry stack tailings disposal,

Both projects have completed at a prefeasibility level of accuracy, and will move to feasibility during 2017.

Both projects include general arrangement drawings at designated locations that have been assessed for suitability. Estimates include provisions for the feasibility study and detailed engineering, equipment costs, installation, spares, commissioning, and contingency.

21.1.5 Infrastructure Capital Costs

A new 138 kV power line is included in the Vazante Deepening project.

21.1.6 General and Administrative Capital Costs

Minor capital is allocated for safety, health, and environment initiatives in 2017. There are no other specific allocations to this area.

21.1.7 Owner (Corporate) Capital Costs

No Owners' capital costs are included.

Table 21-1: Mine Major Projects Capital Costs (US$ million)

	2018	2019	2020	2021	2022	Total
EB140	34.2	3.1	9.1	2.4	0.4	49.2
SE Principal	—	0.1	—	—	—	0.1
New Shaft II	5.5	—	—	—	—	5.5
EB347	0.5	9.2	—	—	—	9.7
138kV Electrical Network - CEMIG	1.4	7.7	4.8	—	—	13.8
Development	4.7	4.0	1.7	0.7	0.1	11.2
Project Definition Cost	—	—	—	—	—	—
Management Cost Management	1.1	0.9	1.0	1.0	1.0	5.0
Detailed Engineering Cost	0.2	—	—	—	—	0.2
Contingency	—	0.7	0.5	0.1	—	1.3
Total	***47.6***	***25.7***	***17.1***	***4.2***	***1.5***	***96.0***

Note: Totals may not sum due to rounding.

21.1.8 Sustaining Capital

Sustaining capital costs of $7.9 million, $7.9 million, $5.5 million, $3.9 million, and $2.4 million are included for 2023 to 2027 respectively.

21.1.9 Capital Cost Summary

Votorantim has prepared a major projects capital schedule including expansion and modernization projects; safety, health, and environment; and sustaining capital projects from 2017 to 2022. Table 21-2 provides a summary of the expected major project capital costs.

Table 21-3 provides the LOM capital cost estimate, inclusive of the sustaining capital allocations from 2023–2027.

21.2 Operating Cost Estimates

21.2.1 Basis of Estimate

Operating costs are developed in Brazilian Real, and referenced to historical operating costs (Table 21-4). Costs are broken into variable and fixed components.

Reagents, explosives, and diesel costs are calculated based on specific usage rates per tonne of ore, and projected unit prices for inputs. Usage rates are based on historical performance.

Table 21-2: Planned Major Projects Capital Expenditure by Year (US$ million)

Year	2018	2019	2020	2021	2022
Expansion and modernization	60.1	33.2	17.1	4.2	1.5
Safety, health, and environment	15.6	5.7	0.0	0.0	0.0
Sustaining capital	5.1	1.9	7.9	7.9	7.9
Total capital	***80.8***	***40.8***	***25.0***	***12.0***	***9.3***

Note: Totals may not sum due to rounding.

Table 21-3: LOM Capital Costs

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total LOM
Expansion and modernization											
Vazante Deepening mine extension	47.6	25.7	17.1	4.2	1.5						96.0
Extremo Norte mine	0.0	0.0	0.0	0.0	0.0						0.0
Vertimill plant expansion	12.5	7.5	0.0	0.0	0.0						20.0
Automation Simba 7 M6C	0.0	0.0	0.0	0.0	0.0						0.0
Total expansion and modernization	60.1	33.2	17.1	4.2	1.5						116.0
Safety, health and environment											
Tailings filtration and dry-stack	13.6	5.7	0.0	0.0	0.0						19.4
Lumiadeira II surface raise	1.9	0.0	0.0	0.0	0.0						1.9
Aroeira tailings dam life extensions	0.0	0.0	0.0	0.0	0.0						0.0
Other safety, health, and environment improvements	0.0	0.0	0.0	0.0	0.0						0.0
Total safety, health and environment	15.6	5.7	0.0	0.0	0.0						21.3
Sustaining capital											
Extension of EB297	5.1	1.9	0.0	0.0	0.0						6.9
Overhaul AEG winch	0.0	0.0	0.0	0.0	0.0						0.0
Other sustaining capital	0.0	0.0	7.9	7.9	7.9	7.9	7.9	5.5	3.9	2.4	51.1
Total sustaining capital	**5.1**	**1.9**	**7.9**	**7.9**	**7.9**	**7.9**	**7.9**	**5.5**	**3.9**	**2.4**	**58.0**
Total capital	**80.8**	**40.8**	**25.0**	**12.0**	**9.3**	**7.9**	**7.9**	**5.5**	**3.9**	**2.4**	**195.4**

Note: totals may not sum due to rounding.

Table 21-4: Historical Operating Costs, 2015–2016

Cost area	2015	2016
Variable costs BR$ M		
Primary materials	20.3	23.4
Electricity	29.3	31.5
Diesel	6.3	6.2
Royalties and CFEM	4.3	6.2
Other variable	17.2	13.8
Total variable costs	*77.4*	*81.1*
Fixed costs BR$ M		
Salaries and benefits	40.6	37.3
Social programs	18.7	20.9
Maintenance services	28.3	32.1
Other fixed	18.8	20.2
Total fixed costs	*106.4*	*110.6*
Total costs BR$ M	***183.8***	***191.7***
FX BR$:US$	3.34	3.61
Variable costs US$ M	23.2	22.5
Fixed costs US$ M	31.8	30.6
Total costs US $ M	***55.0***	***53.1***
Tonnes milled (inc. float) *	1,360,089	1,370,519
Total unit costs US$/t	***40.46***	***38.74***

Note: Float is historical low-grade dense media material sourced from historic calamine processing that is treated when the mill has available capacity, and metal prices are high enough to warrant treating the material.

Electricity costs are based on projected electricity consumption multiplied by the forecast electricity unit price (Table 21-5). Electricity consumption is divided into mine dewatering and other uses (mainly the process plant). For mine dewatering, power consumption is calculated from the volume of mine dewatering multiplied by the specific power consumption per volume pumped. For the mine, plant and general administration area, electricity consumption is estimated from the main power loads, including additional power for the new Vertimill in the process plant.

Overall electricity costs are forecast to increase substantially in 2018 compared with 2016. This is primarily due to the higher electricity unit price, which was BR$0.14/kWh in 2016, compared with a forecast of BR$0.206/kWh in 2018. Consumption continues to rise through life of mine, mainly due the increasing requirements for mine water pumping.

Table 21-5: Projected Electrical Costs (BR$)

	Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Mine loads											
Tonnes milled	kt/y	1,346	1,267	1,356	1,482	1,442	1,515	1,459	1,547	1,600	1,287
Specific consumption	kWh/t	16.36	14.67	15.46	15.34	15.34	15.34	15.34	15.34	15.34	15.34
Other consumption	MWh/y	22,026	18,589	20,965	22,727	22,114	23,234	22,386	23,735	24,546	19,740
Mine water pumping											
Water volume	m^3/h	11,576	12,219	12,234	12,333	12,219	12,809	12,634	12,671	13,770	13,779
Specific pumping energy	kWh/m^3	1.42	1.46	1.49	1.59	1.70	1.79	1.87	1.96	2.05	2.14
Pumping consumption	MWh/y	144,442	155,766	160,279	171,796	182,049	200,363	208,076	218,110	247,424	212,394
Mill and general administration loads											
Tonnes milled	kt/y	1,346	1,267	1,356	1,482	1,442	1,515	1,459	1,547	1,600	1,287
Specific consumption	kWh/t	58.7	60.4	74.9	73.7	75.6	72.2	74.7	70.8	68.6	69.1
Other consumption	MWh/y	78,995	76,472	101,595	109,183	108,963	109,366	109,061	109,545	109,837	88,871
Total electricity consumed	MWh/y	245,463	250,828	282,838	303,706	313,126	332,963	339,523	351,390	381,806	317,464
Electricity price	R$/kWh	0.206	0.184	0.194	0.193	0.193	0.193	0.193	0.193	0.193	0.193
Electricity cost	R$ M/y	50.5	46.2	54.9	58.5	60.4	64.2	65.4	67.7	73.6	61.2
FX	R$:US$	3.35	3.33	3.36	3.38	3.38	3.38	3.38	3.38	3.38	3.38
Electricity cost	US$ M/y	15.1	13.9	16.3	17.3	17.9	19.0	19.4	20.1	21.8	18.1

Note: Totals may not sum due to rounding.

21.2.2 Mine Operating Costs

Mine operating costs include those costs associated with the excavation of lateral and vertical development headings, production stoping, and transport of ore from the mine and the infrastructure required to support those operations.

This includes drilling, blasting, ground support, haulage, and mine services, as well as permanent infrastructure such as mine dewatering sumps and pumping installations, mine ventilation fans and controls (doors, regulators) and electrical substations to support extension of operations.

Mining costs for the Vazante Operations are well developed based upon historical values from previous years' production and development. Unit costs should decrease as production is increasing by 20% in 2018 without significant increases in manpower or infrastructure. The associated fixed costs (especially dewatering) will be reduced proportionally. Operating costs in 2026 and 2027 will increase as the mine production rate decreases as the Mineral Reserves are depleted. There will be a corresponding rise in mine unit costs.

Operating costs, in BR$, are included in Table 21-6.

21.2.3 Process Operating Costs

The main process operating costs are consumables including electricity, steel grinding media and flotation reagents. Specific media and flotation reagents consumption is assumed constant, and projected unit prices are assumed. These consumables costs increase with the throughput expansion in 2020.

Electricity costs for milling rise in 2020 with the commissioning of the 2.24 MW Vertimill. The Vertimill required 19 mm diameter steel grinding media, which amounts to approximately US$2 million per year of increased operating costs. The overall milling unit cost increase is partially offset by the increase in mill throughput from 2020.

Ore transport from the Extremo Norte Mine to the mill is included in other variable costs.

Concentrate transport costs are based on unit rates of US$15.90/t zinc concentrate to Tres Marias smelter, and US$164/t to US$174/t of lead concentrate to market.

Mill operating costs also increase in 2020 due to the start-up of tailings classification, filtration, and dry stacking, which ramps to BR$7.8 million per annum (US$2.5 million per year).

Table 21-6: Mine Operating Costs (BR$ x 1,000)

Mine	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Variable - mine											
Fuel	6,110	6,253	7,266	8,240	7,925	8,496	8,315	8,674	8,114	6,821	76,214
Electricity	6,656	6,656	5,569	6,037	5,875	6,172	5,947	6,305	4,918	1,967	56,103
Operational services	2,035	964	632	1,000	968	905	979	940	950	494	9,866
Other variable costs	6,083	6,736	7,630	7,708	7,385	7,718	7,190	6,958	5,244	6,010	68,661
Total mine variable costs	20,884	20,608	21,098	22,985	22,152	23,291	22,430	22,877	19,226	15,292	210,843
Fixed - mine											
Personnel	21,524	21,524	22,024	22,024	22,024	22,024	22,024	22,024	22,024	15,624	212,838
Maintenance	22,842	22,842	24,208	24,208	24,208	24,208	24,208	24,208	24,208	12,104	227,241
Services	355	355	355	355	355	355	355	355	355	177	3,369
Others	6,101	6,101	6,101	6,101	6,101	6,101	6,101	6,101	6,101	3,051	57,960
Total mine fixed costs	50,821	50,821	52,687	52,687	52,687	52,687	52,687	52,687	52,687	30,956	501,408
Total mine costs	***71,704***	***71,429***	***73,785***	***75,673***	***74,839***	***75,978***	***75,118***	***75,564***	***71,913***	***46,248***	***712,251***

Note: Totals may not sum due to rounding.

21.2.4 Infrastructure Operating Costs

Infrastructure and maintenance costs include the electricity for mine water pumping. The other main items are salaries for maintenance personnel, and maintenance service contractors

21.2.5 General and Administrative Operating Costs

General and administrative costs include general management, safety, health, and environment. human resources, information technology, administration, and community engagement. These are considered fixed costs, and do not change from year to year.

The Vazante Operations makes significant use of contractors to support the operations on site. There are currently 46 contractors on site employing 933 personnel. A list of contractors on site is included as Table 21-7.

21.2.6 Owner (Corporate) Operating Costs

Corporate costs do not appear to be included in the cost model.

21.2.7 Operating Cost Summary

The historical operating costs for 2016 are presented in Table 21-8, broken out by fixed and variable components. Historically, costs were divided approximately 48% variable and 52% fixed.

Table 21-9 presents the LOMP operating cost forecast. Forecast costs in Table 21-9 do not include concentrate transport, unlike historical costs. The largest component of variable costs is electricity.

Table 21-10 provides a breakdown of the fixed and variable costs by department for the LOMP. Table 21-11 provides a breakdown of the LOMP operating costs by department and cost centre. Table 21-12 is the unit operating costs for the LOM by department.

The overall operating cost is forecast to be approximately US$50/t over the LOM. The ratio of variable to fixed costs starts at approximately 46:54 in 2018, but as tonnes milled rise in 2020, the ratio allocated to the variable fraction starts to rise to approximately 51:49 by 2021.

Table 21-7: Contractors

Area	Contractor
Employee Benefits and Services	Ana Cristina De Oliveira Me
	Carlos Adolfo Silva E Cia Ltda
	Central Nacional Unimed Cooperative
	Clinica Odontologica Sorriso Ltda
	Conservo Servicos Gerais Ltda
	Consultorio Odonto Marca Ltda
	Consultorio Odontologico Matos
	Expresso Leaozinho Ltda
	Gama Eletrotecnica E Telecomunicaco
	Gr S A
	Plantao Servicos De Vigilancia Ltda
	Target
	Wca Rh Belo Horizonte Ltda
Subtotal Employee Benefits and Services	*13*
Geology	Centro Tecnologico De Referencia Su
	Clean Environment Brasil Engenharia
	Polisat Comercio Manutencao Locac
Subtotal Geology	*3*
Information Technology	Colaboracao Virtual
Subtotal Information Technology	*1*
Maintenance	Egc Projetos Manutencoes E Instalac
	Eletrica Batista Pato Ltda Me
	Empresa Brasileira De Tecnologia E
	J & G Comercio De Pecas E Servicos
	Macrotec Ltda
	Minas Brasilia Mecanica Industrial
	Ouro Verde Locacao E Servico Sa
	Repave Comercio De Pecas E Servicos
	Unimaq Locacoes Ltda Me
Subtotal Maintenance	*9*
Management	Algar Telecom S A
	Ns Locadora Ltda Me
	Telefonica Brasil S A
Subtotal Management	*3*

Area	Contractor
Mining	Orica
	Xylem Brasil Solucoes Para Agua Ltd
Subtotal Mining	*2*
Process Plant	P H Transportes E Construcoes Ltda
Subtotal Process Plant	*1*
Safety/Health/Environment	Arbore Consultoria Ambiental Ltda
	Arbore Servicos Ltda
	Camp Fertilidade Do Solo E Nutricao
	Consermais Conservacao Ambiental
	Daria Carolina Santos Fonseca Cpf
	Geoconsultoria Ltda
	Itms Do Brasil Ltda
	Laboratorio Sao Judas Tadeu Ltda
	Meam Locacao De Equipamentos Ambien
	Medicoes Ambientais Consultoria Ltd
	Ms Clinica Medica Ltda
	Roberto Cesar De Araujo & Cia Ltda
	Sollus Solucoes Ambientais Ltda M
	Thais Maria Merlino Domenes
Subtotal Safety/Health/Environment	*14*
Total Vazante Site	***46***

Table 21-8: Historical Operating Costs for 2016

Cost area	Mine	Mill	Maintenance	General	Total
Variable costs BR$ M					
Primary materials	5.8	17.6	0.0	0.0	23.4
Electricity	3.2	10.4	17.8	0.1	31.5
Diesel	4.0	1.9	0.2	0.0	6.2
Royalties and CFEM	0.0	6.2	0.0	0.0	6.2
Other variable	2.7	11.1	0.0	0.0	13.8
Total variable costs	***15.7***	***47.3***	***18.0***	***0.1***	***81.1***
Fixed costs BR$ M					
Salaries and benefits	15.0	5.8	9.9	6.6	37.3
Social programs	8.8	3.4	5.8	2.9	20.9
Maintenance services	19.2	5.6	6.7	0.6	32.1
Other fixed	7.7	2.1	2.4	8.0	20.2
Total fixed costs	***50.7***	***16.9***	***24.8***	***18.1***	***110.6***
Total costs BR$ M	66.4	64.2	42.8	18.2	191.7
FX BR$:US$	3.61	3.61	3.61	3.61	3.61
Total costs US$ M	***18.4***	***17.8***	***11.9***	***5.0***	***53.1***
Tonnes mined	1,298,550		1,298,550		
Unit costs US$/t	14.16		9.14		
Tonnes milled (inc. float)	1,370,519	1,370,519	1,370,519	1,370,519	1,370,519
Unit costs US$/t	13.42	12.98	8.66	3.68	38.74

Note: tonnes milled includes contributions from barrage materials (tailings reclaim), which were not in the mine plan.

Table 21-9: LOMP Operating Costs (US$ million)

Cost area	Units	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Variable												
Primary materials	BR$ M/a	23.2	24.4	28.6	30.2	30.0	30.1	29.9	29.7	25.2	17.3	268
Electricity	BR$ M/a	50.9	50.7	54.2	60.2	62.2	65.7	67.2	69.1	74.8	63.3	618
Diesel	BR$ M/a	8.2	8.7	10.2	11.6	11.5	11.6	12.0	11.8	9.1	5.5	100
Royalties and CFEM	BR$ M/a	4.5	4.5	4.6	5.3	5.3	4.7	4.0	4.4	3.6	1.6	43
Tailings stacking	BR$ M/a	0.0	3.9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	66
Other variable	BR$ M/a	15.7	15.6	16.2	17.7	17.5	17.4	17.7	17.5	14.8	7.9	158
Total variable costs	***BR$ M/a***	***102.5***	***107.8***	***121.6***	***132.7***	***134.3***	***137.3***	***138.6***	***140.3***	***135.3***	***103.4***	***1,254***
Fixed												
Salaries and benefits	BR$ M/a	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	30.8	427
Social programs	BR$ M/a	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6	15.8	219
Maintenance services	BR$ M/a	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	17.5	332
Other fixed	BR$ M/a	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	11.1	212
Total fixed costs	***BR$ M/a***	***123.9***	***123.9***	***123.9***	***123.9***	***123.9***	***123.9***	***123.9***	***123.9***	***123.9***	***75.3***	***1,190***
Total	BR$ M/a	226.4	231.7	245.5	256.6	258.1	261.2	262.5	264.2	259.2	178.6	2,444
FX	BR$:US$	3.35	3.33	3.36	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.37
Operating costs	US$ M/a	67.6	69.5	73.0	76.0	76.4	77.3	77.7	78.2	76.8	52.9	725
Tonnes milled	kt/a	1,346	1,267	1,356	1,482	1,442	1,515	1,459	1,547	1,600	1,287	14,300
Unit operating cost	US$/t	50.20	54.83	53.81	51.28	53.02	51.06	53.26	50.56	47.97	41.11	50.72

Note: Totals may not sum due to rounding. FX = foreign exchange

Table 21-10:LOMP Forecast Variable and Fixed Costs by Department (BR$ million)

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Variable costs											
Mine	21	21	21	23	22	23	22	23	19	15	211
Process	51	55	71	73	73	73	72	73	70	44	656
Maintenance	30	29	31	33	35	39	40	42	48	29	355
General and Admin	0	0	0	0	0	0	0	0	0	0	0
Total variable costs	*102*	*105*	*123*	*130*	*130*	*135*	*135*	*138*	*137*	*89*	*1,223*
Fixed costs											
Mine	51	51	53	53	53	53	53	53	53	31	501
Process	18	19	20	20	20	20	20	20	20	13	192
Maintenance	29	29	29	29	29	29	29	29	29	19	280
General and Admin	26	26	26	26	26	26	26	26	26	16	248
Total fixed costs	*124*	*125*	*128*	*128*	*128*	*128*	*128*	*128*	*128*	*78*	*1,221*
Total costs											
Mine	72	71	74	76	75	76	75	76	72	46	712
Process	69	75	91	94	93	93	92	93	90	57	849
Maintenance	59	58	60	62	64	68	69	71	77	48	635
General and Admin	26	26	26	26	26	26	26	26	26	16	248
Total operating costs	***226***	***230***	***251***	***257***	***258***	***263***	***262***	***266***	***265***	***167***	***2,444***

Note: Totals may not sum due to rounding.

Table 21-11:LOMP Operating Costs by Department and Cost Centre (US$ million)

	Mine	Process	Maintenance	G & A	Total
Variable costs					
Fuel	23	7			30
Electricity	17	70	105		192
Sodium sulphide		28			28
Operational services	3				3
Dry stack tailings		25			25
Royalties and CMEF		13			13
Other variable costs	20	52	—		73
Total variable costs	***63***	***195***	***105***	***-***	***363***
Fixed costs					
Personnel	63	36	56	42	197
Maintenance	67	13	19	3	102
Services	1	2	1	17	21
Others	17	7	7	11	42
Total fixed costs	***149***	***57***	***83***	***73***	***363***
Total costs	***211***	***252***	***189***	***73***	***725***

Note: Totals may not sum due to rounding.

Table 21-12: LOM Unit Operating Costs by Department

Department	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Tonnes milled	kt	1,346	1,267	1,356	1,482	1,442	1,515	1,459	1,547	1,600	1,287	14,300
Mine unit costs	US$/t	15.90	16.91	16.17	15.12	15.37	14.85	15.24	14.46	13.31	10.64	14.78
Process unit costs	US$/t	15.39	17.66	19.92	18.74	19.19	18.26	18.77	17.88	16.75	13.13	17.62
Maintenance unit costs	US$/t	13.02	13.67	13.19	12.42	13.17	13.23	14.03	13.60	14.20	10.97	13.19
G & A unit costs	US$/t	5.71	6.09	5.64	5.14	5.29	5.03	5.22	4.92	4.76	3.66	5.14
Total unit costs	***US$/t***	***50.02***	***54.33***	***54.93***	***51.44***	***53.02***	***51.37***	***53.26***	***50.87***	***49.02***	***38.40***	***50.72***

Note: Totals may not sum due to rounding

21.3 Comments on Section 21

Votorantim has a capital schedule to support the expansion of the mine and process plant by 2020, and the conversion to dry-stack tailings to support ongoing operations as the Aroeira tailings facility reaches the end of its operational life.

The process capital projects for the Vertimill and tailings filtration and dry-stack have been completed to pre-feasibility level and include some contingency as provision for changes that could occur in feasibility and detailed engineering.

The main increases in operating costs compared with 2016 relate to electricity, due to both increased load for mine water pumping and process plant grinding upgrades, in combination with increased power unit price (R$/kWh).

Mine and plant consumables costs have been calculated based on recent specific usage rates, which are a reasonable basis.

The operating cost forecast assumed fixed costs for salaries, social programs, maintenance, and general services remain unchanged to end of mine life.

22.0 ECONOMIC ANALYSIS

22.1 Cautionary Statement

The results of the economic analyses discussed in this section represent forward-looking information as defined under Canadian securities law. The results depend on inputs that are subject to a number of known and unknown risks, uncertainties and other factors that may cause actual results to differ materially from those presented here. Information that is forward-looking includes:

- Mineral Resource and Mineral Reserve estimates
- Exchange rates
- The proposed mine production plan
- Projected recovery rates
- Sustaining costs and proposed operating costs
- Assumptions as to closure costs and closure requirements
- Assumptions as to environmental, permitting and social risks.

Additional risks to the forward-looking information include:

- Changes to costs of production from what is assumed
- Unrecognized environmental risks
- Unanticipated reclamation expenses
- Unexpected variations in quantity of mineralised material, grade, or recovery rates
- Geotechnical and hydrogeological considerations during mining being different from what was assumed
- Failure of plant, equipment, or processes to operate as anticipated
- Accidents, labour disputes and other risks of the mining industry.

22.2 Methodology Used

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

The Project has been valued using a discounted cash flow (DCF) approach on a 100% basis. Estimates have been prepared for all the individual elements of cash revenue and cash expenditures for ongoing operations. Cash flows are assumed to occur at the end of each period.

22.3 Financial Model Parameters

Votorantim produced a stand-alone financial model for the Vazante Operations that was checked and validated by Amec Foster Wheeler. The model included the mine and mill production plans, and all on-site and off-site costs, smelter and refinery payment terms and costs, and estimated taxes. All costs and prices are in real 2018 Brazilian Real and US dollars.

22.3.1 Mineral Resource, Mineral Reserve, and Mine Life

The financial model covers life of mine production from 2018 to 2027.

Mineral Reserves in the financial model are as summarized in Section 15.

22.3.2 Metallurgical Recoveries

The financial model includes the projected metal recoveries presented in Section 13.

22.3.3 Smelting and Refining Terms

The model assumes the following for concentrate treatment and refining:

- All zinc concentrates are treated at Votorantim's Tres Marias smelter. The assumed conversion cost is approximately US$510 to US$550/t contained zinc in concentrate, at an overall zinc recovery of 94.9%. Transport costs of approximately $19/dmt are included
- Lead concentrates are sold externally and include provision for typical lead treatment charges (US$196 to US$279/dmt concentrate), and transport costs of approximately US$170/dmt. Payment is received for 89% of lead and 23% of zinc contained in lead concentrate
- Silver is paid at 88% in lead concentrate. There is a refining charge of $0.90/payable oz Ag in lead concentrate.

22.3.4 Metal Prices

Metal prices used were provided in Section 19 (refer to Table 19-1). Exchange rate assumptions were included in Table 19-2.

Because the zinc concentrate is internally treated at the Tres Marias smelter, a zinc premium is assigned to the mine. This adds revenue of US$205/t to US$250/t of recovered zinc at the smelter.

22.3.5 Capital Costs

The financial model includes the LOM capital cost schedule, totalling US$195 million (see Section 21.1).

22.3.6 Operating Costs

The financial model includes operating costs outlined in Section 21.2, totalling US$726 million over the LOM.

22.3.7 Working Capital

The financial model includes a schedule of working capital. This includes adjustments for inventories, accounts receivable and accounts payable. There is no net cash generated by working capital changes over the LOM, and working capital has a negligible effect on mine economics.

22.3.8 Taxes and Royalties

Information on taxation applicable to the Project has been provided by Votorantim.

Corporate Income Tax

Brazilian companies are subject to income tax on their Brazilian and non-Brazilian income.

Corporate income tax, or IRPJ (Imposto de Renda da Pessoa Jurídica), is levied on the taxable profits of an entity at a rate of 15.00% (for profits up to approximately $75,000 per year), plus a 10.00% surtax on the excess, which basically provides for a 25.00% tax rate. In addition, the social contribution on profits, or CSLL (Contribuição Social Sobre o Lucro), is levied on taxable profits at a 9.00% rate. Thus, the combined applicable rate for income tax (IRPJ plus CSLL) is 34.00%.

Tax losses incurred in one fiscal year may be carried forward indefinitely but the offset with future profits is capped at 30 percent of the taxable income for each year. The carryback of losses is not allowed.

Vazante does not have any special income tax regime and is thus subject to a 34.00% income tax rate, which was considered in the financial model.

Taxable Income

Operating profits are defined as gross operating receipts, less the cost of goods sold or services rendered; commercial, administrative, and operating expenses; and other charges, reserves and losses authorized by law. Dividends received from other Brazilian companies and income from premiums on the issuance of new shares is not included in taxable income.

Under the Brazilian system, the taxable basis is the income before income taxes (IRPJ and CSLL), adjusted by add-backs (such as non-deductible expenses) and deductions (such as dividend income and equity results from investments).

Depreciation and Amortization

Fixed assets and intangibles are subject to different depreciation and amortization rates according to the useful life of the asset. Accounting and fiscal useful lives may also differ as shown in Table 22-1, and the fiscal useful life is the one used for income tax purposes. For the model, Votorantim calculated an average fiscal depreciation and amortization rate of 6.40%, considering the balances of each category of assets.

Net Operating Losses

Votorantim has not considered any operating or non-operating tax losses in the financial models.

Federal Taxes (PIS and COFINS)

Gross income is subject to the social integration program (programa de integração social or PIS) and the social security financing contribution (contribuição para financiamento de seguridade social or COFINS) at 1.65% and 7.60% rates respectively, thus for a combined 9.25% rate. These are a non-cumulative (value-added tax type) tax and PIS and COFINS credits may be available. Exports are exempt of PIS and COFINS. The financial model considers the revenue net of such taxes.

State Value-Added Tax (ICMS)

ICMS (Imposto sobre Circulação de Mercadorias e Serviços) is a state value-added tax imposed on the supply of goods and services with varying rates according to the state. The ICMS of Minas Gerais state, where Vazante is located, is 18.00%. Supply of goods within Minas Gerais state is subject to 18.00% while sales to other states may be subject to 7.00% (North, Northeast, and Central regions and Espírito Santo state) or 12.00% (South and Southeast regions). Exports are exempt of ICMS. The financial model considers the revenue net of ICMS.

Mining Charges (CFEM)

Brazilian companies that hold mining concessions are subject to a royalty payment known as Financial Compensation for the Exploitation of Mineral Resources (Compensação Financeira pela Exploração de Recursos Minerais or CFEM), imposed by the Brazilian National Department of Mineral Production (Departamento Nacional de Produção Mineral or DNPM).

Table 22-1: Depreciation and Amortization (rate per year)

Asset	Accounting (%)	Tax (%)
Land	0	0
Buildings and other constructions	2	4
Machinery and equipment	5	9
Vehicles	24	24
Furniture and fixtures	10	10
Mines	6	6

Revenues from mining activities are subject to CFEM, based on the sales value of minerals, net of taxes and transportation and insurance expenses. When the produced minerals are used in its internal industrial processes, the amount of CFEM is determined based on deducting the costs incurred to produce them. The rate to be applied varies according to the mineral product (currently 2% for zinc, lead, copper, and silver).

The financial model considers the revenue net of CFEM.

22.3.9 Closure Costs and Salvage Value

The financial model includes closure costs of US$49 M, allocated in 2028. Zero salvage value is assumed.

22.3.10 Financing

There are no financing costs in the financial model.

22.3.11 Inflation

There is no allowance for inflation in the financial model.

22.4 Economic Analysis

The gross LOM revenue for Vazante Operations is US$3,272 million, the main contributor being zinc with a gross revenue of US$3,213 million. The net LOM revenue is US$2,515 million. Zinc concentrate makes up over 98% of the net revenue for the Vazante Operations, as shown in Table 22-2. Table 22-3 is a LOMP for the mill production, which results in 1.28 Mt of recovered zinc of concentrate delivered to the smelter. Table 22-4 provides the LOM cashflow projections.

Table 22-2: Life-of-Mine Revenue by Metal and Product (US$ million)

Metal	Zinc Concentrate	Lead–silver Concentrate	Total
Zinc	3,210	3	3,213
Lead	0	15	15
Silver	0	43	43
Gross revenue	3,210	61	3,272
Transport	(64)	(5)	(69)
Conversion/treatment/refining	(678)	(9)	(687)
Net revenue	***2,468***	***47***	***2,515***

Table 22-3: Mill Production Plan

Period	Units	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Ore milled	kt/a	1,346	1,267	1,356	1,482	1,442	1,515	1,459	1,547	1,600	1,287	14,300
Days per year	d/a	365	365	366	365	365	365	366	365	365	365	3,652
Tonnes per day	t/d	3,688	3,471	3,705	4,059	3,950	4,150	3,987	4,239	4,384	3,525	3,916
Zinc	% Zn	11.22	11.86	11.13	10.15	10.41	9.90	10.29	9.71	9.39	10.96	10.45
Lead	% Pb	0.28	0.30	0.31	0.28	0.26	0.31	0.31	0.29	0.29	0.25	0.29
Ag	Ag - g/t	16.7	18.5	17.2	10.8	12.1	13.5	19.1	18.6	16.7	13.3	15.7
Zinc Concentrate Production												
Zinc recovery	%	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8
Contained zinc in concentrate	Zn kt/a	130	129	130	129	129	129	129	129	129	121	1,282
Zinc concentrate grade	% Zn	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7
Zinc concentrate	kt/a	335	333	335	333	333	332	333	333	333	313	3,311
Lead-Silver Concentrate Production												
Lead recovery (overall)	%	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6
Contained lead in concentrate	Pb kt/a	0.8	0.8	0.9	0.9	0.8	1.0	0.9	0.9	1.0	0.7	8.5
Lead grade	% Pb	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Lead concentrate	kt/a	2.8	2.8	3.1	3.0	2.8	3.5	3.3	3.3	3.4	2.3	30.3
Silver recovery (overall)	%	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3
Silver grade	g/t Ag	2,965	3,070	2,713	1,917	2,279	2,117	3,062	3,191	2,840	2,664	2,680
Zinc grade	% Zn	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Tailings production	kt/a	1,009	931	1,018	1,145	1,106	1,179	1,123	1,211	1,264	972	10,959

Note: Totals may not sum due to rounding

Table 22-4: Cashflow Analysis (US$ million)

Period	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Gross payable metal	368	345	331	319	320	321	322	322	323	302	0	**3,272**
Offsite costs	(79)	(74)	(74)	(73)	(73)	(73)	(75)	(75)	(78)	(82)	0	**(756)**
Net revenue	289	271	257	246	246	247	247	247	245	220	0	**2,515**
Operating costs	(67)	(69)	(74)	(76)	(76)	(78)	(78)	(79)	(79)	(50)	0	**(726)**
Other costs/provisions	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	0	**(39)**
EBITDA	217	199	179	165	166	166	165	165	162	166	0	**1,750**
Depreciation	(17)	(20)	(23)	(23)	(24)	(24)	(25)	(25)	(25)	(25)	0	**(231)**
EBIT	201	178	156	142	142	141	140	140	137	141	0	**1,518**
Income tax	(68)	(61)	(53)	(48)	(48)	(48)	(48)	(48)	(47)	(48)	0	**(516)**
Net income	132	118	103	94	94	93	93	92	90	93	0	**1,002**
Depreciation	17	20	23	23	24	24	25	25	25	25	0	**231**
Provisions	3	3	3	3	3	3	3	3	3	3	0	**32**
Working capital	3	0	0	0	0	0	(0)	0	0	(1)	(2)	**0**
Closure	0	0	0	0	0	0	0	0	0	0	(49)	**(49)**
Capex	(81)	(41)	(25)	(12)	(9)	(8)	(8)	(6)	(4)	(2)	0	**(195)**
Free cashflow	74	101	104	108	112	113	113	115	115	118	(51)	**1,021**
Discounted @ 9%	71	88	84	80	76	70	64	60	55	52	(20)	
NPV @ 9%	**681**											

Note: Totals may not sum due to rounding. EBITDA = earnings before interest, taxes, depreciation, and amortization; EBIT = earnings before interest, taxes

Vazante Operations generate NPV at 9% of US$680 million over LOM. Substantial free cash flow is generated in every year of mine life. Given that the mine is generating an immediate positive cash flow, payback period and IRR calculations are not relevant. Over the LOM, Vazante Operations is assumed to pay US$13 million of CFEM, and US$516 million of income tax.

22.5 Sensitivity Analysis

The sensitivity of NPV was determined against the following parameters:

- Metal prices (all metals)
- Head grade (all metals)
- Site operating costs
- Zinc conversion costs
- Capital costs.

Table 22-5 shows the summary of NPV for -20% to +20% variations in the above parameters. These are also shown in Figure 22-1.

NPV is most sensitive to changes in metal prices, then head grade. NPV is relatively insensitive to capital costs, as remaining capital requirements are comparatively low.

If the Tres Marias smelter was unable to transfer the zinc metal premium to the mine, and assuming all other parameters remained unchanged, NPV would drop to US$557 million, similar to the effect of a 10% reduction in metal prices.

22.6 Comments on Section 22

The Vazante Operations show an NPV of US$681 million based on the LOMP. Net revenue is almost entirely generated by zinc concentrate. NPV is sensitive to head grade and metal prices, and the ability of the Tres Marias smelter to transfer zinc metal premium to the mine revenue.

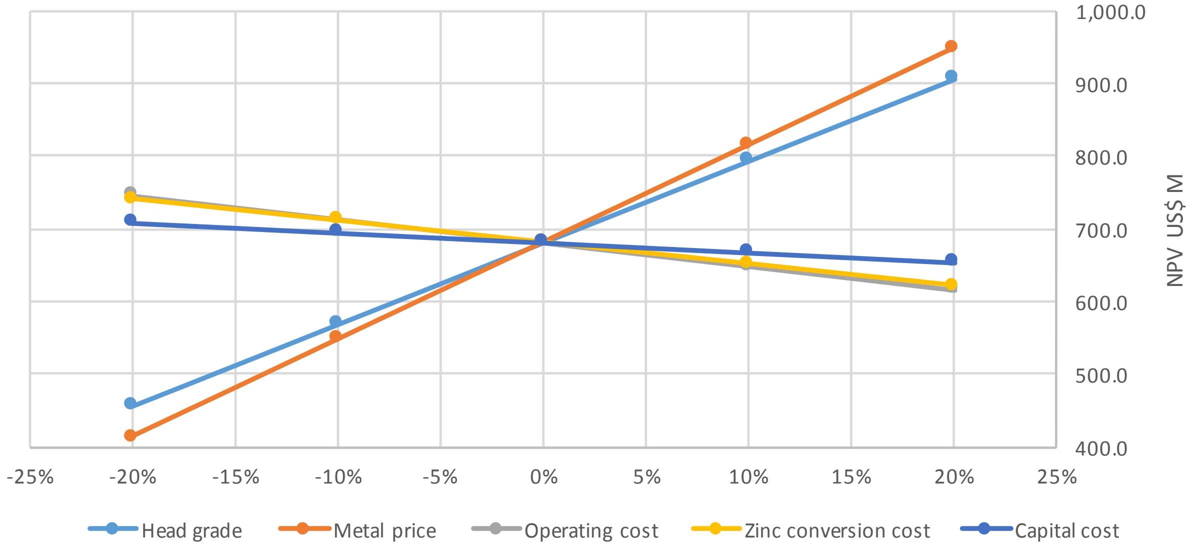
Under the assumptions in this Report, the Vazante Operations show a positive cash flow over the life-of-mine and support Mineral Reserves. The mine plan is achievable under the set of assumptions and parameters presented.

It is possible that Votorantim has been conservative in its forecast of plant electricity loads, and that overall site electricity use and hence costs will come in at lower levels than included in the LOMP. This could result in a modest increase in profitability.

Table 22-5: NPV Sensitivity (US$)

Range	Head Grade (all metals)	Metal Price (all metals)	Operating Cost	Zinc Conversion Cost	Capital Cost
-20%	455	413	745	741	708
-10%	568	547	713	711	694
0%	681	681	681	681	681
10%	794	815	649	651	667
20%	906	948	616	621	654

Figure 22-1: Sensitivity Analysis



Note: Figure prepared by Amec Foster Wheeler, 2017.

23.0 ADJACENT PROPERTIES

This section is not relevant to this Report.

24.0 OTHER RELEVANT DATA AND INFORMATION

24.1 Risks and Opportunities

24.1.1 Geology and Exploration

Opportunities

- Continued exploration activities in the mine area, such as infilling areas where no data are currently available, and using mining knowledge and structural interpretations to identify areas where mineralization may be present, has the potential discover additional mineralization that may support Mineral Resource estimation
- There are a number of regional exploration targets, that with further work, represent upside opportunity to potentially add to the resource base.

24.1.2 Geotechnical Considerations

Opportunities

- A reconciliation process to incorporate production tonnages from haulage data and post mining cavity monitor surveys has not been established that links the block model through to the stope; this should be undertaken to improve the understanding of mechanisms and sources of unplanned dilution in the dilution control plan
- To reduce dilution, it is suggested that development in the hanging wall ore drives should incorporate the hanging wall contact and a partial shanty design. This allows for fan patterns of cable bolting into the hanging wall to provide additional stope support thereby reducing unplanned overbreak.

Risks

- The mining method combines vertical retreat and long hole stoping method (with up and down holes). Some stopes have incurred significant unplanned dilution and this is a major economic factor for the mine. It is understood that the mine is establishing a dilution control plan to manage this aspect.

24.1.3 Hydrogeological Considerations

Risks

- Interception during mining of major structural and/or karstic features may cause sudden increases in mine water inflows, and potentially, mine flooding

- Flooding from the Santa Caterina River may temporarily result in increased water flows to the mine, increased pumping requirements, and potentially, mine flooding
- Estimations of pumping rates for mine planning purposes rely on calibration of the FEFLOW groundwater model to historical data. Given climate change, there is presently more uncertainty associated with relying on historic records to predict frequency and magnitude of severe rainfall events and associated peak mine water pumping. Amec Foster Wheeler considers that the risk of mine flooding during an extreme rainfall event, including any associated flooding of the Santa Catarina River, likely represents the greatest risk to mine operations from a water management perspective
- There is a well-documented history of doline/sinkhole development with water table drawdown as the mine has developed. Unexpected doline development has the potential to impact surface infrastructure
- The FEFLOW groundwater model may under-predict future mine water inflows, particularly during peak climatic events when inflows are likely to be much higher than the average mine water inflows presently predicted. Therefore, current and planned pumping assumptions may not match eventual requirements
- No studies have been undertaken to assess issues with groundwater rebound on cessation of pumping and mine closure. Due to changes in the groundwater heads and aquifers as a result of mining, there is potential for localized flooding to occur in the Santa Caterina River valley post-cessation of mining.

24.1.4 Mineral Reserve Estimates and Mine Plan

Opportunities

- The mobile equipment fleet outlined in this Report is the actual equipment meeting production targets at the Vazante Operations. An opportunity exists to reduce the fleet through better utilization of existing equipment. Votorantim is currently undertaking a study to address the equipment usage
- If dilution can be better controlled in some of the underground stopes, there is an opportunity maximize mill recoveries from higher-grade material.

Risks

- Extraction of the Mineral Reserves below the EB326 horizon is dependent upon successful development and commissioning of the EB140 pump station. Should the water inflows exceed the design pumping capacity of the pump station, these Mineral Reserves would be at risk.

24.1.5 Metallurgy, Process Plant, and Marketing

Opportunities

- Zinc recovery is sensitive to grind size, and there is significant potential to improve zinc recovery by reducing grind size to approximately p80 of 100 µm. This should be achieved with the installation of the Vertimill in 2019
- Following the planned capacity increases, there is an opportunity after about 2025 for the plant to be able to treat more mill feed material, should additional Mineral Resources that can support conversion to Mineral Reserves be identified
- Votorantim has tested ore-sorting technologies. If successful, ore-sorting could allow mining of material that is below the current cut-off grade, which could subsequently be upgraded to feed the process plant. The benefits could include lower combined mining and process costs, and additional mill feed material and resulting metal production.

Risks

- Lead recovery falls at low head grades, and in general the lead recovery from Extremo Norte ores is poor. This may limit the ability to consistently produce a lead–silver concentrate
- The Plant C ball mill shell has recently experienced excessive wear, which could lead to a prolonged outage and loss of approximately 20% of the total processing capacity. Votorantim has taken steps to complete repairs
- In the event that Tres Marias was unable to process concentrates from the Vazante Operations, mine economics would be affected due to the significantly higher transport and treatment charges that would apply to an alternative customer. In addition, due to the low zinc and high silica grades of the zinc concentrate, the terms for selling onto world custom concentrate markets would be much less favourable than for typical zinc sulphide concentrates
- If Tres Marias is unable to keep the current balance of different feed supplies to control chemistry and costs, then there is a risk that the zinc premium currently paid could be reduced, thereby reducing profitability of the operation.

24.1.6 Tailings

Opportunities

- The planned shift of the tailings storage methodology to dry stack may be able to reduce risks in the existing wet storage facility, by reducing the amount of stored water, and proceeding to earlier closure and rehabilitation. There are also opportunities with the dry stack facility to better control the overall water balance.

24.1.7 Infrastructure

Opportunities

- The current upgrading of the site electrical power, and associated infrastructure redundancies present a future opportunity for mill feed expansion should additional Mineral Resources that can support conversion to Mineral Reserves be identified through exploration success.

Risks

- Decreases in rainfall may cause lower reservoir and river levels, potentially impacting the ability of the hydroelectric stations to provide sufficient power to meet operational needs.

24.1.8 Environmental, Permitting and Social

Risks

- There is a risk that the final closure costs are underestimated because elements that will require closure and rehabilitation do not appear to be fully addressed in the four plans prepared to date
- Sending general waste to an unlicenced facility carries a potential liability risk if pollution and seepage occur from the waste facility
- Authorization from the competent environmental authorities is required prior to work being conducted that may affect Permanent Preservation Areas (APPs). There is a risk that future approvals to impact APPs may not be granted for mineral concessions where the approval process has not been completed, and this may affect planned work programs such as exploration and drilling activities.

24.1.9 Financial Analysis

Opportunity

- It is possible that Votorantim has been conservative in its forecast of plant electricity loads, and that overall site electricity use and hence costs will come in at lower levels than included in the LOMP. This could result in a modest increase in profitability

Risks

- There is a risk that the contingency allocation may be underestimated for the major capital projects, in particular the Vertimill and the dry stack tailings facility
- Creation of new taxes, fees, and/or royalties or significant changes to the assumptions as to these in the Report will affect the cashflow estimates
- Hedging is not considered in the financial evaluation, which is performed at the mine level. Votorantim has corporate hedging arrangements in place. Should a future decision be made to implement hedging at the mine level, the cashflow estimates could be affected.

25.0 INTERPRETATION AND CONCLUSIONS

25.1 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.

25.2 Mineral Tenure, Surface Rights, Water Rights, Royalties, and Agreements

Amec Foster Wheeler was provided with legal opinion that supports that Project ownership is in the name of Votorantim Metais Zinco S.A.

25.3 Geology and Mineralization

The Vazante and Extremo Norte deposits are classified as examples of epigenetic zinc silicate deposit types.

The geological setting, mineralization style, and structural and stratigraphic controls are sufficiently well understood to provide useful guides to exploration, Mineral Resource estimation, and mine planning.

25.4 Exploration, Drilling and Analytical Data Collection in Support of Mineral Resource Estimation

Exploration completed to date has resulted in delineation of a number of mineral deposits and exploration targets.

Drilling equipment and procedures are consistent with industry standards and are adequate to support Mineral Resource estimation and mine planning.

The quantity and quality of the lithological, recovery, collar and downhole survey data collected are consistent with industry standards and are adequate to support Mineral Resource estimation and mine planning.

In some cases, drill intercepts, and thus sample lengths, are perpendicular to the mineralized bodies and the sample length will be equal to the true thickness. In most cases, however, the true thickness is less than the sample thickness because the drill holes intersect the mineralized bodies at oblique angles.

Sampling methods for core and channel samples are consistent with industry practices and adequate to support Mineral Resource estimation and mine planning.

Sample preparation procedures at the mine laboratory and at ALS Global are consistent with typical industry practices at the time the samples were prepared, and are adequate to support Mineral Resource estimation. Sample analysis at the mine laboratory and ALS Global was performed using standard procedures that are widely used in the industry at the time the analyses were performed. In both cases, analytical procedures are adequate to support Mineral Resource estimation and mine planning.

Amec Foster Wheeler considers the QA/QC data collected between 2009 and 2016 to be adequately accurate and precise to support Mineral Resource estimation and mine planning.

The density data determination methods employed at the Project are widely used in the mineral industry, and the procedures are adequate to support Mineral Resource estimation and mine planning.

Sample security procedures met industry standards at the time the samples were collected. Current sample storage procedures and storage areas are consistent with industry standards.

Data collected were subject to validation. Verification is performed on all digitally collected data uploaded to the database, and includes checks on surveys, collar coordinates, lithology data, and assay data. The checks are appropriate, and consistent with industry standards.

Three audits have been performed by independent third-parties, in 2010, 2012, and 2014. Votorantim advised that recommendations from these external audits were taken into consideration and applied to improve the resource estimation process. Amec Foster Wheeler performed a gap analysis in support of this Report. As part of his 2017 site visit, the QP performed high-level reviews of the database and procedures were performed. These included reviews of sampling procedures, geological logging procedures, core drilling and core handling procedures, and QA/QC procedures.

Amec Foster Wheeler has reviewed the appropriate data and reports and is of the opinion that the data verification programs undertaken on the data collected in previous campaigns adequately support the geological interpretations, and the analytical and database quality. The QP considers the analytical data to be sufficiently accurate and precise to support Mineral Resource estimation and mine planning and the project database to be sufficiently error free to support Mineral Resource estimation and mine planning.

25.5 Metallurgical Testwork

Metallurgical studies have been completed since plant operations began in 1969. Studies incorporated mineralogy, grinding characteristics and flotation separation testing. The test programs have followed geometallurgy principles.

Mineralogy has a significant influence on the concentrate grades and metal recoveries that can be achieved. Votorantim has developed a zinc recovery regression using head grades and mineral abundance. The presence of certain non-willemite zinc minerals such as franklinite can result in higher losses. Zinc recovery is sensitive to grind size, and there is significant potential to improve zinc recovery by reducing grind size to approximately p80 of 100 to 125 µm. Lead recovery falls at low head grades, and in general the lead recovery from Extremo Norte ores is poor. This may limit the ability to consistently produce a lead–silver concentrate.

Grinding, flotation, and mineralogy test programs have been established, and include variability sampling of planned stopes in the production schedule. These help predict zinc recovery based on hardness, head grade, and mineralogy.

The presence of willemite in Vazante Operations ore results in zinc concentrates that are unusually high in silica for feed to an electrolytic zinc smelter. However, the Tres Marias smelter has been configured to manage this. Deleterious elements that need particular management in the concentrate are MgO and fluorine.

25.6 Mineral Resource Estimates

Mineral Resource estimation was performed by Votorantim staff, and based on four geological or grade models. Grade estimates were completed for zinc, lead, iron, and silver grades.

Mineral Resources have an effective date of 31 December, 2016 and are stated exclusive of Mineral Reserves on an in-situ basis. Mineral Resources have had reasonable prospects of eventual economic extraction considerations applied.

Factors that may affect the estimate include: additional infill and step out drilling; changes in local interpretations of mineralization geometry and continuity of mineralization zones; density and domain assignments; changes to design parameter assumptions that pertain to stope design; dilution from internal and contact sources; changes to geotechnical, hydrogeological, and metallurgical recovery assumptions; and changes to the assumptions used to generate the NSR value including long-term commodity prices and exchange rates.

25.7 Mineral Reserve Estimates

The mine plan is based on Measured and Indicated Mineral Resources. The Mineral Reserves have been established based on actual costs and modifying factors from the Vazante Operations, and on operational level mine planning and budgeting. Mineral Reserves are reported inclusive of recovery losses and dilution.

The current Mineral Reserve estimates are based on the most current knowledge, permit status and engineering and operational constraints. Mineral Reserves have been estimated using standard practices for the industry, and conform to the 2014 CIM Definition Standards.

Factors that may affect the ability of the Vazante Operations to extract the Mineral Reserves safely and economically include: commodity prices and exchange rate assumptions, global markets, internal operating costs, government actions including changes to environmental, permitting, taxation and royalty regulations and laws, social licence to operate, geological unknowns, availability of skilled labor, and variations in metallurgical performance. Votorantim may also have site-specific issues due to the underground operations. including deterioration of ground conditions due to geological or hydrogeological changes, mining-induced seismic events limiting access to mining areas, and higher than predicted ground water or surface water inflow events.

25.8 Mine Plan

The Vazante Operations are fully mechanized using rubber-tired diesel equipment for development and production activities. Access is through two portals for Vazante and one portal for Extremo Norte. As development progresses at Extremo Norte a connecting drift will be established from Vazante to Extremo Norte.

Current mining uses SLOS or VRM methods with backfill in the VRM stopes. The mining methods being used are appropriate for the deposits being mined. Life of mine planning is based upon a phased expansion of mine throughput between 2020 and 2024 which will see a 13% percent increase in the annual production rate from 1.38 Mt/a to 1.60 Mt/a (averaging about 1.5 Mt/a).

The general assumption is the mine will operate at an average of 4,098 t/d for 365 days per year.

The ventilation circuit is push–pull, and conventional for the industry. The Vazante Mine ventilation infrastructure will be expanded starting in 2018 to support additional mining faces. Ventilation infrastructure for Extremo Norte Mine will begin expansion in 2020 to support additional mining faces.

The mobile equipment fleet is acceptable for the mine plan proposed. The mining fleets are not restricted to the currently-assigned mines and can be moved between sites as operational requirements dictate.

25.9 Recovery Plan

Processing is conducted in two adjacent plants (C and W) based on crushing, grinding and flotation with some interconnected concentrate handling systems. The main differences between the flowsheets for the plants is that Plant W incorporates a sulphide flotation stage for recovery of a lead–silver concentrate. Both plant flowsheets include crushing, grinding and willemite flotation. Willemite concentrate is filtered for transport to the smelter, and combined Plant W and Plant C tailings are thickened prior to disposal in the TSF.

To support incremental mine production increases, it is planned to install a Vertimill, which is due to be commissioned in late 2019. After the increase to 153 t/h, grind size will also be reduced; however, it is possible that there will be some bottlenecks and inefficiencies in the Plant W zinc flotation circuit due to increased volumetric flow. If the scoping and subsequent studies of zinc flotation capacity improvements are successful, Vazante may be able to improve zinc recovery in the future.

25.10 Infrastructure

All infrastructure required for the current mining and processing operations has been constructed and is operational. This includes the underground mines, access roads, powerlines, water pipelines, offices and warehouses, process plant/concentrator, conveyor systems, waste rock facilities, temporary ore stockpiles, paste-fill plants, and tailings storage facilities.

The incremental mill expansion planned will require installation of a Vertimill and a new pack of hydrocyclones in the process plant.

25.11 Environmental, Permitting and Social Considerations

25.11.1 Environmental Considerations

Compilation of the results from monitoring programs, research studies, and public data was completed in 2017 for climate, air quality, noise, hydrology, groundwater, water quality, seismicity, biology, and social setting.

Environmental licensure requires a number of on-going monitoring programs. Votorantim provided documentation that supported that the required 2016 monitoring and reporting was completed, and the reports sent to the relevant regulatory authorities.

25.11.2 Tailings Storage Facility

The Aroeira TSF is used for tailings storage and as a water supply dam for the process plant. The last raise on the dam embankment was completed in 2014, and the dam will cease being used for tailings storage at or about the end of 2020/start of 2021. The Aroeira TSF dam will remain as the main water storage dam to meet process water requirements. A dry stack facility, Pilha Garrote, will be constructed from July 2018, and will be operational in about late 2020 or early 2021. The facility will operate until 2026, when Mineral Reserves will be depleted. Votorantim has indicated that the mined-out 3A pit at Extremo Norte may also be available for tailings backfill storage, if needed. Permits for this usage would have to be obtained.

Instrumentation in the Aroeira TSF is monitored regularly by Votorantim staff and external consultants. A monitoring plan has been developed for Pilha Garrote.

25.11.3 Water Management

Water is primarily derived from four areas: surface water, groundwater, recirculated water, and rainfall. The main water source (by annual volume for 2016) for industrial purposes is the underground mine.

Hydraulic infrastructure such as diversion channels have been implemented to ensure hydrological stability for the mine facilities, and to divert water around the operations to natural watercourses.

25.11.4 Closure and Reclamation Planning

Four conceptual Closure Plans are approved for the Vazante Operations: Vazante Mine decommissioning plan (2008, updated in 2013), waste rock facility and decommissioning plan (2011), Extremo Norte Mine decommissioning plan (2012), and the former process plant decommissioning plan (2013).

Associated closure costs are reported in the dollar values at the time the estimate was completed.

25.11.5 Permitting Considerations

The mine holds a number of current permits in support of the current operations. Compliance with permitting is monitored via semi-annual evaluations carried out by consulting companies, and annual audits.

25.11.6 Social Considerations

Votorantim developed a Socioeconomic Characterization Plan in 2015–2016 that outlines the social commitments and responsibilities that Votorantim will undertake toward the municipality of Vazante.

25.12 Markets and Contracts

Vazante and Extremo Norte are operating mines with concentrate sales contracts in place. As a result, market studies are not relevant to the operation.

Zinc concentrates are sold to the Tres Marias smelter, operated by Votorantim. Due to the low zinc and high silica grades of the zinc concentrate, the terms for selling onto world custom concentrate markets would be much less favourable than for typical zinc sulphide concentrates. This highlights the importance of Tres Marias as the customer of Vazante Operations concentrate.

Lead-–silver concentrates are sold to the Mitsui Hachinohe smelter in Japan, which has a contract in place with Votorantim. Over the last 15 years, there has been significant closures of smelters using ISF technologies, which would limit alternative marketing of the lead concentrate should the Hachinohe smelter close.

Contracts to 46 firms have been let for provision of goods and services for the Vazante Operations.

25.13 Capital Cost Estimates

Capital costs are allocated in the LOM for major projects from 2017–2022. From 2023 to 2027, all costs are sustaining capital. LOM capital costs are US$195 million.

25.14 Operating Cost Estimates

The overall operating cost is forecast to be approximately US$50/t over the LOM. The ratio of variable to fixed costs starts at approximately 46:54 in 2018, but as tonnes milled rise in 2020, the ratio allocated to the variable fraction starts to rise to approximately 51:49 by 2021.

25.15 Economic Analysis

Under the assumptions in this Report, the Vazante Operations show a positive cash flow over the life-of-mine and support Mineral Reserves. The mine plan is achievable under the set of assumptions and parameters presented.

Net revenue is almost entirely generated by zinc concentrate. NPV is sensitive to head grade and metal prices, and the ability of the Tres Marias smelter to transfer zinc metal premium to the mine revenue.

25.16 Risks and Opportunities

A number of risks and opportunities were identified by Amec Foster Wheeler staff, and have been discussed in the Report in the relevant discipline areas or in Section 24.

Opportunities include:

- Continued exploration activities in the mine area, such as infilling areas where no data are currently available, and using mining knowledge and structural interpretations to identify areas where mineralization may be present, has the potential discover additional mineralization that may support Mineral Resource estimation.
- There are a number of regional exploration targets, that with further work, represent upside opportunity to potentially add to the resource base
- Zinc recovery is sensitive to grind size, and there is significant potential to improve zinc recovery by reducing grind size to approximately p80 of 100 µm. This should be achieved with the installation of the Vertimill in 2019

- Following the planned capacity increases, there is an opportunity after about 2025 for the plant to be able to treat more mill feed material, should additional Mineral Resources that can support conversion to Mineral Reserves be identified
- Votorantim has tested ore-sorting technologies. If successful, ore-sorting could allow mining of material that is below the current cut-off grade, which could subsequently be upgraded to feed the process plant. The benefits could include lower combined mining and process costs, and additional mill feed material and resulting metal production
- The mobile equipment fleet outlined in this Report is the actual equipment meeting production targets at the Vazante Operations. An opportunity exists to reduce the fleet through better utilization of existing equipment. Votorantim is currently undertaking a study to address the equipment usage
- A reconciliation process to incorporate production tonnages from haulage data and post mining cavity monitor surveys has not been established that links the block model through to the stope; this should be undertaken to improve the understanding of mechanisms and sources of unplanned dilution in the dilution control plan
- To reduce dilution, it is suggested that development in the hanging wall ore drives should incorporate the hanging wall contact and a partial shanty design. This allows for fan patterns of cable bolting into the hanging wall to provide additional stope support thereby reducing unplanned overbreak
- If dilution can be better controlled in some of the underground stopes, there is an opportunity maximize mill recoveries from higher-grade material
- The planned shift of the tailings storage methodology to dry stack may be able to reduce risks in the existing wet storage facility, by reducing the amount of stored water, and proceeding to earlier closure and rehabilitation. There are also opportunities with the dry stack facility to better control the overall water balance
- The current upgrading of the site electrical power, and associated infrastructure redundancies present a future opportunity for mill feed expansion should additional Mineral Resources that can support conversion to Mineral Reserves be identified through exploration success
- It is possible that Votorantim has been conservative in its forecast of plant electricity loads, and that overall site electricity use and hence costs will come in at lower levels than included in the LOMP. This could result in a modest increase in profitability.

Risks include:

- The mining method combines vertical retreat and long hole stoping method (with up and down holes). Some stopes have incurred significant unplanned dilution and this is a major economic factor for the mine. It is understood that the mine is establishing a dilution control plan to manage this aspect
- Interception during mining of major structural and/or karstic features may cause sudden increases in mine water inflows, and potentially, mine flooding
- Flooding from the Santa Caterina River may temporarily result in increased water flows to the mine, increased pumping requirements, and potentially, mine flooding
- Estimations of pumping rates for mine planning purposes rely on calibration of the FEFLOW groundwater model to historical data. Given climate change, there is presently more uncertainty associated with relying on historic records to predict frequency and magnitude of severe rainfall events and associated peak mine water pumping. Amec Foster Wheeler considers that the risk of mine flooding during an extreme rainfall event, including any associated flooding of the Santa Catarina River, likely represents the greatest risk to mine operations from a water management perspective
- There is a well-documented history of doline/sinkhole development with water table drawdown as the mine has developed. Unexpected doline development has the potential to impact surface infrastructure
- The FEFLOW groundwater model may under-predict future mine water inflows, particularly during peak climatic events when inflows are likely to be much higher than the average mine water inflows presently predicted. Therefore, current and planned pumping assumptions may not match eventual requirements
- No studies have been undertaken to assess issues with groundwater rebound on cessation of pumping and mine closure. Due to changes in the groundwater heads and aquifers as a result of mining, there is potential for localized flooding to occur in the Santa Caterina River valley post-cessation of mining
- Extraction of the Mineral Reserves below the EB326 horizon is dependent upon successful development and commissioning of the EB140 pump station. Should the water inflows exceed the design pumping capacity of the pump station, these Mineral Reserves would be at risk
- Lead recovery falls at low head grades, and in general the lead recovery from Extremo Norte ores is poor. This may limit the ability to consistently produce a lead–silver concentrate

- The Plant C ball mill shell has recently experienced excessive wear, which could lead to a prolonged outage and loss of approximately 20% of the total processing capacity. Vazante Operations has taken steps to complete repairs
- In the event that Tres Marias was unable to process concentrates from the Vazante Operations, mine economics would be affected due to the significantly higher transport and treatment charges that would apply to an alternative customer. In addition, due to the low zinc and high silica grades of the zinc concentrate, the terms for selling onto world custom concentrate markets would be much less favourable than for typical zinc sulphide concentrates
- If Tres Marias is unable to keep the current balance of different feed supplies to control chemistry and costs, then there is a risk that the zinc premium currently paid could be reduced, thereby reducing profitability of the operation
- Decreases in rainfall may cause reservoir and river levels to decrease, impacting the ability of the hydroelectric stations to provide sufficient power to meet the mine's needs
- There is a risk that the final closure costs are underestimated because elements that will require closure and rehabilitation do not appear to be fully addressed in the four plans prepared to date
- Sending general waste to an unlicenced facility carries a potential liability risk if pollution and seepage occur from the waste facility
- Authorization from the competent environmental authorities is required prior to work being conducted that may affect APPs. There is a risk that future approvals to impact APPs may not be granted for mineral concessions where the approval process has not been completed, and this may affect planned work programs such as exploration and drilling activities
- The contingency allocation may be underestimated for the major capital projects, in particular the Vertimill and the dry stack tailings facility
- Creation of any new taxes, fees, and/or royalties or significant changes to the assumptions as to these in the Report will affect the cashflow estimates
- Hedging is not considered in the financial evaluation, which is performed at the mine level. Votorantim has corporate hedging arrangements in place. Should a future decision be made to implement hedging at the mine level, the cashflow estimates could be affected.

26.0 RECOMMENDATIONS

26.1 Introduction

Recommendations have been broken into two phases. The Phase 1 recommendations are made in relation to exploration activities. Recommendations proposed in Phase 2 are suggestions for improvements in current operating procedures, and the program is not contingent on the results of Phase 1 work. The total cost for the Phase 1 work is about US$25 million. Phase 2 is estimated at US$2.8 million to US$3 million.

26.2 Phase 1

Votorantim has prepared provisional exploration programs and budgets for near-mine and regional exploration (Table 26-1). The target of the programs is identifying mineralization that can support Mineral Resource estimation, and potential conversion to Mineral Reserves.

Amec Foster Wheeler notes that exploration expenditures of this type depend on the results of previous efforts and that the budget for regional exploration may change significantly if new mineralization is discovered.

26.2.1 Mine Area

Continuing brownfields exploration in the vicinity of the Vazante and Extremo Norte Mines will improve confidence in the existing Mineral Resources and likely add to that resource by identifying mineralization that is currently unknown or poorly defined.

Additional exploration at depth in the mines below known mineralization has the potential to extend sulphide mineralization at depth. Lateral exploration may identify further oxide and sulphide material (refer to areas 2 and 3 in Figure 9-15). There is some potential to add to mineralization by drilling along the strike of known deposits (refer to area 1 in Figure 9-15).

The mine area program will involve about 63,000 m of core drilling, at an average cost of about US$141/m. Some underground drilling will be required to support drill programs. Additional geological mapping, geophysical surveys, and geochemical surveys are planned to support the drilling effort.

The planned budget of about US$3.8 M/a for both mines is appropriate for the type of deposit and stage of development.

Table 26-1: Proposed Exploration Programs

	Units	Vazante Mine	Extremo Norte Mine	Regional	Total
Core Drilling	m	35,000	28,000	45,000	108,000
Core Drilling	US$ million	4.94	3.95	6.35	15.20
Underground Development	US$ million	1.50	1.20	—	2.70
Geology	US$ million	0.25	0.25	1.00	1.50
Geochemistry	US$ million	0.50	0.40	0.60	1.50
Geophysics	US$ million	0.01	0.01	0.31	0.30
Permits and Authorizations	US$ million	0.15	0.15	0.20	0.50
Support	US$ million	1.08	0.87	1.24	3.20
Total Expenditures	***US$ million***	***8.43***	***6.83***	***9.69***	***25.0***

26.2.2 Regional

Votorantim have generated a number of attractive regional targets for additional exploration, which are at various stages of exploration testing. Additional geological mapping, geophysical surveys, and geochemical surveys will be required to support drilling programs.

The regional area program will involve about 45,000 m of core drilling, at an average cost of about US$141/m. Additional geological mapping, geophysical surveys, and geochemical surveys should be undertaken to support the drilling effort.

The proposed budget of about US$2.5 M/a is appropriate for a regional exploration program for the deposit type.

26.3 Phase 2

26.3.1 Hydrology and Hydrogeology

Present annual updates of the FEFLOW groundwater model should be documented in an annual update report so that a record of the calibration is maintained and changes made to the model are recorded systematically to preserve the utility of this key water management tool. Some predictive sensitivity analysis should be undertaken to address parameter uncertainty to assess impacts on predicted mine water pumping, particularly for short-term (1–3 year) mine development plans. This should include an assessment of potential impacts from climatic extreme events.

The FEFLOW groundwater model should be used to assess groundwater rebound on mine closure and predict locations and magnitudes of discharges to surface water. Results from this work should be incorporated in the groundwater risk management plans.

The hydrometric monitoring network should be reviewed and new monitoring points installed as the mine is deepened below 300 masl and expanded to the north towards the Extreme Norte area. An assumption has been made that approximately 50 new monitoring wells, with an average depth of 200 m would be required.

The FEFLOW groundwater model should be reviewed by independent experts every three years. The budget proposed is inclusive of a first review only.

Depending on whether the work performed is done internally or by a third party, the frequency at which reviews are undertaken, these programs are estimated to total about US$2.2 million to US$2.3 million

26.3.2 Mineral Resource

The mine currently does not have formal reconciliation process. A detailed reconciliation study should be conducted to assess the accuracies of the long-term Mineral Resource model, and devise formal mine reconciliation operating procedures.

This program is estimated at US$50,000 to US$100,000.

26.3.3 Mine Planning

A study should be performed to determine how best to reduce the current rates of dilution.

This program is estimated at US$275,000 to $300,000.

26.3.4 Environmental, Social and Permitting

Amec Foster Wheeler recommends that the findings outlined in the audit document (Correa and Fideles, 2016) be reviewed and addressed as applicable. Where there may be gaps or inconsistencies in permitting, these should be rectified. Where the audit has identified areas of non-compliance, mitigation or control plans should be developed.

An overarching closure plan should be developed for the entire mining operations to ensure that all closure and rehabilitation requirements are fully understood and budgeted. This plan should incorporate elements of the existing plans where still applicable. It would be useful to refine the closure plan cost estimates from the current ±25–30% accuracies.

These programs are estimated at US$250,000 to $300,000.

27.0 REFERENCES

Aecom Do Brasil Ltda, 2012: Plano Conceitual De Descomissionamento Expansão da Área de Lavra da Mina Subterrânea de Willemita – Extremo Norte.

Aecom Do Brasil Ltda, 2013: Plano Conceitual de Descomissionamento- Unidade de Vazante.

Almeida, F.F.M., 1977: O Cráton São Francisco: Brasil; Brazilian Journal of Geology (formerly Revista Brasileira de Geosciências), no. 7, pp. 349–364.

Almeida, F.F.M., Hasui, Y., Brito Neves, B.B., and Fuck, R.A., 1977: Províncias Estruturais Brasileiras: in: Simp. Geol. Nord., 8. Campina Grande, 1977. SBG/NE. pp. 363–391

Amec Foster Wheeler, 2017: Vazante and Extremo Norte Gap Analysis Report: report prepared for Votorantim, May 2017, 159 p.

Anderson, M.P., Woessner, W.W. and Hunt, R.J. 2015: Applied Groundwater Modelling – Simulation of Flow and Advective Transport: Second edition, Elsevier.

Appold, M.S., and Monteiro, L.V.S., 2009: Numerical Modeling of Hydrothermal Zinc Silicate and Sulphide Mineralization in the Vazante Deposit, Brazil: Geofluids, 9, pp. 96–115.

Ausenco Peru SAC, 2016: Vazante Tailings Dams Cross Check Report 101862-03-RPT-001, February, 2017.

Babinski, M. 2005: A Idade do Supergrupo São Francisco: Revisão e Implicações nas Glaciações Neoproterozóicas: SBG, Simpósio sobre o Cráton do São Francisco, v. 3, pp. 135–138.

Barbosa, O., Braun, O.P.G., Dyer, R.C., and Rodrigues Da Cunha, C.A.B., 1970: Geologia da Região do Triângulo Mineiro: Rio de Janeiro. DNPM/DGM. bol. 136. 140 p.

Bechir, J.L.C., Metsavaht, V., Lemos, M.G., Martins, E.L.C., Souza, A.D., Lopes, L.M.C., Lima, J.R.B., Oliveira, C.A.M., and Melo, J.M.C., 2015: DeterminaçÃo Da Granulometria Ideal Para A FlotaçÃo De Zn Da Usina De Vazante: report prepared for Votorantim.

Bechir, J.L.C., Metsavaht, V., Lemos, M.G., Martins, E.L.C., Souza, A.D., Lopes, L.M.C., Lima, J.R.B., Oliveira, C.A.M., Melo, J.M.C., 2015: Determinação da Granulometria Ideal para a Flotação de Zn da Usina de Vazante – Votorantim Metais, XXVI Encontro Nacional de Tratamento de Minérios e Metalurgia Extrativa Poços de Caldas-MG, 18 a 22 de Outubro 2015

Bittencourt, C., de Bessa, V. and Eufrasio de Araújo, E. 2008: The Vazante Underground Mine, Brazil – An Example of Controlled Water Table Drawdown in Karstic Areas: 11th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, Tallahassee, Florida, USA, published in Geotechnical Special Publication of the American Society of Civil Engineers, 183; pp 732–741.

Beurlen, H., 1974: Sobre A Origem Singenenetico-Sedimentar De Alguns Corpos Mineralizados Em Chumbo, Zinco E Fluorita No Grupo Bambuı´ E Dispersa˜o Geoquı´Mica Prima´Ria Dos Elementos Mineralizantes: Proceedings of the XXVII Congresso Brasileiro de Geologia, Sociedade Brasileira de Geologia, SBG-RS, vol. 6, pp. 49–60.

Branco, J.J.R., 1962: Principais Ocorrências de Zinco em Minas Gerais: in SINGEG – II Semana de Estudos – Alumínio e Zinco Publicação (2) pp.148–184.

Brandt Meio Ambiente, 2001: Estudo de Impacto Ambiental Mina Subtarrânea Willemita.

Brugger, J., McPhail, D.C., Wallace, M., and Waters, J., 2003: Formation of Willemite in Hydrothermal Environments: Economic Geology, 98, 819–835.

Buttrick, D., van Schalkwyk, M., Kleywegt, R.J., Watermeyer, R. 2001: Proposed Method for Dolomite Land Hazard and Risk Assessment in South Africa: Journal of the South African Institution of Civil Engineering. 43(2):27–35.

Campos Neto, M.C. 1973: Considerações Preliminares Sobre a Geologia da Região de Morro Agudo: internal report by Metais de Minas Gerais S. A.. Projeto Zinco - Bambuí Sul, 28 p.

Canadian Institute of Mining, Metallurgy and Petroleum (CIM), 2003: Estimation of Mineral Resources and Mineral Reserves, Best Practice Guidelines: Canadian Institute of Mining, Metallurgy and Petroleum, November 23, 2003.

Canadian Institute of Mining, Metallurgy and Petroleum (CIM), 2014: CIM Standards for Mineral Resources and Mineral Reserves, Definitions and Guidelines: Canadian Institute of Mining, Metallurgy and Petroleum, May, 2014.

Canadian Securities Administrators (CSA), 2011: National Instrument 43-101, Standards of Disclosure for Mineral Projects, Canadian Securities Administrators.

Castro, C., de Freitas, P.A. and Garcia, P., 2012: Mining Law Juridictional Comparisons, Brazil: report prepared by Veirano Advogados, first edition, 2012.

Correa, A., and Fideles, P., 2016: Auditoria De Requisitos Legais - Ciclo 2015

Coulto, L.C.G. and Catão Silva Nascimento, G., 2017: Mina de Vazante – Desenvolvimento De Galerias En Ambiente Cárstico Com Grandes Afluxos D'agua: IV Congreso Brasiliero de Túneis e Estruturas Subterrãneas, Seminário Internacional 'Latin American Tunnelling Seminar – LAT 2017'.

Da Rocha Araujo, P.R., Flicoteaux, R., Parron, C., and Trompette, R. 1992: Phosphorites of Rocinha mine - Patos de Minas (Minas Gerais Brasil): Genesis and Evolution of a Middle Proterozoic Deposit Tectonized by the Brasiliano Orogeny: Econ. Geol., v. 87, pp. 332–351.

Dardenne, M.A. 1978: Síntese Sobre a Estratigrafia do Grupo Bambuí no Brasil Central: in Congresso Brasileiro de Geologia. pp. 597–610.

Dardenne, M.A., 1979: Les Minéralisations De Plomb, Zinc, Fluor Du Proterozoique Supérieur Dans Le Brésil Central: PhD thesis, University of Paris VI, 251 p.

Dardenne, M.A. 2000: The Brasília Fold Belt: In Cordani, U.G., Milani, E.J., Thomaz-Filho, A., and Campos, D.A. (Eds.), Tectonic Evolution of South America. 31st International Geological Congress, Rio de Janeiro, pp. 231–263.

Dardenne, M.A. and Schobbenhaus, C.S. 2000: The Metallogenesis of South America Platform: *in* Cordani, U.G., Milani, E.J., Thomaz Filho, A., and Campos, D.A. (Eds), Tectonic Evolution of South America, Rio de Janeiro. 31st International Geological Congress, Rio de Janeiro, pp.755–850.

Dardenne, M.A., Freitas-Silva, F.H., Nogueira, G.M.S., and Campos, J.E.G., 1998: Evolução Tectono-Sedimentar Do Grupo Vazante No Contexto Da Faixa De Dobramentos Brasilia: Congresso Brasileiro de Geologia, 40, SBG, Belo Horizonte, Anais, p. 26.

DHI, 2013: Estudo de Caracterizaçao da Dinâmica de Fluxos Subterrâneos a Partir da Injeçao de Técnicas Basedas na Utilizaçao de Traçadores Corantes – Restreamento de Conexões Hidráulicas e Quantificações dos Fluxos do Rio Santa Catarina que Estão Infiltrando na Mina Subterrânea de Vazante: Report for Votorantim Metais, Unidade Vazante.

Ecolab Medio Ambiente, 2016: Estudo de Impacto Ambiental Projeto de Disposição de Rejeitos Secos Pilha Garrote.

Ecolab Medio Ambiente, 2017: Estudo de Impacto Ambiental Projeto Modificação e Ampliação da USICON.

Eufrasio de Araújo, E., Catão Silva Nascimento, G. and de Bessa, V. 2016: Modelamento Hidrogeológico Regional Em Leapfrog / FEFLOW Da Região De Vazante: XIX Congreso Brasiliero de Águas Subterrãneas, Campinas, Sao Paulo, Brazil.

Freitas-Silva. H.F. 1991: Enquadramento Litoestratigráfico e Estrutural do Depósito de Ouro do Morro do Ouro, Paracatu – MG: dissert. Mestrado (Master's Thesis), Universidade de Brasilia (IG-UnB), Brasília, 151 p.

Geoconsultoria, 2016: Dam Safety Review, Technical Report CM18-RT46, pgs 5, 12, August 2016.

Gonzaga, G.M. and Towkins, L.A., 1991: Geologia Do Diamante: *in* Schobbenhaus, C., Queiroz, E.T., and Coelho, C.E.S., eds.: Principais Depósitos Minerais do Brasil. Gemas e Rochas Ornamentais. Brasília. DNPM/CPRM. v. 4a. pp. 53–116.

Guimarães, D., 1962: Genese do Miniero de Zinco de Vazante, Minas Gerais: Sociedad Intercambeo Cultural e Estudios Geologia, Ouro Preto, 2, pp. 101–147.

Iyer, 1984: A Discussion on the Lead Isotope Geochemistry of Galenas from the Bambui Group, Minas Gerais — Brazil: Mineralium Deposita, April 1984, Volume 19, Issue 2, pp 132–137.

Iyer, S.S., Hoefs, J., and Krouse, H.R., 1992: Sulfur and Lead Isotope Geochemistry of Galenas From Bambuı´ Group, Minas Gerais, Brazil: Implications on Ore Genesis: Economic Geology, 87, pp. 437–443.

Iyer, S.S., Krouse, H.R., and Babinsky, M., 1993: Isotope Investigations on Carbonates Rocks Hosted Lead-Zinc Deposits from Bambuí Group. Minas Gerais, Brazil. Implications on Ore Genesis and Prospect Evaluation: *in*, II Simpósio do Cráton São Francisco. Anais, Salvador, pp. 338–339

Jackson, T., and Green, K.P., 2016: Fraser Institute Survey of Mining Companies, 2016: 74 p.

Golder Associates Brasil Consultoria e Projetos Ltda, 2011: Relatório Técnico Reabilitação de Parte das áreas de aterro, Pilhas de Estéril e cava da Unidade Vazante.

Hidrogeo, 2016: Classification of Tailings from Flotation of Vazante, RT-01-01-GE-17-16-F, pgs. 20-21, September 2016.

Hidrovia, 2012: Caracterização Hidrogeológica Integrada da Área de Influência da Mina Zinco da Votorantim Metais, Unidade Vazante/MG, Relatório Técnico: Report for Votorantim Metais, Unidade Vazante.

Hitzman, M.W., 1997: Observations from the Vazante Zinc Mine, Minas Gerais, Brazil: internal report prepared for for Votorantim.

Hitzman, M.W. and Beaty, D.W., 1996: The Irish Zn-Pb-(Ba) Orefield: *in* Sangster, D.F., ed., Carbonate-hosted Lead-Zinc Deposits: Society of Economic Geologists Special Publication 4, pp. 112–143.

Hitzman, M.W., Thorman, C.H., Romagna, G., Oliviera, T.F., Dardenne, M.A., and Drew, L.J., 1995: The Morro Agudo Zn-Pb Deposit, Minas Gerais, Brazil: A Proterozoic Irish-type Carbonate-hosted Sedex-replacement deposit [abs.]: Geological Society of America Abstracts with Programs, v.27, p. A408.

Hitzman, M.W., Reynolds, N.A., Sangster, D.F., Allen, C.R., and Carman, C.E., 2003: Classification, Genesis, and Exploration Guides for Non-Sulphide Zinc Deposits: Economic Geology, 98, pp 685–714.

International Union for Conservation of Nature (IUCN), 2015: Red List of Threatened Species: http://www.iucnredlist.org/.

Journel, A.G., and Huijbregts, Ch, 1978: Mining Geostatistics, Academic Press Inc., New York.

Lagodourado.com, date unknown: Summary of Brazilian Mining Legislation: accessed 30 June, 2015: lagodourado.com/pdfs/articles/Summary_of_Brazilian_Mining_Legislation.pdf.

Laranjeira, N.P.F., 1993: A Plataforma Mista de Siliciclásticos e Carbonatos do Grupo Paranoá na Região de Unaí - MG. Brasília: dissert. mestrado (Master's Thesis), Universidade de Brasilia (IG_UnB), Brasilia.

Madalosso, A. 1979: Stratigraphy and Sedimentation of the Bambuí Group in Paracatu region, MG, Brazil: M.Sc. Thesis, University of Missouri, 127 p.

McGladrey, A.J., 2014: The Integration of Physical Rock Properties, Mineralogy and Geochemistry for the Exploration of Large Hypogene Zinc Silicate Deposits: a Case Study of the Vazante Zinc Deposits, Minas Gerais, Brazil: MSc thesis, Queens University, Canada, 177 p.

Misi, A., Azmy, K., Kaufman, A.J., Oliveira, T.F., Sanches, A.L. and Oliveira, G.D., 2014: Review of the Geological and Geochronological Framework of the Vazante Sequence, Minas Gerais, Brazil: Implications to Metallogenic and Phosphogenic Models: Ore Geology Reviews 63 (2014) pp. 76–90.

Monteiro, L.V.S., 1997: Contribuição à Gênese das Mineralizações de Zn da Mina de Vazante, MG: Dissertação de Mestrado, (Master's Thesis) Universidade de São Paulo. São Paulo. 115 p.

Monteiro, L.V.S., 2002: Modelamento Metalogenético dos Depósitos de Zinco de Vazante, Fagundes e Ambrósia, Associados ao Grupo Vazante, Minas Gerais: Tese de Doutorado (Ph.D. Dissertation), Universidade de São Paulo, São Paulo.

Monteiro, L.V.S., Bettencourt, J.S., Spiro, B., Graca, R., and Oliveira, T.F., 1999: The Vazante Zinc Mine, Minas Gerais, Brazil: Constraints on Willemitic Mineralization and Fluid Evolution: Exploration and Mining Journal, 8, pp. 21–42.

Monteiro, L. V. S., Bettencourt, J. S., Juliani, C., and De Oliveira, T. F. 2006: Geology, Petrography, and Mineral Chemistry of the Vazante Non-Sulphide and Ambrósia and Fagundes Sulphide-Rich Carbonate-Hosted Zn–(Pb) Deposits, Minas Gerais, Brazil: Ore Geology Reviews, 28(2), pp. 201–234.

Monteiro, L.V.S., Bettencourt, J.S., Juliani, C., Oliveira, T.F., 2007: Non-Sulphide and Sulphide-Rich Zinc Mineralizations in the Vazante, Ambrosia and Fagundes Deposits, Minas Gerais, Brazil: Mass Balance and stable Isotope Characteristics of the Hydrothermal Alterations. Gondwana Res. 11, pp. 362–381.

Pinho, J.M.M., 1990: Evolução Tectônica Da Mineralizacao De Zinco De Vazante, Brasília: M.Sc. thesis Universidade de Brasília, Brasília.

PwC, 2013: Doing Business and Investing in Brazil: accessed 30 June, 2015: https://www.pwc.de/de/internationale-maerkte/assets/doing-business-and-investing-in-brazil.pdf.

Rigobello, A., Branquinho, J. A., Dantas, M.G.S., de Oliveira, T.F., and Neves Filho, W., 1988: Mina de Zinco de Vazante, Minas Gerais: *in*, Schobbenhaus, C. and Coelho, C.E.S., eds., Principais Depósitos Minerais do Brasil. Metais Básicos não Ferrosos, Ouro e Alumínio; Brasília, DNPM. v. 3. pp.101–110.

Roscoe Postle Associates (RPA), 2014: Mineral Resource and Ore Reserve Audit of the Vazante Mine, Minas Gerais State, Brazil. Relatório De Auditoria: report prepared for Votorantim.

Schlumberger Water Services (SWS), 2011: Avaliação Hidrogeológica Revisão do Modelo de Fluxo (FEFLOW): Report for Votorantim Metais, Unidade Vazante.

Scanlon, B.R., Mace, R.E., Barrett, M.E. and Smith, B. 2003: Can We Simulate Groundwater Flow in a Karst System Using Equivalent Porous Media Models? Case Study, Barton Springs, Edwards Aquifer, USA: Journal of Hydrology, 276, pp. 137–158.

Sete Soluções e Tecnologia Ambiental, 2013: Plano Executivo de Descomissionamento da Planta Antiga - Unidade Vazante.

Sial, A.N., Dardenne, M.A., Misi, A., Pedreira, A.J., Gaucher, C., Ferreira, V.P., Silva Filho, M.A., Uhlein, A., Pedrosa-Soares, A.C., Santos, R.V., Egydio-Silva, M., Babinski, M., Alvarenga, C.J.S., Fairchild, T.R., and Pementel, M.M., 2010: Neoproterozoic-Cambrian Evolution of the São Francisco Palaeocontinent: *in*, Gaucher, C., Sial, A.N., Halverson, G.P., and Frimmel, H.E., eds., Neoproterozoic-Cambrian Tectonics, Global Change and Evolution A Focus on Southwestern Gondwana; Elsevier, pp. 31–69.

Simón, A., 2005: La Calidad de los Datos en la Estimación de Recursos: Conferencia Magistral, XXVII Convención Minera EXTEMIN, Arequipa, Septiembre 15 de 2005.

Slezak, P., 2012: Geology, Mineralogy, and Geochemistry of the Vazante Northern Extension Zinc Silicate Deposit, Minas Gerais, Brazil: MSc thesis, Queens University, Canada, 497 p.

Slezak, P.R., Olivo, G.R., Olivera, G.D. and Dardenne, M.A., 2013: Geology, Mineralogy, and Geochemistry of the Vazante Northern Extension Zinc Silicate Deposit, Minas Gerais, Brazil: Ore Geology Reviews, 56, pp 234–257.

Snowden, 2012: Votorantim Metals S/A: External Audit 2012 - Vazante Zinc Operations - Project No. B01050: report prepared for Votorantim.

SRK, 2010: Auditoria Dos Recursos Minerais De Chumbo E Prata Associados Ao Depósito De Zinco De Vazante, MG, Votorantim Metais: report prepared for Votorantim.

Votorantim, undated: Plano de Gerenciamento de Risco Dolomitos (PGRD). PG-VM-ZINCO-HIDRO-005, Rev. 3.1.

Votorantim, undated: Sondagem Para Pequisa / Desenvolvimento. PG-VM-ZINCO-HIDRO-003, Rev. 2.1.

Votorantim, undated: Descrição Hidrogeológica e Classificação de Testemunhos de Furos de Sonda. PG-VM-ZINCO-HIDRO-006, Rev. 1.

Votorantim, undated: Mineralogia aplicada a otimizaáao da recuperaáao de Zn_rev01.pdf.

Votorantim, 2016: Apresentação Geomet 2016.pdf, Apresentação - Estudo de Variabilidade - 2018 a 2028.pdf

Votorantim, 2017: Relatório de Atendimento à Condicionante 06 Licença de Operação – LO 10/2012 PA COPAM 104/1988/049/2011

Votorantim Metais, undated: Recuperação de Zinco, Efeito dos contaminantes, Unidade Vazante

Votorantim Metais, undated: Recuperação de Zinco por regiões da mina Unidade Vazante

Votorantim Metais, 2015: Análise Minério Vazante 2014/2015

Votorantim Metais, 2016a: Relatório Processo

Votorantim Metais, 2016b: Geometalurgia Aplicada na Mina de Zinco de Vazante, Minas Gerais

Votorantim Metais Holding, undated: Unidade de Três Marias, Technical Report

Votorantim Technology, 2016: Mineralogia Aplicada a Otimizaáao da Recuperaáao de Zn_rev01.pdf, 2016.

Votorantim Metais Zinco S/A, Unidade Vazante/MG, 2017: Votorantim Metais Zinco – Unidade Vazante, Balanço Hídrico – Fluxograma.

Votorantim Metais Zinco Tecnologia, 2015: Minério de Vazante 2016 - Geometalurgia

Votorantim Metais Tecnologia Zinco e Niquel, 2015: Redução das Perdas de Zinco na Unidade de Vazante

Walm, 2016: Garrote Tailings Stack Basic Design Report, MD-I721015037-0902CIV0100-R3, 2016.