Public Report and Feasibility Study for the Chvaletice Manganese Project, Czech Republic

PRESENTED TO

Euro Manganese Inc.

EFFECTIVE DATE: JULY 27, 2022
RELEASE DATE: SEPTEMBER 12, 2022
704-ENG.VMIN03093-01
TETRA TECH CANADA INC. PERMIT TO PRACTICE #: 1001972

QUALIFIED PERSONS:

CHRIS JOHNS, P.ENG.
DAVOOD HASANLOO, P.ENG.
HASSAN GHAFFARI, P.ENG.
JAMES BARR, P.GEO.
JIANHUI (JOHN) HUANG, PH.D., P.ENG.
MAUREEN MARKS, P.ENG.

Tetra Tech Canada Inc.
Suite 1000 – 10th Floor, 885 Dunsmuir Street
Vancouver, BC V6C 1N5 CANADA
Tel 604.685.0275 Fax 604.684.6241

This page left intentionally blank.

TABLE OF CONTENTS

TETRA TECH

LIST OF TABLES

TETRA TECH

LIST OF FIGURES

TETRA TECH

ACONYMS / ABBREVIATIONS

Acronym/Abbreviation	Definition
AACE	American Association Of Cost Engineering
ABA	Acid-Base Accounting
ALS	ALS Laboratories
AM	Asian Metal
ARD	Acid Rock Drainage
ASX	Australian Securities Exchange
BAT	Best Available Technology
BD	Bulk Density Value
BEV	Battery Electric Vehicle
BGRIMM	BGRIMM General Research Institute for Mining and Metallurgy
BPV	Baltic Vertical Datum
CAGR	Compound Annual Growth Rate
CAM	Cathode Active Materials
CCTV	Closed-Circuit Television
CEZ	České Energetické Závody
CIM	Canadian Institute For Mining, Metallurgy, and Petroleum
CMP	Chvaletice Manganese Project
CP	Competent Person
CPM or CPM Group	CPM Group LLC
CPT	Cone Penetration Testing
CRIMM	Changsha Research Institute of Mining and Metallurgy Co
CRM	Certified Reference Material
CWP	Construction Work Package
CZK	Czech Koruna
DCS	Distributed Control System
DDP	Delivered, Duty Paid
DEM	Digital Elevation Model
DSOs	Distribution System Operators
DTM	Digital Topographic Model
E	East
EC	Electrical Conductivity
EDS	Energy Dispersive X-Ray Spectroscopy
EDX	Energy Dispersive X-Ray Detection
EEX	European Energy Exchange
EIA	Environmental Impact Assessment

Acronym/Abbreviation	Definition
EIA Notification	Preliminary Environmental And Social Impact Assessment
EMD	Electrolytic Manganese Dioxide
EMM	Electrolytic Manganese Metal
EMN	Euro Manganese Inc
EPCM	Engineering, Procurement, And Construction Management
ERT	Electric Resistivity Tomography
ERU	Energy Regulatory Office
ESIA	Environmental And Social Impact Assessment
ESS	Energy Storage Systems
EV	Electric Vehicle
EWP	Engineering Work Package
FID	Financial Investment Decision
FS	Feasibility Study
Geomin	Geomin s.r.o.
GET	GET s.r.o.
GIC	Gabarit International De Chargement
Global ARD	Global ARD Testing Services Inc.
GoO	Guarantees Of Origin
GPS	Global Positioning System
Grant Thornton	Grant Thornton Tax & Accounting s.r.o
GWh	Gigawatt-Hours
HAZOP	Hazard And Operability Assessment
HPEMM	High-Purity, Selenium (Se)-Free, 99.9% Electrolytic Manganese Metal
HPMSM	High-Purity Manganese Sulphate Monohydrate
HPMSS	High Purity Manganese Sulphate Solution
HR-type	Horizontal Ring-Type
HSEC	Health, Safety, Environment and Community
ICE	Internal Combustion Engine
ICP	Inductively Coupled Plasma
ID3	Inverse Distance (Cubed)
IRR	Internal Rate of Return
ISO	International Organization for Standardization
JORC	JORC Code
Kemetco	Kemetco Research Inc.
KPIs	Key Performance Indicators
kWh	Kilowatt-Hours

Acronym/Abbreviation	Definition
LB	Lower Bound
LC	Local Biocorridor
LFP	Lithium-Iron-Phosphate Batteries
LiB	Lithium-Ion Battery
LiDAR	Light Detection and Ranging (Remote Sensing)
Li-ion	Lithium-Ion Battery
LK	Local Biocentre
LLO	Low Level Outlet
LOM	Life of Mine
LOP	Life of Project
Longi	Longi Magnet Co., Ltd.
LR	Leach Residue
M2CAM	Metal To Cathode Active Material
Mangan	Mangan Chvaletice S.R.O
MB	Master Blend
Met-Solve	Met-Solve Laboratories Inc.
MFI	Magnetic Field Intensity
MKZ	Manganese And Pyrite Enterprise
ML	Metal Leaching
MLA	Mineral Liberation Analysis
MoE	Ministry of Environment
MRE	Mineral Resource Estimate
MSDS	Material Safety Data Sheet
MSM	Manganese Sulphate Monohydrate
MSQ	Market Sounding Questionnaire
MSS	Manganese Sulphate Solution
MTOs	Material Take-Offs
MVR	Mechanical Vapour Recompression
MWh	Megawatt-Hours
N	North
NECP	National Energy and Climate Action Plan
NHD	Jiangsu New Hongda Group
NI 43-101	National Instrument 43-101
NMT	Non-Magnetic Tailings
NMT/LR	Non-Magnetic Tailings / Leach Residue
NPR	Neutralization Potential Ratio
NSR	Net Smelter Return

Acronym/Abbreviation	Definition
OIS	Operator Interface Stations
Orex	Orex Consultants s.r.o.
PED	Pardubice
PESIA	Preliminary Environmental And Social Impact Assessment
PHEV	Plug-In Hybrid Electric Vehicle
PLC	Programmable Logic Controllers
PMC	Process Mineralogical Consulting Ltd.
PRG	Vaclav Havel Airport Prague
QA	Quality Assurance
QA/QC	Quality Assurance / Quality Control
QC	Quality Control
QQ	Quantile-Quantile
Residue	Non-Magnetic Tailings and Leach Residue
ROW	Right-of-Way
RSF	Residue Storage Facility
SEM	Scanning Electron Microscopy
SFE	Shake Flask Extraction
SGS	Sgs Minerals Services
S-JTSK	System Jednotne Trigonometricke Site Katastralni
SLon	Slon Magnetic Separator Ltd.
SMM	Shanghai Metal Markets
sMn	Soluble Manganese
SRS	Shallow Refraction Seismic
SWOT	Strength-Weakness-Opportunities-Threats
Tetra Tech	Tetra Tech Canada Inc.
TGA	Thermogravimetry
The Property	The Chvaletice Property
TMI	Tianyuan Manganese Industry
tMn	Total Manganese
TOC	Total Organic Carbon Content
TSO	Transmission System Operator
TSXV	TSX Venture Exchange
UBC	University of British Columbia
UIC	International Union of Railways
ÚSES	Territorial System of Landscape Ecological Stability)
USSR	Union of Soviet Socialist Republics
UTM	Universal Transverse Mercator

Acronym/Abbreviation	Definition
VRB	Vanadium Redox Flow Battery
VR-type	Vertical Ring-Type
VSP	Vertical Seismic Profiling
WBS	Work Breakdown Structure
WGS	World Geodetic System
WHMIS	Workplace Hazardous Materials Information Systems
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

UNITS OF MEASURE

ampere	A
annum (year)	a
bank cubic metres	bcm
billion tonnes	Bt
billion	B
centimetre	cm
circular mils	cmils
Coefficients of Variation	CVs
cubic centimetre	cm^3
cubic metre	m^3
day	d
days per week	d/wk
days per annum (year)	d/a
dead weight tonnes	DWT
degree	°
degrees Celsius	°C
diameter	ø
dollar (American)	US$
dollar (Canadian)	Cdn$
dry metric tonne	dmt
foot	ft
gallon	gal
gallons per minute (US)	gpm
gigawatt hours	Gwh
gigawatt	GW
gram	g
grams per litre	g/L
grams per tonne	g/t
gravitational constant	*g*
greater than	>
hectare	ha

horsepower	hp
hour	h
hours per day	h/d
hours per week	h/wk
hours per annum (year)	h/a
inch	in
kilo (thousand)	k
kilogram	kg
kilograms per cubic metre	kg/m^3
kilograms per day	kg/d
kilograms per hour	kg/h
kilograms per square metre	kg/m^2
kilometre	km
kilometres per hour	km/h
kilonewton	kN
kilopascal	kPa
kilotonne	kt
kilovolt	kV
kilowatt hour	kWh
kilowatt hours per tonne	kWh/t
kilowatt hours per annum (year)	kWh/a
kilowatt	kW
less than	<
litre	L
litres per hour	L/h
litres per second	L/s
Megaannum (million years)	Ma
megavolt-ampere	MVA
megawatt	MW
metre	m
metres above sea level	masl
metres per second	m/s
metres per annum (year)	m/a
microns	µm
milligram	mg
milligrams per litre	mg/L
millilitre	mL
millimetre	mm
million	M
million tonnes	Mt
minute (plane angle)	'
minute (time)	min
month	mo
ounce	oz
parts per billion	ppb
parts per million	ppm

Pascal	Pa
percent	%
pound(s)	lb
pound(s) per square inch	psi
revolutions per minute	rpm
second (plane angle)	"
second (time)	s
specific gravity	SG
square centimetre	cm^2
square kilometre	km^2
square metre	m^2
square millimetre	mm^2
three-dimensional	3D
tonne (1,000 kg) (metric ton)	t
tonnes per day	t/d
tonnes per hour	t/h
tonnes per annum (year)	t/a
volt	V
week	wk
weight/weight	w/w
wet metric tonne	wmt

1.0 SUMMARY

1.1 Introduction

The Chvaletice Manganese Project (CMP) is located in the western area of the Pardubice region of the Czech Republic, approximately 89km by road east of Prague, on the southern shore of the Labe River (Figure 1-1). Euro Manganese Inc. and its wholly-owned subsidiary, Mangan Chvaletice s.r.o (Mangan) (collectively referred in this Public Report as ‘EMN’, or the ‘Company’) plans to reprocess fine-grained tailings material for production of high-purity, selenium (Se)-free, 99.9% electrolytic manganese metal (HPEMM) and high-purity manganese sulphate monohydrate (HPMSM), at a hydrometallurgical refinery located adjacent to the tailings cells. The tailings were deposited into three separate above-ground tailings cells, referred to as Cell #1, Cell #2, and Cell #3, from historical mining and processing activities.

EMN retained Tetra Tech Canada Inc. (Tetra Tech) to prepare a Public Report and Feasibility Study (FS) based on the data generated from work completed on the CMP by EMN to date. This FS report has been prepared in accordance with the Joint Ore Reserves Committee Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code, 2012 Edition) and following Canadian National Instrument 43-101 (NI 43-101) guidelines and following Canadian Institute for Mining, Metallurgy, and Petroleum (CIM) Best Practices. The effective date for this report is July 27, 2022.

1.2 Property Description and Location

The Chvaletice Property (the Property) is the subject of two exploration licences, numbered 631/550/14-Hd and MZP/2018/550/386-Hd (together the Exploration Licences) and a Preliminary Mining Permit, numbered MZP/2021/550/768-Hd, which is registered to include mineral rights over an area of 0.98 km^2 (the Protected Area, covering approximately 98 ha and encompassing all three tailings cells) (Figure 1-2). The Preliminary Mining Permit is a precursor to applying for a Mining Permit and grants EMN the right to conduct an environmental impact assessment (EIA).

The Exploration Licences and the Preliminary Mining Permit are held by Mangan (a private Czech company) that was repurposed in 2014, as a partnership between GET s.r.o. (GET), Geomin s.r.o. (Geomin), and Orex Consultants s.r.o. (Orex). Today, EMN owns 100% of Mangan. Terms of the purchase agreement dated May 2016 included a transfer of the exploration licence, number 631/550/14-Hd, from GET to Mangan and the purchase of 100% of Mangan by EMN. The original exploration licence number 631/550/14-Hd was originally valid until September 30, 2019, this licence was originally extended on December 4, 2018, to May 31, 2023 (extension reference MZP/2018/550/1484-Hd) and then extended again on July 2, 2021 to May 31, 2026 (extension reference MZP/2021/550/698-Hd). On May 4, 2018, the Czech Ministry of Environment (MoE) issued Mangan an additional exploration licence, MZP/2018/550/386-Hd, allowing it to drill the slopes on the perimeter of the tailings cells. The additional exploration license became effective May 23, 2018, and was originally valid until May 31, 2023, but was extended on July 2, 2021, to May 31, 2026 (extension reference MZP/2021/550/698-Hd). Three net smelter royalty (NSR) agreements, having an aggregate NSR of 1.2%, were held by the three original shareholders of Mangan. The NSR agreements were granted as part of the purchase transaction by EMN for 100% ownership of Mangan. On May 31, 2021, EMN entered into termination agreements with each of the three shareholders, and on January 31, 2022, terminated the royalty agreements in full through the issuance of shares and an aggregate payment of U$1,800,000.

On April 17, 2018, with effect from April 28, 2018, Mangan was issued a Preliminary Mining Permit by the MoE, Licence No. MZP/2018/550/387-HD and referred to by the MoE as the prior consent with the establishment of the Mining Lease District (the Preliminary Mining Permit). The Preliminary Mining Permit was valid until April 30, 2023, and covered the areas included in the Exploration Licences and secures Mangan's rights for the entire deposit area. On July 20, 2021, Mangan was issued a new Preliminary Mining Permit, Licence No. MZP/2021/550/768-Hd, valid until May 31, 2026, which replaces the original Preliminary Mining Permit.

Figure 1-1: Location of the Chvaletice Manganese Project

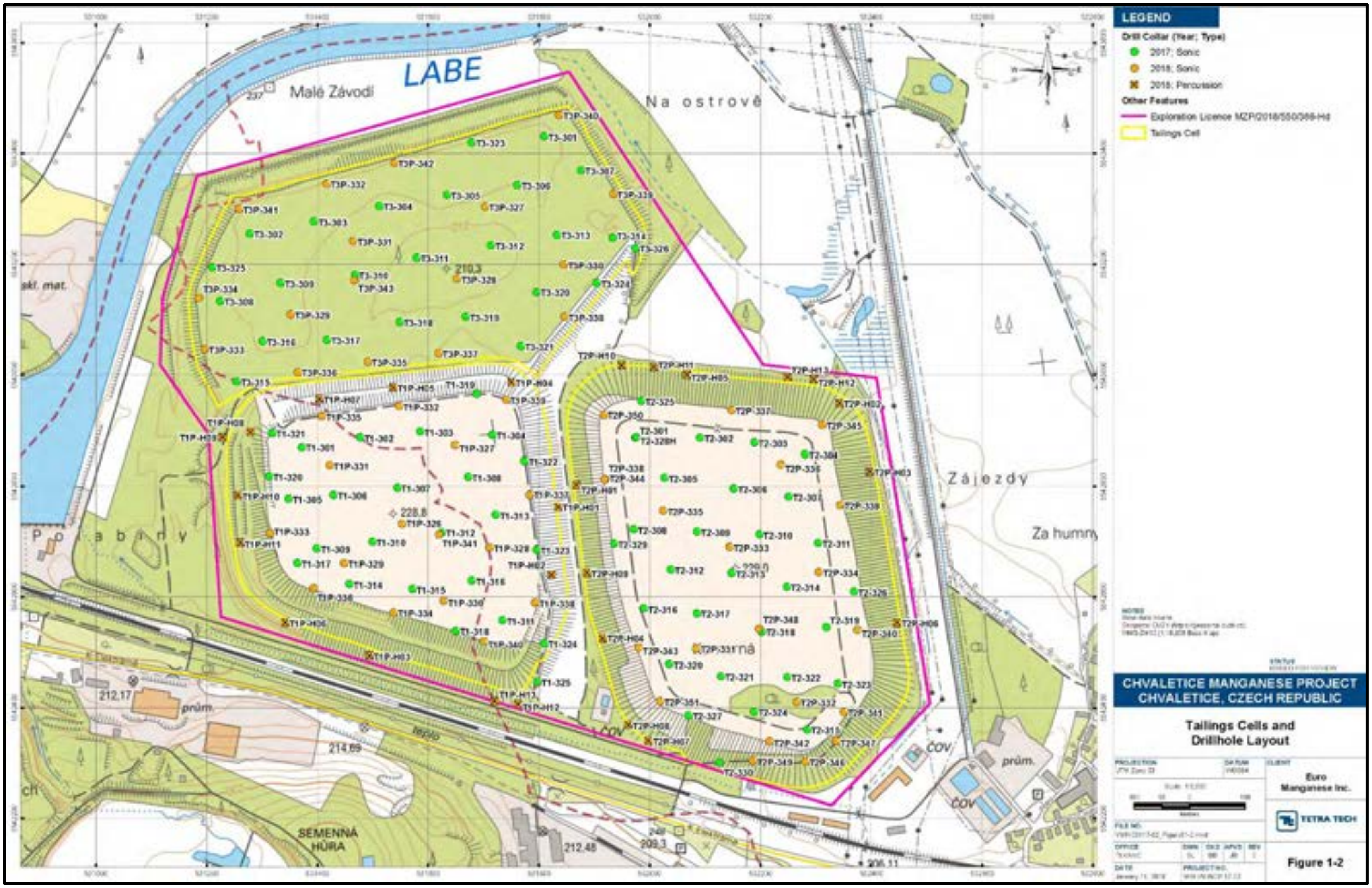
Infrastructure in the vicinity of and accessible to the CMP includes highways, a major rail corridor, a navigable river, water supply, a natural gas line, an 820 MW coal-fired power station, a pre-cast concrete plant, an asphalt plant, and a newly constructed cast iron foundry.

The region surrounding the CMP is rural, yet quite industrialized. Within 25 km of the CMP one can find several automotive plants, chemical plants, metal fabricators, and numerous heavy and light industrial facilities. A significant skilled and trainable labour workforce is accessible in the nearby communities, including the villages of Chvaletice (population of 3,200) and Trnavka (population 250) and the nearby towns and cities of Kutna Hora (population 21,000), Kolin (population 31,000), Pardubice (population 89,000), Hradec Kralove (population 93,000), and Prague (population 1,200,000).

Mining supplies, equipment, services, and technical expertise can be found mainly in Ostrava, Prague, and Pardubice.

At present, Mangan does not hold surface rights to the whole of the CMP area, which is considered as those lands of original ground elevation surrounding and those parcels of original ground underlying and immediately surrounding Cells #1, #2, and #3. The area of interest for the CMP overlies 16 privately owned land parcels with surface rights. To date, Mangan received the consent to conduct exploration activities and to access the site from the landowners whose surface properties underlie the tailings.

Figure 1-2: CMP Tailings Cells – 2017 and 2018 Drill Hole Layout



Adjacent to the tailings area, EMN has a contract to purchase a 2.96 ha parcel of land (signed May 11, 2019) with the Municipality of Trnavka on which the Company plans to construct a visual and acoustic barrier between Trnavka and the Chvaletice Manganese Project tailings as well as a utility corridor. The Village of Trnavka formally approved rezoning of the land underlying approximately 85% of the tailings deposit area. The remaining area of the underlying land falls under the authority of the Municipality of Chvaletice, which lies just to the west of the Project. The Municipality of Chvaletice previously voted unanimously to approve the initiation of the rezoning process under its municipal land use plans. This process is progressing, and Mangan anticipates the rezoning of the Chvaletice land underlying the Project's tailings deposit to be formally approved for mining by the end of calendar 2022.

Additionally, a land package totalling 7.2 ha located on the northern-eastern portion of the tailings area has a purchase agreement (dated June 7, 2022) with the company Helot (owned by the Vanek family farmer) which will be used as the started area for the residue storage facility (RSF). This land purchase agreement provides additional room and flexibility for the CMP residue storage facility layout.

On June 6, 2022, Mangan also signed a lease agreement with the Municipality of Chvaletice for a total area of 26.6 ha, which represents approximately 19% of the total land area required for the Project and approximately 15% of the total tailings area. The lease agreement grants Mangan access to this surface area until the earlier of a 40-year period or upon remediation of the land. Mangan continues to negotiate the acquisition of the balance of the surface rights with the remaining two landowners.

An aggregated parcel of land located immediately to the south and across the highway from the tailings deposit comprising a total 27.19 ha is proposed for development and construction of a high-purity manganese processing facility and related infrastructure. The land purchase and agreement includes 19.94 ha of industrial zoned land in option agreement with EP Chvaletice s.r.o (signed October 17, 2018), a 1.7 ha parcel of land purchased by EMN (dated November 2017), a 5.0 ha parcel of land including a rail spur extension in agreement with Sprava Nemovitosti Kirchdorfer CZ s.r.o (signed December 18, 2020), a 0.2 ha section of land encompassing Rail Spur no. 1 purchased from Sev.en EC, a.s., the owner of the Chvaletice power plant, and a 0.35 ha right-of-way for a period of 30 years in lease agreement with Galmet Trade, spol s.r.o. as option for a proposed conveyor route. As a result of these agreements, Mangan has completed its land assembly for the proposed Chvaletice commercial plant.

EMN had initiated planning and preparation of the CMP's permit application since 2016. The EIA Notification for the Project was published by the MoE in December 2020. The conclusions of the EIA screening procedure did not result in any unexpected requirements.

The second and final stage of the Project's Environmental and Social Impact Assessment ("ESIA") is under preparation and is expected to be submitted to the Czech MoE in September 2022.

1.3 History

Historical mining in the region dates back to approximately 677 AD through to medieval times according to records of iron (Fe) production from small local mines. Intermittent mining for iron in the region continued through until the mid-19th Century, when iron and manganese (Mn) minerals near Chvaletice were discovered. Systematic underground mining within the Chvaletice Mine produced manganese ore between the years 1915 and 1945. Thereafter, from 1951 to 1975, open pit mining and milling operations occurred for the recovery of pyrite as the raw material for the production of sulphuric acid and gave rise to the the three adjacent CMP tailings deposits. Conversion from underground to bulk tonnage open pit mining occurred during this period, during which time an estimated 32 Mt of material was mined for pyrite, with approximately 20 Mm3 of waste rock along with approximately 17 Mm3 of flotation waste, which were placed into the unlined tailing ponds. These tailings ponds are the target of the CMP and are referred to as Cells #1, # 2, and #3. Mining, milling, and production of tailings material was terminated in 1975.

An extensive evaluation of the tailings material was conducted between April 1986 and July 1988 by Bateria Slany, the former Czechoslovakian, state-owned manufacturer of batteries, for the potential manufacture of electrolytic manganese dioxide (EMD). The results from their investigation included a "reserve calculation", currently registered as the "Řečany – Tailings Pond 3" and "Chvaletice – Tailings Ponds 1, 2" as a "State Reserve" with the Czech Republic Government. This historical calculation comprised 27,557,441 t of "reserves", containing 25,496,299 t at a grade of 5.15% leachable manganese (7.06% total manganese [tMn]) at a "C2" category, and 2,061,143 t of material average grade of 4.97% of leachable manganese (7.39% tMn) at a "C1" category. The definition of C2 and C1 categories references a system developed in the Union of Soviet Socialist Republics (USSR) for classification of mineral "resources" and "reserves", where resources classified as C1 are supported in greater detail than those that are classified as C2. The Czech system differs significantly from the classification system defined under the CIM Terms and Definitions as referenced by NI 43-101 and cannot be misconstrued to imply a similar level of confidence. This historical calculation cannot be relied upon as being accurate, particularly since the raw data that served as the basis for these calculations has not been found by EMN, as it appears to have been lost or destroyed following the end of Communism in the Czech Republic.

1.4 Mineral Resources

Based on work conducted by EMN under the supervision of Tetra Tech, the three tailings cells are estimated to contain approximately 18.6 Mm^3 of material, with approximately 17.8 Mm^3 comprised of silt and clay sized particulate tailings material. The remaining estimated 0.8 Mm^3 is native soils that were used for dam construction, erosion and dust control, and slope stabilization. Cell #1 averages approximately 26.6 m thick, with a surface area of approximately 326,400 m^2, and has a volume of approximately 6,720,300 m^3. Cell #2 averages approximately 28.7 m thick, with a surface area of approximately 393,200 m^2, and has a volume of approximately 8,035,200 m^3. Cell #3 averages approximately 11 m thick, with a surface area of approximately 313,200 m^2, and has a volume of approximately 3,035,900 m^3.

EMN began recent exploration activity on the Property in 2014, when a series of near surface samples were collected from auger holes and test pits for preliminary materials characterization. In June 2017, EMN initiated an 80-hole sonic drilling campaign totaling 1,679.3 m within Cells #1, #2, and #3 to evaluate the mineral resource potential both horizontally and vertically through the full tailings profile, referred to as the 2017 Drilling Program. Drill hole spacing was approximately 100 m throughout each cell. The perimeter embankments of each cell were not safely accessible to the sonic drill rig and were not drilled. To verify the composition of the embankments, four additional drill holes were collared on access ramps. Each drill hole intersected a layer of topsoil with average thickness of approximately 1 m, manganese bearing tailings material, and terminated in native basal soils at elevations consistent with other drill holes. During the summer of 2018, EMN conducted a second campaign of drilling at the CMP with a total of 80 drill holes, totalling 1,509.5 m. The program included completion of 35 vertical and 19 inclined 100 mm diameter sonic holes, totalling 1,409.5 m. An additional 26 mobile percussion drill holes, totalling 100 m, were completed around the perimeter embankments of the tailings piles in areas which were not previously accessed for sampling. The tailings material observed, sampled, and analyzed was generally very consistent in terms of total and soluble manganese grade and mineralogy. There has been no additional drilling or tailings investigations programs completed since 2018.

Information collected during these investigations is available for the purposes of mineralogy, hydrological, geotechnical, metallurgical, environmental, and process engineering design.

Samples were collected on intervals ranging from 0.925 to 4.1 m with the majority of samples and average length representative of the 2 m core runs. Each sample was logged for lithology, moisture content, particle size, wet mass, and recovery in the field. A total of 1,484 samples were split in the field longitudinally along the core. In 2017, a 25% sub-sample split of each sample was shipped to SGS Minerals Services (SGS) laboratories in Bor, Serbia, for analysis and test work. The remaining 75% sub-sample was shipped to Changsha Research Institute of Mining and Metallurgy Co. Ltd. (CRIMM) in China, for bulk sample metallurgical and process test work. In 2018, the sample was split with a 25% sub-sample collected for test work in the Czech Republic, and the remaining 75% collected and stored in vacuum-sealed bags, which were then placed in steel barrels, in a warehouse located near the CMP site, in order to remain fresh and unaltered, and available for future metallurgical and pilot plant testing.

A rigorous quality assurance (QA) and quality control (QC) program was implemented by EMN, which included use of field duplicates, lab duplicates, insertion of three certified reference materials (CRMs), and insertion of two certified blank materials. Drill hole twins completed in 2018 were used to verify the 2017 sample database. Quality control methods were reviewed by Tetra Tech's Competent Person (CP) James Barr, P.Geo. (Geology CP), during site visits to the Property. Following receipt of analytical results, Tetra Tech undertook compilation of the geological database, the verification of laboratory data, and the QA/QC program for data validation. The CP is satisfied that the sampling method and analytical integrity has been preserved throughout sample handling, preparation, and analytical process.

Analysis and test work conducted on the samples, included:

- Multi-element assay using aqua regia and four acid digestions as proxy for soluble manganese (sMn)
- Whole rock analysis using fusion x-ray fluorescence (XRF) for tMn concentrations
- Particle size analysis using laser diffraction and sieve/hydrometer methods
- Mass measurements
- Moisture content measurements
- Specific gravity measurements

EMN conducted a preliminary in situ dry bulk density investigation in advance of the 2017 drilling program using a cylinder test method from near surface samples. This work was followed by an in-depth calculation of in situ dry bulk density using core recovery volumes and dry mass using SGS laboratory measurements following both the 2017 and 2018 drilling investigations. Calculated in situ dry bulk density values for individual samples ranged between 0.35 and 3.154 t/m3, with a 95% probability interval of 0.87 to 2.01 t/m3, and average value of 1.49 t/m3 ±0.017 t/m3.

Manganese is primarily hosted in carbonate minerals with lesser amounts as silicate and oxide minerals, as identified by x-ray diffraction (XRD). Mineralogical studies have been completed by EMN in 2015 and reported by AMEC in their initial investigation in 2016 (AMEC 2016), and by CRIMM in 2017. The combined work identified that 80% of the manganese occurs as carbonate and 19% of the manganese occurred as silicate. The primary manganese carbonate is rhodochrosite ($MnCO_3$), with lesser amounts of manganese bearing carbonates having variable proportions of iron, calcium (Ca), and magnesium (Mg) with carbonate to form a wide variety of minerals from the rhodochrosite (Mn)-siderite(Fe)-dolomite(Mg)-calcite(Ca) spectrum. Scanning electron microscopy (SEM) investigation work identified a rare and locally named mineral kutnohorite ($Ca(Mn^{2+}, Mg, Fe^{2+})(CO_3)_2$) found within this spectrum and identified as a significant manganese bearing carbonate. Manganese bearing silicates include spessartine ($Mn_3Al_2(SiO_4)_3$), rhodonite ($(Mn, Fe, Mg, Ca)SiO_3$), and trace concentrations of sursassite

$(Mn_2^{2+}Al_3(SiO_4)(Si_2O_7)(OH)_3)$. Trace amounts of the manganese oxide pyrolusite (MnO_2) were also detected. Predominant gangue minerals are quartz, albite, muscovite, pyrite, and apatite.

Total sulphur concentration in the tailings averages approximately 3.4% which is sourced from sulphide, sulphate, and organic sulphur origin. Total carbon concentrations average approximately 3.5%, which includes contributions from graphite, organic carbon and carbonate origins. Figure 1- shows photos of core recovered from drill hole T1-312, near the core of Cell #1.

Figure 1-3: Core Photos from Drill Hole T1-312, from Depths 3 to 4 m, 9 to 10 m, and 23 to 25 m

1.4.1 Mineral Resource Estimate

A three-dimensional model was created for Cells #1, #2, and #3 using a digital topographic model (DTM) compiled by GET using data from the 5th generation digital elevation model (DEM) 5G developed by the Land Survey Office in Prague from light detection and ranging (LiDAR) data in the System Jednotne Trigonometricke Site Katastralni (S-JTSK) (Krovak East North) coordinate system and the Baltic Vertical Datum (BPV). The topography has been used to constrain volume estimates for each cell.

Lithology logs were used to construct an upper contacting surface between tailings and topsoil, then used to construct a lower contact surface between tailings and native subsoil. The intervening volume defined the volume of tailings material in each cell and was used to constrain all laboratory analysis and test work data that was subsequently used to model various physical and chemical attributes of the tailings material.

Data was analyzed in Phinar X10-Geo v.1.4.15.8, Snowden Supervisor v8.9.0.2 and Seequent Leapfrog® Geo v.4.4.2, and models were developed using Seequent Leapfrog® Geo v.4.4.2. All sample data was composited to

2 m, and each cell was modelled separately. No capping was applied to manganese grades as no outliers were identified on the normally distributed data.

Interpolated block models were developed for physical parameters including grain size, in situ dry bulk density, and moisture content, as well as an additional 18 elements. Grain size was represented using D_{50}, D_{80}, D_{90}, which are the average diameter of the particles at the 50th, 80th, and 90th percentiles within the sample, respectively, and using P_{75}, which is the percentage of the sample that passes a standard 200 mesh, equivalent to a 75 µm nominal mesh. The model results show that particle size transitions from coarse to fine inwards in each of the cells. Average P_{75} for each cell ranged from 66.48 to 71.29%, indicating that the bulk of the material is silt size or smaller. In situ dry bulk density varies throughout each cell and is a function of the composite mineral densities in addition to the degree of compaction in the soils. Modelled in situ dry bulk density values ranged from 1.10 to 2.15 t/m^3, with an overall average of 1.51 t/m^3. Moisture content measured from each sample ranges from approximately 1.2 to 39.3% and averaged 21.14% overall. As with particle size distributions, moisture shows a strong zonation towards the center of each cell where the material was observed to be saturated with above average moisture content.

Total and soluble manganese concentrations were interpolated using inverse distance (cubed) (ID^3) interpolation method into a sub-block model with 50 m by 50 m by 4 m parent blocks, and 12.5 m by 12.5 m by 2 m sub-blocks. The dry in situ bulk density model was applied to the sub-block model to calculate block tonnages. The block model was classified and validated by the Geology CP, using guidelines set forth by the JORC Code and CIM Best Practices. The Mineral Resource Estimate (MRE) was classified as Measured and Indicated based on sample spacing and variance assessment. Table 1-1 lists the MRE which has an effective date of July 1, 2022. This MRE supersedes the previous MRE with effective date of December 8, 2018.

Table 1-1: Mineral Resource Estimate for the Chvaletice Manganese Project, Effective July 1, 2022

Cell	Class	Volume ('000 m^3)	Tonnage (kt)	In Situ Dry Bulk Density (t/m^3)	Grade Mn (%)
#1	Measured	6,577	10,029	1.52	7.95
	Indicated	160	236	1.47	8.35
#2	Measured	7,990	12,201	1.53	6.79
	Indicated	123	189	1.55	7.22
#3	Measured	2,942	4,265	1.45	7.35
	Indicated	27	39	1.45	7.90
Total	**Measured**	**17,509**	**26,496**	**1.51**	**7.32**
	Indicated	**309**	**464**	**1.50**	**7.85**
Combined	**M&I**	**17,818**	**26,960**	**1.51**	**7.33**

Notes:

1. Estimated in accordance with the CIM Definition Standards on Mineral Resources and Mineral Reserves adopted by CIM council, as amended, which are materially identical to the JORC Code.
2. The Chvaletice Mineral Resource has a reasonable prospect for eventual economic extraction. Mineral Resources do not have demonstrated economic viability.
3. Indicated Mineral Resources have lower confidence that Measured Mineral Resources.
4. A break-even grade of 2.18% tMn has been estimated for the Chvaletice deposit based on preliminary pre-concentration operating costs of USD$6.47/t feed, leaching and refining operating cost estimates of USD$188/t feed, total recovery to HPEMM and HPMSM of approximately 60.5% and 58.9%, respectively, and a combined price

derived using metal prices of 9.60 kg/t for HPEMM and 3.72 kg/t for HPMSM (CPM Group Report, June 2022). The actual commodity price for these products may vary.

5. A cut-off grade has not been applied to the block model. The estimated break-even cut-off grade falls below the grade of most of the blocks (excluding 5,000 t which have grades less than 2.18% tMn). It is assumed that material segregation will not be possible during mining due to inherent difficulty of grade control and selective mining for this deposit type. An applied cut-off grade has no impact on the block model and Mineral Resource Statement.
6. Grade capping has not been applied.
7. Numbers may not add exactly due to rounding

1.5 Mineral Processing and Metallurgical Testing

Starting in 1986, several metallurgical test programs have been carried out to assess metallurgical responses of recovering manganese from the tailings materials that originated from pyrite mining conducted from 1951 to 1975. During 2015, 2017, 2018 and 2019 to 2021, EMN undertook further manganese recovery test programs, including semi-continuous pilot plant testing. The test work conducted before early 2017 has been discussed in the report titled *Technical Report and Mineral Resource Estimate for the Chvaletice Manganese Project, Chvaletice, Czech Republic*, released on June 21, 2018 (Tetra Tech 2018).

A comprehensive test program has been conducted since September 2017 using a total of 743 drilling core interval samples from the 2017 drill program. The main objectives of the test program are to verify the previous test findings and develop and optimize the process flowsheet and conditions to produce HPEMM. A separate test work program was conducted in 2018 to investigate the generation of HPMSM from the magnetic separation concentrate and from the EMM flakes.

During 2019 and 2021 as part of the Feasibility Study, Beijing General Research Institute for Mining and Metallurgy (BGRIMM) conducted a further test program mainly focusing on validating the previous test results generated from the 2017-2018 test program by CRIMM. BGRIMM also conducted equipment sizing testing with several Chinese equipment manufacturers in order to conduct liquid/solid separation and magnetic separation testing. BGRIMM's test work also investigated two key process reagents, which were sourced from European suppliers for solution purification. The Company has taken the strategic approach to source reagents from the EU.

In 2021, Jenike & Johanson (Jenike), based in Ontario, Canada, conducted material characterization and bulk material handling tests on the raw tailings, as well as a blend of non-magnetic tailings (NMT) and leach residue (LR) (NMT/LR or "residue") produced during the tests conducted by BGRIMM.

A total of 25 composite samples were constructed from the 2017 drill core interval samples representing different mineralogical characteristics, including grade, particle size, and spatial location variations. The tMn content of the samples vary from 5.71 to 8.77% tMn. The acid-soluble manganese to tMn ratio fluctuates in a narrow range of 0.75 to 0.85.

The 2017-2018 test work focused on developing and testing a flowsheet for the reliable production of HPEMM and HPMSM using the cleanest available technology to meet all Czech and European Union (EU) health, safety, and environmental standards. The test work program included:

- Process mineralogical study
- Pre-concentration of manganese minerals by high-intensity magnetic separation
- Sulphuric acid dissolution of manganese minerals from the magnetic separation concentrate
- Iron and phosphorus removal and related pregnant solution and leach residue separation

- Pregnant solution purification
- Selenium-free electrowinning followed by chromium (Cr)-free passivation to produce HPEMM
- Magnesium removal without the use of fluorine containing reagents
- HPMSM production directly from magnetic separation concentrate and from electrolytic manganese metal flakes
- Ancillary tests, including leach residue washing, manganese recovery from residual washing solution, and magnetic separation tailings, and leach residue dewatering and detoxification
- Potential equipment vendor verification tests, including magnetic separation, leach residue washing, magnetic separation tailings and leach residue dewatering/solid-liquid separation.

A program of locked-system, semi-continuous pilot plant testing investigated the metallurgical performance of the tailings samples for the flowsheet and process conditions developed from the bench tests and generated sample products, including HPEMM flakes and HPMSM powders.

A process mineralogical study was conducted on the Master Blend (MB) Composite sample prepared by CRIMM. The mineralogical characteristic study includes a mineral component determination by optical microscope, XRD diffraction analysis, SEM, and mineral chemical phase analysis. The study verified the previous findings, indicating that manganese mainly occurs in the form of manganese carbonates, including rhodochrosite and kutnohorite. The manganese carbonates account for approximately 80% of the tMn. The second main manganese mineral group, approximately 19% of the manganese, is in the form of manganese silicates.

Magnetic separation bench tests were conducted using two types of high-intensity magnetic separation machines, vertical ring-type (VR-type) separator and horizontal ring-type (HR-type) separator. The test results show that manganese recovery varies from 76.7 to 94.3% tMn, averaging 87.7% tMn, and on average magnetic separation can improve the feed manganese content from 7.2% tMn to approximately 14% tMn, ranging from 12.0 to 15.4% tMn.

During 2019 and 2021, BGRIMM used the samples that remained from the 2017-2018 CRIMM test program, weighing in total approximately 1.7 t, for the verification testing. Using a rougher separation followed by scavenger separation and scavenger cleaner separation, the test results from the MB composite prepared by BGRIMM produced a 15.1% Mn concentrate (combined rougher and scavenger cleaner concentrate) with a manganese recovery of 86.8%. Comparing with CRIMM's results, BGRIMM concluded that:

- It is feasible to use the magnetic separation process to recover the manganese bearing minerals
- Magnetic field intensity (MFI) of 1.5 T for both of rougher and scavenger separations is proposed, especially for the scavenger separation. This will provide an opportunity for a further improvement in manganese recovery, because the finer than 20 µm particle size is more than 50% w/w.

Considering the downstream iron (Fe)/phosphorus (P) removal treatment, the optimized leach conditions were determined as: leach temperature at approximately 90°C with a leach retention time of 5 to 6 hours and 0.42 acid to 1.0 feed ratio. On average, approximately 75% of the manganese can be extracted by sulphuric acid leaching, ranging from 71.9 to 82.8% tMn. BGRIMM's tests showed some variations in manganese extraction performances in the bench tests. However, in the large scale residue preparation testing using a higher acid to feed ratio (0.48 : 1.0) for generating the residue sample for dewatering produced an average manganese extraction of approximately 79%. BGRIMM also verified heavy metal removal test results using the reagents sourced from European suppliers.

Three semi-continuous pilot plant runs were conducted by CRIMM on the composite samples: a high-grade composite (Composite P1) and a low-grade composite (Composite P2) using the optimum conditions developed from the bench tests. The test flowsheet was based on the batch test results and industrial operation experience. The first pilot plant run on the MB composite sample showed that some of the impurity levels of the electrolytic manganese flakes may exceed some customer requirements (the HPEMM's specifications are confidential and commercially sensitive). Comprehensive testing was further conducted by a quality optimization intervention to optimize solution purification and electrowinning conditions. This optimization testing significantly improved electrowinning circuit performance and electrolytic manganese product quality. It is anticipated that the impurity content of the HPEMM should meet and/or possibly exceed some customer criteria. Using the optimized process conditions, the subsequent second and third semi-continuous pilot plant runs on Composites P1 and P2 were conducted. According to the assay results by CRIMM, the tMn content of the manganese flakes produced was higher than 99.9% (manganese content was calculated by subtracting total impurity content) and impurity levels are anticipated to meet or exceed the threshold specified by potential users. Table 1-2 summarizes the key circuit performances.

Table 1-2: Key Pilot Plant Test Results

Sample	Magnetic Separation		Acid Leach Extraction (% tMn)	Electrowinning	
	Concentrate Grade (% tMn)	Recovery (% tMn)		Current Efficiency (%)	Power Consumption (kWh/t EMM)
MB Composite	15.1	88.3	75.6	59.7	6,900
Composite P1	16.0	89.1	81.8	64.2	6,200
Composite P2	14.8	86.4	73.5	63.4	6,400

A preliminary test program was conducted to investigate the production of HPMSM from the Chvaletice mineral resource. Three different process schemes were tested separately, including HPMSM sample production:

- From direct acid leaching of the magnetic concentrate without electrowinning purification
- From 99.9% HPEMM (selenium and chromium free)
- From 99.7% EMM (selenium and chromium containing)

According to the assays by CRIMM, in general, the impurity content of the HPMSM powders produced from the three process schemes were lower than the target values, excluding the levels of sodium, fluorine, and heavy metals in the HPMSM directly produced from the magnetic concentrate. The best quality HPMSM, containing higher than 32.2% manganese, was produced from the HPEMM flakes generated from the pilot plant runs without the use of fluorine containing reagents.

Using the HPEMM flakes produced by the CRIMM's 2018 pilot plant, BGRIMM further verified and optimized HPEMM dissolution and manganese sulphate solution purification procedures proposed by CRIMM. BGRIMM also investigated MSM crystallization processes using a synthetic solution, one by conventional low temperature evaporation conducted at 70 to 100°C under a vacuum environment and one by high temperature crystallization at 160°C. The test results show that there is no significant difference in product particle size distribution between the crystallization methods. BGRIMM recommended using the conventional evaporation method for the project primarily because this process is a mature technology which is currently used in MSM production.

For the conventional low temperature evaporation testing, the crystallization testing was conducted at 70 to 100°C under a vacuum environment. The results showed that the particle size of MSM crystals increase with the evaporation temperature. The optimum crystallization temperature for the low temperature evaporation crystallization process should be at 100°C or higher. This was the crystallization route chosen for the CMP flowsheet.

Since 2018, EMN conducted various chemical and physical analysis for the HPEMM and HPMSM samples that were prepared from the bench scale tests and the pilot plant tests completed by CRIMM. The evaluation work also reviewed the target HPEMM and HPMSM specifications based on potential customer requirements.

1.6 Mineral Reserve Estimate

The Mineral Reserve estimate was prepared with reference to the 2014 CIM Definition Standards, the 2019 CIM Best Practice Guidelines and the JORC Code, 2012 Edition. Mineral Reserves for CMP are based on the Measured and Indicated Resources and an updated mine design and do not include any Inferred Resources. The estimate results are shown in Table 1-3.

The mineral reserves are estimated at 26,644,344 t at an average grade of 7.41% manganese, inclusive of dilution and other losses. Material economic modifying factors were applied to each block in the block model including mined grade, contained metal, recovery rates for HPEMM and HPMSM, mining operating cost, processing cost, (including HPEMM to HPMSM conversion cost), residue placement cost, general and administrative costs, site service costs, water treatment, shipping cost, product insurance, and royalties. HPMSM and HPEMM pricing used for Mineral Reserve estimation is based on price projection assumptions developed by CPM Group, an independent high-purity manganese market research firm.

Table 1-3: Mineral Reserve Estimate for the Chvaletice Manganese Project, Effective Date July 14, 2022

Cell	Class	Volume (000 m^3)	Tonnage (000 t)	In-Situ Dry Bulk Density (t/m^3)	tMn (%)
1	Proven	6,651	10,132	1.51	7.83
	Probable	141	208	1.52	8.24
2	Proven	7,929	12,106	1.53	6.91
	Probable	119	183	1.54	7.35
3	Proven	2,744	3,979	1.46	7.49
	Probable	25	36	1.46	7.98
Total	**Proven**	**17,325**	**26,217**	**1.5**	**7.36**
	Probable	**284**	**427**	**1.52**	**7.82**
Combined	**--**	**17,609**	**26,644**	**1.51**	**7.41**

Notes:

1. Estimated in accordance with the CIM Definition Standards on Mineral Resources and Mineral Reserves adopted by the CIM council, as amended, which are materially identical to the JORC Code.
2. Probable Reserves have lower confidence than Proven Reserves. No Measured Resources were included within Probable Reserves. Inferred Resources have not been included in the Reserves.
3. A breakeven grade of 2.18% total Mn has been estimated for the Chvaletice deposit based on preliminary pre-concentration operating costs of $6.47/t feed, leaching, and refining operating costs of $188/t feed, total recovery to HPEMM and HPMSM of approximately 60.5%

TETRA TECH

and 58.9% respectively, and product prices of $9.60/kg for HPEMM and $3.72/kg for HPMSM (CPM Group Report, June 2022, forecast price average 2027 to 2031). The actual commodity price for these products may vary.

4. Grade capping has not been applied.
5. Minimal dilution and losses of <1% are expected to occur at the interface between the lower bounds of the tailings cells and original ground due to the uneven surface.
6. Numbers may not add exactly due to rounding.

The CP is not aware of any mining, metallurgical, infrastructure, permitting, or other issues above those discussed in the Public Report that could materially affect the stated Mineral Reserve estimates.

1.7 Tailings Extraction Methods

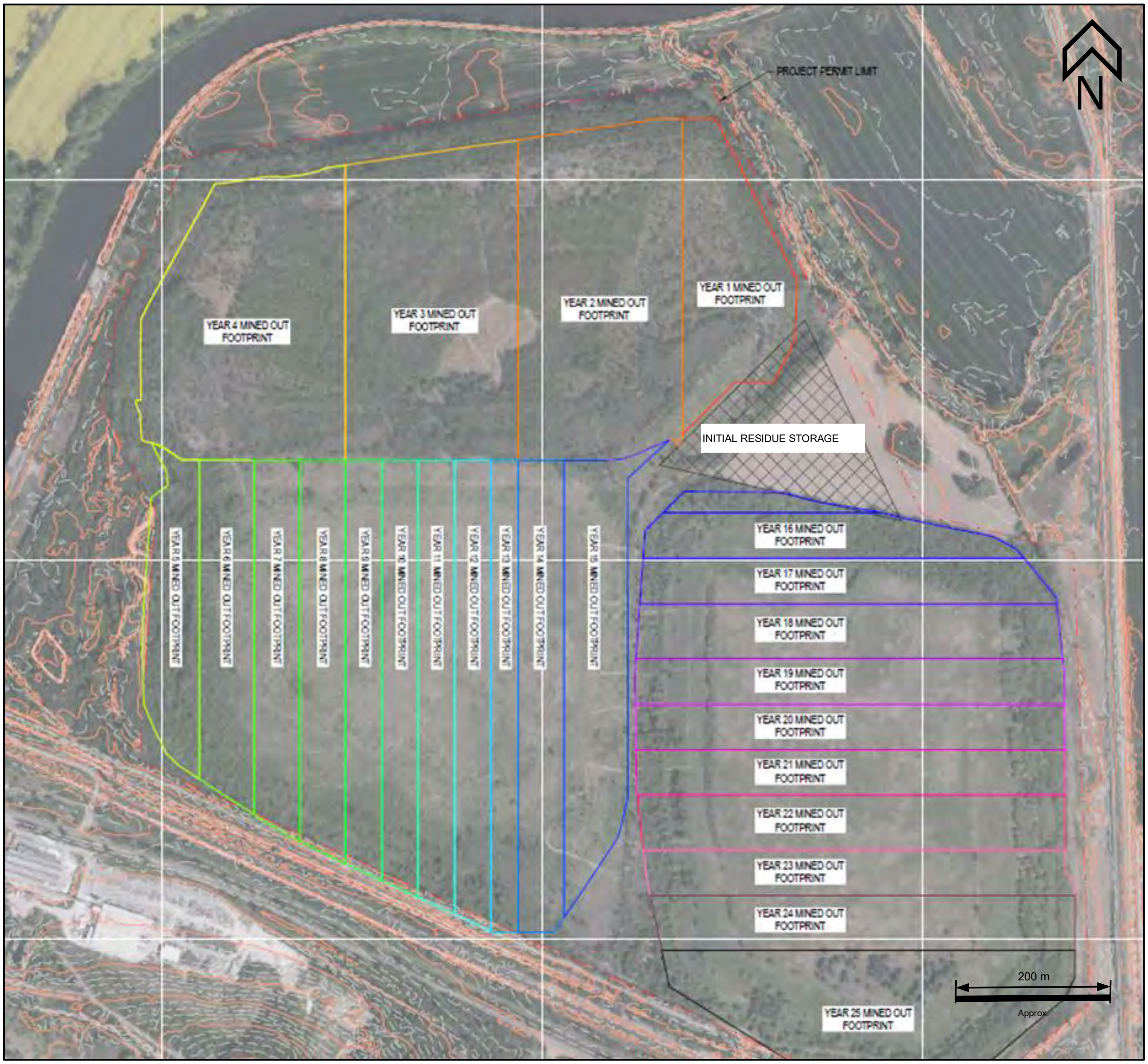
The CMP mine plan is designed to produce approximately 3,000 t/day of tailings feed over a 25-year project life. The mine plan is based on truck and shovel equipment extracting the tailings in benches from the three tailings cells. The mine design criteria were based on the project and regulatory requirements. The bench designs were based on geotechnical and hydrogeological analysis and permits. The tailings will be extracted at a rate that allows the residue to be placed within the existing footprint. A main haul road between the tailings cells to a plant feed storage area will provide access to all cells and temporary haul ramps will be developed in each cell as they advance. No drilling or blasting will be required to mine the cells.

Tailings are extracted from the cells and transported by truck to the raw tailings receiving area, where they are unloaded into a receiving dump pocket and conveyed to the tailings storage stockpile in the plant feed and tailings storage and pulping building and then processed to recover manganese. The process plant produces NMT and LR as a waste product (collectively referred to as ‘residue’). This residue is collected from the process plant and conveyed to the residue storage stockpile within the plant feed and tailings storage and pulping building. The residue is then transported by truck back to the tailings cell area. The residue is deposited in the original footprint of the tailings cells, in the area that has already been mined. Once the trucks have unloaded the residue material, they return to the active mining bench to collect raw tailings material to return to the plant feed and tailings storage and pulping building again in a continuous cycle. As shown in Figure 1-4, the tailings extraction will start from Cell #3, followed by Cell # 1 and Cell #2 sequentially. The primary drivers of the production schedule are mining the tailings to meet the plant production targets and advancement of the toe of the tailings material to allow storage capacity for the residue placement. Topsoil growth on the cells will be removed prior to mining the tailings.

Mining the tailings cells of the CMP will be completed during two eight-hour shifts, weekdays, in daylight hours to minimize community disturbance. Mining operations will be done 250 days a year, 5 days a week, excluding weekends and holidays. The pre-production requirements of the Project are minimal given the absence of significant overburden and topsoil that will need to be stripped on an annual basis. Passive depressurization of the tailings cells from the cut slopes of the mining benches will allow mining equipment to operate on the benches without active dewatering during operations.

The amount of equipment required to meet the scheduled tonnages is calculated based on the mine and residue schedules, equipment availability, usage, and hauling and loading times for the equipment. Selected mine equipment can be sourced and maintained in close proximity to the Project. On-site infrastructure includes a warehouse/administration building, truck maintenance workshop, fuel station, truck washing facility, parking areas, and temporary storage areas for tailings and residue.

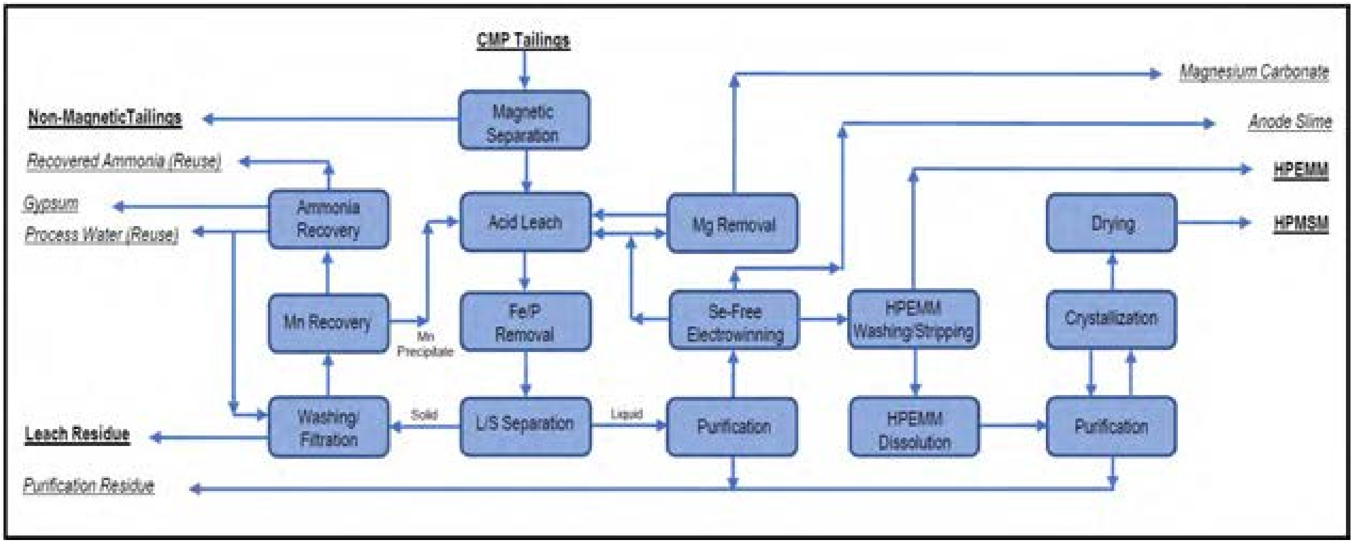
Figure 1-4: Selected Extraction Sequence for the CMP Tailings



1.8 Recovery Methods

The CMP project is designed for a 25-year life at a nominal, nameplate production rate of 50,000 t/a of HPEMM, by extracting approximately 1.1 Mt/a of the CMP tailings. Two-thirds of the annual HPEMM flake production is expected to be converted to approximately 100,000 t/a of HPMSM. HPEMM product containing greater than 99.9% manganese is expected to be sold as flakes and will be produced without the use of selenium and chromium. The CMP HPMSM product will be designed to contain no less than 99.9% manganese sulphate monohydrate (MSM), a minimum of 32.34% manganese, and will be sold in powder form, produced without the use of fluorine. Figure 1-5 shows the proposed process flowsheet.

Figure 1-5: Simplified Process Flowsheet



Excavated tailings will be pulped and pumped via a pipeline carried by an overhead bridge that will cross Highway #322, the rail line, and related rail spur that adjoins to the proposed process plant site located south of the CMP tailings cells.

The tailings slurry will be beneficiated in a wet, high-intensity magnetic separation circuit that will upgrade the manganese grade of the leach feed to approximately 15% tMn and, on average, reject approximately 57% of the feed to NMT, with an expected 86% manganese recovery. The magnetic concentrate and NMT produced will be dewatered using thickeners and filters. The concentrate will be fed to the downstream leach process and the dewatered tailings, together with the washed leach residue, will be dry stacked at the residue storage facility (RSF).

The magnetic concentrate cake will be re-pulped using anolyte solution from the electrowinning tank house and leached, together with recovered manganese carbonate from process solutions, using sulphuric acid at 90°C for approximately six hours. Neutralization of the slurry will be achieved using dry powder lime. Air sparging of the neutralized slurry will be used to cost-effectively co-precipitate the substantial quantities of impurities that leach with the manganese. The leach pulp will be filtered in automatic pressure filters to separate the pregnant leach solution from the LR.

The leach residue will then be repulped with the washing water from the downstream filter cake washing process. The slurry will be then dewatered using pressure filtration equipped multi-stage onstream washing using process water. The washed LR filter will be blended with the NMT filter cake and conveyed to the tailings extraction site prior to co-disposal in a lined dry stack tailings storage facility that will be progressively constructed in excavated areas of the CMP tailings cells.

The wash water from the leach residue washing circuit will be treated for manganese and ammonia recovery in order to minimize manganese and ammonia losses. The wash water recovery system will recover manganese units to the leaching circuit in the form of manganese carbonate. The spent wash water solution will be subsequently treated to recover ammonia using a conventional lime boil process and will produce a gypsum by-product, the potential value of which is not included in the CMP economics. The recovered ammonia will be re-used in the HPEMM production circuits. The inclusion of the leach residue washing circuit, with its associated wash water recovery circuit, is expected to be a world-leading industry practice for the hydrometallurgical processing of manganese ores. Returning washed tailings to the carefully prepared containment cells in the excavated areas of the CMP tailings progressively remediates the environmental impact risks of legacy mining operations.

The pregnant solution from the leaching circuit will be purified to remove heavy metals and other impurities and stabilized to prevent uncontrolled crystallization of salts to produce a qualified solution for the downstream electrowinning process.

Electrowinning will be conducted in electrowinning cells following the addition of ammonium bisulphite (NH_4HSO_3) as sulphur dioxide (SO_2) source to the tank house feed solution. The tank house shall have a nominal capacity to produce 50,000 t/a HPEMM using an energy-efficient and selenium-free process. The proposed electrowinning circuit is designed to have a plating cycle of 24 hours at a cell voltage of 4.2 to 4.4 V and an average cathode-current density of 320 to 370 A/m^2. Cathodes will be harvested using automatic harvesting machines, washed, and stripped of electrodeposited manganese metal using Chinese based industry-standard automatic cathode plate stripping machines. The design of the CMP tank house includes comprehensive mist emission control and mechanical handling systems that minimize manual handling of cathodes and other processes. Tank house system design features include anode slime handling, as well as diaphragm cleaning and ongoing cell maintenance operations. Approximately two-thirds of the HPEMM flakes would then be used as feed for HPMSM production. The remaining HPEMM flakes would be packed and directly shipped to customers.

A magnesium removal process has been incorporated into the process plant design to ensure efficient electrowinning operations and high-quality products. The magnesium removal process will maintain the magnesium concentration in the electrowinning solutions at a level that prevents uncontrolled precipitation of salts and scaling. The process will use low-cost reagents without incurring significant losses of manganese and reagent units and will not require the use of magnesium removal reagents containing fluorine.

The FS production plan proposes to dissolve approximately two-thirds of the HPEMM flakes using high purity sulphuric acid to produce 100,000 t/a of HPMSM powder. The dissolved HPMSM solution will be further purified to remove trace impurities carried by the HPEMM flakes. The purified mother solution will be concentrated using an energy-efficient, low-temperature mechanical vapor recompression (MVR) crystallization process to generate manganese sulphate monohydrate crystals. The HPMSM crystals will be separated from the saturated MVR crystal slurry using centrifuges. The dewatered crystals will be dried using disc type dryers to produce the final HPMSM powder, while the spent mother solution will return to the mother solution purification circuit or to the crystallization circuit. The dried HPMSM powder product will be packed prior to being shipped in trucks or containers to customers which will primarily be located within the European countries. Table 1-4 summarizes projected manganese product production and metal recovery for the CMP.

Table 1-4: Projected Manganese Product Production and Metal Recovery

Year	Tailings Reprocessed (kt)	Plant Feed Grade (% tMn)	HPEMM Produced (kt)*	HPMSM Produced (kt)*	Overall Recovery (% tMn)
1	718	7.98	10.4	65.0	55.0
2	1,113	7.41	16.7	100.0	59.6
3	1,107	7.44	16.7	100.0	59.6
4 to 25 Average	1,078	7.39	14.9	100.0	59.5
Average	**1,066**	**7.41**	14.9	98.6	59.4

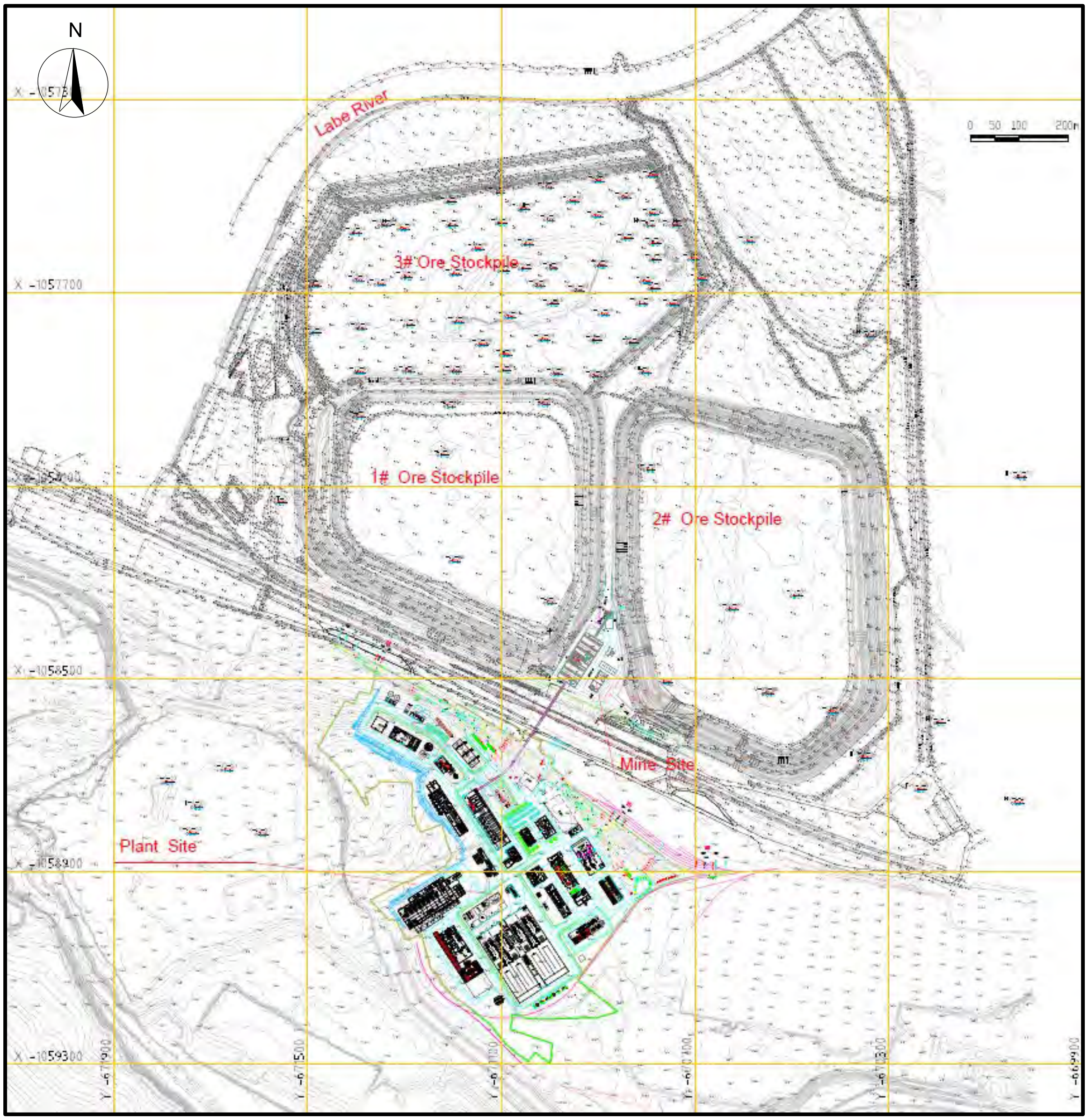
Note: *Approximately two-thirds of the annual HPEMM production is converted to HPMSM on the site, with the balance being sold as HPEMM.

1.9 Project Infrastructure

1.9.1 General Infrastructure

The CMP is a brownfield project adjacent to existing infrastructure which includes an 820 MW coal-fired power station operated by Severní Energetická a.s. (Severní), a pre-cast concrete plant operated by TIBA Chvaletice s.r.o., a main railway, and railway spur lines. A new cast iron foundry by KASI spol. s.r.o. and a new asphalt plant by Obalovna Chvaletice a.s., immediately adjacent to the proposed CMP plant site, were recently constructed. Highway #322 connects to Prague, 89 km away by road, via Kolin and Highway #12. The railway acts as a main transportation line from Prague to communities in the Eastern Czech Republic. The proposed location for the high-purity manganese production plant is located at the same site of the former flotation plant that produced the CMP tailings.

Figure 1-6: CMP Project Site Layout



New infrastructure will be built to service the CMP, including:

- Existing CMP tailings site: CMP tailings excavation and handling facility, including mobile fleet maintenance workshop and office complex, fuel station, sewage treatment plant, the tailings pulping facility and temporary stockpile storage facilities for the plant feed and dewatered residue for dry stacking on a lined RSF. The residue will be conveyed to the stockpile storage area from the process plant and then trucked to the excavated CMP tailings area which will be lined with a geomembrane liner, including basal, sand layer for protection, and drainage of the filtered residue stack.
- South and north site connection bridge (conveyor gallery) which will service the tailings slurry transport from the north site to the south site and the residue mixture transport by a tube conveyor from the south site to the

residue storage area at the north site. The bridge will also provide other services, such as power and water lines.

- Process plant site: Main process facilities, as shown in the layout in Figure 1-7, will be located at the site, including:
  - Magnetic separation facility, including NMT dewatering circuit
  - Magnetic concentrate dewatering and concentrate re-pulping facility
  - Concentrate sulphuric acid leaching and iron and phosphorus removal facility, including residual manganese recovery (from washing water solution)
  - Leach residue washing and residue dewatering facility
  - Ammonia recovery facility
  - Magnesium removal facility
  - Pregnant solution purification facility
  - HPEMM electrowinning, plate cleaning, stripping, packing, and storage facility
  - HPMSM production facilities, including HPEMM dissolution, solution purification, crystallization, HPMSM crystal dewatering and drying, and product handling facilities
  - Central control system

Figure 1-7: Proposed Process Plant Site Layout (3D Format)

TETRA TECH

There will also be other service infrastructure located at the process plant site, including:

- Two 400 kV/37.5 kV/10.5 kV step-down transformers contained within the main plant site substation; four 350 VDC, 36 kA (2 x 18 kA) rectifier transformers and various local step-down transformers
- Emergency power supply generator
- Process equipment maintenance workshop, spare parts and maintenance supply warehouses
- Water supply and management system, including contact water collection and treatment, water cooling systems, and process water treatment facilities, and a fire water system
- Assay and metallurgical test laboratories for operation supporting and QA/QC control
- General management office
- Change rooms and dining facility
- Commercial truck and private car parking areas
- Upgraded rail spur system and related loading and unloading facilities, including sulphuric acid storage tanks, lime silos
- Onsite road network, servicing overall site facilities
- Waste storage, including anode slime storage and other waste material temporary storage prior to being shipped offsite for recycling or disposal

Local electrical power is supplied by the high voltage Czech transmission grid operated by ČEPS, a.s. (CEPS). There is an 820 MW power coal-fired station which is one of key nodes in the Czech electrical generation network. The estimated power demand of the CMP is approximately 75 MVA. Incoming power will feed to two 400 kV/37.5 kV/10.5 kV step-down transformers located at the plant site substation, which shall be supplied by a single, buried 400kV cable connected to dedicated substation bay at the adjacent power plant. Additionally, four 350 VDC, 36 kA (2 x 18 kA) rectifier transformers shall convert alternating power to direct current supply as required by the electrowinning process. Local step-down transformers feeding the main plant overhead, 10 kV, site wide power distribution system will deliver electrical energy throughout the process plant site and tailings excavation site.

The water supply system will consist of fresh make-up water, cooling circulation water, potable water, and fire water supply systems. In-situ water contained within the CMP tailings will be part of the process make-up water and is accounted for in the overall water balance. All the process water used in the process circuits will be directly re-used or treated and re-used as process make-up water which will be supplemented by makeup water (blowdown water from the adjacent Severní power plant). In addition, demineralized water for steam generation and hot water (130°C) for process heating and building heating will be also sourced from the adjacent power plant.

There are two water management systems at both the north and south sites, one for contact water and one for non-contact/storm water. The surface water management is further discussed in Section 1.9.3.

Potable water will be supplied from local water service system.

The steam used for the CMP will be generated from an on-site steam plant fired with natural gas. There will also be a dedicated hydrogen gas boiler contained within the same steam plant which will be fuelled by the hydrogen gas recovered from the HPEMM dissolution circuit The primary use of steam is the ammonia recovery and HPMSM production circuits.

Compressed air servicing various process circuits, mainly for iron/phosphorus removal circuit and filtration circuits, maintenances, and instrumentation systems, will be supplied from a central compressed air station and supplement by various local compressor stations.

1.9.2 Residue Storage Facility

The RSF design involves placement of filtered residue in an engineered and geomembrane-lined containment area constructed within the same footprint as the existing CMP tailings piles. The prepared RSF foundation will incorporate perimeter surface water diversion and a geomembrane liner for contact water collection from the filtered residue stack. The facility will be constructed in stages to suit residue storage requirements. Progressive cover placement/reclamation will be undertaken during the operational life where possible. The design was developed based on project requirements, geotechnical and hydrogeological site investigation, and geotechnical and geochemical laboratory characterization of the proposed residue. The ultimate shape at closure is shown in Figure 1-8.

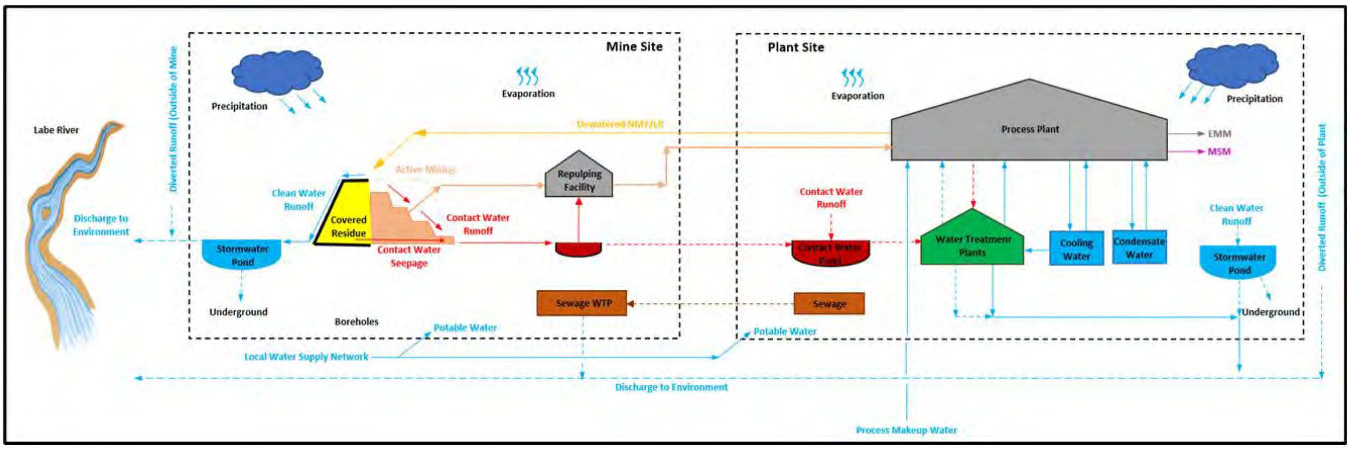
Figure 1-8: RSF Closure Design

1.9.3 Site Wide Water Management Plan

All the water within the plant site will be managed to mitigate potential contamination of the surface and seepage water. Water management for the raw tailings site and the plant site will follow basic principals of keeping clean water clean and managing surface water flows using conveyances, such as collection ditches, ponds and surge tanks, reducing surficial inflow from neighboring properties and use of liners to reduce infiltration into groundwater.

Based on the local water authorities guide, a clean stormwater pond shall be sized such that the peak flow from the clean runoff for the post development condition is reduced to the peak flow from the clean runoff for the predevelopment condition during a 1:10 year, 1-hour storm event. The proposed water management strategy schematic for the CMP project is shown in Figure 1-8.

Figure 1-8: Surface Water Management Concept for Chvaletice Manganese Project Site



1.9.3.1 Mine Site Water Management

The surface and groundwater drainage from the existing Chvaletice mine area currently enters the natural environment as seepage to groundwater and as runoff to the Labe River.

During the mining activity period, the contact runoff and seepage from the active mining area and the RSF will be collected through collection ditches and then routed into a collection pond and surge tanks at the mine site. The water will be used as process makeup water for the raw tailings pulping process. Flows from any storm event exceeding the capacity of this contact water storage (up to 1:200 year storm event) will be diverted towards the main contact water collection pond in the plant site. The water in the collection pond at the plant site will be treated and then either used as process makeup water or discharged to the environment. The collection ponds and ditches will be lined to control seepage. The seepage from the reclaimed RSF is expected to reduce to a relatively insignificant volume a few years following the completion of installation of the final reclamation cover. Until then and through closure phase, the collected contact water shall be monitored and treated as required prior to being discharged to the environment. The quality of the water that will be discharged into the surrounding environment, including Labe River, is expected to be improved through time as mine contact water is collected and managed.

All the non-contact water will be collected and directed to the non-contact water surge ponds from where the water will be released to the environment at a controlled rate.

TETRA TECH

1.9.3.2 Plant Site Water Management

The proposed process plant will be constructed south of the mine site within an existing industrial park. All the water within the plant site will be managed to mitigate potential contamination of the surface and seepage water.

The contact water from the site will first be collected and directed to a contact water control pond located at the north edge of the plant site. All ditches and the contact water pond that are used to manage contact water will be lined to mitigate seepage. The collected contact water from the site will be treated and used as process makeup water or discharged into the environment if its quality has met the environmental discharge requirement.

Non-contact/storm run-off water from outside of the process plant site will be diverted to the environment. All the non-contact water, including the water from building roofs, will be collected and directed to the site stormwater control pond prior to being released to the environment at a controlled rate or being used as a makeup water source for process use.

1.9.3.3 Sitewide Water Balance

A sitewide water balance analysis using the GoldSIM model for the CMP was completed by evaluating the balance among the inflows, outflows and storage associated to the system. The water balance model was used to estimate:

- The amount of contact water available for process use from both the mine and plant site areas;
- The makeup water requirement from various sources; and
- Annual discharge rates from the stormwater ponds to the Labe River.

1.10 Environmental Studies, Permitting, and Social or Community Impact

The CMP entails the reprocessing of mine tailings deposited in close proximity to several communities, farms, light and heavy industrial operations, recreation areas, forested and rural fauna and flora habitats, as well the Labe River. The tailings cells and proposed process plant area are brownfield sites that have been significantly impacted by past industrial activities. The tailings have been placed directly on former farm fields in the alluvial plain of the Labe Valley without any underlying containment or lining system. These tailings have been leaching metals and minerals into the underlying sediments and aquifer for decades and continue to do so. The proposed plant site contains numerous buildings and infrastructure in various states of disrepair, when the site was used for the production of sulphuric acid, dating back to 1951-1975. Numerous buildings on this site continue to be occupied by small, light industrial businesses. Mining activity at CMP ended in 1975. Czech law exempts landowners and developers from impacts prior to 1989, when communism ended in the then Czechoslovakia.

Mangan started environmental and social baseline programs for the CMP in the summer of 2016 together with work in support of an Environmental Impact Assessment (EIA) Notification. Preliminary results are presented for air quality, noise, hydrology, hydrogeology, fisheries and aquatics, ecosystems, vegetation and soils, wildlife and wildlife habitat, and socioeconomics. Local features of interest were identified and recorded, including sensitive and protected areas, vegetation, landscape elements, and areas or sites of historical, cultural, archaeological, or geological importance. Climate, air, water, soil, natural resources, fauna, flora, and ecosystems, landscape, and population of the area were inventoried.

The crucial point of the project is to participate in the environmental and social impact assessment process and receive a binding statement from the applicable authorities, in this case, the MoE. The EIA permit is the most critical milestone to start project implementation because EIA appropriation is a trigger point for equipment, material and works supply contracts, land planning request, and construction permit initiation.

Several strategies for the EIA process were considered initially and the following strategy for the EIA process was assessed as being the most efficient. A consolidated EIA would be prepared for tailings extraction, dry-stacking, and the process plant, and two-staged process would be pursued for submission to authorities. Stage 1 includes the full scope (beyond the legislative requirements) of the EIA Notification together with expert studies and surveys with a full assessment of the project's anticipated impacts and proposed mitigation measures. Stage 2 includes EIA documentation according to the legislative requirements taking into consideration the requirements arising from the EIA Notification and comments from the authorities which were addressed in project design.

In 2019 – 2020, Bilfinger Tebodin Czech Republic conducted the Preliminary Environmental and Social Impact Assessment (PESIA or EIA Notification) as the first stage of environmental assessment of the Project. Several detailed expert studies were prepared, including a comprehensive site wide biological survey, a detailed air dispersion model and study, an acoustic/noise impact study, a road and rail transportation study, a site wide hydrogeological survey, a health impact assessment, an impact on landscape character study, and a reclamation and remediation study. A screening decision summarizing all received comments on the Company's EIA Notification was published by the MoE in December 2020. The conclusions of the EIA screening procedure did not result in any unexpected requirements.

Socioeconomic studies were prepared by the Faculty of Social Geography at Charles University to evaluate how the CMP might affect population movements and commuting patterns for work. It is anticipated that labour for the CMP could be drawn from the Chvaletice area and broader Pardubice Region, which has an educated, skilled labour pool. The anticipated socioeconomic effects are expected to be modest at a regional scale, but positive and valuable for local communities. Problems such as social polarization, segregation, and other phenomena related to moving or housing are not anticipated to be significant.

The construction of the CMP facilities is expected to last approximately 30 to 36 months. The productive life of the project is planned to be 25 years. Reclamation and restoration activities at the site to facilitate the return to a natural, productive state is expected to take a further one to two years. The vast majority of the reclamation is scheduled to be conducted progressively beginning shortly after commercial operations commence. While extensive efforts have been made to design a world-class manganese operation, applying best international practices and cleanest available technologies, there are numerous site-specific and local sensitivities that still need to be addressed by the CMP development and operations plan, and potential impacts that must still be avoided or mitigated. Many of these have already been addressed and assessed within the initial environmental and social impact assessment (EIA Notification) and will be further identified in the context of an extensive community, stakeholder, and regulatory agency consultation process.

The second and final stage of the Project's Environmental and Social Impact Assessment (ESIA) is under preparation and is expected to be submitted to the Czech MoE in September 2022. The ESIA will include a detailed description of:

- The manganese production process and resulting environmental footprint of the Project;
- Results of baseline and other studies conducted to date;
- Health, safety, and environmental management plans;
- Impact assessment, impact mitigation and avoidance plans/measures;

- Socioeconomic impacts on local communities;
- Reclamation plans/objectives; and
- Acoustic and dispersion modeling results.

1.11 Project Execution Plan

In order to achieve a commencement of commercial production by Q1, 2027, an aggressive front-end initiative must be established. The project should transition from the FS Phase to EPCM in the first quarter of 2023, at which point the company expects to award an EPCM contract. Tender preparations are currently underway and expected to be issued in mid-September 2022. The project is anticipated to move forward in two phases:

- Phase 1 – Upon award of EPCM contract, initial work will involve a basic engineering design phase with the main objective of finalizing and freezing the design in addition to assess further value engineering opportunities for the primary purpose of capex cost reductions and process improvements.
- Phase 2 – Full Project Execution following receipt of project financing and investment decision by the company, concurrent with receipt of major permits and will include a continuation of detailed design, procurement, construction team mobilization, construction, and commissioning.

A Level 1, Project Development Schedule has been prepared during the FS in order to outline the overall timeline and key constraints. The critical path of the project currently falls through the environmental impact assessment, detailed engineering, construction, and commissioning phases.

Based on preliminary guidance by BGRIMM along with quotes received from local construction companies, the detailed design phase is estimated to be 18 months (inclusive of basic design), during which time long lead equipment is identified and ordered. Construction duration of 30 months has been advised due to the small and restricted plant site working area, process complexity, careful interface required with the local community, and labour work hour restrictions in the Czech Republic.

1.12 Logistics

Pinnacle Logistics Solutions conducted a high level logistics study for the CMP project, with particular focus on current major transportation networks available for transport to the site. The basis of the FS was supply of process related equipment from China, along with local supply of materials and labour. Based on this approach, it is envisioned that a combination of road, rail, and ocean transportation should be considered and further investigated.

1.13 Capital and Operating Cost Estimates

1.13.1 Capital Cost Estimate

The total estimated initial capital cost for the design, construction, installation, and commissioning of the CMP is USD$757.4 million. Table 1-5 shows a summary breakdown of the initial capital cost. This total includes all direct costs, indirect costs, Owner's costs, and contingency.

The capital cost estimate produced for the CMP is classified as a Class 3 for the FS with an expected accuracy of -10% to +20% according to the American Association of Cost Engineering (AACE). All costs are shown in United States Dollars (USD) unless otherwise specified.

Table 1-5: Capital Cost Summary

Area		Cost (USD$ million)
Direct Costs		
10	Overall Site	57.5
30	Tailings Extraction	4.6
35 & 40	Process	352.8
50	Residue Management	5.6
70	On-site Infrastructure	82.9
Direct Cost Subtotal		**503.4**
Indirect Costs		
90	Project Indirect Costs	128.4
98	Owner's Costs	47.2
Indirect Cost Subtotal		175.6
99	Contingency	78.4
Total		**757.4**

The base currency of the estimate is USD. Tetra Tech used the foreign currency exchange rates shown in Table 1-6 where applicable. The foreign exchange rates are based on three-year average foreign exchange rates, up to May 31, 2022.

Table 1-6: Foreign Exchange Rates

Base Currency (USD$)	Foreign Currency
1.00	CAD$1.30
1.00	CZK22.43 Kč
1.00	EUR€0.87
1.00	RMB¥6.71

1.13.2 Operating Cost Estimate

On average, the on-site operating costs are estimated as USD$194.79/t of CMP tailings reprocessed, or USD$4.43/kg manganese metal produced (equivalent). The on-site operating costs are defined as the direct operating costs, including CMP tailings extraction, processing, water treatment, residue dry stacking, site servicing, and G&A costs, and excluding offsite costs, such as product freight costs, sales related costs, government royalties, which are included in the economic analysis (Section 22.0).

The estimates are based on an average annual plant feed rate of approximately 1.1 Mt of the CMP tailings, or an average annual manganese metal production of 47.5 kt (tMn equivalent in HPEMM and HPMSM, ranging from 45,582 to 49,428 t/a of manganese), excluding the first ramp-up year. Table 1-7 shows the life of project (LOP) average cost breakdown for various areas and Figure 1-9 shows the cost distribution. The major cost for the CMP is the HPEMM and HPMSM processing cost (Figure 1-10), which accounts for approximately 73.4% of the total cost, excluding service costs required for water and steam supply and water treatment. A contingency of 5% is included in the estimate.

Table 1-7: LOP Average HPEMM and HPMSM Production Operating Cost Summary

Area	Unit Operating Cost	
	(USD$/t processed)	(USD$/kg Mn)*
Tailings Extraction	2.44	0.05
Magnetic Separation, HPEMM and HPMSM Processing	143.18	3.26
Site Services and Water Treatment	25.46	0.58
Tailings Stacking/Storage	0.66	0.02
G&A	13.78	0.31
Contingency on Operating Costs	9.28	0.21
Total Operating Cost	**194.79**	**4.43**

Note: * Unit cost per kilogram manganese metal produced (equivalent) contained in HPEMM and HPMSM.

Figure 1-9: Overall Operating Cost Distribution by Area

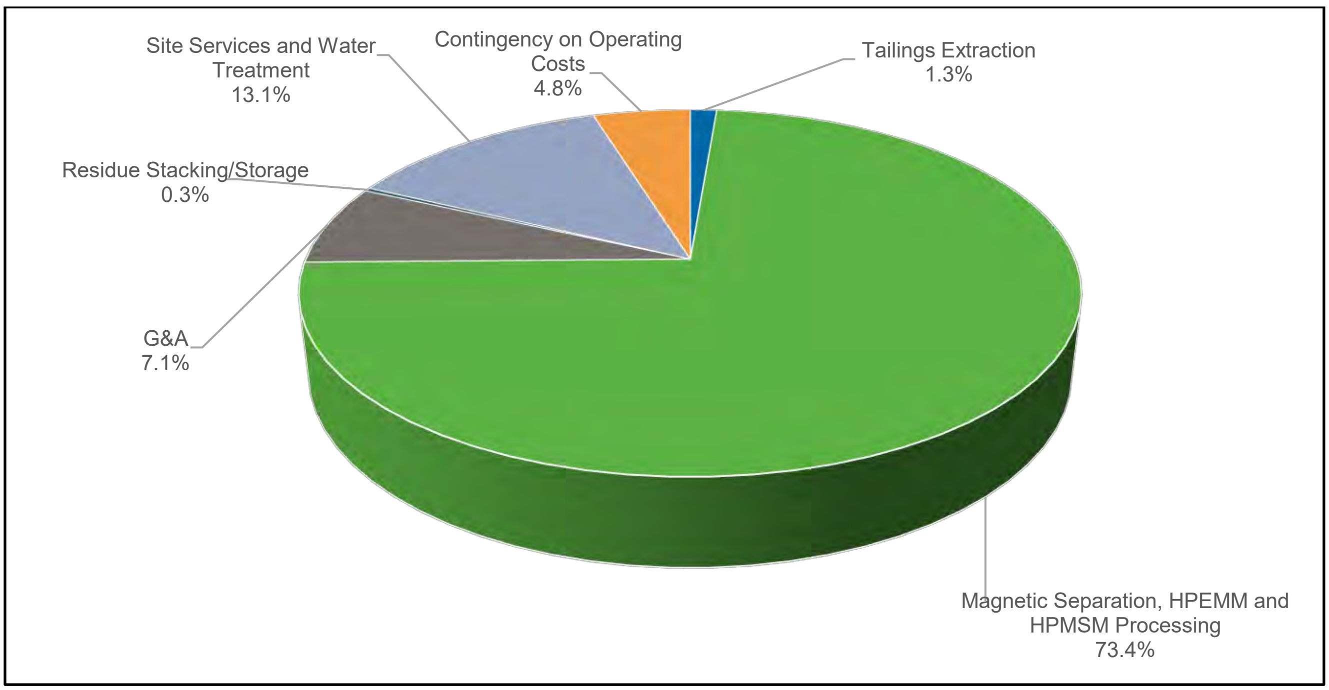
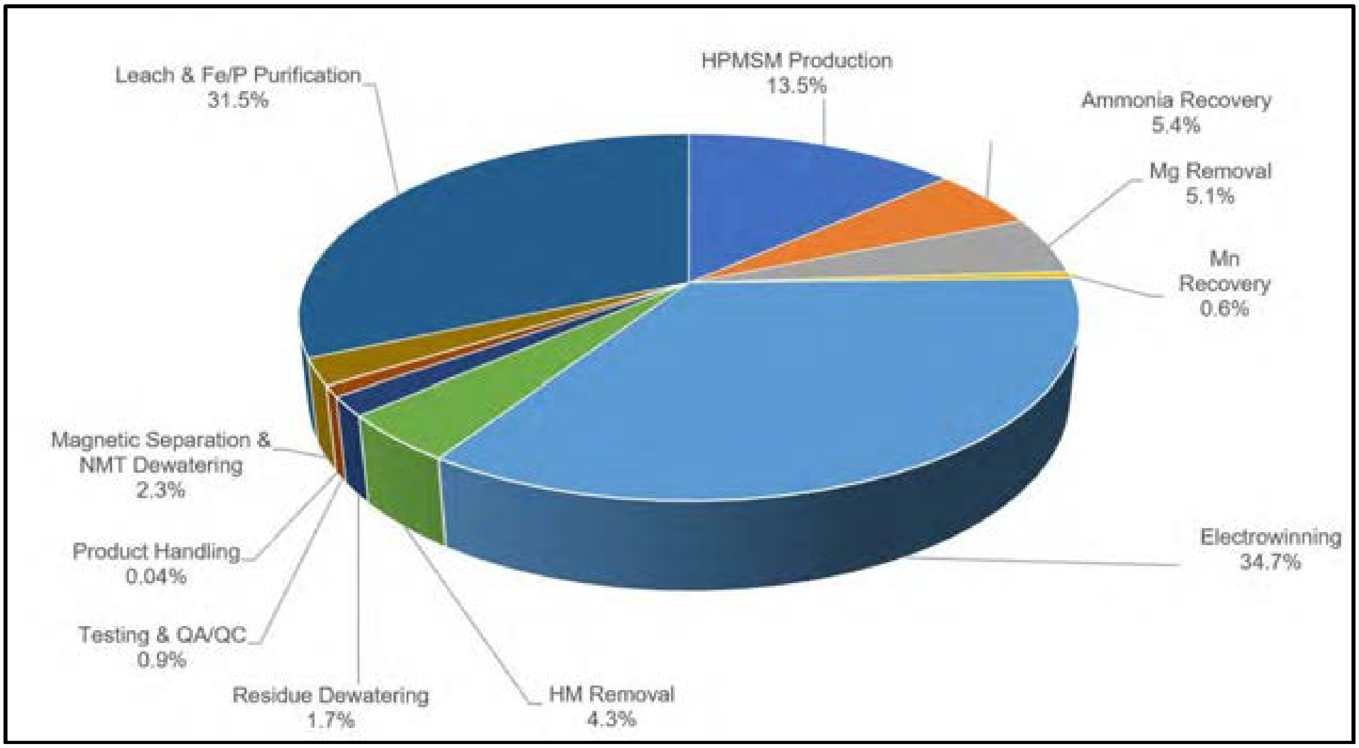


Figure 1-10: Process Operating Cost Distribution by Area



1.14 Highlights of Independent HPEMM and HPMSM Market Study

EMN commissioned the independent research and consultancy firm of CPM Group LLC (CPM or CPM Group) to provide an HPEMM and HPMSM product market outlook study for the CMP. The CPM team prepared a comprehensive market research report, including an extended executive summary of the report that summarizes market information for high purity manganese products, including market demand and supply and projected HPEMM and HPMSM prices. The Extended Executive Summary of the CPM market outlook entitled “Market Outlook for High-Purity Electrolytic Manganese Metal and High-Purity Manganese Sulfate Monohydrate,” dated July 06, 2022, is reproduced in Section 19.0 of this report. The following represents selected highlights from the Extended Executive Summary.

Electrolytic manganese metal (“conventional” or “standard quality” EMM containing ~99.7% Mn) is used principally by comparatively small markets of steel and aluminium alloys, while manganese sulphate monohydrate (MSM, 98% $MnSO_4 \bullet H_2O$) is used mainly by the agrochemical and pharmaceutical industries. Only approximately 8 - 10% of all manganese mined is processed into EMM and MSM, while the vast majority is used for the production of ferroalloys: silicomanganese and ferromanganese (60 - 80% Mn).

These niche markets behave more like high-tech product markets or specialized chemical markets than traditional metal markets. Prices paid depend more on the purity (or lack of certain impurities) of the material rather than on the underlying manganese prices in the ferroalloys industry.

The number of high purity Mn producers is very limited: HPEMM is produced by three plants in China and one plant in South Africa (total output in 2021: 33,500 t produced by one plant in South Africa and one in China). HPMSM is produced by 16 plants in China, 1 in Belgium, and 4 small operations in Japan (total output in 2021: 296,000 t of HPMSM at 32% Mn).

Traditional applications for HPEMM are mainly in steel alloys, super alloys, aluminium alloys, and welding powders. In 2021 approximately 23% was used in the production of rechargeable batteries (through its conversion to high purity manganese sulphate solution [HPMSS] by precursor and battery makers). The use of HPEMM for the production of battery cathode precursors is expected to increase in the future in absolute numbers.

Production of rechargeable lithium-ion batteries (Li-ion or LiB) for electric vehicles (EVs) is expected to dominate the market for HPEMM and HPMSM over the next two decades, dwarfing any other application for these products. Following E-Source's research into battery markets and combining it with its own research, CPM forecasts a 20-fold increase in the use of manganese in rechargeable Li-ion batteries between 2021 and 2036.

Europe will play an important part in this EV revolution, with 18 rechargeable battery factories already in operation and 56 expected to be operational by 2031. Europe is expected to become the second most important centre (after China) of the global electric car and battery industries. Major car makers like Volkswagen, Stellantis, Renault-Nissan, and Volvo declared their intentions to make 70 - 100% of their vehicles produced in Europe electric by 2031. EMN's Chvaletice project is strategically positioned to become an important integral part of the European supply chains for these industries.

Manganese Demand from Batteries

Although battery use currently accounts only for a very small fraction of overall manganese consumption (approximately 2%), this specialized sub-sector is expected to achieve a double-digit compound annual growth rate (CAGR) over the next two decades and should be on the radar of every manganese producer.

Secondary batteries are also known as rechargeable batteries. One particular type of secondary battery, the lithium-ion battery (also called Li-ion or LiB), has recorded an extraordinary growth in demand: production of these batteries since 2010 grew at a rate of 25% p.a. (CAGR). One of the applications for Li-ion batteries is the propulsion of EVs. Demand for batteries for EVs is expected to grow at a CAGR of 25% between 2021 and 2031 and at a slightly slower rate (around 10% CAGR) for the period 2031-2041. The majority of chemistries using manganese for secondary battery production require HPMSM as the feedstock. A very small proportion (the LMO chemistry, <1% of battery market) needs manganese in the form of the EMD, but these are likely to be discontinued after 2025.

CPM's forecast for manganese use in Li-ion batteries also includes other battery applications such as Energy Storage Systems (ESS) (grid-electricity storage or renewable sources electricity storage) and consumer electronics. However, the demand from batteries for EVs is likely to dominate the battery market and is expected to claim approximately 87% market share by 2025.

Global Battery Industry

The Li-ion battery industry has its own structure and supply chain with many specialized manufacturers. A prospective producer of HPEMM and/or HPMSM, such as EMN, is positioned at the beginning of the chain as a supplier to the makers of precursor materials that are used in making cathodes. EMN can sell its products to different manufacturers depending on the level of supply chain integration by the various battery and EV manufacturers: some make just cathode powders or cathodes, and others (e.g., Tesla) have many stages of battery production within their manufacturing operations. The ultimate product is a battery pack sold to or made by an EV manufacturer.

Until 2018, China, Japan, and Korea accounted for almost 90% of the world's Li-ion battery cell production. Ramping up of production in the Tesla 'Gigafactory' in Nevada has brought the USA into second place, while Europe barely registered as a battery-making region. Since then, a lot has changed, and today (June 2022), Europe has 18 operating rechargeable battery factories, 7 of which are known as "gigafactories," i.e., factories with an annual production capacity greater than 1 GWh. Despite the efforts of Europe and North America (five operating plants in 2021), China still dominates battery cell production accounting for approximately 70% of global capacity.

Battery Industry in Europe

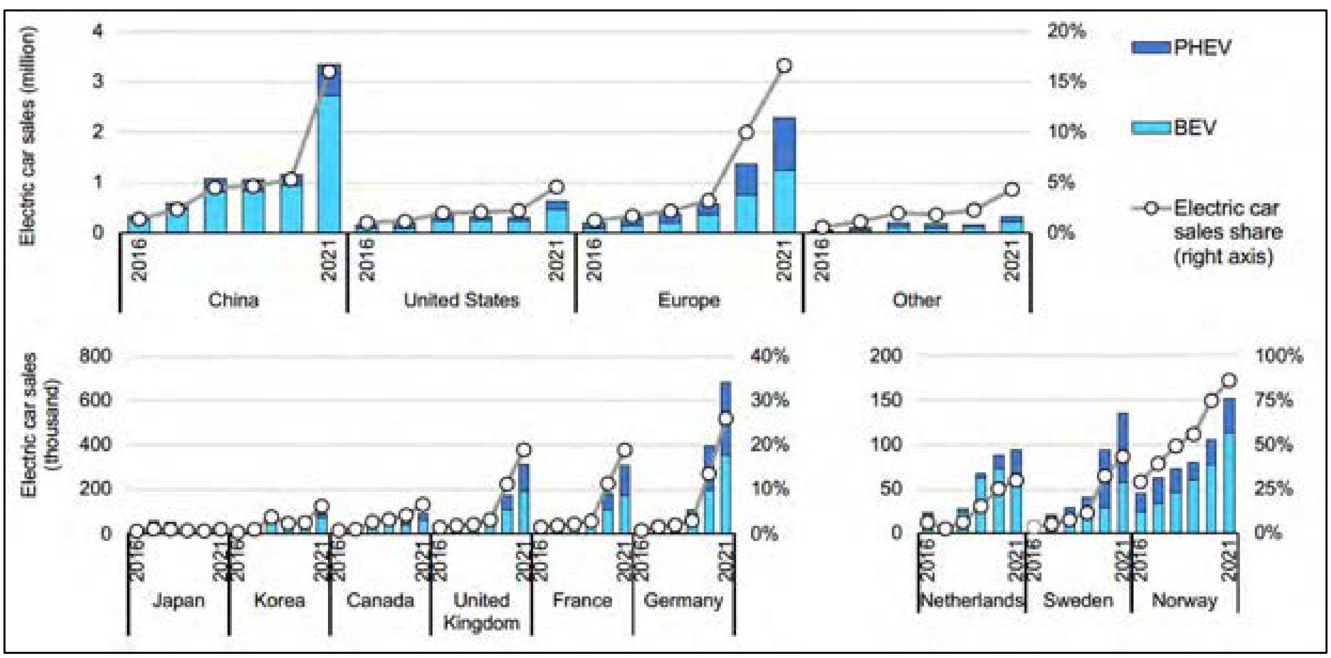
Currently, there are 18 operating rechargeable battery factories in Europe, 7 of which are known as gigafactories. Their combined capacity is 62 GWh, which gives Europe an 8% share in the global market. The Chvaletice Manganese Project owned by EMN is located in the Czech Republic, hence the European market for HPEMM and HPMSM is important for this project. CPM believes that the entire planned output of the Chvaletice project can be easily consumed by the growing lithium-battery sector in Europe.

Local supply chains are being built in Europe and apart from the convenient logistics, companies within the European single market benefit from frictionless trading and strong support from the European Commission and national governments. The European Battery Alliance is a powerful body created by the EU to ensure that the EV industry in Europe secures all the regulatory approvals and funding required. The Chvaletice Manganese Project currently stands to become the only primary producer of manganese products for the battery industry within the EU, making it of significant potential strategic importance in the context of the creation of a European battery raw materials supply chain.

Electric Vehicles Market

According to battery industry forecasts, EVs will generate 87% of rechargeable battery demand as soon as 2025. This share makes electric cars a key driver of demand for cathode materials, including manganese.

Figure 1-10: Electric Car Registrations and Sales Share (2016 – 2021)



Source: International Energy Agency, May 2022

Electric car sales accounted for 9% of the global car market in 2021 – four times their market share in 2019. All the net growth in global car sales in 2021 (of any propulsion) came from electric cars. Sales were highest in China, where they tripled relative to 2020 to 3.3 million after several years of relative stagnation, and in Europe, where they increased by two-thirds year-on-year to 2.3 million. More electric cars were sold in China in 2021 (3.3 million) than in the entire world in 2020 (3.0 million). Together, China and Europe accounted for more than 85% of global electric car sales in 2021, followed by the United States (10%), where they more than doubled from 2020 to reach 630,000. The increases are illustrated in Figure 1-10.

Looking into the future, the IEA's base case (the so-called STEP scenario) projects 2030 annual EV sales reaching 25.5 million units, 86% of which will be cars, and the remaining 14% vans, trucks, and buses.

Energy Storage Systems

A sector which seems to have a double-digit growth potential in driving the demand for Li-ion batteries is Energy Storage Systems (ESS), which store grid energy generated at times of low demand to be used later, during peak times, or store electricity generated by renewable generators. Peak shifting (which accounts for the vast majority of battery usage on the grid) is gravitating towards Li-ion because of its small footprint, low maintenance, high efficiency, and long life. Lithium batteries also have other advantages: production is becoming ubiquitous (because of the EV revolution), costs are declining, and in 5 - 8 years' time, there will be a surplus supply of used EV batteries with decreased capacity[1] (due to aging/cycle life) that can be used for grid storage.

HPEMM and HPMSM Supply Demand Balance

The HPEMM and HPMSM markets are going to be radically transformed over the coming decades as a result of the 'EV revolution'. Most, but not all, of the lithium-ion batteries that power EVs are expected to use manganese in their cathodes, and these manganese-intensive types of battery chemistries are likely to dominate the battery market for the next two decades.

As a result, CPM expects that the demand for manganese from the battery sector is increase 13 times between 2021 and 2031 (from 90 kt to 1.1 Mt of manganese contained) and 50 times between 2021 and 2050 (to 4.5 Mt).

Such a massive demand increase requires a supply response, but the currently known expansions and new projects do not come anywhere near to satisfying this demand. What is unknown is what other market entrants and capacities may appear 15 to 20 years down the line. It is also worth remembering that the EV market is still a nascent industry, and technologies may change (to less or more manganese-intensive cathode chemistries). This, however, is not as likely in the next 10-15 years, as having made their investments, automotive and battery companies will want the return on their capital and are unlikely to make radical changes to their plants and technologies lightly.

The manganese product that battery makers ultimately need is HPMSS, the soluble form of HPMSM (powder), with many buying HPEMM (metal) and to make HPMSS in-house or buying HPMSM to make the solution. As the industry matures, CPM expects that battery cathode makers are more likely to buy more third-party HPMSM and use less HPEMM. Therefore, it is a very much an "either/or" case.

CPM's assessment of the industry indicates that there are very few large-capacity HPEMM projects planned at the moment, but it is difficult to say what projects might appear in 15 or 20 years' time. There are currently six non-Chinese HP Mn projects which are likely to come on stream before 2030. These projects add up to 221 ktpy of new supply of HP Mn. When added to the current declared (but not fully utilized) production capacity of max 180 ktpy, they bring the total capacity available in 2031 to 401 ktpy of metal contained. Meanwhile, 2031 projected HP Mn

[1] EV batteries need replacement when they cannot hold more than 80% of their original nameplate capacity.

TETRA TECH

demand from the battery sector alone stands at 1,094 ktpy (1,127 ktpy when metallurgical uses are included). This creates a supply deficit of 726 kt.

CPM also considered new HP Mn supply from recycling old EV batteries. Assuming 50% recycling rate and 100% Mn recovery (unlikely), this supply stream could satisfy 6% of 2031 HP Mn demand. With all the above supply corrections, the 2031 deficit comes down from 726 kt to 475 kt. If battery demand continues to grow as expected and no new projects come to the market, the deficit would increase to one million t by 2037. If this deficit is to be reduced to zero, the HP Mn industry would have to increase its capacity 11-fold (and produce at a close-to-100% utilization rate).

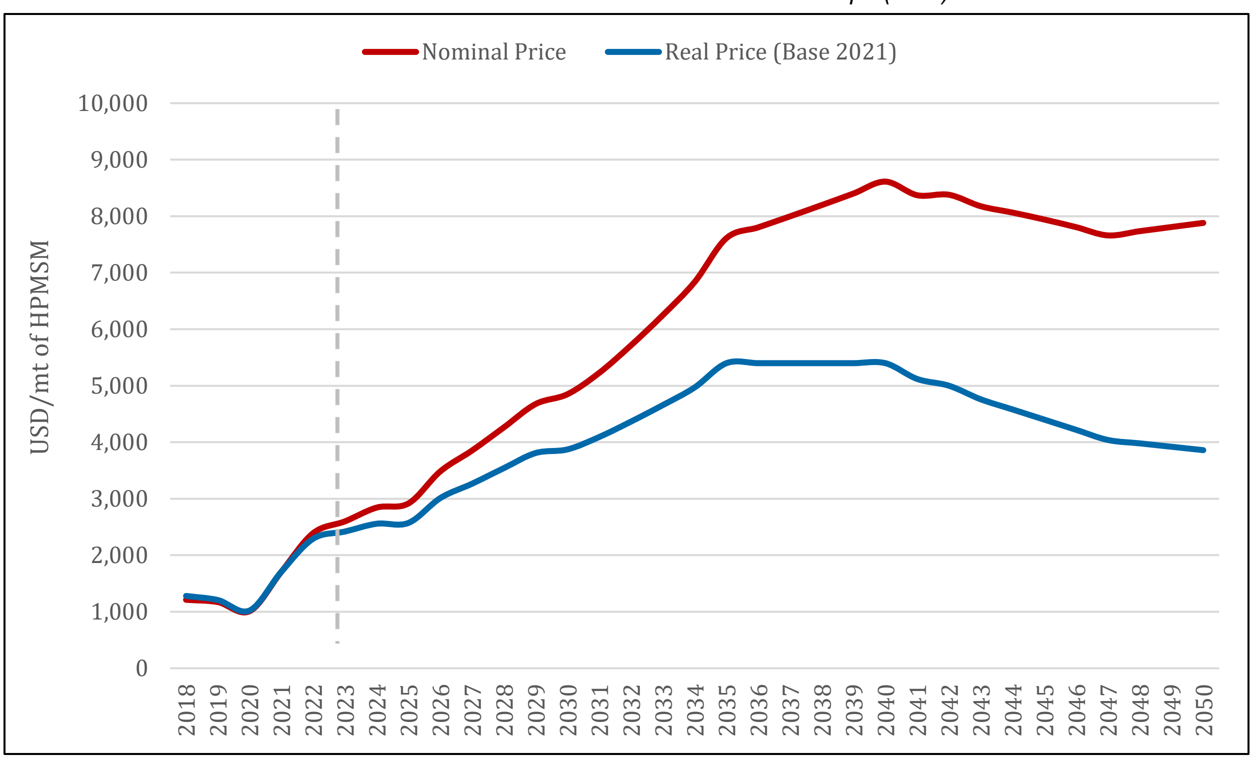
HPEMM and HPMSM Price Outlook

The base price modelled in this forecast is the HPMSM price “Ex Warehouse China”, based on reference pricing reported by Asian Metal (AM), Argus Media, and Shanghai Metal Markets (SMM). Various modifying factors (cost of freight, different premiums) are added to arrive at the European price and a North American price, which are then plotted and shown in tables. The European price is assumed to be on a Delivered, Duty Paid (DDP) basis, i.e., at the gate of a cathode plant. Berlin was used as a proxy for numerous Central and Eastern European locations of battery factories

HPMSM prices are expected to remain at elevated levels as a result of the developing deficit. The prices of ‘standard quality’ EMM (product for the metallurgical industry, 99.7% Mn) and both the high purity product HPMSM (chemical product for batteries) and HPEMM (metallurgical and battery applications) seem to be more and more divergent according to previous CPM Group forecast reports.

Figure 1-11: HPMSM Price Projection in Europe

Prices delivered to Central/Western Europe (DDP)



Source: CPM Group’s calculations based on supply-demand assessment and historical prices reported by Bloomberg, AM, Argus, SMM, and industry

TETRA TECH

Looking forward, we see the HPMSM prices in China remaining strong and becoming more and more divergent from the metallurgical quality EMM prices. The looming deficit of the 'battery grade' HPMSM described elsewhere in this report will hit China badly unless it expands its production base. In CPM's projections, we allowed for an additional 490 ktpy of new Chinese production (2.8 times the 2021 output), including 327 ktpy of as-yet-unannounced new capacity. We believe such a new capacity will be announced in the coming years under intense demand pressure. CPM's price forecast for HPMSM is shown in Figure 1-11.

The same logic applies to North American prices. There is no HPMSM production in North America at present. When Prince's Tampico plant in Mexico is converted to produce HPMSM, this will be the first North American producer of this material. Its planned output (including Phase Two) is likely to meet only 10% of the American battery industry demand for HPMSM in 2030. More plants are needed, but for the foreseeable future, most of the HPMSM needed will be imported, predominantly from China.

CPM expects a significant diversification of qualities (and premiums) within the 'high-purity' spectrum of HPEMM and HPMSM. The critical factor with these new chemistries is not so much the manganese content, but rather the levels of impurities contained within the last 0.1% of the chemical composition of these products

CPM believes that post-2025, the demand for HPEMM may significantly increase, leading to strong competition for supplies between metallurgical users and battery industry users of HPEMM. The latter is likely to be able to bear higher prices and exert more 'gravitational force' on the pricing, and as a result, the HPEMM pricing is forecast to be derived from the manganese sulphate price rather than the price of the "metallurgical only" 997 EMM. Therefore, the price of HPEMM would be established at a discount to HPMSM price[2] rather than at a "back-calculated" premium to the 997-EMM price. Despite the increased demand for HPEMM, we still see HPMSM as a dominant product on the market and hence a benchmark for pricing of high purity manganese products used in the battery industry.

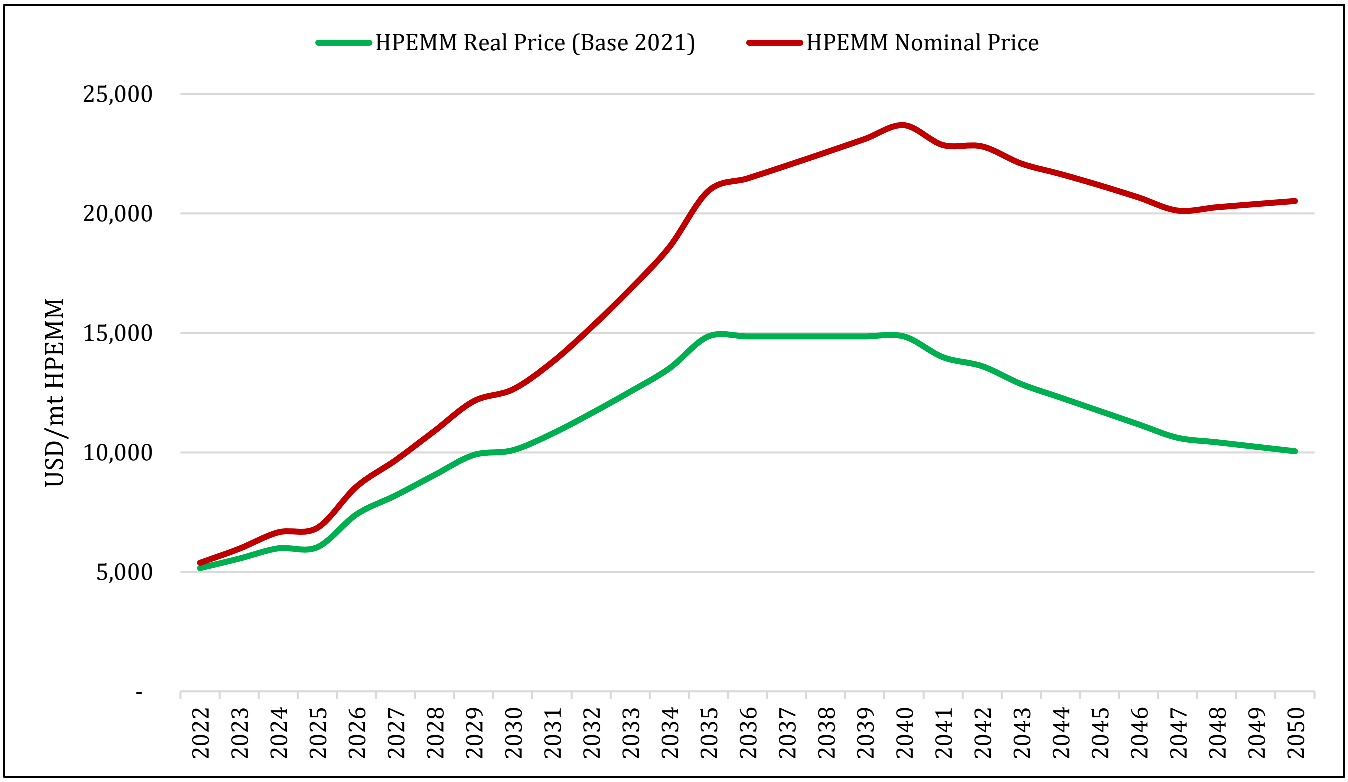
CPM's forecast annual prices in Europe through 2050 of manganese flake (EMM 99.7% Mn) and HPEMM (99.9% Mn) are presented in Section 19.0 of this report and summarized in Figure 1-12.

---

[2] Per unit of metal contained

Figure 1-12: HPEMM Price Projections in Europe

Prices delivered to Central/Western Europe (DDP)



CPM's forecast annual prices through 2050 of manganese metal contained in HPMSM and HPMSM are presented in Chapter 19 of this report. it should be noted that prices on CPM's graphs and tables are expressed in real 2022 US dollars, unless otherwise stated.

1.15 Economic Analysis

Tetra Tech completed a pre-tax economic analysis based on estimated costs and revenues for extracting and reprocessing the tailings from the Chvaletice deposit. The economic analysis is based on the sale of two products: HPEMM and HPMSM. The product prices used for the analysis were based on the projection by CPM. The economic analysis concluded the following pre-tax financial results:

- Pre-tax NPV of USD$1,750 million at an 8% discount rate
- Pre-tax IRR of 24.9%
- Pre-tax payback period of 3.6 years.

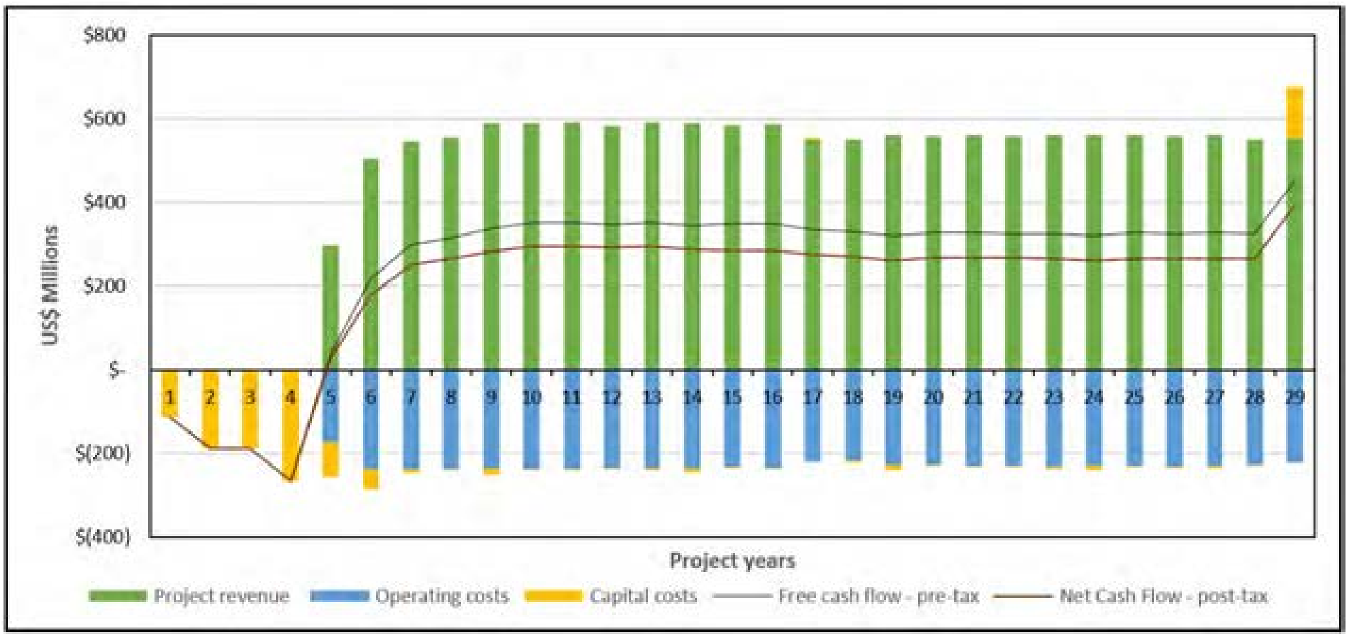
Grant Thornton Tax & Accounting s.r.o. (GrantThornton), based in the Czech Republic, prepared both the Czech tax depreciation calculations based on the capital expenditure information and the allocation of such expenditures into the Czech tax depreciation groups, and the Czech corporate income taxes payable for the CMP economic analysis based on existing income tax legislation in the Czech Republic.

The post-tax economic analysis for the life of the project yielded the following financial results:

- Post-tax NPV of USD$1,342 million at an 8% real discount rate
- Post tax IRR of 21.9%
- Post-tax payback period of 4.1 years

Figure 1-13 shows a summary of the financial modelling results in graphical form.

Figure 1-13: Summary of Pre-Tax and Post-Tax Financial Results



1.16 Recommendations

The CMP is considered to be economically viable based on the results of the work presented in this report, and the Project should proceed to the next development phase. Tetra Tech recommends additional engineering and testing for refinement of the processing and material properties of both tailings and residue and investigation into additional geotechnical data related to the next phase of detailed engineering work. Also process optimization, potential cost savings, and additional revenue generating opportunities should be further investigated, including the planned demonstration plant campaign. Table 1-8 shows the cost breakdown by discipline for future recommended work. Recommendations are further detailed in Section 26.0.

Table 1-8: Estimated Costs for Recommended Future Work

Area	Estimated Cost (USD$)
Tailings Extraction	427,000
Mineral Processing and Metallurgical Testing*	460,000
Recovery Methods/Trade-off Studies	50,000
Infrastructure	200,000
Marketing and Transportation Studies	180,000
Total Cost	**1,317,000**

Note: Excludes costs already allocated for operation of the Demonstration Plant

2.0 INTRODUCTION

Euro Manganese Inc. (TSX Venture Exchange [TSXV]: EMN, and Australian Securities Exchange [ASX]: EMN) retained Tetra Tech to prepare this Public Report and FS in accordance with and the JORC Code, 2012 Edition, guidelines for the Chvaletice deposit, located in the Pardubice region of the Czech Republic. Mineral tenure for the Property is held by Mangan, a 100% owned subsidiary of EMN, based in Chvaletice, Czech Republic, 89 km by road east of Prague. The effective date for this report is July 27, 2022. The effective date of the Mineral Resource Estimate (MRE) is July 1, 2022, and the effective date of the Mineral Reserve Estimate is July 14, 2022.

The CMP name is derived from the local Chvaletice community, which was the site of historical, state-owned open pit mining operations and processing of pyrite from 1951 to 1975, which produced sulphuric acid from the pyritic shales. No additional mining or metal production is known to have been conducted on the Property since 1975. The mineral deposit being evaluated for the CMP comprises three tailings material stockpiles placed as a by-product of this historical production. These deposits are referred to as Cell #1, Cell #2, and Cell #3. EMN is evaluating the potential of reprocessing this tailings material for potential production of HPEMM and/or HPMSM at a hydrometallurgical refinery.

Since 2014, EMN has conducted various exploration, mineralogical, and materials testing campaigns as part of the preliminary site investigation efforts to characterize the deposits and potential recovery methods. Work to-date has confirmed manganiferous mineralization in carbonate form is present within dry to fully saturated compacted predominantly silty soil which comprises the tailings deposit.

The following terms of reference for the CMP are included throughout this report:

- The CMP tailings materials, CMP tailings deposit, raw tailings, and Cells #1, #2, and #3, all refer to the man-made tailings deposits located near the community of Chvaletice, which comprises the mineralized material that is the subject of this report.
- The Chvaletice bedrock deposit refers to the original bedrock material that was mined historically for pyrite and production of sulphuric acid and is not part of EMN's interest in the CMP.

References used for this document include publicly available government documents, existing project test work, internal company reports, and verbal communication with EMN personnel. Current work includes a detailed description of technical investigations completed by EMN.

2.1 Site Visits

In accordance with JORC Code and NI 43-101 guidelines, the CPs for this report and their responsibilities are outlined in Table 2-1.

Mr. James Barr, P.Geo., completed a site visit to the Property from July 1 to 3, 2017, and from July 30 to 31, 2018. During the site visits, Mr. Barr reviewed the Property layout, drill operations, sample collection methods, quality control protocols, and collected independent verification samples. Conversations with on-site EMN technical personnel, including Tomas Pechar Jr. (Mining Engineer and Project Implementation Manager) and Jaromir Tvrdý (Senior Project Geologist) of GET and Joseph Simek (geologist) with Geomi, covered topics relating to drilling recoveries, moisture content, soil class interpretation, surface property ownership, mineral tenure, and other project considerations.

Mr. Jianhui Huang, Ph.D., P.Eng., visited the Property on February 5, 2018 and May 3, 2022, as well as visited the CRIMM laboratory and pilot plant facility five times between January 20, 2017 and September 20, 2018, to witness sample preparation and test/assay facilities and to discuss test program and results with CRIMM's technical team. Mr. Huang also visited the SGS laboratory on June 29, 2017. In addition, Mr. Huang visited BGRIMM's laboratory four times between September 3, 2019 and January 25, 2020. Mr. Huang oversaw the bench scale validation test work and discussed test work program and results with BGRIMM's technical team.

Mr. Chris Johns, P.Eng., visited the project site on February 5, 2018, and May 3, 2022, for a general overview of the tailings cells and proposed infrastructure sites.

Mrs. Maureen Marks, P.Eng., and Mr. Hassan Ghaffari, P.Eng., visited the project site on May 3, 2022, for a general overview of the tailings cells and proposed infrastructure sites.

Table 2-1: Competent Person Responsibilities

Report Section		Company	CP
1.0	Summary	Tetra Tech	All CPs
2.0	Introduction	Tetra Tech	Jianhui (John) Huang, Ph.D., P.Eng.
3.0	Reliance on Other Experts	Tetra Tech	James Barr, P.Geo. Maureen Marks, P.Eng. Jianhui (John) Huang, Ph.D., P.Eng.
4.0	Property Description and Location	Tetra Tech	James Barr, P.Geo.
5.0	Accessibility, Climate, Local Resources, Infrastructure and Physiography	Tetra Tech	James Barr, P.Geo.
6.0	History	Tetra Tech	James Barr, P.Geo.
7.0	Geological Setting and Mineralization	Tetra Tech	James Barr, P.Geo.
8.0	Deposit Types	Tetra Tech	James Barr, P.Geo.
9.0	Exploration	Tetra Tech	James Barr, P.Geo.
10.0	Drilling	Tetra Tech	James Barr, P.Geo.
11.0	Sample Preparation, Analyses and Security	Tetra Tech	James Barr, P.Geo.
12.0	Data Verification	Tetra Tech	James Barr, P.Geo.
13.0	Mineral Processing and Metallurgical Testing	Tetra Tech	Jianhui (John) Huang, Ph.D., P.Eng.
14.0	Mineral Resource Estimates	Tetra Tech	James Barr, P.Geo.
15.0	Mineral Reserve Estimates	Tetra Tech	Maureen Marks, P.Eng.
16.0	Mining Methods	Tetra Tech	Maureen Marks, P.Eng.
17.0	Recovery Methods	Tetra Tech	Jianhui (John) Huang, Ph.D., P.Eng.
18.0	Project Infrastructure	Tetra Tech	Hassan Ghaffari, P.Eng. Chris Johns, P.Eng. Davood Hassanloo, P.Eng.
19.0	Market Studies and Contracts	Tetra Tech	Jianhui (John) Huang, Ph.D., P.Eng.

table continues...

Report Section		Company	CP
20.0	Environmental Studies, Permitting and Social or Community Impact	Tetra Tech	Jianhui (John) Huang, Ph.D., P.Eng.
21.0	Capital and Operating Cost Estimates	Tetra Tech	Jianhui (John) Huang, Ph.D., P.Eng. Maureen Marks, P.Eng. Chris Johns, P.Eng.
22.0	Economic Analysis	Tetra Tech	Maureen Marks, P.Eng.
23.0	Adjacent Properties	Tetra Tech	James Barr, P.Geo.
24.0	Other Relevant Data	Tetra Tech	Hassan Ghaffari, P.Eng.
25.0	Interpretations and conclusions	All	All CPs
26.0	Recommendations	All	All CPs
27.0	References	All	All CPs

2.2 Project Assumptions for Reporting

The coordinates system used for the CMP is the System Jednotne Trigonometricke Site Katastralni (S-JTSK) (Krovak East North) coordinate system and the Baltic Vertical Datum (Bpv), a system designed for the Czech Republic, as described further in Section 5.5. The accuracy of the topography and surveyed drillhole collar locations as provided is assumed to be reliable. Tetra Tech has approximately verified drill collar surveys in the field using handheld global positioning system (GPS).

Manganese grades are reported as percent elemental manganese (Mn%). Where necessary, they have been converted from manganese (II) oxide (MnO%) using as factor of 1.2912. Manganese grades may not have a direct linear correlation to the amount of manganese product that could be produced. CRIMM and BGRIMM conducted extensive metallurgical test work and CINF Engineering Co., Ltd. (CINF) and BGRIMM conducted process engineering to evaluate material recovery effectiveness. The assay methods were selected to measure total elemental concentration in addition to measuring partial digestion concentrations of manganese as a proxy for “soluble manganese”. In this report, total manganese refers to the results of the lithium borate fusion and XRF methods, and soluble manganese refers to the results of the aqua regia digestion with MS or atomic absorption spectrometry (AAS).

Sample collection and handling were observed by the geology CP during two separate site visits. It is assumed that the methods and protocols observed during these periods, and as described in this report, were consistent with those used for the whole duration of the drilling investigation. Metallurgical tests were observed by the metallurgy CP during various laboratory visits. The CP believes that the methods and protocols observed during these periods, and as described in this report, were appropriate.

2.3 Effective Date

The effective date of the Mineral Resource Estimate that support the FS is July 1, 2022. The effective date of the Mineral Reserve Estimate is July 14, 2022, and the effective date of the Report is July 27, 2022. The CPs are not aware of any new information that is available for this Public Report as of the effective date.

2.4 Previous Public Reports

EMN has previously filed the following Public reports on the CMP project:

- Tetra Tech, 2019. Public Report and Preliminary Economic Assessment for the Chvaletice Manganese Project, Chvaletice, Czech Republic. January 29, 2019.
- Tetra Tech, 2018. Public Report on Mineral Resource Estimation for the Chvaletice Manganese Project, Chvaletice, Czech Republic, December 8, 2018.
- Tetra Tech, 2017. Public Report on Mineral Resource Estimation for the Chvaletice Manganese Project Chvaletice, Czech Republic, October 14, 2017

3.0 RELIANCE ON OTHER EXPERTS

3.1 Mineral Tenure and Ownership

EMN provided Tetra Tech with information regarding mineral tenure and ownership of surface rights described in Section 4.0, based on a title opinion provided by PRK Partners s.r.o. in the Czech Republic in a letter dated August 9, 2022. The letter confirms that EMN is the sole shareholder of Mangan, Mangan is registered and in good standing under the laws of Czech Republic, and that Mangan holds valid exploration licences and a Mining License for the CMP. Tetra Tech has not sought legal verification of the information, but believes the information to be true.

The Czech MoE approved a new preliminary mining licence in a document dated July 20, 2021, and with reference to MZP/2021/550/768-Hd which is valid until May 31, 2026. Details of this authorization are included in Section 4.1.

3.2 Environmental Studies

Jianhui (John) Huang, Ph.D., P.Eng., relied on EMN/Mangan and Tania Perzoff, R.P.Bio., P.Ag., of Tetra Tech for matters relating to the environmental permitting plan and social or community impact in Section 20.0. Ms. Perzoff reviewed the environmental and permitting related reports/documents prepared by EMN and other consultants.

3.3 Economic Analysis

Maureen Marks, P.Eng., relied on Grant Thornton Tax & Accounting s.r.o (GrantThornton), based in the Czech Republic, for preparation of the post-tax analysis in Section 22.0, including the Czech tax depreciation calculations based on the capital expenditure information and the allocation of such expenditures into the Czech tax depreciation groups, and the Czech corporate income taxes payable for the CMP economic analysis based on existing income tax legislation in the Czech Republic.

The information comes from the letter titled *Assistance with the tax portion of the economic analysis prepared by Tetra Tech Canada Inc ("Tetra Tech") in connection with the Feasibility Study Report (the "Report") on the Chvaletice Manganese project (the "Project")* and dated July 14, 2022.

3.4 Manganese Product Marketing Study

Jianhui (John) Huang, Ph.D., P.Eng. and Maureen Marks, P.Eng., relied on information pertaining to high-purity marketing study prepared by CPM Group, New York, USA, including the projected prices for HPEMM and HPMSM. The marketing report is titled as *"Market Outlook for High-Purity Manganese Products,"* dated July 6, 2022

4.0 PROPERTY DECRIPTION AND LOCATION

The Property is located in the western area of the Pardubice region of the Czech Republic at approximate latitude-longitude coordinates 15.444279°east (E) and 50.038069°north (N). Communities within the immediate vicinity of the Project include Trnávka, Chvaletice, and Řečany nad Labem. Prague is located 89 km due west (Figure 4-1).

The tailings are deposited in three separate facilities, referred to as cells, which were built upon and are elevated with respect to the natural ground elevation in the region. Cell #1, the oldest deposit, covers a total surface area of approximately 326,400 m^2, and has an average thickness of approximately 26.6 m. Cell #2 covers a total surface area of approximately 393,200 m^2 and has an average thickness of approximately 28.7 m. Cell #3 covers a total surface area of approximately 313,200 m^2 and has an average thickness of approximately 11 m. Figure 4-2 shows a plan map of the Property.

4.1 Mineral Tenure

Governing authorities that regulate mineral resources and mining activities in the Czech Republic include the Czech Mining Authority, District Mining Authorities, the Ministry of the Industry and Trade, and the MoE of the Czech Republic. The CMP lies within the Hradec Králové and Pardubice Region District Mining Authority. These authorities administer the *Mining Act* (44/1988). Mineral tenure is regulated under the *Geological Act* (62/1988) and administered by the MoE in consultation with the Ministry of the Industry and Trade and with the Czech Mining Authority.

Application for the mineral tenure of the "Trnávka Exploration Area" was made by GET in April 2014. The area of interest was considered to have been discovered by State Resource which allowed for competing bids. Following the MoE's review of competing bids, exploration license 631/550/14-Hd which encompasses the "Řečany (currently Trnávka) - Tailings Pond 3" and "Chvaletice - Tailings Ponds 1, 2" was awarded to GET.

Mangan is a private company established in the Czech Republic in 1997. Mangan was used as the corporate vehicle for an incorporated partnership between GET (33%), Geomin (33%), and Orex (34%). On December 15, 2014, an Option Agreement was signed between EMN, Mangan, and its affiliates, granting EMN the right to earn an 80% equity interest in Mangan. In May 2016, the Option Agreement was amended and EMN purchased 100% ownership of Mangan from the Mangan shareholders, for an aggregate share value (EMN common shares) of CAD$1,500,000 and future prorated NSR payments of 1.2% to the original Mangan partners. Conditions precedent to the EMN-Mangan purchase agreement included transfer of the exploration licence number 631/550/14-Hd from GET to Mangan.

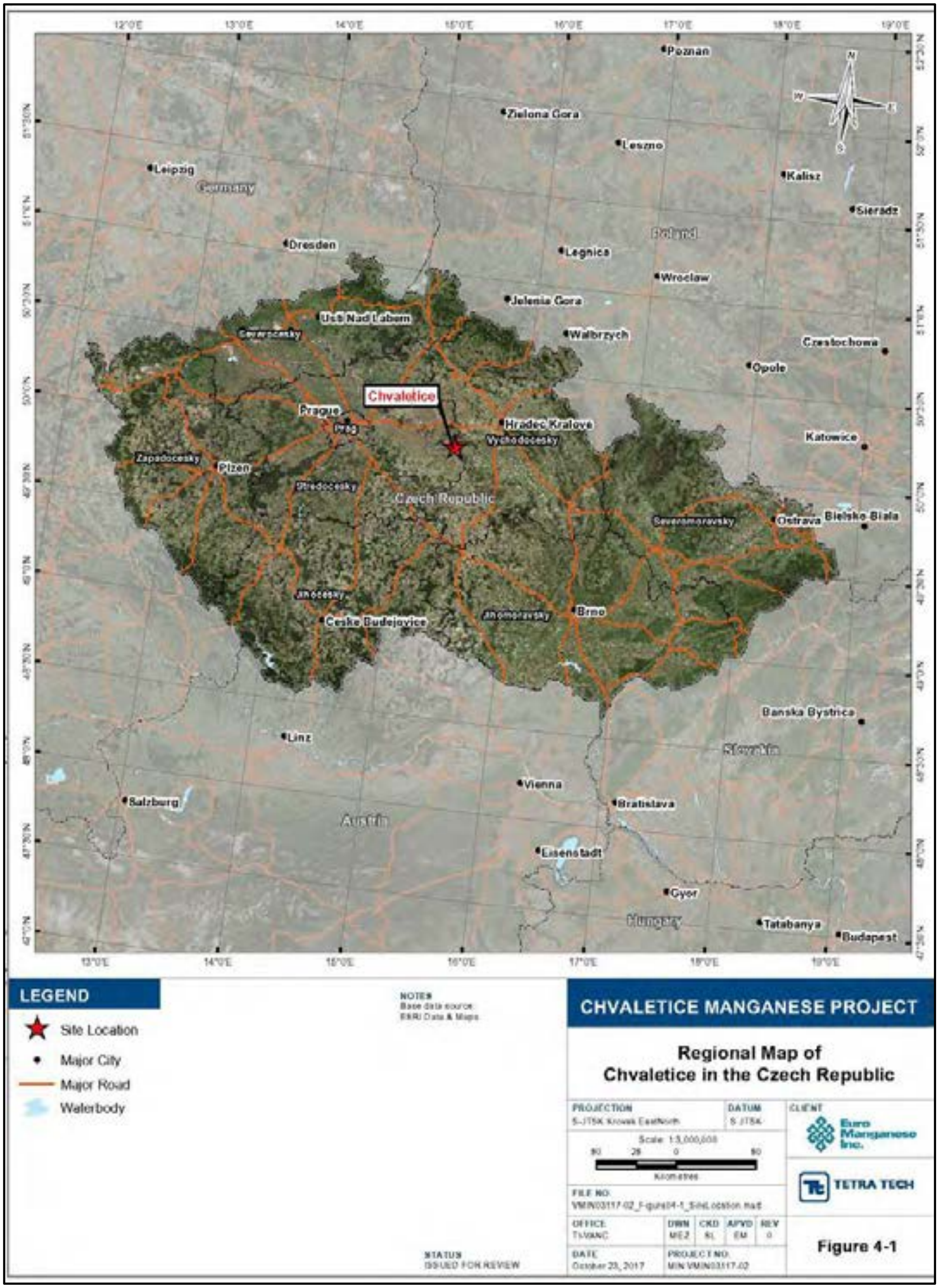
Exploration licence number 631/550/14-Hd is registered to include mineral rights on a total area of 0.98 km^2 (98 ha), of which 0.82 km^2 is located within the Municipality of Trnávka, and 0.16 km^2 is located within the Municipality of Chvaletice. Exploration Licence No. 631/550/14-Hd expires May 31, 2026 (extension reference MZP/2018/550/1484-Hd). On May 4, 2018, the Czech MoE issued Mangan an additional exploration Licence No. MZP/2018/550/386-Hd allowing it to drill the slopes on the perimeter of the tailings piles. Exploration Licence No. MZP/2018/550/386-Hd became effective May 23, 2018, and is valid until May 31, 2026.

On April 17, 2018, with effect from April 28, 2018, Mangan was issued a Preliminary Mining Permit by the MoE, Licence No. MZP/2018/550/387-HD and referred to by the MoE as the prior consent with the establishment of the Mining Lease District (the Preliminary Mining Permit). The Preliminary Mining Permit, which was valid until April 30, 2023, covers the areas included in the Exploration Licences and secures Mangan's rights for the entire deposit area. On July 20, 2021, Mangan was issued a new Preliminary Mining Permit, Licence No. MZP/2021/550/768-Hd, valid until May 31, 2026, which replaces the original Preliminary Mining Permit.

The Preliminary Mining Permit provides an exclusivity to proceed with Environmental Impact Assessment and forms one of the prerequisites for the application for the establishment of the Mining Lease District and represents one of the key steps towards final permitting for the CMP. Based on the Preliminary Mining Permit and other documents, including the Environmental Impact Assessment (which may commence after the Preliminary Mining Permit has been issued), Mangan has until May 31, 2026, to apply for the establishment of the Mining Lease District covering the areas included in the Exploration Licences. The establishment of the Mining Lease District, the application for the final Mining Permit, and applications for permits relating to the construction of infrastructure required for the project, are required prior to mining at the CMP. The Preliminary Mining Permit bounds are shown in Figure 4-3.

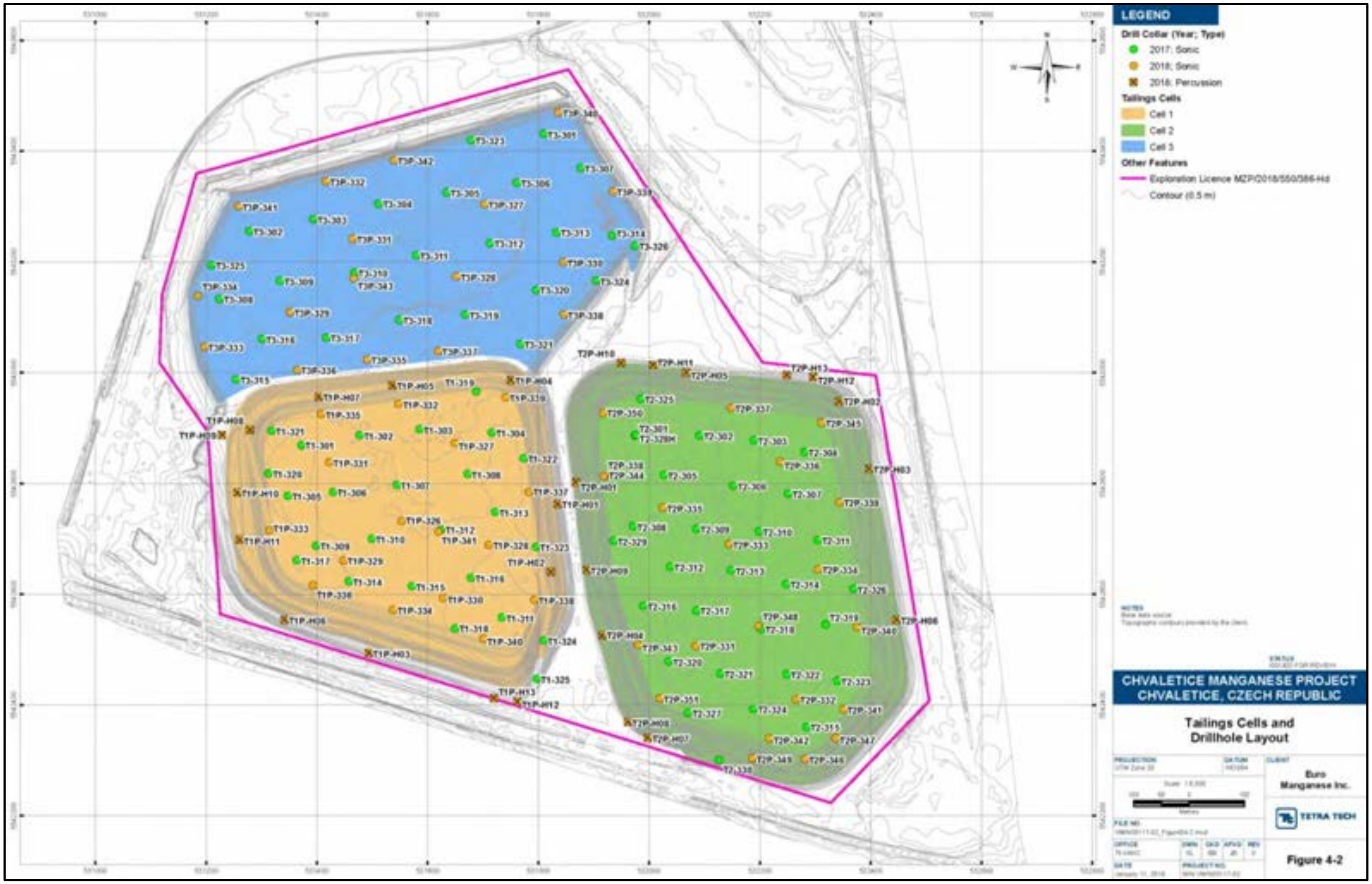
In December 2017, the Chvaletice tailings manganese resource was accepted in the Czech national register, confirming Mangan as the recognized administrator of these resources.

Figure 4-1: Chvaletice Manganese Project Location



TETRA TECH

Figure 4-2: Plan Layout of the Project Tailings Deposits, Cells #1, #2, and #3



TETRA TECH

4.2 Surface Ownership and Land Access Agreements

4.2.1 Tailings Area

At present, Mangan does not hold surface rights to the whole CMP area, which are considered to be those lands of original ground elevation surrounding and immediately underlying the protected area that contains tailings Cells #1, #2, and #3. The area of interest for the CMP overlies and adjoins 16 privately owned land parcels with surface rights described as (Petru 2015) (Figure 4-3):

- The principal plots of land parcels 1170/1, 1170/4, 1170/7, 1217/1, 1490/2, and 1180/30 in the cadastral area of Chvaletice.
- The principal plots of land parcels 349/2, 481/1, 613/1, , 661/2, 1050, 1017/1, 1017/3, 1065, and 1180/30 in the cadastral area of Trnávka.

Total area of interest inside and outside Protected Deposit area is 133 ha. Currently EMN owns or possesses either rent contract or purchase option agreements 28% of the area of the interest so far. EMN intentionally purchased/rent land owned by Municipalities as first. Negotiation with owners of the remaining land is in progress.

Land access agreements and permissions were obtained by Mangan from private landowners as well as the Trnávka and Chvaletice Municipalities for sampling, surveys, studies, road-building, and drilling that were conducted in 2016, 2017, and 2018.

On June 7, 2022, Mangan signed a purchase agreement with company Helot, spol. s.r.o. (owned by Vanek farmer family) and with Mr. Vanek Martin directly for a total area of 7.2 ha, which is located on the northern portion of the Chvaletice Manganese Project tailings.

On May 11, 2019, Mangan signed a purchase contract with the Municipality of Trnavka for a 2.96 ha parcel of land adjacent to the Chvaletice Manganese Project tailings, on which the Company plans to construct a visual and acoustic barrier between Trnavka and the Chvaletice Manganese Project tailings and a utility corridor.

Additionally, on June 6, 2022, Mangan signed a lease agreement with the Municipality of Chvaletice for a total area of 26.6 ha, which represents approximately 19% of the total land area required for the Project and approximately 15% of the total tailings area.

4.2.2 Plant and Infrastructure Areas

An aggregated land package covering 27.19 ha has been purchased, or has option agreement to be purchased, by Mangan. The parcel of land is proposed for development and construction of a high-purity manganese processing facility and related infrastructure (Figure 4-3).

On October 17, 2018, Mangan closed an option agreement with EP Chvaletice s.r.o to purchase a 19.94 ha industrial zoned parcel of land located immediately to the south and across the highway from the tailings deposits, and contiguous with a 1.7 ha parcel of land purchased by EMN's Czech subsidiary in November 2017. On December 18, 2020, Mangan entered into the agreement with Sprava Nemovitosti Kirchdorfer CZ s.r.o. to acquire a 5.0 ha parcel of land, including a rail spur extension that provides additional room and flexibility for the Chvaletice commercial plant layout. On April 29, 2020, Mangan purchased from Sev.en EC, a.s., the owner of the Chvaletice power plant, a 0.2 ha section of land encompassing Rail Spur no. 1, through which the proposed Chvaletice manganese process plant will be serviced and connected to existing rail infrastructure. It provides the Company with a second rail connection through the existing rail siding of the neighboring power plant. This is expected to provide greater logistical capacity and flexibility for the Project.

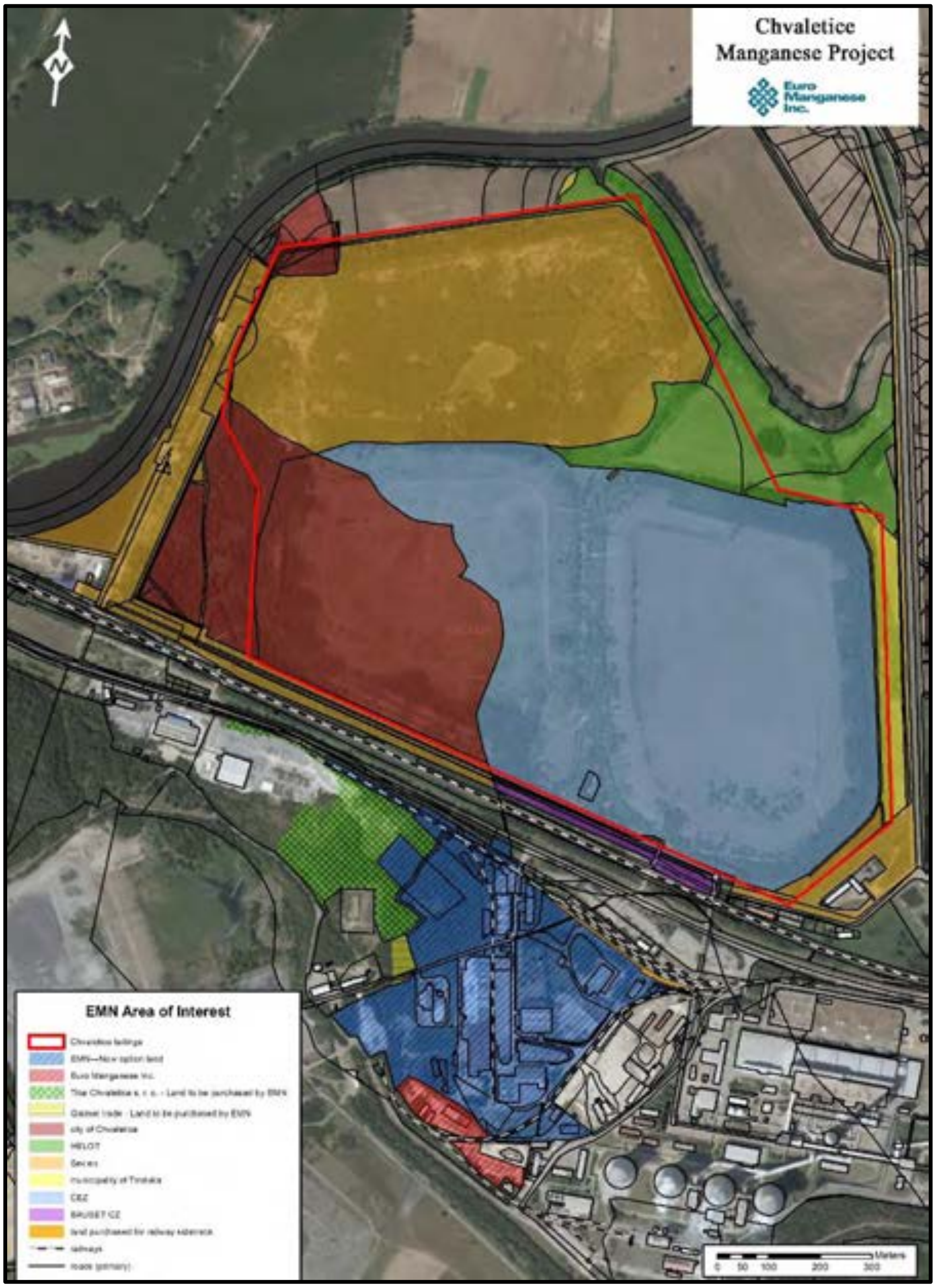
On January 2, 2020, Mangan singed a lease agreement with Galmet Trade, spol s.r.o. for a 0.35 ha right-of-way for a period of 30 years to allow the straightening of a proposed conveyor route. Mangan has an option to purchase this land parcel.

4.3 Royalties and Liens

Three NSR agreements with an aggregate NSR amount of 1.2%, which were held by the original shareholders of Mangan, and were granted as part of the purchase transaction by EMN for 100% ownership of Mangan, were terminated on May 31, 2021. EMN fully settled the agreed consideration on January 31, 2022. EMN has informed Tetra Tech that Mangan has not granted any other royalties or liens on the CMP.

Income taxes and fees imposed by the Government of Czech Republic on mineral resource projects are clearly defined in statutes. Corporate income tax of 19% has been applied in the financial modelling assumptions. The royalty to the Czech government per t of manganese produced is CZK2,308.

Figure 4-3: Plan Map with Surface Ownership and Preliminary Mining Permit Boundaries



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

5.1 Climate

The climate in the western Pardubice region of central Czech Republic is seasonally variable and typical of European continental conditions with warm dry summers and cold winters. It is one of the driest and warmest regions in the Czech Republic. Annual average temperatures are around 8°C, and total annual precipitation is between 700 to 800 mm (Czech Hydrometeorological Institute). The area experiences a net negative precipitation after factoring in evaporation. Monthly average temperatures vary from -3.1°C in January to 16.6°C in July.

5.2 Physiography

The physiography of the Chvaletice region is described as flat lying with some rolling hills. The Property lies immediately south of the Labe River (German: Elbe) which is a regional hydrographic drainage merging with the Vltava River north of Prague. The property is within the Upper and Middle Labe River Basin which is administered by the Elbe River Board under the Ministry of Agriculture.

Forests in the region are classified as boreal. Well-established vegetation on the tailings cells is comprised of grasses and small shrubs on the upper plateau, and juvenile to semi-mature birch trees along the side slopes.

The gentle landscape and moderate climate promotes a healthy agricultural industry in the region, with arable lands that produce corn, barley, sugar beet, canola, and other crops, which occupy the majority of the rural landscape.

5.3 Local Resources

The Chvaletice deposit is located immediately adjacent to both an 820 MW lignite coal-fired power station operated by Severní Energetická a.s., and a pre-cast concrete plant operated by Tiba Chvaletice s.r.o.

A rail line is located immediately to the south of the Property which acts as the main transportation line from Prague to communities of Eastern Czech Republic. Spur lines are used to transport and unload coal to the power station, and to service an adjacent industrial park which is the site of the former processing facilities that produced the tailings deposits.

5.3.1 Water

Groundwater supplies the agriculture, urban, and industrial water requirements in the region. The Labe River follows the northern and western boundary of the project.

Water resources in the Czech Republic are jointly managed at the national level by the Ministry of Agriculture (policies and regulates services), the MoE (regulates wastewater discharge), National Institute of Public Health (controls drinking water quality), and the Ministry of Finance (regulates tariffs), all in conjunction with local municipalities.

Currently, activities being undertaken on the Property have minimal to no water demand. Hydrogeological and environmental studies have been completed to assess local water quality and baseline conditions. These studies are described in Section 20.6. A site Water Management Plan, which will be used to support water use permit applications, is described in Section 18.8.

5.3.2 Power

The Czech electrical grid will supply electrical power supply for the CMP. The Chvaletice power station operates an 820 MW lignite coal-fired power station, which is a key node in the Czech electrical grid. The power station provides power to the Czech electrical grid system. A description of the project requirements for Power Supply and Distribution are described in Section 18.4.

5.3.3 Infrastructure

No infrastructure exists on the Property.

5.3.4 Community Services

A significant labour workforce is accessible in the nearby communities, including the villages of Chvaletice (population 3,200) and Trnavka (250), as well as the towns and cities of Kutna Hora (21,000), Kolin (31,000), Pardubice (89,000), Hradec Kralove (93,000), and Prague (1,200,000).

Mining supplies, services, and technical expertise can be found mainly in Prague and Pardubice.

5.4 Property Access

The Property is located along paved Highway #322 which connects to Prague, approximately 89 km by road, via Kolin and Highway #12. The Property is accessed by a short gravel road and locked gate, which is maintained by Severní Energetická.

5.5 Topographic Reference

Spatial survey in Czech Republic is conducted using the S-JTSK (Krovak East North) coordinate system and the Bpv, a system designed for the Czech Republic. Czech transformation key has an average positional error of 0.2 m and height error 0.3 m. The CMP is located with midpoint at approximately -670,860 E, -1,057,920 N, and 206 masl (S-JTSK), which would have a Universal Transverse Mercator (UTM) (World Geodetic System [WGS]84) equivalent coordinate of approximately 531,840 E, 5543000 N, and 250 masl. The S-JTSK (Bpv) system is used as the base coordinate system and datum for the CMP.

Topography for the CMP was provided by GET using the 5G DEM developed by the Land Survey Office in Prague. A map was provided by GET in MicroStation software format (.dgn file type) using the S-JTSK Bpv coordinate system, which included topographic contours extracted from the 5G DEM to represent the site. After adjustment, the surface generated from the survey has total standard error of 0.18 m of height in the bare terrain and 0.3 m in forested terrain.

6.0 HISTORY

Historically, from 1915 to 1945, several small underground mining operations near Chvaletice produced manganese raw ore and concentrates that were principally shipped to German steel mills. Thereafter, from 1951 to 1975, open pit mining and milling operations occurred for the recovery of pyrite to produce sulphuric acid for the chemical plants in nearby Pardubice which produced the three adjacent tailings deposits.

The following recount was extracted from the Bateria Slany report compiled for the Property in 1989. References to Mineral Resources, Reserves, or “ore” in this section are historical, have not been directly verified by the CP and cannot be relied upon.

6.1 Mining of Iron Ores

The first mention of iron mining at Chvaletice dates to the year 677. The medieval production of iron in the surrounding area can be linked to the origin of the name of Železné hory (Iron Mountains), whose northwestern tip includes the Chvaletice mining district. Mining took place intermittently until the early 17th century. Mining ceased after the Thirty Years' War (1618 to 1648) and resumed at the end of the 18th century.

In the mid-19th century the Česká Montánní Společnost (Böhmische Montangesellschaft) came into the region and was the leading manufacturer of pig iron, the owner of a foundry and rolling mill and the iron mines in the Czech Lands. Zones of iron and manganese deposits at Chvaletice were found to extend over a length of about 12 km and were relatively well explored. In 1885, mining produced about 400 t of iron oxide from iron cap containing 20% each of iron and manganese.

6.2 Mining of Manganese Mineralization

Mining was managed by the Pražská železářská společnost (Prager Eisenindustrie-Gesellschaft), which in 1909 took over the mines. Systematic extraction of metal at Chvaletice began in 1915. After mining out the minor gossan occurrences, mining focused on the west side of Chvaletice, where the No. IX underground mine was built. The annual production of manganese ranged between 10,000 and 50,000 t. After World War II, the Pražská železářská společnost was nationalized, and on January 1, 1946, was incorporated into the state enterprise Středočeské uhelné a železnorudné doly (Central Bohemian Coal and Iron Ore Mines). Small-scale, intermittent surface mining of manganese mineralization continued in Chvaletice until 1952.

6.3 Mining of Pyrite 1951-1975

From 1951 onwards, pyrite mined by open pit methods at Chvaletice became the basic raw material for the production of sulphuric acid. Pyrite in Czechoslovakia had been imported mainly from Rio Tinto in Spain and Boliden in Sweden, and from Yugoslavia after the war. After the Communist putsch in February 1948, the shipments of pyrite iron raw material from Western European countries stopped. Since heavy chemical industry and other downstream industries would be jeopardized, alternative sources were then obtained from pyrite shales from the Chvaletice deposit. In 1949, the No. IX mine was re-organized into a separate national enterprise called Manganorudné a Kyzové Závody Chvaletice (Manganese and Pyrite Enterprise [MKZ]). In the following year, a new processing plant and housing for employees was built. Its operation was officially launched on the occasion of the anniversary of the so-called Victorious February on February 25, 1951. Exploration work showed that the processing plant was inappropriately located and obstructed the mining of part of the deposit. The concept of underground mining was abandoned, and the mining method changed to open pit mining.

In the years 1958 to 1960 the Czechoslovak chemical industry began to phase-out Chvaletice pyrite for the production of sulphuric acid, preferring imported sulphur from Poland. The economic production of manganese ore could never be achieved, given the low grade of the open pit ore and the metallurgical challenges of producing a concentrate.

In 1975, the production of pyrite concentrate was terminated. The MKZ changed its name to Energostroj and started manufacturing machinery and equipment for the power industry.

During the entire period 1951 to 1975 the open pit reached 2 km long, 700 m wide, and 150 m deep. Over 32 Mt of pyrite was mined and produced 7,467,000 t of concentrate containing 38.3% of sulphur.

The mining lease for Chvaletice was canceled in 1981. The primary deposit is still recorded as having 108,805 kt of potentially economic "Reserves" (according to the current Czech classification) containing 12.86% of total manganese. The residual "Mineral Resource" of pyrite, estimated to be 39,573 kt, with an average of 12.99% sulphur, is not kept in the State's balance sheet.

Figure 6-1: Photo of Original Chvaletice Iron and Manganese Mine, circa 1978

Figure 6-2: Photo of Original Chvaletice Iron and Manganese Mine, circa 1974

6.4 Elektrárna Chvaletice (Power Station)

After the closure of the mine, the plant site was used for the construction of a power plant. The site was chosen to minimize disturbance of agricultural land and to permit storage of fly ash in the mined-out pit area. The construction of the power plant was carried out in the years 1973 to 1979. The power plant provided employment opportunities not only for the former employees of the MKZ, but also expanded the population and 172 housing units were built. The waste heat from the power plant continues to be supplied as steam to Chvaletice, Trnávka, and the adjacent industrial areas.

To supply the power plant with thermal coal, the river Labe from Mělník was made navigable and the Chvaletice port was built. Regular shipping of approximately 3.5 Mt of coal from mines in northern Czech Republic took place from 1977 until 1996, when it was completely transferred to rail.

Chvaletice power station has four generating units with a total installed capacity of 820 MW. The power station stack reaches a height of 303 m, and its cooling towers are approximately 120 m high.

Figure 6-3: Current Power Plant

Note: The CMP tailings are to the left in the photo and the historical open pit mine is behind the plant (looking southeast), taken in 2018.

6.5 Use of Tailings Ponds as a Source of Manganese

The flotation waste was deposited into Cell #1 until 1961, then between 1962 and 1970 into Cell #2, and from 1971 until 1975 into Cell #3. The cessation of the production of pyrite concentrate occurred in 1975.

The waste tailings slurry suspension was placed into the ponds so that the coarser tailings accumulated on the edge, the fine sludge accumulated in the central part of the pond, and water was pumped back into the process plant via a decantation system. The tailings deposit has a volume of over 16 Mm^3 registered with the State as potentially economic "Reserves" "Chvaletice – tailing ponds No. 1, 2" and "Řečany – tailing pond No. 3" with estimated Mineral Resources of 29,996 kt (note: Tetra Tech's current estimates, as documented in Section 14.0, indicate the volume of tailings exceeds 17 Mm^3).

A geological evaluation and technological investigation of the three tailings ponds took place in the years 1985 to 1989 to confirm that the raw materials were available for the manufacture of EMD. The client was the former state-owned manufacturer of batteries, Bateria Slany. An extensive evaluation of the tailings material conducted between April 1986 and July 1988 resulted from their investigation including a "reserve calculation". Raw data has not been sourced by EMN; however, reporting has been recovered and translated into English for reference. The work was stopped due to the collapse of the communist regime in 1989.

In September 2014, the Ministry of the Environment issued an exploration license over the area, following a public tender, which entitles the holder to carry out further exploration and to possess the mineral rights. The rights to the territory called Trnávka was obtained by GET who then they transferred the rights to Mangan in 2015. This transaction is described in Section 4.0.

6.6 Construction of Tailings Facility

Construction of the tailings facilities is believed to have commenced in 1950. Cell #1 was the first facility to have been constructed. Historical documentation has indicated that the cell's foundation is built from local native soils, which were also excavated and compacted to form the original perimeter starter dam. The dimensions of the starter dam are reported to have a trapezoidal cross-section being approximately 20 m wide at the base, 5 m wide at the top surface, and with overall height of approximately 3 m. This approach is assumed to be the same for construction of Cells #2 and #3. It is also assumed that the dam raises were constructed in an upstream direction using dried and compacted tailings material. Four sonic drill holes were completed by EMN in the summer of 2017 and 26 mobile percussion holes were completed in the summer of 2018 to test for these historical structures but were not successful in intersecting them.

Perforated decantation towers (approximately 30 m high) (Figure 6-4) were constructed to channel water into a pit at the tailing pond's edge following the sedimentation of the tailings. The tailings were put in place hydraulically. Pipes or gutters transported tailings along the tailing pond perimeter to fill one-half of the pond while the other half dried. Dam lifts were built by bulldozers that scraped dewatered material away from the center of the tailing cells to the edge, after a pond was filled to the brim with tailings.

Figure 6-4: Historical Decantation Tower Located on Cell #3, Near Drill Holes T3-310, 311, and-318

The elevation of the Labe River and the base of the tailing ponds are similar, around 202 masl (Bpv datum). The perimeter of Cell #1 (26.6 m depth by 500 m by 500 m) and Cell #2 (28.7 m depth by 700 m by 550 m) are irregularly shaped polygons and measurements are approximate. Waste crusher fines from a granite aggregate quarry located near Chvaletice were used to cap, stabilize, and reclaim the surfaces of Cell #1 (averaging 1.32 m depth with topsoil) and Cell #2 (averaging 1.23 m depth with topsoil). Cells 1# and #2 are mostly vegetated with grasses, and their embankments were planted with trees and grasses.

Construction of Cell #3 did not reach full capacity and reclamation was not fully completed; however, stands of young birch and aspen trees are most prevalent on Cell #3. This cell abuts the northern toe of Cell #1 and is covered with approximately 0.2 m of overburden material. An exception is in the southern area of Cell #3 where there is some old municipal waste and partial backfills of tailings from iron and manganese mineral extraction in Chvaletice.

6.7 History in Dates

Table 6-1 sets a chronological order of events related to mineral resource extraction near the Chvaletice region.

Table 6-1: Chronology of Mineral Resource Extraction in the Chvaletice Region

Year	Activity
est. 677	▪ According to the legend in the Hájek Chronicle dated 1541, iron was discovered at Chvaletice in 677.
1143	▪ The founding of the Sedlec Monastery, which includes the village of Telčice (a part of today's Chvaletice) in addition to other possessions.
1393	▪ The first written mention of the fortress Chvaletice.
1845	▪ Start of the railway Prague-Pardubice.
1858	▪ The Mining Court in Kutná Hora vested to Count Kinsky a mine area at Chvaletice consisting of four mineral claims.
1886	▪ Česká montánní společnost (Böhmische Montangesellschaft = Bohemian Mining Company) asks for the conferring of the mining areas Karel (Charles) and Nadeje (Hope).
1909	▪ Pražská železářská společnost (Prager Eisenindustrie-Gesellschaft = Prague Iron Company) takes over the mines in Chvaletice mining district.
1915	▪ Ferro manganese mining by Pražská železářská společnost until 1945.
1946	▪ Pražská železářská společnost was nationalized and incorporated into n. p. Středočeské uhelné a železnorudné doly (Central Bohemian Coal and Iron Ore Mines).
1949	▪ Founded n. p. MKZ.
1951	▪ The ceremonial opening of the secondary mining school – because underground mining actually never started, the school never served its purpose, and today is a secondary school of agriculture. ▪ The new MKZ pyrite mining and processing plant started.
1952	▪ Manganese mining was discontinued.
1973	▪ The new Power Plant Chvaletice construction began.
1975	▪ Pyrite mining ended and the reorganization of the MKZ to Energostroj Chvaletice.
1977	▪ Start of transport of thermal coal on the Elbe water way. ▪ Start of trial operations at Chvaletice power plant.
1979	▪ Full operations at Chvaletice power plant .

table continues…

Year	Activity
1981	▪ Chvaletice obtained Town status. ▪ Chvaletice mining lease expired.
1989	▪ The end of three years of studies by Bateria Slany.
1996	▪ All transport of coal to the power plant was switched to rail.
2013	▪ The state-controlled power company České Energetické Závody (CEZ) sells Chvaletice power plant to Severní Energetická Společnost for 4.12 billion crowns.
2014	▪ GET granted the exploration license Trnávka for the exploration survey of manganese deposit in the tailing ponds Nos. 1 to 3.
2015	▪ License transferred to Mangan. ▪ EMN initiates preliminary studies of the CMP, whose goal is to recycle the Chvaletice tailings to produce EMM.
2016	▪ EMN acquires Mangan.
2018	▪ EMN lists on TSXV and ASE. ▪ Preliminary MRE is published. ▪ EMN is issued a Preliminary Mining Permit.

7.0 GEOLOGICAL SETTING AND MINERALIZATION

The following discussion is included to provide context of the geological setting of the original bedrock material that was mined and processed to form the tailings material that is the subject of this report. Due to grinding and flotation processes, none of the original textures that would have characterized the in situ rocks will have been preserved in the tailings material.

Mineralogy, specific to the tailings material, is discussed in Section 7.2.

7.1 Regional Geology

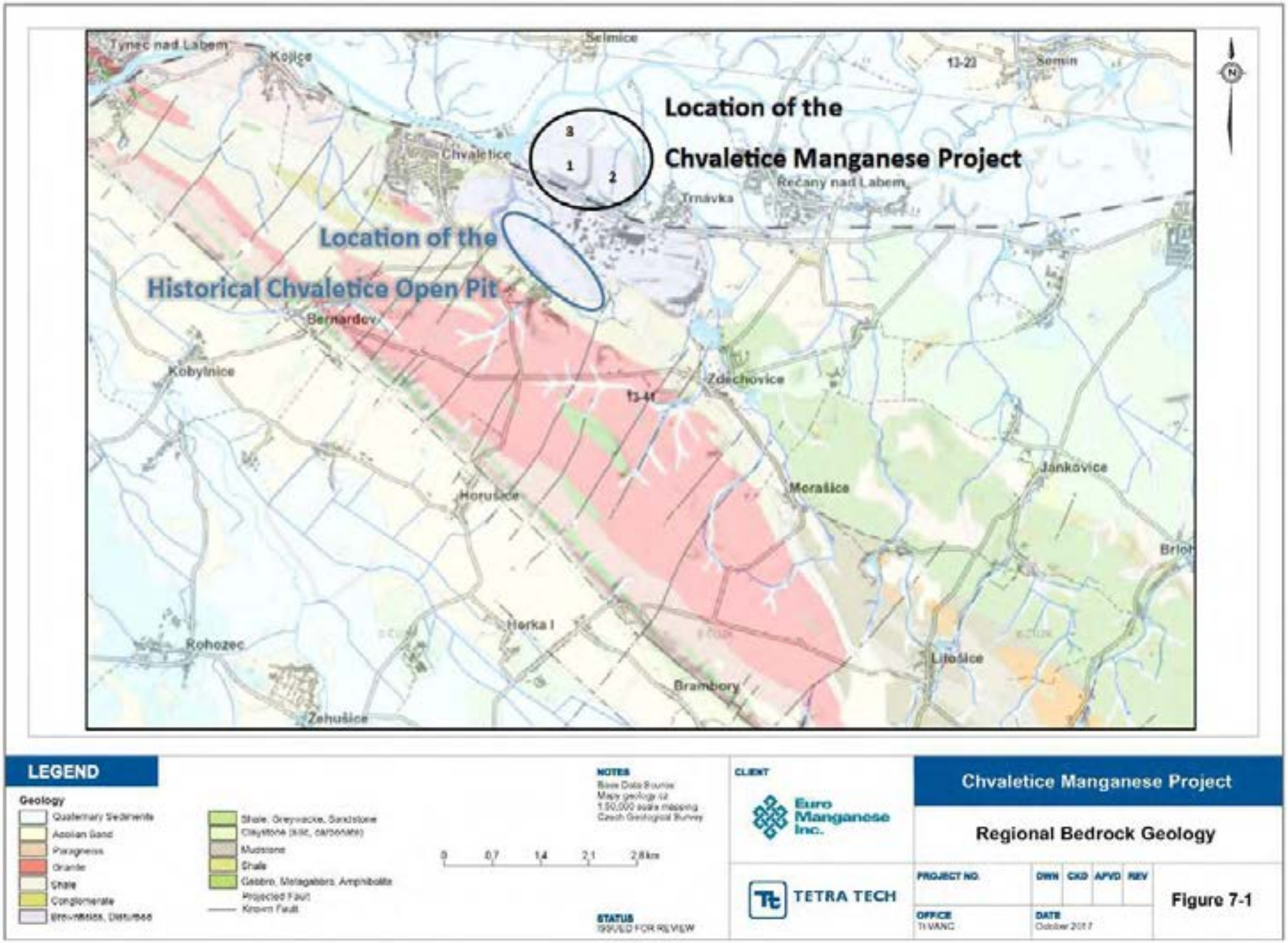
The original Chvaletice bedrock deposit is situated to the south of the CMP by approximately 1 km. Fly ash and other waste products have been used to backfill the original open pit which obscures the majority of exposed bedrock. Here, the bedrock is Proterozoic in age and is comprised of deformed granitic crystalline and overlain meta-sedimentary rocks of the Bohemian Massif, in the marginal area of the Central Bohemian Region.

In the Proterozoic, basement rocks were overlain by the seafloor turbidite sequence off from the continent of Gondwana. Here, the thick layers of fine sediments were deposited in deeper areas of the sea, periodically redeposited by huge subaquatic slumps. At the same time, subaquatic volcanic activity was taking place, associated with extrusions of lavas and assent of hot geothermal fluids. These fluids enriched the host rocks with sulphur, iron, and manganese.

At the end of the Proterozoic, rearrangement of lithospheric plates resulted from the Cadomian Orogeny, with related deformation and development of deep tectonic fracture zones. Magma and hydrothermal fluid ascent through fractures thermally affected the ambient rock domains forming weak to moderately metamorphosed phyllitic shales and greywackes. Intense folding and faulting of the sediments was developed during the orogeny as shown in the historical cross section schematic in Figure 7-1. The meta-sedimentary rocks were cut by dykes and sills which are preserved along the northeastern slopes of Zelezne Hory (Iron Mountains) between Týnec nad Labem, Chvaletice, and Zdechovice. Locally, a lens-shaped body locally called the Chvaletice Massif is composed of this Proterozoic granite and underlies the area south of Chvaletice and Zdechovice. The granite contains brittle deformation zones, altered to a variable degree. The rock is extracted in two quarries and is utilized as aggregate.

Other pyritic and manganiferous mineralized bodies are aligned along a trend that extends from the western edge of the municipality of Chvaletice to the nearby village of Sovolusky forming a 12 km long belt. In the western part, it creates a synclinorium, while towards the east it has developed into irregular zones that are intruded with porphyries. The maximum thickness of the pyritic schist in the western part is about 90 m, while the minimum is approximately 30 m, thereby with an overall average of thickness of some 60 m.

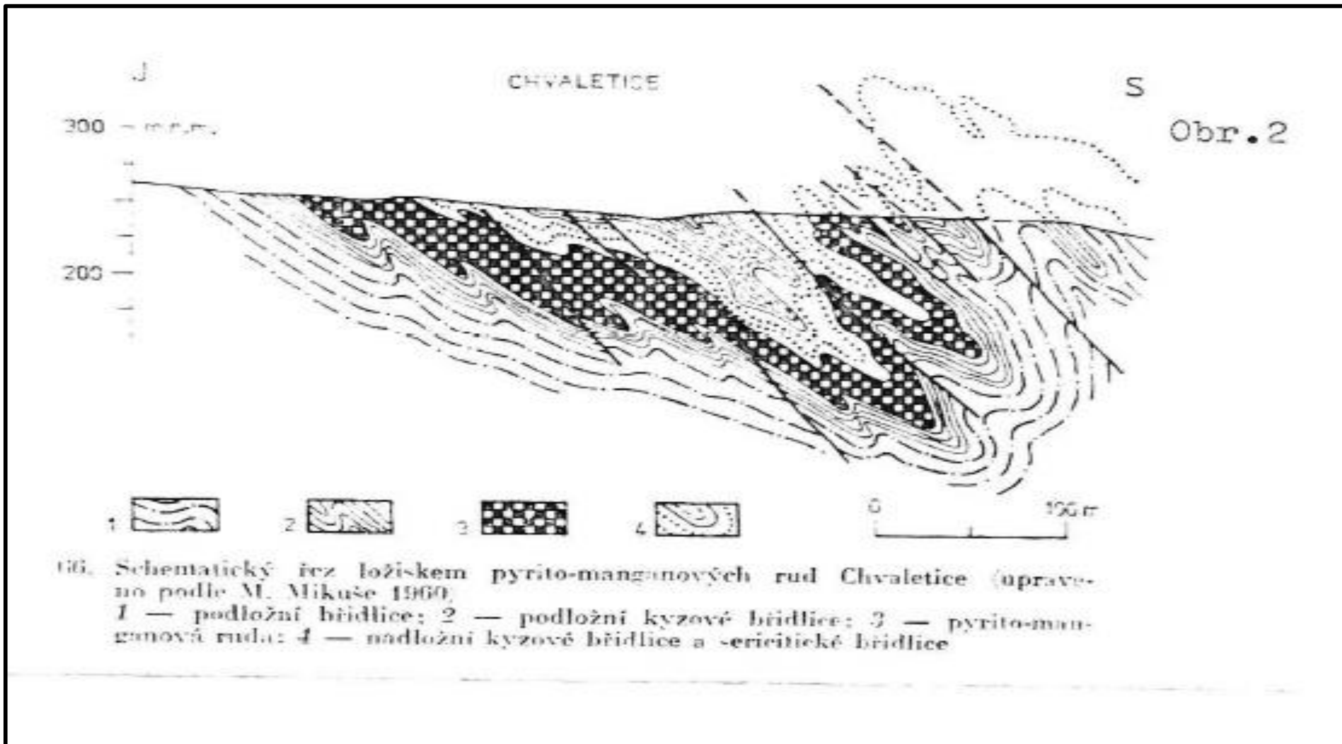
Figure 7-1: Regional Bedrock Geology



The syngenetic Chvaletice deposit of pyrite-manganese mineralization is hosted by the intensely southwesterly directed folded and moderately metamorphosed Neoproterozoic sediments located to the north of the southeasterly trending contact with granite. To the northeast, the sediments are overlain by younger Palaeozoic and Cretaceous strata.

Terrestrial fresh-water to marine claystones, siltstones, sandstones, and conglomerates of the Upper Cretaceous immediately underlie the CMP tailings deposits.

Figure 7-2: A Simplified Schematic of the Geological Section of Pyrite-Manganese Ores in Chvaletice



Notes: The 1) underlying schist; 2) underlying pyrite schist; 3) pyrite-manganese "ore" (black hatch pattern); and 4) overlying pyrite schist and sericite schist.
Source: Mikuš (1960)

7.2 Local Geology

The Chvaletice bedrock deposits of iron and manganese mineralization constitutes one horizon in the meta-sedimentary stratigraphy with variable proportions of carbonate and silicate minerals occurring laterally from west to east. Through mineral processing during historical mining operations, these minerals have been reduced in size and partially blended by grinding and flotation processes.

Through depositionary processes, these mineral particles were distributed throughout the tailings facilities by sedimentation from suspension in a tailings slurry. Thin beds of sediment will have been deposited laterally with a gradation from coarse to fine particles away from the point of deposition. It is then interpreted that grain size and moisture content may have more similarity with materials in a vertical sense and have more variability in a lateral sense. Whereas mineral and grade distribution, being related more to the process rather than deposition, is interpreted to have more similarity with materials in a lateral sense and less direct similarity with materials in a vertical sense. However, as discussed in Section 13.0, a relationship exists between elevated manganese grade with coarser particle size.

Met-Solve completed XRD and SEM-energy dispersive x-ray spectroscopy (EDS) analyses on behalf of EMN in 2015 using the samples collected from test pits in 2015. The analysis identified the main manganese bearing minerals were rhodochrosite ($MnCO_3$) and kutnohorite ($Ca(Mn^{2+}$, Mg, $Fe^{2+})(CO_3)_2$), which forms a series with dolomite and ankerite. These were classified as the principal manganese (Mn)-carbonate minerals. Additionally, the presence of trace quantities of manganese-silicates such as sursassite (a manganese bearing sorosilicate), and oxides such as pyrolusite (a manganese dioxide (MnO_2) and kurchatovite (calcium-magnesium-manganese-iron borate ($Ca(Mg$, Mn, $Fe^{2+)}B_2O_5$) were identified. Pyrite was noted to be the primary form of sulphide mineral, with concentrations in the samples between 5 to 9%. Gangue mineralogy consists of primarily quartz with moderate amounts of plagioclase, feldspars, micas, and apatite. Low concentrations (less than 5%) of kaolinite clay mineral was identified.

Further mineralogy work conducted on a bulk sample by CRIMM on behalf of EMN in 2017, concluded that manganese occurs with variable proportions of iron, calcium, and magnesium with carbonate to form a wide variety of manganese bearing carbonates from the rhodochrosite-siderite-dolomite-calcite spectrum. The work concluded that 80% of the manganese occurred as carbonate and 19% of the manganese occurred as silicate. High concentrations of iron and phosphorus were identified in the gangue minerals which were contained predominantly in pyrite and apatite, respectively.

Whole rock lithogeochemical analysis conducted on sonic drill samples collected during the 2017 program measured total sulphur concentration in the tailings with an average of approximately 3.1% which is sourced form sulphide, sulphate, and organic origin. Total carbon concentrations averages approximately 3.4%, which includes contributions from graphite, organic, and carbonate origin.

8.0 DEPOSIT TYPES

On the world scale, the most important manganese minerals are oxides, including pyrolusite, a manganese (IV) oxide. Other economically important manganese ores usually show a close relationship to the iron ores. Land-based resources are large but irregularly distributed. About 80% of the known world manganese resources are in South Africa, with other important manganese deposits found in Ukraine, Australia, India, China, Gabon, and Brazil. Deposits in China are known to be numerous, with low manganese content, but generally are relatively small.

On a purely descriptive basis, manganese ores can be classed as sediment-hosted, volcanic-hosted, or karst-hosted. Chemical distinctions among these types include:

- Much higher silicon dioxide (SiO_2) in volcanic rock-hosted deposits, which likely reflects a more oceanic setting with important contributions from pelagic radiolaria and diatoms
- Higher phosphorus pentoxide (P_2O_5) in sediment-hosted deposits, which may be related to upwelling
- Strong enrichment of barium (Ba) and lead (Pb) in karstic deposits, enabled by the open tunnels in the structure of cryptomelane-group minerals.

The mineralization found in tailings at the CMP has been deposited by manmade processes following grinding and flotation processes of black pyritic shale and is therefore not characteristic of a traditional manganese deposits. The material can be physically characterized as a compacted soil, with varying degrees of particle sizes from clay to coarse sand.

There is sorting of the flotation waste by grain size and weight, resulting from the sedimentation from the edge to the center of the tailings deposit (based on other tailing pond borehole sludge studies (Novotny et al. 1972). Subsequently, three zones of grain sizes in the tailing pond can result with:

- An outer zone of fine-grained sand and silty sand
- A central zone of alternating sandy laminae with the outer and inner zone types
- An inner zone comprised of silt to slightly clayey silt (finest material of all zones)

This zoning is typical for slurry tailings and results from sedimentation of deposited slurries from fluctuation of water levels during decantation operations (removal of water) within the central zone and a gentle slope (1.5%), leaving little to no water in the outer zone (Bateria Slany, Chapter 2 1989).

9.0 EXPLORATION

EMN has been conducting exploration and investigation on the Property since 2014, during which time multiple investigations have been conducted to sample and characterize the chemical and physical subsurface conditions of the tailings materials and surrounding ground. A summary of exploration work by year is included in the following subsections, and as shown in Figure 13-1.

9.1 Hand Auger Sampling, 2014

Four shallow (2.0 to 2.5 m) hand auger drillings were collected for assay and grain size test work from the periphery of the tailings deposits on November 7, 2014. Samples were collected from each auger hole and were identified as T1 to T4.

Results of the program indicated that total and soluble manganese assay results were comparable to those results reported historically by Bateria Slany (1989), but the sampling was considered to be indicative and not representative of the entire deposit with respect to grade and particle size distribution (AMEC 2016) due to the shallow auger holes testing only near surface material.

9.2 Test Pit Sampling, 2015

In 2015, two test pitting programs were conducted using an excavator to collect samples at greater depth, and with more volume than the previous hand auger program. Four pits, identified as T5 to T8, were dug down between 1.8 and 3.1 m deep at the periphery of the cells on November 11, 2015, and three additional pits, identified as T9 to T11, were dug to between 2.5 and 3.8 m deep at the center of each of the cells on December 14, 2015.

Again, results of the program indicated that total and soluble manganese assay results were comparable to those results reported historically by Bateria Slany (1989). With deeper sampling, the small particle size of the tailings in the center of the tailings was identified to be a potential issue for dewatering and further work was recommended (AMEC 2016).

9.3 AMEC Foster Wheeler Scoping Study, 2016

With results from the 2014 and 2015 sampling programs, a process evaluation report was completed by AMEC in September 2016, which considered a potential flowsheet for processing of the tailings with production of high purity, selenium-free EMM. The results of the study were positive and were used to develop a strength-weakness-opportunities-threats (SWOT) analysis. A list of detailed recommendations was presented for further material characterization and metallurgical test work to de-risk and refine the processing flowsheet.

9.4 Seismic and Resistivity Geophysical Survey, 2017

In July of 2017, EMN commissioned a geophysical survey over the tailings. A total of 6.6 km lines of high-resolution electric resistivity tomography (ERT) and seismic refraction was conducted by GImpuls Praha spol. s.r.o.

The purpose of the survey was to enhance the geological knowledge of the area with response from sub-horizontal geological components underlying the surface and to evaluate structures down to a maximum depth of the first tens of metres.

Initial results from ERT measurements show mostly very low resistivity with a maximum of 10 Ωm. According to typical geological ERT results, this may indicate the presence of electrically conductive clay in the rocks (in this case, sandstones with conductive glauconite).

Alternatively, or additionally, the lower measured resistivity values can be attributed to a massive presence of groundwater in the rocks, which, combined with the presence of the chemical infusions from the tailings, could cause low resistivity values. This theory is supported by the results of the seismic refraction that detected bedrock at depths of roughly 5 to 10 m with velocities of approximately 2,000 to 3,000 m/s.

Figure 9-1: Plan Map of Geophysical Survey Lines and Measurement Stations

9.5 Bulk Sample, 2017

A highly-representative bulk sample weighing approximately 15 t was collected using a Sonic drill rig from tailings materials during the 2017 drilling investigation. The material was the 75% split of the core samples collected, as discussed in Section 11. The samples were packed individually in plastic sample bags and steel barrels and shipped via rail to the CRIMM laboratory in China. Further description of the bulk sample analyses is discussed in Section 13.0.

TETRA TECH

9.6 Bulk Sample, 2018

A second bulk sample was collected from half core splits of the Sonic drilling program. The samples were clearly labelled and are currently securely stored in vacuum packed and sealed plastic bags to preserve original moisture content and prevent sample deterioration. The sample bags have been placed into storage in 55 gallon sealed steel drums for future test work.

9.7 Seismic and Downhole Geophysical Survey, 2018

As part of a preliminary geotechnical investigation (cone penetration testing [CPT] investigation described in Section 10.0), shallow refraction seismic (SRS) and vertical seismic profiling (VSP) was conducted on July 13, 2018, on behalf of Mangan by SIHAYA, spol. s.r.o., a geophysical company based in Brno, Czech Republic, specializing in engineering geology and hydrogeology. The survey was conducted from an array of geophones to determine homogeneity and relative density (compactness) and dampness of soils, and the depth and condition of the first 10 m of original soils and bedrock subbase underlying the tailings (SRS survey), and from within three boreholes drilled within the tailings (G 3-7 in Cell #3, GB 1-5 in Cell #1, and GB 2-6 in Cell #2) to determine the to determine S-wave and P-wave velocities of the various soil types within the tailings (VSP survey). The survey resulted in generation of interpreted geology-geophysical section profiles and tabulated measurements and confirmed the presence of native soils comprised of fluvial sands which underlie the tailings deposit.

10.0 DRILLING

Table 10-1 lists the drilling completed to date by EMN on the CMP by year, cell, and drilling method. A description of the 2017 and 2018 drilling programs follow in Sections 10.1 and 10.2, respectively. Figure 10-1 shows a plan view of the drill collars.

Table 10-1: CMP Resource Drilling Completed by EMN, Listed by Cell, Year, and Type

Cell and Year	Drill Type	Number of Holes	Total Metres	Number of Samples
Cell #1				
2017	Eijkelkamp SonicSampDrill CRS-V	25	629	291
2018	Makita HM1317C Mobile Percussion	13	589	285
	Eijkelkamp SonicSampDrill SRS	16		
Total		**54**	**1,218**	**576**
Cell #2				
2017	Eijkelkamp SonicSampDrill CRS-V	30	755.3	346
2018	Makita HM1317C Mobile Percussion	13	728	344
	Eijkelkamp SonicSampDrill SRS	21		
Total		**64**	**1,483.3**	**690**
Cell #3				
2017	Eijkelkamp SonicSampDrill CRS-V	25	295	119
2018	Eijkelkamp SonicSampDrill SRS	17	192.5	101
Total		**42**	**487.5**	**220**
Grand Total		**160**	**3,188.8**	**1,486**

Figure 10-1: Plan View of Drill Collar Layout, 160 Holes Totaling 3,188.8 m at Chvaletice Manganese Project

10.1 2017 Drilling

The 2017 drilling and sampling program was carried out between June 12, 2017, and July 19, 2017, utilizing advanced sonic rig technology provided by Eijkelkamp SonicSampDrill B.V. and crews from Giesbeek, the Netherlands (Figure 10-2). The program was supervised in the field by Chris Baldys, P.Geo. (BC), a non-independent CP at the time of the investigation.

A total of 1,679.3 m was drilled in 80 holes, using 100 mm diameter size rods and sonic core barrel advance (Figure 10-1). Twenty-five holes totaling 629 m were completed on Cell #1, 30 holes totaling 755.3 m were completed on Cell #2, and 25 holes totaling 295 m were completed on Cell #3. All holes were drilled vertically; no downhole surveying was completed. Figure 10-1 shows the drill hole layout. Drill holes were spaced evenly at approximately 100 m centres throughout the upper bench of each cell, encompassing a combined area of 1.2 km by 1.2 km (Figure 10-1).

Coring progressed using 2 m core runs. No casing was installed, and drill rods were pulled for each core run. Minor caving and pooling of water is assumed to have occurred on re-entry; however, this material accumulated in the hollow core rods above the core barrel and is believed to have had minimal effect on the integrity of the recovered sample. This material was dumped on surface adjacent the borehole and has been collected by Mangan for future evaluation if required.

Access to the embankment slopes around the perimeter of the tailings was limited due to safety and not included in this investigation. To verify the composition of the embankments, four additional drill holes (Drill holesT1-324, T1-325, T2-330, and T3-326) were collared on access ramps. Each hole intersected a layer of topsoil with average thickness of approximately 1 m, manganese bearing tailings material, and terminated in native basal soils at an elevation consistent with surrounding drill holes. Based on these drill results, the presence of manganiferous tailings material was confirmed within the perimeter embankment and based on the elevation of the basal soil contact, the historical starter dyke was not identified at these locations.

10.2 2018 Drilling

A total of 80 holes were drilled in 2018, totalling 1,509.5 m. The 2018 program included completion of 54 sonic holes, totalling 1,409.5 m from the top of each cell, and an additional 26 mobile percussion drill holes, totalling 100 m from the perimeter embankments of each cell in areas which were not previously accessed for sampling. The 2018 drilling and sampling program was carried out between July 10 to August 29, 2018. The program was supervised in the field by Tomas Pechar Jr., Ph.D. (Mining), Project Implementation Manager for Mangan.

10.2.1 Sonic Drilling

Sonic boring utilized advanced sonic rig technology provided by Eijkelkamp SonicSampDrill B.V. and crews from Giesbeek, the Netherlands (Figure 10-2). The purpose of the program was to increase the confidence in the distribution and concentrations of tailings geochemistry and physical properties for the purposes of Mineral Resource estimation and ultimately mine planning. This was achieved by conducting infill drilling between holes completed in 2017, and by completion of several holes within the perimeter embankments in areas not sampled during the 2017 program.

Figure 10-2: Showing Eiikelamp SonicSampDrill B.V. and Drill Crew

The Sonic program was divided as 35 vertical (660.5 m) and 19 inclined (749 m) holes using 100 mm diameter size rods and sonic core barrel advance (Figure 10-3) with the remote operated Eijkelkamp SonicSampDrill SRS. Twenty-nine holes totaling 589 m were completed on Cell #1, 34 holes totaling 728 m were completed on Cell #2, and 17 holes totaling 192.5 m were completed on Cell #3. Vertical infill holes were placed at mid-points between three existing holes, resulting in new short-range sample spacing of between 50 and 75 m. The inclined holes were drilled at 45° into the outer perimeter of Cells #1 and #2 to collect samples from the benched perimeter embankment. No downhole surveying was completed for the 2018 program; all holes were assumed to be straight given their short length.

Coring progressed using 2 m core runs. No casing was installed, and drill rods were pulled for each core run. Minor caving and pooling of water is assumed to have occurred on re-entry; however, this material accumulated in the hollow core rods above the core barrel and is believed to have had minimal effect on the integrity of the recovered sample. This material was dumped on surface adjacent the borehole and has been collected by Mangan for future evaluation if required. Any lost core was recorded in the field logs with recovery of zero percent; a total of 6.5 m was logged in 2018 as lost core.

Figure 10-3: Eijkelkamp SonicSampDrill SRS Used for 2018 Sonic Drilling Investigation

10.2.2 Hand Portable Percussion Drilling

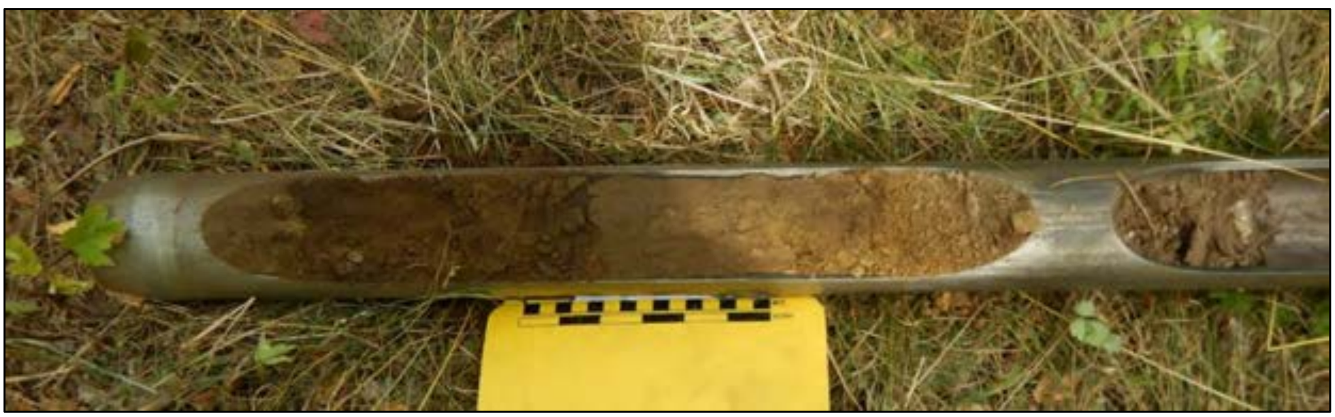
A hand portable percussion drill was used to collect samples within the lower benched portions of the perimeter embankment, where mature tree and vegetation growth prevented access by the Sonic rig. The drill rotor was powered by a generator powered Makita HM1317C drill which used a 3-inch hollow core tube configuration for core recovery (Figure 10-4 and Figure 10-5). The drill barrel was manually advanced and recovered by two operators employed by Mangan.

The percussion drilling program included 26 vertical holes, totalling 100 m, spaced at approximately 2 to 3 holes per side of Cells #1 and #2. The program was developed for sampling of the outer perimeter of the embankment in areas not accessed by drilling during the 2017 program to confirm the presence of manganiferous tailings and provide control on the elevation of the original ground elevation. The percussion holes ranged in depth from 1 m to 6 m.

TETRA TECH

Figure 10-4: Drilling of Perimeter Embankment Hole using Hand Portage Percussion Drill

Figure 10-5: Oxidized Tailings Recovered by Percussion Drill on North Perimeter Embankment Cell #2



10.2.3 Cone Penetration Testing Geotechnical Drilling

Geotechnical investigations using CPT and downhole seismic geophysical testing (geophysics described in Section 9.0) were undertaken in 2018 to characterize existing geotechnical conditions and provide information in support of PEA-level mine planning and conceptual design for the CMP. CPT holes were targeted across all three cells to assess the expected variation in material properties from the perimeter (coarser-grained tailings) to the interior (finer-grained tailings, likely softer/wetter layers) of the cells. The program was conducted between December 4, 2017, and January 15, 2018, using a Geoterend Gouda Truck Mounted Geotechnical rig (on Liaz truck) with 200 kN pushing capacity. The program employed continuous CPT drilling in 24 holes, totaling 554 m, and collected measurements for tip resistance, sleeve friction, pore water pressure, soil density (by gamma-gamma log), natural radiation (gamma), hydrogen index and soil humidity (neutron log), electric conductivity (dielectric log) to evaluate soil type and physical compaction characteristics. Table 10-2 summarizes the CPT drilling program.

Table 10-2: Summary of 2018 Geotechnical CPT Boreholes

Cell	Number of CPT Holes	Total CPT Length Drilled (m)
#1	8	224.3
#2	6	162.9
#3	10	126.8
Original Soils*	4	35.5
Total	**28**	**549.5**

Note: *Testing in original soils was conducted using a Begeman's type mechanical cone.

10.2.4 Hydrogeological Drilling

A hydrogeological investigation was conducted at the CMP between December 5 and 13, 2018. Drilling was completed by Intermarket Company using a SOILMEC 65 piloting rig. Eight new hydrogeological boreholes were drilled. Drilled material was logged by the geologist present on site during drilling and samples were collected into plastic buckets after every 3 m for chemical analyzes. A total of 47 samples were collected. In addition, 10 samples were collected for the Institute of Geological Sciences of Masaryk University in Brno for the purpose of specimen processing for models of water element spreading. Table 10-3 summarizes the hydrogeological drilling.

The hydrogeological study of the tailings piles was undertaken to contribute to the monitoring of changes in flow and chemistry of tailing's water over time, the determination of sorption of tailing's material and quaternary collectors, the determination of hydraulic characteristics (storativity, transmissivity, filtration coefficient) in the body of the tailings piles and of the surrounding area, assessment of the infiltration effect of the water from tailings piles to the surrounding quaternary collector, and for assessment of the dynamics and chemical changes of the groundwater water coming in and out of the bodies of tailings piles. The resulting data will be used to create a complex transport and geochemical model using the Modflow mathematical modeling code (GMS software). The collected data will be needed in the case of legislative procedures (EIA, risk analysis) as part of permitting process.

Water testing is being performed on boreholes CHV1, CHV9, CHV10, and CHV13. Hydrodynamic tests and sampling of groundwater from new boreholes will follow in the near future.

Table 10-3: Summary of 2018 Hydrogeological Boreholes and Groundwater Depth

Borehole	Cell	Ø Borehole (mm)	Ø Borehole Equipment (mm)	Depth from Ground (m)	Depth from Top of Casing (m)	Casing Stick-up (m)	Groundwater Depth from Top of Casing (m)
CHV6	II	600	110	26.7	27.72	±1.00	27.23
CHV7	II	600	110	26.7	27.83	±1.00	--
CHV8	II	600	110	21.9	22.60	±0.70	12.83
CHV9	I	600	110	25.8	26.95	±0.95	21.56
CHV10	I	600	110	26.5	27.34	±0.95	21.55
CHV11	III	600	110	11.5	12.72	±1.00	--
CHV12	III	600	110	11.5	12.62	±0.86	--
CHV13	III	600	110	11.5	12.28	±0.85	12.20

11.0 SAMPLE PREPARATION, ANALYSIS AND SECURITY

The sample preparation and analysis program described in this section was developed by EMN for the 2017 drilling campaign, with input from Tetra Tech, and implemented in the field by technical personnel employed by EMN. The program was designed to evaluate chemical and physical characteristics of the tailings material for the purposes of mineralogy; Mineral Resource estimation; and hydrogeological, geotechnical, metallurgical, and process engineering. The protocols established in 2017 were also used during the 2018 campaign for consistency.

Samples were analyzed and tested for manganese and elemental assay, lithogeochemistry, particle size distribution, mass, moisture content, paste pH, and electrical conductivity (EC) and specific gravity. Wet and dry in situ bulk density was calculated based on core recovery measured in the field, along with the sample mass and moisture data measured at the lab.

The program is summarized in the following bullet points and details of the analysis are included in the subsequent sections.

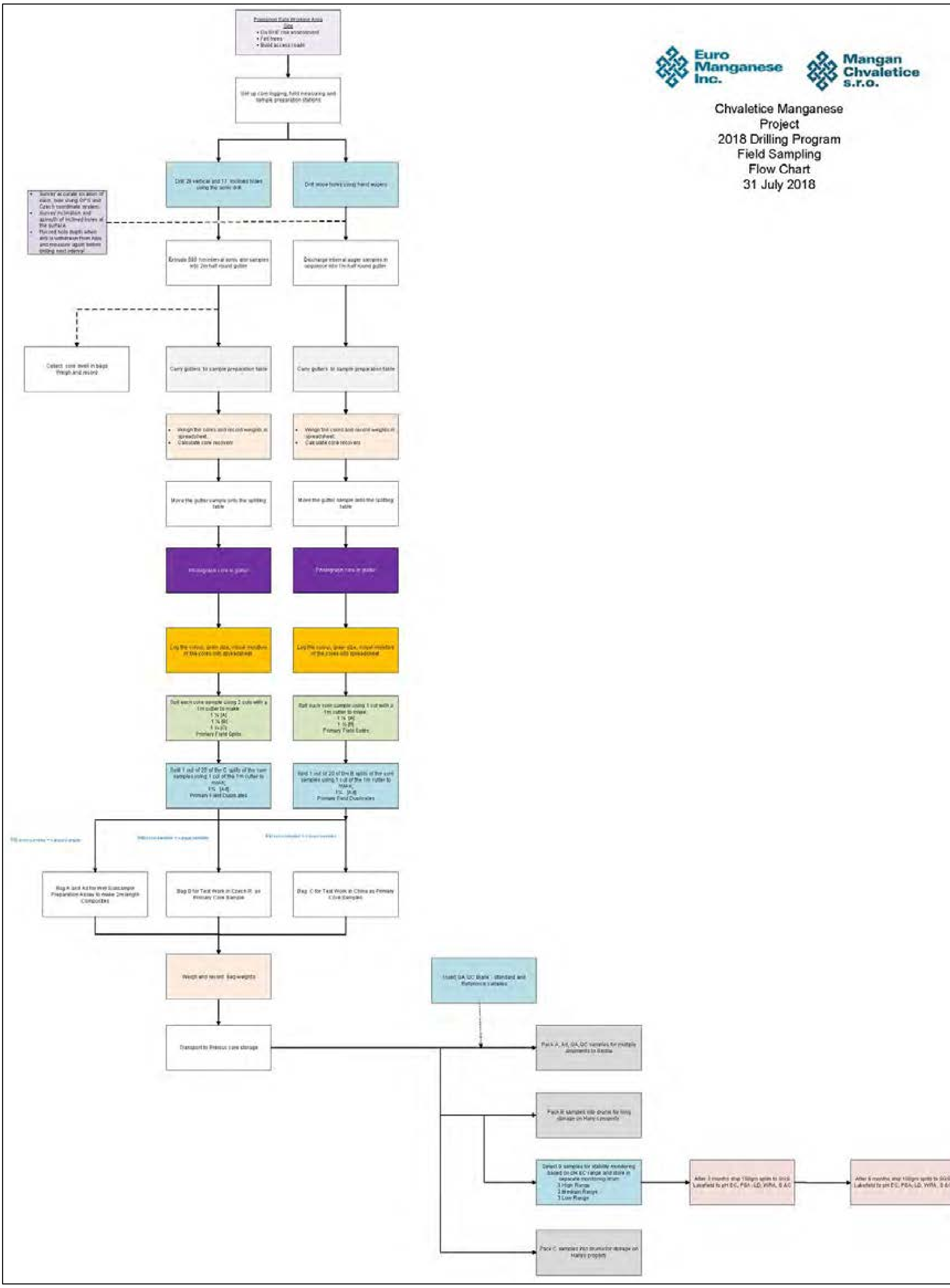
- Seven hundred and fifty-five (755) core samples were recovered in 2017, and 730 in 2018, totaling 1,484 samples which were recorded for analyses and material characterization (these exclude field duplicates and other QA/QC samples).
- One hundred and eight (108) control samples were generated in 2017 and 101 in 2018 by EMN to monitor commercial lab performances.
- Seventy-nine (79) laboratory duplicates (21 in 2017 and 58 in 2018) were generated by the primary lab (SGS) for review and analysis.
- Wet sample mass, recovery, and geological data were logged at the drill sites by a competent team of geologists. Moisture percentage and magnetic susceptibility were measured in 2017.
- Photographs of each core sample were taken for additional reference.
- Shipment of samples to analytical labs was done in accordance with chain of custody.
- Analysis for multi-element assay with aqua regia and 4-acid digestion (inductively coupled plasma [ICP] and AAS) and fusion-XRF.
- Particle size distribution test work with laser diffraction and sieve/hydrometer.
- Wet and dry mass, and moisture measurements were collected in field and lab (used for bulk density calculation).
- Specific gravity by pycnometer measured in the laboratory.

The primary lab selected for sample analysis was SGS with facilities in Lakefield, Canada, and Bor, Serbia. The lab, formerly Société Générale de Surveillance, is a multinational company headquartered in Geneva, Switzerland, which provides inspection, verification, testing, and certification services.

Comparative particle size analysis by sieve and hydrometer methods was completed (only for 2017 investigation) at GEOtest, a.s. (GEOtest) located in Brno, Czech Republic.

The 2018 drilling programs are summarized in Figure 11-1 and Figure 11-2, which show the field and laboratory sampling and analysis flowsheet. Figure 11-3 and Figure 11-4 show core recovered from holes T1-318 and T-312 representing unsaturated materials near the edge of the deposits and saturated materials near the core of the tailings deposits, respectively.

Figure 11-1: Sample Collection and Subsampling Flowsheet Developed by EMN for 2018 Drill Investigation



TETRA TECH

Figure 11-2: Subsample A Handling and Analysis Flowsheet Developed by EMN for 2018 Drill Investigation

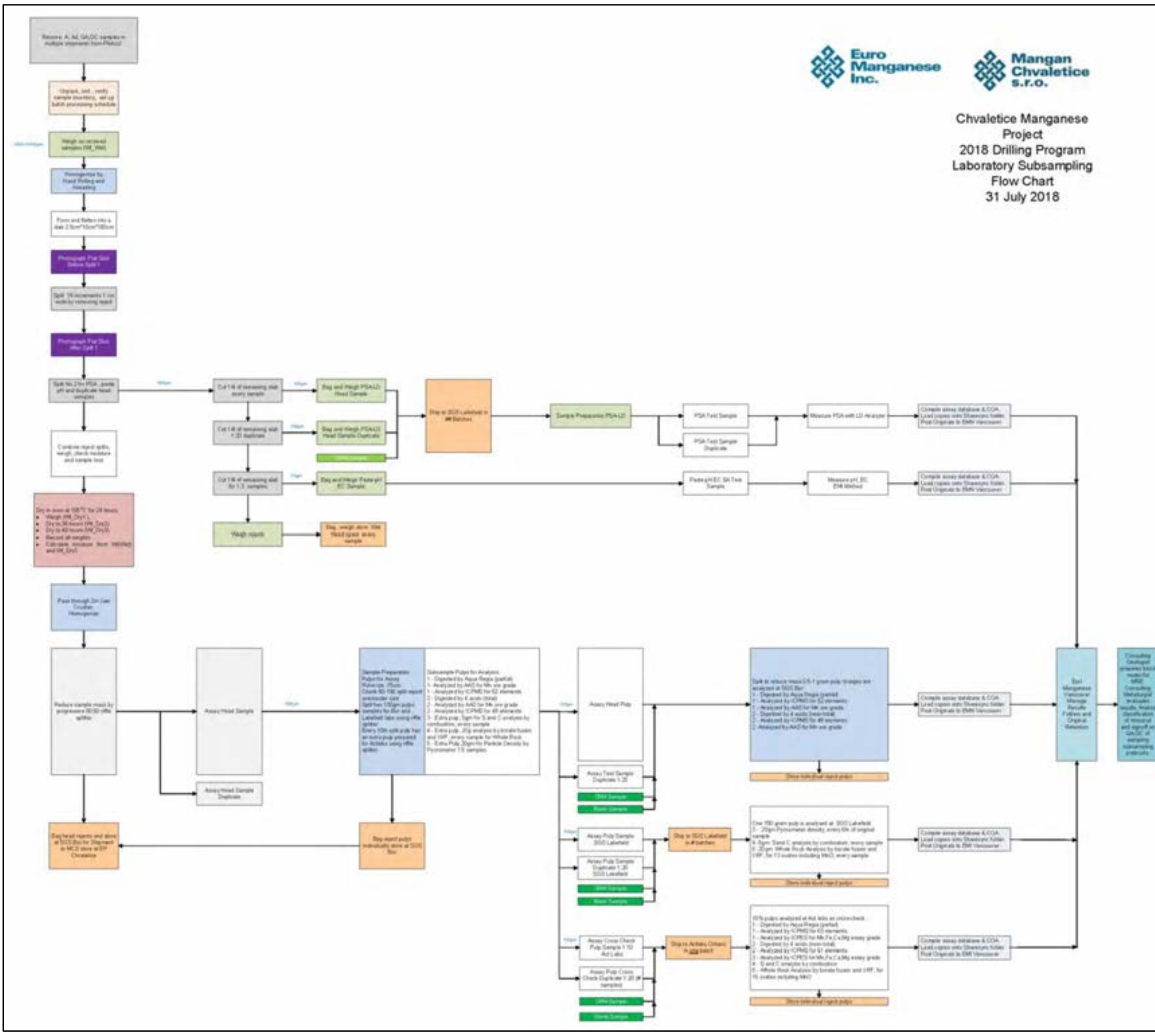


Figure 11-3: Core Photos from Drill Hole T1-318, from Depths 1-2 m, 19-20 m, and 24-25 m

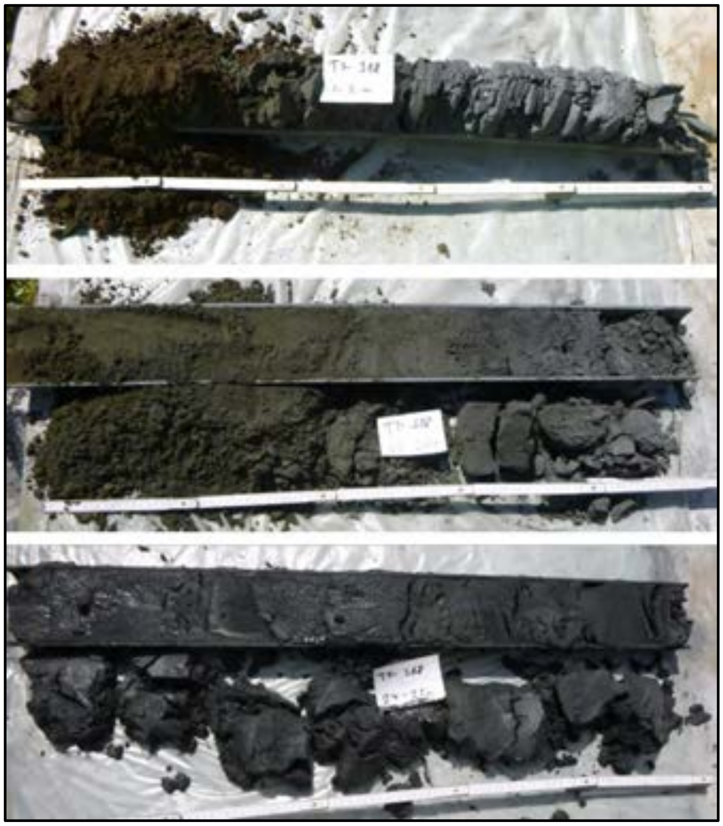
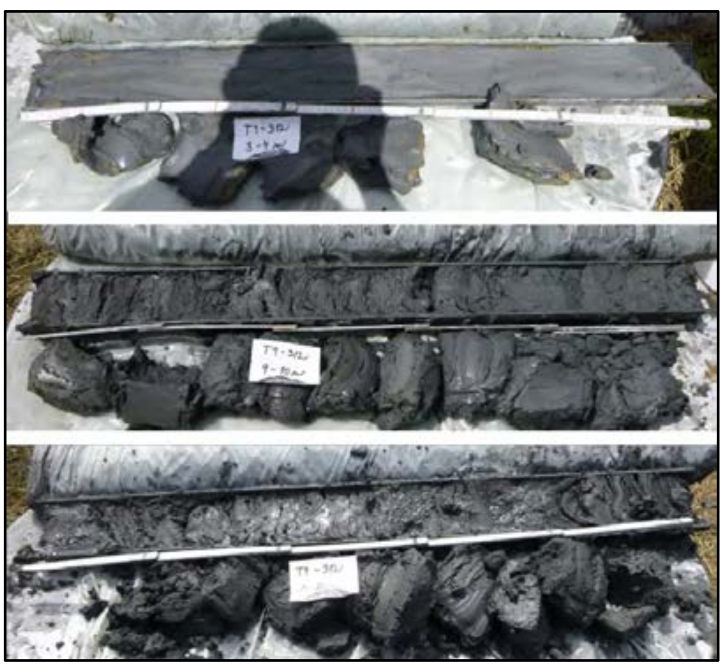


Figure 11-4: Core Photos from Drill Hole T1-312, from Depths 3-4 m, 9-10 m, and 23-25 m



Sample Collection

Core samples were collected continuously from the lower topsoil contact to the base of the tailings material at the subsoil contact. Sampling included only tailings material and excluded the upper topsoil and lower subsoil materials. A total of 755 samples with a combined wet weight of 23,521 kg were collected, representing 1,497.8 m in 2017, and a total of 730 samples with a combined total weight of 13,373 kg representing 1,398.7 m of cross stratigraphy tailings material.

The drilling was advanced on 2 m core runs. The core was extracted from the core tube in 1 m intervals into half cylinder core trays. These sub-samples were logged geologically, and field measurements were collected. Field measurements included sample wet mass, recovery, moisture, and magnetic susceptibility. Core logs and field measurements were recorded on site and later merged into a digital database.

Core recovery was measured on 1 m sub-samples and ranged from 45% to 110%. Some loss of material was encountered during flushing of drill pipes and likewise some elongation of core resulted due to plasticity if the material at certain locations in the deposit.

Each 1 m sub-sample was then quarter split (25:75) using a cutter along the length of the core axis (Figure 11-5) to preserve the in situ material distribution; the samples were not homogenized in the field. The 25% split was bagged and recombined with the corresponding quarter split from the other remaining one metre core run sub-sample. The 75% split was also bagged and recombined with the corresponding 75% core run sub-sample. Identification tags were included with each sample before the bags were sealed.

Figure 11-5: Sample Collection

Notes: A) 1 m core run sub-sample
B) and C) half and quarter splitting or core in field
D) sealed sample bags (bulk samples)

The 25% split samples were assembled for assay and particle size analysis ("assay samples"). The samples were delivered to SGS located in Bor, Serbia, in two shipments, then divided into 19 analytical batches at the lab (7 and 12 batches per shipment, respectively). The samples remained in custody of EMN personnel until being delivered by a commercial logistic company to SGS.

In 2017, the remaining 75% sub-sample was shipped to CRIMM in China, for bulk sample metallurgical and processing test work, respectively. In 2018, the remaining sample was split again with a 25% subsample collected for test work in Czech Republic, and the remaining half core collected for metallurgical test work in China. These samples were collected at a field warehouse which is managed by Geomin in Jihlava, inventoried, and placed into sealed steel drums strapped to pallets which loaded into a 40 ft. shipping container.

11.1 Laboratory Preparation and Sample Splitting

Assay samples received at SGS Bor were weighed (wet) and homogenized by hand using the "Japanese slab cake method" of kneading and rolling the sample. The homogenized sample was rolled out into a slab approximately 10 cm by 180 cm and 2.5 cm thick, as shown in Figure 11-6.

Figure 11-6: Example of Sample Splitting by the Wet Japanese Slab Cake Homogenization Method

A first split was achieved by forming 15 smaller slabs from the original sample volume by cutting and removing the reject from around the perimeter of the slabs.

A quarter of each of the small slabs was cut from one to make about 100 g of head sample. This split was not dried and was sent for laser diffraction particle size analysis (PSA-LD) at SGS in Lakefield, Canada. In 2017, one out of twenty (1:20) samples were sent as duplicates to GEOtest (Brno, Czech Republic) for comparative hydrometer particle size analysis (PSA-H); hydrometer tests were not completed as part of the 2018 test program. Approximately 75 g of materials as extracted for pH and EC measurement using a paste pH method.

The remaining slab material was dried at 105°C and homogenized using standard lab methods.

The wet cut method was selected to preserve the in situ state of the particles for PSA-LD. The total mass of material extracted from the PSA-LD, PSA-H, paste pH, and EC splits was approximately 500 g.

Duplicate splits which are master head assay duplicates were again taken 1:20 for heterogeneity/sampling error monitoring. These are identified as “lab duplicates” in the QA/QC assessment in Section 11.9.3.

All reject materials from the PSA splits were recombined, weighed, and dried. Moisture content of the sample was determined from the moisture loss measured at this stage of preparation. The sample was again homogenized and approximately 1 kg of material was extracted for assaying. These samples were pulverized to -75 µm.

The remaining head rejects were bagged, inventoried, and shipped for storage at the Geomin field warehouse in Jihlava.

11.2 Trace Element Assay

A total of 1,694 (863 in 2017 and 831 in 2018, including QA/QC samples) assay samples, averaging approximately 4.5 kg each (except for 50 g certified reference standards), were delivered to SGS in Bor, Serbia, for assay. The samples were submitted for the analyses listed in Table 11-1. The assay methods were selected to measure total elemental concentration in addition to measuring partial digestion concentrations of manganese as a proxy for “soluble manganese”. In 2017, total manganese was initially inferred from the results of the 4-acid digestion methods, however, this practice was revised in 2018 when total manganese was measured from total digestion methods with XRF detection. Soluble manganese refers to the results of the aqua regia digestion.

A sample assay exceeding 10,000 ppm manganese, which is the upper detection limit of the ICP-MS equipment was submitted for ore grade analysis using AAS. A sample split was digested in four acids (hydrochloric acid, nitric acid, hydrofluoric acid, and perchloric acid) for a near total digestion of the sample and a second split was digested in a weaker aqua regia solvent for partial digestion and as proxy for the “soluble manganese” mineral phases contained in the sample.

Table 11-1: Tabulated Description of Analytical Methods used for Assay of Tailings Sample

Digestion	Finish	SGS Method	Description
Aqua Regia	ICP-MS or AAS	IMS14B, AAS15Q	52 trace elements, includes analysis for “soluble” manganese
4-acid	ICP-MS or AAS	IMS40B, AAS42S	49 trace elements
Borate Fusion	XRF	GO_XRF76V	Total digestion lithogeochemistry; major cation oxides, includes analysis for “total” manganese
Combustion	LECO or SC632	GE_CSA06V	Inorganic carbon and sulphur assay

11.3 Particle Size Analysis

Particle size distribution throughout the deposit varies significantly due to the processed nature of tailings slurry material and the dynamics during deposition and particle settlement. Grain size may influence the manganese recovery process that is developed for the CMP. As regrinding of the tailings was not envisaged, understanding of particle size distribution was considered a critical variable for the deposit.

The primary method for particle size distribution analysis was by laser diffraction technology (PSA-LD) in a Malvern Mastersizer located at SGS in Lakefield, Canada (SGS method ME-LR-MIN-MET-SC-A03) using wet material. This equipment is able to analyze particle sizes from 0.02 to 2,000 µm, which is ideal for very fine materials such as silt and clays. A total of 830 PSA-LD results were received, which included 720 primary tailings samples. An additional 76 sample duplicates were submitted by EMN, 5 sample duplicates prepared internally by SGS, and 31 internal QC standards.

Particle size distribution analysis was also conducted through sieve and hydrometer methods using the European standard International Organization for Standardization (ISO) TS 17892-4, at GEOtest located in Brno, Czech Republic. The method includes passing dried material through standard screens, with the smallest screen size at 0.063 mm. Fractions passing this screen are classified as silt and clay and subjected to hydrometer testing. A total of 93 samples were submitted for hydrometer tests.

Grain sizing used for the CMP incorporates both North American standard ASTM International (ASTM) D-422 and the European standard ISO14688-1/-2.

11.4 Lithogeochemistry

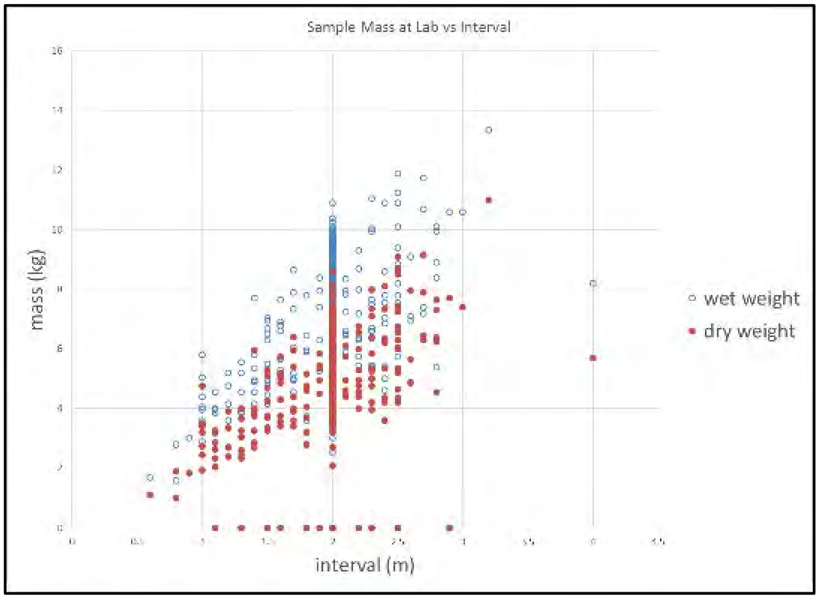
Lithogeochemistry was conducted at SGS in Lakefield using lithium borate fusion with XRF detection of 12 major oxides including manganese (II) oxide. A total of 1,448 (714 in 2017 and 734 in 2018, excluding QA/QC samples) samples were submitted for analysis.

Total inorganic carbon and inorganic sulphur were analyzed at SGS Lakefield using LECO furnace (combustion and infrared detection).

11.5 Moisture and Mass

Mass was measured in the field as wet mass on 1 m core run sub-samples, and also as wet and dry mass at the SGS laboratory in Bor in Serbia on the 25% split samples which represented the full 2 m core run sample size. Figure 11-7 depicts the relationship between wet and dry mass measured at SGS in Bor with the total represented sample interval length.

Figure 11-7: Wet and Dry Mass Measured at SGS Bor vs. Sample Interval



Approximate moisture content was measured in the field during the 2017 drilling program using a Delta-T MT3 soil moisture sensor (Figure 11-8), and at SGS in Bor from the assay samples that were received. The field moisture measurement approximated values ranged from 4% to 33%, with average value of 17.9%. Comparatively, laboratory moisture was calculated from the mass lost after wet samples were dried with values ranging from 5.6% to 27.4%, with average value of 17.4%. This procedure was not implemented during the 2018 field program.

Figure 11-8: Collection of Moisture and Magnetic Susceptibility Data in the Field

11.6 Specific Gravity

Specific gravity analysis was conducted at SGS Bor on splits from the assay sample using method ME-LR-MIN-MET-DS-A01. The pycnometer tests results are directly proportional to the individual densities of the mineral grains in the sample and can be used in estimating the in situ porosity of the tailings materials. The pycnometer specific gravity results ranged from 2.90 to 3.28 with average value of 3.05.

11.7 Bulk Density

Calculation of in situ dry bulk density was based on core recovery estimated in the field and the dry mass weights measured at SGS Bor. Further description of in situ bulk density calculation is included in Section 14.5.6.

11.8 2017 Sampling and Laboratory Analysis QA/QC Program

A systematic QA/QC program was designed in connection with the 2017 drill-sampling and analytical work. The program consisted of the following:

- Insertion of control samples (CRMs, duplicates, and blanks) into the analytical sample stream to monitor the performance of the labs, representing 15.7% of overall analytical results
- Review of internal QC data generated by the labs
- Re-analysis or repeat of the test work on batches and samples that fail the QC criteria
- Independent QA assessment completed by Tetra Tech.

A total of 755 samples were shipped to SGS for elemental analysis. This included 695 assays, 3 CRMs (33 analyses), 35 blanks, and 41 field duplicates. The laboratory included 21 additional lab duplicates. This resulted in a total of 884 assay results reported to EMN.

11.8.1 Certified Reference Materials

Three CRMs were inserted in sequence with the samples that were shipped to SGS in Bor. The name of the samples was recorded on the sample tag and was delivered to the lab as a blind sample with composition unknown to the lab. CRM insertions assess the accuracy of the analysis being performed and are intended to be present at a rate of at least one CRM per sample batch. Batch sizes at SGS included approximately 45 samples per batch, including field and laboratory QC sample insertions.

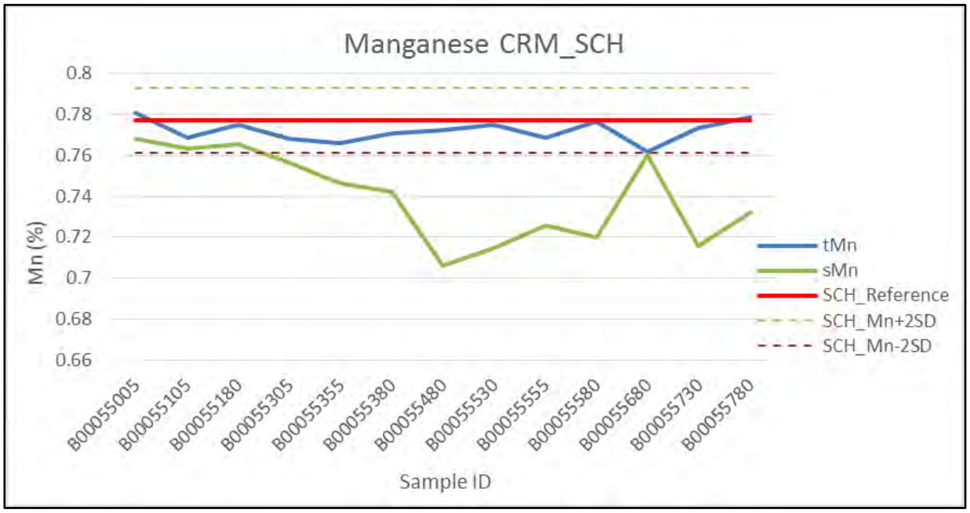
Three reference materials were selected by EMN at the onset of the program to be used as standards: as described in the following sub-sections.

11.8.1.1 Certified Reference Material – NRC-SCH-1

The NRC-SCH-1 reference was supplied by the National Research Council of Canada CANMET and was prepared from iron ore as hematite with various hydrous oxides of iron from the Schefferville Mine in Quebec, Canada. The expected mean manganese grade is 0.777% with 95% confidence interval of 0.008% manganese.

This sample accounted for thirteen analyses. Figure 11-9 shows the performance of the standard, where total manganese grade falls within the confidence interval of ±2 standard deviations. Soluble manganese values fall below the confidence interval, as expected, with somewhat variable correlation to the total manganese values.

Figure 11-9: CRM_SCH-1 Performance Plot for Total and Soluble Manganese

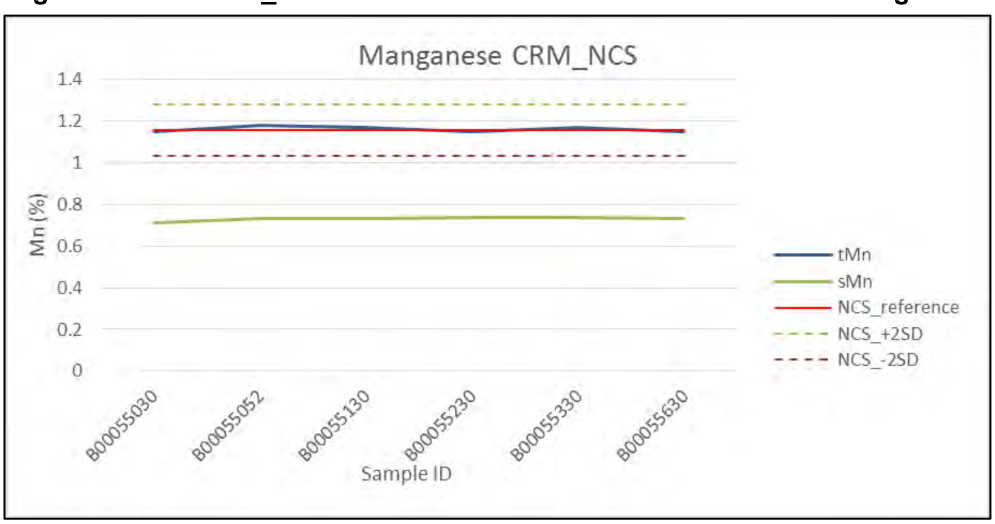


11.8.1.2 Certified Reference Material – NCS-DC-70007

The NCS-DC-70007 reference was supplied by China National Analysis Center for Iron and Steel. The source material is not disclosed in the material datasheet. The expected mean manganese (II) oxide grade of 1.49% (1.154% manganese) and standard deviation of 0.08% manganese (II) oxide (0.062% manganese).

This sample accounted for seven analyses. Figure 11-10 shows the performance of the standard, where total manganese grade falls within the confidence interval of ±2 standard deviations. Soluble manganese values fall below the confidence interval, as expected, with good correlation to the total manganese values.

Figure 11-10: CRM_NCS Performance Plot for Total and Soluble Manganese

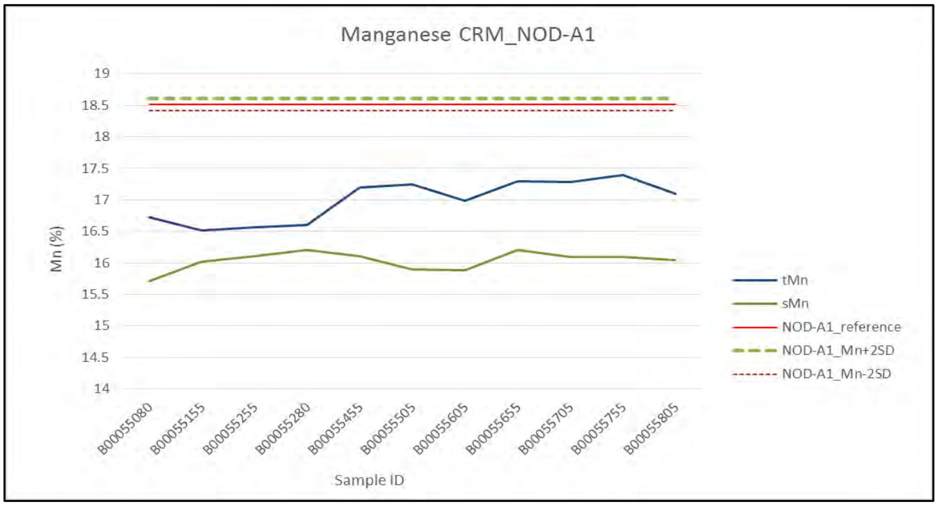


11.8.1.3 Certified Reference Material – NOD-A1

The NOD-A1 reference was supplied by the United States Geological Survey and was prepared from Atlantic Ocean seamount manganifeous nodules from the Blake Plateau. The expected mean manganese (II) oxide grade is 23.9% (18.51% manganese) with standard deviation of 0.065%.

This sample accounted for eleven analyses. Figure 11-11 shows the performance of the standard, where total manganese grade falls below the confidence interval of standard deviations and soluble manganese values falls further below with good correlation to the total values. This performance failure has been identified by others (Cullen et al. 2013) whereby it was concluded that “the primary meta-borate fusion and ME-ICP06 analytical package did not provide sufficient extraction of manganese and iron to match reference material results that were based on XRF analysis”. This CRM is not believed to be a suitable reference standard for control of exploration data as the results of this control measure are considered highly susceptible to analytical method. The materials do not assess, with validity, the digestion and equipment calibration used in this program’s analysis.

Figure 11-11: CRM_NOD-A1 Performance Plot for Total and Soluble Manganese



11.8.2 Blank Analysis

11.8.2.1 Certified Blank – ST08

The ST-08 Certified Blank was supplied by Sklopísek Strelec, Czech Republic, as a high purity silica sand with low impurity concentration. The standard was manufactured for grain size distribution analysis and reports an expected manganese concentration; however, this is expected to be negligible.

This sample accounted for twenty-three analyses. Figure 11-12 and

Figure 11-13 show the performance of the blank for iron and manganese concentrations. One sample failure (B00055034) was observed for manganese with a concentration of 0.77%. The remaining concentrations were below 150 ppm. This ambient concentration may be due to residual manganese within the grinding equipment, but it was determined to be insignificant. Overall sample failure is less than 5% which is interpreted by the CP as acceptable.

Figure 11-12: Certified Blank – ST08 – Iron

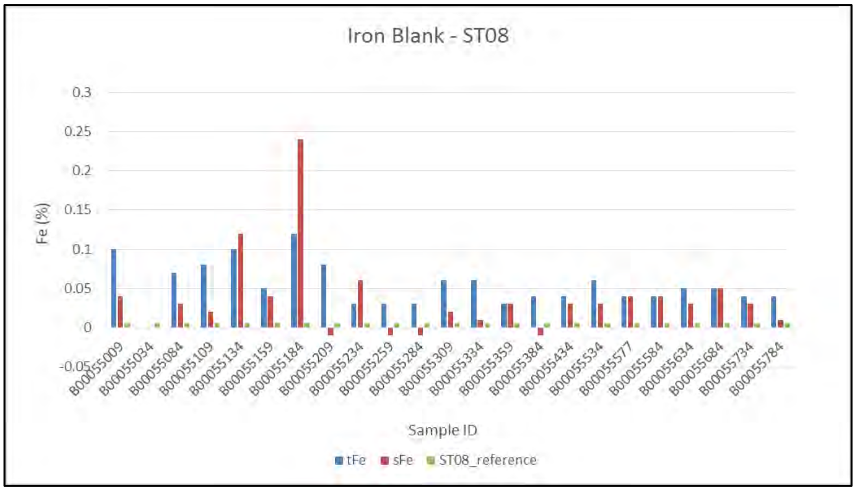
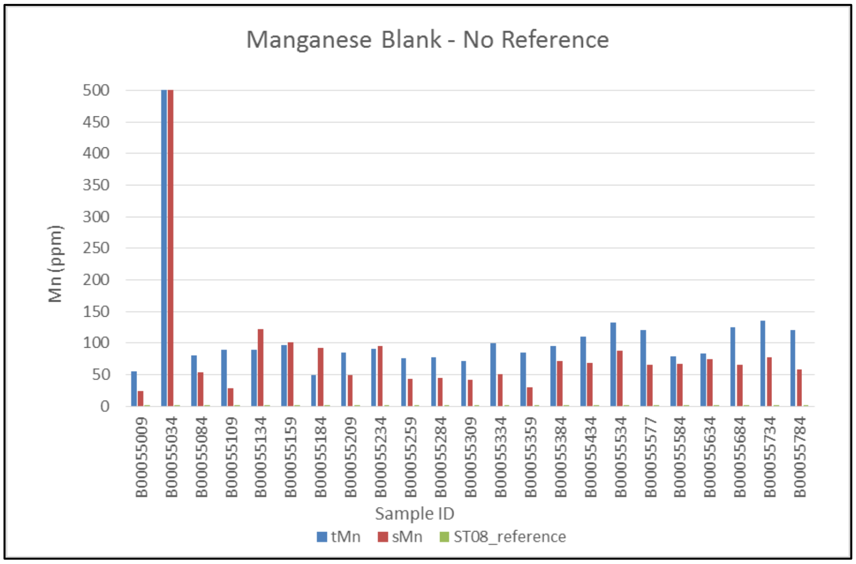


Figure 11-13: Certified Blank – ST08 – Manganese

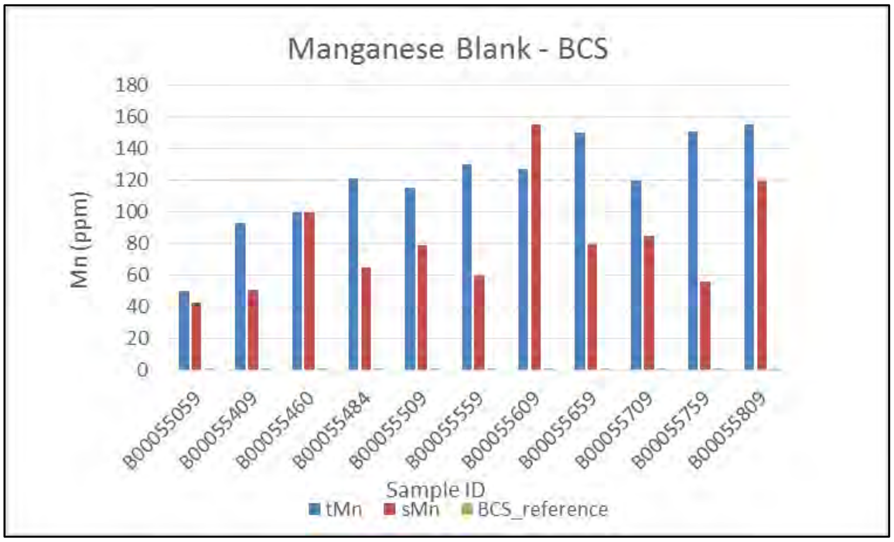


11.8.2.2 Certified Blank – BCS

The BCS certified blank was supplied by Bureau of Analysed Samples Ltd, based in England, prepared as low iron sand that passes a nominal 250 µm aperture. The standard has a “certified value” of 0.00014% manganese (II) oxide with 95% confidence interval of 0.0003%.

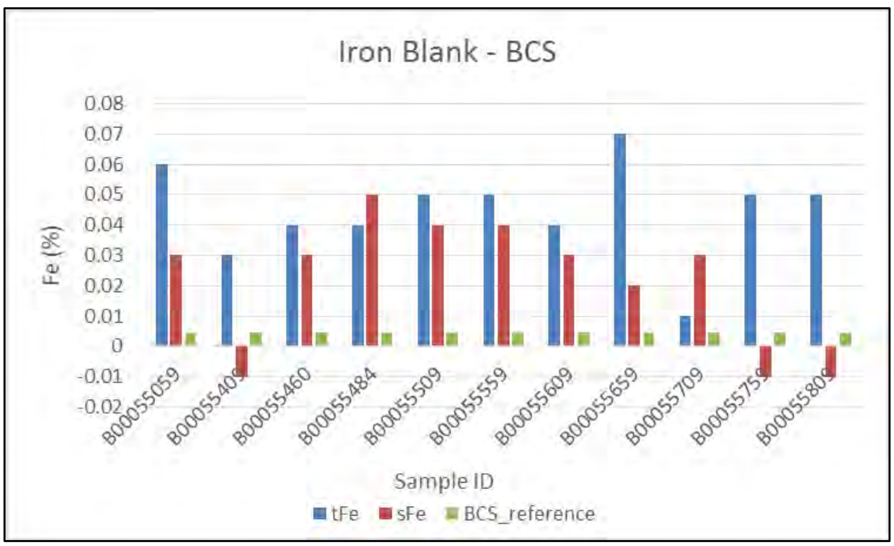
This sample accounted for eleven analyses. Figure 11-14 and Figure 11-15 show the performance of the blank for manganese and iron concentrations. The manganese concentrations were below 150 ppm. This ambient concentration may be due to residual manganese within the grinding equipment, but it was determined to be insignificant.

Figure 11-14: Certified Blank – BCS – Manganese



The certified blank, BCS, (green) is consistently shown as having less manganese percentage than the total manganese, 4-acid AAS, (blue) or soluble manganese, aqua regia AAS, (red).

Figure 11-15: Certified Blank – BCS – Iron



11.8.3 Lab Duplicates

Lab duplicates represent those samples which were homogenized and split from the coarse material into to replicate sub-samples internally by the lab, on request of EMN, prior to being pulverized and analyzed. The results of the lab duplicate assays allow for pairwise assessment of the laboratory's sample preparation, homogenization and splitting procedures prior to pulverization and digestion for analyte.

A total of 20 pairs of lab duplicates were collected, with 16 result pairs for soluble manganese and 18 result pairs for total manganese. In the assay database, each pair was identified with the same sample number with one labelled with DUP as suffix and the second with no suffix. The duplicate sets were evaluated using simple linear regression and the Pearson's coefficient, and also for relative percent difference (RPD) as a measure of precision. An RPD of less than 10% within 90% confidence interval is considered to be a reasonable variation for evaluation of the quality of the data.

Figure 11-16 shows the duplicate regression for soluble manganese (aqua regia AAS) and Figure 11-17 shows the regression for total manganese (4-acid AAS) against a 1:1 unity line in red. The soluble manganese regression indicated a slope of 1.0049 with Pearson's coefficient of 0.83, mainly due to one outlier. Total manganese indicated a slope of 0.9423 with Pearson's coefficient of 0.97.

Figure 11-16: Linear Regression of Soluble Manganese Assay Lab Duplicate Results

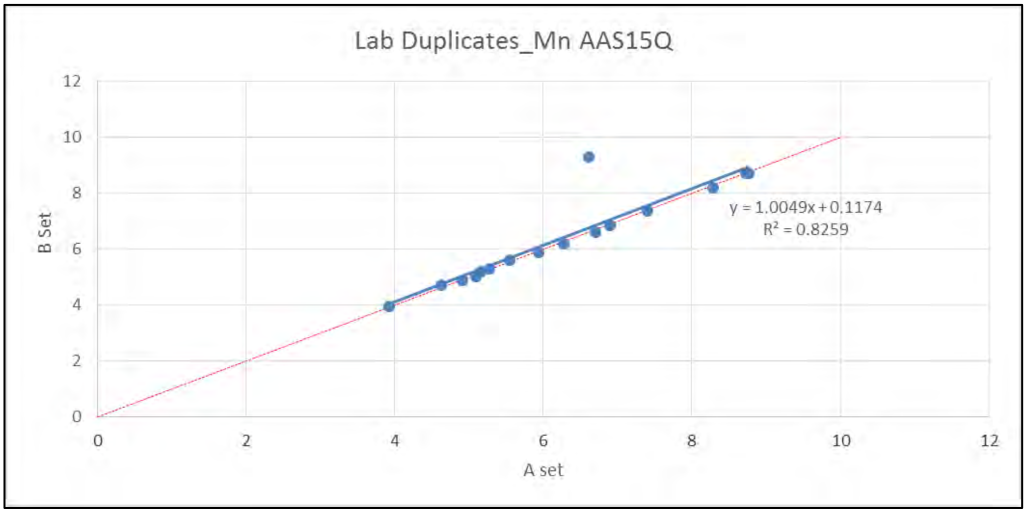
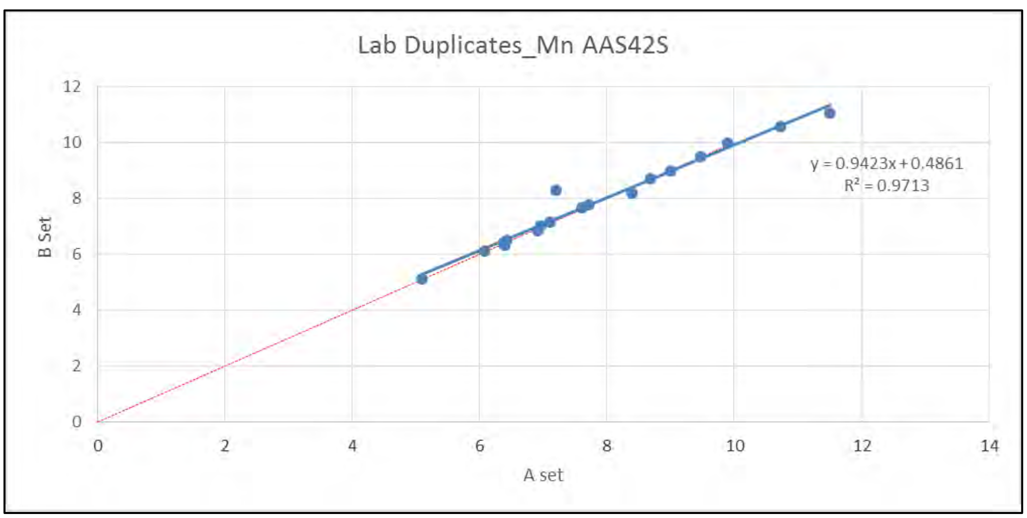


Figure 11-17: Linear Regression of Total Manganese Assay Lab Duplicate Results



RPD analysis of the field duplicates results for soluble manganese shows 15 of 16 pairs with a value of less than 1.72% and one sample pair with value of 33.82%. RPD analysis of the lab duplicates results for total manganese show 17 of 18 pairs with a value of less than 3.99% and one sample pair with value of 14.19%. A greater precision was observed for the total manganese assays.

11.8.4 Field Duplicates

Field duplicates represent those samples split and collected by EMN field staff at the drill and delivered to the lab as a blind duplicate. The results of the field duplicate assays allow for pairwise assessment of the procedures used in the field to split and collect samples prior to being delivered to the lab for analysis.

A total of 41 pairs of field duplicates were collected with reportable results. In the assay database, each pair was identified with the same sample number with one labelled with A as suffix and the second with B as the suffix. The A and B sets were evaluated using simple linear regression and the Pearson's coefficient, and also for RPD as a measure of precision. An RPD of less than 10% within 90% confidence interval is considered to be a reasonable variation for evaluation of the quality of the data.

Figure 11-18 shows the duplicate regression for soluble manganese (aqua regia AAS) and Figure 11-19 shows the regression for total manganese (4-acid AAS) against a 1:1 unity line in red. The soluble manganese regression indicated a slope of 0.9174 with Pearson's coefficient of 0.94, and total manganese indicated a slope of 0.9977 with slope of 0.98.

Figure 11-18: Linear Regression of Soluble Manganese Assay Duplicate Results

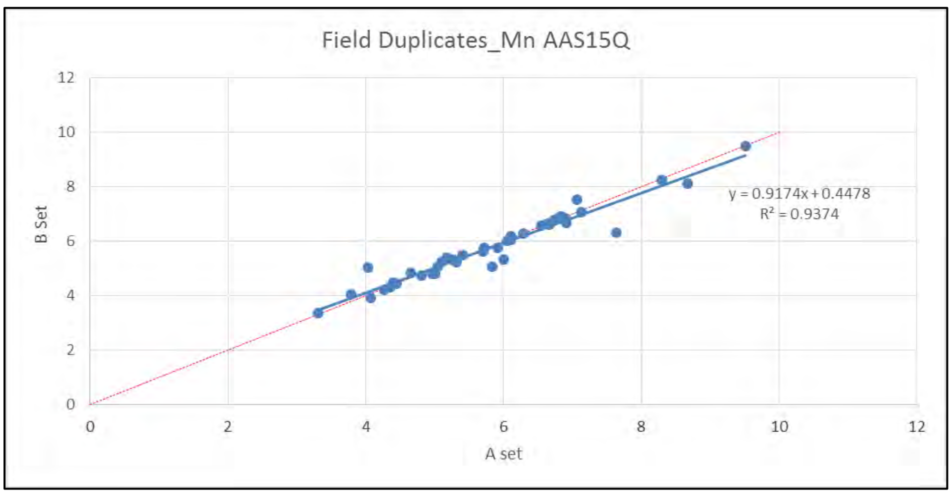
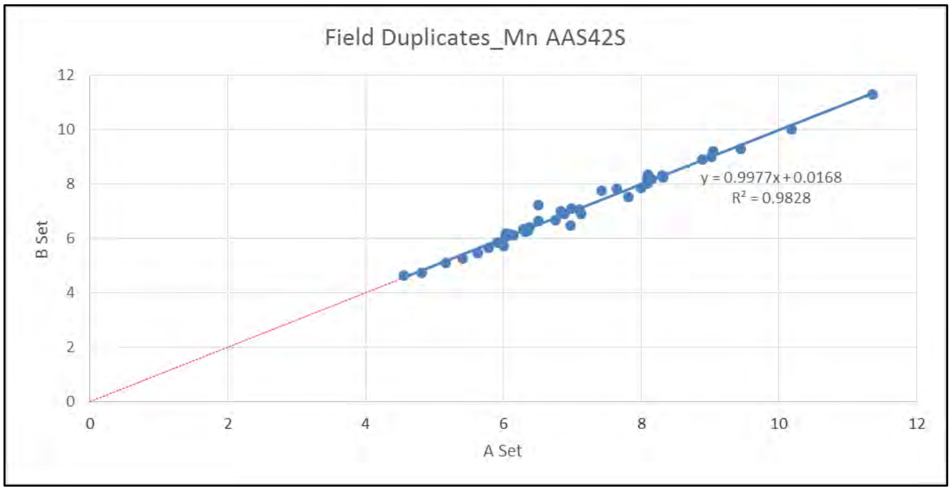


Figure 11-19: Linear Regression of Total Manganese Assay Duplicate Results



RPD analysis of the lab duplicates results for soluble manganese show 37 of 41 pairs with a value of less than 6.90% and four samples pair with values between 11.64% and 22.47%. RPD analysis of the lab duplicates results for total manganese show 40 of 41 pairs with a value of less than 7.43% and one sample pair with value of 10.48%. A greater precision was observed for the total manganese assays.

11.8.5 SGS Re-Analyses

Upon initial receipt of the laboratory data, instances were observed by EMN whereby concentrations of soluble manganese exceeded the reported concentrations of total manganese. As this is technically not possible, re-analysis of three batches was requested by EMN and completed by SGS. The re-runs were comprised of a split of the pulverized and homogenized sample.

Results of the re-analysis reduced the occurrence of soluble manganese exceeding total manganese to two samples, both of which were blank control samples at or below the detection limit.

11.8.6 External Laboratory Assay Verification

An external laboratory was selected by EMN to replicate the assay procedure for verification of assay splits that were prepared at SGS following initial receipt, drying, weighing and pulverizing of the sample. A total of 89 samples were shipped to Activation Laboratories Ltd. (Actlabs), located in Ancaster, Ontario, Canada. Comparison of total manganese grades from Actlabs with the SGS results are shown in Figure 11-20, and comparison of the soluble manganese grades are shown in Figure 11-21.

The results of the external laboratory verification indicate a reasonable comparison for both the total (4-acid) manganese and soluble (aqua regia) manganese data. Total manganese values show a slight scatter around a linear regression with Pearson's coefficient of 0.95, and slight bias to the Actlabs data with and slope of 0.98. A total of 14 total manganese grades, representing 16% of the data, showed RPD values of greater than 10%. Soluble manganese values show a slight scatter around a linear regression with Pearson's coefficient of 0.95, and slight bias to the Actlabs data with and slope of 0.96. A total of 46 soluble manganese grades, representing 51% of the data, showed RPD values of greater than 10%.

Figure 11-20: Linear Regression of Total Manganese Assay from Umpire Lab

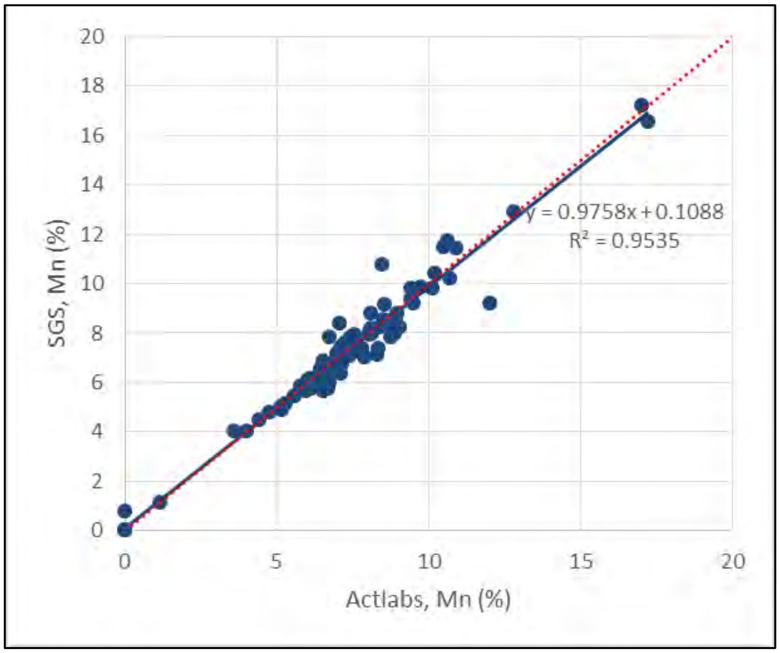
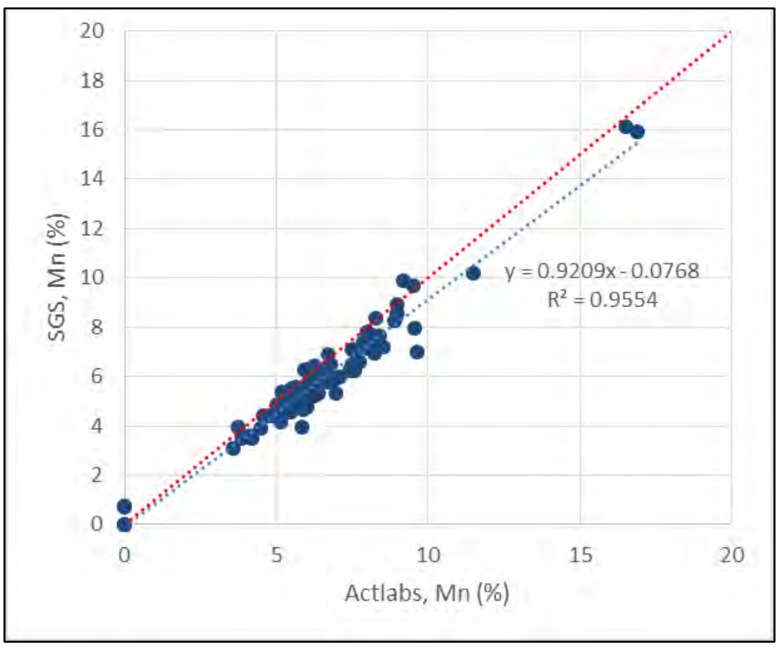


Figure 11-21: Linear Regression of Soluble Manganese Assay from Umpire Lab



Linear regression of the external laboratory assay verification supports the manganese grades reported from SGS analysis, however, RPD analysis suggests some variability exists between the laboratory analyses. This may be caused by heterogeneity in sampling in the field.

11.9 2018 Sampling and Laboratory Analysis QAQC Program

A systematic QA/QC program was designed in connection with the 2018 drill-sampling and analytical work. The program consisted of the following:

- Insertion of control samples (CRMs, duplicates, and blanks) into the analytical sample stream to monitor the performance of the labs, representing 17.8% of overall analytical results
- Review of internal QC data generated by the labs
- Re-analysis or repeat of the test work on batches and samples that fail the QC criteria
- Independent QA assessment completed by Tetra Tech.

A total of 830 samples were shipped to SGS laboratories located in Bor, Serbia, for elemental analysis. This included 730 assays, 33 CRMs (3 materials), 30 blanks (2 materials) and 37 field duplicates. The laboratory included 48 additional lab duplicates from preparation and analytical stages. This resulted in a total of 888 assay results reported to EMN.

All analytical certificates were delivered directed to both EMN and to Tetra Tech allowing QA assessments to be conducted by Tetra Tech. A database was compiled, and various checks and measures were performed by Tetra Tech. Tetra Tech did not identify any significant QA concerns; however, high variability was identified in manganese concentrations reported from the partial and near-total digestion methods. Due to this, it was decided that manganese reported by lithium borate fusion and XRF was more reliable and was selected as the basis for total manganese grades for development of the MRE. The compiled database was validated for use in mineral resource estimation.

11.9.1 Certified Reference Materials

Three CRMs were inserted in sequence with the samples that were shipped to SGS in Bor. The name of the samples was recorded on the sample tag retained by EMN; the samples were delivered to the lab as blind control samples with unknown composition. CRM insertions assess the accuracy of the sample solution preparation and accuracy of the analytical equipment being used. CRMs are intended to be present at a rate of at least one CRM per sample batch. Batch sizes at SGS included approximately 45 samples, including field and laboratory QC sample insertions.

Three reference materials were selected by EMN at the onset of the program to be used as standards as described in the following sub-sections.

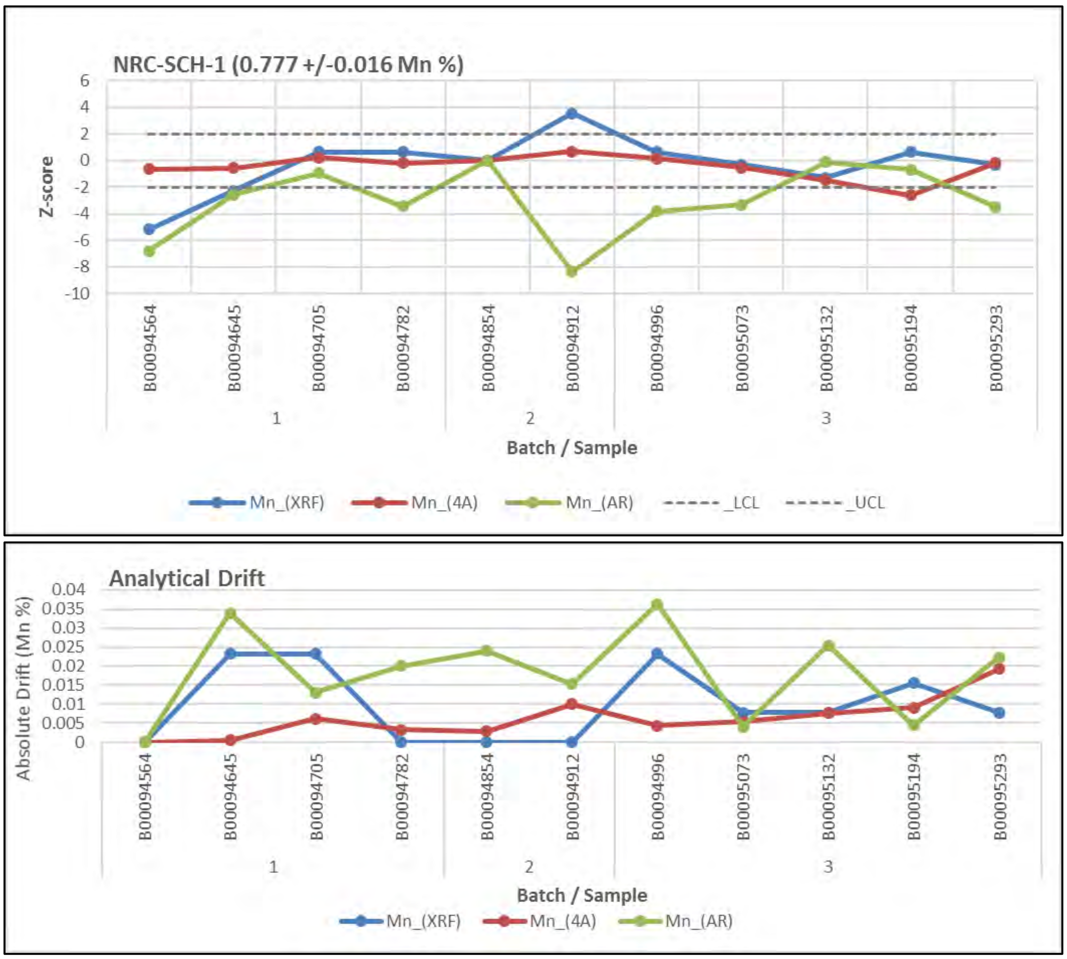
11.9.1.1 Certified Reference Material – NRC-SCH-1

The NRC-SCH-1 reference was supplied by the National Research Council of Canada CANMET and was prepared from iron ore as hematite with various hydrous oxides of iron from the Schefferville Mine in Quebec, Canada. The expected mean manganese grade is 0.777% with 95% confidence interval of 0.008% manganese. This CRM was selected to evaluate samples with manganese concentration less than 1%, which were analyzed using ICP-MS and by XRF.

This sample accounted for eleven analyses. The manganese assays from XRF analysis (Mn_XRF), and both digestions with the ICP methods (4-acid digestion: Mn_4A, and aqua regia digestion: Mn_AR) were transformed to Z-score values and plotted against the expected mean and confidence interval to assess the performance of the CRM. The CRM performance chart and analytical drift chart are shown in Figure 11-22. Sample B00094854 (certificate AV011733) was mislabeled at SGS in Lakefield, Ontario for XRF analysis and has not been shown in Figure 11-22 for CRM performance.

The results show good performance for the XRF analysis where 73% of samples were measured within range, and the 4-acid ICP-MS methods where 82% of samples were measured within range. The aqua regia ICP-MS methods measured 27% of samples within range, which is an expected performance as only a portion of the sample is digested. The aqua regia digestion does have variable performance in relation to the 4-acid digestion suggesting the digestion method has strong influence on measured manganese concentration for this CRM. Overall, elevated variability is observed for manganese concentrations in this “low grade” range.

Figure 11-22: CRM Performance and Analytical Drift Charts for NRC-SCH-1



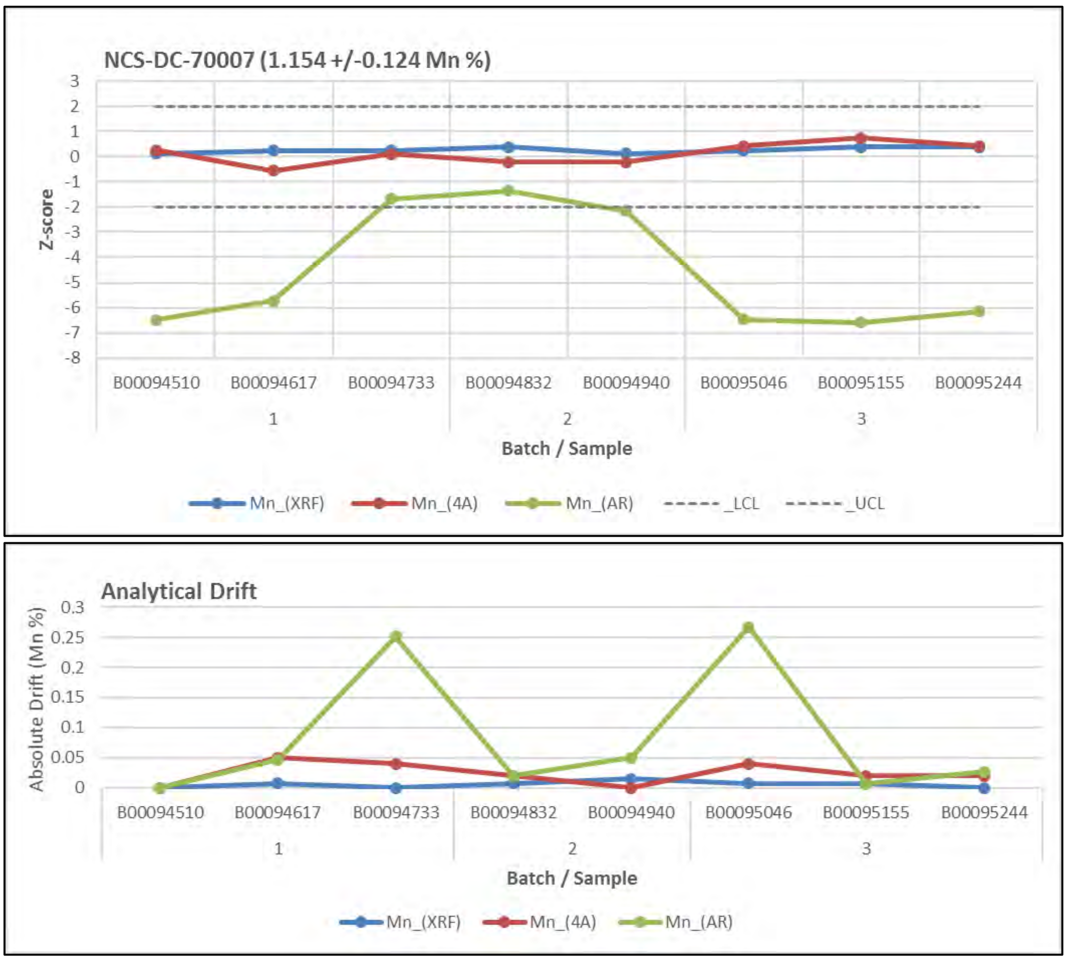
11.9.1.2 Certified Reference Material – NCS-DC-70007

The NCS-DC-70007 reference was supplied by China National Analysis Center for Iron and Steel. The source material is not disclosed in the material datasheet. The expected mean manganese (II) oxide concentration is 1.49% (1.154% manganese) with a standard deviation of 0.08% manganese (II) oxide (0.062% manganese). This CRM was selected to evaluate samples with manganese concentration in low range greater than 1%, which were analyzed with “ore grade” methods using AAS and by XRF.

This sample accounted for eight analyses. The manganese assays from XRF analysis (Mn_XRF), and both digestions with the AAS methods (4-acid digestion: Mn_4A, and aqua regia digestion: Mn_AR) were transformed to Z-score values and plotted against the expected mean and confidence interval to assess the performance of the CRM. The CRM performance chart and analytical drift chart are shown in Figure 11-23.

The results show excellent performance for the XRF analysis where 100% of samples were measured within range, and the 4-acid ICP-MS methods where 100% of samples were measured within range. Th aqua regia ICP-MS methods measured 25% of samples within range, which is an expected performance as only a portion of the sample is digested. The aqua regia digestion does have variable performance in relation to the 4-acid digestion suggesting the digestion method has strong influence on measured manganese concentration for this CRM. The measurements by the XRF method were the most accurate.

Figure 11-23: CRM Performance and Analytical Drift Charts for NCS-DC-70007



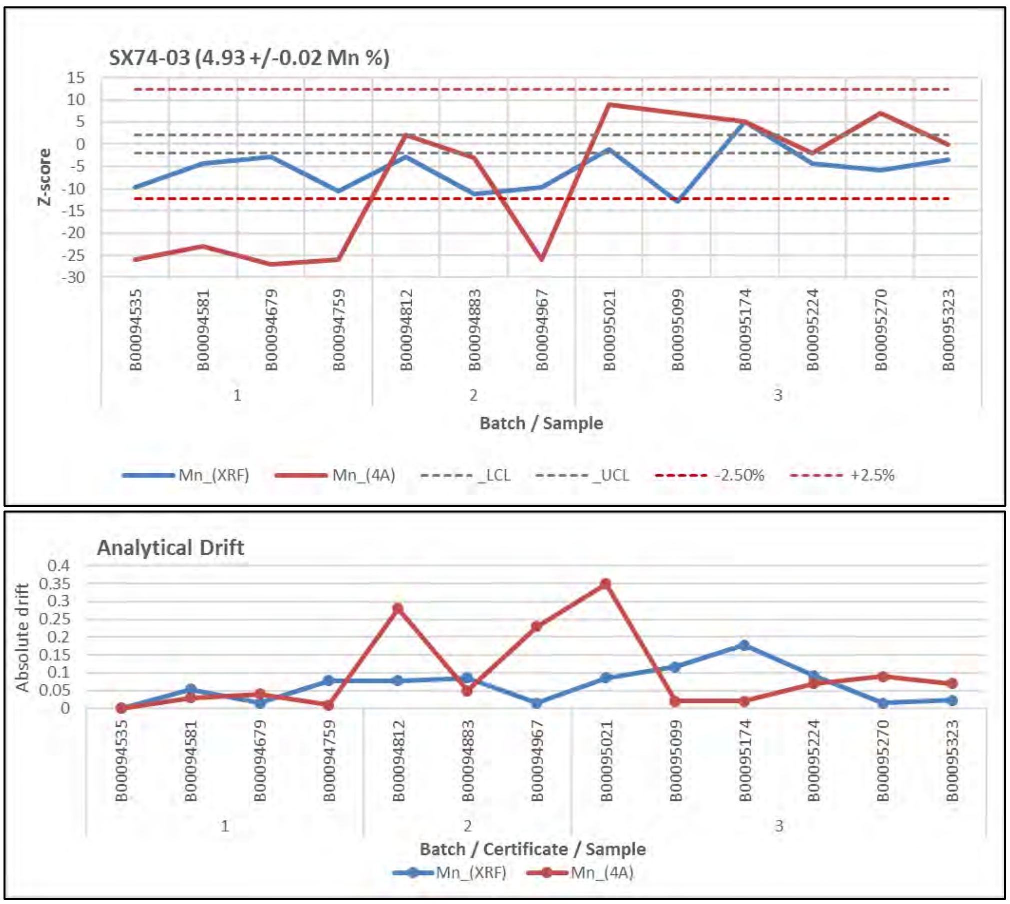
11.9.1.3 Certified Reference Material – SX74-03

The SX74-03 reference was supplied by Dillinger Hütte Laboratories, Germany, manufacturers of steel products. The material source is a silicomangenese slag product with expected mean manganese concentration of 4.93% with a reported 95% confidence interval of 0.01%. This CRM was selected to evaluate samples with manganese concentration in mid-range greater than 1%, which were analyzed with "ore grade" methods using AAS and by XRF.

This sample accounted for thirteen analyses. The manganese assays from XRF analysis (Mn_XRF), and only the results of the 4-acid digestion with the AAS analysis (Mn_4A) were transformed to Z-score values and plotted against the expected mean and confidence interval to assess the performance of the CRM. The CRM performance chart and analytical drift chart are shown in Figure 11-24. Twice the original confidence interval of 0.01% is shown in Figure 11-24. The aqua regia digestion with AAS analysis results were not plotted.

The reported confidence interval for the SX74-03 reference is very narrow. The results show good performance for the XRF analysis where 92% of samples were measured within ±2.5% of the expected value, however, only 23% within twice the original confidence interval. The 4-acid AAS methods measure 62% of samples within ±2.5% of the expected value, however, report a higher variability and 30% within twice the original confidence interval. The aqua regia ICP-MS methods did not measure any samples to be within ±2.5% of the expected value and were not plotted. It was observed that the measurements from 4-acid AAS methods had a positive drift over time from below to above the threshold value. The measurements by the XRF method showed least variability and consistently low accuracy, compared to higher variability results of the 4-acid AAS analysis for this CRM.

Figure 11-24: CRM Performance and Analytical Drift Charts for SX74-03



TETRA TECH

11.9.2 Certified Blank Materials

11.9.2.1 BCS-CRM-531 Blank

The BCS-CRM-531 certified blank was supplied by Bureau of Analysed Samples Ltd, based in England, prepared as low iron sand that passes a nominal 250 µm aperture. The standard has a "certified value" of 0.00014% manganese (II) oxide within 95% confidence interval of 0.0003%.

Fifteen BCS-CRM-531 blanks were submitted for analysis to SGS. The assays from both 4-acid and aqua regia digestion with AAS analysis of these 15 samples are plotted in Figure 11-25 through Figure 11-27 for manganese, calcium, and iron concentrations, respectively. Three of the 4-acid AAS manganese results were measured above 150 ppm including one with concentration of 217 ppm (B00095250). This ambient concentration may be due to residual manganese within the grinding equipment, but it was determined to be insignificant. The results from the aqua regia AAS preparation appear to have lower overall manganese concentrations; all measured below 150 ppm. Although no specific failure threshold has been applied, the CP interprets that the sample contamination has not been introduced through sample handling and preparation in the lab.

Figure 11-25: Certified Blank – BCS-CRM-531 – Manganese

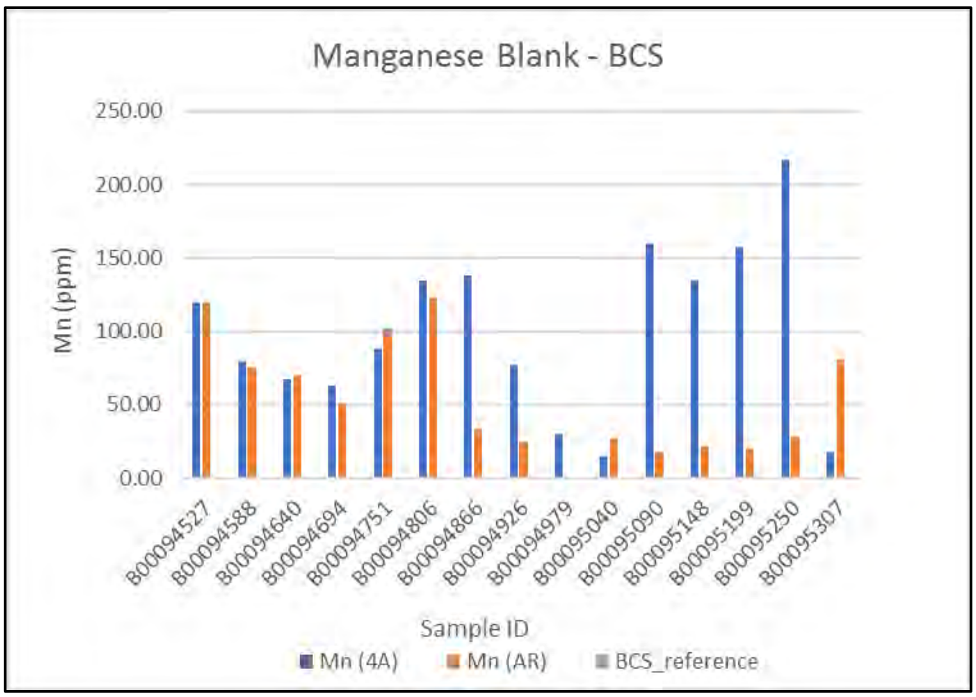


Figure 11-26: Certified Blank – BCS-ST-531 – Calcium

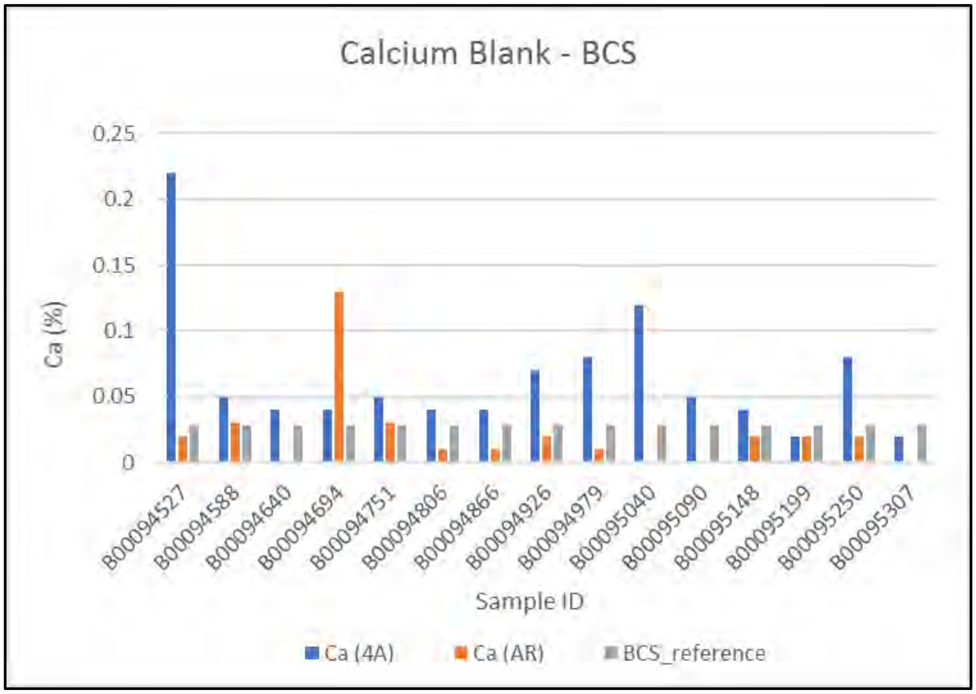
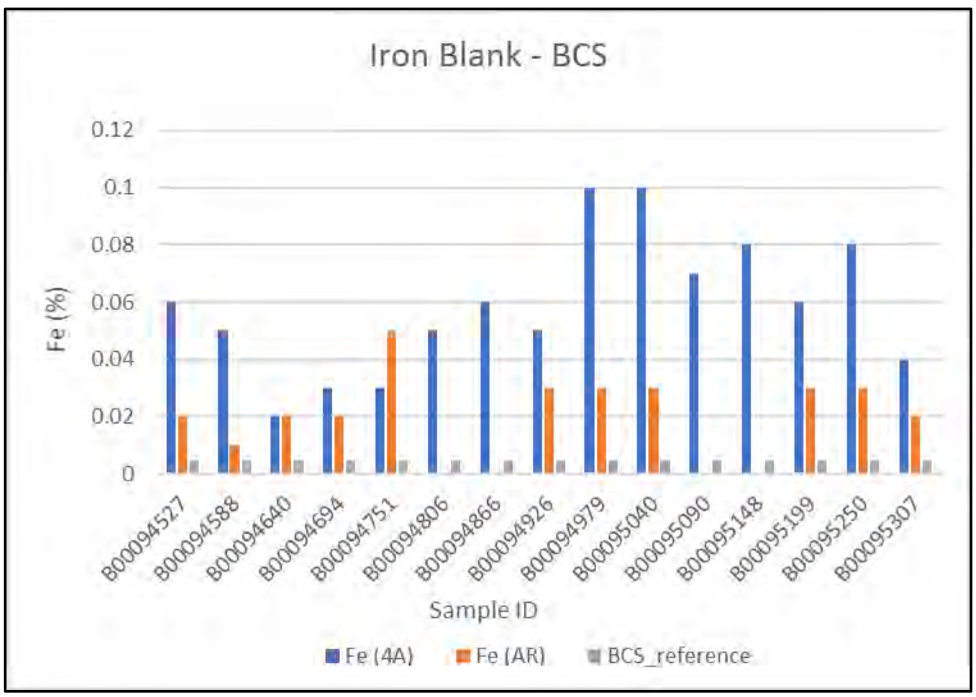


Figure 11-27: Certified Blank – BCS-ST-531 – Iron

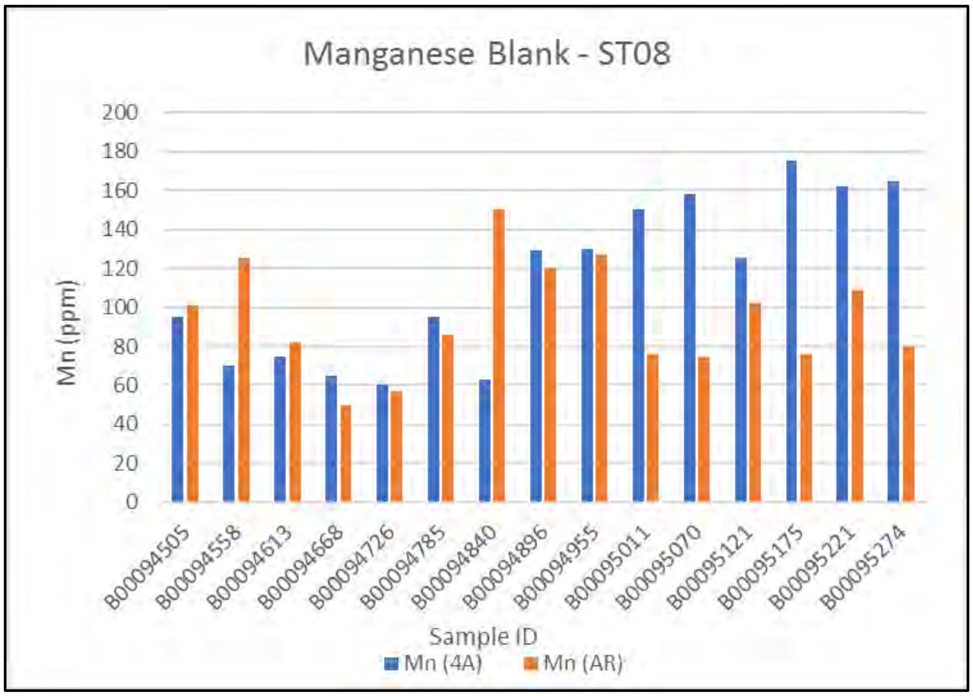


11.9.2.2 ST-08 Blank

The ST-08 certified blank was supplied by Sklopísek Strelec, Czech Republic, as a high purity silica sand with low impurity concentration. The standard was manufactured for grain size distribution analysis and reports an expected manganese concentration; however, this is expected to be negligible.

Fifteen ST-08 blanks were submitted for analysis to SGS. The assays from both 4-acid and aqua regia digestion with AAS analysis of these fifteen samples are plotted in Figure 11-28 through Figure 11-30 for manganese, iron, and calcium concentrations, respectively. Four of the 4-acid AAS manganese results were measured above 150 ppm and less than 200 ppm, and one aqua regia AAS sample was measured at 150 ppm. This ambient concentration may be due to residual manganese within the grinding equipment, but it was determined to be insignificant. Although no specific failure threshold was applied, the CP interprets that the sample contamination has not been introduced through sample handling and preparation in the lab.

Figure 11-28: Certified Blank – ST-08 – Manganese



TETRA TECH

Figure 11-29: Certified Blank – ST-08 – Iron

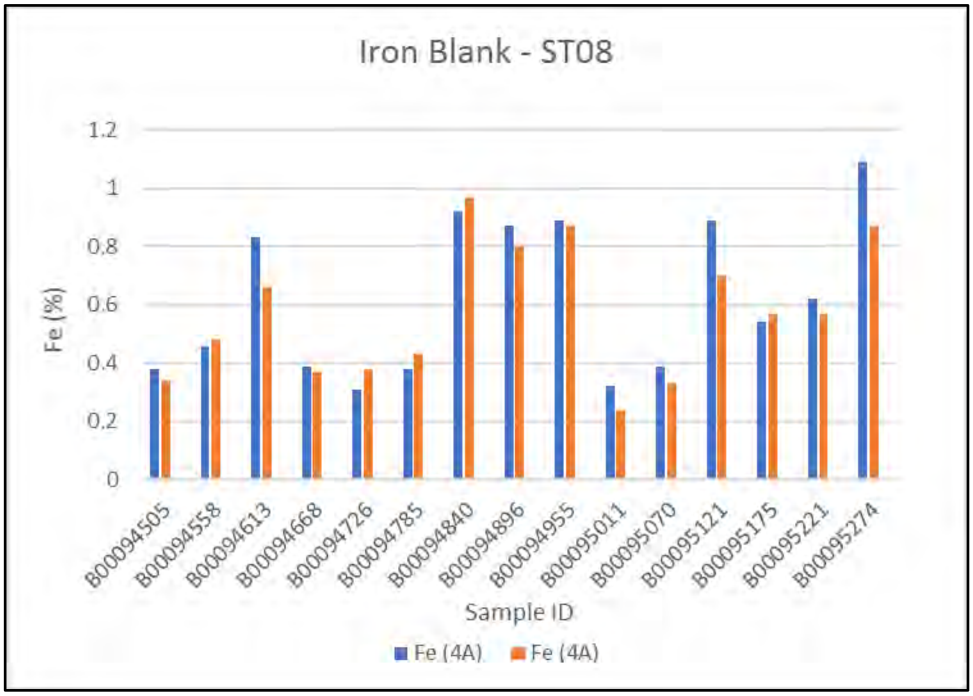
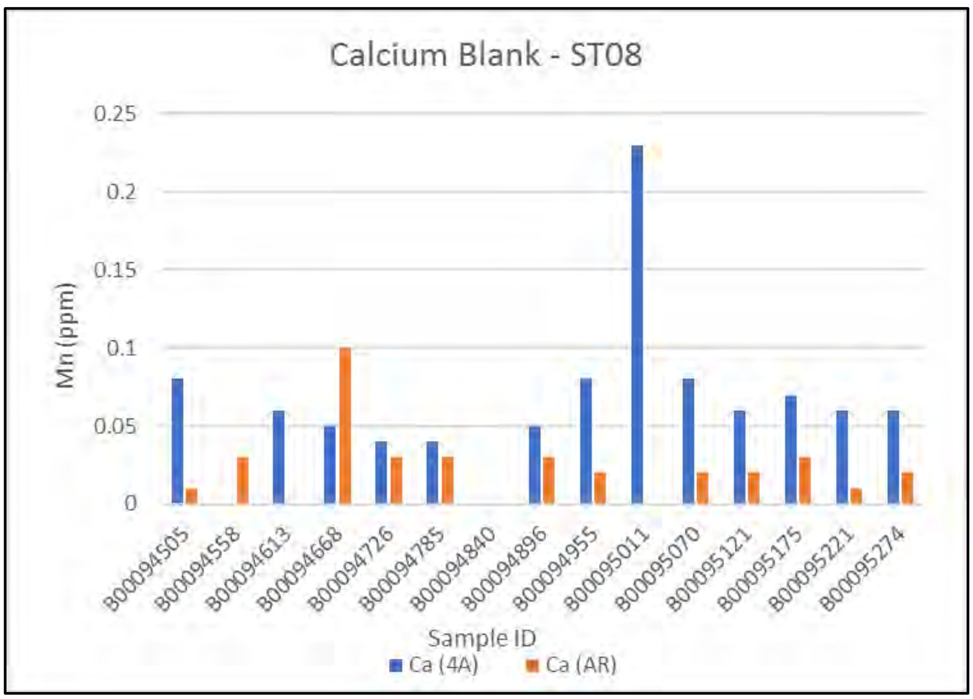


Figure 11-30: Certified Blank – ST-08 – Calcium



11.9.3 Field Duplicates

Field duplicates represent those samples collected by EMN field staff at the drill and delivered to the lab as a blind duplicate. The results of the field duplicate assays allow for pairwise assessment of analytical reproducibility, or precision.

A total of 37 field duplicate pairs were collected with reportable results. In the assay database, each pair was identified with the same sample number with one labelled with A as suffix and the second with B as the suffix. The A and B sets were evaluated using simple linear regression and the Pearson's coefficient, and also for RPD as a measure of precision. An RPD of less than 30% within 90% of samples is considered to be an acceptable threshold of variation for field duplicates.

Figure 11-31 shows the duplicate regression for manganese measured by 4-acid digestion with AAS and Figure 11-32 shows the regression for manganese measured by aqua regia with AAS against a 1:1 unity line in red. The 4-acid manganese regression indicated a slope of 0.9237 with Pearson's coefficient of 0.7851, and with 97% of samples having RPD less than 30%. The aqua regia manganese indicated a slope of 0.8972 with Pearson's coefficient of 0.7285, and with 95% of the samples having RPD less than 30%.

Figure 11-31: Linear Regression of 4-Acid AAS Manganese Field Duplicates

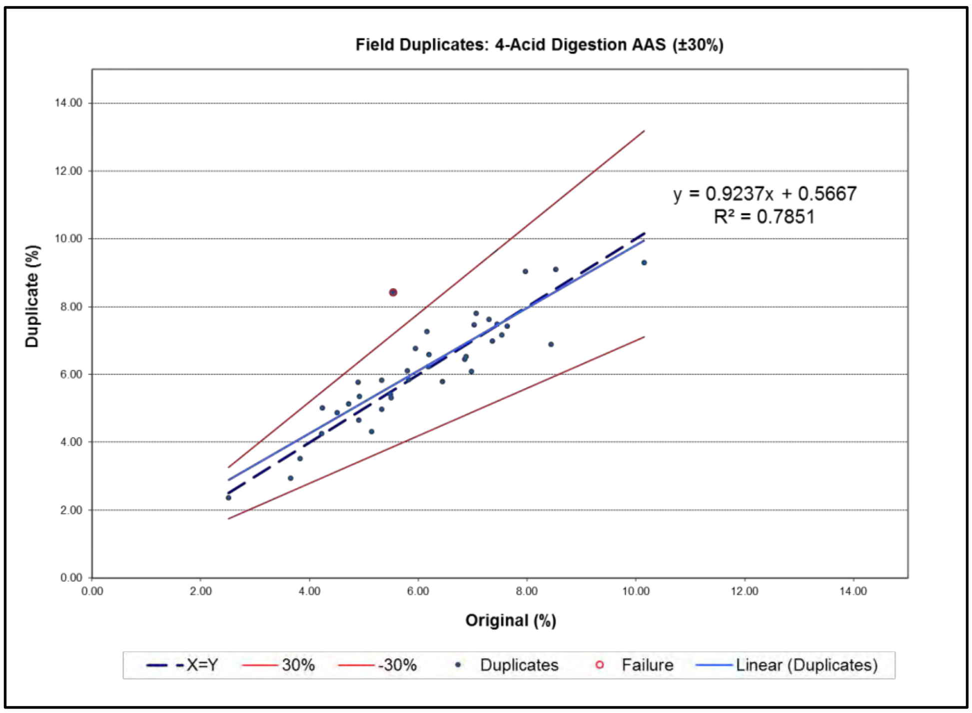
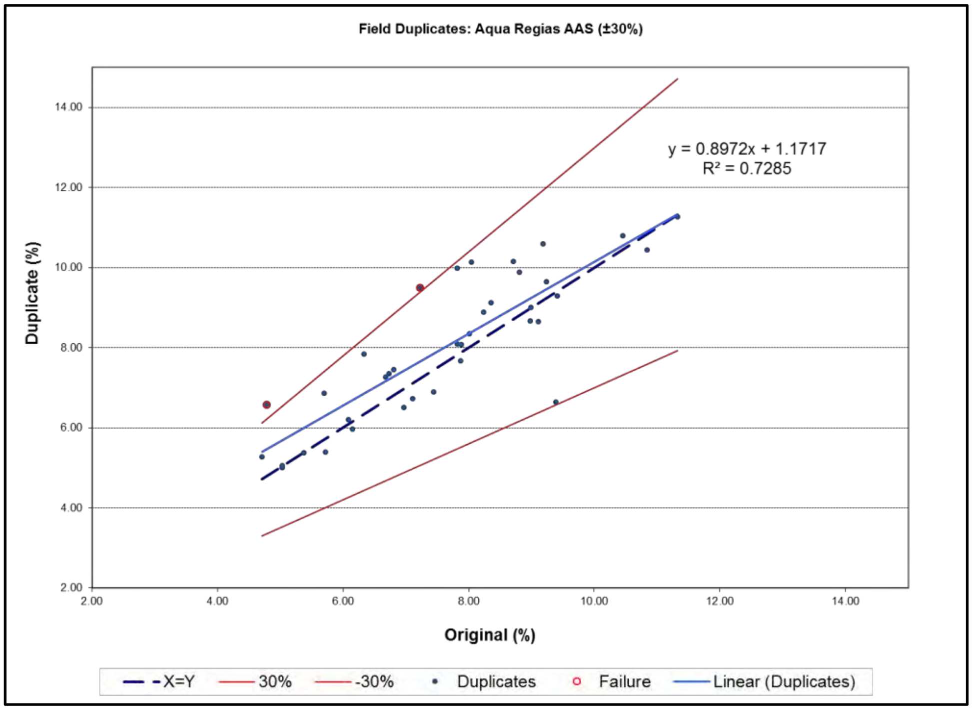


Figure 11-32: Linear Regression of Aqua Regia AAS Manganese Field Duplicates



11.9.4 Lab Duplicates

Lab duplicates represent those samples analyzed in duplicate internally by the lab, by request of EMN, to assess the precision and quality of the homogenization, sample splitting and preparation methods. EMN directed SGS to collect preparation duplicates (i.e., before pulverizing) and analytical duplicates (i.e., following pulverization) at a frequency of 1:20 samples.

11.9.4.1 Preparation Duplicates

A total of 40 preparation duplicate pairs were collected with reportable results. In the assay database, each pair was evaluated using simple linear regression and the Pearson's coefficient and also for RPD as a measure of precision. An RPD of less than 20% within 90% of samples is considered considered to be an acceptable threshold of variation for preparation duplicates.

Figure 11-33 shows the duplicate regression for manganese measured by 4-acid digestion with AAS and Figure 11-34 shows the regression for manganese measured by aqua regia with AAS against a 1:1 unity line in red. The 4-acid manganese regression has a slope of 0.9647 with Pearson's coefficient of 0.9614, and with 95% of samples having RPD less than 20%. The aqua regia manganese has with a slope of 0.984 with Pearson's coefficient of 0.9762, and with 98% of the samples having RPD less than 20%.

Figure 11-33: Linear Regression of 4-Acid AAS Manganese Preparation Duplicates

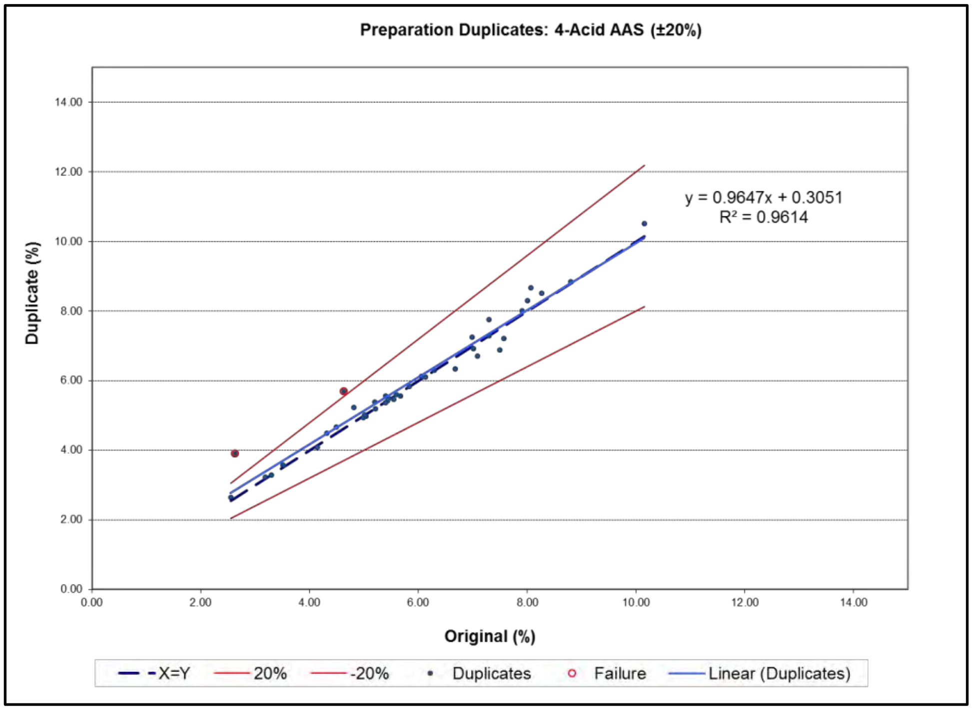
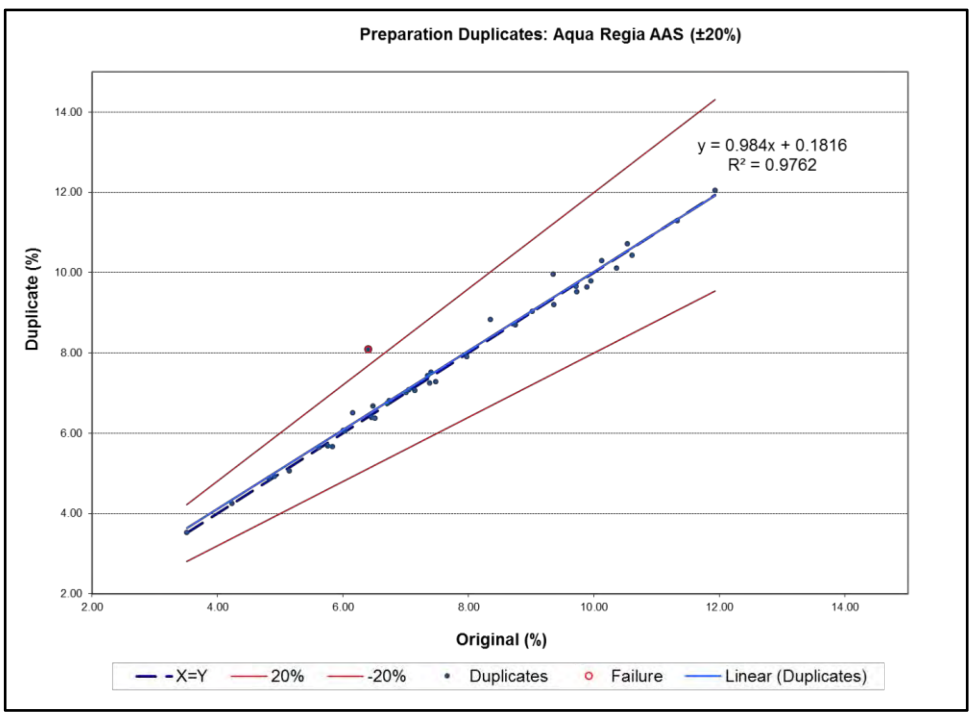


Figure 11-34: Linear Regression of Aqua Regia AAS Manganese Preparation Duplicates



11.9.4.2 Analytical Duplicates

A total of 18 analytical duplicate pairs were collected with reportable results. In the assay database, each pair was evaluated using simple linear regression and the Pearson's coefficient, and also for RPD as a measure of precision. An RPD of less than 10% within 90% of samples is considered considered to be an acceptable threshold of variation for analytical duplicates.

Figure 11-35 shows the duplicate regression for manganese measured by 4-acid digestion with AAS and Figure 11-36 shows the regression for manganese measured by aqua regia with AAS against a 1:1 unity line in red. The 4-acid manganese regression has a slope of 0.9965 with Pearson's coefficient of 0.9989, and with 100% of samples having RPD less than 10%. The aqua regia manganese has with a slope of 0.9936 with Pearson's coefficient of 0.9849, and with 94% of the samples having RPD less than 10%.

Figure 11-35: Linear Regression of 4-Acid AAS Manganese Analytical Duplicates

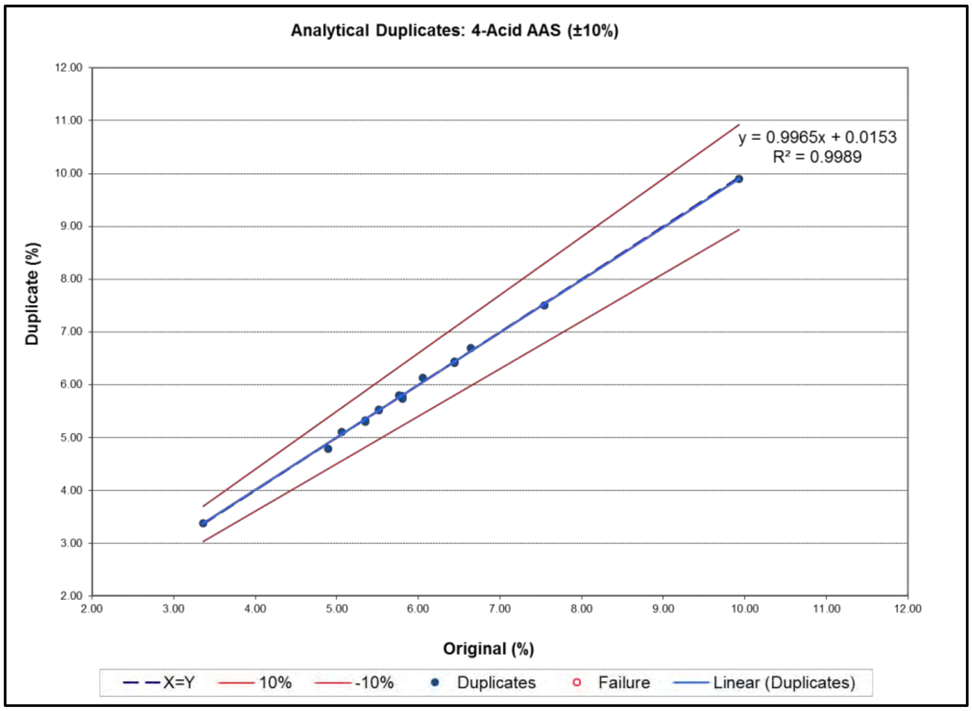
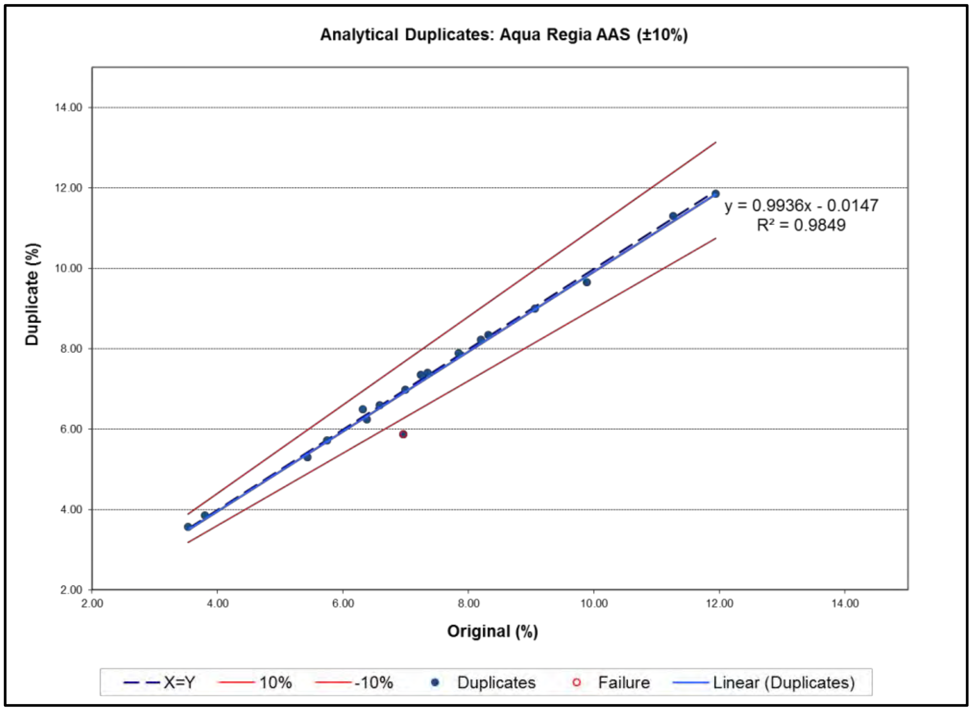


Figure 11-36: Linear Regression of Aqua Regia AAS Manganese Analytical Duplicates



11.9.5 External Laboratory Assay Verification

External laboratory verification analysis was conducted again in 2018 using Actlabs based in Ancaster, Ontario, Canada. EMN selected Actlabs to replicate the assay procedures for verification of reported SGS analysis results following initial receipt, drying, weighing, and pulverizing of the sample. A total of 96 samples were shipped to Actlabs, including QA/QC samples. The suite of analyses included aqua regia and 4-acid digestion using ICP-MS and AAS analysis for trace elements, and XRF for major cations.

Comparison of manganese grades from Actlabs with the SGS results are shown in Figure 11-37 through Figure 11-39 by sample batch, as delivered to the lab.

Manganese assays from XRF analysis show low scatter with Pearson's coefficient ranging from 0.954 to 9987 and RPD ranging between -2.12% to -1.60%, compared to coefficients of 0.8986 to 0.9675 and RPD ranging between -3.99% to 5.57% for 4-acid AAS results, and coefficients of 0.67 to 0.9713 with RPD ranging between -26.54 to -8.52 for the aqua regia AAS results.

The results of the external laboratory verification indicate an excellent correlation from XRF assays, and moderate correlation from both the 4-acid and aqua regia AAS assays. In particular, the 4-acid AAS results reported from Batch 3 revealed possible positive bias in high grade ranges towards the SGS results. The results were assessed, and a selective batch of samples were requested for re-assay at SGS (results discussed in Section 11.10.6).

Figure 11-37: Linear Regression of Manganese by XRF Assay from Umpire Lab

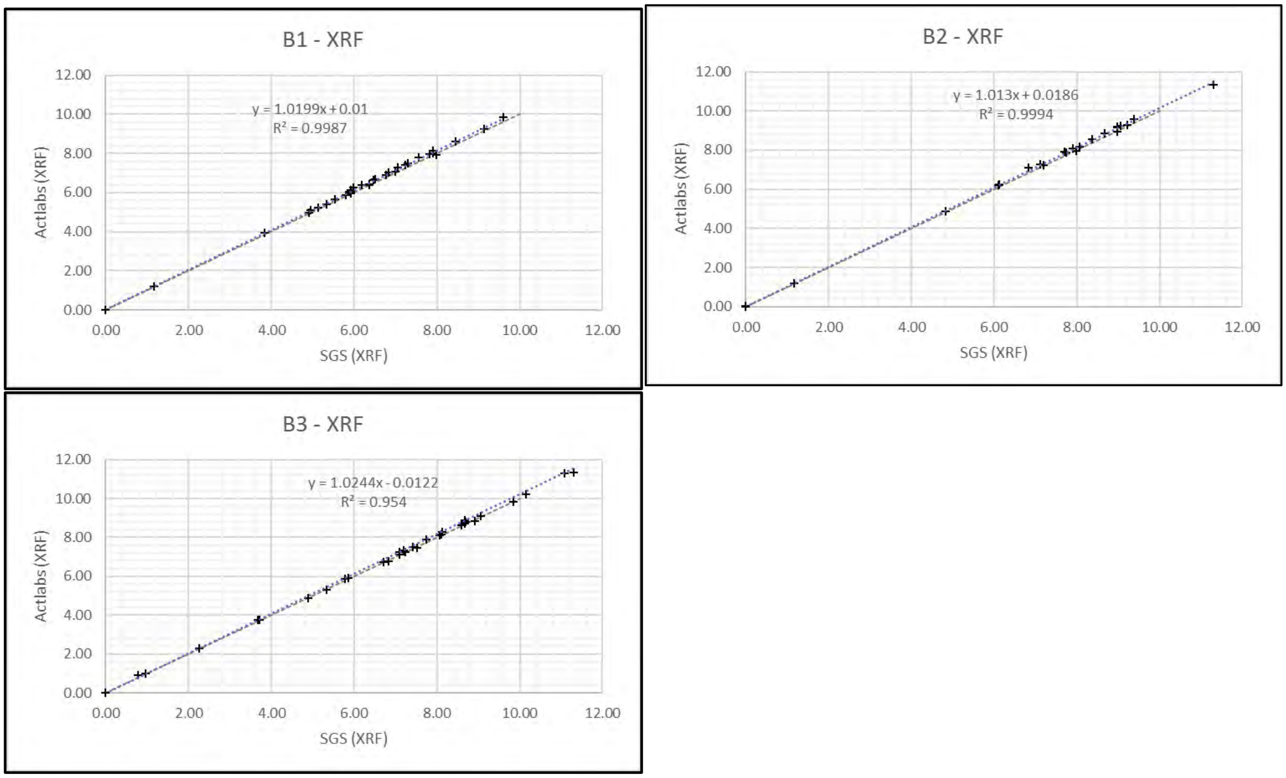


Figure 11-38: Linear Regression of Manganese by 4-Acid AAS Assay from Umpire Lab

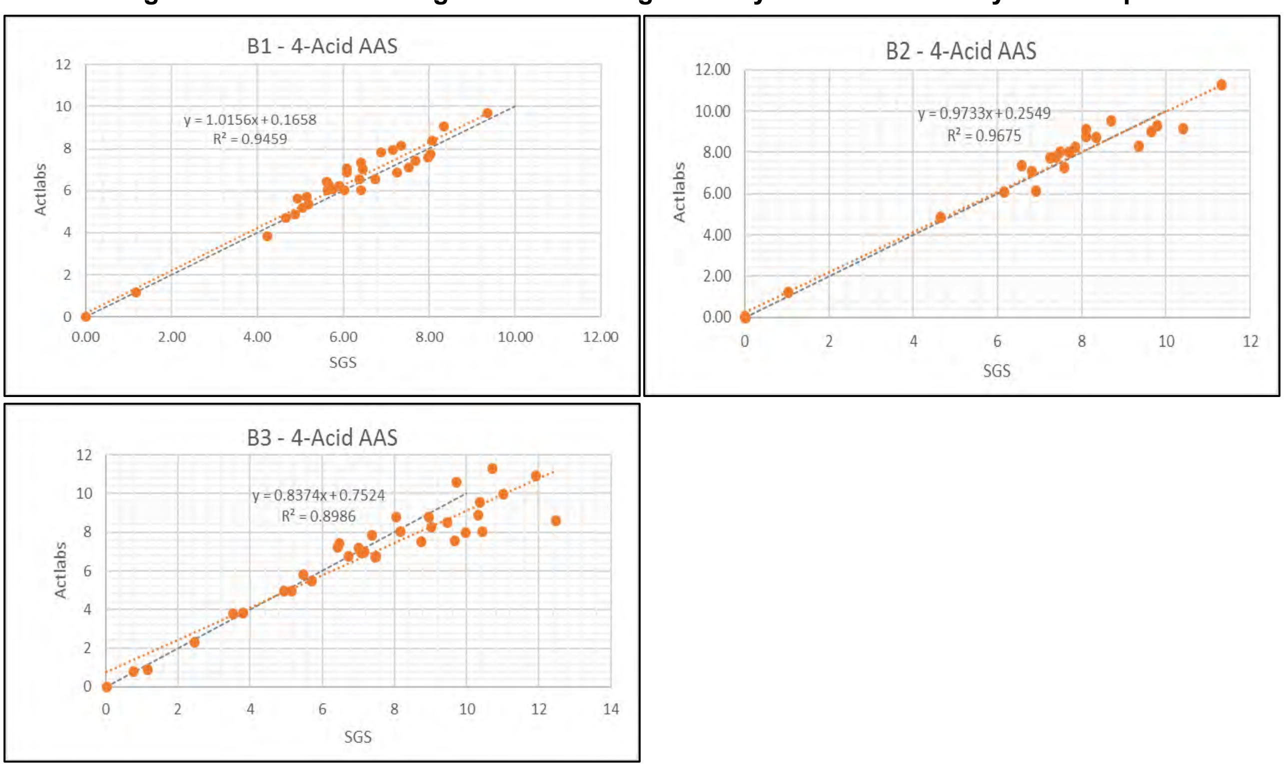
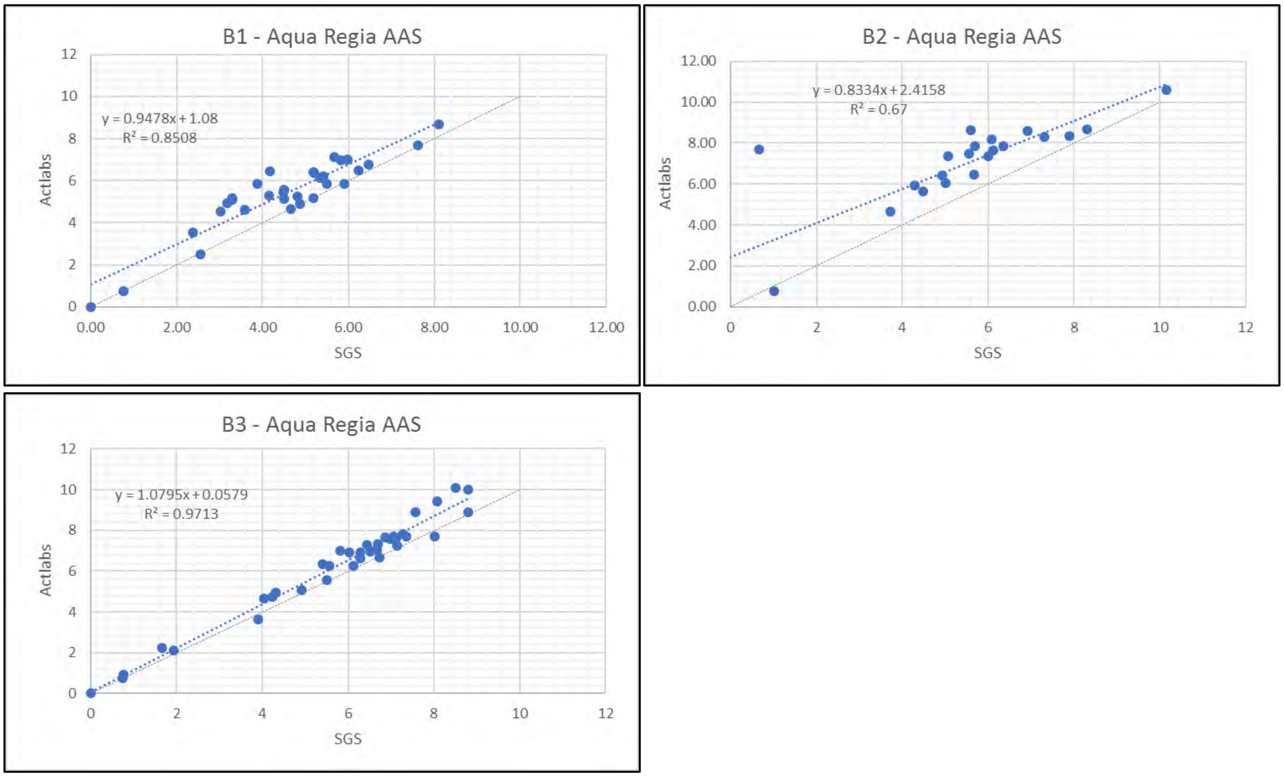


Figure 11-39: Linear Regression of Manganese by Aqua Regia AAS Assay from Umpire Lab

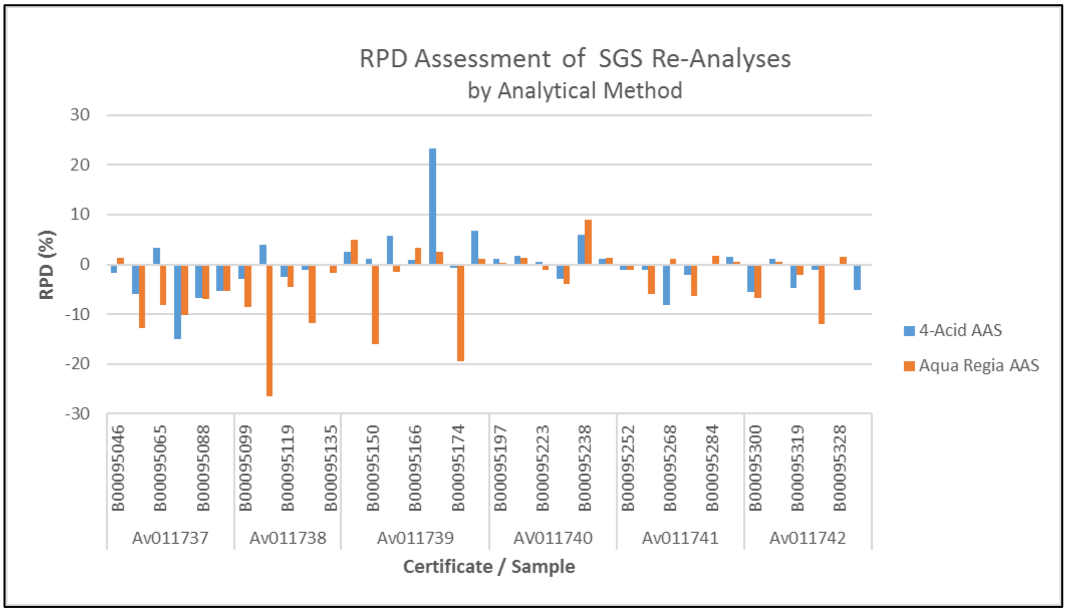


11.9.6 SGS Re-analyses

A possible assay bias was identified by external laboratory verification analysis for the reported 4-acid AAS analysis results. A selection of 35 samples from six separate analytical certificates were sent for re-analysis. The results were assessed using RPD and are plotted in Figure 11-40. The RPD results were evaluated to meet analytical duplicate threshold of at least 90% samples having less than 10% RPD. The 4-acid AAS re-assays met the threshold having 94% of samples with less than 10% RPD. The aqua regia re-assays did not meet the threshold having only 80% of samples with less than 10% RPD, with the majority of re-assays having lower assays than the original values.

The re-analysis supported the consistency in assay procedures used by SGS for the 4-acid AAS analysis but did not explain the potential bias identified by external laboratory verification. Examination of internal CRMs used by the laboratories for calibration of equipment for manganese grades above 7% revealed usage of the NOD-A1 produced by United States Geological Survey and the GMN-04 produced by Geostats PTY Ltd. Conclusions from previous QA/QC on the CMP in 2017 concluded that the NOD-A1 CRM is not suitable for wet-digestion analytical procedures such as the 4-acid and aqua regia methods applied to this program.

Figure 11-40: RPD Assessment of SGS Sample Re-Analysis



11.10 CP Opinion on Sample Collection, Preparation, and Analyses

The methods implemented by EMN for sample collection, preparation and analysis were developed with great detail and with reference to applicable ISO and/or ASTM standards in advance of the drilling investigation. The procedures maximize use of sample volumes to measure physical and chemical parameters relevant to current and future project studies. The labs selected by EMN are recognized accredited laboratories which adhere to recognized ISO, ASTM or internally reproducible standards. The CP feels the collection, analysis and security is reliable and adequate.

Comparison of the various analytical methods for manganese has determined that the results of the XRF analysis provide a more consistent and accurate result compared to the 4-acid AAS methods. An unresolved discrepancy exists with a potential bias between 4-acid AAS results reported for manganese by SGS and Actlabs. The CP concludes that the manganese grades measured by XRF are more reliable measurements as total manganese concentration compared to the measurements from the 4-acid AAS analyses and are thus used as the basis for mineral resource estimation.

More work should be undertaken to establish a suitable and reliable assay method for wet-digestion analytical procedures should EMN choose to use these in the future. In particular, evaluation of equipment calibration at manganese grade above 7% and use of suitable CRMs should be considered. It is recommended that EMN incorporate use of CRM GMN-04 produced by Geostats PTY Ltd, Western Australia, with expected manganese (II) oxide concentration of 17.33%, standard deviation of 0.16 at a 95% confidence interval of ±0.06 (reported by XRF analysis) for calibration of high-grade manganese analyses.

12.0 DATA VERIFICATION

12.1 Audit of the Drill Hole Database

12.1.1 Collar Survey and Topography

The Property topography was provided by GET as a MicroStation software format, dgn file, based on LiDAR imagery. The contours were extracted from these files and converted to a common .dxf file format. The original data was provided in Czech projection S-JTSK using the Bpv datum.

GET completed drill hole collar surveying on-site using a Trimble model R4 GNSS GPS receiver equipment. The survey was reported in S-JTSK (Bpv), UTM (WGS84), and Lat-Lon (WGS84). It was observed that the average elevation difference between the Bpv and WGS84 datum equaled approximately 44.25 m. The elevation difference for drill hole T3-319 initially was reported as 46.36 m; however, this was later corrected to accurate Bpv equivalent elevation. The CMP references the S-JTSK (Bpv) coordinate system.

A comparison between the corrected collar elevation surveys with the local topographic DEM was undertaken. Of the 160 drill holes completed on the Property, a mean deviation in elevation of 0.049 m was calculated between the collars and the DEM, with values ranging from -0.348 to +0.580 m. The site survey correlates well with the drill collar survey and is considered of high quality for spatial modelling.

12.1.2 Downhole Logs and Measurements

GET compiled a drill hole database using the field logs and measurements collected on-site. This database was inspected using digital validation tools within Leapfrog® Geo modelling software. The validation tools assess the data for common errors such as overlapping intervals, major data gaps, drill hole depths versus sample depths, etc. These errors must be corrected prior to modelling to ensure the data is accurately represented.

Errors that were initially identified in the database were mainly due to the consolidated structure of the database that listed data measurements related to intervals for samples (2 m), core runs (1 m), and lithological intervals (variable lengths) on a single master spreadsheet. For modelling purposes, these various interval classes were parsed into three separate data sheets to represent data on 2 m sample intervals, 1 m field measurements, and the logged lithology sub-intervals.

These three subsets were again inspected in Leapfrog® Geo for common errors. This resulted in fewer errors which were corrected in the final database.

12.1.3 Geological Database Compilation

Tetra Tech received the raw data from laboratory test work and analysis. The data was verified for completeness and was then compiled, processed, and assessed for use in mineral resource estimation. The analytical data is saved in digital format as a geological database.

12.1.4 Cross Verification of Certificate of Analysis and Digital Data

Tetra Tech undertook verification of the data transfer and compilation process at SGS through visual comparison of the issued certificates of analysis with the digital assay records. This assessment was approached by first comparing the upper 25^{th} percentile of assays reported for total manganese (n = 175), followed by a random spot check of an additional 10% of the remaining data (n = 55). No significant reporting errors were identified.

12.1.5 Independent CP Site Visits

Two site visits have been completed by the Geology CP, the first between the dates July 1 to 3, 2017, and again between July 30 and 31, 2018. Both visits were coincident with the summer drilling investigations during which time he observed drilling, sample collection and preparation, sample logging, and sample storage facilities. An overview of the GPS tracks and sample collection locations are seen in Figure 12-1, this does not include GPS tracking of off-site facilities and locations.

Figure 12-1: Overview Map of GPS Track and Waypoints from 2017 and 2018 CP Site Visit

12.1.5.1 Independent Check Assay, 2017 Site Visit

Two samples were collected by the Tetra Tech CP geologist during the site visit. The samples were extracted as splits from recovered drill core weighing approximately 3 kg, placed in separate plastic bags, labelled with a generic sample identification, and zip tied. One sample was extracted from hole T1-312 between depths of 22 and 23 m (EMN sample B00055404), and the second sample was extracted from hole T1-313 between depths of 22 and 23 m (EMN sample B00055416). Each sample weighed approximately 2 kg.

The samples were then transported by the CP to Prague and delivered to the GET office where shipping via DHL was arranged. Upon receipt of the samples in Canada, the packaging, polyethylene bags, zip ties, and labelling was inspected. Evidence of tampering was not observed.

The samples were submitted to ALS Laboratories (ALS) in North Vancouver, Canada, for a selective leach check analysis. The selective leach analysis progressively dissolved the sample in stages using stronger solvents for digestion. Table 12-1 lists the digestion solvent in successive order. Table 12-2 shows the cumulative percent of the manganese that is dissolved at each stage along with the total manganese grade for the sample. The samples reported 80% and 74% leaching of the total manganese in the first three stages of the selective leach, with the majority of this being dissolved at the aqua regia digestion stage.

Table 12-3 compares the total and soluble manganese concentrations between the Tetra Tech sampling and the EMN reported results. RPD analysis shows some variability in the assay comparisons with values of between 3% and 16% for soluble, and 1 to 13% for total. The check assay does repeat the general magnitude of the manganese assay value within the SGS results.

Table 12-1: Tabulated Description of Selective Leach Analytical Methods used for Independent Check Assay

Digestion	Finish	SGS Method	Mn Detection Limits (ppm)
Aluminum Acetate	ICP-MS	ME-MS04	0.05-5,000
Cold Hydroxylamine-Hydrochloride	ICP-MS	MS05	0.05-5,000
Aqua Regia	ICP-MS, ICP-AES	MS42	5-50,000
4-acid	ICP-MS, ICP-AES	MS62	5-50,000

Table 12-2: Cumulative Leaching Results from Selective Leach Analysis

Sample ID	ME-MS04 (cum_Mn%) (%)	ME-MS05 (cum_Mn%) (%)	MS42 (cum_Mn%) (%)	MS62 (cum_Mn%) (%)	Total Mn% (%)
CT1312 (T1-312, 22-23)	6	9	80	100	10.35
CT1313 (T1-313, 18-19m)	7	11	74	100	6.44

TETRA TECH

Table 12-3: Independent Check Assay Comparison with EMN Results

	CT1312 (B00055404)	CT1313 (B00055416)
Tetra Tech tMn (%)	10.35	6.44
EMN tMn (%)	10.42	7.36
RPD (%)	**1**	**13**
Tetra Tech sMn (%)	9.54	5.16
EMN sMn (%)	8.14	5.30
RPD (%)	**16**	**3**

12.1.5.2 Acid-Base Accounting

Acid-base accounting (ABA) tests were also performed to measure total sulphide sulphur concentration using LECO furnace and net neutralization potential ratios of the sample. Total sulphide sulphur values for samples CT1312 and CT1313 were measured at 2.48% and 2.45%, respectively, and neutralization potential ratio (NPR) values were reported as 3.11 and 1.94 (using Sobek method). In accordance with standard methodologies and as per guidelines set forth in MEND 1.20.1, Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials (Price 2009), NPR values greater than 2 indicate the material is not potentially acid generating, materials with NPR between 1 and 2 have uncertain potential for net acid generation and materials with NPR less than 1 indicate they have potential for net acid generation. Based on these results, sample CT1312 does not have potential for acid generation, and sample CT1312 has uncertain potential for acid generation.

Summary of previous acid rock drainage (ARD)-metal leaching (ML) test work is discussed in Section 13.7. The results of the analysis of two samples identified NPR of 0.94 and 0.4 indicating that the material has potential for acid generation.

The tailings materials, and their processed by-product, should be fully characterized for acid generating potential.

12.1.5.3 Independent Check Assay, 2018 Site Visit

One sample was collected by the Geology CP during the site visit in July 2018. The CP observed drilling advance and recovery of the sample from the core tube, sample logging procedures, and sample splitting procedures. The sample was extracted as a quarter split from 1 m of recovered drill core and weighed approximately 1.90 kg. The sample was placed directly in a clear plastic bag, labelled with a generic sample identification, zip tied, and kept in possession of the CP.

The sample was collected from hole T2P-346 between depths of 6 and 7 m and was located approximately midway up the southeastern access ramp on the outer perimeter of Cell #2. The material was dark grey to black (when wet) and was comprised of fine- to medium-grained sand, with trace visible amounts of pyrite. The material was considerably drier than those samples observed from the center of Cell #1 during the 2017 CP site visit. Table 12-4 lists the sample and manganese concentrations, which correspond well with the concentrations reported for the sample submitted by EMN. The “soluble” portion of the sample collected by Tetra Tech accounts for 74% of the overall sample, which is slightly lower but generally consistent with the assay results collected by EMN. Trace element concentrations (not shown) are also generally consistent with average values of assay results collected by EMN. Figure 12-2 shows the sample being quarter split and Figure 12-3 shows a close-up of the material.

Table 12-4: Identification and Mn Concentration of Tetra Tech Check Sample

Hole	From (m)	To (m)	Sample Number	Mass (kg)	Mn (Aqua Regia ICP-MS)	Mn (4-acid ICP-MS)
T2P-346	6	7	TT18-001 (Tetra Tech)	1.90	4.95	6.73
	6	8	B00094802 (EMN)	1.99	5.18	7.46

Note: Tetra Tech sample was only 1 m of the overall 2 m interval collected by EMN and sent to SGS for analysis; absolute manganese concentrations may vary due to mineralogical composition of the full 2 m sample.

Figure 12-2: View of 1 m Tailings Core Being Quarter Split (uphole direction is to right), T2P-346, 6-7m

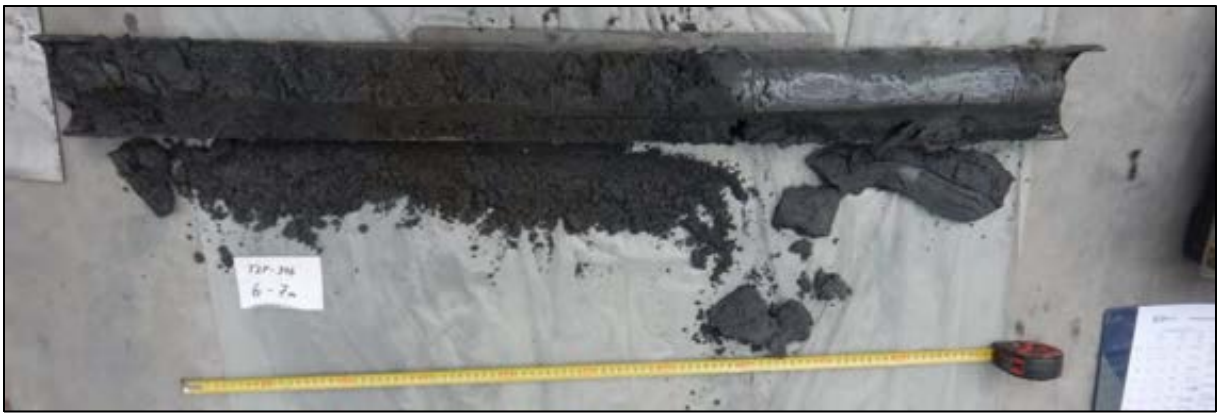


Figure 12-3: Close-up of Tailings Material, T2P-346, Sample TT18-001

The sample was submitted by ALS for XRD and Rietveld quantitative analysis at AuTec Innovative Solutions located in Vancouver, Canada, by request of the CP.

The sample was ground for approximately five minutes in a McCrone Micronizing Mill using reagent alcohol. Grinding in the Micronizing Mill reduces particles to between 5 and 10 µm in size without distorting the crystal lattices which are critical for diffraction of X-rays.

Diffraction data was collected over the range of 5-75º2θ with CoKα radiation using a Bruker D8 Focus Bragg-Brentano diffractometer. The diffractometer uses a 0.6 mm divergence slit and incident and diffracted-beam Soller slits. The system is equipped with a LYNXEYE-Super Speed Detector.

Diffraction data produced is analyzed and peaks are identified using HighScore Plus software by Panalytical using the Crystallography Open Database. Refinement of diffraction data is done using Topas 5.0 by Bruker AXS.

Detection limits for XRD depend on multiple factors, but as a general rule, if the peak to background ratio is low, the detection limit is approximately 2.0 wt%. For samples in which the peak to background ratio is high and there is good crystallinity, the detection limit can be less than 0.5 wt%. If a phase is present at less than 0.5 wt%, it could still be identified, but confidence decreases. Table 12-5 lists the model abundance derived from the Rietveld Quantitative Analysis. The main manganese bearing mineral was listed as spessartine, with major gangue minerals being quartz, albiten, and kaolinite. Dolomite was the only carbonate mineral listed which may include minor amounts on manganese carbonate not recognized by the XRD.

Table 12-5: Mineralogy Results of Rietveld Quantitative Analysis

Mineral	Ideal Chemical Formula	Modal Abundance (wt%, normalized)
Quartz	SiO_2	36.5
Albite	$NaAlSi_3O_8$	11.7
Kaolinite	$Al_2Si_2O_5(OH)_4$	0.3
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$	12.4
Dolomite	$CaMg(CO_3)_2$	10.8
Pyrite	FeS_2	5.4
Fluroapatite	$Ca_5(PO_4)_3F$	2.4
Spessartine	$Mn_3Al_2Si_3O_{12}$	5.6
Amorphous	--	14.9
Total		**100.0**

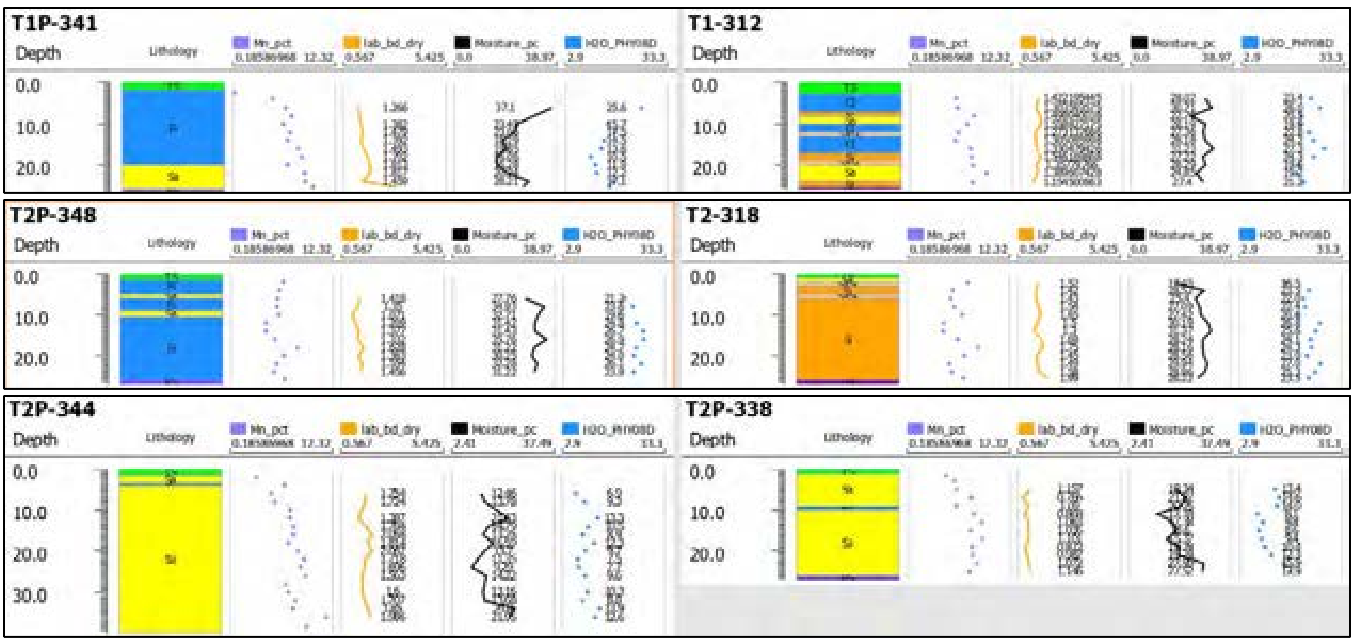
12.1.6 Drill Twinning Program, 2018

A twin drilling program was executed during the 2018 investigation. Two twin pairs were established in the center of Cell #1 and #2, and a third pair near the northwestern extent of Cell #2. The third pair, however, was comprised on an inclined hole and a vertical hole which resulted in a total 30.23 m of horizontal difference at the base of the holes. Table 12-6 lists the holes and Figure 12-3 shows a visual strip log.

Table 12-6: List of Twin Holes Drilled in 2018

Cell	2017 Original Hole	2018 Twin Hole	Comments
1	T1-312	T1P-341	Twin holes located in center of Cell #1
2	T2-318	T2P-348	Twin holes located in center of Cell #2
2	N/A	T2P-344 (inclined) T2P-338 (vertical)	Sonic holes drilled from same collar location at northwest perimeter of Cell #2; results differ due to inclined and vertical orientations

Figure 12-4: Strip logs for Twin Hole Pairs



An RPD comparison was conducted to assess the reproducibility of manganese concentrations, the calculated in situ dry bulk density value (BD) and total moisture content (H_2O). The threshold applied to the RPD assessment was 30% as the accepted variability for field replicate samples. The assessment concluded that the manganese concentrations measured by 4A AAS and AR AAS have high variability compared to the results of the XRF analysis. The calculated values for in situ dry bulk density had moderate variability, and the total moisture has the most variability. In situ moisture has seasonal variability and is expected to be different between years; these results were observed from shallow and deep samples. Table 12-7 shows the results of the RPD assessment, where cells highlighted in red have an RPD of greater than 30% and those cells highlighted in green have an RPD of less than -30%.

Table 12-7: RPD Comparison of Twin Drill Holes

2018 Twin Hole			Relative Percent Difference (2017:2018)					2017 Original Hole		
Hole ID	From	To	Mn (4A AAS)	Mn (AR AAS)	Mn (XRF)	BD (t/m³)	H_2O (%)	Hole ID	From	To
T1P-341	2	3.2	--	--	--	--	--	--	--	--
T1P-341	3.2	5	48.2	44.5	14.7	30.9	-30.8	T1-312	2.9	5
T1P-341	5	7	8.0	12.5	-8.7	3.0	-18.9	T1-312	5	7
T1P-341	7	9	16.1	24.5	8.6	71.0	-30.1	T1-312	7	9
T1P-341	9	11	20.7	0.2	12.7	12.1	18.4	T1-312	9	11
T1P-341	11	13	-11.5	-20.1	-15.2	-15.0	17.1	T1-312	11	13
T1P-341	13	15	2.2	-6.8	-17.6	-6.5	42.6	T1-312	13	15
T1P-341	15	17	-6.1	-17.2	-6.7	-11.5	44.6	T1-312	15	17
T1P-341	17	19	-2.5	-16.6	-10.1	-9.6	51.6	T1-312	17	19
T1P-341	19	21	46.6	42.0	14.2	-28.7	53.9	T1-312	19	21
T1P-341	21	23	8.5	7.5	7.1	-26.6	20.0	T1-312	21	23
T1P-341	23	25	-12.1	-15.0	-13.6	-23.3	-2.9	T1-312	23	25.4
T2P-348	0.8	3	32.9	36.5	14.1	128.5	-83.3	T2-318	1.2	3
T2P-348	3	5	47.6	48.6	-6.4	17.7	-84.7	T2-318	3	5
T2P-348	5	7	21.3	-1.8	-6.7	4.6	-46.4	T2-318	5	7.3
T2P-348	7	9	43.6	24.1	2.0	-1.6	-97.1	T2-318	7.3	8.5
T2P-348	9	11	8.7	2.0	13.1	48.8	-95.1	T2-318	8.5	11
T2P-348	11	13	81.2	75.9	4.0	23.0	-98.1	T2-318	11	13
T2P-348	13	15	74.7	63.1	2.8	44.4	-89.1	T2-318	13	15
T2P-348	15	17	52.4	35.4	13.4	6.9	-102.5	T2-318	15	17
T2P-348	17	19	5.7	-3.5	5.9	34.8	-77.8	T2-318	17	18.5
T2P-348	19	21	55.7	45.4	7.4	24.7	-99.9	T2-318	18.5	19.6
T2P-348	21	23	41.0	43.1	-8.5	12.5	-89.8	T2-318	19.6	22
T2P-348	23	25	46.1	36.7	2.4	35.7	-49.9	T2-318	22	24
T2P-348	25	26.4	6.2	-13.8	4.6	-14.7	-36.8	T2-318	24	25.1

12.2 CP Opinion on Data Verification

The CP has audited the field data and drilling logs, compared digital analytical data to laboratory certificates, compiled the geological database, observed field sample collection and splitting methods, conducted independent sample verification following two site visits, and reviewed the results of a twin drill hole program. The CP is satisfied that the samples have been properly collected, the geological database accurately reflects field observations and laboratory analysis, and that the data is suitable to support mineral resource estimation.

13.0 MINERAL PROCESSING AND METALLURGICAL TESTING

EMN plans to recover manganese by reprocessing the CMP tailings from three adjacent tailings dumps that originated from pyrite mining conducted from 1951 to 1975. The recovered manganese will be in forms of HPEMM and HPMSM for rechargeable battery industry. The potential recovery processing includes:

- Pre-concentration of manganese minerals using high-intensive magnetic separation
- Sulphuric acid dissolution of magnetic concentrate
- Iron and phosphorus removal and related solid-liquid separation and residue washing
- Pregnant solution purification
- Selenium-free electrowinning to produce HPEMM
- Production of HPMSM from HPEMM

13.1 Metallurgical Test Programs

Several metallurgical test programs have been carried out to assess the metallurgical responses of the tailings material. From 1986 to 1989, Bateria Slany, a Czechoslovak-state battery producer, undertook extensive metallurgical studies and process design work focused on the production of EMD. EMN undertook the latest test programs from 2015 through 2021 that included two major test programs conducted by CRIMM and BGRIMM and semi-continuous pilot plant testing. Table 13-1 lists the recent metallurgical testing programs.

Table 13-1: Metallurgical Test work Programs

Year	Program ID	Laboratory	Mineralogy	Pre-concentration	Leaching/EW	Others
2015	-	UBC	√	-	-	-
2015-2016	-	PMC	√			
2016	100301	Kemetco	-	-	√	-
2016	Eu Mn J0201	Kemetco	-	-	-	√
2016	-	Kemetco	-	√	-	-
2016	1656	Met-Solve	√	√	-	√
2017	-	CRIMM	-	√	√	-
2017	16204-001	SGS	√	-	√	-
2017-2018	-	CRIMM	√	√	√	√
2018	-	Slon	-	√	-	-
2018	-	NHD	-	-	-	√
2018	-	Jingjin	-	-	-	√
2018	-	Longi	-	√	-	-

table continues…

TETRA TECH

Year	Program ID	Laboratory	Mineralogy	Pre-concentration	Leaching/EW	Others
2021	-	Jenike	-	-	-	√
2021	-	ALS	√	-	-	√
2019-2021	-	BGRIMM	√	√	√	√

Notes: Global ARD – Global ARD Testing Services Inc.; Kemetco – Kemetco Research Inc.; Met-Solve – Met-Solve Laboratories Inc.; PMC – Process Mineralogical Consulting Ltd.; UBC – University of British Columbia; CRIMM – Changsha Research Institute of Mining and Metallurgy Co.; SLon – SLon Magnetic Separator Ltd.; Longi – Longi Magnet Co., Ltd.; NHD – Jiangsu New HongDa Group; BGRIMM – BGRIMM General Research Institute for Mining and Metallurgy; Jenike – Jenike & Johanson; ALS – ALS Metallurgy

Early test work, including the test work completed by UBC, Kemtco, Met-Solve, CRIMM, and SGS since 2015, was conducted on randomly collected samples. Early test work included the following:

- Preliminary mineralogical studies indicate that manganese is mainly present as rhodocrosite and as kutnohorite, with lesser amounts as sursassite, pyrolusite, and kurchatovite (grouped as manganese-silicate minerals). The grain size of manganese-carbonates varies significantly with significant amounts occurring as liberated and middling grains. Lesser amounts are present as sub-middling and locked grains. The manganese-carbonates are mainly in complex associations with other carbonates, quartz, and feldspars, or manganese-silicate minerals. The main gangue mineral is quartz. Pyrite is the dominant sulphide mineral. On average, approximately 80 to 85% of the manganese is present as acid-soluble manganese. Residual pyrite is also identified by the preliminary mineralogical studies. A significant amount of the manganese carbonate minerals occurs as a liberated form. The particle sizes of theses samples vary significantly from sample to sample.

- Pre-concentration of the tailings samples used flotation, gravity concentration, and magnetic separation in an effort to upgrade the manganese content from the tailings samples without a significant loss of the manganese. The test results show that magnetic separation with a strong background magnetic intensity can recover the manganese minerals into a concentrate of approximately 15% tMn at a recovery of approximately 86%, depending on the magnetic intensity applied and the sample tested.

- Early test results show that the ratio of acid soluble manganese to total manganese for the samples collected during 2015 and 2017 ranges from 66 to 91%, averaging 81%. As reported by AMEC Foster Wheeler (2016), the Bateria Slany (1989) report indicated that the average sulphuric acid soluble manganese content of 968 samples was 70% of the total manganese content with only a minor difference in leachable fraction between the three tailings cells.

- The acid leaching tests conducted by Kemetco show that approximately 74% of the total manganese was extracted, at pH 1.5 and in 24 hours. It is likely that the manganese extraction may be improved by finding optimum leaching conditions using a different leaching test work procedure.

- The preliminary test results by CRIMM show that the manganese extractions were 49% for the head sample and 57% for a magnetic separation concentrate at the leaching temperature of 60°C. The extraction improved to 52% and 64%, respectively, when the leaching temperature was increased to 90°C.

- SGS conducted mineralogical determination and sulphuric acid leach tests on a head sample, a magnetic concentrate sample, and a magnetic tailings sample produced by CRIMM. The tests were conducted at an initial pulp solid density of 27% w/w at a temperature of 50°C for eight hours. The results indicate that manganese leach extraction improved with an increase in initial sulphuric acid dosage. The head sample and the magnetic concentrate sample produced similar manganese extraction rates: 78.6% for the head sample with adding 300 kg/t of sulphuric acid and 76.7% for the concentrate sample with adding 500 kg/t of sulphuric acid. The non-magnetic tailings showed a much better metallurgical response. Approximately 87.8% of the manganese was extracted from the low-grade sample at an acid dosage of 200 kg/t.

The early test work has been summarized in *Public Report on Mineral Resource Estimation for the Chvaletice Manganese Project, Chvaletice, Czech Republic*, released on December 8, 2018 (Tetra Tech 2018).

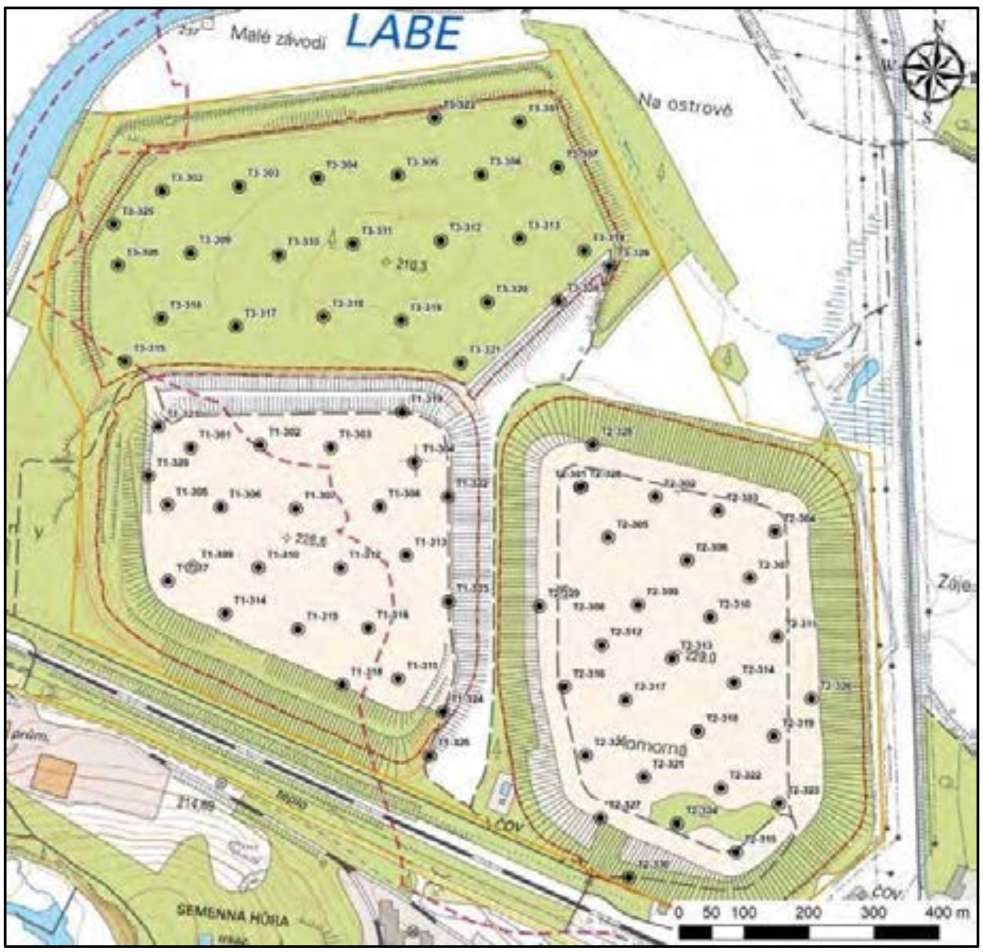
This section will focus on the test results from the two comprehensive test programs conducted by CRIMM and BGRIMM on various drill core interval samples generated during the 2017 drilling program. The test work completed by BGRIMM mainly focused on verifying the previous test results generated from 2017-2018 test program by CRIMM.

EMN conducted a separate large scale batch test program to generate sample products for potential customers in 2022, the results are not available for the report. EMN is also constructing a demonstration plant to further evaluate the proposed process circuits and product specifications and produce samples for potential customers for testing.

13.2 Metallurgical Test Samples

A total of 743 drilling samples were shipped to CRIMM on September 23, 2017, including 2 separate samples collected before the drilling program for preliminary flotation tests. All the drill core samples were collected from three tailings cells. Figure 13-1 shows the metallurgical sample drillhole distribution plan. The CP believes that the samples used for testing are representative.

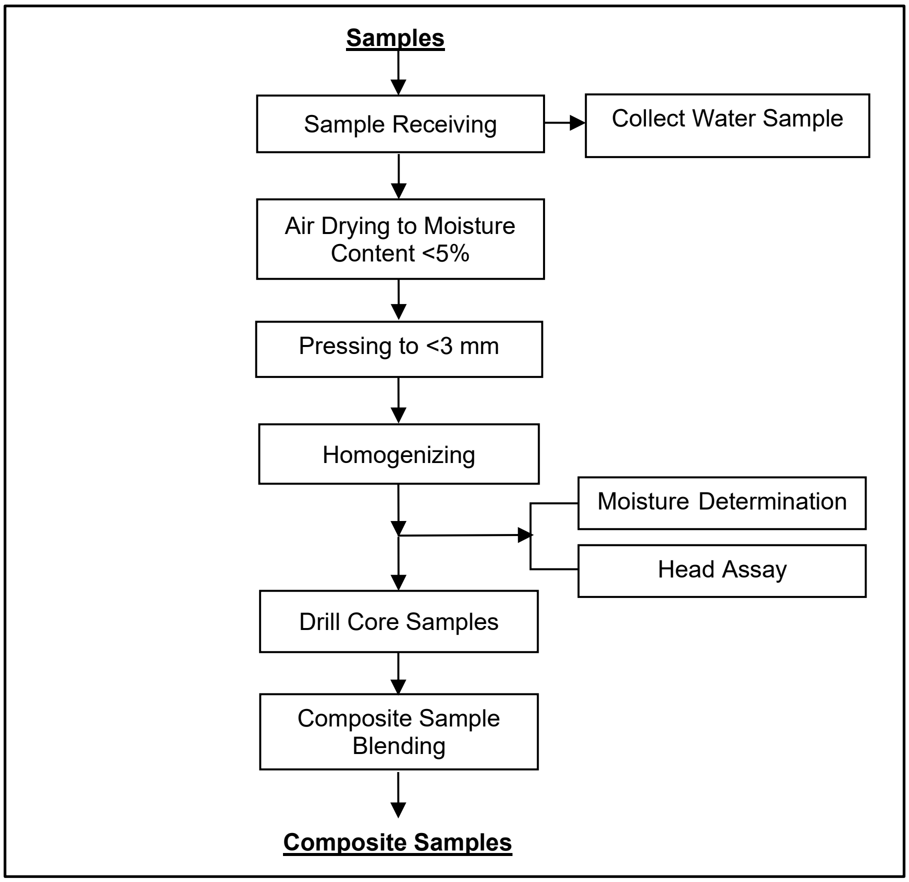
Figure 13-1: Metallurgical Sample Drillhole Location



Source: Tetra Tech (2017)

The drill core samples received were naturally dried in an open area under the sun, and then pressed to break aggregates, followed by a thorough blending. The homogenized samples were bagged prior to being used for preparing various composite samples for various metallurgical tests. Figure 13-2 depicts the metallurgical test sample preparation procedure.

Figure 13-2: Sample Preparation Flowsheet



CRIMM randomly checked the total manganese contents of some dried drill core samples. Table 13-2 shows the head assay comparisons with the projections according to drill core assay data. The total manganese assay difference is less than ±10%, excluding Samples #5191 and #5251 which show a higher variation to +15.5% and -12.1% respectively. The average absolute difference is less than 1%.

Table 13-2: Head Assay Comparison

Sample ID	Total Manganese Content (% tMn)		Difference (%)	
	Resource Estimates	CRIMM	Absolutely	Relatively
5010	8.70	8.83	0.13	1.5
5071	5.93	5.93	0.00	0.0
5131	6.32	6.9	0.58	9.2
5191	5.61	6.48	0.87	15.5
5251	6.36	5.59	-0.77	-12.1
5371	7.22	7.13	-0.09	-1.2
5431	8.62	9.17	0.55	6.4
5491	9.35	8.57	-0.78	-8.3
5551	7.02	7.45	0.43	6.1
5611	6.31	6.56	0.25	4.0
5691	5.80	5.83	0.03	0.5
5760	9.02	8.45	-0.57	-6.3
Average	**7.19**	**7.24**	**0.05**	**0.7**

A total of 25 composite samples were constructed from these drill core interval samples representing different variation characteristics and spatial locations, including:

- One Master Blend (MB) Composite (large sample for bench scale test condition optimization testing and pilot plant testing)
- Two manganese grade variation master composites (large samples for pilot plant testing)
- Three particle size variation composites
- Nineteen various spatial location samples, including three samples representing three tailings piles.

The composite samples were thoroughly homogenized by blending prior to being used for the metallurgical tests. Table 13-3 details the sample identifications and related characteristic of theses composites.

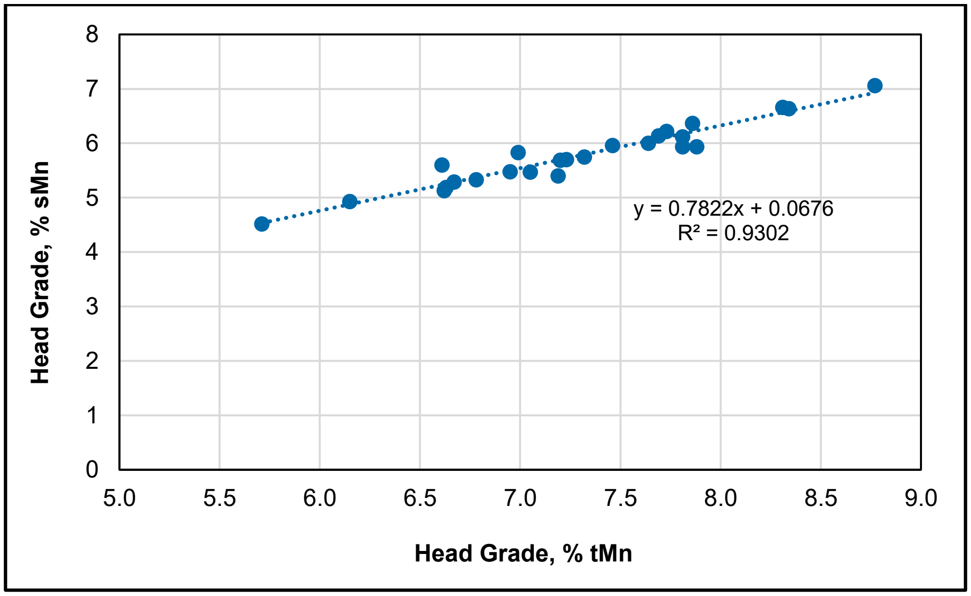
Table 13-3: Head Assay Data – Master Composite and Variability Test Samples

Sample ID	Individual Drill Core Samples[1]	Weight (with Moisture) (kg)	Particle Size Distribution (% passing 200 mesh[2])	Head Grade (%)				Note
				Calculated[4]		CRIMM		
				tMn	sMn	tMn	sMn	
MB	741	5,261	79.1[3]	7.39	5.90	7.20	5.69	Master Composite
HF-V-P1	280	1,671	70.8	8.05	6.44	7.81	6.12	High-grade/Coarse Composite
HF-V-P2	342	2,118	77.7	6.81	5.47	6.62	5.13	Low-grade/Fine Composite
HF-V-VF	251	371	96.4	6.76	5.55	6.61	5.60	Fine Particle Size Composite
HF-V-VM	252	367	81.1	7.39	5.86	7.23	5.70	Medium Particle Size Composite
HF-V-VC	237	354	43.5	8.00	6.30	7.81	5.94	Coarse Particle Size Composite
HF-V-V1	280	28.5	70.8	8.05	6.44	7.73	6.22	Cell #1 Composite
HF-V-V2	342	26.1	77.7	6.81	5.47	6.63	5.19	Cell #2 Composite
HF-V-V3	119	25.9	69.6	7.42	5.84	7.32	5.75	Cell #3 Composite
HF-V-V4	46	25.5	90.5	7.73	6.03	6.99	5.83	Cell #1 Central Composite
HF-V-V5	59	25.8	71.2	8.10	6.55	7.86	6.37	Cell #1 Northeast Composite
HF-V-V6	63	25.6	74.9	7.84	6.23	7.69	6.14	Cell #1 Northwest Composite
HF-V-V7	62	25.4	53.8	8.42	6.76	8.34	6.64	Cell #1 Southeast Composite
HF-V-V8	50	25.4	68.9	7.91	6.39	7.88	5.94	Cell #1 Southwest Composite
HF-V-V9	124	26.4	65.6	7.53	5.99	7.05	5.47	Cell #1 Lower Section Composite
HF-V-V10	156	26.4	75.5	8.51	6.84	8.31	6.66	Cell #1 Upper Section Composite
HF-V-V11	117	26.0	95.4	6.10	5.03	6.15	4.93	Cell #2 Central Composite
HF-V-V12	101	25.7	74.6	7.19	5.71	7.19	5.40	Cell #2 North Composite
HF-V-V13	124	25.6	62.1	7.29	5.77	6.78	5.33	Cell #2 South Composite
HF-V-V14	30	25.8	93.0	6.41	5.20	6.67	5.29	Cell #3 Central Composite
HF-V-V15	52	25.5	63.1	7.91	6.14	7.64	6.00	Cell #3 East Composite
HF-V-V16	37	25.7	61.2	7.54	5.96	7.46	5.96	Cell #3 West Composite
HF-V-V17	248	25.2	79.6	5.77	4.43	5.71	4.52	Low-grade Sample
HF-V-V18	251	25.9	74.1	7.22	5.77	6.95	5.48	Medium-grade Sample
HF-V-V19	242	25.4	67.5	9.19	7.51	8.77	7.06	High-grade Sample

Notes: [1] Number of individual drill core samples used for the composite sample preparation
[2] Estimated from MRE
[3] Actual screen analysis data
[4] Calculated from the MRE data

The total manganese content varies from 5.71 to 8.77%. The acid soluble manganese to total manganese ratio fluctuates in a narrow range from 0.75 to 0.85. Figure 13-3 shows the relationship between total manganese and acid soluble manganese.

Figure 13-3: Relationship Between Total Manganese Grade and Acid Soluble Manganese Grade – All Samples



The particle size distribution in percentage passing 200 mesh ranges from 43.5 to 96.4% with 79.1% for the MB Composite. As shown in Figure 13-4, it appears higher-grade material shows coarser particle size.

Figure 13-4: Particle Size vs. Head Grade – All Samples (Based on CRIMM Assay Data)

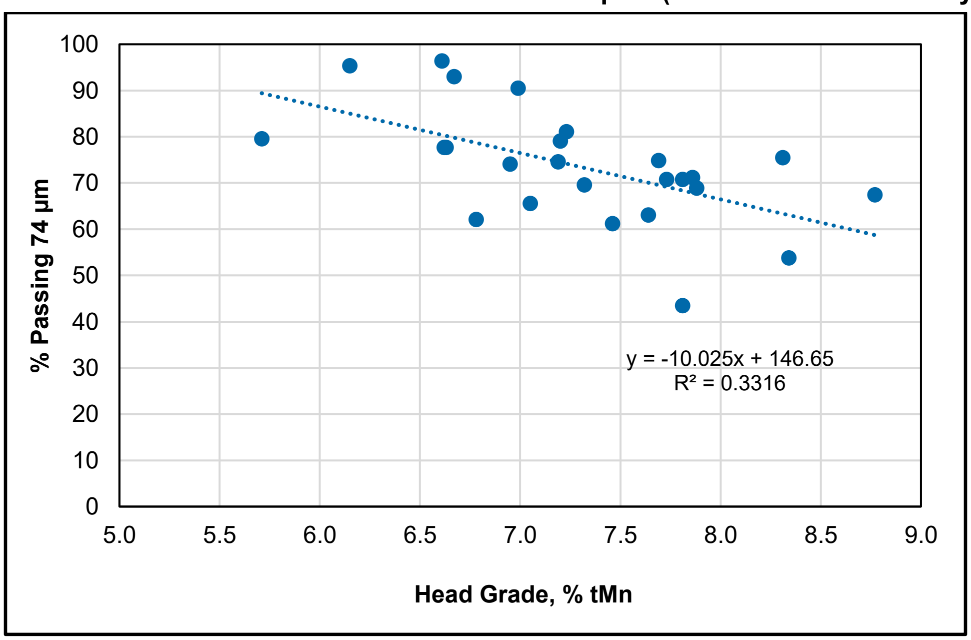


Table 13-4 shows the multi-element analysis by XRF analysis on the MB Composite and Table 13-5 lists the other analysis data, including whole rock analysis.

Table 13-4: X-Ray Fluorescence Semi-Quantitative Spectrometric Analysis Results – MB Composite

Element	tMn	Fe	Ti	V	Cr	Ni	Cu	Zn	Rb	Sr	Y
Content (%)	7.42	5.6	0.39	0.028	0.023	0.004	0.012	0.008	0.003	0.036	0.009
Element	**Zr**	**Ba**	**Si**	**Al**	**Ca**	**Mg**	**Na**	**K**	**P**	**S**	**Cl**
Content (%)	0.010	0.663	20.53	7.14	3.73	1.32	0.689	1.04	1.31	2.20	0.027

Notes: Fe – iron; Ti – titanium; V – vanadium; Cr – chromium; Ni – nickel; Cu – copper; Zn – zinc; Rb – rubidium; Sr – strontium; Y – yttrium; Zr – zirconium; Br – barium; Si – silicon; Al – aluminum; Ca – calcium; Mg – magnesium; Na – sodium; K – potassium; S – sulphur; Cl – chlorine

Table 13-5: Whole Rock Analysis and Other Assay Results – MB Composite

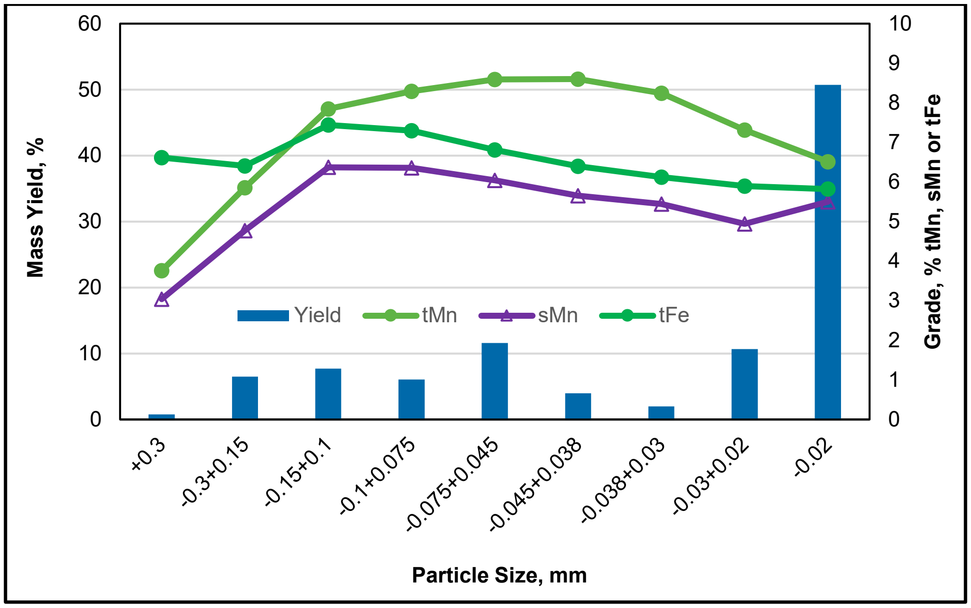
Component	tMn	sMn	tFe	Fe^{2+}	TiO_2	V_2O_5	BaO	SiO_2	Al_2O_3
Content (%)	7.20	5.69	6.10	5.25	0.50	0.052	0.47	44.5	9.80
Component	**CaO**	**MgO**	**Na_2O**	**K_2O**	**P**	**S**	**C**	**Cl**	**LOI***
Content (%)	4.96	2.22	0.79	1.07	0.98	2.94	3.40	0.043	13.42

Notes: tFe – total iron; Fe2+ - ferrous ion; TiO2 – titanium dioxide; V2O5 – vanadium pentoxide; BaO – barium oxide; SiO2 – silicon dioxide; Al2O3 – aluminum oxide; CaO – calcium oxide; MgO – magnesium oxide; Na2O – sodium oxide; K2O – potassium oxide; P – phosphorus; C – carbon; LOI – loss on ignition

The XRF assay data show that the MB Composite contains approximately 1.32% magnesium, 5.6% iron, and 1.31% phosphorus, which may be key major impurities for the manganese recovery by electrowinning process. The ratios of manganese/iron and manganese/phosphorus are relatively high. The assay also indicates that the sulphur content of the MB Composite is approximately 2.94%.

Figure 13-5 shows the particle size distribution of the MB Composite. The mass distribution of finer than 200 mesh (74 µm) is approximately 79%, while the finer than 20 µm fraction is 50.7%. The coarser than 0.3 mm fraction is small, only less than 1% and it also has the lowest manganese grade. The data indicates fine particle size distribution characteristics for the sample.

Figure 13-5: Particle Size and Metal Distributions – MB Composite



The drill core samples collected contain a high moisture (pore water) of approximately 15 to 25% with some samples reaching to approximately 30%. Table 13-6 presents the chemical analysis on the pore water collected from a composite of samples received by CRIMM, while Figure 13-6 shows the paste pH and electrical conductivity measurement for 261 samples collected from the 2017 drill program.

Table 13-6: Chemical Analysis Results – Pore Water

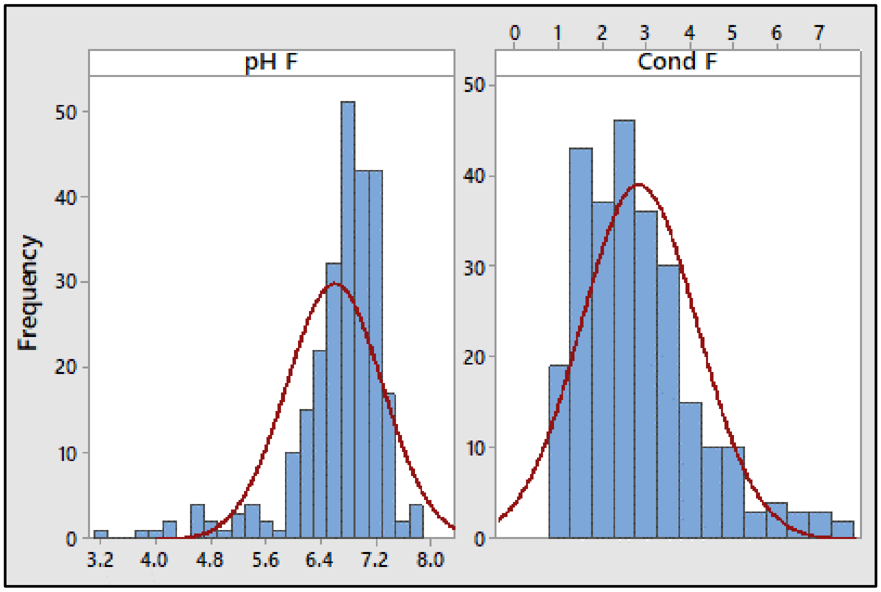
Element	Na (mg/L)	Mg (mg/L)	K (mg/L)	Ca (mg/L)	Mn (mg/L)	Zn (mg/L)	Sr (mg/L)	Cl (mg/L)	$SO_4^{(-2)}$ (mg/L)	N (mg/L)	COD (mg/L)	Conductivity (mS/cm)	pH
CRIMM	25/84	121	35	430	21.3	36.9	1.5	36	3,960	22	58.6	4.19	7.5
ALS	79	378	163	507	80.2	42.5	1.6	--	--	--	--	--	--

Note: COD - chemical oxygen demand; N – nitrogen; $SO_4^{(-2)}$ – sulphate group

In 2019, BGRIMM used the samples that remained from the 2017-2018 CRIMM test program, weighing approximately 1.7 T in total in 26 bags. They were shipped to BGRIMM in October 2019 for the verification testing.

Based on the mine plan from the previous study, one composite sample (MB) and eight variability samples (VB) were constructed for the test work, including five variability samples (P1, P2, F, M, C) constructed by CRIMM. Table 13-7 shows the sample information.

Figure 13-6: pH and Conductivity Variations



Note: Paste pH and conductivity readings were made by diluting the sample with the same water volume which was determined in the sample

Table 13-7: Head Sample Description

Sample ID	Sub-Samples Number	Sample Description	Head Grade, %					Particle size, % Passing 74/20 µm	Sample Weight, kg (approx.)
			tMn	Mg	Fe	P	Ca		
MB	741	Composite	7.20	1.19	5.64	1.01	3.23	78.59/53.94	1,400
HF-V-P1	280	Pile 1	7.74	1.17	6.54	1.09	3.10	--	40
HF-V-P2	342	Pile 2	7.05	1.41	6.15	1.01	3.26	--	40
HF-V-P3	119	Pile 3	7.45	1.38	6.21	0.96	3.76	--	40
HF-V-F	251	Fine Particles	6.98	1.50	5.66	1.06	3.36	87.51/74.75	40
HF-V-M	252	Middle Particles	7.45	1.31	6.18	0.98	3.40	79.31/46.62	40
HF-V-C	237	Coarse Particles	7.92	1.16	7.16	0.99	3.44	57.31/15.49	40
LGS	342	Low Grade	6.11	1.46	5.82	0.91	3.37	80.50/54.60	40
HGS	280	High Grade	8.89	1.25	6.98	1.16	3.71	72.43/45.39	40

Separate head assays were completed on the MB samples prepared by CRIMM and BGRIMM separately. The assay data are compared in Table 13-8, showing the key element contents are similar, although the BGRIMM's sample is much lower in phosphorous content.

Table 13-8: Head Assay Results

Sample ID	Content, %												
	Al_2O_3	BaO	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	S
CRIMM MB Raw Tailings (HD)	9.33	0.52	4.27	0.04	7.91	0.94	2.06	9.13	0.54	2.38	42.7	0.55	2.91
BGRIMM MB Raw Tailings (HD)	8.86	0.51	4.31	0.04	8.44	0.90	1.86	10.5	0.64	1.31	45.5	0.57	2.64

Note: Sulphur assays were completed using a LECO, other assays were completed as part of the whole rock analysis.

13.2.1 Process Mineralogical Study

A detailed process mineralogical study was conducted on the MB Composite sample by BGRIMM. The mineralogical characteristic study includes mineral component determination by optical microscope, XRD, SEM, and mineral chemical phase analysis.

13.2.2 Manganese and Iron Mineral Phase Analysis

CRIMM conducted mineral phase analysis to determine the manganese and iron mineral occurrences. Table 13-9 shows the determination results for manganese minerals and Table 13-10 for iron minerals.

Table 13-9: Mineral Phase Analysis Results – Manganese Minerals

Mineral Phase	Units	Mn in Carbonates	Mn in Silicates	Mn as Manganese Oxides with High Value	Mn in Ferro-manganese Oxides	Total
Content	% tMn	5.70	1.36	0.04	0.10	7.20
Distribution	%	79.20	18.90	0.50	1.40	100.00

Table 13-10: Mineral Phase Analysis Results – Iron Minerals

Mineral Phase	Units	Fe in Magnetite	Fe in Carbonates	Fe in Sulphides	Fe in Silicates	Fe as Ferric Oxide	Total
Content	% Fe	tiny	1.77	2.49	1.38	0.46	6.10
Distribution	%	-	29.00	40.80	22.60	7.60	100.00

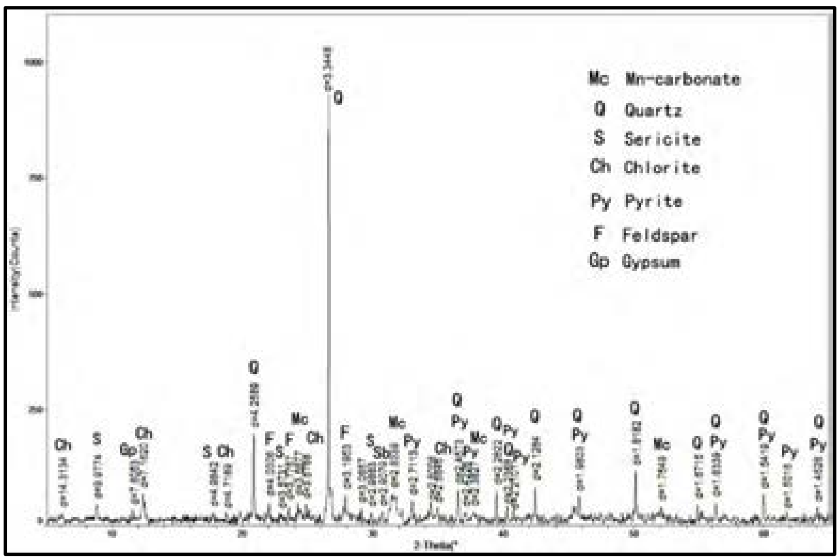
Manganese mainly occurs in the form of manganese carbonates, including rhodochrosite and kutnohorite. The manganese carbonates account for approximately 80% of the total manganese. The second main manganese mineral group is in the form of manganese silicates; approximately 19% of the manganese occurs in the minerals, including spessartine and occasionally rhodonite.

The occurrence of iron minerals is relatively complex. The iron is mainly in the form of sulphides, followed by carbonates, and silicates. The iron distributions in these minerals are 29.0%, 40.8%, and 22.6%, respectively. In addition, approximately 7.54% of the iron occurs as ferric oxide (hematite and limonite).

13.2.3 Occurrence of Main Minerals

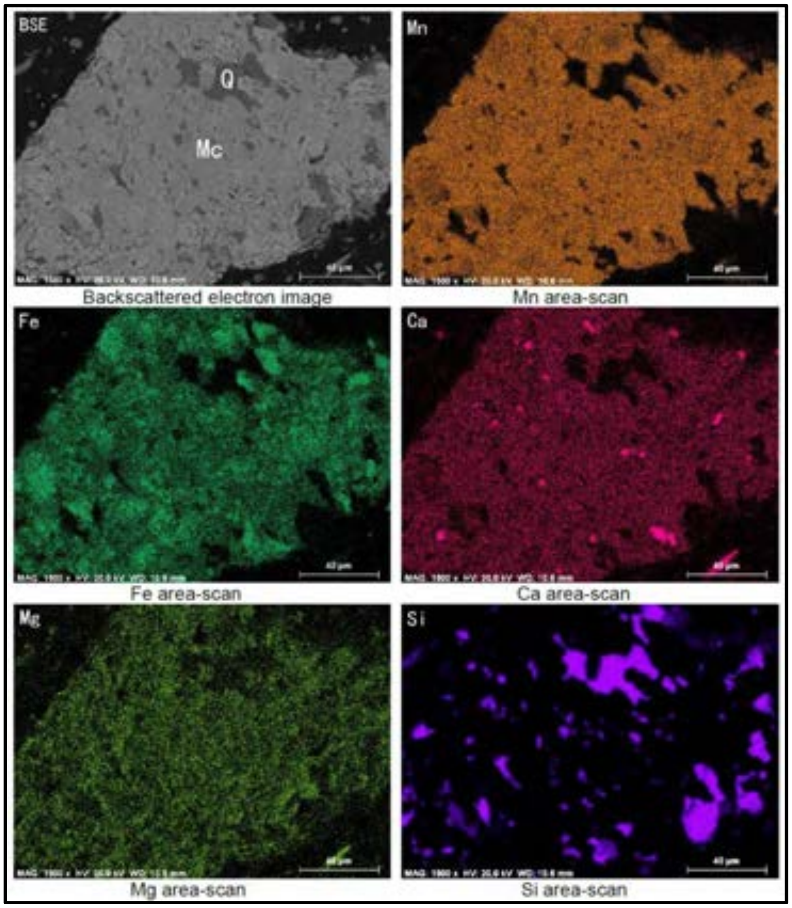
The determination by optical microscope, XRD, and SEM indicates that the manganese minerals in the sample are mainly manganese carbonates, including rhodochrosite and kutnohorite. The minor manganese minerals are manganese silicate minerals, including spessartine and occasionally rhodonite. The gangue minerals are mainly quartz, followed by feldspar, sericite/muscovite, pyrite, apatite, kaolinite, chlorite, pyroxene, hornblende, andradite, gypsum, dolomite, and calcite. Pyrite is the main sulphide mineral and pyrrhotite was occasionally noted. Metal oxides—including limonite, rutile, and ilmenite—were also observed as trace abundances. Figure 13-7 and Figure 13-8 illustrate the mineral occurrence.

Figure 13-7: XRD Spectrum – MB Composite



Source: CRIMM (2017)

Figure 13-8: Manganese Carbonate Mineral Occurrence with Iron, Calcium, Magnesium, and Silicon



Notes: Mc – manganese carbonate minerals in aggregation, including manganese, iron, calcium, magnesium, silicon, and quartz (Q)
Source: CRIMM (2017)

As shown in Figure 13-8, the XRD determination results show that the main minerals in the MB Composite are quartz, manganese carbonates, sericite, feldspar, pyrite, and chlorite.

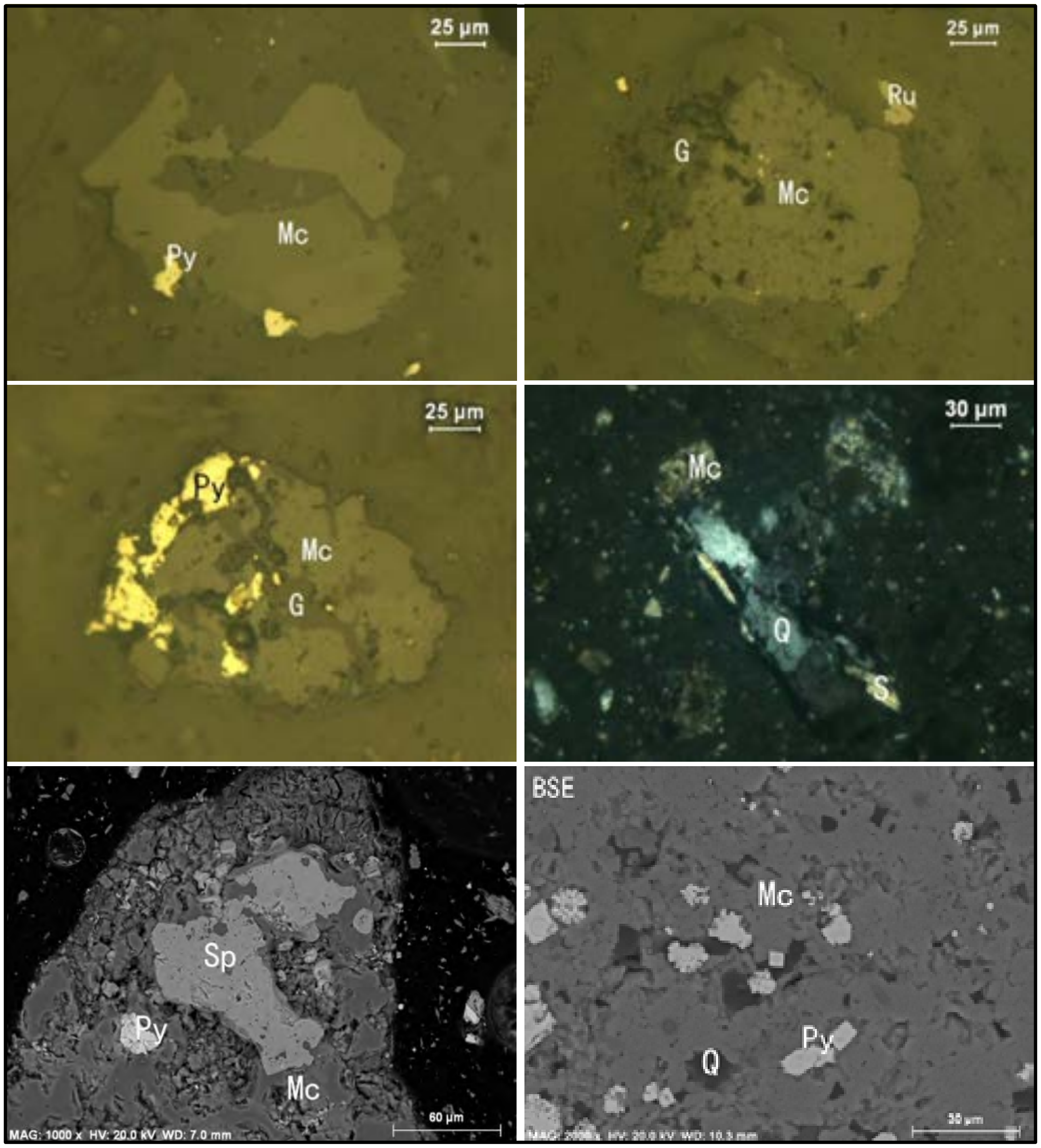
SEM together with mineral liberation analysis (MLA) identified the main minerals and their mass distribution. Table 13-11 shows the determination results.

Table 13-11: Content of Main Minerals – MB Composite Sample

	Manganese Carbonates	Ca/Mn Siderite	Siderite	Spessartine	Rhodonite	Mn/Fe Dolomite
Content (%)	19.7	3.20	1.09	6.88	0.16	1.79
	Calcite	**Pyrite**	**Hematite/ Limonite**	**Rutile /Ilmenite**	**Quartz**	**Sericite/ Muscovite**
Content (%)	0.15	5.50	0.29	0.44	37.0	5.80
	Albite	**Apatite**	**Kaolinite**	**Chlorite**	**Hornblende/ Andradite**	**Others**
Content (%)	8.75	3.90	2.13	1.21	1.02	1.0

MLA was used to determine the liberation and dissemination of manganese and other minerals in the MB Composite sample. Figure 13-9 shows the relationship of the manganese mineral dissemination with other minerals. Approximately 54% of the manganese carbonates and silicates occurs in the form of liberated minerals. The manganese minerals closely associated with the other minerals (less than 25% exposed) are relatively small; only 5.3% for manganese carbonates and 7.1% for manganese silicates. The determination results may suggest that no further grinding is required for mineral separation treatments or manganese concentration treatments.

Figure 13-9: Various Mineral Occurrence



Notes: Mc – manganese carbonate minerals; Q – quartz; G – silicate gangue minerals; Py – pyrite; Ru – rutile; Sp – spessartine
Source: CRIMM (2017)

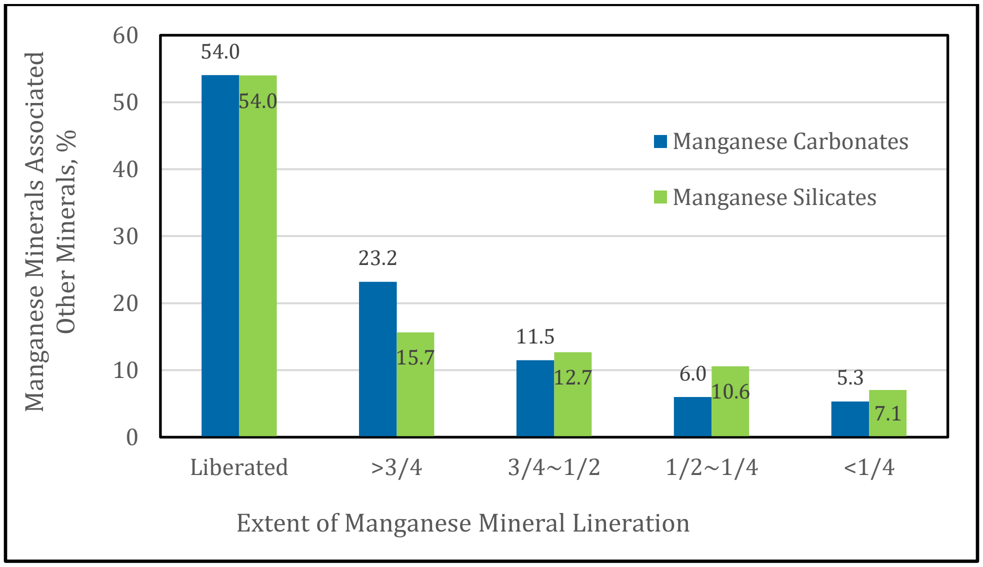
In 2020, a separate mineralogical study was conducted by ALS Metallurgy on the CRIMM and BGRIMM MB head samples using the QEMSCAN® technique. The results are shown in Table 13-12. Compared to the CRIMM's head sample, it appears that the BGRIMM sample contains slightly more manganese bearing minerals (Ca/Mn carbonates and spessartine). However, the BGRIMM's sample contains more manganese/calcium carbonates than the CRIMM's sample. It should be noted that the determination indicates that ratio of spessartine to Mn/Fe carbonates is much higher than the previous test results. The substantial determination results may be caused by the software used at ALS Metallurgy not suitable for the manganese mineral determination.

Table 13-12: Mineralogical Determination Results

Minerals	MB Raw Tailings	
	CRIMM	BGRIMM
Pyrite/Pyrrhotite	3.9	4.8
Iron Oxides	1.8	1.9
Quartz	32.5	33.9
Ca/Mn Carbonates	7.4	10.3
Spessartine	12.5	10.5
Feldspars	11.4	12.0
Chlorite	6.8	4.6
Micas	8.3	8.6
Apatite	5.1	5.7
Kaolinite	2.7	2.6
Sulphate Minerals	2.3	<0.1
Titanium Minerals	0.6	0.5
Amphibole	1.8	1.6
Epidote	0.1	0.1
Others	2.9	2.8

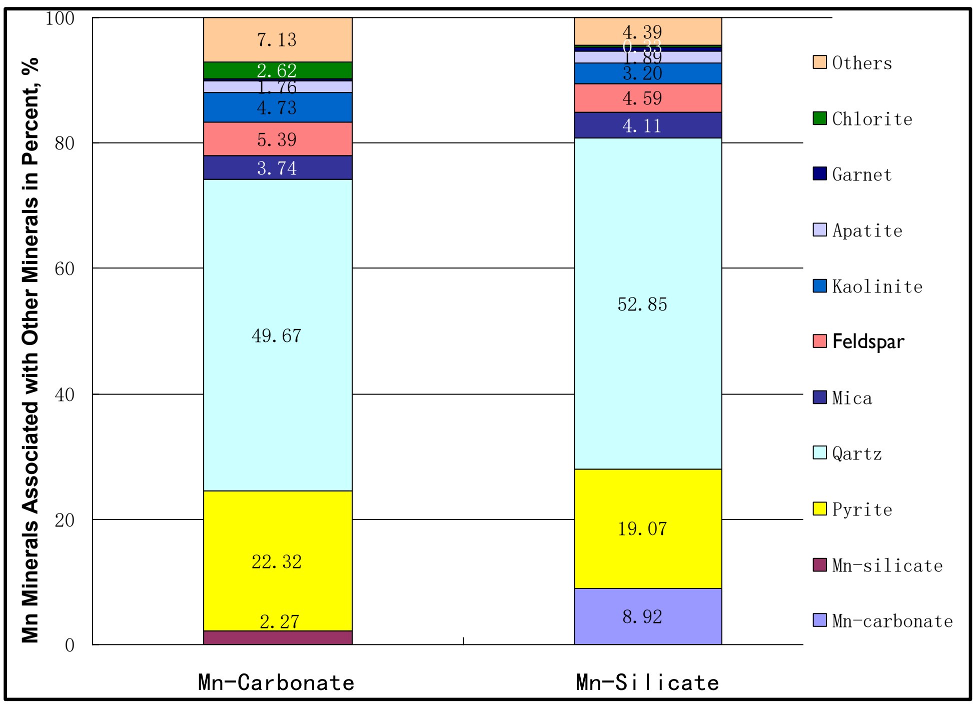
Figure 13-10 and Figure 13-11 show the percentage of the manganese minerals interlocked with other minerals and the dissemination characters of the manganese carbonate and silicate minerals with other minerals, respectively. The main minerals associated with the manganese carbonates and silicates are quartz and pyrite. The manganese minerals are less closely associated with the other gangue minerals.

Figure 13-10: Percentage of Manganese Carbonates and Manganese Silicates Associated with Other Minerals



Source: CRIMM (2017)

Figure 13-11: Relationship between Non-liberated Manganese Carbonates/Silicates and Other Minerals



Source: CRIMM (2017)

More manganese silicates disseminate within manganese carbonates, compared to manganese carbonates in manganese silicates. The high liberation degree of the manganese minerals may suggest that selective grinding occurs in the historical treatment.

13.2.4 Manganese Mineral Component Analysis

Manganese minerals were determined for their chemical components, using energy dispersive x-ray detection (EDX). The analysis results indicate significantly different manganese contents among the manganese minerals. Table 13-13 shows the average EDX results.

Table 13-13: Average Chemical Components by EDX – Manganese Carbonate Minerals

Mineral	Mn (%)	MnO (%)	FeO (%)	CaO (%)	MgO (%)
Rhodochrosite	41.9	53.9	3.08	3.50	1.22
Ca-Fe Rhodochrosite; Mg-Ca Rhodochrosite	28.7	36.9	15.7	5.63	3.41
Manganosiderite	15.9	20.4	37.4	1.97	1.92
Manganosiderite; Ferromanganese Dolomite; Tetalite	3.66	4.71	30.5	18.9	7.58

Notes: MnO – manganese dioxide; FeO – iron oxide; CaO – calcium oxide; MgO – magnesium oxide

In general, manganese carbonate minerals occur as rhodochrosite-siderite ($MnCO_3$-$FeCO_3$) minerals with low calcium oxide and magnesium oxide contents. High manganese carbonate minerals, mainly in the forms of calcium and iron rhodochrosite, are only approximately 10%. The rest are manganosiderite, ferromanganese dolomite, and tetalite. Ferromanganese dolomite contains high calcium oxide and magnesium oxide concentrations. The manganese carbonate minerals are high in iron and low in manganese.

The EDX results show that manganese silicate minerals are mainly spessartine, and sparsely as rhodonite. Spessartine contains mainly manganese oxide, aluminum oxide, and silicon dioxide, with minor calcium oxide and iron oxide. Compared with manganese carbonate minerals, iron content in manganese silicate minerals is low. Table 13-14 shows the EDX analysis results.

Table 13-14: EDX Results – Spessartine

Component	Mn	MnO	FeO	CaO	MgO	Al_2O_3	SiO_2	TiO_2
Content (%)	28.6	36.8	1.76	4.20	0.54	21.8	34.4	0.43

Both the manganese carbonate and silicate minerals are expected to be recoverable by high-intensity magnetic separation with a high metal recovery because they are weakly magnetic minerals with similar magnetism. However, the two groups of minerals may be difficult to separate by the magnetic separation treatment. The main gangue minerals, including pyrite and quartz, have a very weak magnetism character and most of them should be rejected into the tailings during magnetic separation.

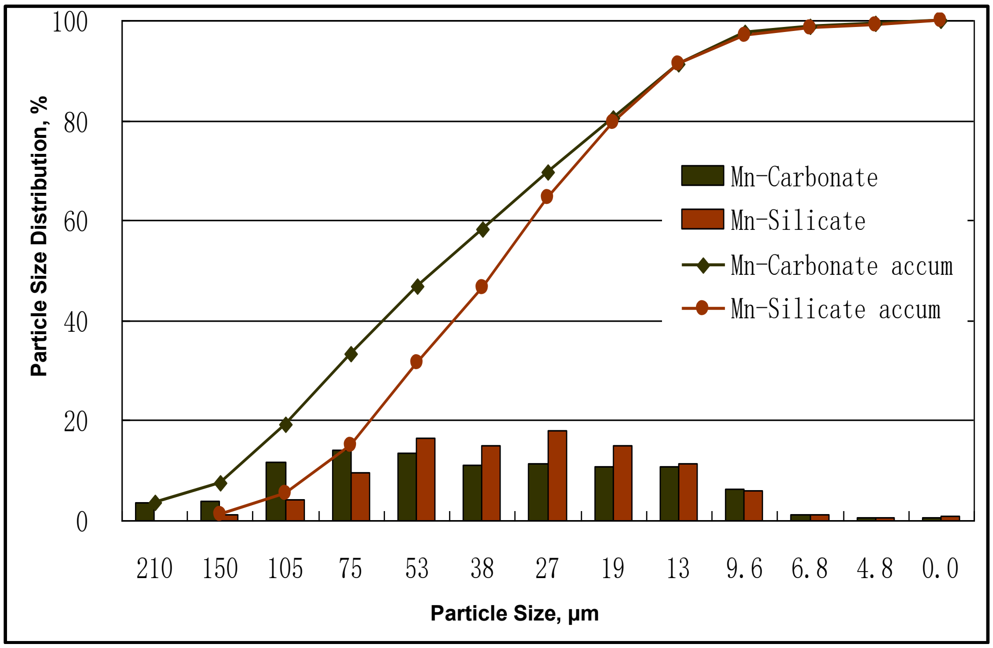
The mineralogical investigation indicates that due to high iron content in manganese carbonates, it is expected that the iron should be concentrated together with manganese carbonate into concentrate during pre-concentration treatments. A part of the iron in the mineralization should be dissolved in acid leaching. Spessartine, a main manganese silicate with a low iron concentration, should not be acid soluble, or weak to acid leaching; therefore, the iron that occurs in this mineral is not anticipated to be acid leachable.

CRIMM suggests further investigation into the recovery of spessartine as a by-product of the acid leach residue and determination of the impurity levels of the by-product.

13.2.5 Particle Size Distribution – Manganese Minerals

Manganese carbonates and silicates were also measured for their particle size distributions using MLA (Figure 13-12).

Figure 13-12: Particle Size Distribution – Manganese Minerals – MB Composite



In general, minerals occur in fine grained particles. Approximately 33.3% of the manganese carbonates are coarser than 74 µm with approximately less than 4% of the minerals coarser than 200 µm. Compared to the manganese carbonates, the manganese silicates show a finer particle size distribution. All the manganese-silicate minerals are finer than 200 µm with only approximately 15% coarser than 74 µm. The finer than 38 µm fraction is approximately 41.9% for the manganese-carbonate minerals and 53.4% for the manganese-silicate minerals.

As indicated in Section 13.2.2, approximately 54% of the manganese carbonates and silicates occur as liberated forms. The liberation degree should be sufficient for separating the manganese minerals from the gangue minerals using magnetic separation. Additional grinding may result in overgrinding the target minerals.

13.3 Magnetic Separation

Both CRIMM and BGRIMM conducted comprehensive test work to investigate the metallurgical responses of various samples to high intensity magnetic separation.

13.3.1 Magnetic Separation Tests - CRIMM

The magnetic separation test work completed in 2017 and 2018 by CRIMM and potential magnetic separator suppliers, including Slon and Longi, includes:

- Operation condition optimization using the MB Composite
- Twenty-four variability tests to investigate the effect of various head grades, particle sizes, and spatial locations
- Magnetic separation machine type, Horizontal Ring (HR) and Vertical Ring Wet High Intensity Magnetic Separation (WHIMS) tests
- Three large scale pilot plant runs: one on the MB Composite and two on the particle size/grade variability samples

Different operation conditions were tested to optimize the operation conditions, including:

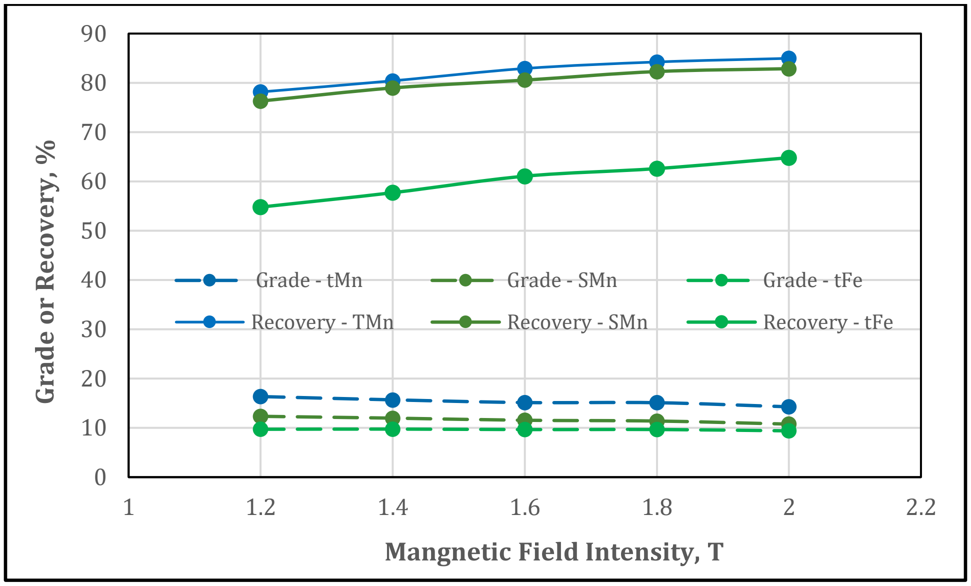
- Grind size
- Magnetic field intensity (MFI)
- Washing water pressure/flowrate
- Feed solid density
- Feed flowrate
- Magnetic separation machine type: VR-type separator and HR-type separator
- Separation zone gap and number of separation discs (HR-type separators)

After the condition tests, further optimization and flowsheet development testing was conducted to verify the magnetic separation performances.

13.3.1.1 Magnetic Separation Condition Tests

CRIMM conducted the magnetic separation tests using HR-type magnetic separation machines. In general, manganese recovery can be improved by increasing magnetic field intensity, feed slurry solid density and separation zone gap, and reducing back washing water pressure/flowrate. However, the improvement in the manganese recovery is achieved at the cost of reduction in concentrate grade. The effects of the magnetic strength on manganese and iron recovery and magnetic concentrate grade are plotted in Figure 13-13.

Figure 13-13: Manganese Recovery and Concentrate Grade vs. Magnetic Field Intensity



The various process condition optimization tests are summarized below:

- The test results indicate that grinding the head sample to 89.8% and 95.6% passing 75 µm, the concentrate grades improved slightly to 16.1% and 16.4%, but manganese recovery was reduced by 1.5% and 2.4% respectively.
- As shown in Figure 13-13, total manganese recovery improved significantly with the magnetic field intensity, ranging from 78.2 to 85.0%. However, manganese grade dropped from 16.4 to 14.3% tMn. The test results also show that the increase in magnetic field intensity did not significantly affect the iron content of the concentrate. In addition, the test results show that the iron recovery increases slightly faster than manganese recovery. CRIMM recommends the optimum magnetic field intensity of 1.6 to 1.8 T for the MB Composite sample considering both concentrate grade and recovery.
- At a magnetic field intensity of 1.8 T, three different back-washing water flow rates (pressures) were tested. The test results show that an increase in the washing water pressure from 0.1 to 0.2 MPa, magnetic concentrate grade improved from 13.6 to 15.4% tMn; however, the total manganese recovery reduced from 86.8 to 84.0%. To ensure a concentrate grade of approximately 15% tMn, a washing water pressure of 0.2 MPa at a washing water flowrate of 14 L/min for the concentrate and 9.4 L/min for the tailings was selected for the other tests.
- Three different feed solid densities were tested for their effect on the magnetic separation performance of the MB Composite. The tested solid densities were 15.0, 30.8, and 40.0% w/w. At a solid density of 15% w/w, a 15.5% tMn concentrate was obtained and compared to a 14.0% tMn concentrate at a feed solid density of 40%. To effectively reject gangue impurities CRIMM suggests using a low solid density of 15 to 30% for further tests.
- Using a three-disc HR-type machine, the effect of the separation space gap on the magnetic separation performance was tested by adjusting the lower disc separation space gap (no change in upper and middle discs). The test was conducted at a magnetic field intensity of 1.8 T. The test results show that with an increase in the lower disc gap, the combined concentrate grade produced from the three discs improved from 13.7 to 15.0% tMn. However, a reduction in manganese recovery by approximately 2% was observed. CRIMM suggests that a wide gap in a range of 1.2 to 1.5 mm for the lower disc should be used.

- Three different separation disc arrangements—single disc, double discs, and triple discs—were also tested to investigate the effect of the disc arrangements on the magnetic separation performance of the MB Composite. In general, the test results show that the change in the disc number did not have a significant effect on the magnetic separation performance. However, CRIMM indicates that double and triple disc machines are more reliable in the industrial operations; therefore, a double disc-type separator is suggested for further tests.

According to test results, the following separation conditions are selected as the optimized process conditions for the HR-type machines:

- MFI: 1.8 T
- Washing water pressure 0.2 MPa with 14 L/min for concentrate and 9.4 L/min for tailings washing
- Feed solid density: 30% w/w
- Feed rate: 5 L/min
- Two discs

Using these conditions, CRIMM conducted a confirmation test on the MB Composite and showed that the magnetic separation produced a 15.3% tMn concentrate with a recovery of 83.9% tMn.

13.3.1.2 Flowsheet Development

Several different flowsheets were tested, including with or without cleaner and scavenger separation. Table 13-15 compares the test results and the flowsheets.

Table 13-15: Magnetic Separation Flowsheet Test Results – MB Composite

Flowsheet/Magnetic Field Intensity	Product	Yield (%)	Grade (%)		Recovery (%)	
			tMn	sMn	tMn	sMn
Rougher Separation (1.8 T)	Rougher Concentrate	41.2	14.8	11.4	85.7	84.1
Rougher and Scavenger Separation (1.8 + 1.8 T)	Rougher Concentrate	38.5	15.5	11.8	84.6	84.0
	Scavenger Concentrate	3.0	5.5	4.7	2.4	2.6
	Rougher and Scavenger Concentrate	41.5	14.7	11.3	87.0	86.6
Rougher and Cleaner Separation (1.8 + 1.8 T)	Cleaner Concentrate	32.5	17.1	13.7	78.6	76.1
	Cleaner Tailings	6.7	5.9	5.2	5.6	6.1
	Rougher Concentrate	39.2	15.2	11.9	84.2	82.2
Rougher + Cleaner + Scavenger Separation (1.8 + 1.6 + 1.8 T)	Cleaner Concentrate	34.6	16.7	12.8	81.5	79.6
	Cleaner Tailings	3.8	4.9	4.2	2.7	2.9
	Scavenger Concentrate	7.3	5.0	4.4	5.2	5.8
	Cleaner + Scavenger Concentrate	41.9	14.6	11.3	86.7	85.4
	Rougher + Scavenger Concentrate	45.7	13.8	10.7	89.4	88.3

The test results show that additional scavenger separation can further recover approximately 2 to 6% of the manganese from the rougher separation tailings depending on the manganese recovery at the rougher stage. Although the scavenger concentrate grade is low, only approximately 5 to 6% tMn, the acid soluble manganese is approximately 85% of the total manganese, compared to approximately 76% in the rougher concentrate. A cleaner separation can upgrade the magnetic concentrate grade by approximately 2% tMn, but with a loss of 2 to 6% tMn. The test results appear to show that a scavenger separation should be included as a part of process flowsheet to improve overall metallurgical performances. The further tests by both CRIMM and BGRIMM confirmed that scavenger separation should be incorporated into the magnetic separation.

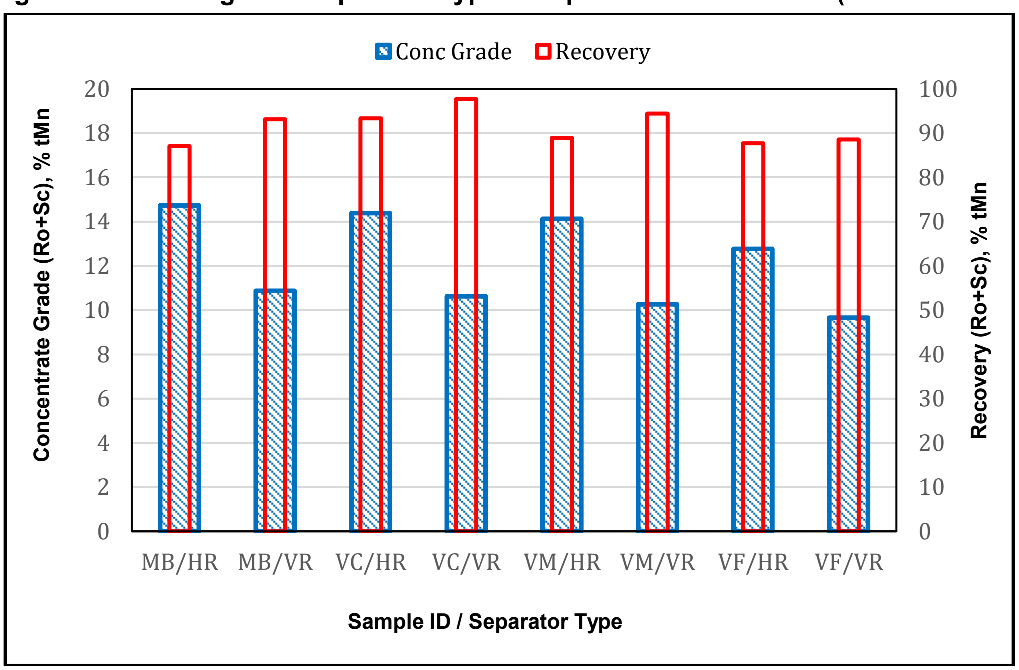
CRIMM also tested the magnetic separation on two different particle size materials screened from the MB Composite. The tested cut-off particle sizes were ±74 µm, ±45 µm, and ±20 µm, respectively. The coarse fraction was treated by VR-type separator (Model 100) and the finer fraction was separated by a single disc HR-type separator. Compared to the whole material separation, the separation on the two particle size fractions screened at 20 microns produced a higher concentrate grade to approximately 18.1% tMn, however, the total recovery dropped to 58.3% tMn.

13.3.1.3 Magnetic Separator Type Tests

Several comparison tests were conducted to compare the metallurgical responses of various samples to the VR-type and HR-type high-intensity magnetic separators. The magnetic field intensities applied by HR-type magnetic separators are higher at approximately 1.8 T, while the VR-type machine (Type 500) has lower magnetic field intensities ranging from 1.0 to 1.5 T.

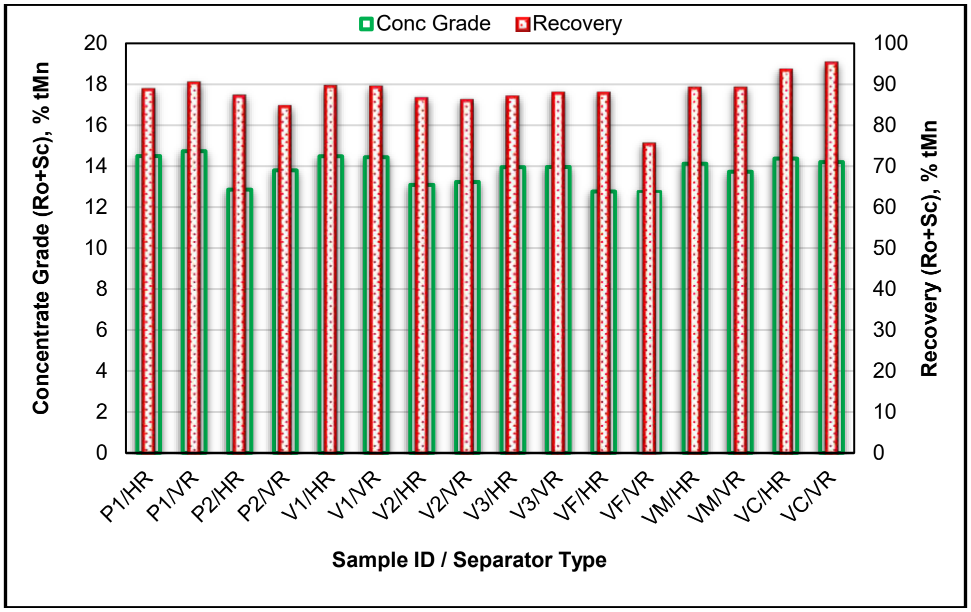
Figure 13-14 shows the test results for the MB, HF-V-VC, HF-V-VM, and HF-V-VF composites. In general, the comparison test results show that the VR-type magnetic separator produced lower concentrate grades (combined concentrate from rougher and scavenger concentrates), compared to the concentrate from the HR-type machine. however, with higher recoveries.

Figure 13-14: Magnetic Separator Type Comparison Test Results (Model VR-500)



Using a Model VR-100 magnetic separator with further optimization of the process conditions and combined rougher and scavenger separation flowsheet, both the HR and VR magnetic separators appear to generate similar metallurgical performances, excluding the fine particle samples which responded better to the HR-type separator. Figure 13-15 illustrates the comparison test results. With further optimization of the process flowsheet, the manganese-bearing material should show similar metallurgical responses to both types of the separators.

Figure 13-15: Magnetic Separator Type Comparison Test Results (Model VR-100)



The test results show that the mineral samples responded well to the high-intensity magnetic separation treatment; however, the operating conditions should be further optimized using large-scale equipment. The optimization testing should include flowsheet optimization.

13.3.1.4 Variability Tests

Using an HR-type double disc separator (Model 560), the magnetic separation tests were conducted on 24 variability test samples to investigate the effect of head grade, particle size, and sample original spatial location on magnetic separation performance. The main conditions used for the testing were: 1.8 T MFI, flushing pressure 0.15 MPa back washing water pressure, and 30.8% slurry solid density. The test results are plotted in Figure 13-16 and Figure 13-17.

Figure 13-16: Magnetic Separation Performance vs. Head Particle Size

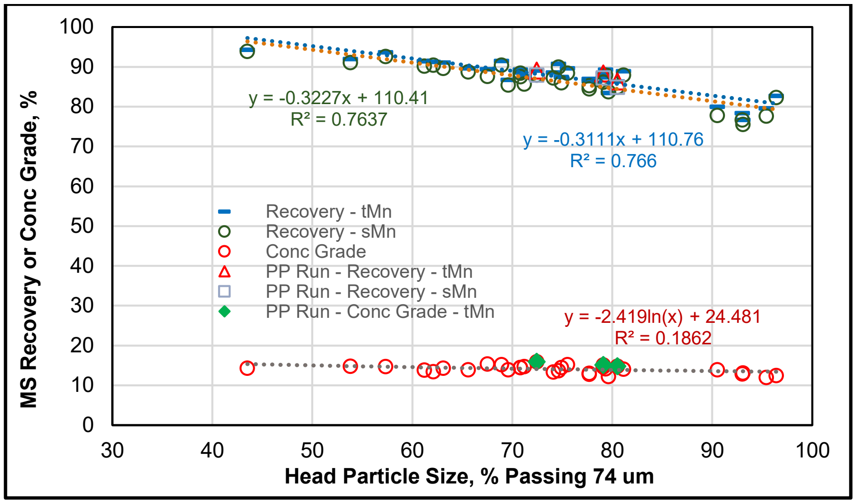
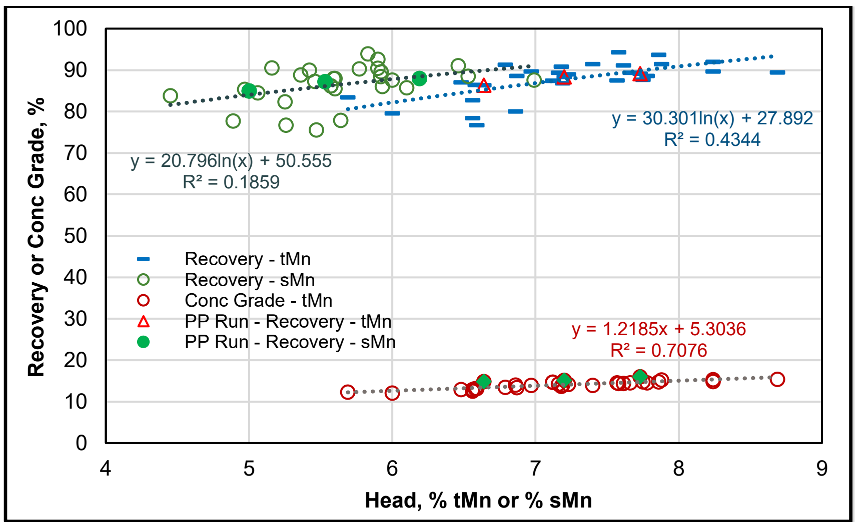


Figure 13-17: Magnetic Separation Performance vs. Head Grade

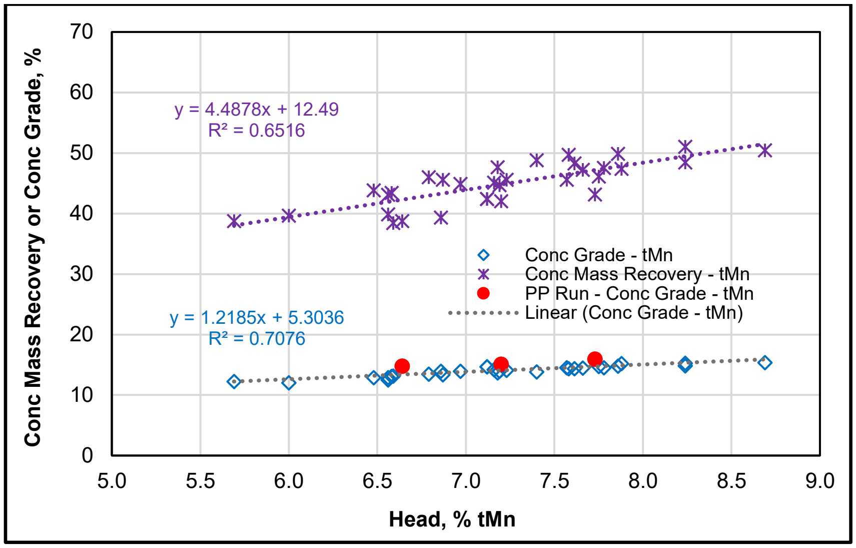


At the test conditions, both the metal recovery and the concentrate grade improve with an increase in feed grade; however, they reduce with an increase in the particle size fineness of the head samples.

The total manganese recovery varies from 76.7 to 94.3%, averaging 87.7%. With the magnetic pre-concentration, on average the magnetic concentrate can be improved from 7.2% tMn to approximately 14% tMn, ranging from 12.0 to 15.4% tMn.

As shown in Figure 13-18, approximately 38 to 51% of the magnetic separation feed was recovered into the magnetic concentrate, or, 49 to 62% of the magnetic separation feed can be rejected as a tailings product with the magnetic separation, averaging 55%. More tailings material was rejected from the low head grade materials, compared to the high-grade material.

Figure 13-18: Concentrate Grade and Mass Recovery vs. Head Grade - Variability Tests



13.3.2 Magnetic Separation Tests – BGRIMM

BGRIMM also conducted the magnetic separation tests to verify the results produced by CRIMM and generated concentrate samples for downstream leach tests. The tests were based on the test conditions using VR-type magnetic separators as developed by CRIMM. The tests were mainly conducted at the Slon's testing facility due to the magnetic separators at the BGRIMM's facility did not perform as expected.

Using a rougher separation followed by a scavenger separation and a scavenger concentrate cleaner separation, the test results from the MB composite showed that the manganese recovery to the combined rougher and scavenger cleaner concentrate of 15.1% Mn was 86.8%.

Table 13-16 shows the test results of rougher magnetic separation on eight variability samples. All tests were conducted as per MB sample test conditions. The HF-V-F sample with finer particle size gives the lowest recovery performance.

Table 13-16: Magnetic Separation Test Results – Variability Samples

	Product Name	Mass recovery %	Head Grade %		Concentrate Grade %		Recovery %	
			tMn	sMn	tMn	sMn	tMn	sMn
1	HF-V-P1	36.9	7.28	5.91	15.5	12.9	86.4	85.4
2	HF-V-P2	38.4	6.31	5.05	13.5	11.2	87.6	86.6
3	HF-V-P3	38.0	6.82	5.58	14.3	11.5	88.6	87.9
4	HGS	32.5	8.43	6.74	15.2	13.2	91.1	88.3
5	LGS	34.9	5.54	4.43	13.5	10.8	84.0	82.4
6	HF-V-C	44.6	7.47	5.84	13.9	11.5	94.4	94.6
7	HF-V-M	43.1	6.77	5.52	13.6	11.6	88.2	87.7

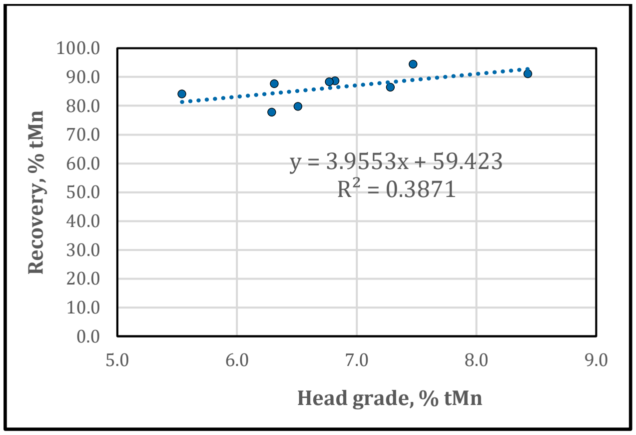
table continues…

TETRA TECH

	Product Name	Mass recovery %	Head Grade %		Concentrate Grade %		Recovery %	
			tMn	sMn	tMn	sMn	tMn	sMn
8	HF-V-F	33.6	6.29	5.29	13.3	11.6	77.7	75.1
9	MB	32.9	6.51	5.51	15.8	13.2	79.7	78.7

Figure 13-19 shows the relationship of total manganese recovery to manganese head grade. The results appear to show that the manganese recovery improves with an increase in head grade.

Figure 13-19: Relation of Manganese Grade to Head Grade



In order to produce manganese concentrate for acid leaching tests, a series of magnetic concentrate production runs were performed using an industrial scale Slon-500 separator. To simplify the production process, only rougher separation was carried out in an open circuit. Table 13-17 shows the metallurgical performances of the magnetic separation.

Table 13-17: Mn Concentrate Production Performances

Product Name	Mass Recovery, %	Head Grade, %		Concentrate Grade, %		Recovery, %	
		tMn	sMn	tMn	sMn	tMn	sMn
CMP_MS_5005	35.4	7.66	6.05	14.5	12.7	71.5	63.8
CMP_MS_5005	33.4	7.49	5.80	15.6	13.3	73.3	64.4
CMP_MS_5006	37.9	7.49	5.98	15.7	13.4	87.1	83.7
CMP_MS_5007	40.5	7.53	6.09	15.2	12.9	87.8	85.2
CMP_MS_5007	37.3	7.24	5.96	15.5	13.3	86.3	85.2
CMP_MS_5008	33.4	7.63	6.07	15.8	13.6	83.4	78.1
CMP_MS_5009	36.2	7.80	6.09	15.1	13.2	80.0	81.7
CMP_MS_5010	37.0	7.17	5.73	15.2	12.5	79.8	74.6

table continues…

TETRA TECH

Product Name	Mass Recovery, %	Head Grade, %		Concentrate Grade, %		Recovery, %	
		tMn	sMn	tMn	sMn	tMn	sMn
CMP_MS_5011	36.5	7.26	5.68	15.4	12.9	84.5	79.8
CMP_MS_5012	37.9	7.40	5.73	15.1	12.6	87.8	85.6
Average	**36.9**	**7.42**	**5.85**	**15.3**	**12.9**	**84.0**	**81.1**

Table 13-18 shows the wet screening results of the manganese concentrate produced from the MB samples, while Table 13-19 shows the wet screening results of the tailings produced from the MB samples. These test results indicate that:

- The particle size of the produced manganese concentrate (60% finer than 74 µm) is much coarser than that of the produced tailings (79% finer than 74 µm).
- The produced Mn concentrate contains much less in finer than 20 µm particles (24% finer than 20 µm) than the produced tailings (53% finer than 20 µm)
- In the production tailings, 71.1% manganese is lost in the particle size fraction of less than 20 µm.
- The particle size fraction of finer than 20 µm has the highest manganese grade in the produced manganese concentrate, and the highest manganese grade in the produced tailings as well.

Table 13-18: Concentrate Size Analysis

Size	Weight		Cumulative, %		Grade, %	Distribution, %
µm	grams	%	Oversize	Undersize	tMn	tMn
+200	6.0	3.1	3.1	100.0	10.1	2.2
-200 +150	20.9	10.8	13.9	96.9	12.3	9.0
-150 +75	51.1	26.4	40.2	86.1	13.4	24.2
-75 +38	50.9	26.2	66.5	59.8	14.6	26.2
-38 +20	18.5	9.5	76.0	33.5	15.6	10.1
-20	46.5	24.0	100.0	24.0	17.3	28.3
Head	193.9	100.0	--	--	14.7	100.0

Table 13-19: Tailings Size Analysis

Size	Weight		Cumulative, %		Grade, %	Distribution, %
µm	grams	%	Oversize	Undersize	tMn	tMn
+200	2.2	1.6	1.6	100.0	1.6	1.2
-200 +150	7.1	5.1	6.6	98.4	1.6	3.9
-150 +75	20.4	14.5	21.1	93.4	1.4	10.0
-75 +38	24.6	17.5	38.6	78.9	1.1	9.2
-38 +20	12.2	8.7	47.2	61.4	1.1	4.6
-20	74.3	52.8	100.0	52.8	2.7	71.1
Head	140.8	100.0	--	--	2.0	100.0

Comparing with CRIMM's results (Table 13-20), BGRIMM concludes that

- Slon WHIMS is an effective magnetic separator for recovering the manganese minerals.
- It is feasible to apply the magnetic separation process to achieve a concentrate grade higher than 14.5% tMn with a manganese recovery of higher than 85%.
- In actual production, the scavenger concentrate can be sent back to rougher separation to form a closed circuit flowsheet, which is similar to adding a cleaner scavenger separation.
- MFI of 1.5 T for both of rougher and scavenger separations is proposed, especially for the scavenger separation. This will provide an opportunity for a further improvement in manganese recovery because the finer than 20 µm particle size is more than 50% w/w.

Table 13-20: Comparison between Test Results of BGRIMM and CRIMM

	Flowsheet	Head Grade %		Concentrate Grade %		Recovery %	
		tMn	sMn	tMn	sMn	tMn	sMn
CRIMM	Rougher + scavenger	7.15	--	15.1	--	85.2	--
BGRIMM	Rougher + scavenger + scavenger cleaner	6.51	5.51	15.1	12.7	86.9	86.3

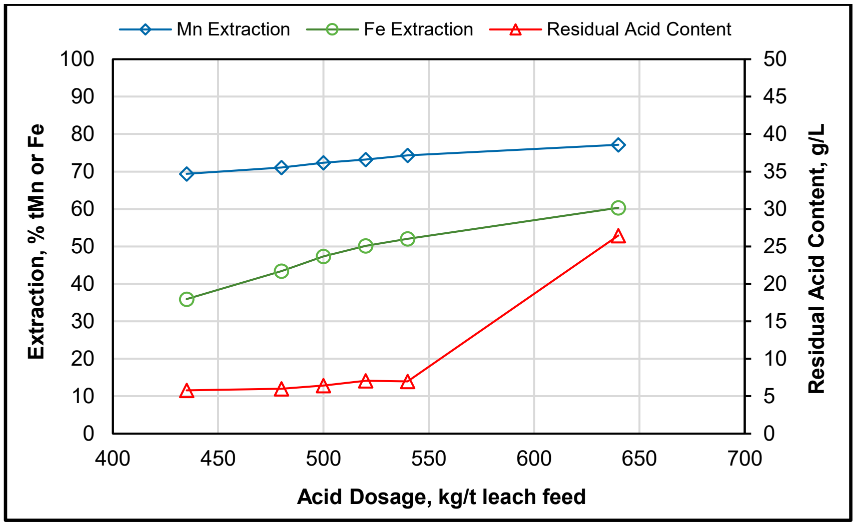
13.4 Acid Leaching

Comprehensive sulphuric acid leach test work was completed on the concentrates produced from the MB Composite and the variability test samples by both CRIMM and BGRIMM. The tested leach process conditions included acid to ore ratio, leach temperature, and leach retention time.

13.4.1 Acid Leaching - CRIMM

The preliminary test results are summarized in Figure 13-20, illustrating the effect of the acid dosage on manganese and iron extractions at a leach temperature of 50°C and a leach retention time of six hours.

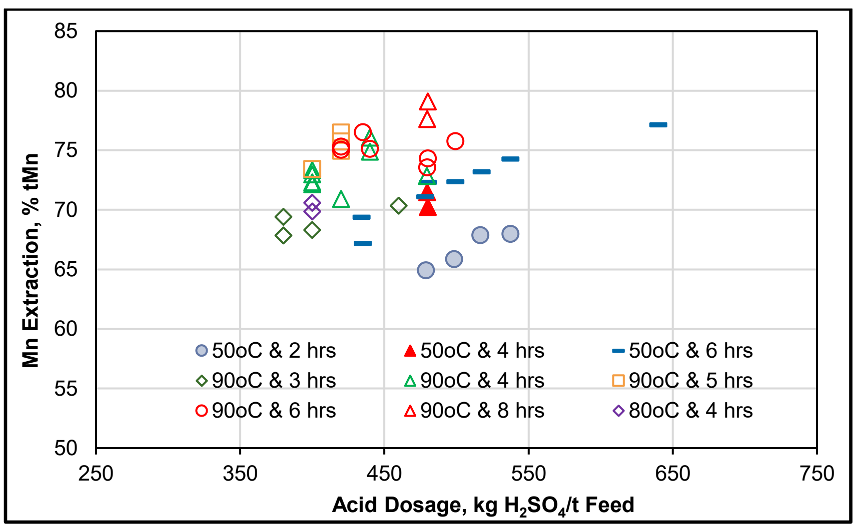
Figure 13-20: Acid Leach Test Results (50°C, 6-hour Retention Time) – MB Concentrate



The test results show that manganese extraction improved from 69.4 to 77.2% tMn, while the iron extraction increased significantly from 35.9 to 60.3%. With an increase in acid consumption, the iron extraction increased obviously faster than the manganese extraction, indicating that a large amount of iron silicates may have been leached at the high acid dosage. It is recommended not to use a high acid dosage (with a high free residual acid) to leach the manganese mineral material.

Further leaching condition optimization tests were conducted at different leach retention times, acid dosages, and temperatures. The test results are shown in Figure 13-21. As observed from the earlier tests, the test results show that manganese extraction improved with an increase in the acid dosage. In addition, the test results show that the manganese extraction increased with both leach retention time and leach temperature.

Figure 13-21: Acid Leach Test Results at Different Leach Conditions – MB Concentrate

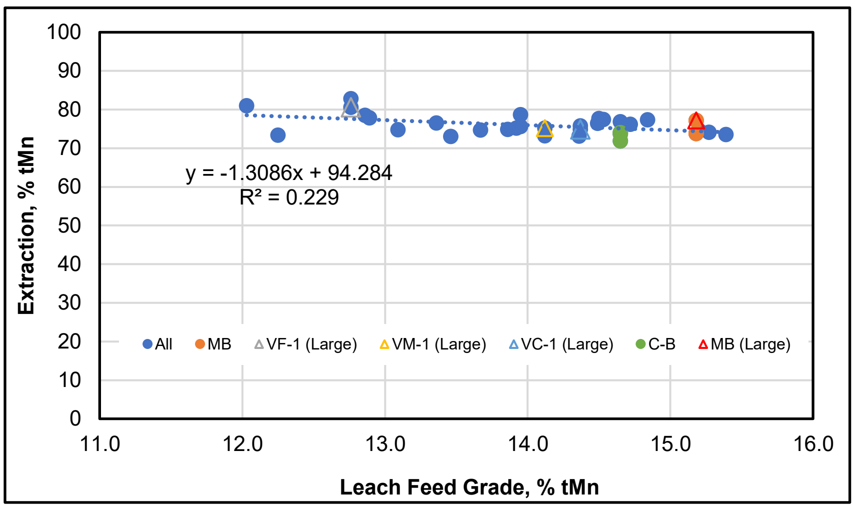


Considering the downstream iron/phosphorus removal treatment, the optimized leach conditions were determined as:

- A leach temperature of approximately 90°C
- A leach retention time of 5 to 6 hours
- A 0.42 acid to 1.0 leach feed ratio.

Using the developed acid leach conditions, the magnetic concentrates produced from various variability samples were tested for their metallurgical responses to the leach treatment. Figure 13-22 shows the test results. On average, approximately 75% of the manganese can be extracted by sulphuric acid leaching, ranging from 71.9 to 82.8% tMn.

Figure 13-22: Acid Leach Test Results – Variability Test Samples



13.4.2 Acid Leaching – BGRIMM

In 2019 to 2021, BGRIMM conducted a separate test program to verify CRIMM's acid leaching results. The magnetic concentrates from head samples of Composite MB and eight variability composites were used for the acid leaching verification test. Based on the acid leaching verification test results, BGRIMM concludes that:

- CRIMM acid leaching test results are basically repeatable, even though there are some differences between the test results of BGRIMM and CRIMM.
- When an anolyte solution is used to prepare a slurry for the Mn leaching test, a soaking pre-treatment in anolyte solution for two hours is recommended.

Table 13-21 shows key element assay results of the leach feeds. The total manganese content contained in these samples is in the range of 13.7% to 16.2%.

Table 13-21: Chemical Analysis Result of Acid Leach Feed Samples

Sample	Element Content, %				
	tMn	Mg	Ca	Fe	P
MB	16.2	1.75	3.85	10.2	1.14
Pile 1	15.4	1.51	3.48	10.4	1.14
Pile 2	13.8	1.75	3.57	10.4	1.13
Pile 3	14.7	1.71	3.91	10.2	1.08
HGS	15.6	1.52	4.01	10.2	1.36
LGS	13.8	1.73	3.27	10.6	0.99
Coarse*	14.3	1.45	3.71	10.3	1.25
Middle*	14.2	1.57	3.62	10.1	1.19
Fine*	13.7	1.76	3.32	9.7	1.09

Note: * Approximately Particle Sizes: Coarse: 57.3%; Middle: 79.3%; Fine: P80 93.1%

Table 13-22 shows the comparison between the MB feed samples of BGRIMM and CRIMM. The contents of tMn and Fe in the BGRIMM's sample are slightly higher than that in CRIMM's samples.

Table 13-22: Comparison between BGRIMM and CRIMM Acid Leach Feed Samples

Sample	BGRIMM		CRIMM			
	MB		C-B*		MB	
Element	tMn	Fe	tMn	Fe	tMn	Fe
Content %	16.2	10.2	14.7	9.5	15.2	9.8

Note: * C-B is a separate concentrate produced from the MB composite for leach condition development tests

Table 13-23 shows the comparison of mineralogical composition between the feed samples of BGRIMM and CRIMM. BGRIMM MB sample contains more Mn oxide, while CRIMM C-B samples contains more Mn silicates. BGRIMM MB sample also contains more Mn carbonate than the CRIMM C-B samples.

Table 13-23: Comparison of Mineralogical Compositions Between Samples of BGRIMM and CRIMM

Sample		tMn	High Valent Oxide	Mn-Fe Oxide	Mn Carbonate	Mn Silicate
BGRIMM MB Sample	Mn Content, %	16.3	0.8	1.4	12.5	1.6
	Mn Distribution, %	100.0	4.8	8.5	76.9	9.8
CRIMM C-B Sample	Mn Content, %	14.7	0.1	0.2	11.1	3.3
	Mn Distribution, %	100.0	0.1	1.4	75.8	22.7

A synthetic anolyte solution, consisting approximately 15 g/L Mn, 130 g/L $(NH4)_2SO_4$, 5 g/L Mg and 40 g/L H_2SO_4, was prepared for the concentrate leaching tests to simulate the recirculation of anolyte expected in industrial operation. Table 13-24 shows the comparison of BRGIMM verification test results with CRIMM acid leaching test results.

Table 13-24: BGRIMM Verification Test Results

Test ID	Acid Dosage Kg/t	Leach Retention Time hour	Temperature °C	Free Acid Content g/L	Mn Extraction Rate %	Fe Extraction rate %	Residue Mass Rate %	Note
AL-01/02	420	6	90	8.3	67.8	40.9	67.9	With anolyte
AL-23	420	6	90	0.77	74.7	49.6	63.8	Without anolyte
AL-24	450	6	90	3.64	74.6	52.7	62.1	
AL-25	480	6	90	5.02	77.2	55.3	62.8	
AL-26	540	6	90	14.0	76.4	56.5	61.7	
CRIMM	420	6	90	<1.0	74.7	45.9	65.7	

BGRIMM verification tests include:

- acid consumption,
- multi-stage acid addition,
- leaching retention time,
- leaching temperature,
- regrinding leaching feed, and
- using fresh acid solution or synthetic leaching feed solution.

As shown in Table 13-24, the test results indicate that when fresh water is used to prepare the leaching feed slurry, there is a very little difference in the acid leaching performances between the leaching tests of BGRIMM and CRIMM under the same leaching test conditions. However, when using the synthetic anolyte solution to prepare the leaching feed slurry, the manganese extraction by the leaching significantly decreases from 74.7% to 67.8%. As discussed with BGRIMM, one of the potential causes of the lower extraction may be due to overheating of the magnetic concentrates during the concentrate sample preparation. BGRIMM test results also show that the manganese leaching extraction could be improved from 67.8% to 75.8% when the acid dosage is increased from 420 kg/t to 660 kg/t.

BGRIMM also investigated the effect of the $(NH_4)_2SO_4$ concentration in the synthetic anolyte solution on manganese extraction. The test results show that the $(NH4)_2SO_4$ concentration had an insignificant impact in the tested ammonium sulphate content range ranging from 80 g/L to 130 g/L, the manganese extraction was approximately 72%.

The further test work indicates that the pre-treatment of soaking the feed sample with the anolyte solution can improve manganese leach extraction. The test results are shown in Table 13-25 and highlighted below:

- The pre-treatment of soaking feed samples with the anolyte solution before acid leaching could significantly improve the manganese leaching rate.

- With the soaking pre-treatment of half hour, the manganese leaching rate target of 75% could be achieved at the acid addition of 540 kg/t.
- If the soaking pre-treatment time is extended to two hours, the acid addition could be further reduced to 480 kg/t.

Table 13-25: Effect of Pre-treatment of Soaking with Anolyte Solution on Manganese Extraction

Test ID	Acid Dosage (Kg/t)	Leach Retention Time (hours)	Temp. (°C)	Free Acid (g/L)	Mn leaching rate (%)	Fe leaching rate (%)	Residue Mass Rate (%)	Soaking in Anolyte (hours)
AL-01/02	420	6	90	8.3	67.8	40.9	67.9	0
AL-40	420	6	90	1.6	72.1	47.0	64.9	0.5
AL-12/13	480	6	90	16.2	71.6	49.1	64.2	0
AL-42	480	6	90	10.1	72.9	47.1	63.8	0.5
AL-14/17	540	6	90	22.5	72.1	54.5	62.5	0
AL-47	540	6	90	15.6	75.1	55.3	61.9	0.5
AL-43	586	6	90	20.9	76.0	60.9	62.4	0.5
AL-18	600	6	90	30.7	74.6	63.0	59.0	0
AL-19	660	6	90	36.1	75.8	56.9	61.4	0
AL-49	450	6	90	2.7	74.8	50.4	63.0	2.0
AL-46	480	6	90	4.2	75.3	54.8	62.1	2.0

Table 13-26 shows the leaching test results on the eight-variability samples using a synthetic anolyte solution. There are some differences in the manganese leach rate between the samples, and Sample F with a finer particle size gives the highest manganese extraction rate.

Table 13-26: Acid Leaching Test Results – Variability Samples

Test ID	Sample	Acid Dosage Kg/t	Leach Retentio n Time (hr)	Temp. (°C)	Soaking Time in Anolyte (hr)	Free Acid (g/L)	Mn leaching rate (%)	Fe leaching rate (%)	Residue Mass Rate (%)
AL-50	P1	480	6	90	2	15.9	71.1	43.4	67.0
AL-51	P2	480	6	90	2	12.9	71.3	51.1	69.1
AL-52	P3	480	6	90	2	14.8	72.2	49.4	65.7
AL-53	H	480	6	90	2	10.8	74.5	46.0	67.5
AL-54	L	480	6	90	2	18.6	70.9	52.8	65.7
AL-55	C	480	6	90	2	13.5	73.9	44.8	69.8
AL-56	M	480	6	90	2	15.2	72.4	48.4	69.2
AL-57	F	480	6	90	2	13.0	76.8	52.4	66.7
AL-46	MB	480	6	90	2	4.2	75.3	54.8	62.1

To prepare the samples for leach residue filtration tests, BGRIMM used a 2-m^3 vessel for the leaching testing. The test setup is illustrated in Figure 13-23. The test conditions and results are summarized in Table 13-27.

Figure 13-23: Leaching Testing for Preparing Slurry for Dewatering Tests

Source: BGRIMM (2022)

A synthetic anolyte solution with 15 g/L Mn, 130 g/L $(NH_4)_2SO_4$, 5 g/L Mg and 40 g/L H_2SO_4 were used for the leach tests. The test results are summarized in Table 13-27. On average approximately 79% of the manganese was extracted.

Table 13-27: Large Scale Acid Leaching Test Results

Test ID	Acid Dosage, kg $H2SO_4$/t Feed	Leach Retention Time (hr)	Temperature (°C)	Soaking Time, (hr)	Metal Extraction, (%)		Residue Rate (%)
					Mn	Fe	
Mn-13	480	6	90	2	78.5	55.1	61.6
Mn-14	480	6	90	2	78.4	56.7	68.6
Mn-15	480	6	90	2	80.1	47.2	67.7

Note: Feeds was from MB sample for Tests Mn-13 and Mn-15 and from a finer particle size material for Mn-14

13.5 Impurity Removal and Purification

Both CRIMM and BGRIMM investigated iron, phosphorous, and heavy metal removals from acid leach solution to prepare qualified solution for downstream manganese electrowinning.

13.5.1 Iron and Phosphorus Removal - CRIMM

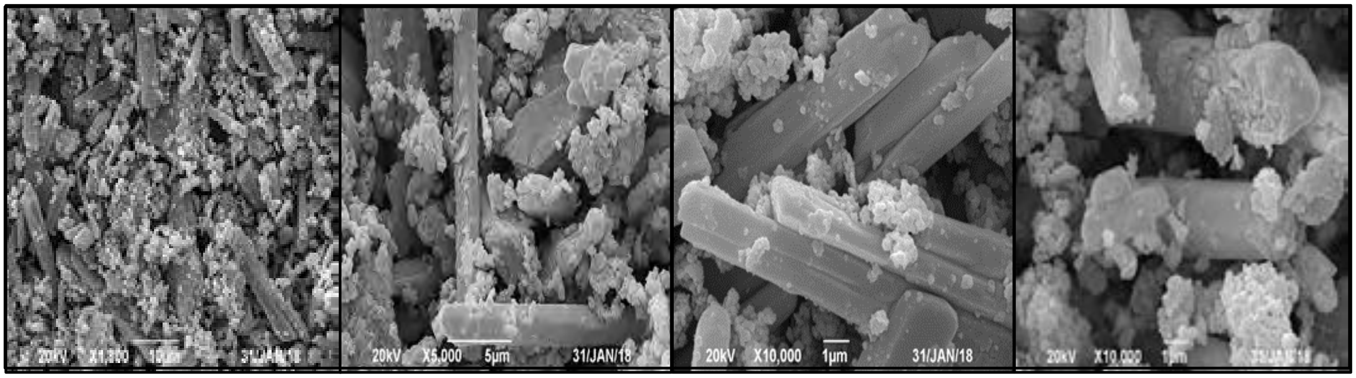
Two iron removal methods; oxidation-hydrolysis and goethite, were investigated. The tests investigated iron removal efficiency and the effect of iron processes on subsequent solid-liquid separation. The test results show that both methods can achieve the iron and phosphorous removal targets; however, the test results indicate that the residues produced by the oxidation-hydrolysis iron removal method are much more difficult to separate from solution in subsequent liquid-solid separation. Phosphorous dissolved during the acid leaching can be effectively co-precipitated with the iron precipitates and report to the neutralized leach residues.

Further tests were conducted to investigate the effects of various operation parameters on iron and phosphorous removals and residue liquid and solid separation efficiency. The key parameters tested included oxidant type and dosage, reaction temperature, reaction retention time, pH, aging time, and seeding addition. Using a high-grade manganese oxide ore as oxidant at a leaching temperature of 85 to 90°C, reaction retention time of four hours, and a controlled pH, the iron content in the leach solution was reduced to less than 1 mg/L. The iron redissolution from the precipitates was insignificant after the slurry was kept for 24 hours. However, the filtration tests showed that the moisture of the leach residue filtration cake was high, approximately 50% w/w solids. The tests also confirm that the dissolved phosphorous during the acid leaching can be reduced to less than 1.6 mg/L.

The test program also investigated the effect of using air as an oxidant and hydrated lime as neutralization reagent, instead of high-grade manganese oxide ore and ammonia water. The confirmation tests indicate that it is feasible to using the goethite method for iron and phosphorous removals by adding air as an oxidant and lime as a pH neutralizer.

The particle size distributions and compositions were determined using laser particle analysis, XRF analysis, and ICP scan. The leach residue, which was treated by iron, phosphorous, and heavy metals purification, was scanned using SEM. The SEM images, illustrated in Figure 13-24, show that the residue contains significant quantities of elongated gypsum crystals adsorbed with fine gangue mineral clusters.

Figure 13-24: SEM Scan of Purification Treated Leach Residue (After Washing) – MB Composite



Source: CRIMM (2018)

13.5.2 Iron and Phosphorus Removal - BGRIMM

In 2021, BGRIMM conducted a separate test program to verify the iron and phosphorous removal results completed by CRIMM. The testing used the same procedure used by CRIMM for the previous tests. Table 13-28 shows BGRIMM's verification test results of the Fe/P removal process. Using the optimum test conditions recommended by CRIMM, BGRIMM verifies that the test results of CRIMM are repeatable. Both the iron and phosphorous contents at the end of the process can be reduced to less than 1.0 mg/L.

Table 13-28: Iron and Phosphorous Removal Verification Test Results*

Test ID	Temperature °C	pH	Reaction Retention Time hour	End Point Fe Content mg/L	End Point P Content mg/L	Filtration Rate mL/min/ cm^2**	Note
CTT-7	80	5.0-6.5	5	<1	--	0.34	CRIMM
Mn-5	90	5.8	8	0.68	--	--	BGRIMM
Mn-7	90	5.9	6	0.44	0.53	1.31	BGRIMM
Mn-9	90	5.6	6	0.56	0.98	0.92	BGRIMM
Mn-10	90	5.9	6	0.59	0.59	2.07	BGRIMM

Notes: * air for oxidation and hydrated lime for slurry neutralization;
** by laboratory Büchner funnel

The large-scale iron and phosphorous removal testing for preparing dewatering test feed also shows that the iron and phosphorous concentrations can be reduced to lower than 1 ppm using air as oxidant and lime as neutralizer.

13.5.3 Heavy Metal Removal – CRIMM

Several different heavy metal removal methods using sulphidization treatments were tested. The reagents used included an organic chelating agent and inorganic sulphides, such as ammonium sulphide ($(NH_4)_2S$) and barium sulphide (BaS). The heavy metal removal is one of key treatments for producing high-purity and selenium-free electrolytic manganese metal which is more sensitive to heavy metal levels in qualified solution, compared to low-quality electrolytic manganese metal (99.7% EMM) production using selenium as an additive to improve electrowinning current efficiency and performance.

The tests were conducted on leach pregnant solution and leach slurry separately. The test results indicate that the chelating agent tested can selectively and effectively precipitate the heavy metals from the leach solutions and reduce the heavy metal concentrations to approximately 1 ppm or less. The heavy metal contents in the leach solutions after heavy metal removal are shown below:

- Copper: 0.21 to 0.36 mg/L
- Nickel: 1.46 to 3.62 mg/L
- Cobalt: 1.01 to 2.29 mg/L
- Zinc: 0.80 to 4.11 mg/L
- Lead: 2.05 to 3.05 mg/L.

The test results show that the organic reagent dosage is more sensitive to copper and zinc removal compared to nickel and cobalt. Lead seemed insensitive to the organic chelating agent, however, the treated solutions contained approximately less than 3 mg/L lead which is considered to meet the purification target.

Detailed purification tests, including reaction retention time, reagent dosage, and reaction temperature were conducted to investigate heavy metal removal efficiency, and precipitate filtration rate and manganese loss into the precipitates. CRIMM recommended using the organic chelating reagent for the CMP.

13.5.4 Heavy Metal Removal - BGRIMM

BGRIMM carried out a further leach solution purification test program to verify CRIMM's proposed heavy metal removal method and develop a more effective heavy metal removal process. The program included testing three heavy metal removal reagents sourced from local potential suppliers in comparison to the reagent from a Chinese supplier tested by CRIMM. The heavy metal compositions in the purification test feed solution are shown in Table 13-29.

Table 13-29: Heavy Metal Compositions in Raw Solution

Composition, mg/L				
Zn	Ni	Co	Cu	Pb
16	8.2	12.5	0.5	5.8

Table 13-30 shows the heavy metal removal test results using the four types of the organic chelating reagents. BGRIMM's test result indicate that:

- Three organic chelating reagents from the potential local suppliers basically give the same heavy metal removal performances.
- At the same organic chelating reagent dosage, the Chinese reagent gives a slightly better heavy metal removal efficiency.
- The organic purification reagents have a better removal efficiency on copper, nickel, and cobalt, but a relatively poorer removal efficiency on zinc and lead.

Table 13-30: Heavy Metal Removal Test Result Using Four Different Organic Chelating Reagents

Test No.	Reagent ID	Temp (°C)	Reaction Retention Time (hr)	Dosage (mL/L or g/L)	Composition (mg/L)					Removal Efficiency (%)				
					Zn	Ni	Co	Cu	Pb	Zn	Ni	Co	Cu	Pb
HMR -1	A	60	0.5	0.28 ml/L	6.55	0.81	2.81	0.02	2.64	59.9	90.3	78.0	95.9	55.0
HMR -2	B	60	0.5	0.28 ml/L	6.00	0.93	2.41	0.01	2.18	64.0	89.1	81.5	97.5	63.6
HMR -3	C	60	0.5	0.28 ml/L	6.20	0.64	2.34	0.02	3.12	62.0	92.3	81.7	96.7	46.8
HMR -21	Chinese	60	0.5	0.15 g/L	3.80	0.90	2.09	0.03	1.83	77.7	89.7	84.3	94.0	70.1

The effect of the organic chelating reagent (Reagent "A") dosage on heavy metal removal was tested. The results indicates that the residual metal contents of copper, nickel, cobalt, and lead in the solution decrease with an increase of the reagent dosage. At the Reagent "A" dosage of 0.7 mL/L, the residual metal contents of copper, nickel, cobalt, and lead are all less than 0.01 mg/L. However, the zinc content in the solution basically maintains less affected.

To improve the zinc removal efficiency, the combination of Reagent "A" and barium sulphide was tested. The test results indicate that the combined reagent regime can significantly improve the performances of heavy metal removal process, and residual zinc content can be reduced to approximately 0.2 to 0.3 mg/L.

In an effort to further improve the quality of the solution and reduce the content of organic materials in the solution after heavy metal removal treatment, BGRIMM conducted further solution purification tests using activated carbon as residual impurity adsorption media. BGRIMM's test results indicate that using activated carbon adsorption treatment can slightly decrease the total organic carbon content (TOC) content in the purified solution.

13.5.5 Magnesium Removal

Two magnesium removal locations were tested by CRIMM: one on leach solution and the other on anolyte. The test results indicate that ammonium fluoride (NH_4F) can effectively remove magnesium from the leach solution, but the treatment was ineffective for magnesium removal from synthetic anolyte solution. The test program also investigated the magnesium removal from anolyte using calcium fluoride (CaF_2). The test results indicate that the magnesium removal rate was very low, which shows that it is not feasible to use calcium fluoride for magnesium removal.

The magnesium removal tests show that using a proprietary crystallization method can effectively remove magnesium from both leach solution after iron removal and anolyte. It appears that the crystallization method was more effective for magnesium removal from both anolyte and leach pregnant solution, compared to magnesium removal using fluoride precipitation.

It was suggested by CRIMM that the magnesium removal should be conducted immediately after the iron and phosphorous removal to efficiently utilize the thermal energy required for the iron removal treatment. The crystallization solid products were relatively amenable to the conventional filtration for solid and liquid separation.

The proprietary magnesium removal treatment tests also investigated the effects of various process conditions on magnesium removal, such as reagent regime, reaction retention time, and temperature. The preliminary testing appears to show that the magnesium content control method would be able to control the magnesium level lower than the threshold that may cause a detrimental impact on electrowinning. Further optimization investigations using the proprietary technology to control the magnesium level should be conducted.

In 2021, based on the CRIMM's test results, BGRIMM conducted two preliminary independent tests to verify the proprietary magnesium removal treatment proposed by CRIMM using synthetic solution. Based on the test results, BGRIMM concluded that the treatment would effectively remove the magnesium to the target level. Because the tests were conducted on a synthetic solution only, further test work is required to systematically investigate the magnesium removal performance using real solutions generated from the planned demonstration plant campaign.

13.6 Manganese Electrowinning

EMN plans to use a selenium-free electrowinning method for the CMP to produce HPEMM from a purified leach solution. To optimize the process conditions for HPEMM production, the effect of various operation factors on the manganese electrowinning from qualified solutions were investigated. The tested operation conditions included:

- Current density
- Cell temperature
- Catholyte pH
- Sulphur dioxide (SO_2) dosage
- Manganese contents in feed solution and in catholyte
- Ammonium sulphate ($(NH_4)_2SO_4$) concentration
- Type of cell diaphragm.

Figure 13-25 shows a typical electrowinning cell arrangement used for the tests.

Figure 13-25: One of Electrowinning Test Devices

Source: CRIMM (2018)

The solutions used for the tests were generated from the MB Composite. The leach solutions were purified to reduce the concentrations of impurity metals to meet the requirements for producing HPEMM. The plated manganese metals were washed by water and then passivated prior to being stripped and weighed.

The optimization tests confirmed that selenium-free EMM flakes can be produced from the qualified solutions produced from the magnetic separation concentrates of the MB Composite. The tests indicate that the qualified solution should contain approximately 30 to 40 g/L manganese and 110 to 130 g/L ammonium sulphate. The manganese concentration of catholyte was determined to be 10 to 20 g/L. Sulphur dioxide was required for the electrowinning. A current density of 260 to 360 A/m^2 was required to maintain reasonably well electrowinning performance. With an increase in cell temperature, cell voltage noticeably reduced; however, a reduction in current efficiency was observed. The optimum electrowinning conditions determined are similar to those widely used in the industry.

The assays on the EMM flakes produced showed some of the impurity levels, such as carbon, sulphur, zinc and iron contents, may be higher than the requirements. Further optimization tests were conducted to focus on reducing these impurities. The optimization tests significantly improved the electrolytic manganese metal quality and showed that selenium-free HPEMM flakes can be produced from the qualified solutions produced from the magnetic separation concentrates of the MB Composite.

A number of different chromium-free EMM flake passivation methods were also tested.

13.7 Manganese and Ammonia Recovery from Barren Solution

Preliminary tests were conducted on the leach washing solution (barren solution) to recover residual manganese. Two recovery methods were tested: one using hydrated lime to precipitate the manganese and the other using ammonium bicarbonate. The tests showed that with a hydrated lime dosage at 1.2 times of stoichiometric requirement and at 30°C on solution basis the precipitated manganese was only 53.2% with a reaction retention of 30 minutes. The precipitates mainly contained dehydrate gypsum ($CaSO_4 \cdot 2H_2O$) and calcite and the formed manganese hydroxides were amorphous.

The manganese recovery by ammonium bicarbonate and ammonia water was investigated in more detail. The tested conditions covered ammonium bicarbonate dosage, ammonia water dosage, reaction temperature and reaction retention time. The test results indicated that both ammonium bicarbonate and ammonia water dosages had a more significant influence on manganese precipitation. When ammonium bicarbonate and ammonia water dosages were 1.1 times and 2.0 times, respectively, as required by stoichiometric equivalents, based on solution, 95.0% of the residual manganese can be recovered with a reaction retention time of 30 minutes at a reaction temperature of 30°C. The precipitate mainly was manganese carbonate ($MnCO_3$).

In 2021, BGRIMM conducted an exploratory test using a synthetic solution and carbon dioxide (CO_2) gas, instead of ammonium bicarbonate, to precipitate manganese from the synthetical solution. The results show that CO_2 gas can be used for recovering the manganese from the solution. However, further tests are required at the planned demonstration plant campaign to verify the operation parameters.

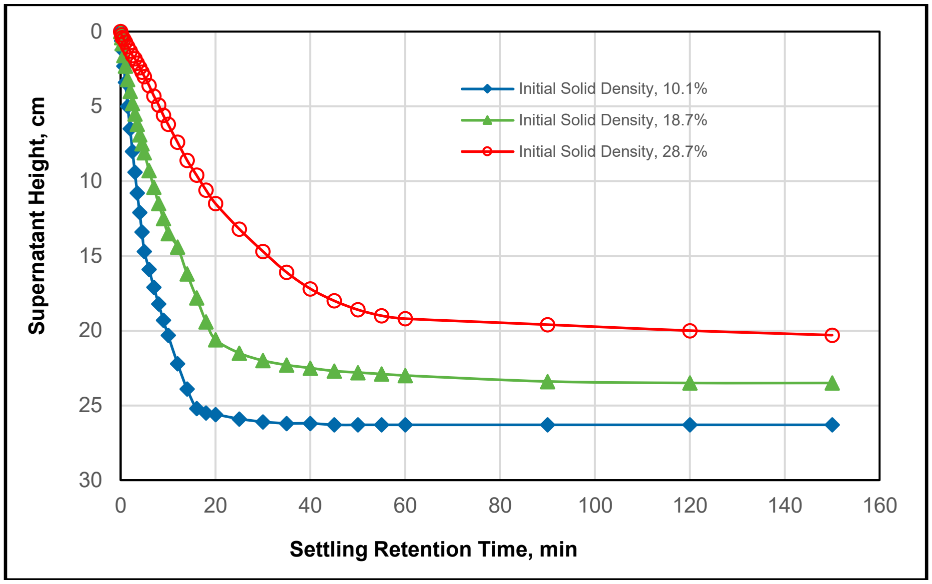
A preliminary stripping test was conducted to recover ammonia from the manganese-depleted filtrate by CRIMM. It was shown that the ammonia stripping rate of the solution was approximately 63%. Further optimization tests are required to better understand the ammonia stripping efficiency. The tests should be also conducted by potential ammonia recovery system supplier(s).

13.8 Dewatering Tests

13.8.1 Settling Tests – CRIMM

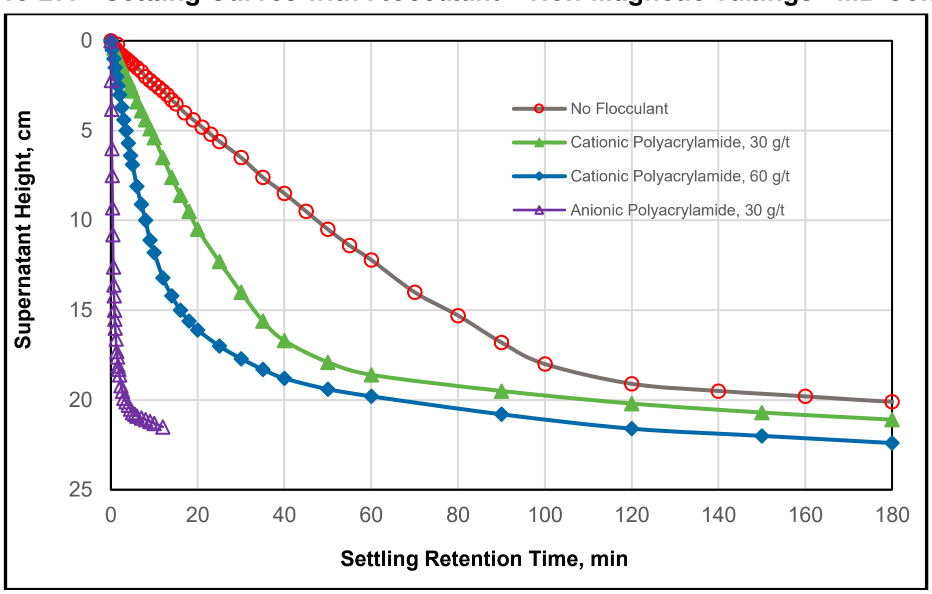
CRIMM conducted settling tests on the magnetic concentrate, non-magnetic tailings, and washed leach residue samples. Figure 13-26 to Figure 13-28 present the settling curves achieved at various conditions for these samples.

Figure 13-26: Settling Curves at Different Initial Solid Density – Concentrate – MB Composite



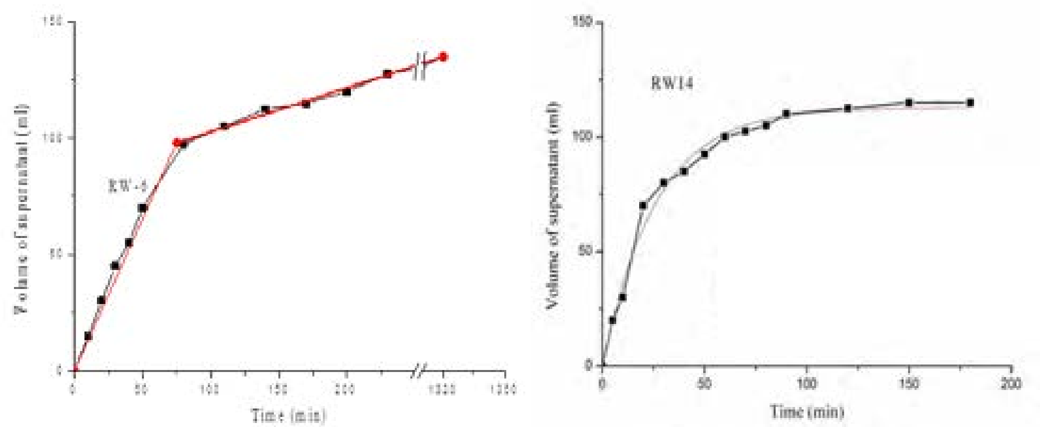
Source: Jingjin (2018)

Figure 13-27: Settling Curves with Flocculant – Non-Magnetic Tailings –MB Composite



Source: CRIMM (2018)

Figure 13-28: Settling Curves – Leach Residue –MB Composite



One Stage Washing

Six Stage Washing

Source: CRIMM (2018)

The results show that without adding flocculant, the magnetic concentrate thickening performance improved significantly with a reduction in initial feed solid density. When the initial solid density was 28.7% w/w, the settling rate was only 0.40 cm/min; however, the settling rate improved to an average rate of 1.42 cm/min at an initial feed solid density of 10.1 % w/w.

For the non-magnetic tailings, the settling performance improved significantly with adding flocculant, especially when adding an anionic polyacrylamide flocculant. The average settling rate improved to an average settling rate of 13.1 cm/min, compared to 0.18 cm/min without adding flocculant.

A separate settling test program was conducted by NHD (one of potential thickener manufacturers) on the magnetic tailings, magnetic concentrate, and leach residues produced from the MB Composite sample. The tests determined:

- Feed particle size distribution
- Unit settling rates required at different initial feed solid density
- Flocculant type screening and dosage optimization

According to settling performance curves, NHD recommends the thickener type and sizing for the three slurry products, respectively. The proposed thickeners are high-rate thickeners. The estimated thickener diameters are 15 m for the magnetic concentrate, 16 m for the magnetic tailings, and 20 m for the leach residue.

The test program also determined the relationship between thickener underflow solid density and slurry yield stress (pa) and simulated the leach residue washing using a count current decantation (CCD) treatment. The recommended CCD underflow solid density is 45% w/w. The simulation estimated the washing efficiency would be approximately 98.8% with five stages of CCD washing or 99.9% with eight stages of CCD washing. The ratio of washing water to solid was not provided.

13.8.2 Settling Tests – BGRIMM

In 2020, NHD conducted the settling tests on the magnetic separation concentrate and tailings. Magnetic concentrate slurry sample and tailings slurry sample, weighing approximately 50 kg respectively, were produced by Slon from the large-scale testing using a Slon-500 unit. The following tests were carried out by NHD on the samples:

- Natural settling rate determination without flocculant addition at different slurry densities (30%, 25%, 20%, 15%, and 10%, respectively).
- Effect of different types of flocculants on settling.
- Static settling rate determination at the optimal flocculant addition.
- Dynamic underflow compaction tests using a laboratory-scale NHD device with a feed slurry density of 7% solids and the optimal flocculant addition. Samples were taken at a different time intervals to measure thickener underflow density.
- Measurement of the yield stress of the thickening device underflow taken from the dynamic underflow compaction testing using a rheometer.

Based on the test results on the magnetic concentrate sample, NHD concludes that:

- The underflow density of magnetic concentrate thickener can reach 78% solids after 4 hours of settling.
- The recommended design settling rate of the concentrate is 130 ~ 150 mm/min.
- At a feed rate of 1,500 t/d and at the optimal operations, one high efficiency thickener with a diameter of 10 m is recommended.

Based on the test results on the tailings sample, NHD concludes that:

- The maximum underflow density of tailings thickener is 61% solids with 4 hours of settling. A further extension of settling time has very little effect on the improvement of the underflow density.
- The recommended design settling rate of the tailings is 100 ~ 120 mm/min.
- At a feed rate of 1,500 t/d and at the optimal operations, one high-efficiency thickener with a diameter of 16 m is recommended.

In 2020, a separate settling and filtration test program was conducted by NHD on the fresh manganese leach residue produced at the NHD facility using the acid leaching and iron and phosphorus removal treatment procedures developed by BGRIMM. A CCD washing test was also conducted using a simulated test procedure.

The manganese leaching residue was prepared using the optimum process conditions provided by BGRIMM. The settling testing was conducted at 7% w/w solids with a flocculant addition dosage of 60 g/t. A DN120-mm dynamic thickening tester was used to conduct underflow compaction test. A rheometer was used to measure the yield stress of each compacted underflow sample. According to the test results, NHD recommended a five-stage CCD washing process with a CCD washing water to solid ratio of 2.7 to 3. The estimated washing efficiency is 99.5% at a thickener underflow density of 45% w/w solids.

13.8.3 Filtration Tests – CRIMM

CRIMM conducted preliminary filtration tests using a vacuum filtration procedure on the non-magnetic tailings, magnetic concentrate, and leach residue. To better understand the responses of the slurry materials to pressure filtration proposed for the project, preliminary filtration test work was conducted by Jingjin, one of potential filter press manufacturers. The tests were conducted on the magnetic tailings and the leach residues. The filtration cake moisture content for the non-magnetic tailings was 12.6% w/w with a cycle duration of 19 minutes. The cakes produced from the washed leach residue were higher: 26.4% w/w with a cycle duration of 27 minutes and 24.7% w/w with a cycle duration of 32 minutes. The cakes produced from both the non-magnetic tailings and the leach residue seem in reasonably good shape (Figure 13-29 and Figure 13-30).

Figure 13-29: Filtration Cakes – Non-Magnetic Tailings (12.6% w/w Moisture)

Source: Jingjin (2018)

Figure 13-30: Filtration Cakes – Leach Residue (a: 26.4% w/w Moisture; b: 24.7% w/w Moisture)

Source: Jingjin (2018)

As part of bench leaching and iron, phosphorous, and heavy metal removal tests, CRIMM conducted preliminary leach residue washing tests. Three leach residue washing methods were tested on three different leach residues produced (leach residues without iron, phosphorous, and heavy metal removal treatment and leach residues with iron, phosphorous, and heavy metal removal treatment) to remove the dissolved metals and residual ammonia in the filtration cakes:

- Direct washing with spray water on the filtration cake in a laboratory Büchner funnel
- Repulping-filtration
- Combination of both methods above

Both tested washing water usages have water to solid weight ratios of 2:1 and 1:1. The test results show that one stage of direct spray water washing on the filtration cakes can remove approximately 80% (1:1 washing ratio) to 90% (2:1 washing ratio) of the dissolved target metals and ammonia entrained in the cakes. The impurity removal efficiency was approximately 10 to 20% lower using the repulping-filtration method, compared to the direct spray water washing. The combined washing method showed the best washing performance for the leach residues.

Six-stage washing on the leach residue with the iron, phosphorous, and heavy metal removal treatment was conducted using the direct spray water washing method with a washing water temperature of 60°C. The washing water to solid weight ratio was 1:1. The test results show that at Stage 2, more than 90% of manganese, magnesium, and ammonia in the solution phase were removed. At Stage 4, more than 99% of the magnesium and ammonia in the solution phase was washed out, excluding manganese of which only approximately 97% was removed. It is noted that the manganese content in the washing solution at Stage 6 was 0.2 g/L. This may suggest that some of the manganese may re-dissolve from precipitates. Also, a reduced filtration rate was recorded with an increase in the washing stage.

13.8.4 Filtration Tests – BGRIMM

In 2020 further pressure filtration tests were conducted by Jingjin to verify the pressure filtration performances of the magnetic concentrate and non-magnetic tailings produced from the large-scale SLon 500 testing.

A Model-500 filter press (laboratory-scale, single-chamber, and dual side filtration) with a size of 500 x 500 mm and a total filter area of 0.64 m^2 was used for the filtration test of magnetic concentrate. Two types of filtration cloth were selected, Type F6 cloth with an air permeability of 30 $L/m^2/s$ and Type #1 cloth with an air permeability of 20 $L/m^2/s$.

The filtration test results of the magnetic concentrate sample show that the cake moisture of the magnetic concentrate can be reduced to approximately 10.5% to 12% with relatively clean filtrates. The filtration performance was not affected significantly by filter press feed solid content. Based on these test results, Jingjin concludes that the magnetic concentrate sample can be categorized suitable for pressure filtration. Jingjin recommends Type F6 for the concentrate.

Two laboratory-scale chamber diaphragm filter press, Model-250 and Model-630, were used for the pressure filtration testing for the non-magnetic tailings sample. Two types of filter cloth, Type 2370 with an air permeability of 100 $L/m^2/s$ and Type 1323 with an air permeability of 300 $L/m^2/s$ were selected for the testing.

The pressure filtration test results show that the cake moisture of the tailings is relatively higher, ranging from 16.5% to 21.5%.

In 2020 BGRIMM conducted a large-scale acid leaching and iron and phosphorous removal test to generate the leach residue sample for downstream dewatering and residue washing testing. Four different types of large-scale dewatering equipment were tested for separating the pregnant solution from the residue. The equipment, including horizontal filter press, vertical filter press, belt filter and centrifugal decanter, was provided by potential suppliers.

Table 13-31 shows the solid-liquid separation test results. It can be seen that there is no significant difference in the filter cake moisture content between horizontal filter press and vertical filter press. BGRIMM recommends using horizontal filter press for the leaching residue dewatering, based on its better operating reliability, higher capacity, less required maintenance work, and cake online washing availability. The test results also conclude that belt filter and centrifugal decanter may not be suitable for the dewatering treatment.

Table 13-31: Solid-Liquid Separation Test Results For Leaching Residue Slurry

Equipment	Horizontal Filter Press	Vertical Filter Press	Belt Filter	Centrifugal Filter
Manufacturer	Jingjin	Toncin Group		Saideli
Cake moisture content %	24.8	25.9	41.3	29.7

Jingjin suggested that six 650-m^2 horizontal type filter presses could meet the process requirements with the residue feed rate of 61 t/h. Jingjin also conducted on-stream washing tests on the residue filter cake. At a washing water to solid ratio of 1:1, two stages of washing would achieve a higher than 95% washing efficiency. The washing efficiency is expected to increase to higher than 98% if the cake was washed for five stages.

13.9 Pilot Plant Tests

Three semi-continuous and locked-cycle pilot plant runs were conducted on the MB Composite sample, high-grade composite (Composite P1) sample, and low-grade composite (Composite P2) sample using the conditions developed from the batch tests. Figure 13-31 shows the pilot plant testing flowsheet which is based on the batch test results and industrial operation experience. Figure 13-32 shows the key processing steps and the equipment used for the pilot plant runs.

Figure 13-31: Semi-continuous Pilot Plant Run Flowsheet – HPEMM

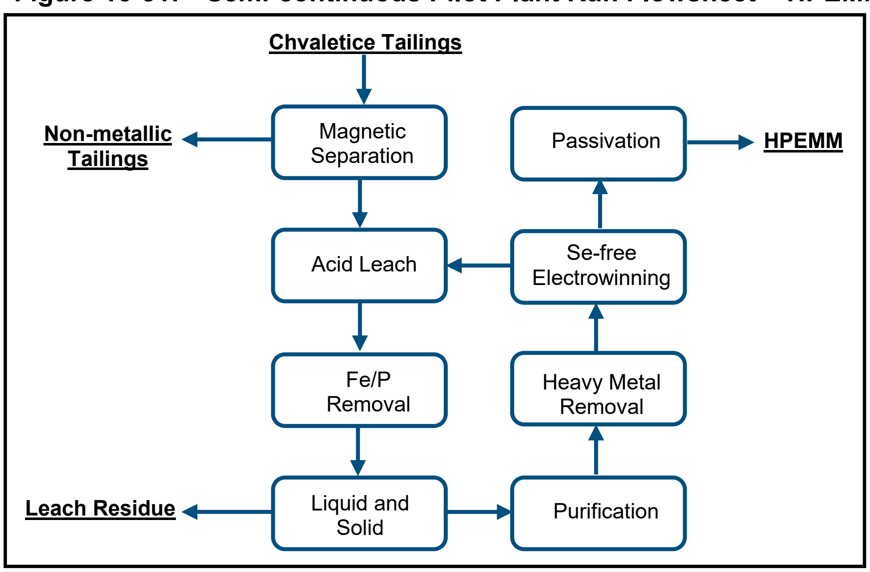


Figure 13-32: Key Processing Equipment Used for Pilot Plant Testing

Source: CRIMM (2018)

13.9.1 Magnetic Separation

Magnetic separation tests were conducted using two HR-type high-intensity magnetic separators equipped with dual separation discs at a magnetic field of 1.8 T. The magnetic separation consisted of one stage of rougher separation and one stage of scavenger separation on the rougher separation tailings. Table 13-3 summarizes the test results.

Table 13-32: Magnetic Separation Test Results – Pilot Plant Runs

Sample	Product	Yield (%)	Grade (%)			Recovery (%)		
			tMn	sMn	Fe	tMn	sMn	Fe
Composite MB	Rougher Concentrate	38.7	15.8	11.9	9.9	85.0	83.5	62.3
	Scavenger Concentrate	3.3	7.3	6.2	8.0	3.3	3.7	4.3
	Rougher and Scavenger Concentrate	42.1	15.1	11.5	9.7	88.3	87.2	66.6
	Tailings	58.0	1.45	1.22	3.55	11.7	12.8	33.4
	Head	100.0	7.20	5.53	6.16	100.0	100.0	100.0
Composite P1	Rougher Concentrate	40.3	16.5	13.0	9.6	85.7	84.2	62.9
	Scavenger Concentrate	2.9	9.1	8.0	8.7	3.4	3.7	4.1
	Rougher and Scavenger Concentrate	43.2	16.0	12.6	9.6	89.1	88.0	67.0
	Tailings	56.8	1.48	1.31	3.58	10.9	12.0	33.0
	Head	100.0	7.73	6.19	6.17	100.0	100.0	100.0
Composite P2	Rougher Concentrate	37.0	15.2	11.2	10.0	84.8	83.3	63.8
	Scavenger Concentrate	1.7	5.9	4.8	7.9	1.5	1.6	2.3
	Rougher and Scavenger Concentrate	38.8	14.8	11.0	9.9	86.4	84.9	66.1
	Tailings	61.3	1.48	1.23	3.22	13.6	15.1	33.9
	Head	100.0	6.64	5.00	5.82	100.0	100.0	100.0

table continues…

Sample	Product	Yield (%)	Grade (%)			Recovery (%)		
			tMn	sMn	Fe	tMn	sMn	Fe
Average	Rougher Concentrate	38.7	15.8	12.0	9.8	85.2	83.7	63.0
	Scavenger Concentrate	2.6	7.4	6.3	8.2	2.7	3.0	3.6
	Rougher and Scavenger Concentrate	41.4	15.3	11.7	9.7	87.9	86.7	66.6
	Tailings	58.7	1.47	1.25	3.45	12.1	13.3	33.4
	Head	100.0	7.19	5.57	6.05	100.0	100.0	100.0

The test work produced very encouraging results, indicating the pre-concentration treatment can effectively reject more than 58.7% of the magnetic separation feed and approximately double the leach feed manganese grade. On average, approximately 87.9% of the manganese was recovered with the concentrate grade of 15.3% tMn. The high-grade feed (Composite P1) shows a better metallurgical performance.

13.9.2 Leaching, Purification and Electrowinning

The magnetic separation concentrates from the magnetic separation pilot plant campaigns — approximately 430, 340, and 510 kg produced from the MB Composite, Composite P1, and Composite P2, respectively — were used for the acid leaching using the combination of synthetic anolyte solution and sulphuric acid, pregnant solution purification and selenium-free electrowinning tests. The pilot plant tests used a semi-continuous and locked-cycle procedure.

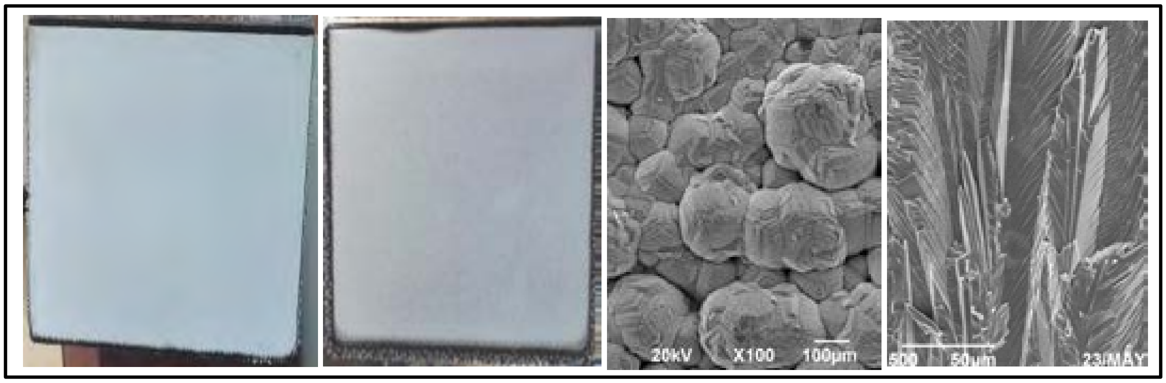
The acid leaching tests on the concentrates with an acid to feed ratio of 0.42 t to 1 t showed that, on average, manganese leach recovery was approximately 77%. The leach slurries and the manganese-bearing pregnant solutions were subjected to impurity metal removal including iron, phosphorous, and heavy metals. No magnesium removal treatment was tested during the pilot plant campaigns because no detrimental impact by the presence of magnesium was identified.

The average current efficiency by the selenium-free electrowinning process ranged from 59 to 65%, while the direct current electricity consumption varies from 6,200 to 6,900 kWh/t EMM. A current efficiency of 68.7% was achieved when the electrowinning circuit reached its stable state.

The first pilot plant run on the MB Composite sample showed that some of impurity contents of the electrolytic manganese flakes may exceed the customer’s requirements (the HPEMM specifications are confidential and commercially sensitive). As indicated in the bench electrowinning section above, a program of further bench scale tests was conducted to optimize solution purification and electrowinning conditions. This optimization test work significantly improved electrowinning circuit performance and electrolytic manganese product quality in the subsequent second and third semi-continuous pilot plant runs over seven days each on composites P1 and P2. As reported by CRIMM, the total manganese contents of the manganese flakes produced were higher than 99.9% (manganese contents were calculated by subtracting impurity contents). CRIMM conducted a separate assaying program to verify the previous results of the high purity manganese metal flakes produced. In general, the new assay results agreed well with the previous assay results. It is anticipated that the impurity concentrations of the optimized HPEMM products would be lower than the criteria typically specified for manganese metal products. Independent laboratory analysis by multiple laboratories has validated the assaying of the EMM samples. reported by CRIMM.

Figure 13-33 shows the HPEMM plates produced from the stable pilot plant runs and typical HPEMM surface micro-structures. Table 13-33 summarizes the average key circuit performance results.

Figure 13-33: Freshly Harvested HPEMM Cathodes and Metal Microstructures from the Pilot Electrowinning Cells



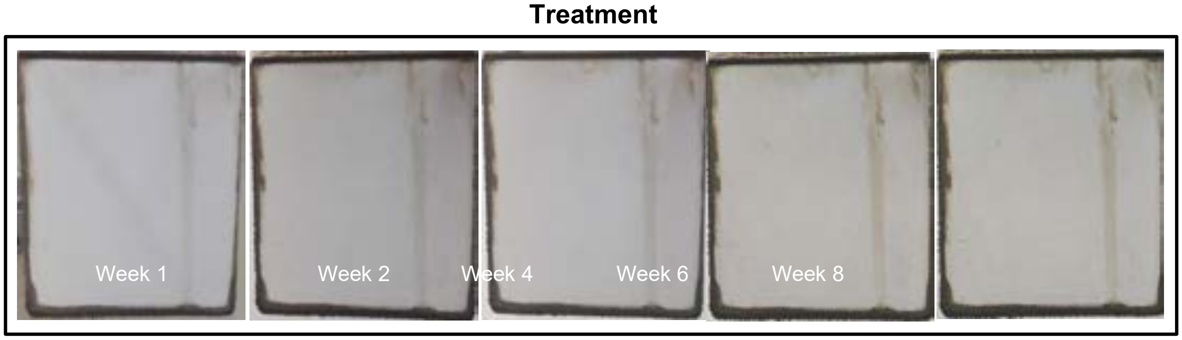
Source: CRIMM (2018)

Table 13-33: Average Leaching and Electrowinning Circuit Key Parameters – Pilot Plant Runs

Sample	Leach Extraction (% tMn)	Electrowinning	
		DC Current Efficiency (%)	DC Power Consumption (kWh/t EMM)
MB Composite	75.6	59.7	6,900
Composite P1	81.8	64.2	6,200
Composite P2	73.5	63.4	6,400

Several chromium-free cathode passivation tests were also preliminarily investigated. Compared to the conventional chromium-passivation treatment, the developed chromium-free passivation treatment was able to protect cathode surfaces from severe oxidation. Figure 13-34 shows the surface oxidation progress for a chromium-free passivated cathode recorded weekly.

Figure 13-34: Eight Week Surface Aging Observation of HPEMM Plates with Chromium-free Passivation Treatment



Source: CRIMM (2018)

13.10 High-Purity Manganese Sulphate

A test program was conducted to investigate production of HPMSM from the Chvaletice tailings resource. Three different process schemes were tested separately. The test program also included producing samples of HPMSM and high-purity manganese sulphate solution (HPMSS) for evaluation by potential customers:

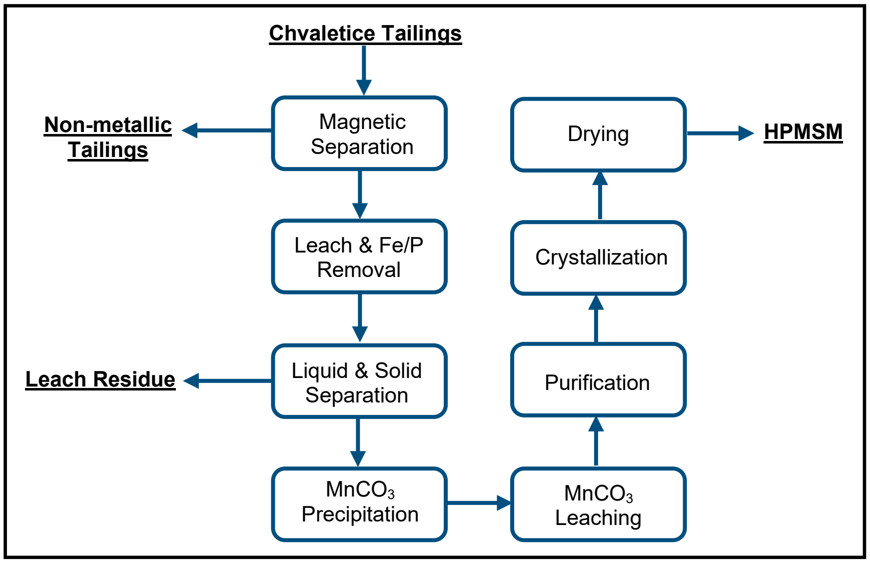
- From direct acid leaching of a manganese carbonate product produced from the leaching of magnetic concentrate without the manganese electrowinning process
- From 99.9% HPEMM (selenium and chromium free; from the Chvaletice mineral samples)
- From 99.7% EMM (selenium and chromium containing; from a Chinese EMM plant)

13.10.1 HPMSM Produced from Magnetic Concentrate - CRIMM

The proposed flowsheet for HPMSM production directly from the magnetic concentrate, as shown in Figure 13-35, includes:

- Magnetic concentration
- Concentrate acid leaching
- Iron/phosphorus removal
- Liquid/solid separation
- Manganese (II) carbonate ($MnCO_3$) precipitation from pregnant solution
- Manganese (II) carbonate re-dissolution by sulphuric acid leaching
- Pregnant solution deep purification
- Mother solution evaporation and crystallization
- HPMSM crystal drying

Figure 13-35: Test Flowsheet for HPMSM Production – Directly from Magnetic Concentrate



The testing investigated the effect of the various leach conditions. CRIMM indicated that a modified leaching process procedure, including iron and phosphorous removal, developed for the manganese extraction from the magnetic separation concentrate are suitable for generating the pregnant solution for HPMSM production. It was anticipated that high calcium and magnesium contents might affect the downstream processes; preliminary calcium and magnesium control procedures were proposed and tested.

The pregnant solution was then treated by manganese carbonate precipitation to selectively precipitate manganese. Various process conditions were tested, including carbonate reagent dosage, reaction retention time, reaction temperature, and reagent feeding methods. The filtration and washing performances of the precipitates were also investigated.

The resulting manganese carbonate precipitates were re-dissolved using sulphuric acid. The relationship between acid dosage and manganese extraction was tested to determine the optimized re-dissolution conditions.

A large-scale test was conducted on the Chvaletice magnetic concentrate using the conditions developed to generate a manganese-enriched solution containing approximately 95 g/L manganese for further tests. A combined purification treatment was tested to further remove the impurities such as iron, heavy metals, calcium, magnesium, and others. The testing also investigated the filtration characters of the purified solutions. The combined purification procedure can effectively remove the impurities, the resulting qualified solution containing less than 20.0 mg/L calcium and magnesium, lower than 1.0 mg/L main heavy metals, and below 0.5 mg/L iron. However, it was found that sodium concentration exceeded 100 mg/L in the purified solution, which may result in higher than 50 ppm sodium in the crystallized manganese sulphate.

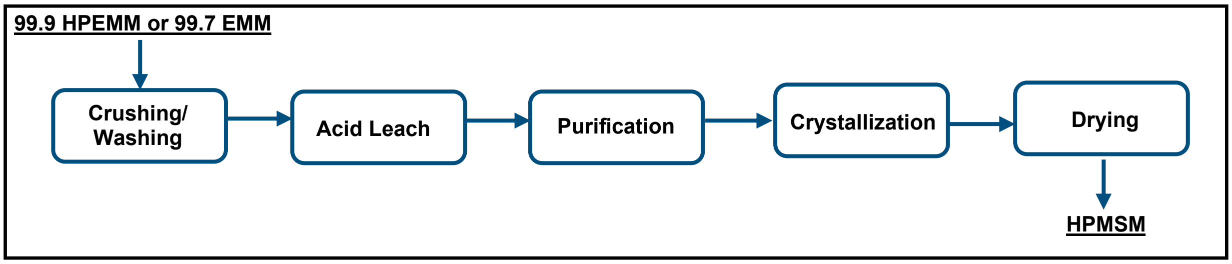
The test program also investigated manganese sulphate crystallization by evaporation at atmosphere, crystal-liquid separation, and manganese sulphate crystal drying processes. The manganese sulphate crystal products were assayed and analyzed for their chemical and physical characteristics.

The test results show that MSM can be produced directly from the Chvaletice tailings. The test results also show that sodium and fluorine contents in the MSM produced directly from the Chvaletice tailings may exceed the requirements of some of users. A sodium content reduction method was proposed and preliminarily tested. Further testing would be required to improve the quality of the product and economics of the process for MSM produced directly from the magnetic concentrate without electrowinning.

13.10.2 HPMSM Produced from High-purity Electrolytic Manganese Metal – CRIMM

Two additional tests were conducted to evaluating production of HPMSM from two types of EMM flakes, one from the HPEMM (99.9% manganese) produced from the Chvaletice HPEMM pilot plant campaigns and the other from a conventional EMM (99.7% manganese), produced from a selenium-containing EMM product produced from a Chinese EMM plant. Figure 13-36 shows the flowsheet used for testing.

Figure 13-36: Test Flowsheet for HPMSM Production from EMM Flakes



The bench tests included the EMM flake washing, sulphuric acid dissolution, and solution purification. Following the preliminary acid redissolution, large-scale tests (10 L solution) were conducted to further evaluate the metal dissolution followed by various tests to verify the responses of the solutions to deep purification, crystallization, and drying. With iron and heavy metal removal treatments, the impurity contents of the qualified solutions were significantly reduced. The iron and zinc concentrations were reduced to less than 0.1 mg/L and 0.3 mg/L, respectively. Similar manganese crystallization, crystal-liquid separation, and manganese sulphate crystal drying tests were conducted on the deeply purified solutions produced from the 99.7% and 99.9% electrolytic manganese metal flakes. The manganese sulphate crystal products were assayed and analyzed by chemical analysis, SEM scanning and thermogravimetry (TGA) for their chemical and physical characteristics.

Figure 13-37 shows the powder produced from the 99.9% HPEMM generated from the pilot plant runs.

Figure 13-37: HPMSM Produced from the Selenium- and Chromium-free 99.9% HPEMM Flakes

Source: CRIMM (2018)

Compared to the manganese sulphate powder directly produced from the Chvaletice tailings material (without electrowinning), the impurity content levels in the manganese sulphate powder products from the EMM flakes reduced substantially, in particular the levels of sodium, fluorine, and heavy metals. The HPMSM produced from the HPEMM flakes which were generated from the pilot plant runs shows the best product quality. It is anticipated that the impurity concentrations of the HPMSM products, in particular from the HPEMM flakes, would be lower than the criteria typically specified for high-purity manganese sulphate products. The fluorine contents in the HPMSM products from the EMM were lower than the target criteria because of using fluorine-free purification treatment methods. To verify the previous assay results of the high purity manganese metal sulphate produced, CRIMM conducted a separate assaying program. In general, the new assay results agreed well with the previous assay results. Independent laboratory analysis by multiple laboratories has validated the assaying of the HPMSM samples. HPMSM Produced from High-Purity Electrolytic Manganese Metal – BGRIMM

13.10.2.1 HPEMM Dissolution and Purification

In 2019, 10 kg of HPEMM flake samples, which were generated by the CRIMM's pilot plant test work in 2018, were shipped to BGRIMM. BGRIMM used the HPEMM flakes samples to prepare manganese sulphate solution and the deep purification test procedure developed by CRIMM and verified the test results produced by CRIMM .

BGRIMM test results indicate that using the CRIMM recommended deep purification process, the zinc and iron contents in the manganese sulphate solution after the zinc and iron removal can be reduced to lower than 0.1 mg/L and 1.0 mg/L, respectively, indicating that the CRIMM's deep purification procedure is feasible and repeatable. The test work also investigated the effect of temperature on the deep purification treatment. The results show no significant impacts for the zinc removal deep purification treatment in the tested temperature range of 60 to 98°C.

BGRIMM also tested iron removal by hydrogen peroxide and air oxidation. The results show that both the oxidants can be used for reducing iron concentration in the solution.

In addition, BGRIMM investigated the effect of metal flake dissolution methods, including addition of sulphuric acid in one stage and in multi stages. Based on the test results and BGRIMM's observation, dosing the acid at a control rate for HPEMM dissolution was recommended by BGRIMM for the process design. The fine fraction of electrolytic manganese metal flakes should be used for solution neutralization. The optimum reaction retention time for the HPEMM dissolution reaction was estimated to be approximately 3.5 to 4 hours.

13.10.2.2 MSM Mother Solution Crystallization

Two MSM evaporation methods were tested by BGRIMM, one by conventional evaporation and one by high temperature crystallization. The crystal physical characteristics were measured to compare the crystals produced by the two methods. High-purity manganese sulphate reagent was used to prepare manganese sulphate stock solution with a manganese concentration of 105 g/L for the bench tests.

For the conventional low temperature evaporation testing, the crystallization testing was conducted at 70 to 100°C under a vacuum environment. The results show that the particle size of MSM crystals increases with the evaporation temperature. The optimum crystallization temperature for the low temperature evaporation crystallization process should be at 100°C or higher.

The high temperature crystallization was conducted in a pressurized vessel at a temperature ranging from 120 to 160°C. BGRIMM recommended that the optimum crystallization temperature of the high temperature crystallization process should be conducted at 160°C.

The test results show that there is no significant difference in product particle size distribution between the two crystallization methods. The high temperature crystallization is expected to be more energy conservative. However, BGRIMM recommended using the conventional evaporation method for the project because this process is a mature technology which has been currently used in the MSM production.

13.11 Mill Feed and Non-Magnetic Tailings and Leach Residue Material Handling Tests

In 2021, EMN contracted Jenike & Johanson (Jenike) to perform material flow property tests on three samples from the project, two are the historic raw tailings samples, and the other is NMT/washed LR blended sample. The test objective is to provide preliminary material flow-ability data for handling the raw tailings and NMT/LR blended materials. Table 13-34 shows the test results of sample moisture and particle size distribution while Table 13-35 presents the test results of compressibility.

Table 13-34: Sample Moisture Content and Particle Size Distribution

Sample		Moisture Content (%)	Percentile Particle Size Diameter, µm			
			D10	D50	D90	D_{Max}
NMT/LR Blend		23.7	1.5	11.7	116.2	1,100
Raw Tailings 1	Pile 1	25.7	1.7	9.8	99.2	2,190
	Pile 2	24.5				
Raw Tailings 2	Pile 1	21.6	2.5	13.9	167.8	555
	Pile 2	22.4				

The bulk density was determined as a function of consolidation pressure using a procedure similar to ASTM D6683 and the particle density was measured by liquid displacement method in water using a 100 ml volumetric flask. The ranges of bulk densities measured are given in Table 13-35.

Table 13-35: Test Results of Compressibility

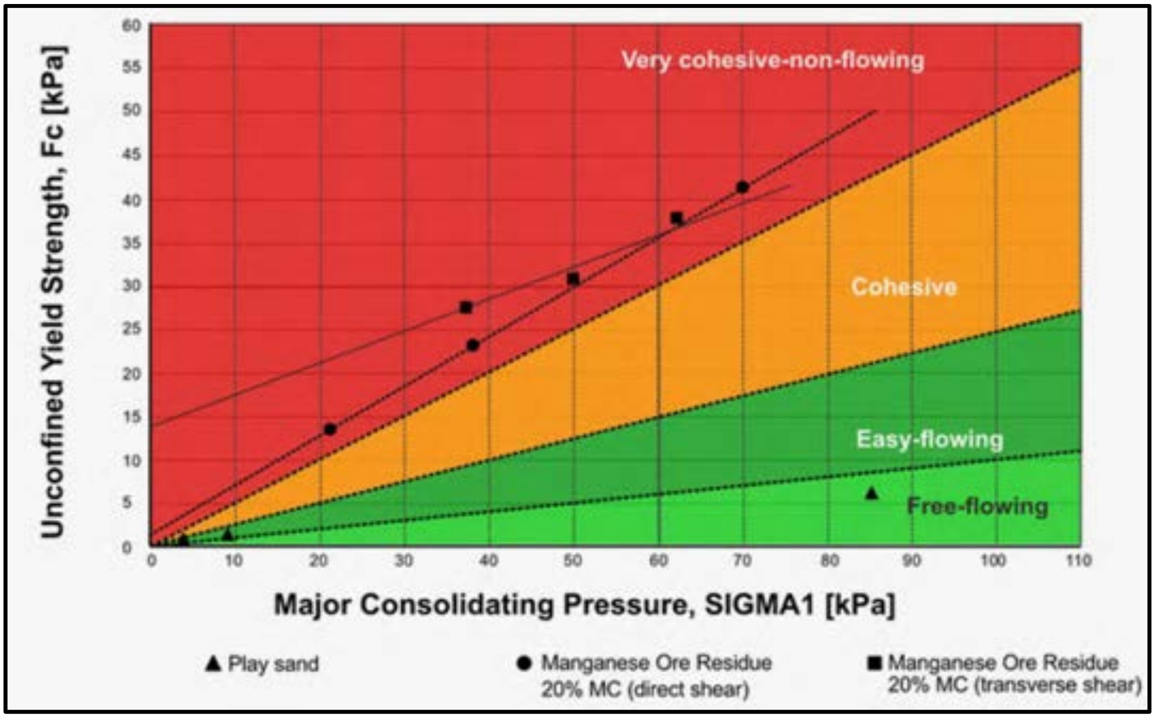
Material*	Sample Size (L)	Moisture Content (%)	Measured Bulk Density**, (kg/m^3)	Particle Density, (kg/m^3)
NMT/LR Blend	0.06	23	1,460 - 1,856	-
		20	1,250 - 1,829	-
	<0.03	0	-	2,748
Raw Tailings 1	0.06	21	1,200 – 1,803	-
	<0.03	0	-	2,625
Raw Tailings 2	0.06	21	1,510 - 2,103	-
		20	1,290 - 2,046	-
		16	1,160 - 1,590	-
	<0.03	0	-	2,732

Notes: * as received particle size;
** EH (Effective Head or consolidating load on material) in a range of 0.5 -5 m

TETRA TECH

Figure 13-38 compares direct shear (circles) and transverse shear (squares) test results for the NMT/LR blend sample at 20% moisture content against a backdrop of the original flowability classifications as proposed by Jenike in 1976. While both the methods indicate that the NMT/LR blend is "very cohesive-non-flowing", and produced similar strengths at high pressures, the direct shear test indicated lower strengths than the transverse shear test at lower pressures.

Figure 13-38: Direct Shear (Black Circles) and Transverse Shear (Black Squares) Data for NMT/LR Blend at 20% Moisture Content



Note: Play Sand (Triangles) Shown for a Reference; Source: Jenike (2021)

Based on the test results, Jenike concluded that:

- Both NMT/LR blend and raw tailings sample are highly cohesive and have the ability to form a very large stable rathole if it is stored in a funnel-flow hopper. In addition to this "no flow" problem, funnel flow can cause erratic flow, reduce the live capacity of the hopper, and induce high loads on the storage structure/equipment due to collapsing ratholes and eccentric flow channels. Funnel-flow discharge from a bin or silo should be avoided, and the materials should be handled in a mass flow hopper provided arching (bridging) can be avoided.
- To achieve mass flow pattern in a hopper, which can eliminate ratholes and stagnant material in the hopper, the material at the tested moistures will require impractically large hopper opening size to prevent arching.

Table 13-36 shows the maximum calculated mass flow wall angles with different lining materials. To achieve a mass flow in a hopper, the hopper walls must be steep enough and have sufficiently low friction to allow the material to flow down them.

Base on the calculated results of the hopper opening size and hopper wall angles, Jenike concludes that it is unlikely for the materials handled at or above the tested moisture to achieve mass flow.

Table 13-36: Maximum Calculated Mass Flow Wall Angles

Material/Wall Surface	θp [Degrees from Vertical] For Planar [5] Hopper with Outlet Width = 1.3 m[2]	
	Continuous Flow	After 24 Hours of Storage at Rest
NMT/LR Blend, 23% MC		
Mild Carbon Steel Plate, Mill Finish [3]	38°	~30°
TIVAR 88-2 (Lorien) [4]	40°	~38°
NMT/LR Blend, 20% MC		
Mild Carbon Steel Plate, Mill Finish	23°	7° [1]
TIVAR 88-2 (Lorien)	34°	33°
Raw Tailings 1, 21% MC		
Mild Carbon Steel Plate, Mill Finish	26°	7[2]
TIVAR 88-2 (Lorien)	36°	32°
Raw Tailings 2, 21% MC		
Mild Carbon Steel Plate, Mill Finish	45°	32°
TIVAR 88-2 (Lorien)	49°	40°
Raw Tailings 2, 16% MC		
Mild Carbon Steel Plate, Mill Finish	15°	[2]
TIVAR 88-2 (Lorien)	29°	28°

Notes: [1] Flow along the walls is questionable at any hopper wall angle
[2] The selected 1.3 m outlet width is not sufficient to prevent cohesive arch formation for this material condition, hopper wall angle values are included here for comparison only
[3] Mill finish carbon steel plate, smooth and free of corrosion. Plate thickness
[4] Ultra-high molecular weight polyethylene (UHMW-PE) manufactured by Mitsubishi Chemical Advanced Materials
[5] Hoppers with elongated outlets are defined as those where the outlet is at least three times as long as it is wide. Conical hoppers require significantly steeper angles than hoppers with elongated outlets (typically 10° to 12° more steep)

The chute test results are summarized in Table 13-37. These tests were to determine angles required for non-converging flat chutes to reinitiate flow after an impact that reduces the material velocity to zero. In order to maintain material flow in a chute, its inside surface walls must be steep enough and have sufficiently low friction to allow the material to flow along them. These angles can be used to determine the minimum chute angle required at an impact point to overcome adhesion and ensure flow.

Based on the test results, Jenike recommends a low drop height to minimize the impact of material falling onto the chute.

Table 13-37: Chute Test Results

Sample	Material/Wall Surfaces	Impact Pressure, kPa	Maximum Measured Chute Angle, degrees from horizontal
NMT/LR Blend, 23% MC	Mild Carbon Steel Plate, Mill Finish	0.43 to 10.75	52º to 90°*
	TIVAR 88-2 (Lorien)	0.43 to 10.75	47º to 90°*
NMT/LR Blend, 20% MC	Mild Carbon Steel Plate, Mill Finish	0.41 to 10.73	43º to 90°*
	TIVAR 88-2 (Lorien)	0.41 to 10.73	42º to 90°*
Raw Tailings 1, 21% MC	Mild Carbon Steel Plate, Mill Finish	0.43 to 10.75	67º to 90°*
	TIVAR 88-2 (Lorien)	0.42 to 10.75	63º to 90°*
Raw Tailings 2, 21% MC	Mild Carbon Steel Plate, Mill Finish	0.45 to 10.78	80º to 90°*
	TIVAR 88-2 (Lorien)	0.46 to 10.78	64º to 90°*
Raw Tailings 2, 16% MC	Mild Carbon Steel Plate, Mill Finish	0.38 to 10.73	32º to 90°
	TIVAR 88-2 (Lorien)	0.41 to 10.73	31º to 86°

Note: * Did not release at 90°

Table 13-38 provides the measured repose and drawdown angles, referenced from horizontal at bench scale with minimal particle momentum.

Table 13-38: Angle of Repose and Drawdown (Degree from Horizontal)

Material	Test Identifier	Repose Angle		Drawdown Angle	
		Average	Range	Average	Range
NMT/LR Blend	“Big Lumps”	41°	37° – 43°	–	–
	“Small Lumps”	47°	33° – 61°	–	–
Raw Tailings 1	Bench-scale	46°	45° – 47°	67°	65° – 68°
Raw Tailings 1 & 2	Combined	43°	41° – 45º	–	–

13.12 High Purity Product Chemical and Physical Analysis

EMN conducted various chemical and physical analysis for the HPEMM and HPMSM samples that were prepared from the bench scale tests and the pilot plant tests from the CRIMM test work for the customers that manufacture cathode active materials (CAM) and lithium-ion batteries (Li-ion or LIB) between 2018 and 2022. The work includes evaluating sampling methods, analytical methods, establishing analytical quality assurance and control (QA/QC) protocols, characterizing the physical properties of HPEMM and HPMSM, making improvement recommendations and assembling a body of knowledge regarding specification and assaying of high purity manganese products.

Global accredited commercial laboratories, including laboratories in China, North America, and Europe, have analyzed CMP and other manganese product samples. Several European laboratories are being contracted to analyze solution and product samples from the planned demonstration plant campaign. Preliminary quality assurance protocols and tolerances have been established and used to evaluate and improve the performance of some of the impurity assaying methods due to very low impurity targets in the planned CMP products. The QA/QC protocols also include sourcing standard samples and preparing certified reference materials by professional companies.

The evaluation work also reviews available HPEMM and HPMSM specifications, including specifications and requirements from potential customers, and develops CMP's product specifications according to the potential customer's requirement. EMN expects that the HPEMM and HPMSM products should meet and/or exceed most of the customer's requirements.

Further improvement of analytical methods and the QA/QC protocols should be reviewed and updated, including preparation and certification of ultra high purity reference materials. Further EMM test work is required to obtain metallurgical measurements that characterize electrodeposited manganese both on and off the cathode and thereby verify the conditions required to consistently electrodeposit, smooth, low impurity, compact, and strippable manganese in the future evaluations.

Data, information, and knowledge regarding the impact of impurities in manganese raw materials on the performance of CAM for LIB should be obtained through cooperation with prospective customers and LIB technology partners and added to the body of knowledge.

13.13 Metallurgical Performance Projection

According to the test work results, manganese metallurgical performance for the CMP is projected and shown in Figure 13-15.

Table 13-39: Metallurgical Recovery Projection

Area	Projected Recovery, %
Magnetic Separation	= 30.301 x Ln(Head Grade, % tMn) + 25.641
Leach Extraction	= 75.00
Purification and Refinery	= 93.60
Total Manganese to HPEMM	= (30.301 x Ln(Head Grade, % tMn) + 25.641) x 75% x 93.6%
HPEMM to HPMSM	= 97.00

13.14 Test Work Recommendations

EMN is constructing a demonstration plant to further verify the proposed process and produce HPEMM and HPMSM samples for potential customers. The demonstration plant runs will further verify product quality and metallurgical performances, optimize processing conditions, and generate process design related data. The recommended test work is detailed in Section 26.0.

14.0 MINERAL RESOURCE ESTIMATES

14.1 Basis of Current Mineral Resource Estimate

The current MRE was based on 1,485 samples taken from a total of 160 drill holes collected by EMN in the summer of 2017 and 2018. Samples were collected from three tailings cells within an above ground tailings facility. Tailings were generated from historical mining operations. The block model developed in 2018 is unchanged and has been restated here according to updated break-even cost values.

Data was analyzed in Phinar X10-Geo v.1.4.15.8, Snowden Supervisor v8.9.0.2 and Leapfrog® Geo v.4.4.2, and models were developed using Seequent Leapfrog® Geo v.4.4.2.

A MRE was developed for total and soluble manganese concentrations and is effective July 1, 2022. All technical and scientific data that is relevant to the MRE and made available to the CP up to an including the effective date has been incorporated into this report. Additional geochemical and physical parameters have been included in the modelling process to help characterize and inform interpretation of the tailings material; these variables include 18 trace and major elements, in situ dry bulk density, total moisture, and various grain size indicators. These additional parameters are not reported as part of the MRE.

14.2 Historical Mineral Resource Estimates

Two historical MREs reported by Bateria Slany are described in this section as they are considered relevant to the Mineral Resource presented herein. The key assumptions, parameters, and methods used to prepare the estimates is unknown and the results cannot be relied upon. Neither Tetra Tech nor EMN accepts these historical estimates as a current Mineral Resource or Mineral Reserves estimate.

Upon transfer of the Chvaletice mine from the federal government to the Chvaletice Energy Company in 1978, an estimation of “reserves” within the tailings facility, identified as “flotation sludge”, totaled 26,600,000 t at a grade of 7.09% Mn (tMn). The “reserve” was considered uneconomic, however, research into possible processing technologies was initiated.

From 1985 to 1989, Bateria Slany completed 956.3 m of drilling to characterize the physical and chemical properties of the tailings sludge, in addition to over 200 m^3 of trenching. Extensive testing and analysis of the samples was undertaken by Bateria Slany, who in 1989, evaluated that the tailings deposits comprised 27,557,441 t of “reserves”, containing 25,496,299 t at a grade of 5.15% leachable manganese (7.06% tMn) at a C2 category, and 2,061,143 t of material at an average grade of 4.97% of leachable manganese (7.39% total Mn) at a C1 category. The definition of C2 and C1 categories references a system developed in the Czech Republic for classification of mineral “resources” and “reserves”, where resources classified as C1 are supported in greater detail than those classified as C2. The Czech system differs significantly from classification defined under the CIM Terms and Definitions as referenced by NI 43-101 or the JORC Code and cannot be misconstrued to imply a similar level of confidence.

14.3 Previous Mineral Resource Estimate

A MRE with an effective date of April 27, 2018, was developed for the CMP using data from samples collected by EMN during the summer of 2017. The MRE was based on 755 samples from 80 vertical Sonic drill holes completed within the three tailings cells.

The block model was classified with Indicated and Inferred Resources in accordance with CIM Definitions Standards (2014). Inferred blocks were those located around the perimeter embankments of the tailings deposits which were untested and unable to be verified as being comprised of manganiferous material. Indicated blocks were those that were able to be tested by drilling from the upper bench, with average spacing of approximately 100 m. Total manganese estimates were based on the 4-acid digestion and ICP-MS and/or AAS detection; this was revised in the 2018 MRE where total manganese estimates were based on fusion XRF analyses. Table 14-1 shows the previous MRE, which is superseded by the current MRE stated in Section 14.8 and should no longer be relied upon as being accurate.

Table 14-1: Previous Mineral Resource Estimate for the Chvaletice Manganese Project, Effective April 27, 2018

Cell	Class	Volume ('000 m^3)	Tonnes (kt)	Bulk Density (t/m^3)	Total Mn (%)	Soluble Mn (%)
T1	Indicated	5,684	8,832	1.55	8.08	6.46
	Inferred	1,004	1,497	1.49	8.60	6.87
T2	Indicated	6,773	10,567	1.56	6.86	5.48
	Inferred	996	1,648	1.65	7.90	6.05
T3	Indicated	2,772	3,973	1.43	7.34	5.78
	Inferred	250	363	1.46	7.84	6.14
Total	**Indicated**	**15,229**	**23,372**	**1.53**	**7.40**	**5.90**
Total	**Inferred**	**2,250**	**3,508**	**1.56**	**8.21**	**6.43**

Notes:

- Mineral Resources do not have demonstrated economic viability but have reasonable prospects for eventual economic extraction. Inferred Resources have lower confidence than Indicated Resources. The estimate of Mineral Resources may be materially affected by environmental, permitting, legal, title, taxation, sociopolitical, marketing, or other relevant issues.
- A cut-off grade has not been applied. No capping has been applied.
- Numbers may not add exactly due to rounding.

14.4 Reconciliation with Previous Resource Estimate

Overall, the current model shows a good reconciliation with the previous model. Differences between the models are largely the result of additional drilling information and modelling approaches. The most significant changes are observed in blocks located in the perimeter slopes where sampling was not conducted in 2017. The data acquired in 2018 from additional Sonic and hand-portable percussion drilling conducted within the perimeter slopes reduced the spacing of samples and increased confidence of interpolated grades in the perimeter slope.

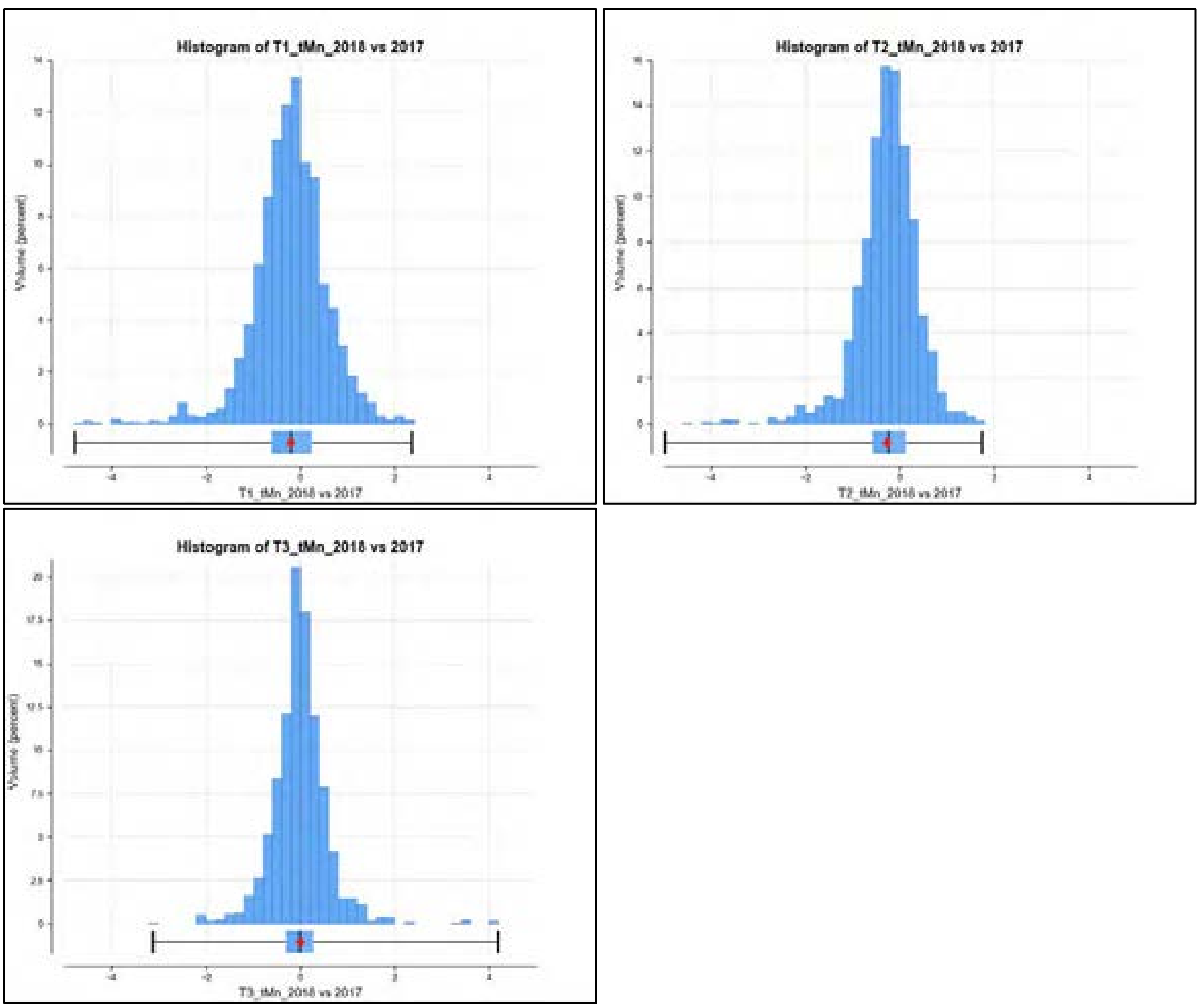
Table 14-2 lists the percentage change observed in the current block model compared to the previous block model. It was observed that the slight changes in modelled volume and interpolated bulk density together have influenced the reported tonnages.

Table 14-2: Percentage Change in Current Block Model Compared to Previous Block Model

Cell	Volume (%)	Tonnage (%)	Insitu Dry Bulk Density (t/m^3)	tMn (%)	sMn (%)
#1	101	99	99	98	100
#2	104	101	97	97	98
#3	98	99	101	100	97
Total	**102**	**100**	**98**	**98**	**98**

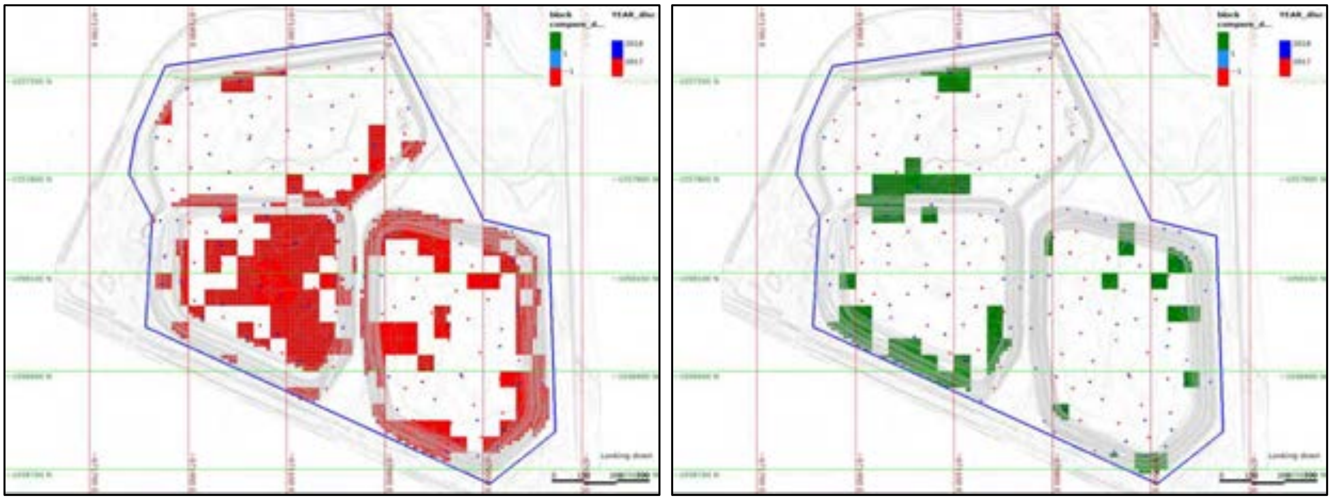
Figure 14-1 shows a histogram distribution, by cell, of the changes in total manganese block grades and Figure 14-2 depicts the location of all blocks where a decrease of more than 1% total manganese (left, red) and an increase of more than 1% total manganese (right, green) are observed.

Figure 14-1: Frequency Distributions for Change in Total Manganese Block Grades



TETRA TECH

Figure 14-2: Plan View Showing Changes in the Total Manganese Block Model Grades



Notes:
Left image: blocks with decrease greater than 1% manganese
Right image: blocks with increase greater than 1% manganese

14.5 Input Data and Analysis

14.5.1 Compositing

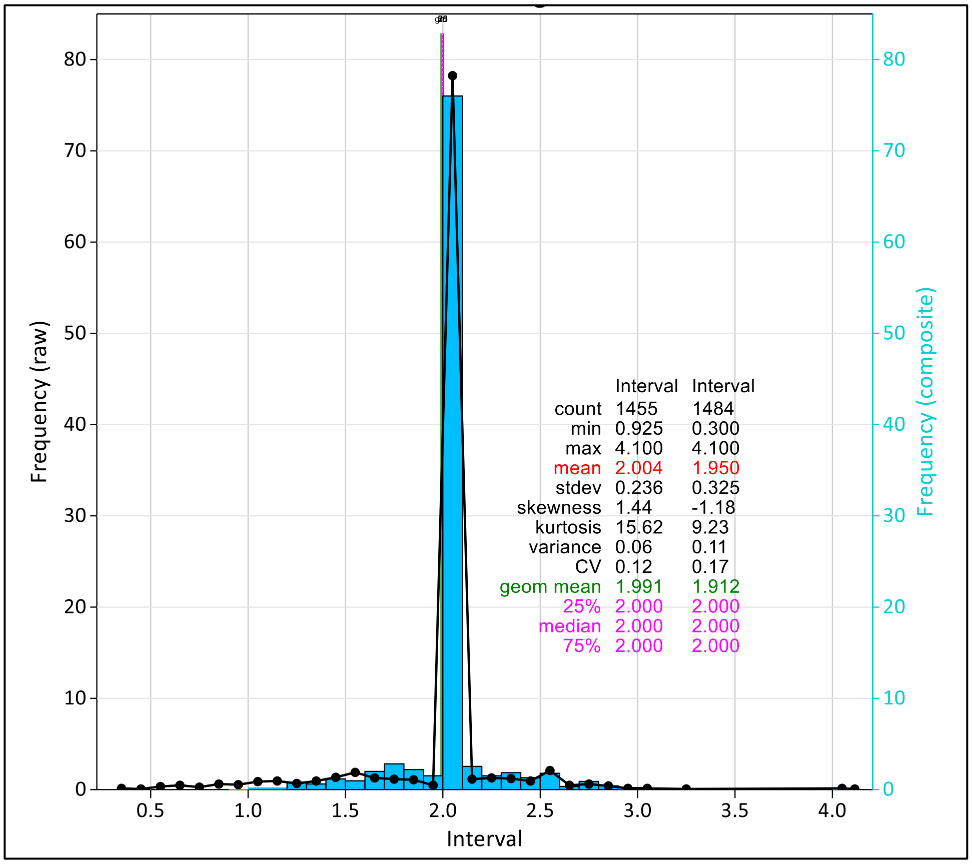
Samples were collected from drill core at an average of 2 m interval lengths equal to each drill run, or the proportion of each drill run at the top and bottom of each hole which was comprised of tailings material. The raw assay data was then composited to 2 m sample lengths. This resulted in a decrease from 1,485 raw samples to 1,456 composite samples (Table 14-3). A total of 183 composite sample lengths (12.5%) were less than 2 m, ranging from 0.3 to 1.99 m. The mean manganese values and overall sample distribution was not significantly impacted by the compositing process.

Table 14-3: Descriptive Statistical Comparison of Raw Data and 2 m Composite Data for Total Manganese

Dataset	Count	Mean	Geometric Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
Raw Data	1,484	7.261	6.982	1.722	0.24	0.186	12.32
2 m Composites	1,455	7.328	7.160	1.519	0.21	1.371	11.69

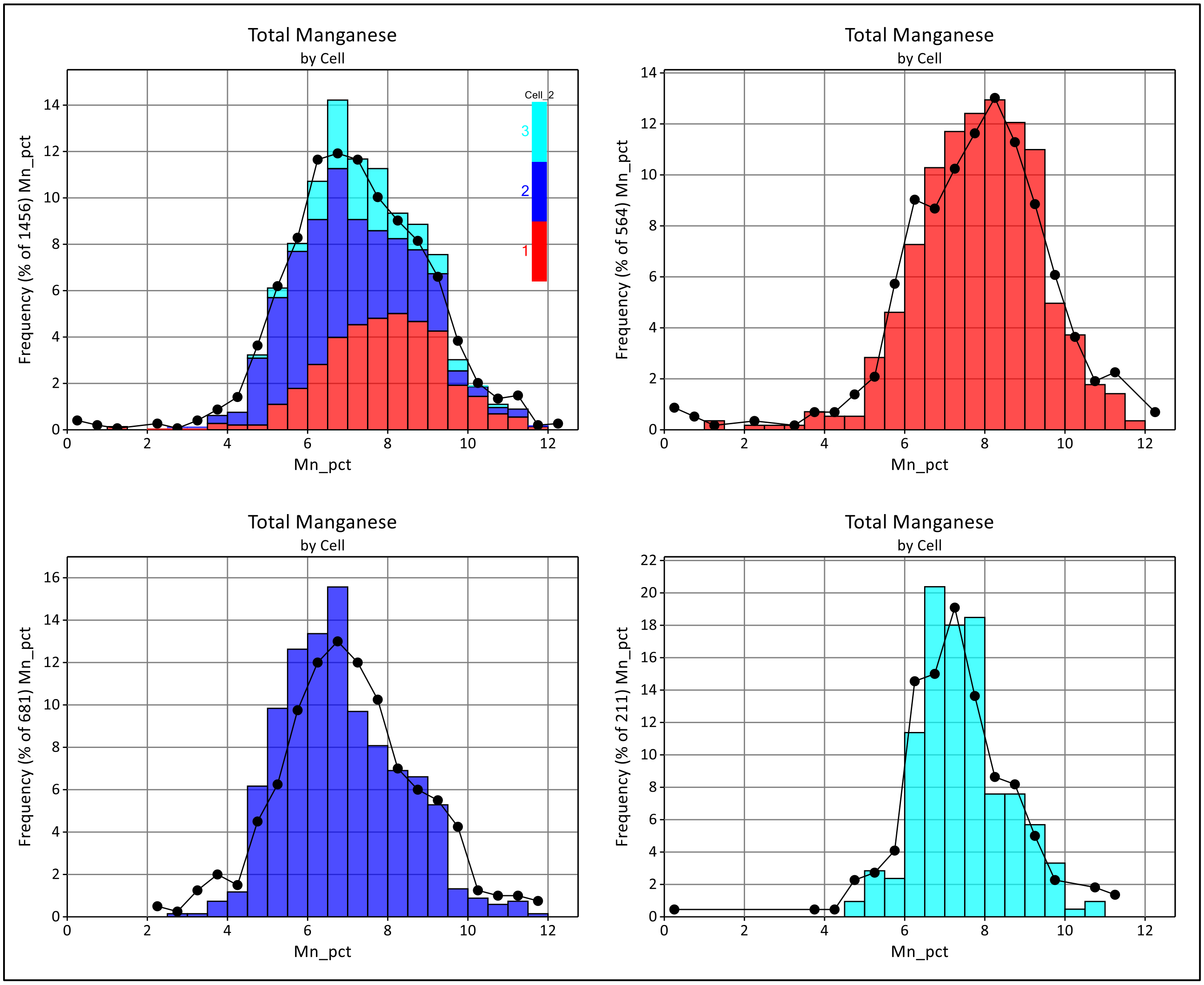
In Figure 14-3, the predominant sample length is 2 m, with range from 0.6 to 4.0 m with standard deviation of ±0.3 m.

Figure 14-3: Frequency Distribution Comparing Raw and Composite Sample Lengths



Histogram comparison of the raw assay values versus the composited assay values show excellent reproduction and confirm that no bias has been introduced in the compositing procedure (Figure 14-4).

Figure 14-4: Frequency Distribtution Comparison Between Raw Assay (Black Line) and 2 m Composites (Coloured Bars) for Total Manganese Concentrations by Cell



14.5.2 Capping Analysis

Manganese grades are normally distributed with low to negligible positive skew. It was observed that values occurring on the high and low ends of the grade distribution tails were located within zones of similar grade trends. It was interpreted that these grades are representative of the natural variance within the deposit and that grade capping was not required.

14.5.3 Variogram Assessment

Variogram analysis was undertaken for each cell using the 2 m composite drill hole sample data using Snowden Supervisor v.8.9.0.2. Downhole variograms used a lag of 2 metres to determine if a nugget (C_0) exists for total and soluble manganese, and horizontal variograms used a lag of 40 m to assess reasonable search radius parameters. These parameters were used only as a guide since kriging was not selected as the interpolation method for the

MRE. The modelled nugget values were identified ranging from 0.05 to 0.38 for total manganese and from 0.05 to 0.40 for soluble manganese. Horizontal major and semi-major axis ranges were defined using spherical models with two internal structures. The first spherical structure of the major axis had ranges between 137 to 188 m and the second structure from 166 to 298 m for total manganese. Soluble manganese ranged between 73 and 135 m for the first structure and between 276 and 549 m for the second structure. Minor axis ranges were between 7 and 17 m. (Table 14-4).

Table 14-4: Summary of Major and Minor Axis Variogram Parameters

	Nugget	Major Structure 1	Major Structure 2	Minor Structure
Cell #1				
Total Mn	0.20	137	249	17
Soluble Mn	0.05	73	276	7
Cell #2				
Total Mn	0.38	188	298	9
Soluble Mn	0.40	135	549	17
Cell #3				
Total Mn	0.05	165	166	6
Soluble Mn	0.23	112	331	7
Model	n/a	150	n/a	8

Drill hole and corresponding assay data within the model is spaced at approximately 75 m on the horizontal plane. Experimental variogram analysis had moderate to good fit for spherical models, with the 2018 drilling allowing for greater short-range variability analysis than the 2017 dataset alone. It was concluded from the variogram analysis that some nugget exists related to the manmade nature of the tailings deposits. A range of 150 m for the major and semi-major axes, and 8 m for the minor axis was selected as an overall range for all cells within which spatial continuity exists for the total and soluble manganese grades.

Figure 14-5: Major Axis Variograms for Total Manganese, Normal Scores, by Cell

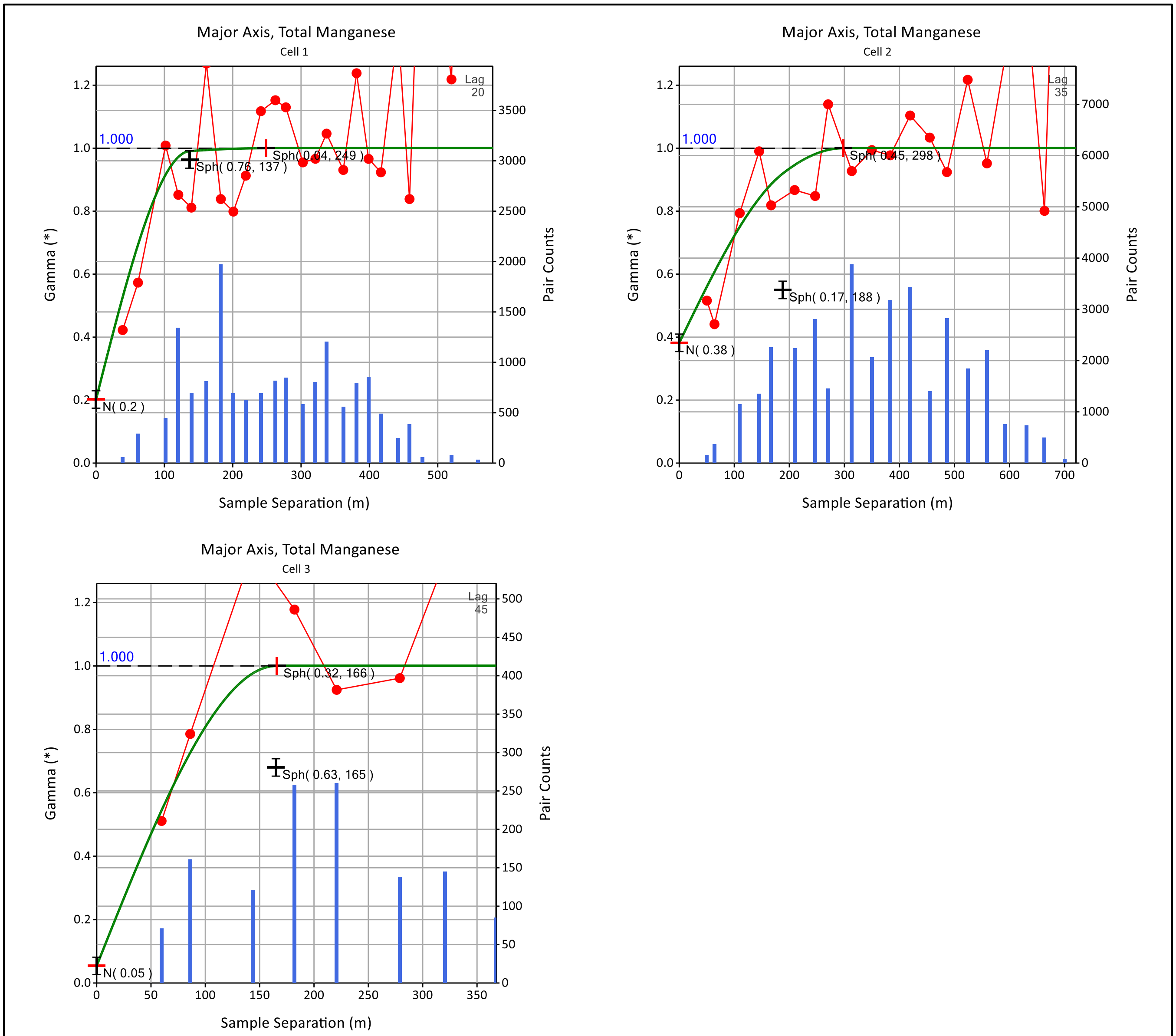
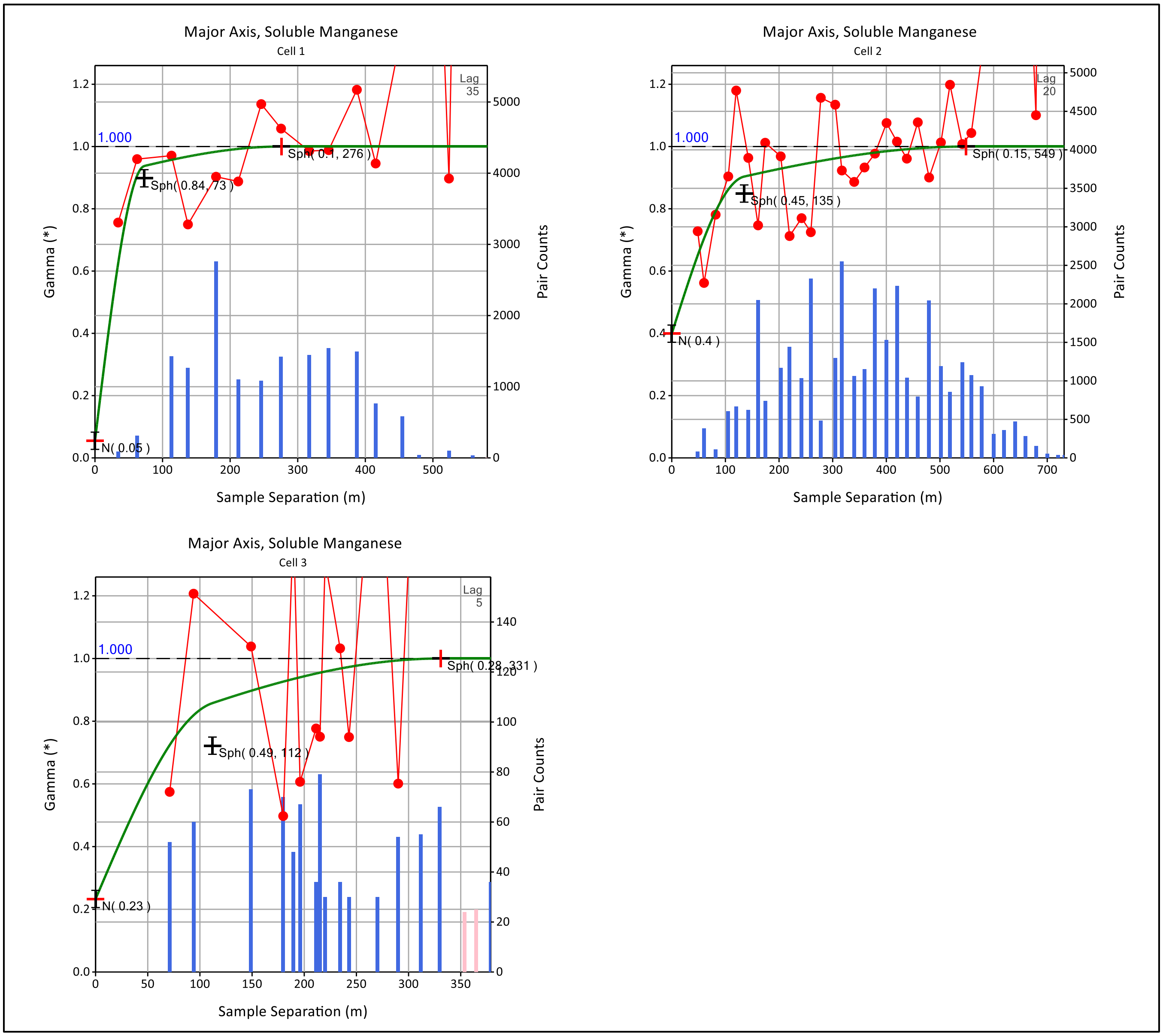


Figure 14-6: Major Axis Variograms for Soluble Manganese, Normal Scores, by Cell



14.5.4 Search Parameters

Interpolation searches were performed using inverse distance squared (to third exponent) for manganese grades, nearest neighbour for particle size indicators, and the spheroid model in Leapfrog® for supporting geochemical values. These methods were selected to minimize bias within the local search neighbourhood. All searches were performed with major and semi-major axes orientation on the horizontal plane, and the minor axis in the vertical.

14.5.5 Block Size Determination

A sub-block model was used to determine volumes of the Chvaletice tailings deposits, allowing for higher resolution with smaller block sizes around the perimeter slopes of the model. Parent block size for the model was determined based on drill hole spacing and de-clustered mean analysis. Using the de-clustering cell size optimization utility in GEOVIA GEMS™, it was determined that a 50 m cell size was the optimal size (Figure 14-7). The model was established using a parent cell size of 50 m by 50 m by 4 m, and minimum sub-cell size of 12.5 m by 12.5 m by 4 m.

Table 14-5 lists the de-clustered mean values for total and soluble manganese concentrations. The sub-block model was established with overall model dimension as listed in Table 14-6.

Figure 14-7: De-clustered Mean Versus Cell Size

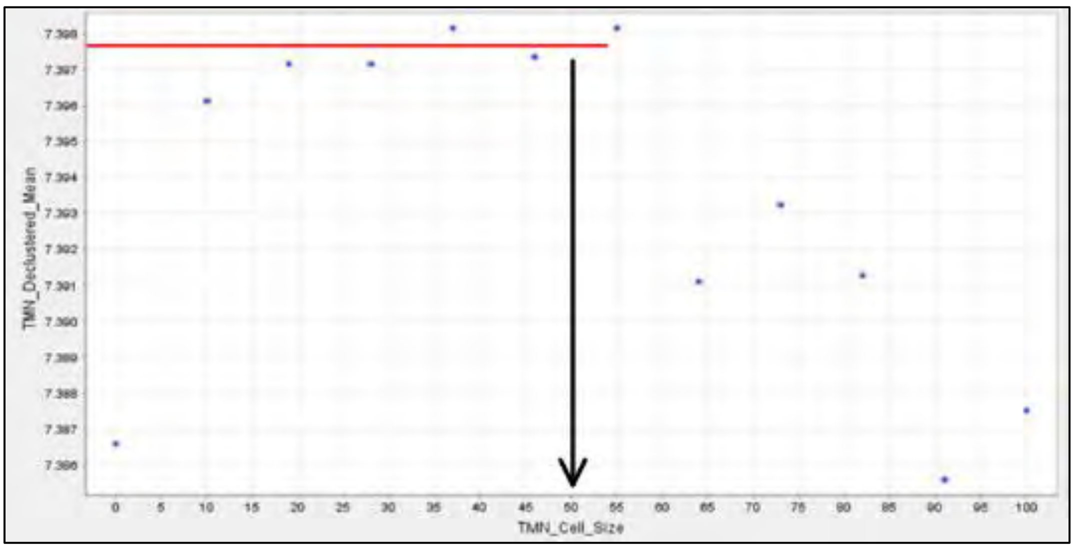


Table 14-5: Block Size Determination De-Clustered Manganese Concentrations

Dataset	Value	Count	Mean	De-clustered Mean
T1	tMn	564	7.86	8.01
	sMn	-	6.40	6.40
T2	tMn	681	6.85	6.62
	sMn	-	5.44	5.19
T3	tMn	211	7.43	7.42
	sMn	-	5.65	5.63

Table 14-6: Block Model Dimensions (S-JTSK Coordinate System)

Model	Origin_X	Origin_Y	Origin_Z	Size_X	Size_Y	Size_Z	Blocks_X	Blocks_Y	Blocks_Z
Parent	-671,600	-1,058,750	240	50	50	4	27	28	23
Sub-block	-	-	-	12.5	12.5	4	-	-	-

14.5.6 Bulk Density Estimation

Mineralogy, grain size, and the method used for deposition of historically processed material as a slurry into the tailings deposits has a significant influence on the final in situ dry bulk density of the tailings material. Water content, particle size gradations, mineral density composition, and degree of compaction from overlying material all contribute to grain settlement and packing. Recovery of the tailings material from the Sonic drill core tube was conducted using methods to minimize the disturbance of in situ material conditions. In practice, controlled core recovery is nearly impossible for saturated tailings and very challenging in under saturated material. Slumping and plasticity of the material caused some variability in the estimated core recoveries.

Core recovery values were collected during field logging along with the moisture and mass measurements collected from laboratory sample processing were used as the basis for calculating in situ bulk density for the tailings material.

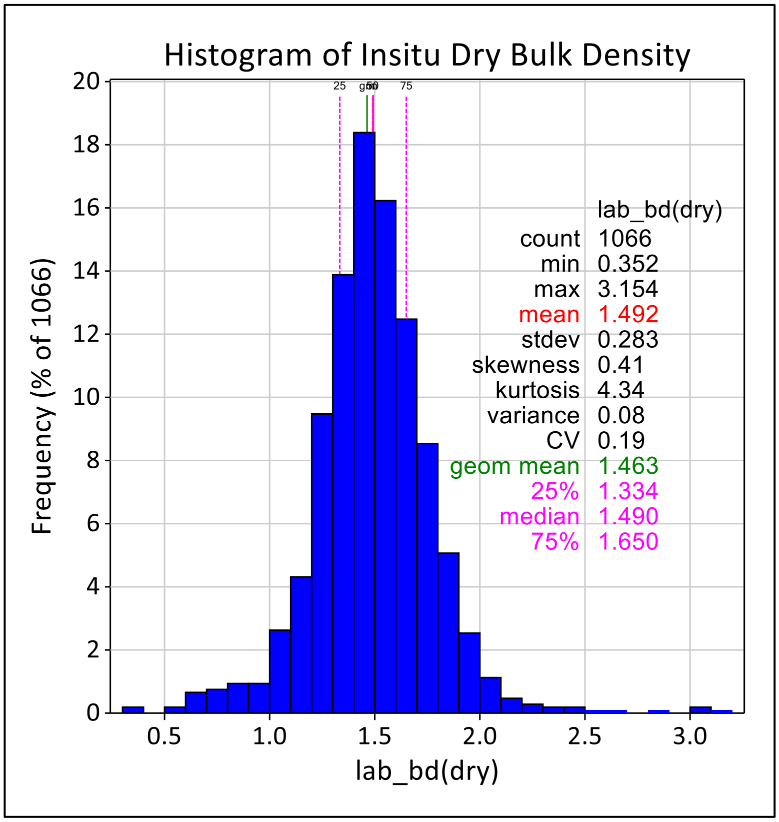
Idealized core volumes for the one metre sub-samples were factored for core volume recovery and then back calculated to the full 2 m core run volume before being factored again by 0.25 to represent the volumes of 25% split assay samples that were sent to SGS.

All samples were weighed as wet samples on receipt at the lab, then again following split extraction for the PSA-LD samples. They were then dried at 105°C until no additional moisture loss was measured. In situ dry bulk density was calculated based on the wet mass of the assay sample received at SGS prior to extraction of the PSA-LD sample split, and then was factored to account for moisture loss during the PSA-LD sample preparation and from drying the final sample to estimate the dry mass of the assay sample as received. This dry mass was then factored over the sample volume estimated to have been received at the lab, using the following formula:

$$Insitu\ Dry\ bulk\ density = \frac{(Wet\ mass\ of\ sample\ as\ received) - (Mass\ of\ Total\ Moisture\ Content)}{Assay\ sample\ volume, measured\ in\ field}$$

In situ dry bulk density values for individual samples, as calculated from field and laboratory data, range between 0.35 and 3.154 t/m^3, with 95 percent probability interval of 0.87 to 2.01 t/m^3, and average of 1.49 t/m^3 ±0.017 t/m^3 (95% chlorine) as depicted in the frequency distribution shown in Figure 14-8. Immeasurable moisture loss in the field and visual estimation of core recovery, in addition to mineralogy and grainsize, influences the wide range of in situ dry bulk density. The in situ dry bulk density values were composited to 2 m and included as variables in the final model interpolation. This result in spatially unique values applied to the block model.

Figure 14-8: Frequency Distribution of Calculated In Situ Dry Bulk Density, Represented On Raw Sample Intervals



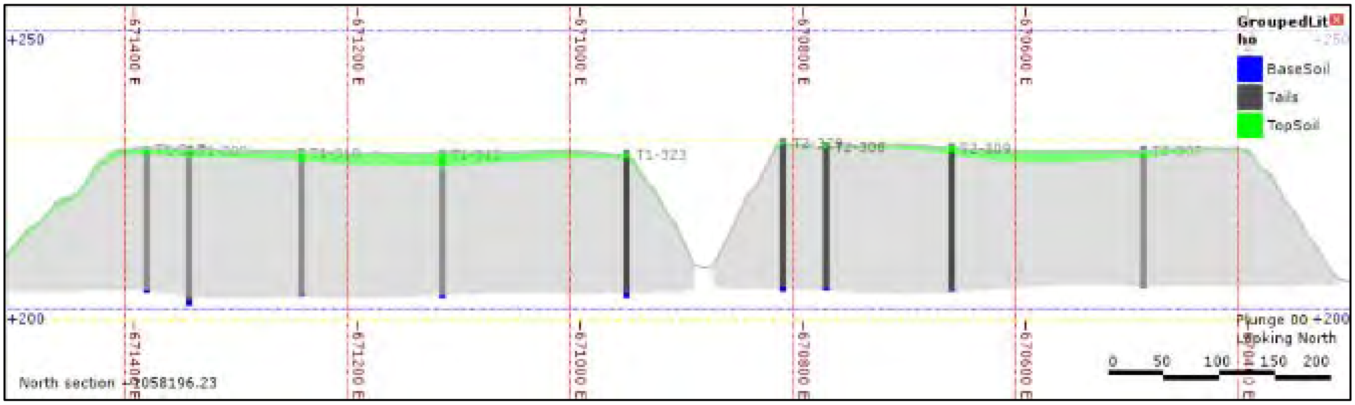
14.6 Volume Estimations

Volume estimates for the cells were developed using the topographic DEM to constrain upper surfaces and deposit perimeters, and logged drill hole data were used to constrain the lower boundary of tailings with original ground soils. A simplified lithological model was developed for each cell to identify topsoil, tailings and subsoil. The volume of material defined as tailings was then used to confine all numerical models and estimates reported for each cell under the MREs. Table 14-7 lists the volume estimates for tailings material contained in each cell and Figure 14-9 shows a typical section through Cells #1 and #2 with the three simplified lithologies identified.

Table 14-7: List of Estimated Volume of Tailings within Each Cell, Constrained by Topography

Cell	Surface Area	Topsoil Volume (m^3)	Tails Volume (m^3)
#1	326,400	284,870	6,720,300
#2	393,200	365,820	8,035,200
#3	313,200	167,030	3,035,900
Total	**1,032,800**	**817,720**	**17,791,400**

Figure 14-9: Typical Section Looking North Through Cells #1 and #2 Showing the Simplified Lithology and Tailings Volume Used for Deposit Modelling (5x Vertical Exaggeration)



14.7 Geological Interpretation for Model

The mineralization found in tailings at the CMP was deposited by manmade processes following grinding and flotation processes of black pyritic shale and is therefore not characteristic of a traditional bedrock hosted manganese deposit. The material can be physically characterized as a compacted soil, with varying degrees of particle sizes from clay to coarse sand. Mineralogy has been quantified by limited XRD analyses, with resulting manganese bearing mineral phases identified as rhodochrosite (and other manganese-bearing carbonates), spessartine (and other manganese-silicates); quartz was the main gangue mineral, and pyrite was the main sulphide mineral.

Deposition of tailings materials was episodic over the life of the historical mining operations. The material was deposited from processed materials with mixed particle sizes suspended in slurry. The deposits are characterized by the broad lateral (i.e., horizontal to sub-horizontal) extent of particle segregation as the slurry flooded the tailings facility. Thin beds of sediment would have been deposited and flowed laterally outwards with a particle gradation from coarse to fine away from the point of discharge. It is interpreted that grain size and moisture content may have more similarity with materials in a vertical sense and have more variability in a horizontal sense. It has been demonstrated by metallurgical test work that a weak relationship exists with increasing manganese grade and with increasing particle size. However, variogram assessment has indicated that the best spatial continuity, in a statistical sense, occurs laterally within the horizontal plane. All searches for block model interpolation were undertaken relative the horizontal plane using a relatively flat elliptical search.

Local beds, or lenses, of oxidized tailings material were observed in core logging to exist along the upper, or outermost surfaces including perimeter slopes, and infrequently at depth within the deposit with thicknesses typically less than 0.5 m. These zones are due to oxidized pyrite and other sulphide minerals contained in under saturated tailings that were exposed to air for long durations, representing periods of hiatus or where local beaching occurred within the tailings at a distance to the point of deposition. These zones have not been modelled in detail and are considered to be insignificant in the broader sense of the deposit. For the purpose of the MRE, all tailings materials are considered to be primary, or unoxidized, materials.

A deposit model was developed using Seequent Leapfrog® Geo v.4.4.2 to represent the volume of tailings within each facility, and to further subdivide the tailings into domains representing ranges in elemental concentration, particle size and in situ dry bulk density.

Each cell was first segmented into lithology volumes for topsoil, tailings and subsoil, based on descriptions in the field logs. The tailings unit for each cell was applied as an external shell to constrain the grade, particle size, moisture and bulk density models.

The particle size model was based on data from the laser diffraction particle size analysis. The grain size distribution was simplified to percentages of clay, silt, sand, and gravel using both European and North American soil classification standards. Additionally, the data was simplified to single value indices to characterize the distribution. Particle diameters measured for each decile of the distribution characterizes how the particles are statistically distributed throughout the deposit, where D50 represents the particle size of the 50th percentile (or median value), and D80 represents the particle diameter at the 80th percentile. Alternatively, the distribution was also characterized by the percent of the sample which passes a defined screen mesh, such as P75 which describes the percentage of the sample which passes nominal screen size of 75 µm (i.e., 200 mesh). Table 14-8 lists the average value for these indices as modelled, by cell.

The moisture model was based on moisture data measured by SGS labs from mass measurements on receipt of the sample and after drying, after applying a correction for mass loss from the PSA-LD sample split.

Table 14-8: List of Average Values for Modelled Variables Compared, Listed by Cell

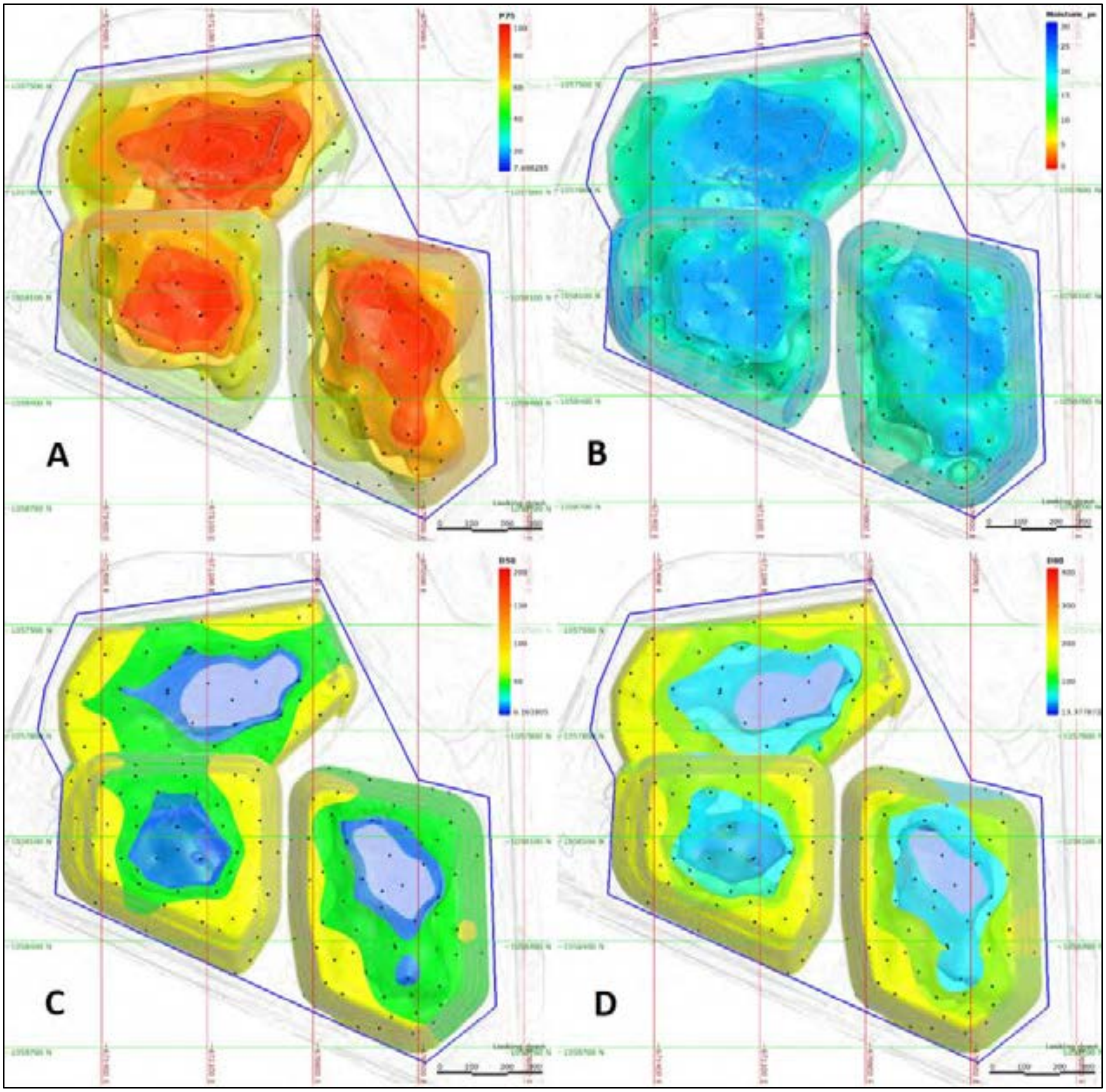
Cell	Particle Size				Moisture (%)
	D50 (µm)	D80 (µm)	D90 (µm)	P75 (%)	
T1	64.14	152.90	219.01	66.48	21.20
T2	49.46	125.38	185.02	71.29	21.46
T3	66.96	157.08	230.42	67.48	20.68

An additional 18 elemental concentrations were interpolated into the block model to help inform metallurgical studies and mine planning exercise (Table 14-9). These elements are not included as part of the Mineral Resource statement.

Table 14-9: Additional Elements Interpolated into Block Model

Element	Method
As	4-Acid AAS
Ca	4-Acid AAS
Cd	4-Acid AAS
Co	4-Acid AAS
Cu	4-Acid AAS
Fe	4-Acid AAS
Hg	4-Acid AAS
K	4-Acid AAS
Mg	4-Acid AAS
Na	4-Acid AAS
Ni	4-Acid AAS
P	4-Acid AAS
Pb	4-Acid AAS
Se	4-Acid AAS
Zn	4-Acid AAS
P	XRF
C	LECO
S	LECO

Figure 14-10: Plan Views of Geological Model Volumes



Notes:

A – P75 grain size indices
B – moisture
C – D80 grain size indices
D – D50 grain size indices

14.8 Manganese Break-Even Grade

Market studies are ongoing as EMN evaluates production of high-purity, selenium-free, 99.9% HPEMM and/or HPMSM products.

Based on preliminary on-site and off-site operating cost estimates and metal recovery estimates, the breakeven grade is estimated to be 2.18% tMn. All the costs and recoveries are based on preliminary estimates and may not be representative of the actual project costs and parameters. Assumptions for this grade calculation include:

- A combined material price derived from metal price of 9.60kg/t for HPEMM and metal price of 3.72 kg/t for HPMSM (CPM Group, June 2022)
- A pre-concentration operating cost of USD$6.47/t feed
- A leaching and refining operating cost estimate of USD$188.00/t feed
- Total recovery to HPEMM and HPMSM is approximately 60.5% and 58.9%, respectively
- It is assumed that mining selectivity will not be applied due to inherent difficulty of grade control and selective mining for this deposit type.

The deposit is being considered as a bulk tonnage operation and it is assumed that selective mining will not be applied. All tailings material will be sent to the process plant on a diluted basis as a re-pulped slurry, and no cut-off grade can reasonably be applied to the deposit (i.e., no mining waste will be generated). The case for economic extraction relies on the net value of resources being sent to the plant to be positive; the average feed grades must be greater than the breakeven grade (cost equivalent) of 2.18% tMn. The estimated breakeven cut-off grade falls below the grades of most of the blocks (excluding 5,000 t which has grades lower than 2.18% tMn).

14.9 Mineral Resource Estimate

The MRE was calculated using Seequent Leapfrog® Geo Edge using Phase 1 and Phase 2 drilling results for the total and soluble manganese grades and bulk density values. The 2 m composited data were interpolated into a sub-block model and reported on a block tonnage weighted basis. Table 14-10 lists the MRE for in situ tailings material at the CMP. The Public Report, entitled “Technical Report and Mineral Resource Estimate for the Chvaletice Manganese Project, Chvaletice, Czech Republic”, with an effective date of December 8, 2018 (the "**Mineral Resource Estimate**"), was filed on SEDAR on February 6, 2019, 2019. No additional drilling or data collection pertaining to the technical disclosure of mineral inventory has been undertaken since the completion of the Mineral Resource Estimate, and the effective date for this Mineral Resource Estimate is revised to July 1, 2022. This estimate adheres to guidelines set forth by the JORC Code and NI 43-101 and the CIM Best Practices.

Table 14-10: Mineral Resource Estimate for the Chvaletice Manganese Project, Effective July 1, 2022

Cell	Class	Volume ('000 m^3)	Tonnage (kt)	In Situ Dry Bulk Density (t/m^3)	tMn (%)	sMn (%)
#1	Measured	6,577	10,029	1.52	7.95	6.49
	Indicated	160	236	1.47	8.35	6.67
#2	Measured	7,990	12,201	1.53	6.79	5.42
	Indicated	123	189	1.55	7.22	5.30
#3	Measured	2,942	4,265	1.45	7.35	5.63
	Indicated	27	39	1.45	7.90	5.89
Total	**Measured**	**17,509**	**26,496**	**1.51**	**7.32**	**5.86**
	Indicated	**309**	**464**	**1.50**	**7.85**	**6.05**
Combined	**M&I**	**17,818**	**26,960**	**1.51**	**7.33**	**5.86**

Notes:

- Estimated in accordance with the CIM Definition Standards on Mineral Resources and Mineral Reserves adopted by CIM council, as amended, which are materially identical to the JORC Code.
- The Chvaletice Mineral Resource has a reasonable prospect for eventual economic extraction. Mineral Resources do not have demonstrated economic viability.
- Indicated Resources have lower confidence that Measured Resources.
- A breakeven grade of 2.18% tMn has been estimated for the Chvaletice deposit based on preliminary pre-concentration operating costs of USD$6.47/t feed, leaching and refining operating cost estimates of USD$188.00/t feed, total recovery to HPEMM and HPMSM of approximately 60.5% and 58.9%, respectively, and a combined price derived using metal prices of 9.60 kg/t for HPEMM and 3.72 kg/t for HPMSM (CPM Group Report, June 2022).. The actual commodity price for these products may vary
- A cut-off grade has not been applied to the block model. The estimated breakeven cut-off grade falls below the grade of most of the blocks (excluding 5,000 t which have grades less than 2.18% tMn). It is assumed that material segregation will not be possible during mining due to inherent difficulty of grade control and selective mining for this deposit type.
- Grade capping has not been applied.
- Numbers may not add exactly due to rounding.

Figure 14-11 shows a plan view of the block model for Cells #1, #2 and #3 and definition of sections A-A' and B-B'. Figure 14-12 shows vertical cross sections along these lines for soluble manganese block values and for P75 block values.

Figure 14-11: Plan View of Block Model Showing Section Lines and Soluble Manganese Grade Distribution at Surface

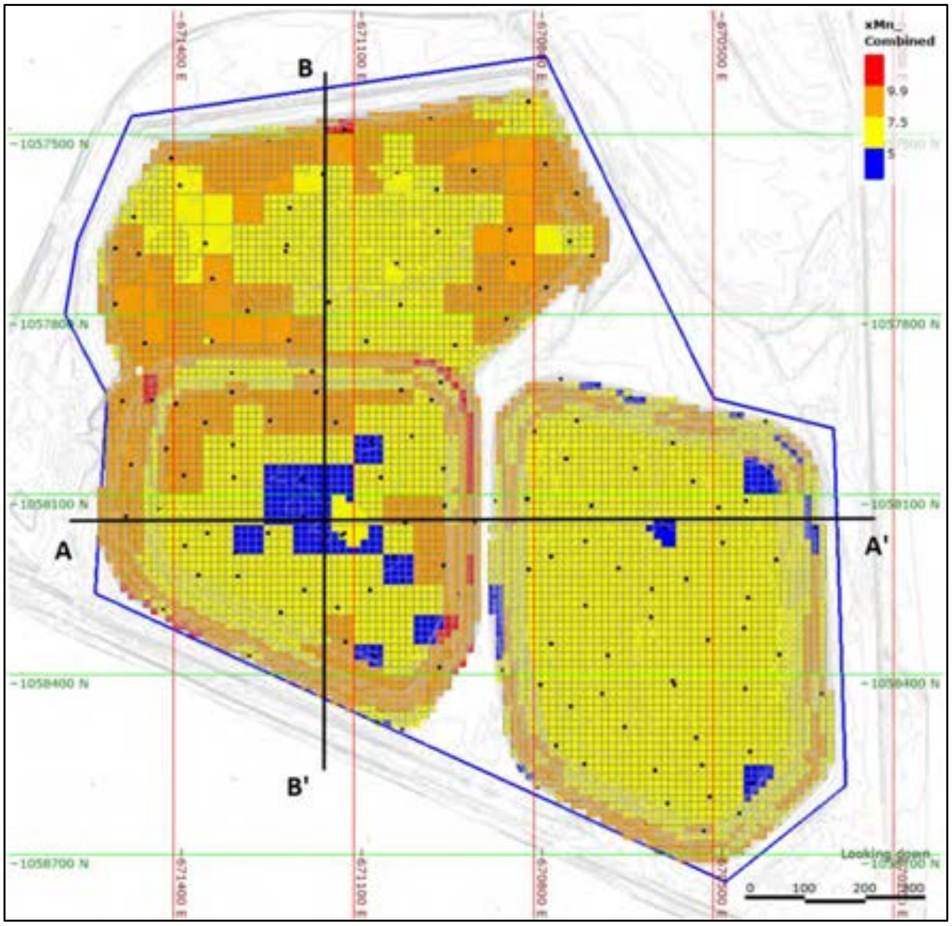
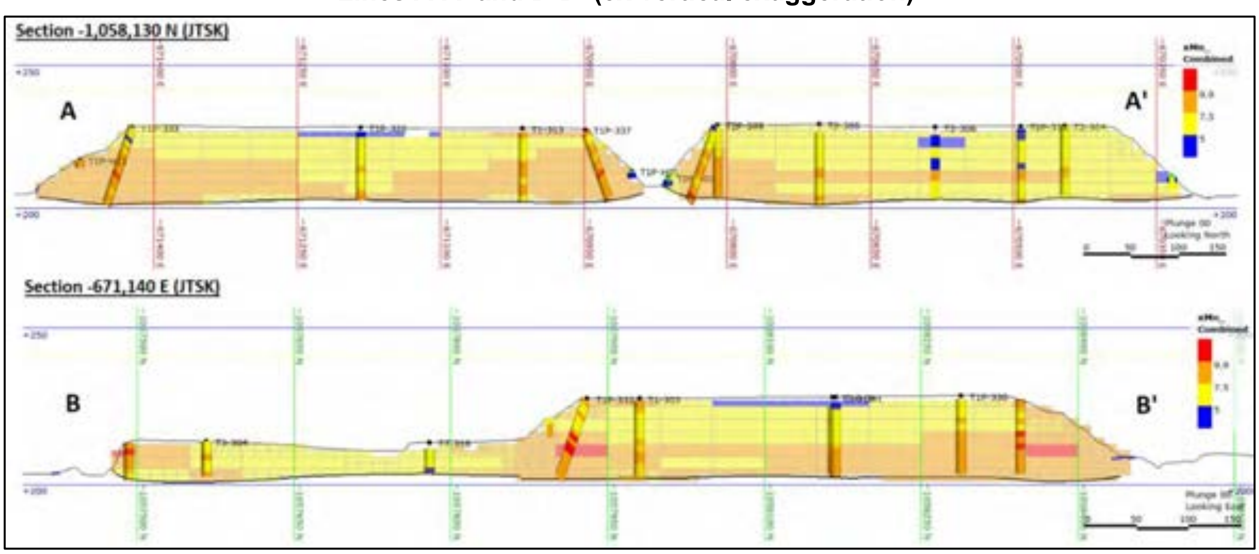


Figure 14-12: Vertical Cross-Section View Showing Total Mn Block Values Along Lines A-A' and B-B' (3x vertical exaggeration)



14.10 Classification

Mineral Resource classification was performed in reference to CIM Best Practices. No set standard exists for classification of resources for tailings deposits.

In accordance with CIM Definitions Standards (2014) the CP is of the opinion that the CMP is a reasonable prospect for eventual economic extraction on the basis of:

- Extensive drill investigation and geochemical assaying of representative samples collected from the Chvaletice tailings storage facility has confirmed the material has continuous and anomalous concentration of manganese throughout the tailings material contained above the original ground surface and below a topsoil reclamation cap
- The net average Measured (7.32%) and Indicated (7.85%) total manganese grades reported for the MRE are greater than the breakeven grade of 2.18% manganese, and only 10,000 t of tailings material have grade less than the breakeven grade of 2.18% manganese (Section 14.6)
- The tailings deposits are located above ground surface, with immediately accessible transportation infrastructure and are located in proximity to industrially zoned land that is suitable for process plant development
- Further engineering and financial assessments will be conducted to validate the economic viability of the CMP.

Measured Mineral Resources are those materials with evidence derived from detailed and reliable exploration, sampling and testing which is sufficient to confirm geological and grade or quality continuity between points of observation. The materials comprising Measured Mineral Resources have quantity, grade or quality, densities, shape, and physical characteristics that are estimated with confidence sufficient to allow the application of modifying factors to support detailed mine planning and final evaluation of the economic viability of the deposit. Confidence ranges for Measured Resources were evaluated using the total manganese variograms and by variance sensitivities of the closest sample and average distance of samples for each cell within the block model. Blocks have been classified as Measured where total manganese grades have been based on a minimum of five samples within a maximum average distance of 100 m and with closest sample within a maximum of 75 m. The majority of the model blocks have been classified as Measured.

Indicated Mineral Resources are those materials where evidence is derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological and grade or quality continuity between points of observation. Distribution and concentration of manganese concentrations have been reasonably defined for the majority of the deposits by drilling spaced at approximately 100 metre spacing confirming trends with three-dimensional continuity and allowing for modelling of grade distribution in conjunction with numerous other chemical and physical parameters. Indicated Resources have a lower confidence than Measured Resources. Those blocks within the established bounds of the tailings deposits that did not meet the criteria established for Measured Mineral Resources have been classified as Indicated. Presence of tailings material in these locations is very probable however given the distances to supporting samples the grade has been estimated with lower confidence than Measured Resources. Figure 14-13 depicts the model blocks which have been classified as Indicated Mineral Resources, representing approximately 2% of the overall resource tonnage.

Figure 14-13: Plan View Showing Extent of Indicated Resource Blocks (Red); Measured Blocks are not Shown (All Remaining Blocks)

14.11 Grade Tonnage Curves

As means of a reference to tonnage sensitivity and distribution of manganese grade, Figure 14-14 shows the grade-tonnage curve. The grade-tonnage tabulation includes all blocks contained within the model and have not been segmented based on Mineral Resource classification.

TETRA TECH

Figure 14-14: Grade-Tonnage Curve for the Chvaletice Manganese Project, Total Manganese

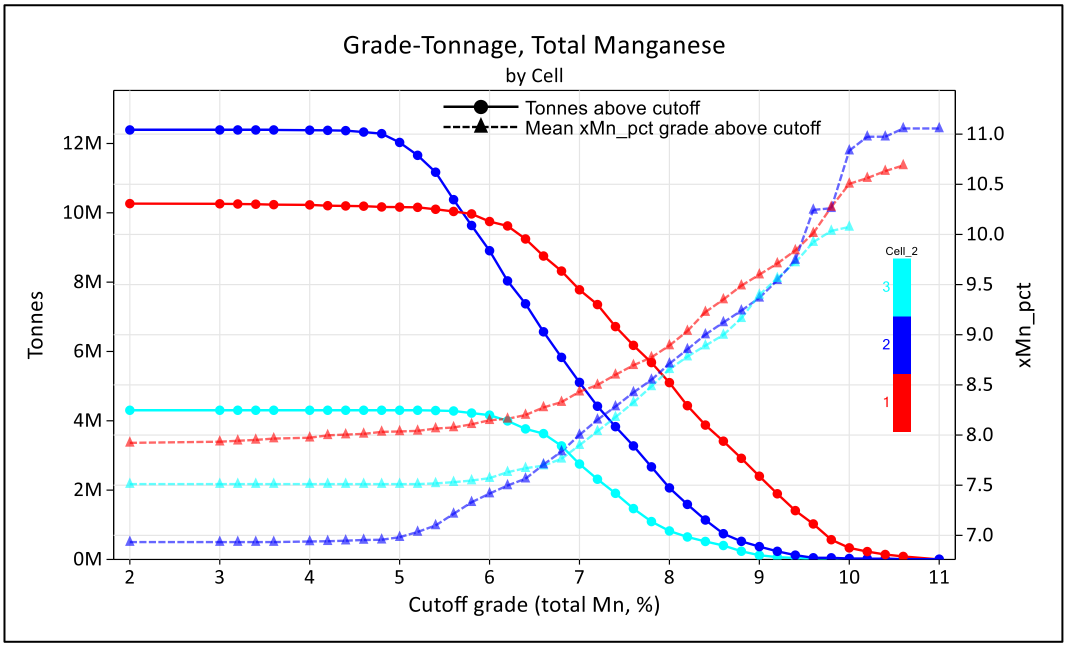
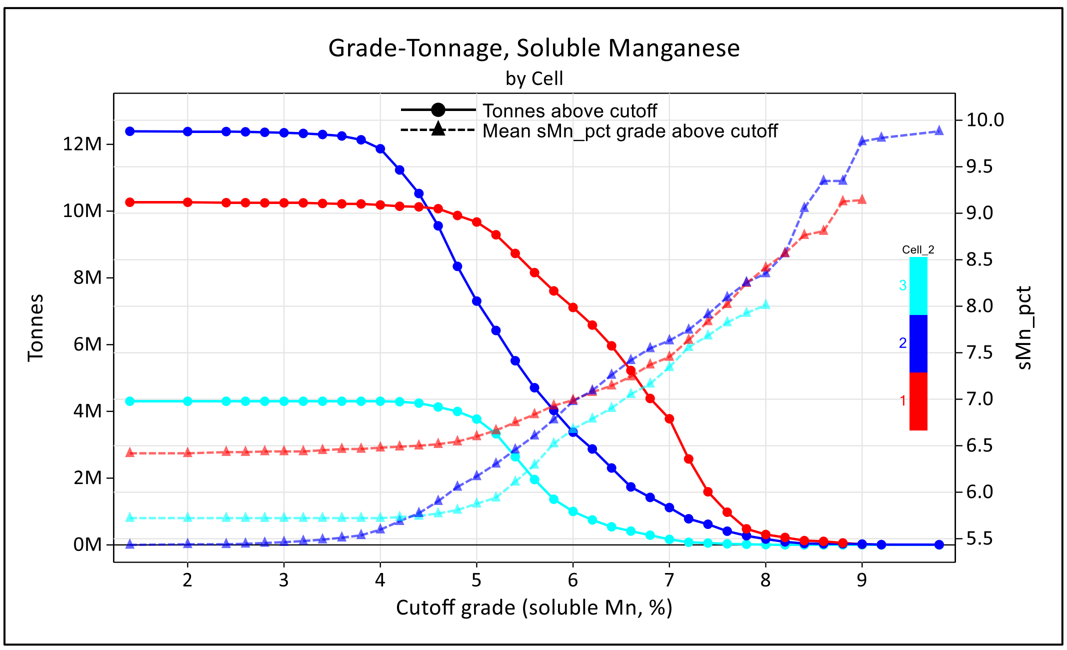


Figure 14-15: Grade-Tonnage Curve for the Chvaletice Manganese Project, Soluble Manganese



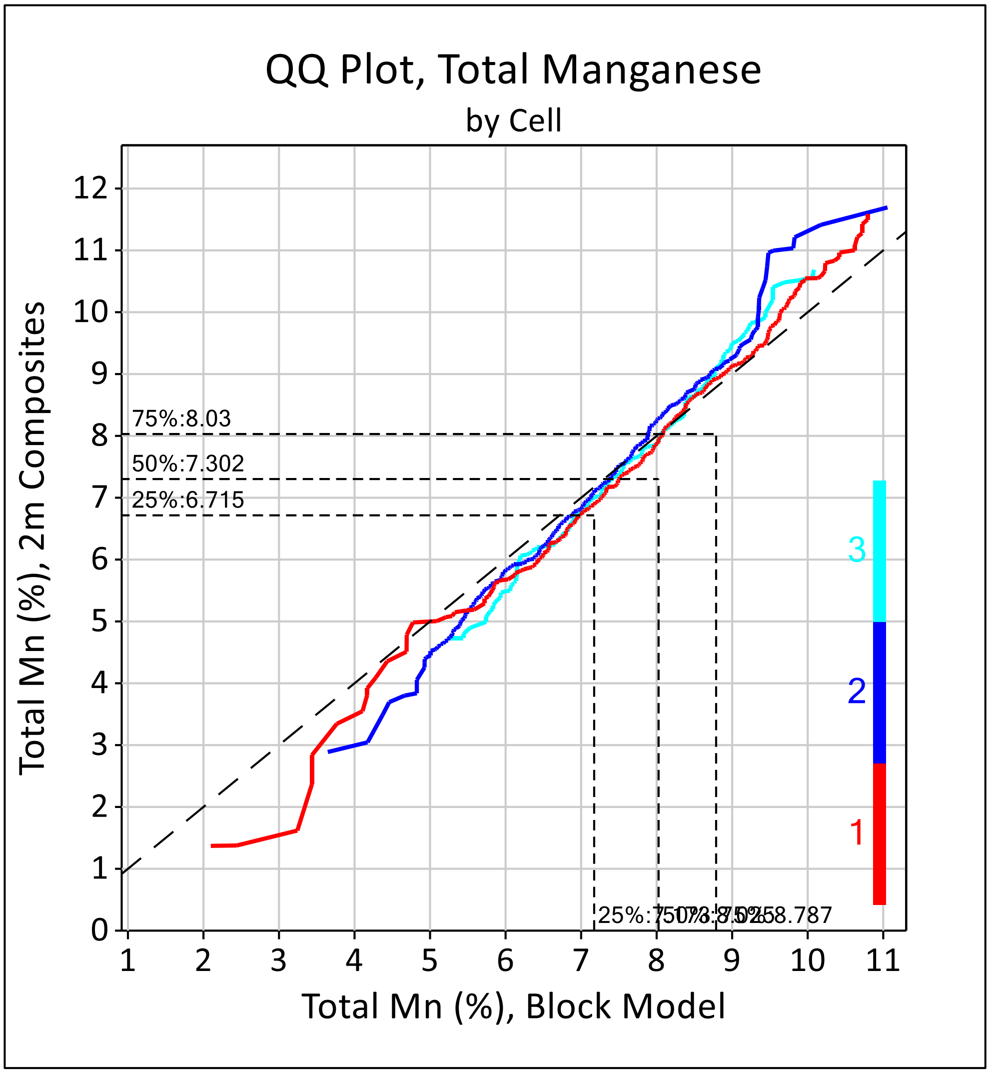
14.12 Model Validation

Model validation was conducted by visual inspection, and various geostatistical comparisons.

A visual inspection of the modelled variables along vertical cross sections comparing raw values, composite values and block values was conducted. No visual concerns were observed, and the interpolated models fit the drill hole sample data well.

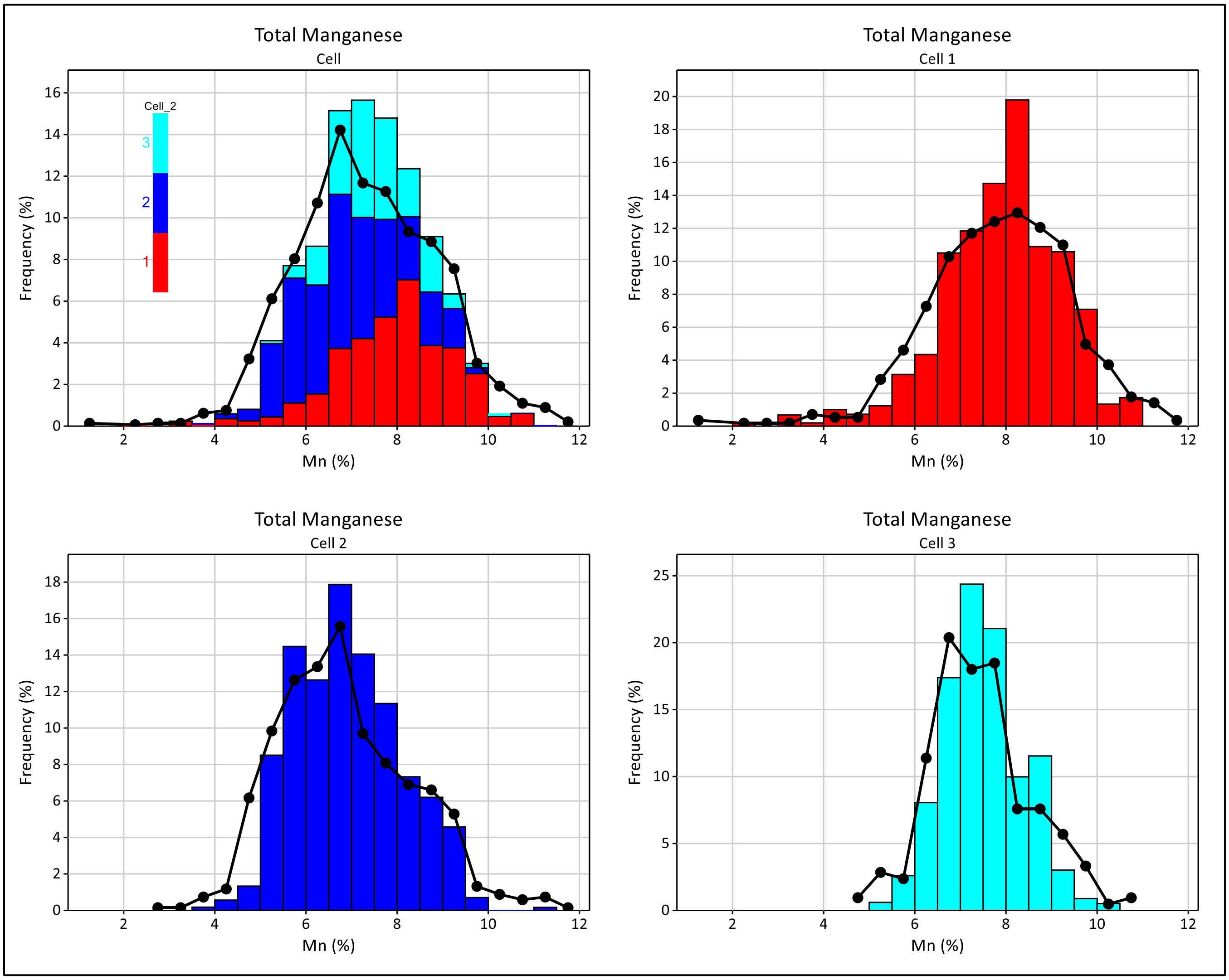
A quantile-quantile (QQ) assessment is used as a visual check to compare shape of two dataset distributions. Figure 14-16 shows a QQ plot by cell where quantiles of the composite total manganese values are compared with the block total manganese values. It is observed that excellent correlation exists for data in the middle two quantiles, with slight deviation in the higher and lower grade ranges due to minor smoothing of data in the block model.

Figure 14-16: Quantile-Quantile Plot for 2 m Composites and Block Model Values of Total Manganese



Comparison of histogram distribution between the input 2 m composite data and the block model output is also used as a visual check to compare the data distributions, to verify that a bias has not been introduced during the interpolation procedure. Figure 14-17 shows excellent correlation exists between the datasets, where overall shape and tails have been preserved.

Figure 14-17: Histogram Comparison for 2 m Composites and Block Model Values of Total Manganese



A swath plot analysis was completed on the both the entire dataset and individual cell datasets. The analysis enables spatial verification for reasonable congruence of original assay data to the interpolated values along the three principal axes of the model. Figure 14-18 shows swath plots along the X-axis, Figure 14-19 along the Y-axis, and Figure 14-20 along the Z-axis. The analysis results indicate good correlation of the modelled blocks and no major bias has been introduced to the model during the interpolation process.

Figure 14-18: Swath Plots Along X-Aixs, Total Manganese Values Shown

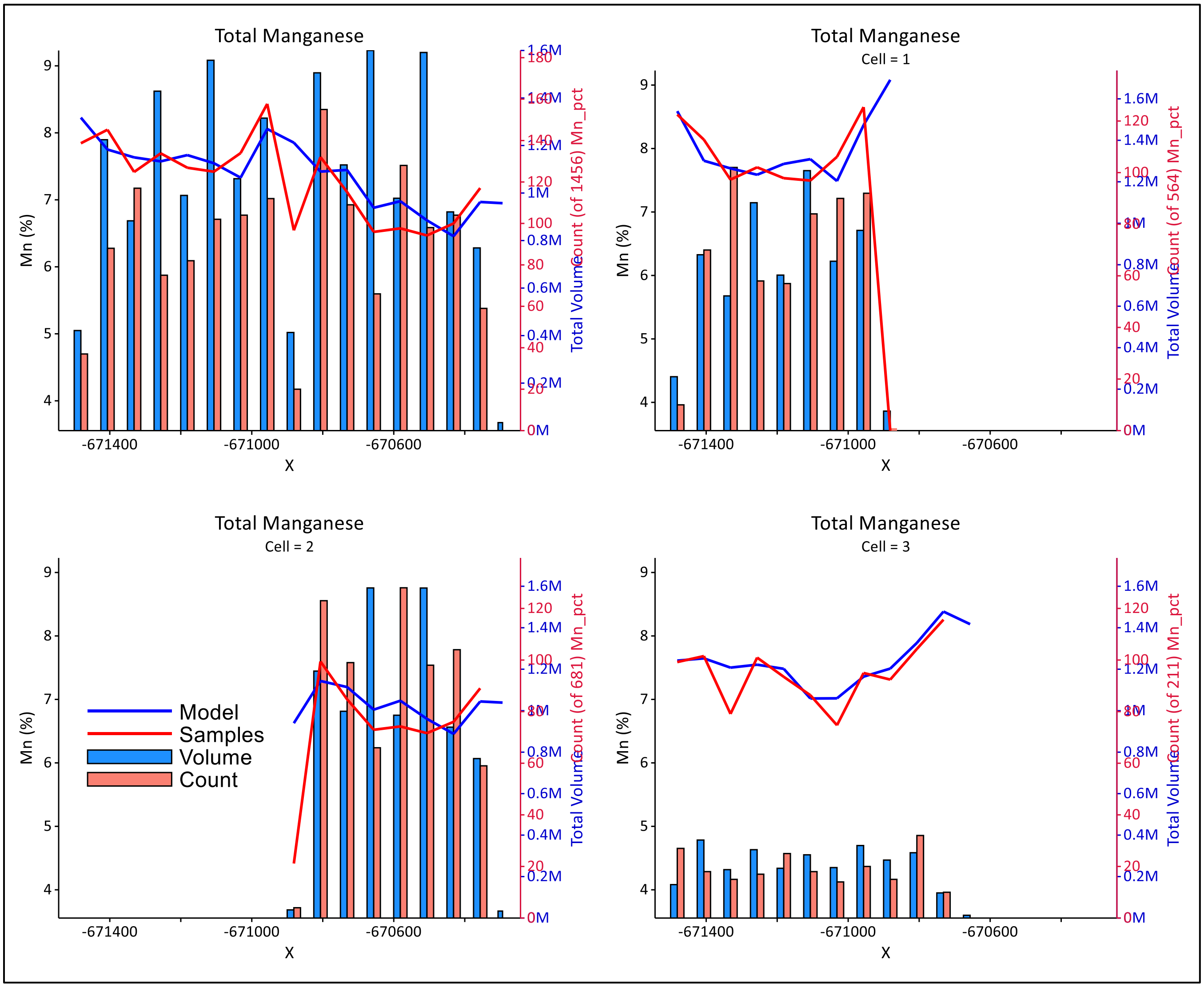


Figure 14-19: Swath Plots Along Y-Axis, Total Manganese Values Shown

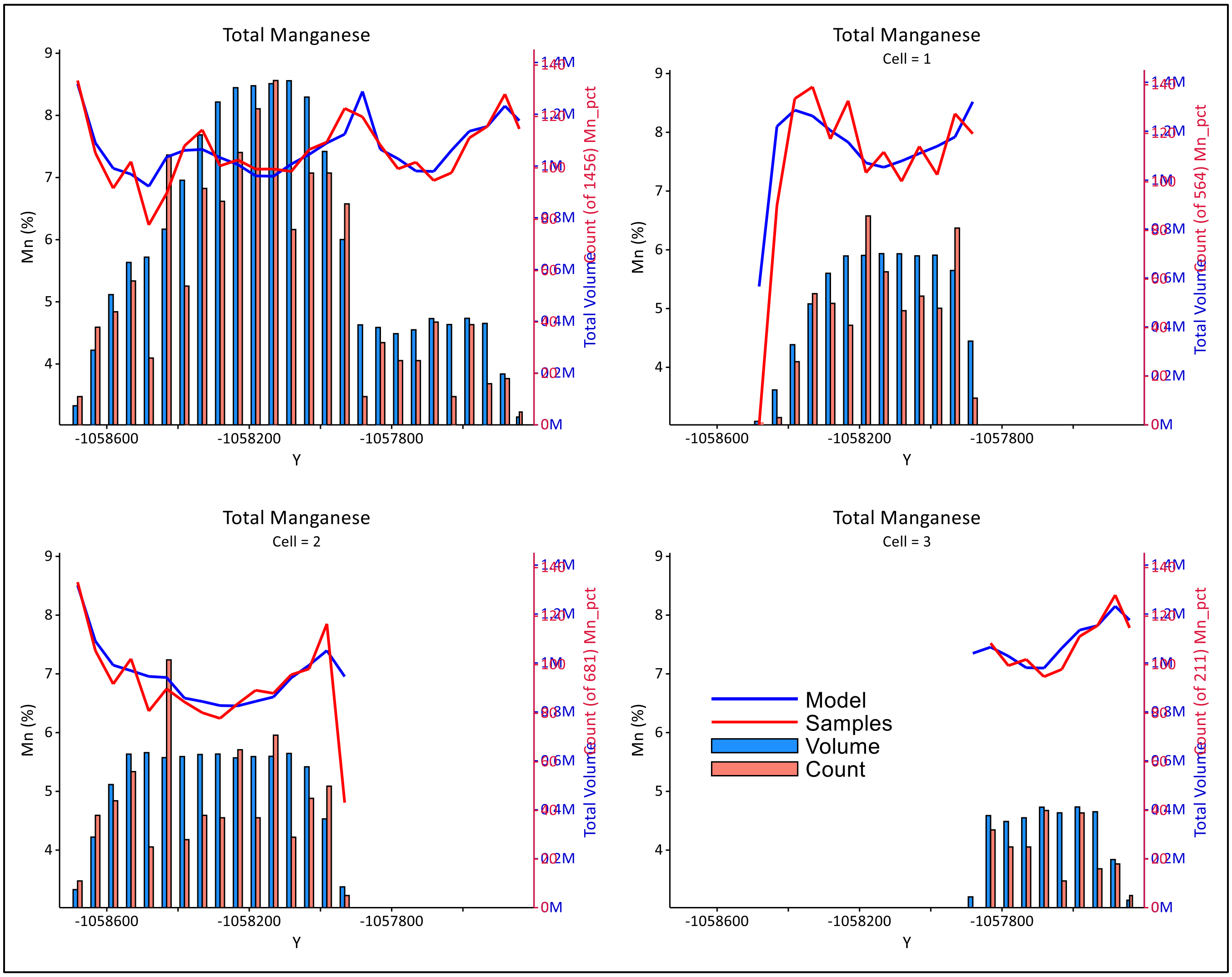
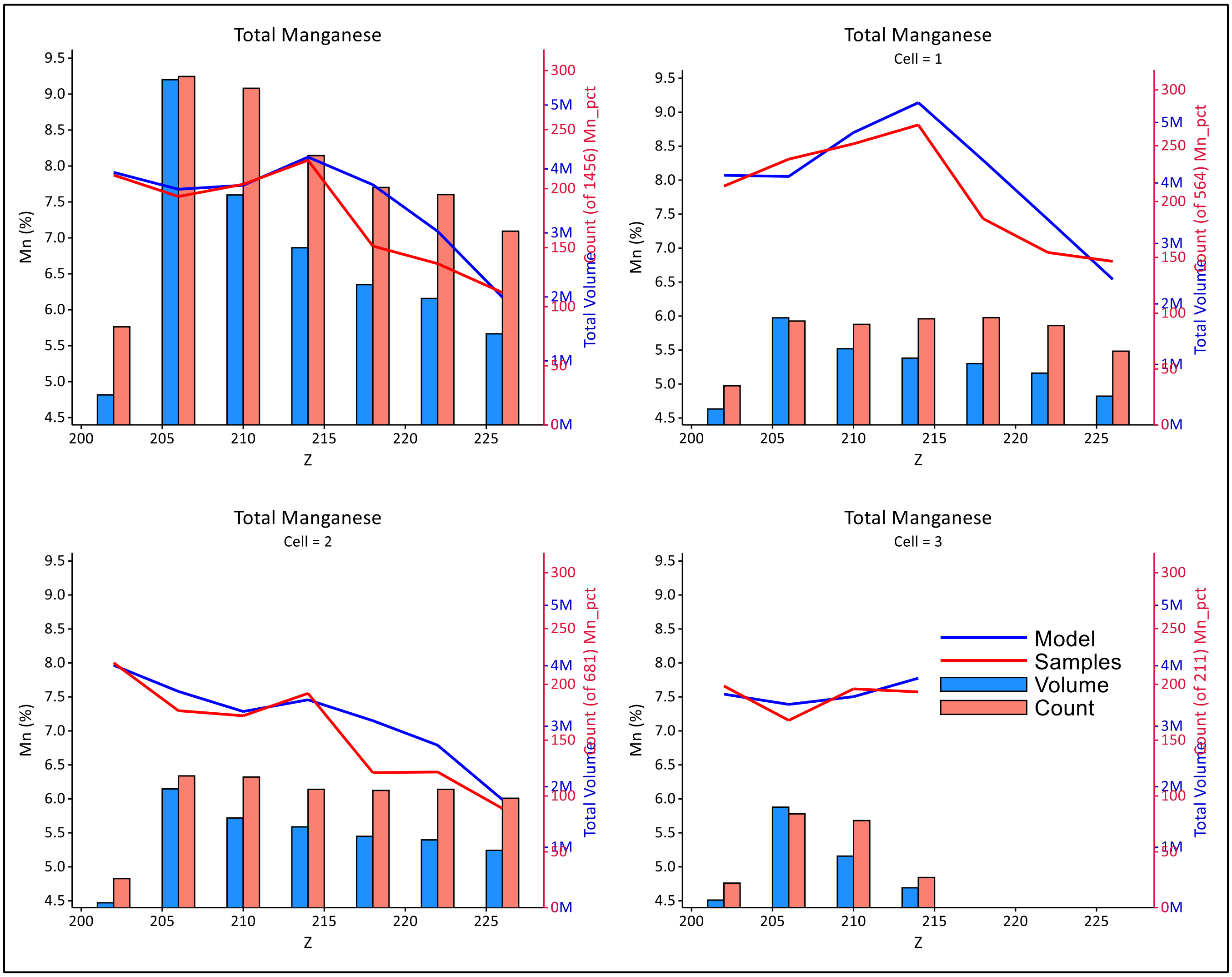


Figure 14-20: Swath Plots Along Z-Axis, Total Manganese Values Shown



The CP has conducted various forms of model validation and believes the model is a fair and reasonable representation of the sampling data collected from on-site investigations completed to date.

15.0 MINERAL RESERVE ESTIMATES

15.1 Introduction

Mineral Reserves for the Chvaletice Manganese Project are based on the Measured and Indicated Resources presented in Section 14.0, and an updated mine design presented in Section 16.0.

The Mineral Reserve estimate is consistent with the CIM Standards and the JORC Code on Mineral Resources and Mineral Reserves and is suitable for public reporting. As such, the Mineral Reserves are based on Measured and Indicated Mineral Resources and do not include any Inferred Mineral Resources.

The Mineral Reserves are considered economically feasible to mine based on the following:

- Application of appropriate modifying factors including but not limited to mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social, and governmental factors
- Completion of financial modelling based on Mineral Reserves
- No known legal or political matters that preclude mining
- Mining and processing operations are technically and economically feasible under current and foreseeable economic conditions
- Metallurgical recoveries from test work are understood

15.2 Reserve Estimation Parameters

A Net Smelter Return (NSR) model was created for the Mineral Reserves and used the parameters summarized in Table 15-1 below.

NSR models are used to calculate the value of a tonne of ore mined, processed, concentrated, and sold to a smelter. The NSR refers to the revenue expected from each tonne of mill feed, taking into account mill recoveries and deductions for transport to the smelter, treatment, and refining charges.

Tetra Tech used the NSR model to estimate the value of blocks in the reserve, and determine a breakeven grade for which to check reserve constraints against. The NSR model was also used to estimate reserve sensitivity, as described in Section 15.3.4 below.

The NSR for each block in the Mineral Resource model was calculated including the following factors: mined grade, contained metal, recovery rates for HPEMM and HPMSM, mining and processing operating costs, EMM to MSM conversion cost, residue placement cost, general and administrative costs, water treatment, shipping cost, product insurance, and royalties.

A break-even grade of 2.18% has been estimated as part of the reserve estimation. Resource to reserve conversion totals 98.8%.

Table 15-1: Net Smelter Return Calculation Parameters

	Unit	Value
MINE PRODUCTION SCHEDULE		
Minimum Mn Grade Mined for Processing	%	2.18
Total Contained Mn Mined (LOM)	kt	1973.4
PRODUCT SPECIFICATION		
Electrolytic Manganese Metal	%	99.9
Manganese Sulfate Monhydrate	%	332.5
MILL PRODUCTION SCHEDULE		
Ore Tonnes Processed	kt/a	1,066
Minimum Contained Metal - Mn Processed per Year	kt/a	23.4
Metallurgical Recoveries HPEMM (%)	%	34.6
Metallurgical Recoveries HPEMM to HPMSM (%)	%	97.0
Minimum HPEMM Produced	kt/a	8.11
	t Mn/t ore	0.008
HPEMM Produced _ Final	t Mn in EMM/t ore	0.003
HPMSM Produced _ Final	t Mn in MSM/t ore	0.005
EXCHANGE RATE		
USD:CZK	--	22.43
OFF SITE COSTS		
Shipping	USD/t EMM	116
Insurance	%	0.04
Selling	%	0.5
METAL PRICE		
HPEMM	USD/kg EMM	9.604
HPMSM	USD/kg MSM	3.717
NET METAL VALUE CALCULATION		
Total Offsite Charge	USD/t ore	3.227
NSR	**USD/t ore**	**76.78**

Note: All costs and metal prices were based upon conservative estimates and used solely for the generation of the NSR model and delineation of the Mineral Reserves. Metal production is calculated using the break-even grade and is independent from production schedule in Section 16 which is based off of annual feed grade.

15.3 Mineral Reserve Estimate

15.3.1 Mineral Reserve Statement

Table 15-2 below presents the Mineral Reserve tabulated by tailings cell and reserve category. All Mineral Reserves are scheduled in the life of mine plan, presented in Section 16.0.

Mining extents used for reserve estimation extend horizontally to the limits of all three cells, and are controlled vertically by original ground, with a shallow-graded floor. This floor is designed to maximize reserve extraction while allowing the installation of drainage infrastructure and placement of residue immediately following mining.

Tetra Tech has designed an operation employing conventional truck and shovel equipment to excavate the tailings at the CMP. Tailings cells will be stripped of topsoil, then excavated using 3 m high benches with a 12 m bench width and face angle of 45°. Geotechnical considerations were focused on bench stability and the ability to operate equipment on the benches of the tailings cells. Depressurization of the water contained within the cells is expected to occur during the cut of the first bench and continue with each subsequent advance.

Dilution, defined as waste material that is unable to be separated and as such is included with ore when mining, and losses, defined as ore material remaining in-situ following mining, have been estimated for the CMP. Minimal dilution and losses totaling <1% are expected to occur at the interface between the bottom of the tailings cells and original ground, due to the uneven contact morphology.

Mineral reserves were classified based on resource categories defined during resource estimation. Measured Resources were converted to Proven Reserves, and Indicated Resources were converted to Probable Reserves. No Measured Resources were included within Probable Reserves. No Inferred Resources were included within the reserve classification.

Table 15-2: Mineral Reserve Estimate for the Chvaletice Mining Project, (effective July 14, 2022)

Cell	Class	Volume (000 m^3)	Tonnage (000 t)	In-Situ Dry Bulk Density (t/m^3)	tMn (%)
1	Proven	6,651	10,132	1.51	7.83
	Probable	141	208	1.52	8.24
2	Proven	7,929	12,106	1.53	6.91
	Probable	119	183	1.54	7.35
3	Proven	2,744	3,979	1.46	7.49
	Probable	25	36	1.46	7.98
Total	Proven	17,325	26,217	1.5	7.36
	Probable	284	427	1.52	7.82
Combined	--	17,609	26,644	1.51	7.41

Notes:

1. Estimated in accordance with the CIM Definition Standards on Mineral Resources and Mineral Reserves adopted by the CIM council, as amended, which are materially identical to the JORC Code.
2. Probable Reserves have lower confidence than Proven Reserves. No Measured Resources were included within Probable Reserves. Inferred Resources have not been included in the Reserves.

3. A breakeven grade of 2.18% total Mn has been estimated for the Chvaletice deposit based on preliminary pre-concentration operating costs of $6.47/t feed, leaching and refining operating costs of $188/t feed, total recovery to HPEMM and HPMSM of approximately 60.5% and 58.9% respectively, and product prices of $9.60/kg for HPEMM and $3.72/kg for HPMSM (CPM Group Report, June 2022, forecast price average 2027 to 2031). The actual commodity price for these products may vary.
4. Grade capping has not been applied.
5. Minimal dilution and losses of <1% are expected to occur at the interface between the lower bounds of the tailings cells and original ground due to the uneven surface.
6. Numbers may not add exactly due to rounding.

15.3.2 Mineral Reserve Validation

The Mineral Reserve estimate is reported as a weighted average grade and tonnage based on the search methodology and is not reported within error or confidence limits. Probable Reserves are considered lower confidence with higher margin of error than Proven Reserves. Appropriate modifying factors were considered and applied as part of the conversion from Mineral Resource to Mineral Reserve.

The 2017-2021 metallurgical test programs by CRIMM, BGRIMM, and other laboratories have widely assessed the variability of the various plant mill feed samples, including a total of 25 composite samples representing different variation characters, covering spatial location, grade variation, and particle size variations. A demonstration plant has been planned and under construction.

The capital cost estimates were estimated according to circuit design, general arrangement drawings and material take off estimates. The main equipment costs are from quotations from potential suppliers. Operating costs were estimated by various categories and on circuit and area basis. Operating costs are based on a mining and processing rate of 3,000/t day. Consumable prices were based upon European Union supplies with quotations solicited and received by EMN's director of supply chain, based in the Czech Republic. Both operating cost and capital costs are expected in line with Class 3, compared to FS level cost estimates.

No naturally occurring risks have been identified that may impact the Reserve. Some of the potential product and process technology risks are associated with the Project are:

- Market changes in high-purity manganese products and their acceptance by customers.
- Some metallurgical responses and product assays should be confirmed. More metallurgical test work is required to verify key operating conditions, especially impurity controls.
- Scale up and control of crystallization and purification processes.
- Changes in supply costs.

15.3.3 Mineral Reserve Pricing

HPMSM and HPEMM pricing used for Mineral Reserve estimation is based on price projection assumptions developed by CPM Group, an independent high-purity manganese market research firm. CPM Group's price forecast was based on the following supply and demand dynamics:

- A forecast significant increase in demand of both HPEMM and HPMSM resulting from an estimated increase in the use of manganese in lithium-ion batteries for electric vehicles between 2021 and 2026.
- An estimated project pipeline with six non-Chinese HPMSM projects coming online by 2030, plus additional assumed supply from recycling of batteries and Chinese supply.
- A forecast deficit estimated at 475 kt of Mn equivalent by 2031.

CPM Group forecast HPEMM and HPMSM prices to increase year on year to USD $14,855 and USD $5,399, respectively, in 2035, where prices hold flat until 2040. Following this, a decrease in prices over the remainder of the LOM is forecast, allowing for some market correction and stabilization.

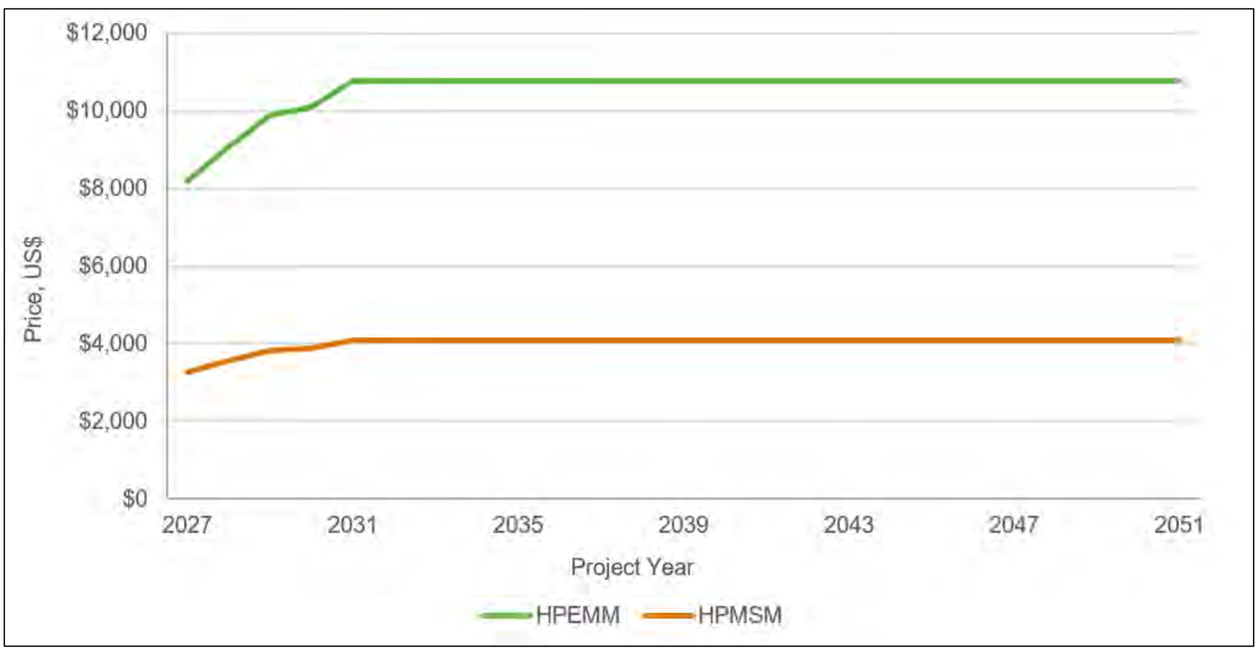
For the purpose of this Feasibility Study, Tetra Tech adopted a lower, risk adjusted price profile with HPEMM and HPMSM prices increasing year on year to USD $10,780 and USD $4,094 respectively in 2031, then holds prices flat until the end of the LOM. Figure 15-1 below shows the LOM price forecast used in the FS.

Tetra Tech used the average prices for HPEMM and HPMSM over the initial CPM forecast period of the first five years of operation from 2027 - 2031 only for Reserve estimation. The prices used are shown in Table 15-3 below.

Table 15-3: Mineral Reserve Pricing

Product	Unit	Value
HPEMM	USD/kg EMM	9.604
HPMSM	USD/kg MSM	3.717

Figure 15-1: Mineral Reserve Pricing



15.3.4 Mineral Reserve Sensitivity

Sensitivity of the Chvaletice Reserves to pricing for both HPEMM and HPMSM pricing is low. The effect of price changes on the Mineral Reserve tonnages is shown below in Figure 15-2 and Table 15-4. Changes in prices and the resulting breakeven grade were modelled using the NSR calculations described in Section 15.2, and the Reserve evaluated against each breakeven grade. The sensitivity spread used in the financial model was applied to the Reserve.

Material within the reserve has an average grade of 7.14%, with a minimum grade of 5.13% and a maximum of 10.51%. This grade distribution is relatively consistent throughout the tailings material as described in Section 14.0

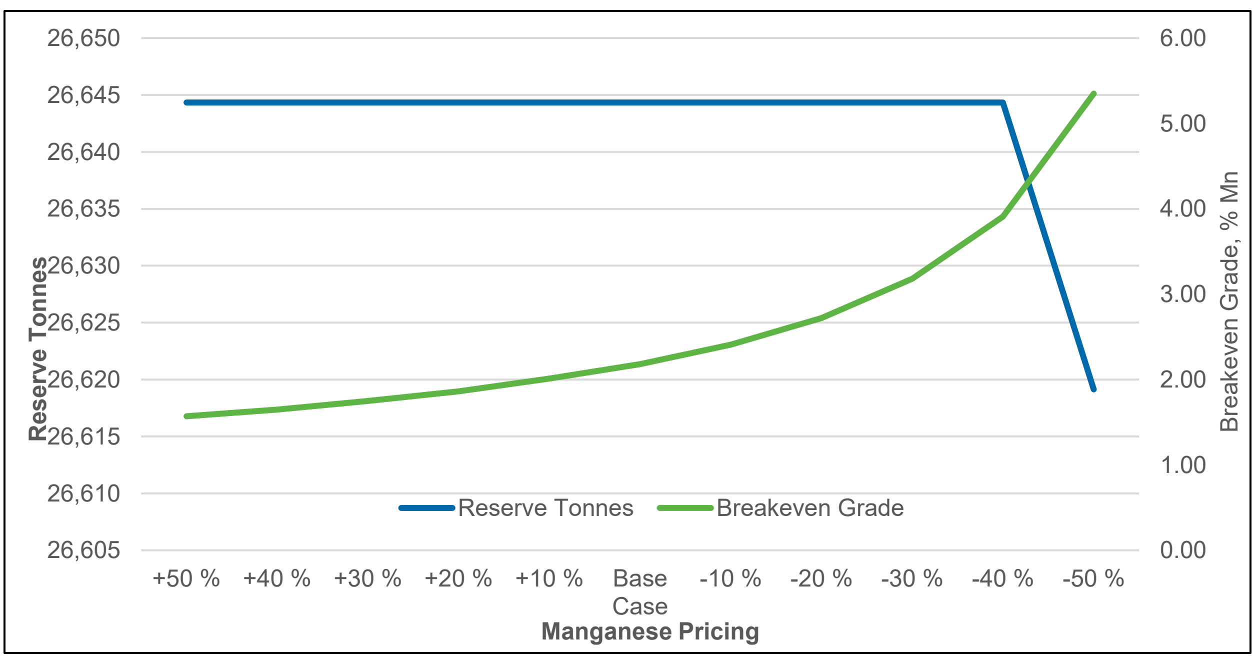
of this study. Due to the consistent nature of the material, the sensitivity of the reserve tonnage available for extraction to both pricing and operating costs is low.

Results of the sensitivity analysis show that the Mineral Reserve is not affected until a 50% drop in HPEMM and HPMSM prices. At this point, the breakeven grade reaches 5.35%, which results in a loss of 25.2 kT or 0.09% of the total Reserve.

Table 15-4: Mineral Reserve Sensitivity to Manganese Pricing

Reserve Sensitivity to Manganese Pricing											
%	+50%	+40%	+30%	+20%	+10%	Base Case	-10%	-20%	-30%	-40%	-50%
EMM US$/t	14,406	13,446	12,485	11,525	10,564	9,604	8,644	7,683	6,723	5,762	4,802
MSM US$/t	5,576	5,204	4,832	4,460	4,089	3,717	3,345	2,974	2,602	2,230	1,859
Breakeven Grade	1.57	1.65	1.75	1.86	2.01	2.18	2.41	2.72	3.18	3.91	5.35
Reserve T ‘000	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,619
% Change	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-0.09%

Figure 15-2: Mineral Reserve Sensitivity to Manganese Price

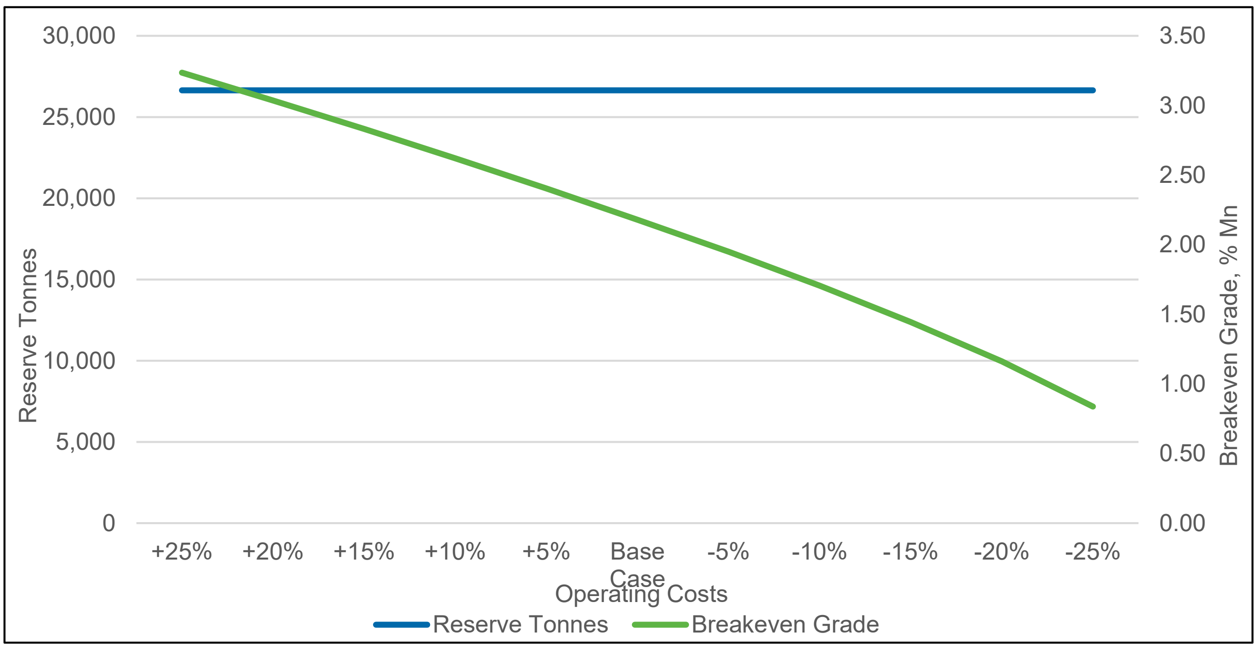


Reserve sensitivity to on-site operating costs is similar, with no change to the Mineral Reserve tonnage over a spread of +25% to -25% in operating costs, shown in Table 15-5 and Figure 15-3 below.

Table 15-5: Mineral Reserve Sensitivity to On-Site Operating Costs

Reserve Sensitivity to Operating Costs											
%	+25%	+20%	+15%	+10%	+5%	0	-5%	-10%	-15%	-20%	-25%
OPEX	95.98	92.14	88.30	84.46	80.62	76.78	72.94	69.10	65.26	61.42	57.59
Breakeven Grade	3.24	3.04	2.83	2.62	2.41	2.18	1.95	1.71	1.45	1.16	0.84
Reserve T '000	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,644	26,644
% Change	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 15-3: Mineral Reserve Sensitivity to On-Site Operating Costs



15.3.5 Discussion of Mineral Reserves

The CP is not aware of any mining, processing, metallurgical, infrastructure, economic, marketing, legal, environmental, social, and governmental modifying factors not discussed in this report that could materially affect the Mineral Reserve Estimate.

16.0 MINING METHODS

16.1 Introduction

The CMP Mineral Reserves, as described in Section 15.0, consist of three tailings cells located near the town of Chvaletice, roughly 84 km by road east of Prague, Czech Republic.

The tailings cells will be mined by conventional open pit mining methods that will have minimal disturbance to the project site's surroundings, promoting both a safe and environmentally favourable project. Tetra Tech has designed a mining operation to produce 3,000 t/day of tailings feed from the Chvaletice deposit over a life of 25 years. Tailings will be extracted by truck and shovel equipment from each cell using benches in parallel mining cuts. The layout of both the site and tailings cells allow for a mining operation which is flexible in terms of ramp placement on the cells throughout the life of mine.

Figure 16-1 below illustrates the location and layout of the three tailings cells at the CMP that will be mined.

Figure 16-1: Plan View of the Three Tailings Cells at the CMP

16.2 Proposed Tailings Extraction Methods

16.2.1 Mine Design Criteria

Mining the tailings cells of the CMP will be completed during two eight-hour shifts, weekdays in daylight hours to minimize community disturbance. Mining operations will be done 250 days a year, 5 days a week, excluding holidays. Mined tailings will be hauled to the plant feed storage and pulping area that will also be used as a temporary stockpile for the tailings and residue. The main mine design criteria were developed based on the project and regulatory requirements and are shown in Table 16-1 below.

Table 16-1: Mine Design Criteria

Parameter	Unit	Value
Operating Days per Year	days	250
Shifts per Day	shifts	2
Hours per Shift	hours	8
Allowable Work Hours	--	6 a.m. – 10 p.m. (summer) 5 a.m. – 9 p.m. (winter)
Operating Days per Week	days per week	5 days per week
In-Plant Maximum Storage 5-day Capacity for Raw Tailings	t	18,000
In-Plant Maximum Storage 5-day Capacity for Residue	t	17,000
Plant Throughput Rate	t per year	700,000 – 1,250,000
Maximum Ramp Gradient	%	12
Double Lane Road Width excluding berms	m	11.4
Single Lane Road Width excluding berms	m	7.6
Ramp Berm Height (Articulated Trucks)	m	1.0
Mining Bench Height (Single Bench)	m	3
Overall Slope Angle	degrees	13° - 15°
Bench Face Angle	degrees	45°
Minimum setback distance from tailings cell crest for residue placement	m	12
Ore Bulk Density (dry)	t/m^3	1.51
Topsoil Density (dry)	t/m^3	2.00
Average In-situ Moisture Content	%	C1 = 21.2, C2 = 21.5, C3 = 20.7

The 26.6 Mt of tailings will be processed at the plant at a variable throughput rate. Mine design criteria are driven by the geotechnical analysis of the tailings to meet required factors of safety for design and operation.

16.2.2 Bench Design

Based on the results of the geotechnical analysis, each of the tailings cells will be mined by an excavator loading haul trucks on 3-m high benches with a 12-m bench width and a bench face angle of 45 degrees. A haul ramp to the crest of each cell will be developed for access for the excavator to mine the benches from the top to the bottom. The bench height of 3 m was chosen as a conservative bench height that could be achieved in all areas of the cells with depressurization of the tailings. The 12-m bench width with the 45-degree face angle will allow slumping of the saturated tailings on the working face without causing a multi-bench failure.

Figure 16-2: CMP Bench Design for Cell 3, Looking North

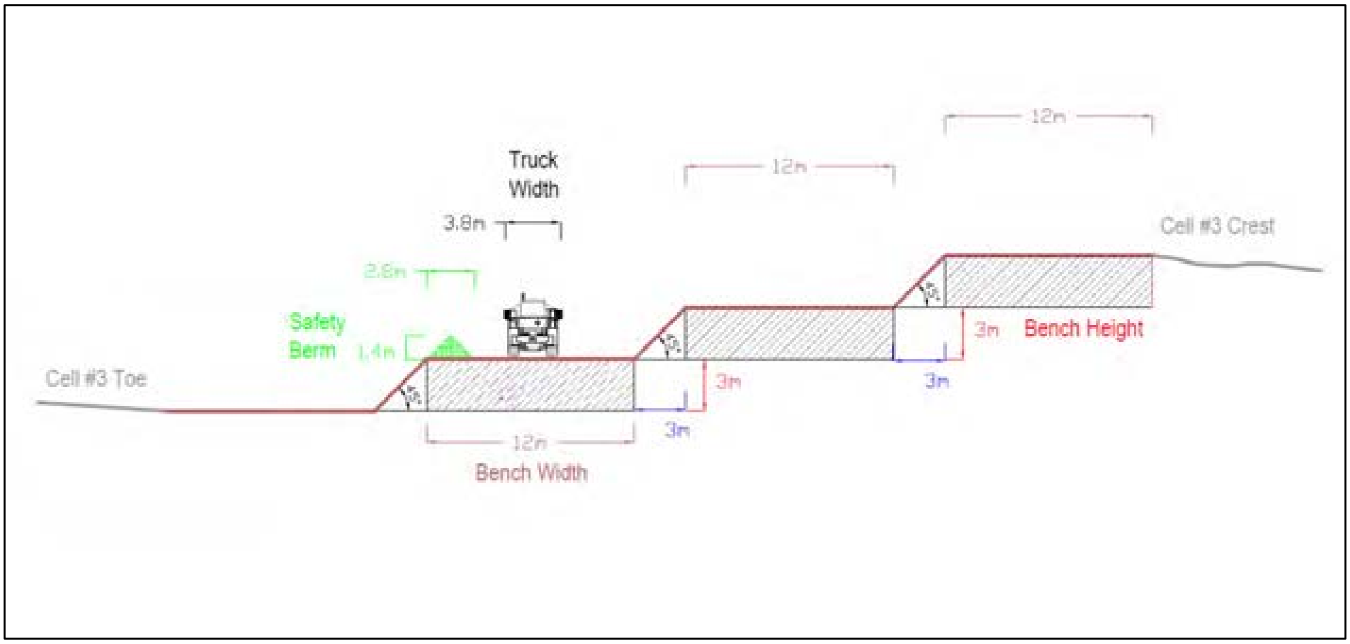
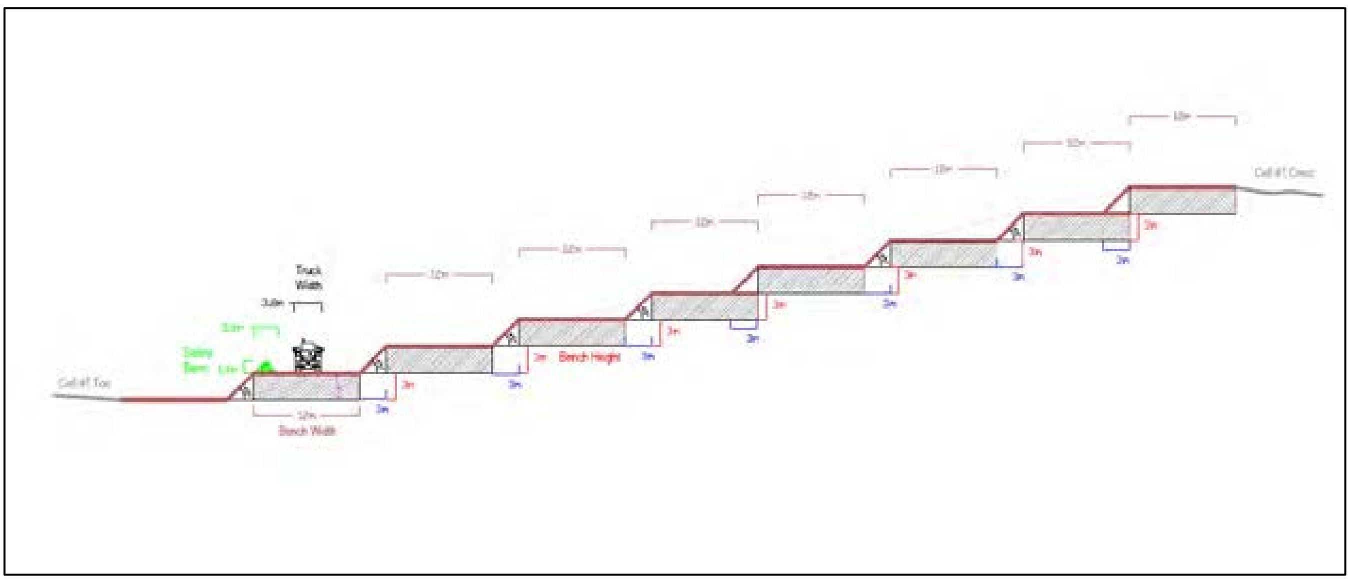


Figure 16-3: CMP Bench Design for Cell 1 and 2, Looking North



16.2.3 Haul Road and Ramp Design Parameters

The primary haul road for the CMP will run from the plant feed storage area between Cells 1 and 2 to allow access to all three tailings cells, as shown in Figure 16-4. The primary haul road will be extended between Cells 1 and 3 after Cell 3 is mined. Roads will be constructed using all-fill techniques, utilizing gravel and overburden that will be removed from the plant site, to achieve design alignment and grade. The roads will be graded as required and dust control will be done using water trucks. All roads on site are considered private roads and access will be controlled by operation.

The main haul road is designed to be double lane with an overall road allowance of 18 m in width, including berms and ditching. The main haul road ditch will have gradient to allow for gravity flow of the contact water to the collection sump. Haul ramps will be designed single lane with an overall road allowance of 14.2 m in width. Ramps are designed with a maximum grade of 12% and a ditch to contain contact water. Figure 16-4 highlights the location of the main haul road. A sump pump at the end of the main haul road will be used to pump the contact water through a 4” pipe to another sump located between Cells 1 and 2. Gravity flow will be used to transport the collected water to the collection point at the stockpile.

The selected road allowance for double lane is accommodating three times the width of the largest truck. The selected road allowance for single lane is accommodating two times the width of the largest truck. All roads have additional room for drainage ditches and safety berms as summarized in Table 16-2 below.

Table 16-2: In-Pit Haul Road Design Parameters

Parameter	Unit	Value
Truck (41 t) operating width	m	3.8
Double Lane – 3 x truck width	m	11.4
Single Lane – 2 x truck width	m	7.6
Berm height (¾ tire height)	m	1.4
Berm width	m	2.8
Ditch Width	m	1
Total Allowance Single Lane	m	14.2
Total Allowance Double Lane	m	18

The haul road will be capped with 50 mm minus gravel and 200 mm minus gravel, and graded regularly to keep water drained away from the roadway. The haul road profiles are shown in Figure 16-5 and Figure 16-6 below.

Figure 16-4: Main Haul Road Location

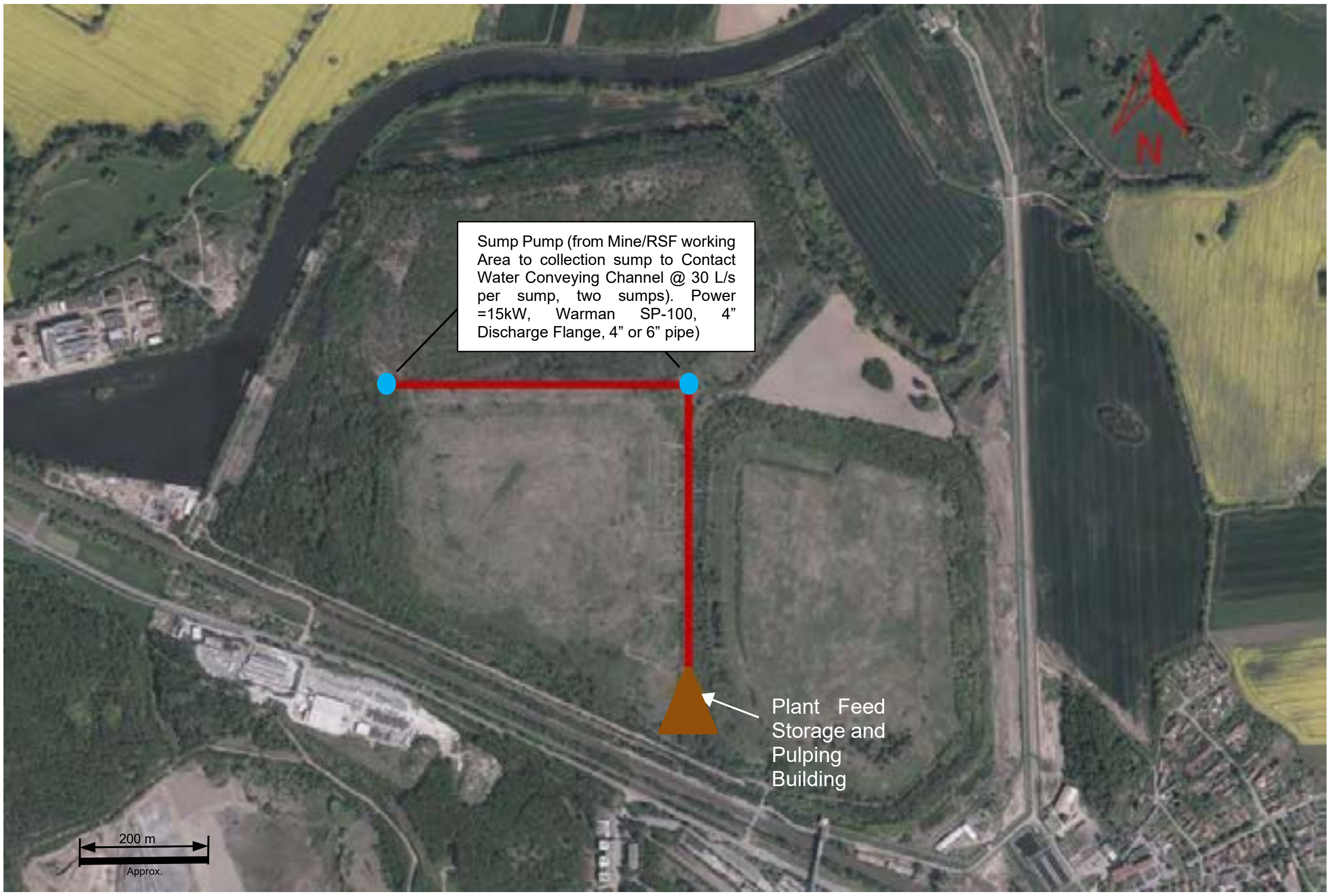


Figure 16-5: Single Lane Ramp Profile

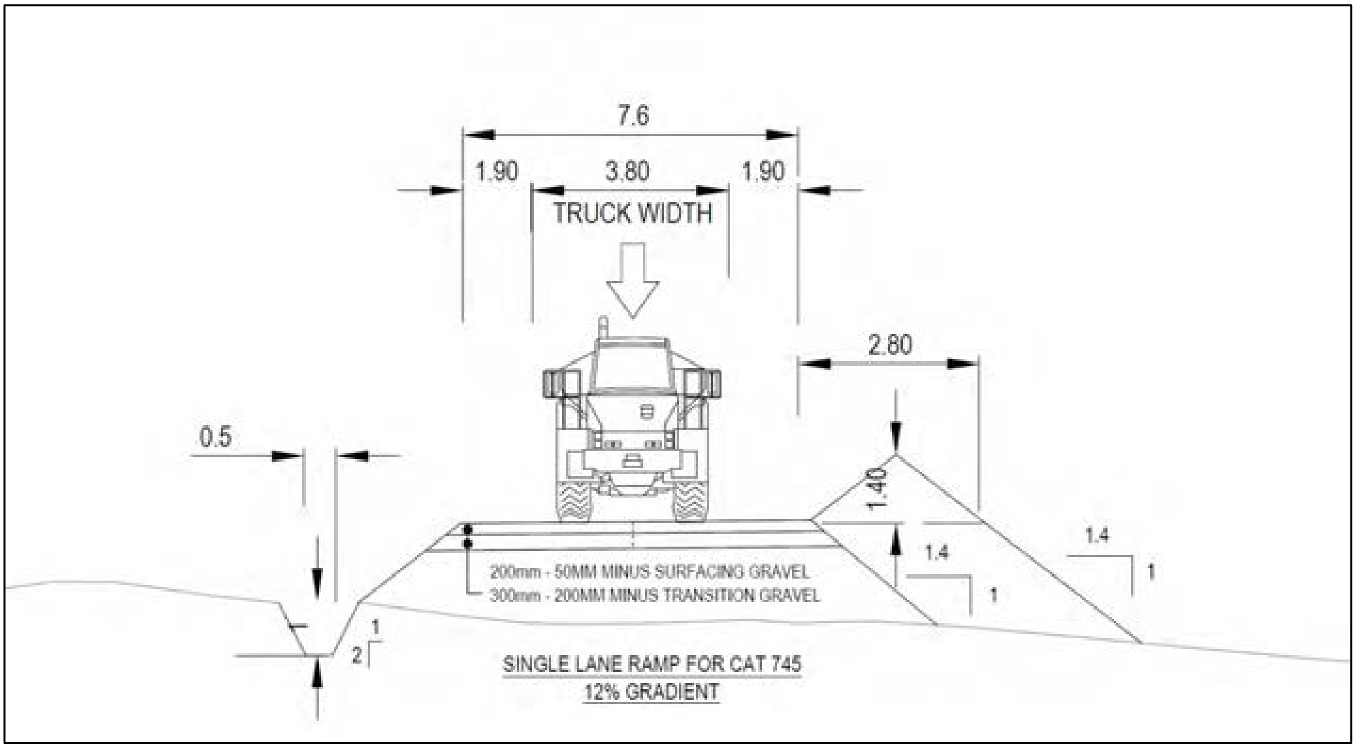
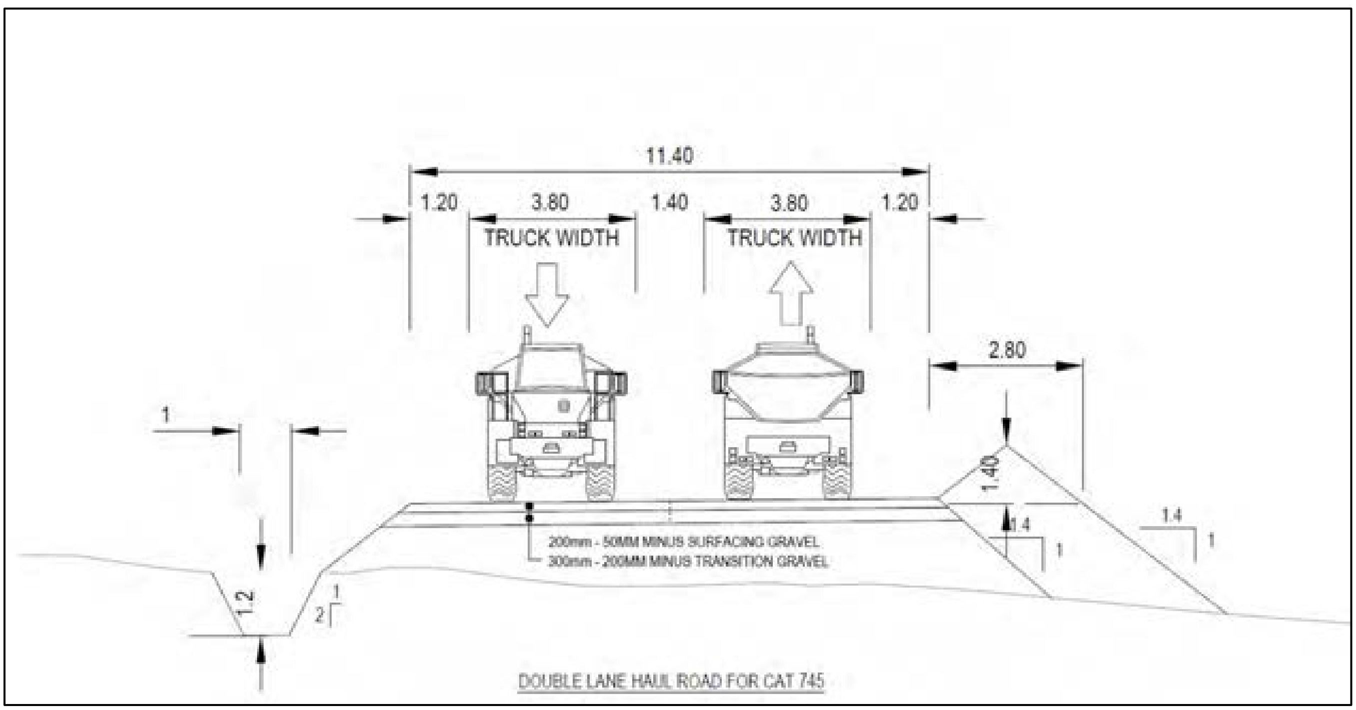


Figure 16-6: Double Lane Haul Road Profile



16.3 Tailings Extraction Sequencing

The primary drivers of the production schedule are mining the tailings to meet the plant production targets and advancement of the toe of the tailings material to allow storage capacity for residue placement. Topsoil growth on the cells will be removed prior to mining the tailings.

Tailings are extracted from the cells and transported by truck, where they are unloaded into a tailings receiving dumping pocket and conveyed to the tailings storage stockpile in the plant feed and tailings storage and pulping building and then processed to recover manganese. The process plant produces NMT and LR as a waste product. This residue is collected from the process plant and conveyed to the NMT/LR (residue) temporary storage area within the plant feed and tailings storage and pulping building.

The residue will then be transported by truck back to the tailings cell area. The residue is deposited in the original footprint of the tailings cells, in the area that has already been mined out. Once the trucks have unloaded the residue material, they return to the active mining bench to collect tailings material to return to the plant feed and tailings storage and pulping building again in a continuous cycle. Tailings extraction will start from Cell #3, followed by Cell # 1 and Cell #1 sequentially.

16.3.1 Pre-production Plan

Construction of the main haul road from the plant feed storage area to the toe of Cell 3 will be undertaken before mining starts. Overburden from the plant site will be used as the base of the main haul road with a gravel capping. Haul ramp access to the crest of the advancement for Year 1 in Cell 3 will be developed, as well as preparation of the starter cell for the residue placement.

16.3.2 Topsoil Removal and Progressive Reclamation

As part of the mine sequence, removal of the topsoil cover on each of the tailings cells will be completed annually. The topsoil volumes for each of the cells is shown in Table 16-3.

Table 16-3: Topsoil Thickness and Volume

Cell	Area	Estimated Topsoil Thickness	Estimated Topsoil
#	m^2	m	m^3
1	334,660	1.5	501,990
2	396,563	1.5	594,845
3	323,824	0.5	148,052

The topsoil cover on each of the cells limits infiltration to the tailings cells, so topsoil removal will be limited to only stripping the topsoil from the crest advancement of each year of mining. Each of the tailings cells will be stripped and grubbed by excavators and haul trucks with the topsoil organics being stockpiled for progressive reclamation as the residue placement achieves final crest. Any small trees in the organic removal will be chipped and removed from the topsoil. Figure 16-7 shows the topsoil stockpiles that will be used when mining the cells.

Figure 16-7: Temporary Topsoil Stockpile Locations

16.3.3 Stockpile for Tailings and Residue

The plant feed storage and pulping building will be located to the south of the tailings cells as shown in Figure 16-4. Haul trucks will dump tailings into a hopper at the site for a stockpile feed for the process plant. Filtered residue will also be stockpiled at the building, where wheel loaders will load filtered residue into haul trucks for transport back for residue placement in the mined-out cells. Full details of the plant preparation site are included in Section 18.0.

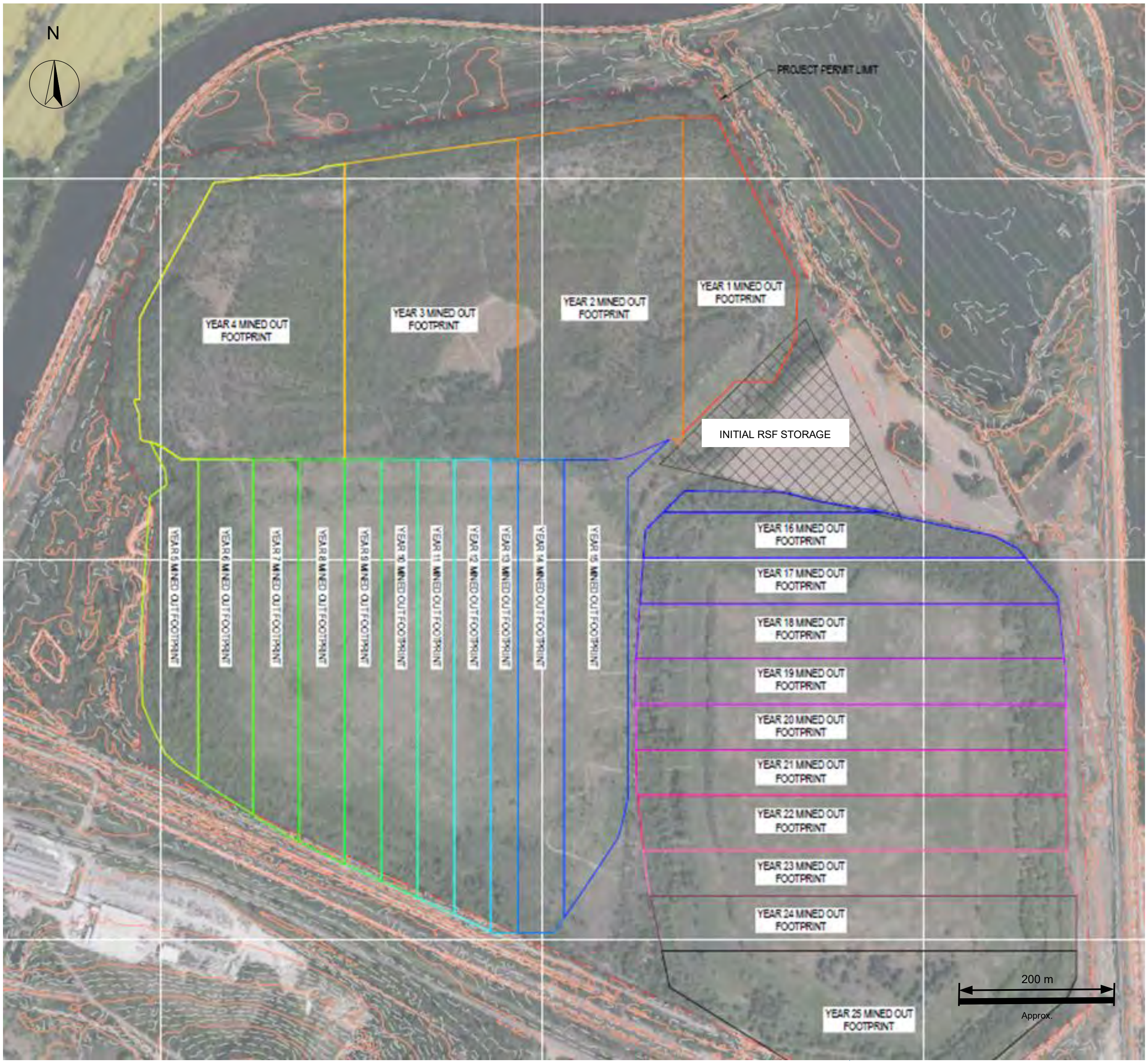
16.3.4 Tailings Mining Sequence

Figure 16-8 shows the mined-out footprint of the mine sequence. The CMP has a 25-year production schedule to mine and process the 26.6 Mt of tailings. The mine sequence for the tailings will begin with Cell 3. Cell 3 has a large ground footprint relative to the amount of time it will take to fully mine Cell 3. Cell 3 is also the shortest of the three cells which will allow rapid advance. As such, Cell 3 will be mined first in order to increase the available footprint for residue construction. Table 16-4 shows the CMP mining sequence.

Table 16-4: Mining Sequence

Cell #	Years to Complete Mining
3	4
1	10.5
2	10.5

Figure 16-8: Plan View of Annual Mined-Out Footprint



The processing plant's targeted production rate is driven by HPEMM production targets. There is a planned period of reduced throughput in the first year of operation to allow for plant commissioning. The grade of the tailings material is relatively consistent, with the total manganese grade ranging from a minimum of 6.58% in Year 22 to a maximum of 8.72% in Year 14. Cell 3 will be mined from E-W, with Cell 1 being mined from W-E. Cell 2 will be mined from N-S with the advancement of the tailings toe the primary focus to provide maximum residue storage capacity. Table 16-5 below shows the tailings processing and residue placement schedule for the CMP.

Table 16-5: Tailings and Residue Schedule

Schedule Year	Topsoil Volume, t	Dry Tailings to Plant, t	Residue to RSF (dry tonnes), t	Total Manganese, %	Contained Manganese, t	Estimated HPEMM Recovery, %	Estimated HPEMM Produced, t
1	57,559	718,131	746,856	7.98	57,285	62.2	35,615
2	66,995	1,112,500	1,157,000	7.41	82,489	60.6	50,002
3	72,027	1,106,900	1,151,176	7.44	82,384	60.7	50,004
4	54,414	1,070,250	1,113,060	7.63	81,675	61.2	50,009
5	120,724	1,012,138	1,052,623	7.96	80,516	62.1	50,011
6	86,637	1,040,279	1,081,890	7.81	81,202	61.7	50,109
7	103,680	1,079,722	1,122,911	7.61	82,212	61.2	50,298
8	89,478	1,096,946	1,140,824	7.43	81,516	60.7	49,450
9	63,913	1,016,181	1,056,828	7.96	80,914	62.1	50,274
10	75,275	1,010,000	1,050,400	7.97	80,467	62.1	50,006
11	72,434	1,016,139	1,056,784	7.89	80,143	61.9	49,632
12	53,971	1,016,685	1,057,353	7.91	80,376	62.0	49,817
13	28,406	906,815	943,087	8.17	74,104	62.7	46,452
14	17,043	833,643	866,989	8.72	72,662	64.1	46,545
15	17,043	1,055,843	1,098,077	7.40	78,080	60.6	47,285
16	110,569	1,085,131	1,128,536	7.24	78,542	60.1	47,206
17	77,141	1,129,690	1,174,877	7.04	79,582	59.5	47,373
18	77,141	1,167,828	1,214,541	6.84	79,880	58.9	47,050
19	92,569	1,236,713	1,286,181	6.60	81,562	58.1	47,407
20	78,427	1,195,889	1,243,724	6.75	80,735	58.6	47,328
21	77,141	1,184,332	1,231,705	6.80	80,479	58.8	47,290
22	78,427	1,235,765	1,285,195	6.58	81,302	58.1	47,215
23	92,569	1,183,309	1,230,641	6.81	80,561	58.8	47,371
24	82,284	1,136,531	1,181,992	6.92	78,672	59.2	46,537
25	87,427	996,988	1,036,867	7.64	76,130	61.2	46,623
Total	**1,833,295**	**26,644,344**	**27,710,118**	**--**	**--**	**--**	**1,196,910**
Maximum	**120,724**	**1,236,713**	**1,286,181**	**--**	**--**	**--**	**50,298**

Figure 16-9 to Figure 16-14 below show cross section views of the tailing cell benches at different periods.

Figure 16-9: Cross Section Locations

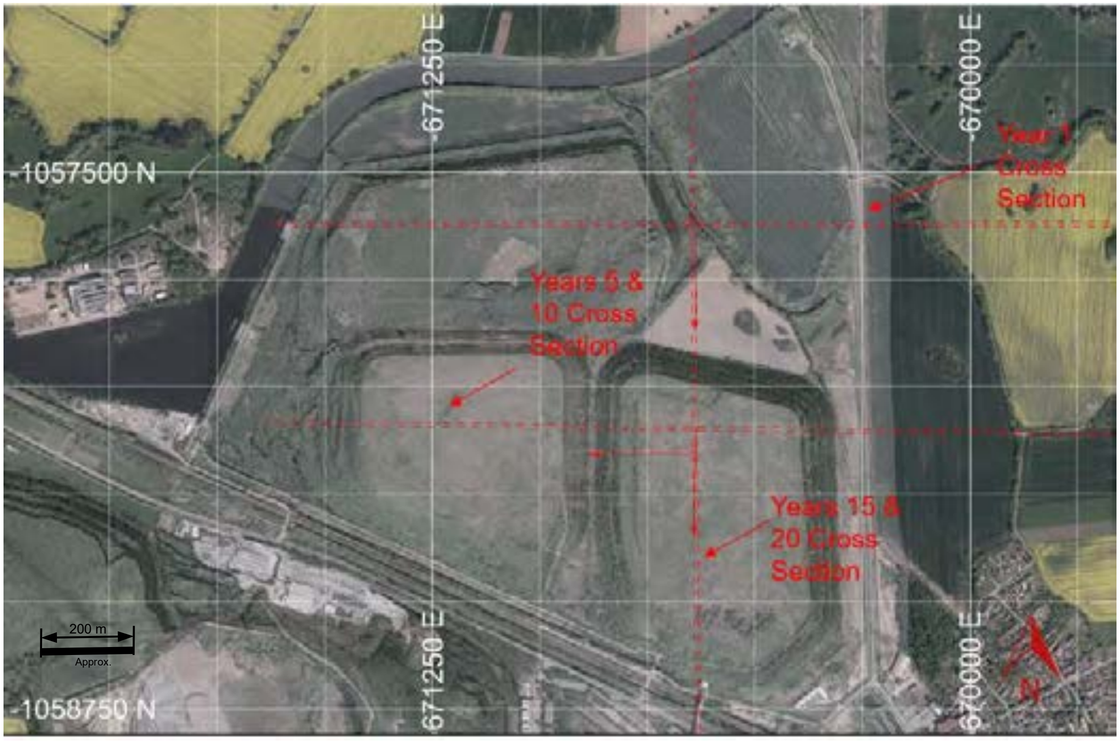


Figure 16-10: End of Year 1 – Section View of Benches, Looking South

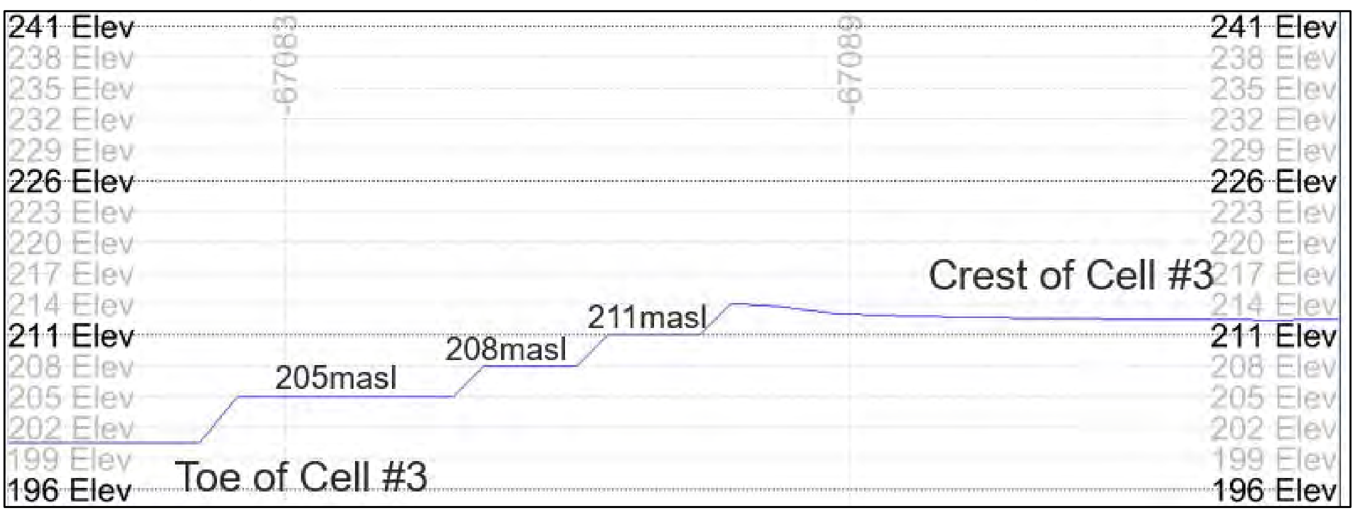


Figure 16-11: End of Year 5 – Section View of Benches, Looking South

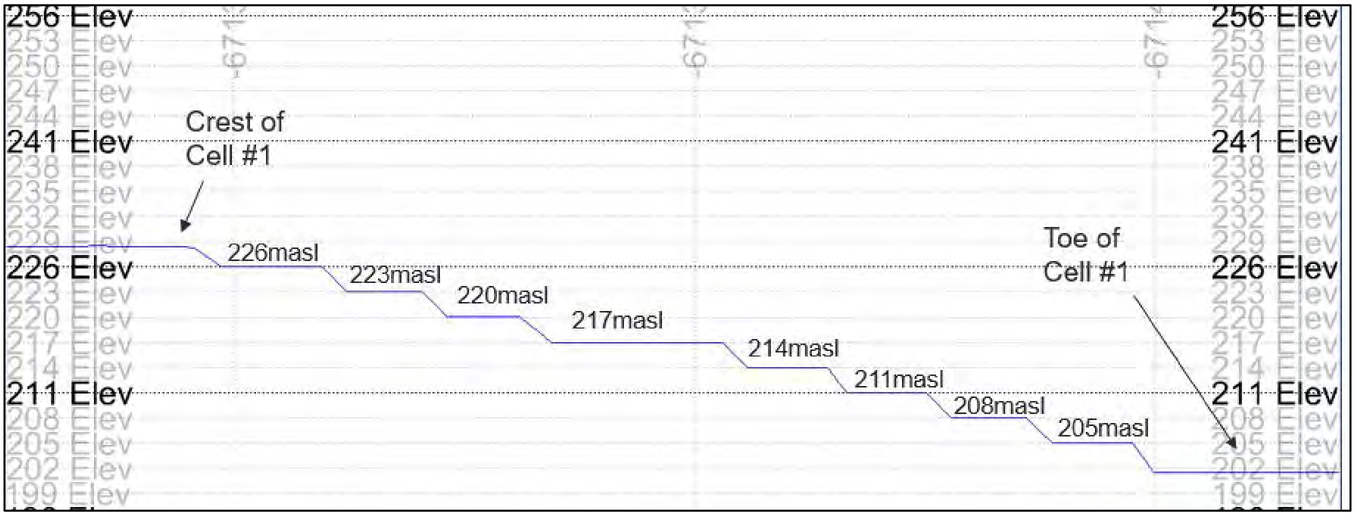


Figure 16-12: End of Year 10 – Section View of Benches, Looking North

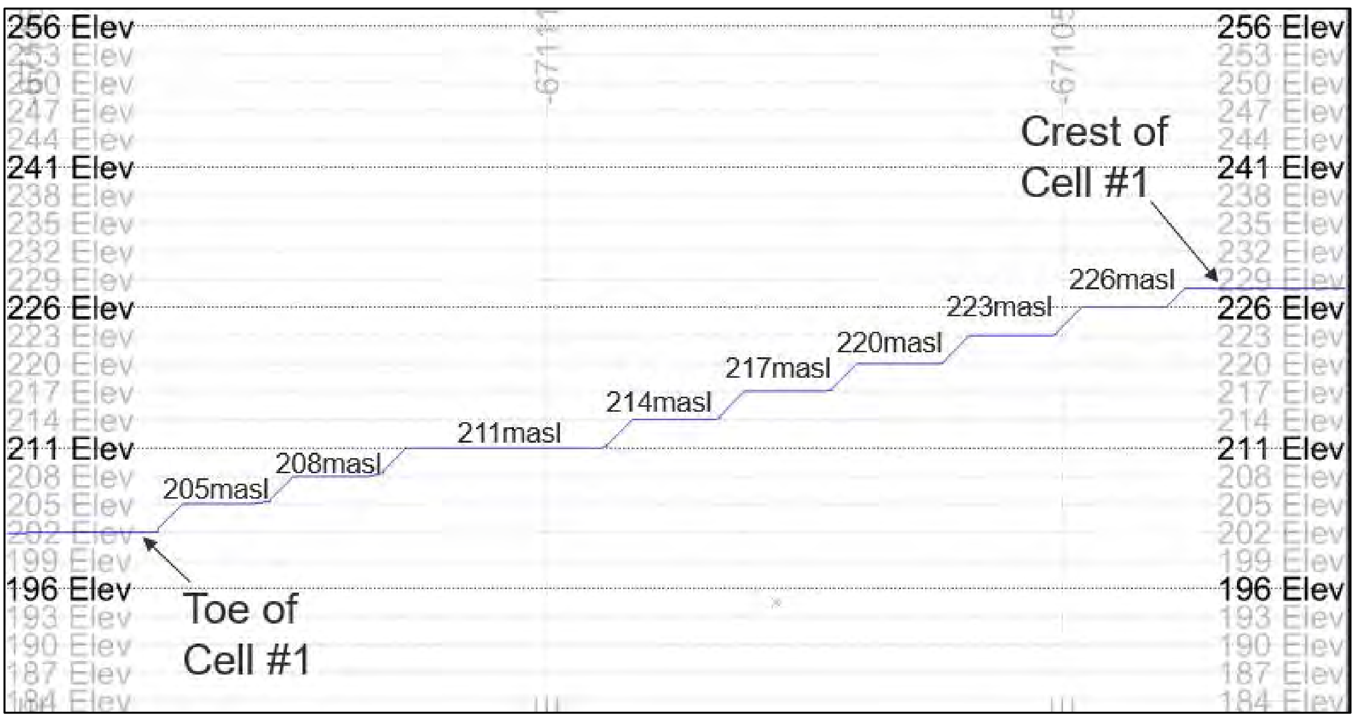


Figure 16-13: End of Year 15 – Section View of Benches, Looking East

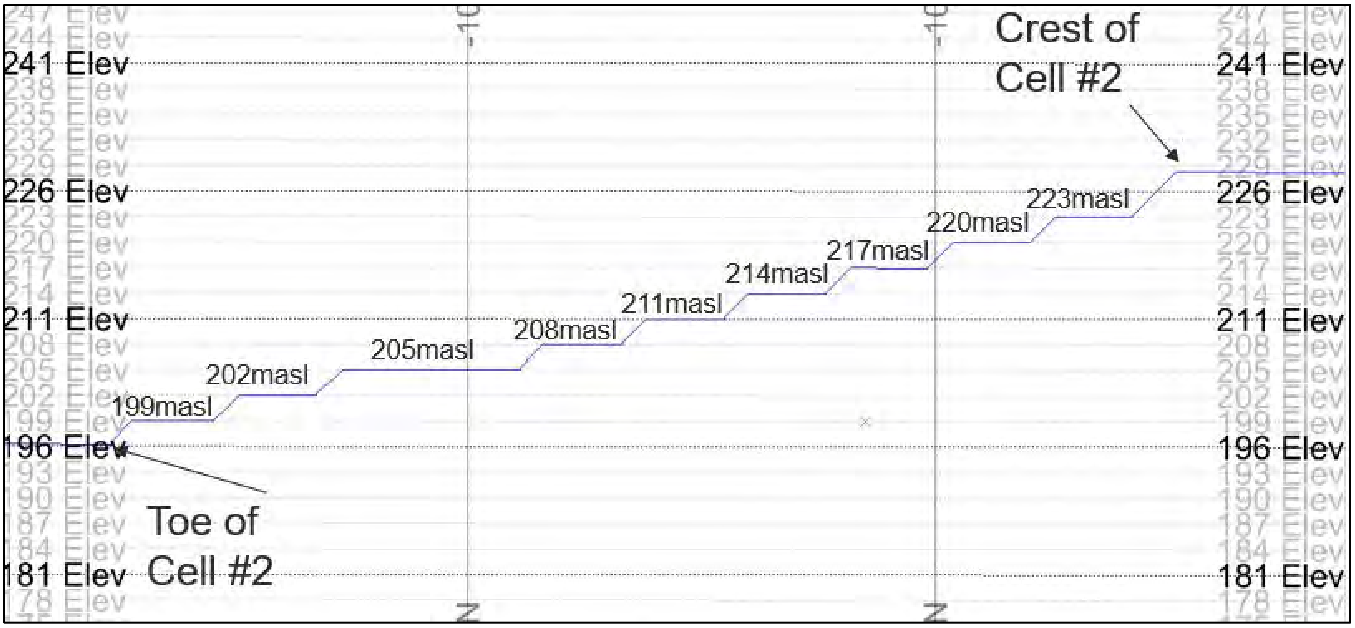
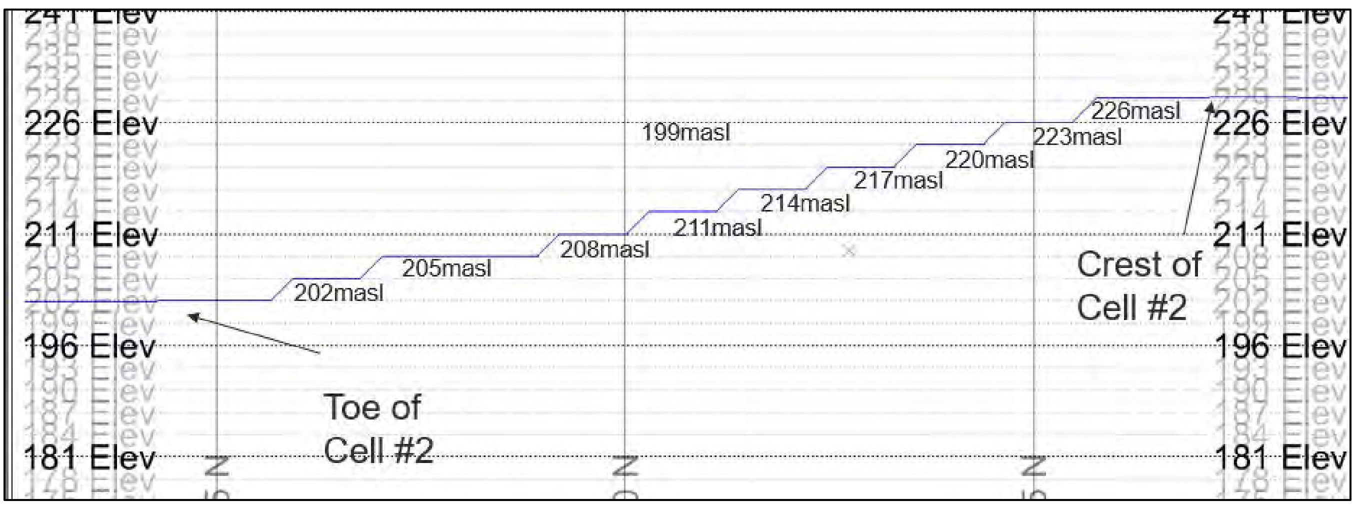


Figure 16-14: End of Year 20 – Section View of Benches, Looking East



16.4 Residue Placement and Haul Road Access

Part of the haulage cycle will be transportation of filtered residue from the stockpile located between existing Tailings Cells 1 and 2. The interim stages of tailings extraction, residue placement , and haul roads are shown in Figure 16-15 through Figure 16-21 below.

Haul ramps will be cut from the existing tailings by the excavator as the crest advances. A single lane haul ramp will be developed on the south side of Cell 3 for tailings extraction. Haul ramps in Cell 3 will be single lane width with a berm at a 12% gradient for an overall length of 92 m. As mining advances into Year 3, a separate haul ramp will be developed on the north side of Cell 3 to allow the excavator to work either north to south or south to north to permit the saturated material in Cell 3 to depressurize as the mining face advances.

The management of contact water from the tailings excavation area and the Residue Storage Facility (RSF) will be integrated during mining operations. Ongoing grading of the benches during operation will direct any contact water on the active mining bench to the haul ramp ditches. The contact runoff and seepage from the active mining face and RSF will be collected through collection ditches incorporated into the haul road design.

Sumps will collect contact water at the base of haul ramps and ditches running along the main haul road will transport contact water to the mine site water collection tank at the stockpile.

Cells 1 and 2 are, on average, 400 m crest to crest, so single lane haul ramps at a 12% gradient with an overall length of 218 m from toe to crest will be cut into existing tailings. Haul ramps will be developed on both sides of the mining advance to allow the excavator to work from both sides for depressurization of saturated material in the centre of the cells.

16.4.1 Tailings Extraction and Residue Placement Haul Cycles

Empty haul trucks will be filled with residue at the plant feed storage and pulping building, and will travel loaded down the double lane haul road. Loaded haul trucks will drive up the single lane haul ramps to dump the residue and then travel empty down the haul ramp and drive to be loaded with tailings on the mining bench. After being loaded with tailings, haul trucks will travel loaded down the single lane haul ramp and then travel back loaded to the plant feed storage building on the double lane haul road. The haul cycle at different stages of the mine life is shown in Figure 16-15 to Figure 16-18 below.

Figure 16-15: Tailings Extraction and Residue Development Year 2

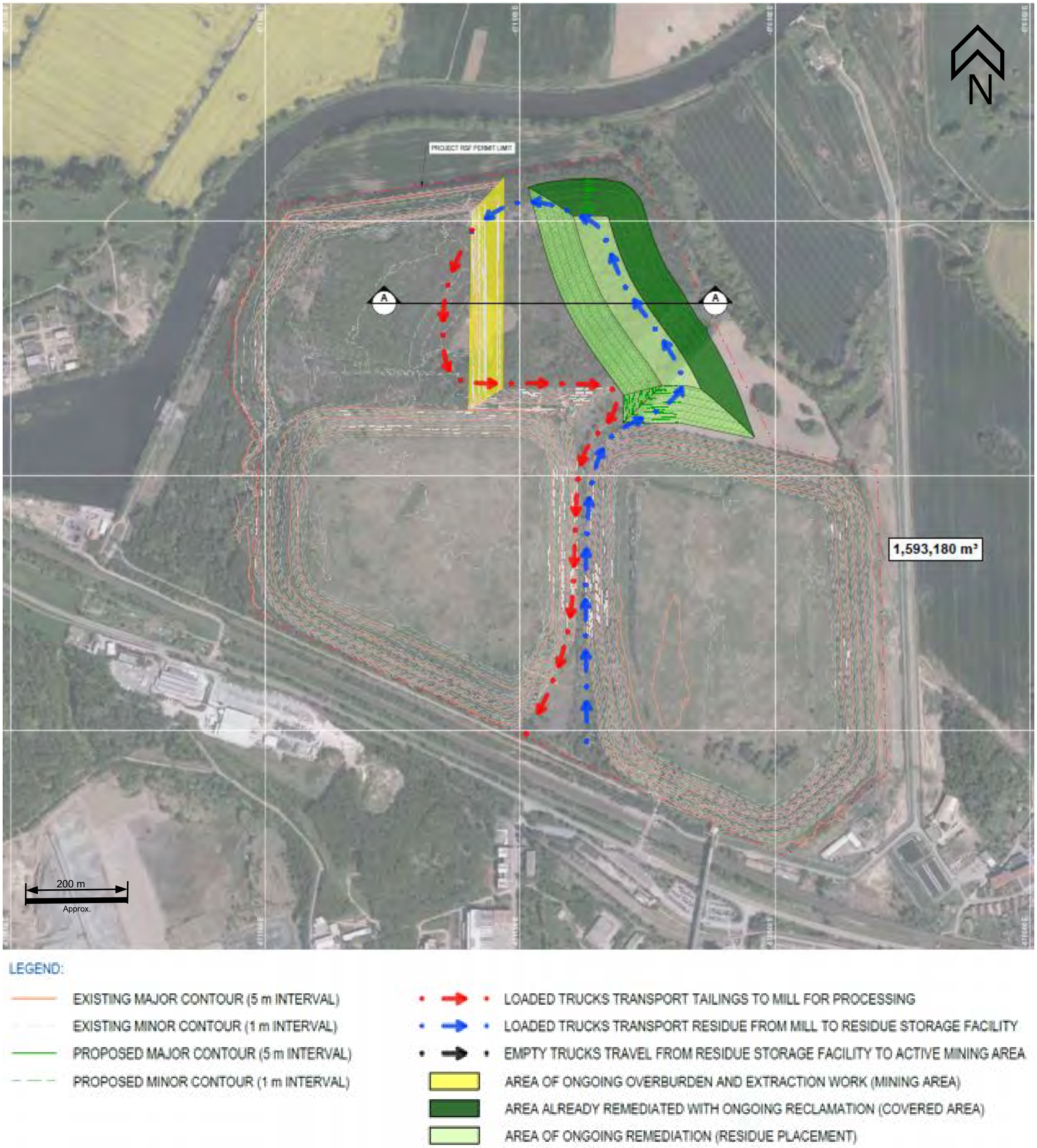


Figure 16-16: Tailings Extraction and Residue Development Year 10

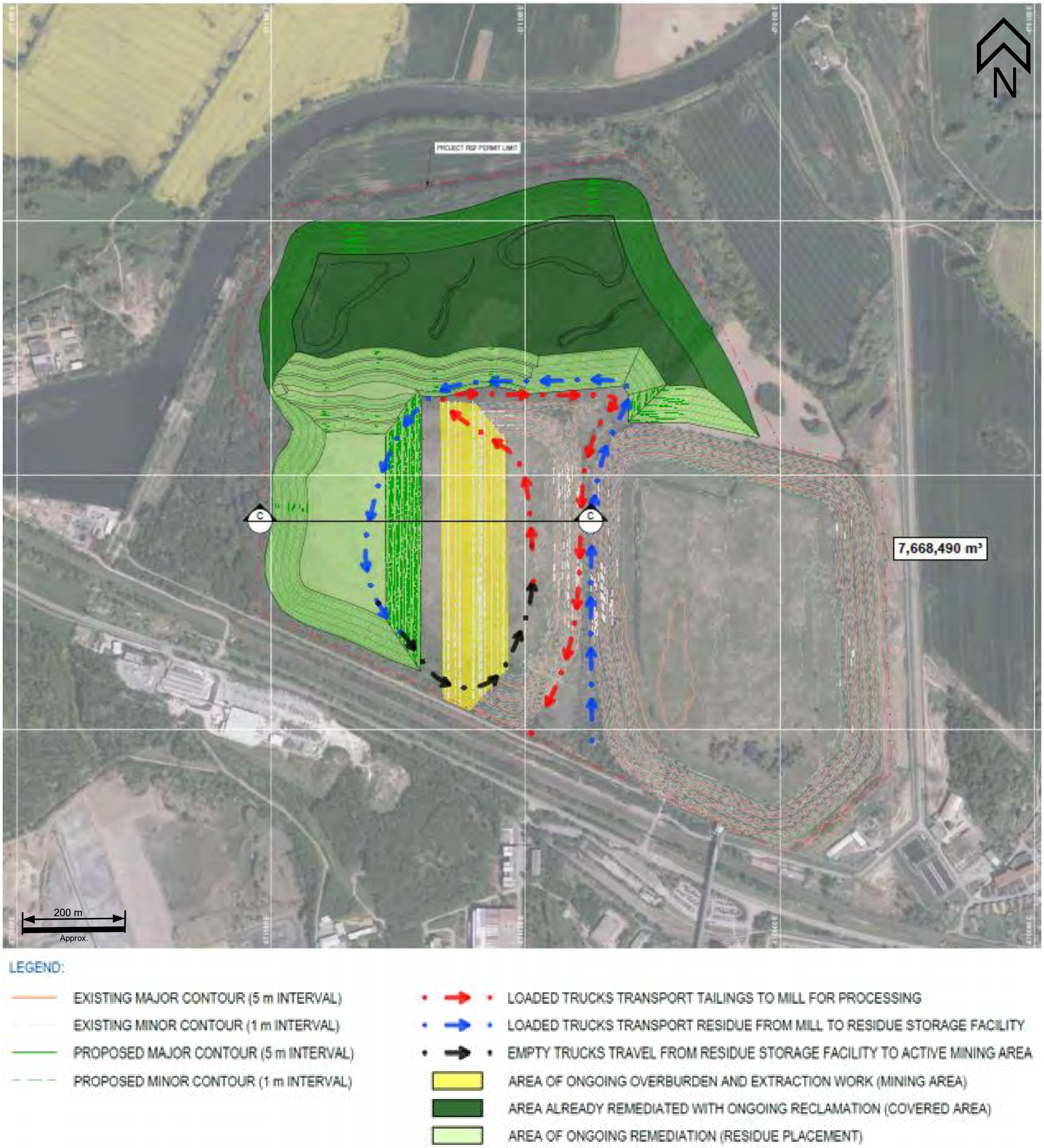


Figure 16-17: Tailings Extraction and Residue Development Year 15

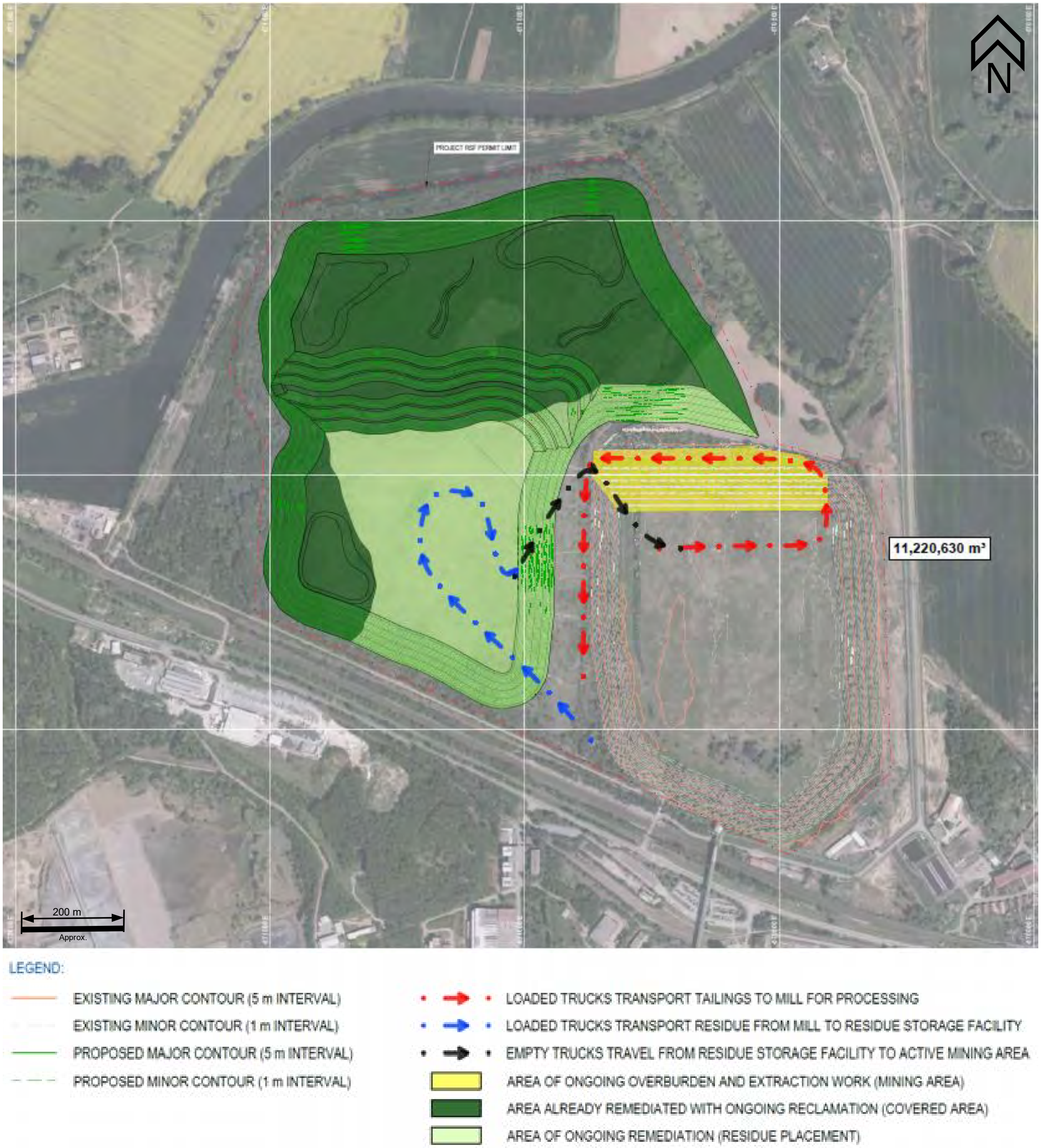


Figure 16-18: Tailings Extraction and Residue Development Year 20

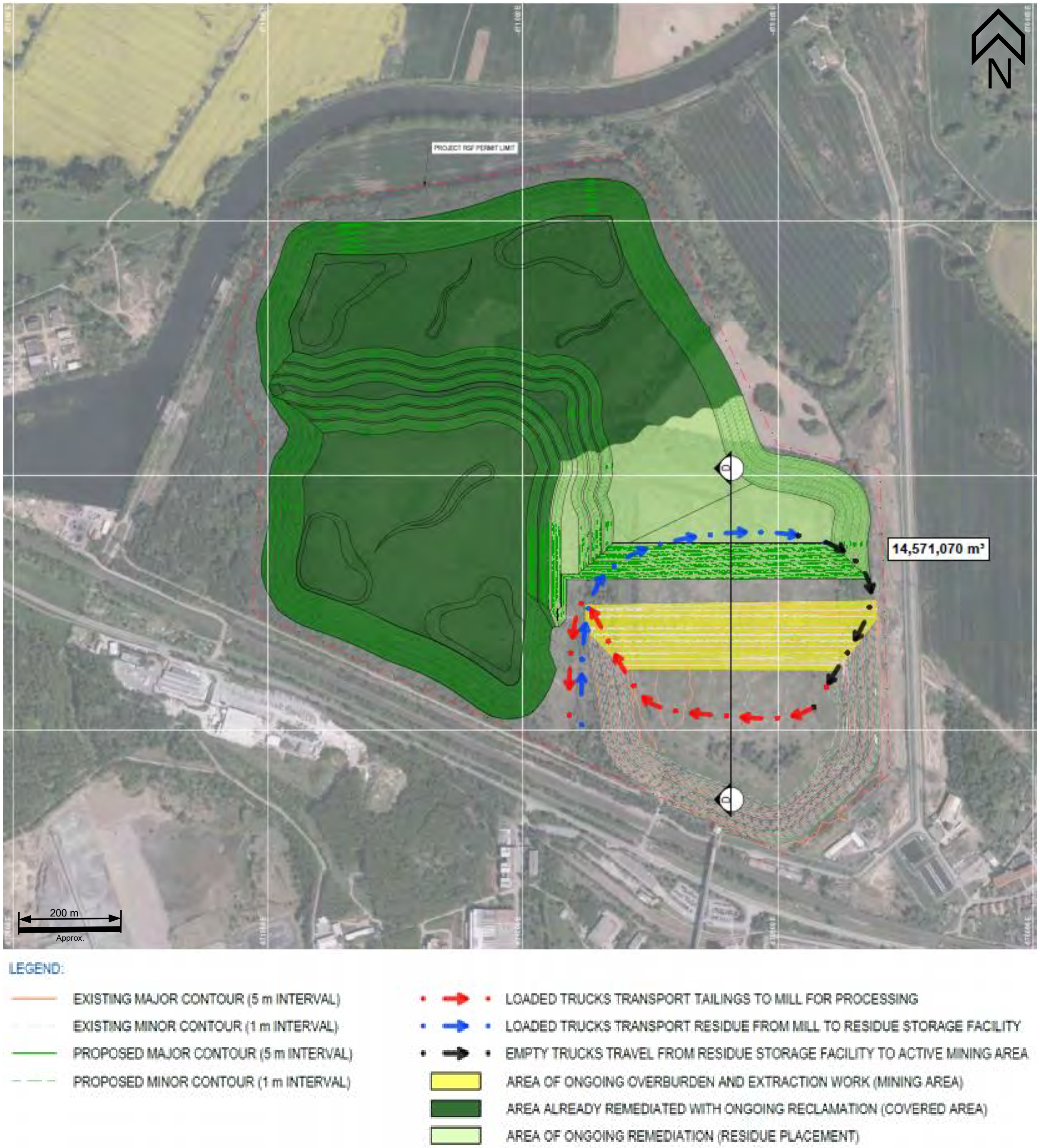
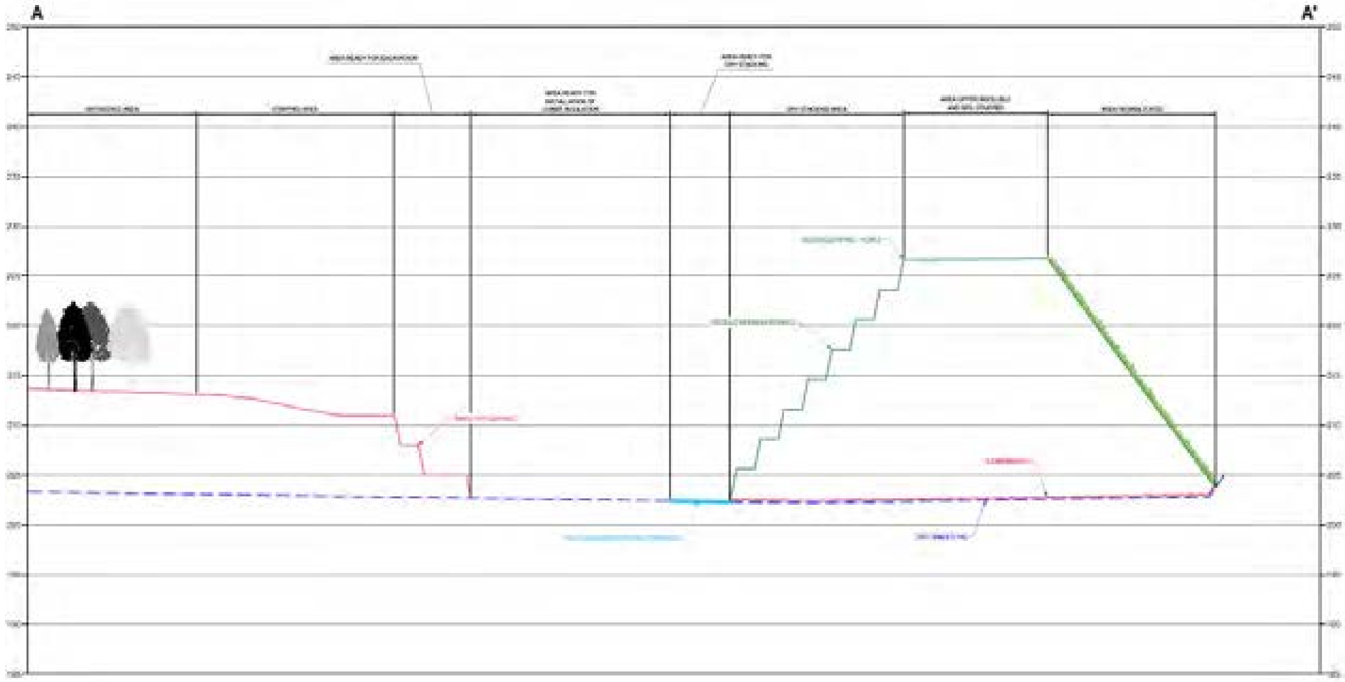
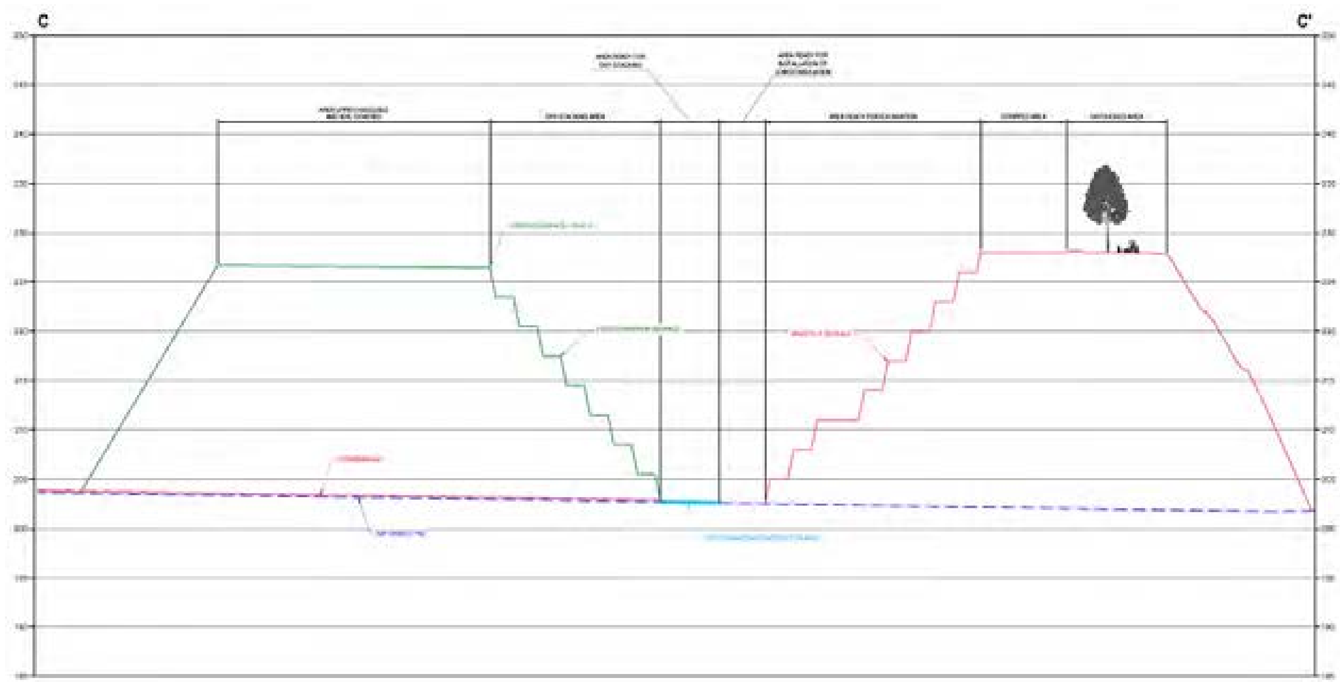


Figure 16-19: Tailings Extraction and Residue Development Section A-A' Looking North



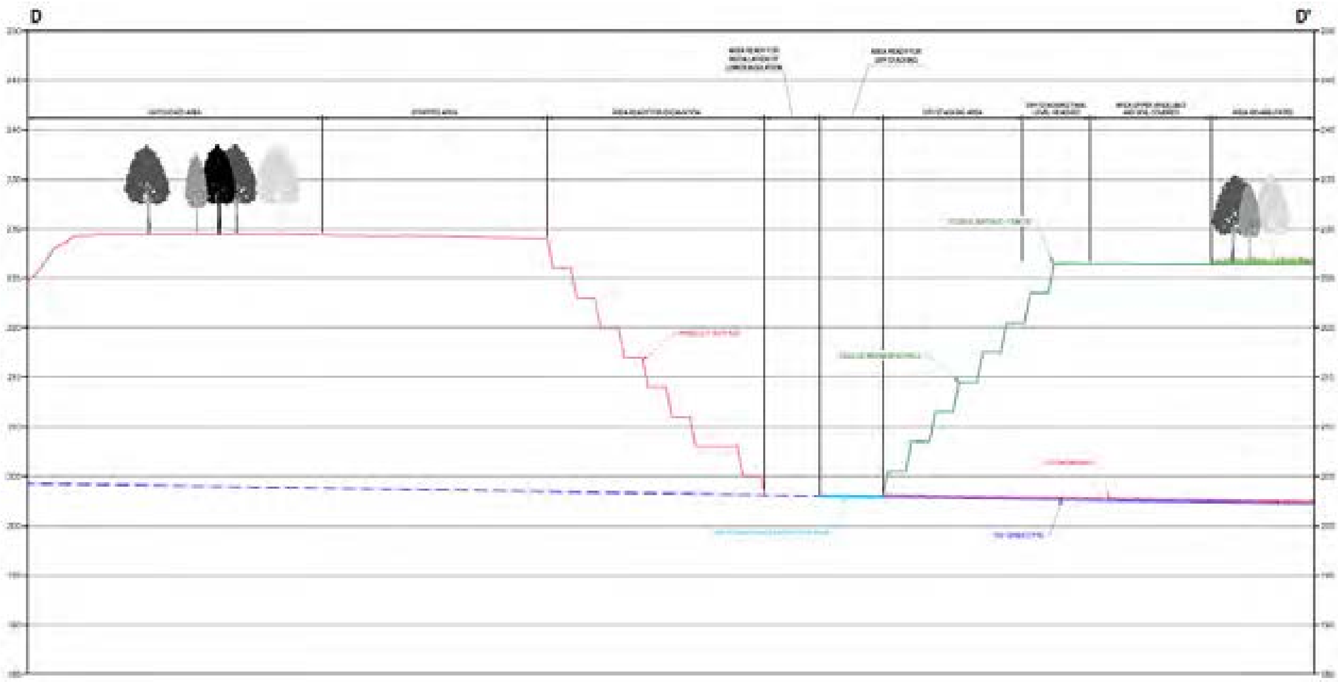
Note: Schematic representation only; vertical exaggeration has been used to highlight landforms

Figure 16-20: Tailings Extraction and Residue Development Section C-C', Looking North



Note: Schematic representation only; vertical exaggeration has been used to highlight landforms

Figure 16-21: Tailings Extraction and Residue Development Section D-D', Looking West



Note: Schematic representation only; vertical exaggeration has been used to highlight landforms

16.5 Hydrogeological Considerations

Each tailings cell has been shown to possess differing material properties between the inner and outer bounds of each cell, and stratigraphically throughout the deposit. Modelling of the tailings cells has been completed, with multiple scenarios run considering differing material properties including grain size, saturated and unsaturated hydraulic conductivity, and the presence of discreet or isolating permeability barriers.

The SEEP/W module of Geostudio 2020 Version 10.2.2.20559 was used to develop two-dimensional transient groundwater flow models for Tailings Cell 1. These models have been used to simulate the hydrogeological conditions within the tailings cell with the objective of identifying if and how saturated pressurized zones of tailings can be managed effectively during mining.

Two material types were modelled: river sediments underlying the tailings cells and in situ tailings, subdivided into coarser material present at the perimeter of the cells and finer tailings in the center, with respective higher and lower associated hydraulic conductivity. There exists a wide range of hydraulic properties which has been reported for the tailings (GEOMIN, 2019 and Tetra Tech, 2021). This introduces uncertainty in the modelling which has been managed by running multiple model scenarios.

For the portion of the model where mining is simulated the model contains benches which are 3 m high sloped at 45 degrees; the benches are 12 m wide.

Using all the available data and literature values for unsaturated hydraulic conductivity where real data is unavailable, eight scenarios were modelled to represent the variety of conditions present within the cells. Both steady-state (present conditions) and predictive (during mining) stages were modelled. Since there is a large degree of uncertainty associated with the material properties of the tailings it was determined that multiple model scenarios would be run to investigate various different combinations of material properties. By doing this, the model can predict the potential range of outcomes and identify sensitive parameters allowing future investigation work to be focused on infilling the most critical data gaps.

This modeling exercise has been undertaken using limited applicable data specifically collected for the purposes of an unsaturated groundwater flow model. Consequently, the available data has been used to run multiple scenarios to explore the likely range of hydraulic parameters and the consequent response of the tailings piles.

The modelling exercise has shown that although the central portion of the tailings cells is saturated, or near saturated, the pore water may well be either under negative, or low positive, pressures. For slope stability purposes the presence, or rapid development of negative pore water pressures, will increase the stability of the cut slope. The modelling has shown that cut slopes in the tailings will result in passive depressurization in a period of between approximately a few days to one month. This passive depressurization will allow mining equipment to operate on the benches without active dewatering during operations.

16.6 Geotechnical Considerations

Tetra Tech undertook a review and analysis of the geotechnical data available from CPTs completed for CMP in 2018 to determine material properties and operating constraints related to cell stability during excavation.

Bench stability analyses were undertaken for each tailings cell under static and loaded conditions to establish a factor of safety. CPT locations are illustrated in Figure 16-22 below. Tetra Tech incorporated the results of this analysis into the block model for use in the mine design and subsequently the mine schedule. General geotechnical design parameters are shown in Table 16-6 below.

The water level indicated by the CPT and used in the analysis is located at an elevation approximately 204 masl to 207 masl within Cell 3. In the analysis, the water is considered to drain towards the toe, and the soil below 203 masl is considered to be saturated. This assumption is based upon depressurization of the central portion of the tailings cells following excavation of the initial benches, and once negative pore pressures have begun to develop. This assumes and is dependent on completion of a trial cut to confirm initial steady-state conditions.

Investigation of the ultimate bearing capacity of the tailings cells was completed in conjunction with the geotechnical analysis. The geotechnical parameters used in estimation of the bearing capacity of the tailings cells were interpreted from the CPT data collected in 2018, with assumed values for embedment depth, foundation width, and foundation length. Geotechnical parameters from Cell 3 were used in analysis to represent the most saturated and lowest-strength material. Two scenarios were modelled, one to represent undrained conditions and another to estimate bearing capacity following depressurization and during loading. Both bearing capacity calculations resulted in an ultimate bearing capacity above the expected loading of the required excavator model.

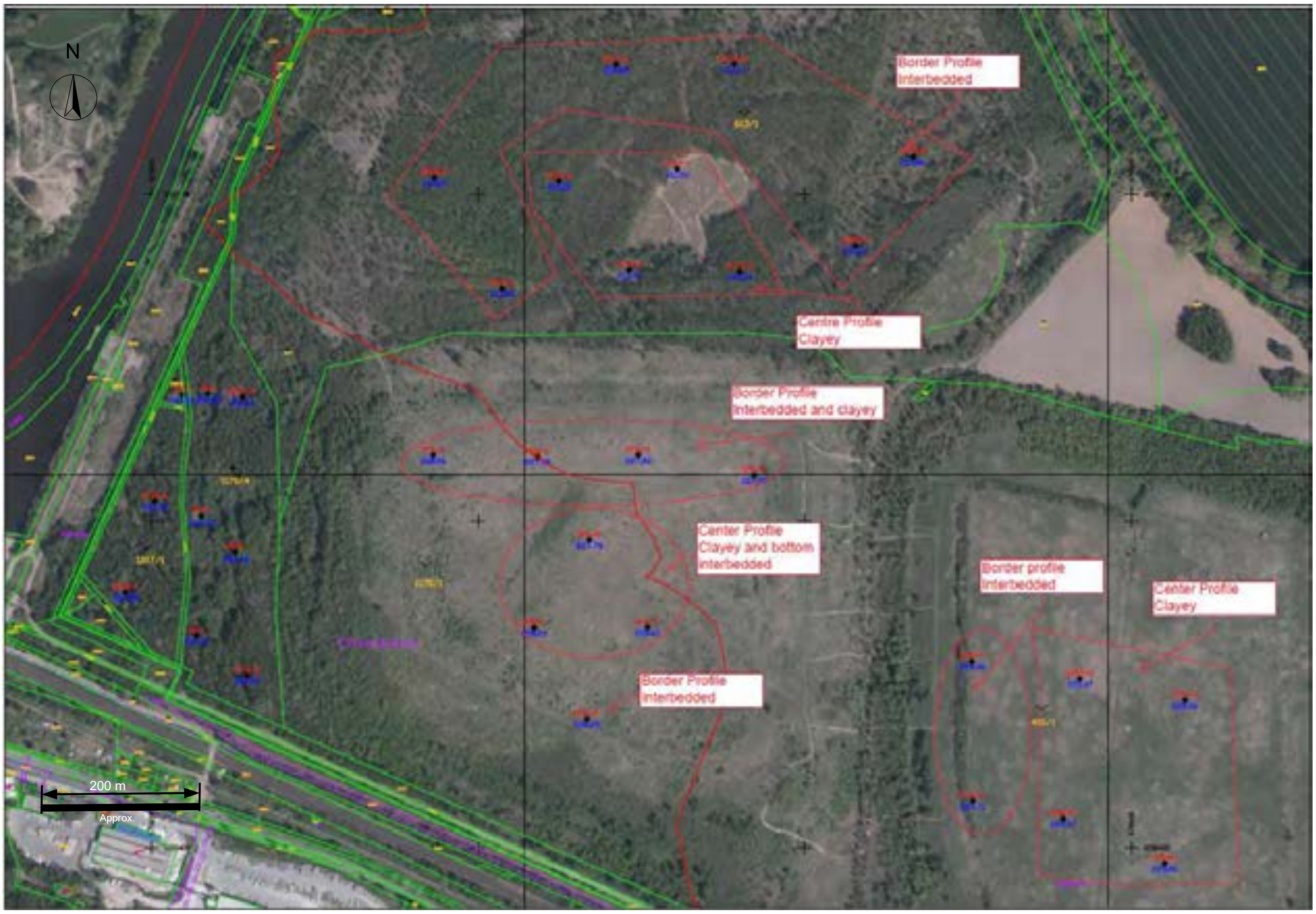
The stability model was run under static conditions and under loaded conditions considering an excavator located 2 m behind the crest and with an operating load of 78 kN/m^2, estimated based on a CAT 374F model. To allow for a more conservative analysis, the full loading of the excavator was used in bench profile geotechnical analysis to determine factor of safety values. As such, a factor of safety of or greater than 1.0 is considered acceptable for initial analysis prior to confirmation of in-situ conditions.

Consolidation of the soil beneath equipment is expected to occur during operations, resulting in compaction and a relative increase in shear strength. The depressurization and dewatering of the tailings cells following initial benching is also expected to contribute to a positive increase in ultimate bearing capacity.

Table 16-6: Geotechnical Design Criteria

Parameter	Unit	Value
Ore Bulk Density (dry)	t/m^3	1.51
Topsoil Density (dry)	t/m^3	2.00
Average In-situ Moisture Content	%	Cell 1 = 21.2, Cell 2 = 21.5, Cell 3 = 20.7

Figure 16-22: Cone Penetration Test Locations and Profile Interpretations



16.6.1 Cell 3

The initial input parameters for material based on grain size are included in Table 16-7 below. These values are based on the interpretation of the CPT results.

Table 16-7: Cell 3 Geotechnical Input Parameters

Material Type	Unit Weight kN/m^3	Friction Angle (˚)	Cohesion (kPa)
Sand	18.0	35	--
Interbedded Sand and Silt	17.0	33	6.5
Silt/Clay	16.5	--	30
Silt/Clay (Lower Bound)	16.5	--	30

The effective cohesion of the interbedded sand and silt layer is based on the undrained shear strength interpreted from CPT data above the groundwater level (min 6.5-7 kPa). This interbedded material exceeds a factor of safety of 1.3 for both the existing slope of 1:1 to 1.25:1. The cohesion for the silt and clay layers is based on mean values of the CPT's in the inner region of the cell. A Lower Bound (LB) value is also used to describe properties more representative of the southwest of the cell.

Factors of safety were determined for the stability of three different section profiles and bench heights. Static and loaded conditions were modelled with the results presented in Table 16-8 and Table 16-9 below.

Table 16-8: Factor of Safety Results for Cell 3 Stability Analysis, Static

Factor of Safety Results (Static)			
Material Type	5 m Bench	3 m Bench	2 m Bench
Clay (Mean)	1.7	>2	>2
Clay (Lower Bound)	1.2	>2	>2
Sand	1.5	--	--

Table 16-9: Factor of Safety Results for Cell 3 Stability Analysis, Loaded

Factor of Safety Results (Static + Excavator Load)			
Material Type	5 m Bench and CAT 374	3 m Bench and CAT 374	2 m Bench and CAT 374
Clay (Mean)	1.0	1.2	1.4
Clay (Lower Bound)	0.7	1.0	1.0
Sand	1.3	--	--

Benches with 5 m height and 1:1 slope are generally acceptable for the sand and silt profile of Cell 3 in the outer regions of the cell. Some local sloughing is expected at locations when excavating due to the interbedded nature of this material. These conditions will be monitored during construction.

For the central regions with higher silt and clay content, benches with 3 m height are acceptable with a factor of safety greater than 1.0. The LB analysis indicates that for areas where the clays are softer in the southwest portion of the cell, a 3 m bench height is acceptable, as long as the excavator is placed at the toe of the bench.

Constant field monitoring of ground conditions will be required during the extraction process to assess at which point the bench geometry should change, or if the extraction method should change due to differing soil conditions.

Following the initial analysis on Cell 3, the resulting friction angles, cohesion values, and unit weights were incorporated into the block model for use in mine design. These parameters were correlated to particle size information within the block model to determine areas where adjusted bench designs are required.

Cross sections were analyzed using the parameters defined for Cell 3 and the distribution of particle size both vertically and horizontally which was obtained from the block model. Table 16-10 shows the parameters incorporated within the block model.

Table 16-10: Material Properties for Block Model Use

Material Type	Unit Weight (kN/m^3)	Friction Angle (˚)	Cohesion (kPa)
Top Sand	18.0	35	--
Interbedded Sand/Clay	17.0	33	6.5
Silt/Clay	16.5	-	30
Silt/Clay LB	16.5	--	20

The results of the geotechnical analysis for Cell 3 confirmed that a 5 m bench height at a 1:1 overall slope angle with 45 degree bench faces were acceptable for mine design for the outer limits of the cell, where the interbedded nature and coarser overall grain size of the material is predicted to improve operating conditions.

Regions towards the centre of Cell 3 with a more cohesive soil profile have an acceptable factor of safety with benches at 3 m high, with a 1:1 slope angle and 45 degree bench faces. The load bearing scenario results indicate that for the southwest portion of Cell 3, 3 m benches are acceptable provided the excavator remains at the toe of the slope, prior to slope depressurization.

Table 16-11: Cell 3 Shear Strength Data

P75	Unit Weight (kN/m^3)	Friction Angle (˚)	Shear Strength* (kPa)
0-12.5	18	35	--
12.5-25	18	33	--
25-50	17	28	15-20
50-75	17	--	10-15
75-100	16.5	--	20-30

Note: * Undrained shear strength

16.6.2 Cells 1 and 2

The stability assessments conducted for Cells 1 and 2 were based on a multi-bench scenario to determine failure criteria and factor of safety. For each cell, two models were simulated for the typical material properties defined for the outer and centre portions of the cell, for both static and loaded scenarios.

Stability modelling was completed for each bench on the section, with a second case completed to determine failure criteria for the slope overall. This analysis assumed the slope was unsaturated and that depressurization occurs at the toe of the lowest bench once excavated.

The highest point of the water table was modelled at 220 masl, lowering to 203 masl at the toe of the lowest bench. The resulting factors of safety for Cell 1 center and border profiles are described in Table 16-12 and Table 16-13, respectively. A factor of safety of 1.0 or greater is achieved in the cohesive central material when equipment is working at the toe of the bench, with ongoing stability monitoring recommended.

Table 16-12: Cell 1 Border Profile Factor of Safety

Bench Number	Factor of Safety Static	Factor of Safety Loaded CAT 374	Material at Toe
1	1.4	1.2	Sand
2	1.4	1.0	Clay
3	>2	1.2	Clay
4	>2	1.3	Clay
5	2	1.1	Interbedded Sand/Silt

Table 16-13: Cell 1 Centre Profile Factor of Safety

Bench Number	Factor of Safety Static	Factor of Safety Loaded CAT 374	Material at Toe
1	1.2	1.0	Clay (Lower Bound)
2	1.7	1.0	Clay
3	>2	1.2	Clay
4	2	1.1	Interbedded Sand/Silt
5	1.3	1.1	Interbedded Sand/Silt

The resulting factors of safety for Cell 2 center and border profiles are described in Table 16-14 and Table 16-15, respectively. A factor of safety of 1.2 is achieved in the cohesive central material when equipment is working at the toe of the bench, with ongoing stability monitoring recommended.

Table 16-14: Cell 2 Border Profile Factor of Safety

Bench Number	Factor of Safety Static	Factor of Safety Loaded CAT 374	Material at Toe
1	1.4	1.2	Sand
2	1.3	1.2	Interbedded Sand/Silt
3	1.3	1.2	Interbedded Sand/Silt
4	1.3	1.2	Interbedded Sand/Silt
5	>2	1.2	Interbedded Sand/Silt

Table 16-15: Cell 2 Centre Profile Factor of Safety

Bench Number	Factor of Safety (Static)	Factor of Safety Loaded CAT 374	Material at Toe
1	1.2	1.0	Clay (Lower Bound)
2	2.0	1.0	Clay
3	>2	1.2	Clay
4	>2	1.1	Interbedded Sand/Silt
5	>2	1.1	Interbedded Sand/Silt

16.7 Tailings Extraction Equipment

16.7.1 Equipment Selection

The mining operations of the CMP will be owner operated. The equipment fleet will consist of conventional trucks and excavators. Given the availability and overall scale of the operation and equipment required, a diesel-powered fleet has been selected.

16.7.2 Equipment Requirements

The equipment requirements are based on the design parameters of the tailings cells, schedule requirements of tailings and residue, selective mining capability, and the relative size-classes in order to pair equipment efficiently. Equipment requirements were estimated on a first principles basis, with haul truck requirements based on measured haul profiles and material movement. Equipment availability and utilization is based on Tetra Tech's experience, judgement, and vendor recommendations.

For mine equipment size selection, the following items are taken into consideration:

- Minimum working bench width
- Required mining selectivity
- Bench height
- Load bearing capacity of equipment

- Equipment capacity
- Capital cost

For determination of mine equipment required, the following is considered in addition to the parameters above:

- Annual production rate
- Haul road profile, length, and gradient
- Operating speeds
- Equipment mechanical availability, utilization, and overall efficiency
- Cycle times including spot, load, haul, dump, and maneuvering times
- Effective life of the machines to be used

The mining equipment described in this section are based on currently available equipment and standard sizes and/or weight classes. Conventional equipment from established suppliers was recommended due to the reliability of proven technology and access to multiple potential vendors and spare components. A summary of the recommended equipment fleet is presented in Table 16-16 below.

Table 16-16: Summary of Mine Equipment

Mine Equipment	Model	Number Required
Hydraulic Excavator	CAT 374F L	2
Wheeled Loader	CAT 972M	2
Articulated Haul Truck	CAT 745	4
Dozer	CAT D6N	2
Auxiliary and Support	**Model**	**Number Required**
Grader	CAT 160	2
Vibratory Compactor	CAT CP12 GC	1
Water Truck	--	1
Fuel and Lube Truck	--	1
Maintenance Truck	--	2
Low Bed Truck	--	1
Pickup Trucks	--	5

16.7.3 Equipment Utilization

Several assumptions were incorporated into equipment selection and usage calculations to model the overall equipment efficiency and estimate working hours for each piece of equipment on an annual basis. Assumptions for mechanical availability, operator efficiency, and operation efficiency are shown in Table 16-17 below.

Table 16-17: Equipment Utilization Factors

Factor	Unit	Value
Mechanical Availability	%	85
Operator Efficiency	%	90
Operation Efficiency	%	80

To complete the equipment performance calculations, parameters based on the specifications of loading and hauling equipment were included to calculate cycle times and estimate the maximum material movement possible based on the remaining available time. Annual truck hours were then derived, with excavator hours based on bucket capacity and individual loading and dumping times. From this, the required equipment numbers on an annual basis are derived.

16.7.4 Loading Equipment

The loading equipment has been sized to support the tailings mining while meeting the required residue placement. Diesel hydraulic excavators and wheeled loaders were selected as the loading equipment. The selection for loading equipment were based on the bench size, material selection control, material type, and ability to effectively load trucks with payloads of 41 t.

The hydraulic excavators with a 4.6 m^3 bucket will mine the tailings material. The wheeled loaders with a 4.8 m^3 bucket will load the residue material from the plant feed storage building. The capacity of loading equipment was calculated based on the operational efficiency, equipment productivity, and the trucking loading times.

The loading will be performed by CAT 374F L and CAT 972M. Both excavator and wheel loader model were chosen due to their high reliability and proven performance in open-pit mines where maneuverability and selectivity are prioritized.

Table 16-18 and Table 16-19 below summarize the loading parameters. In addition, the loading equipment productivities include truck factor, bucket capacity, mechanical availability, operation efficiency, and operator efficiency factors.

Table 16-18: Hydraulic Excavator Parameter

Hydraulic Excavator – CAT 374F L		
Parameter	**Unit**	**Value**
Bucket Size	m^3	4.6
Bucket Fill Factor	%	95
Nominal Bucket Payload	t	6.9
Average Number of Buckets to Load	#	5
Average Bucket Cycle Time	sec	25
Total Time to Load	min	2.7

table continues…

Hydraulic Excavator – CAT 374F L		
Parameter	**Unit**	**Value**
Theoretical Loads Per Hour	#	27
Ground Bearing Pressure	kPa	78
Productivity per day	t/d	8,034
Productivity per hour	t/hr	574

Table 16-19: Wheeled Loader Parameters

Wheeled Loader - CAT 972M		
Parameter	**Unit**	**Value**
Bucket Size	m^3	4.8
Bucket Fill Factor	%	95
Nominal Bucket Payload	t	7.2
Average Number of Buckets to Load	#	5
Average Bucket Cycle Time	sec	30
Total Time to Load	min	3.1
Theoretical Loads Per Hour	#	23
Productivity per day	t/d	6,986
Productivity per hour	t/hr	499

The operating hours for the loading equipment were estimated by the amount of material to be moved within a specified period and the associated productivities. Number of equipment required was then calculated using total operating hours for the period and the operating hours per unit within the period. Operating hours and annual requirement of loading equipment are shown in Table 16-21.

16.7.5 Hauling Equipment

The hauling fleet was selected to match the loading capacity and expected volumes from scheduling. A 41-t capacity articulated truck was chosen with sloped truck box and lined HDPE liner to increase the fill factor and reduce the quantity of fine material retained following dumping. This class of truck was chosen because of the productivity and performance CAT 745 trucks provide in operations worldwide. The 41-t truck will be able to maximize material moved while still operating on the benches versus utilizing smaller trucks that would require a larger fleet, or larger trucks that would have less maneuverability. There is the additional benefit of reduced maintenance and operating costs than larger, heavier trucks.

Haulage profiles were developed for the mine plan for each year over the mine life. Requirements for haulage of tailings to the stockpile plant and residue to the residue storage facility were both accounted for. Table 16-22 summarizes the haul cycle parameters used in calculating truck productivities.

Table 16-20: Haulage Model Parameters

Articulated Haul Truck – CAT 745		
Item	**Unit**	**Value**
Truck Nominal Payload	t	41
Truck Load Factor	%	90
Actual Truck Payload	t	37
Dump Time at Mill	min/cycle	1.5
Dump Time at RSF	min/cycle	1
Ramp Uphill (Loaded)	km/hr	10
Ramp Downhill (Loaded)	km/hr	12
On Bench	km/hr	15
Main Haul Road	km/hr	35
Ramp Uphill (Unloaded)	km/hr	12
Ramp Downhill (Unloaded)	km/hr	17

Haul cycles were created by using the centroid of each year of advance in tailings and sequence of residue placement. Loading and dumping times at the tailings, RSF, and stockpile were based on equipment manufacturer calculations and material type. The annual requirement of haul trucks is shown in Table 16-22 below.

16.7.6 Mine Equipment Maintenance Waste Estimate

The mine equipment's maintenance waste estimates were based on planned maintenance hours recommended by the vendor and equipment specifications. The planned maintenance includes lube oils, grease, fluids, and filters that are specific to the individual mine equipment. Table 16-25 below summarizes the maintenance waste estimates.

Table 16-21: Loading Equipment Requirements

Production Schedule - Year		Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Total Tailings Mined	000 tonnes	26,644	718	1,113	1,107	1,070	1,012	1,040	1,080	1,097	1,016	1,010	1,016	1,017	907	834	1,056	1,085	1,130	1,168	1,237	1,196	1,184	1,236	1,183	1,137	997
Topsoil Mined	000 tonnes	1,833	58	67	72	54	121	87	104	89	64	75	72	54	28	17	17	111	77	77	93	78	77	78	93	82	87
Total Material Moved	000 tonnes	56,188	1,523	2,336	2,330	2,238	2,185	2,209	2,306	2,327	2,137	2,136	2,145	2,128	1,878	1,718	2,171	2,324	2,382	2,460	2,615	2,518	2,493	2,599	2,507	2,401	2,121
Total RSF Placed	000 tonnes	27,710	747	1157	1151	1113	1053	1082	1123	1141	1057	1050	1057	1057	943	867	1098	1129	1175	1215	1286	1244	1232	1285	1231	1182	1037
CAT 374																											
Shovel Hours	Hours	49,626	1,352	2,055	2,054	1,960	1,974	1,964	2,062	2,068	1,882	1,891	1,897	1,866	1,630	1,482	1,870	2,084	2,103	2,170	2,316	2,221	2,198	2,290	2,223	2,124	1,890
Shovels Required	#	2	1	2	2	1	1	1	2	2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	1
CAT 972M																											
Loader Hours	hours	55,549	1,497	2,319	2,308	2,231	2,110	2,169	2,251	2,287	2,119	2,106	2,118	2,120	1,891	1,738	2,201	2,262	2,355	2,435	2,578	2,493	2,469	2,576	2,467	2,369	2,079
Loader Required	#	2	1	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2

Table 16-22: Hauling Equipment Requirements

Production Schedule - Year		Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Total Tailings Mined	000 tonnes	26,644	718	1,113	1,107	1,070	1,012	1,040	1,080	1,097	1,016	1,010	1,016	1,017	907	834	1,056	1,085	1,130	1,168	1,237	1,196	1,184	1,236	1,183	1,137	997
Topsoil Mined	000 tonnes	1,833	58	67	72	54	121	87	104	89	64	75	72	54	28	17	17	111	77	77	93	78	77	78	93	82	87
Total Fill Moved	000 tonnes	910	2	9	49	138	24	65	60	49	45	46	30	28	17	27	7	7	31	20	6	8	13	25	30	53	119
Total RSF Placed	000 tonnes	27,710	747	1,157	1,151	1,113	1,053	1,082	1,123	1,141	1,057	1,050	1,057	1,057	943	867	1,098	1,129	1,175	1,215	1,286	1,244	1,232	1,285	1,231	1,182	1,037
Total Material Moved	000 tonnes	57,098	1,525	2,345	2,379	2,376	2,209	2,274	2,366	2,377	2,182	2,182	2,176	2,156	1,895	1,745	2,178	2,331	2,413	2,480	2,621	2,526	2,506	2,625	2,537	2,454	2,240
CAT 745		Total																									
Truck Hours Tailings/Residue	truck hours	194,366	4,822	7,529	7,650	7,613	7,863	8,155	8,355	8,534	7,807	7,653	7,605	7,507	6,611	6,012	7,535	8,193	8,484	8,760	9,430	8,594	8,486	8,823	7,988	7,631	6,726
Truck Hours Topsoil	truck hours	12,919	372	436	479	372	902	653	771	669	472	548	521	383	199	118	117	803	557	556	679	542	532	538	601	531	567
Truck Hours Fill Material	truck hours	6,495	15	58	458	943	176	491	444	370	334	338	218	201	118	187	50	51	225	145	44	56	92	174	196	342	771
Total Truck Hours	truck hours	213,779	5,209	8,022	8,586	8,928	8,941	9,299	9,571	9,573	8,613	8,539	8,345	8,091	6,928	6,317	7,702	9,046	9,265	9,461	10,153	9,192	9,110	9,535	8,784	8,505	8,064
Total Trucks	Trucks	4	2	3	4	4	4	4	4	4	4	4	3	3	3	3	3	4	4	4	4	4	4	4	4	4	3

Table 16-23: Annual Average Cycle Time

Annual Average Cycle Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Minutes/cycle	14.3	14.4	14.8	15.2	16.6	16.7	16.5	16.6	16.4	16.2	16.0	15.8	15.6	15.4	15.2	16.1	16.0	16.0	16.3	15.3	15.3	15.2	14.4	14.3	14.4

Table 16-24: Mining Fleet Annual Diesel Fuel Consumption Estimate

Total Fuel Usage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
000 litres	363	531	552	564	549	568	584	586	536	533	527	516	454	421	506	563	578	592	628	586	582	607	572	555	521

Table 16-25: Estimated Maintenance Waste

PM Waste Estimates	Total		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Total Filter	1,519	filters	52	63	64	62	60	61	62	62	60	59	59	57	56	53	61	62	63	64	66	64	64	65	63	61	57
Total Waste	458,811	L	14,219	19,556	19,834	19,067	17,916	18,318	18,764	19,021	17,785	17,759	17,438	16,361	15,898	14,888	18,244	18,882	19,421	20,010	20,991	19,876	19,711	20,421	19,191	18,603	16,637

16.7.7 Auxiliary and Support Equipment

The auxiliary and support equipment required for operation have been selected considering load and haul activities, pre-mining activities, maintenance of the waste dump, re-handling of the ROM stockpiles at the plant feed storage building, haul road maintenance, RSF activities, refueling, and maintenance of the heavy equipment fleet.

Equipment allocated for RSF includes tracked dozers for material placement and vibratory compactors. The dozers will also be used for excavator support and clean-up, stockpile maintenance, road construction, and other activities as needed. Graders and water trucks have been allocated for road construction, road maintenance, and pit floor maintenance.

Mobile equipment maintenance trucks, a fuel and lube truck, and low bed are included in the estimate to support heavy equipment during day-to-day operations. Mobile lights will be used for lighting of pits, RSF, and construction areas as needed. A fleet of five light pickup trucks have also been included for staff transport and site activities as well as light maintenance tasks.

16.7.8 Equipment Replacement Criteria

The equipment replacement criteria are based on life of the project and on the average working life of each of the equipment supplied by equipment vendors. Mine equipment component rebuilds will be planned to reduce the number of equipment replacement purchases. The estimated equipment average working life is summarized in Table 16-26 below. Additional maintenance hours have been included for select equipment expected to reach 50,000 working hours in the five years prior to the end of the life of mine, to reduce late capital costs for equipment replacement where possible.

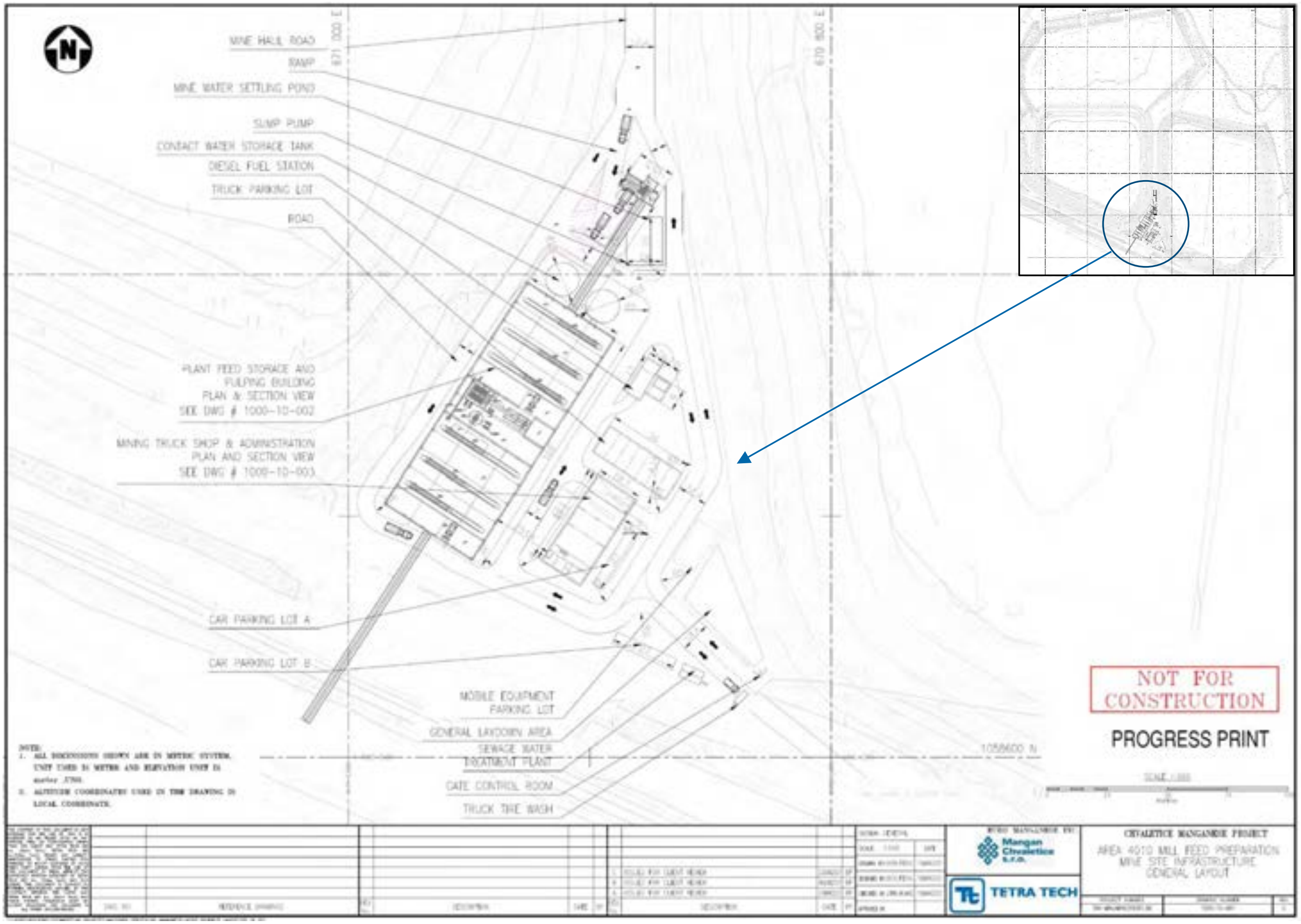
Table 16-26: Estimated Equipment Life

Mine Equipment	Model	Operating Life (hours)
Hydraulic Excavator	CAT 374F L	50,000
Wheeled Loader	CAT 972M	50,000
Articulated Truck	CAT 745	50,000
Dozer	D6N	35,000
Grader	CAT 160	56,000

16.8 Infrastructure

Infrastructure designed to support tailings extraction and residue placement at the CMP is described in detail in Section 18.0 of the Feasibility Study, with mining-specific infrastructure summarized in the following sections. The mine infrastructure area will be located between Cells 1 and 2 at the south edge of the mining area. The mining infrastructure will include a truck maintenance workshop, truck washing facility and parking lots, fuel station, warehouse, and administration and mine-dry-related facilities. The area also will have raw tailings material and residue handling facilities, including raw tailings receiving, storage, repulping, residue storage, and loadout. The site plan view is shown in Figure 16-23. Infrastructure has been planned and designed with consideration for both the scale of the operation and available area on site, to allow for compact yet efficient operational facilities.

Figure 16-23: Mine Site Infrastructure



TETRA TECH

16.8.1 Workshop, Warehouse and Administration Building

A workshop and warehouse have been included for site and heavy equipment maintenance requirements, with a nominal footprint of 18.7 m by 42.1 m. This is designed as a two-story building containing the following:

- Offices and meeting rooms for management and administration staff.
- Kitchen and washroom facilities.
- Mine dry and locker space for operations staff.
- Parking space for light vehicles – capacity of 10 spaces.
- One warehouse bay: 10 m by 18 m by 5.7 m with one mechanical room.
- One truck wash bay: 7 m by 18 m by 9 m, sized for accommodation of CAT 745 truck as largest vehicle planned for use on site.
- Two maintenance bays: 8.1 m by 18 m by 9 m, one inclusive of a repair pit for vehicle undercarriage access and both with overhead crane.

16.8.2 Fuel and Lubricant Storage Area

The diesel fuel, primarily used for the mine fleet, is stored within a bermed containment area located near the truck shop. The double-wall diesel fuel tank will be above ground with capacity of 20,000 L, which will be filled weekly. This size was chosen based on five-day fuel usage estimate with contingency and consideration for smaller on-site footprint. The lubricants will mostly be stored in the warehouse and in the maintenance bay. The fuel and lube truck will attend mine fleets as needed during operation. The annual diesel fuel consumption estimate of the mining fleet is summarized in Table 16-24 in Section 16.7 above.

16.8.3 Heavy Equipment Laydown

The heavy equipment laydown area is situated to the north of the truck shop. Haul trucks will park here overnight and for maintenance. Excavators, dozers, and compactor equipment will remain situated at the tailings cells or residue piles for refuel by fuel truck.

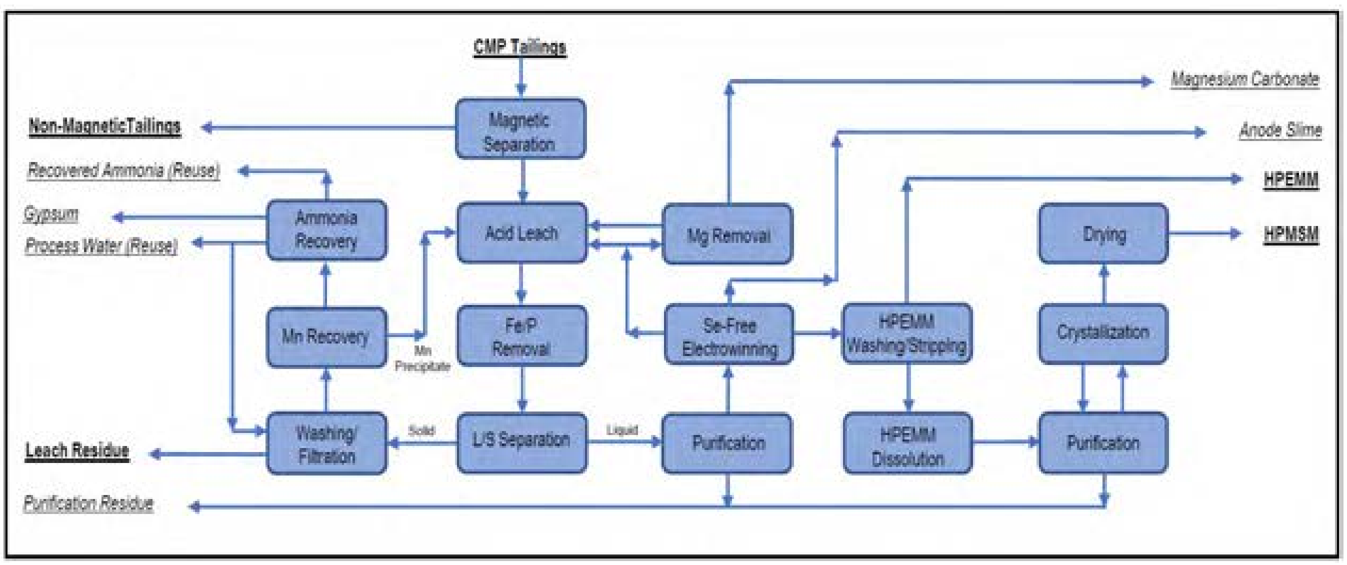
17.0 RECOVERY METHODS

BGRIMM, together with EMN and Tetra Tech, designed the process facilities, including ancillary facilities and process flowsheet for HPEMM and HPMSM productions, based on the comprehensive metallurgical test results provided mainly by CRIMM and the verification test work completed by BGRIMM. Tractebel provided engineering services to define local regulatory design requirements, including review various technical design criteria, especially in local fire protection.

The design work includes various process circuit and process equipment optimization and ancillary service facility design. Mass, energy, and water balances were simulated and estimated using a combination of METSIM™ modelling, calculations using results from the metallurgical test work program, and BGRIMM and Tetra Tech's experience in designing HPEMM and HPMSM process facilities. The design team sized and selected equipment with incorporating inputs from potential Chinese equipment vendors.

The CMP process plant has been designed to have a 25-year project life at a nominal production rate of 50,000 t/a of HPEMM by extracting approximately 1.1 Mt/a of the CMP tailings. On average, more than two-thirds of the annual HPEMM flake production is converted to HPMSM at a nominal capacity of 100,000 t/a. This product mix is expected to best meet the high-purity manganese market demand expected in current and future low-cobalt lithium-ion battery formulations. HPEMM product containing greater than 99.9% manganese is expected to be sold as flakes and is planned to be produced without the use of selenium and chromium. The CMP HPMSM product is designed to contain no less than 99.9% MSM, a minimum of 32.34% manganese, and will be sold in powder form, produced without the use of fluorine. Figure 17-1 depicts the proposed process flowsheet.

Figure 17-1: Simplified Process Flowsheet



Excavated tailings will be stored in a mill feed storage area within the tailings pulping facility. The tailings will be reclaimed, pulped, and then pumped to the plant site located south of the CMP tailings cells. The pipeline will be carried by an overhead bridge that would cross a public rail line, Highway #322, and a related spurs that adjoin the proposed process plant site.

The tailings slurry will be processed in a wet, on average high-intensity magnetic separation circuit that will upgrade the manganese grade of the leach feed to approximately 15% tMn and reject approximately 57% of the feed to non-magnetic tailings (NMT), with an expected 86% manganese recovery. The magnetic concentrate and NMT produced will be dewatered using thickeners and filters. The concentrate will be fed to the downstream leach process and the dewatered tailings, together with the washed leach residue (LR), will be dry stacked at the residue storage facility (RSF).

The magnetic concentrate cake, together with recovered manganese carbonate from process water, will be re-pulped using anolyte solution from the electrowinning tank house and leached using sulphuric acid at 90°C for approximately six hours. Neutralization of the slurry will be achieved using powder lime. Air will be sparged into the neutralized slurry to cost-effectively co-precipitate the substantial quantities of impurities that leach with the manganese. The leach pulp will be filtered in automatic pressure filters to separate the pregnant leach solution from the LR.

The LR will be repulped using the washing water from downstream dewatering circuit where the slurry will be dewatered by pressure filtration equipped with on-steam LR washing. After the dewatering the LR cake, together with the NMT is transported to a lined dry stack tailings storage facility that will be progressively constructed in excavated areas of the CMP tailings cells.

The wash water from the LR washing circuit will be treated for manganese and ammonia recovery in order to minimize manganese and ammonia losses. The wash water recovery system will recover soluble manganese to the leaching circuit in the form of manganese carbonate. The spent wash water solution will be subsequently treated to recover ammonia using a conventional lime boil process and will produce a gypsum by-product which is planned to be sold or handled offsite. The potential value of the gypsum material is not included in the CMP economics. The recovered ammonia will be re-used in the HPEMM production circuits. The inclusion of the LR washing circuit, with its associated wash water recovery circuit, is expected to be a world-leading industry practice for the hydrometallurgical processing of manganese ores. Returning washed residue to the carefully prepared containment cells in the excavated areas of the CMP tailings progressively remediates the environmental impact risks of legacy mining operations.

The pregnant solution from the leaching circuit will be purified to remove heavy metals and other impurities and stabilized to prevent uncontrolled crystallization of salts to produce a qualified solution for the downstream electrowinning process.

Electrowinning will be conducted in electrowinning cells following the addition of ammonium bisulphite (HN_4HSO_3) as the source of sulphur dioxide (SO_2) to the tank house feed solution. The tank house would have the capacity to produce 50,000 t/a HPEMM using an energy-efficient and selenium-free process. The proposed electrowinning circuit is designed to have a plating cycle of 24 hours at a cell voltage of 4.2 to 4.4 V and an average cathode-current density of 320 to 370 A/m^2. Cathodes will be harvested using automatic harvesting machines, washed, and stripped of electrodeposited manganese metal using industry-standard automatic cathode plate stripping machines. The design of the CMP tank house includes comprehensive mist emission control and mechanical handling systems that eliminate manual handling of cathodes and other processes. Tank house system design features include the recovery of anode slimes to minimize manganese losses, as well as diaphragm cleaning and ongoing cell maintenance operations. Approximately two thirds of the HPEMM flakes would then be used as feed for HPMSM production. The remaining HPEMM flakes would be packed and directly shipped to customers.

A magnesium removal process has been incorporated into the process plant design to ensure efficient electrowinning operations and high-quality product. The magnesium removal process will maintain the magnesium concentration in the electrowinning solutions at a level that prevents uncontrolled precipitation of salts and scaling. The process will use low-cost reagents without incurring significant losses of manganese and reagent units.

The FS production plan proposes to dissolve approximately two-thirds of the HPEMM flakes using sulphuric acid to produce 100,000 t/a of HPMSM powder in a dust-free chemical processing facility. The solution with the dissolved manganese will be further purified to remove trace impurities carried by the HPEMM flakes, sulphuric acid, and other used chemicals. After purification, the mother solution will be concentrated using an energy-efficient, low-temperature mechanical vapour recompression (MVR) crystallization process to generate a single specification of manganese sulphate monohydrate crystals. The HPMSM crystals will be separated from the saturated MVR crystal slurry using centrifuges. The dewatered crystals will be dried using disc type dryers to produce the final HPMSM powder, while the spent mother solution will return to the mother solution purification circuit or to the crystallization circuit. The dried HPMSM powder product will be packed prior to being shipped in trucks or containers to customers worldwide.

17.1 Plant Design Basis

The process plant for the proposed 25-year-life project is designed to produce 50,000 t/a of HPEMM, or 48,000 t/a of HPEMM at a LOM average production rate, by extracting approximately 1.1 Mt/a of the CMP tailings. Two-thirds of the annual HPEMM flake production will be converted to approximately 100,000 t/a of HPMSM. Table 17-1 outlines the major process design criteria.

Table 17-1: Major Process Design Criteria

Criteria	Unit	Value
General Design Criteria		
Operating Days per Year	d	365
Operating Hours	h	24
Plant Overall Availability	%	90.4
Operating Shift per Day	shift/d	3
Head Manganese Grade (Average)	%	7.4
Nominal Process Rate		
Magnetic Separation	t/h	139
Leaching/Dewatering	t/h	60
Purification/Electrowinning	t/a HPEMM	50,000
HPMSM Production	t/a HPMSM	100,000
Average Manganese Recovery		
Magnetic Separation	%	86
Acid Leaching	%	75
Purification/Electrowinning/Others	%	93.6
HPEMM to HPMSM	%	97.0
HPEMM Purity	%	>99.9
HPMSM Purity	%	>99.9

The process design is based on the comprehensive metallurgical test work completed by CRIMM, BGRIMM, and potential suppliers. The design also includes preliminary process circuit and process equipment evaluation and optimization. Mass, energy, and water balances were simulated and estimated using a combination of METSIM™ modelling, calculations using results from the metallurgical test work program, and BGRIMM's experience in designing EMM and MSM process plants and other hydrometallurgical processing plants. Key equipment items were sized and selected by the design team incorporating inputs from potential equipment vendors.

17.2 Process Description

The proposed flowsheet (Figure 17-1) includes two main product streams: HPEMM and HPMSM products. As designed, HPMSM will be produced from HPEMM. The main process circuits for HPEMM production include:

- Reclaimed tailings pulping and magnetic separation
- Magnetic concentrate acid leaching
- Iron, phosphorous, and other impurity co-precipitation
- LR washing with residual manganese and ammonia recovery
- LR and NMT dewatering prior to being dry stacked in the RSF
- Leach pregnant solution purification, including heavy metal precipitation
- Manganese electrowinning, manganese metal washing, and stripping from cathode plates
- Magnesium removal from spent anolyte

As designed, one-third of the HPEMM flakes will be sold directly to customers and two-thirds of the HPEMM flakes will be further processed to convert the metal into HPMSM powder. The main process circuits for HPMSM production include:

- Acid dissolution of HPEMM flakes
- Leach solution purification
- Mother solution evaporative crystallization by MVR
- Solid and liquid separation to separate HPMSM crystals from saturated mother solution
- HPMSM drying at controlled conditions.

17.2.1 HPEMM Production

17.2.1.1 CMP Tailings Pulping and Magnetic Separation

The CMP tailings will be extracted from the CMP tailings cells and trucked to the tailings pulping facility located between Cells #1 and #2 at the south end of the cells. Tailings will be dumped onto a mill feed surge bin where the tailings will be reclaimed by an apron feeder and then conveyed to an indoor mill storage facility which has a five-day storage capacity. As planned, the tailings extraction will operate 16 hours per day, 5 days per week.

TETRA TECH

The tailings will be reclaimed by a front-end loader and then transported by a belt conveyor to two pulping trommel screens. The trommel screen undersize will report to a pumpbox and then be pumped to a surge tank equipped with an agitator. The trommel screen oversize materials, which are anticipated to be entrained rocks and other foreign materials, will be backfilled to the RSF. The mill feed slurry will then be pumped to a surge tank located at the main process site, south of the CMP tailings site, via an overhead bridge galley, which will also be used to house the tubular belt conveyor to bring washed LR/NMT filter cakes to the dry stack facility at the north site.

17.2.1.2 CMP Tailings Pre-concentration – Magnetic Separation

The proposed magnetic separation circuit will consist of one stage of rougher separation followed by scavenger separation and scavenger cleaner separation. Three VR-type high intensity magnetic separators with a magnetic field intensity of 1.3 to 1.5 t are proposed for the concentration treatment. The magnetic separators will be connected with a flexible feed slurry by-passing system which will allow the rougher and scavenger separations to operate all the time if one of the separators requires unscheduled maintenance. The magnetic separation is anticipated to upgrade the total manganese grade of the CMP tailings from 7.4% to approximately 15% at a total manganese recovery of 86% and reject approximately 57% of the mill feed.

The magnetic concentrate produced will be dewatered through a 10 m diameter high-rate thickener. The thickener underflow will be pumped to a surge tank where the slurry will be fed to four, 650 m^2 filter presses for further dewatering to approximately 15% moisture or less. The concentrate cakes will then be conveyed to an acid leach circuit to recover acid soluble manganese.

The NMT produced from the scavenger separation will be pumped to a 16 m diameter high-rate tailings thickener. The thickener underflow will be pumped to the tailings filtration facility for further dewatering by six, 650 m^2 filter presses. The tailings filtration cakes, together with the washed LR filtration cakes, will be conveyed to the RSF for storage via an overhead tubular belt conveyor. The moisture content of the dewatered NMT is expected to be less than 20% w/w.

As designed, both the magnetic concentrate and NMT filtration circuits include a standby filter to ensure no operation interruptions due to unplanned filter maintenances.

The water recovered from the tailings and concentrate dewatering circuits will be re-used for pulping the extracted CMP tailings.

17.2.1.3 Acid Leaching

The filtered magnetic concentrate cakes will be conveyed to the acid leach plant. The concentrate cakes will report to a surge bin which will be equipped with a cake breaker below the surge bin. The cake breaker will feed the concentrate into one re-pulping tank at a controlled rate. The concentrate will be mixed in the tank with spent anolyte solution generated from the electrowinning tank house and process water, as required. The anolyte solution will be indirectly heated by two stages of heating, including one stage of heat recovery from the LR slurry.

The re-pulped slurry will then be pumped to seven 400-m^3 leach tanks, including one standby tank, for continuous acid leaching. The recovered manganese carbonate from the LR washing circuit will also report to the acid leach circuit. Concentrated sulphuric acid will be added to the leach circuit at a controlled rate. The estimated ratio of acid to concentrate is approximately 0.4 to 0.5, averaging 0.42. The residual acid at the acid leach discharge will be at approximately 1 to 2 g/L or less. The leaching will be conducted at approximately 90°C with a leach retention time of approximately five to six hours. Main heat will come from the exothermic reactions during the acid leaching. The main chemical reactions which may occur during the leaching include:

- $MnCO_3(s) + H_2SO_4(a) \rightarrow MnSO_4(a) + CO_2(g) + H_2O(a)$ (1)
- $MgCO_3(s) + H_2SO_4(a) \rightarrow MgSO_4(a) + CO_2(g) + H_2O(a)$ (2)
- $CaCO_3(s) + H_2SO_4(a) \rightarrow CaSO_4(a) + CO_2(g) + H_2O(a)$ (3)
- $FeCO_3(s) + H_2SO_4(a) \rightarrow FeSO_4(a) + CO_2(g) + H_2O(a)$ (4)
- $Ca_5(PO_4)_3(OH, F-, Cl-)(s) + 5H_2SO_4(a) \rightarrow 5CaSO_4(a) + 3H_3PO_4(a) + H_2O(a) + (F-, Cl-)(a)$ (5)
- $CaSO_4(a) + 2H_2O(a) \rightarrow CaSO_4 \cdot 2H_2O(a)$ (6)
- $FeO(s)+H_2SO_4(a) \rightarrow FeSO_4(a)+H_2O(a)$ (7)
- $2FeOOH(s)+3H_2SO_4(a) \rightarrow Fe_2(SO_4)_3(a)+4H_2O(a)$ (8)

Each of the tanks will be equipped with a lined agitator. The leach tanks will be lined with acid resisting liners to protect the tank structure and covered with heat insolation layers to minimize heat loss.

Exhaust hoods will be installed for each of the leach tanks to direct off-gas to a central scrubbing system, including a condenser and an off-gas scrubbing purification tower, to remove the acid mist and solid particulates that may generate during the leaching. The purified off-gas will be discharged into the air while part of the carbon dioxide gas from the off-gas will be directed to downstream circuits for magnesium removal and manganese recovery. In addition, sufficient ventilation will be provided for the workshop to maintain healthy work environment.

17.2.1.4 Impurity Removal

Iron/Phosphorous Removal

During acid leaching, iron, phosphorus, magnesium, calcium, heavy metal impurities (including copper, cobalt, nickel, lead, and zinc), and other impurities will also be partially leached out and enter the leach solution. To produce HPEMM, these impurities need to be removed from the liquid phase. The impurity removal will be conducted separately in stages.

The first stage of solution purification will serve as a bulk solution impurity removal step using pH adjustment, which will remove free acid, iron, phosphate, and other impurities from the leach discharge slurry. According to the test results, the goethite method is proposed to remove dissolved iron from the liquid phase by precipitation. The iron removal treatment will be conducted at a temperature of approximately 80 to 85°C using lime to adjust the slurry pH to approximately 6.0 to 6.5. Recycled aqueous ammonia will be also added to balance ammonium sulphate levels required for manganese electrowinning.

Air will also be introduced to the iron and phosphorous removal reactors to oxidize ferrous iron to ferric iron in order to facilitate precipitation.

The key chemical reaction of the iron removal treatment is shown in Equation 9:

- $2Fe^{2+}(a) +1/2O_2 (g) + 3H_2O(a) = 2FeOOH(s) + 4H^+(a)$ (9)

Dissolved phosphorous mainly in phosphates will be co-precipitated with goethite and other precipitates and removed from the liquid phase. Other impurities, such as aluminum and heavy metals, will be partially removed during the treatment.

The treatment will be conducted in six 400-m^3 tanks, including one standby tank. Similarly, each of the tanks will be equipped with a lined agitator. These tanks will be lined with acid resisting liners to protect the tank structure and covered with heat insolation layers to minimize heat loss.

Exhaust hoods will be installed for each of the reactors to direct off-gas to the central scrubbing system, which is a common system for the acid leach and impurity removal circuits. In addition, sufficient ventilation will be provided for the area to maintain a healthy work environment.

After the iron and phosphorous removal treatment, the leach slurry will pass through a heat exchange station to recover residual heat from the slurry prior to being filtered by nine filter presses (eight in operation and one on standby). The filtrate will be pumped to subsequent heavy metal and other impurity removal processes, while the filtration cakes will be re-pulped using washing water generated from downstream LR washing circuit. The slurry will then be dewatered by pressure filtration in which on-stream filter cake washing is incorporated. The filtered LR will be co-deposited together with the filtered NMT into the RSF.

Heavy Metal Purification

The pregnant solution from the LR liquid-solid separation circuit will be treated in the second stage of solution purification, which will further purify the leach solution by sulphidation to remove residual heavy metals such as zinc, cobalt, copper, and nickel. Several heavy metal sulphidation reagents, including an organic chelating agent and inorganic sulphides such as ammonium sulphide ($(NH_4)_2S$) and barium sulphide (BaS), were evaluated. In this study, a combination of the organic chelating agent and BaS is proposed.

The pregnant solution will report to two 6.0 m diameter by 7.0 m high reactors in series. The heavy metal removal reagents will be dosed at a control rate to precipitate the residual heavy metals. The treated solution, together with the precipitates, will report to a filtration feed surge tank. Then the precipitates will be separated from the manganese pregnant solution by filtration.

The precipitates will be stored in a dedicated storage facility, where the material will be transported off-site to professional and commercial waste material handling companies for disposal. The treated solution will report to the subsequent deep purification circuit.

Deep Purification and Qualified Solution Preparation

After being treated by heavy metal removal, the solution may be further purified by activated carbon treatment to further remove residual impurities if specific HPEMM is required by potential customers. The circuit has not included in the study. However, the required space for installing the circuit has been planned in the design. The additional treatment includes carbon powder dosing, carbon-solution mixing, and solution-solid filtration system.

The pregnant solution will report to a settling tank farm which can accommodate the solution for 36 hours. The solution exiting the settling system will be further filtered through polishing filtration to remove ultra-fine residual materials. The filtrate, or qualified solution, or electrolyte solution, will report to six fresh solution stock tanks which provide feeding solution for the electrowinning circuits.

Ammonium bisulphite solution and ammonium water will be added to prepare the qualified solution for the downstream manganese electrowinning. The Project will use a selenium-free electrowinning process with using sulphur dioxide to improve electrowinning efficiency. Sulphur dioxide will come from ammonium bisulphite.

17.2.1.5 Manganese Electrowinning

The qualified solution from the fresh solution stock tanks will be pumped to eight electrowinning head tanks. Ammonia water may be locally added into the electrowinning circuit to maintain solution pH in cathode compartments if required.

The main reductive reactions, including the side reaction at the cathodes, will include:

- $Mn^{2+}(a) + 2e^{-} \rightarrow Mn(s)$ (10)
- $2H^{+}(a) + 2e^{-} \rightarrow H_2(g)$ (11)

The manganese depleted solution from cathode zones will pass through diaphragms and enter anode zones. The key oxidation reactions at the anodes will include:

- $Mn^{2+}(a) + 2H_2O(a) – 2e^{-} \rightarrow MnO_2(s) + 4H^{+}(a)$ (12)
- $2H_2O(a) – 4e^{-} \rightarrow 4H^{+}(a) + O_2(g)$ (13)

Oxygen (O_2) gas will be generated on the surface of the anode sheets. A small portion of the anodic current is expected to be consumed due to the oxidation of manganese (Mn^{2+}) into manganese dioxide (MnO_2), forming part of anodic slimes that have to be removed periodically from the cell.

There will be four manganese electrowinning lines: each line will consist of 240 electrolytic cells, 3.15 m long by 1.12 m wide by 1.07 m high in size, made from polymerized vinyl and cement compounds. Each of these cells will be equipped with an on-wall off-gas exhaust arrangement to mitigate the effect of the gases (hydrogen (H_2), oxygen (O_2), and ammonia (NH_3)), which are evolved at both electrodes, on the work environment. The off-gases will be directed by a ventilation system to two dedicated off-gas scrubbing systems prior to being discharged into the air. The temperature of the electrowinning cells will be controlled by an internal cooling method; cooling water will be circulated through the coils installed inside of the electrolytic cells. The cooling water will be in closed circuit with cooling towers. The inlet cooling water temperature to the cooling coils will be approximately 32°C, while the outlet temperature is approximately 37 to 39°C.

The cathodes will be 316 L stainless steel plates, 795 mm high by 610 mm wide in size, and the anodes will be approximately sized 775 mm high by 570 mm wide sheets fabricated from solid rolled lead-tin-calcium-strontium alloy. The cathodes and anodes will be separated by permeable diaphragms.

The spent acidic anolyte solution will leave the electrolytic cells and enter the anolyte solution collecting sumps and be pumped to an anolyte solution stock tank. Approximately 50% of the anolyte solution will be pumped to the concentrate leach circuit, while the rest will be sent to a magnesium removal circuit. The anode slime will be collected, filtered, and stored in a dedicated area prior to being transported to professional and commercial waste material handling companies for disposal. The used anodes and cathodes will be transported back to suppliers for recycling.

Four separate rectifier systems will provide direct current for the four electrolytic lines. Each of the rectifier systems will include one 16,000 kVA/35 kV rectifier transformer and two 18 kVA/350 V rectifiers. Rectifiers will be cooled down through water circulation. Each rectifier system will be serviced by one dedicated cooling system.

The main operating parameters are listed below:

- Manganese concentration – anolyte solution 14 to 16 g/L manganese

- Cathode current density – nominal 320 to 370 A/m^2
- Anode current density – nominal 450 to 650 A/m^2
- Cell voltage – nominal 4.2 to 4.4 V
- Cell operating temperature 38 to 42°C
- Feed catholyte solution pH 7.0 to 7.5
- Homo-polar distance 65 mm
- Plate harvest frequency 24 hours per cycle

The manganese deposited cathodes will be removed from the cells by four mechanised harvesting systems which will also replace the harvested cells with fresh cathode plates. Prior to the deposited manganese being peeled, the deposited cathodes will be subject to multi-stages of treatments including automatic plate washing and drying. The dried plates will be transported to one of four peeling systems, each with two units, where the deposited manganese metal will be automatically stripped from the cathode plates. The cathode plates will be further treated by cleaning, polishing, and conditioning by sodium silicate ($(SiO_2(Na_2O)_x)$) before they are re-used in the electrowinning circuits.

Manganese metal flakes stripped from the cathode plates are expected to contain an overall purity of higher than 99.9% manganese. According to various assay results, the impurity contents of the HPEMM product is anticipated to meet the specifications required by most of the potential users and downstream HPMSM production.

The HPEMM product will be conveyed to the HPEMM product storage area where the HPEMM flakes will be transported to downstream HPMSM production facility or be bagged in 1-t sack bags, or custom size bags or drums prior to shipment. The HPMSM production is detailed in Section 17.2.2.

A local control system will monitor and control cathode current density, cell voltage, solution pH, solution flowrate, and cell temperature. An on-stream analyzer will analyze manganese and key impurity contents of the feed solutions and anolyte solutions.

17.2.1.6 Leach Residue Washing and Dewatering

The LR that is separated by pressure filtration from the leach slurry is anticipated to have a moisture content of approximately 28% w/w. The residue will contain high concentrations of both manganese and ammonium sulphate which need to be recovered prior to being disposed onto the lined RSF.

The LR filter cakes will be re-pulped using washing water generated from downstream LR washing circuit. The repulped slurry will then be dewatered by pressure filtration. On-stream filter cake washing using the manganese and ammonia depleted process water from the ammonium recovery circuit has been incorporated into the cake washing. The water from the cake washing will be used for repulping the cakes produced from the LR solid-liquid separation circuit.

The filtration with the on-stream cake washing will be conducted in nine 650-m^2 filter presses (eight in operation and one on standby) to a moisture of approximately 25 to 28% w/w. Together with the NMT, the LR will be conveyed from the main process site in the south site via the tubular overhead conveyor to the north site for dry stacking in the lined RSF.

TETRA TECH

17.2.1.7 Manganese Recovery from Leach Residue Washing Supernatant

The supernatant from the LR washing circuit will be subject to two separate treatments to recover manganese and ammonia. The washing solution will be pumped to a 6.5 m diameter by 5.0 m high manganese precipitation tank. The scrubbed off-gas collected from the leach circuit, which contains mainly carbon dioxide, will be sparged at a controlled rate to the reactor, where the manganese will react with the carbon dioxide to form manganese carbonate precipitate. Ammonia water is added to maintain the optimum pH for the manganese recovery process. Equation 14 shows the main reaction as:

- $MnSO_4(a) + CO_2(g) + NH_4OH(a) \rightarrow MnCO_3(s) + (NH_4)_2SO_4(a) + H_2O(a)$ (14)

The precipitate will be filtered through two 650-m^2 filter presses to separate the manganese carbonate precipitate from the ammonia bearing solution which will be treated by an ammonia stripping process to recover ammonia. The manganese carbonate precipitate cake will be leached together with the magnetic concentrate in the acid leach circuit.

17.2.1.8 Ammonia Recovery

The solution from the manganese precipitation circuit will be processed by a slurry-steam stripping process to recover ammonia for reuse in various process circuits, including the purification, Mg removal, Mn recovery and electrowinning circuits.

The filtrate from the solid and liquid separation circuit of the manganese precipitated slurry will report to a lime boil tank where hydrated lime slurry will be added to neutralize and release the aqueous ammonia from ammonium sulphate. The hydrated lime dosage will be approximately 1.25 times the stoichiometry requirement for the lime and ammonium sulphate reaction. The remaining magnesium and other metals in the solution will also be precipitated. Equation 15 to Equation 18 show the key chemical reactions. The slurry with the aqueous ammonia will then be pumped to a surge tank which will be capable of stocking the slurry for six hours.

- $(NH_4)_2SO_4(a) + Ca(OH)_2(s) \rightarrow 2(NH_3(a)/NH_3(g)) + CaSO_4(a) + 2H_2O(a)$ (15)
- $MgSO_4(a) + Ca(OH)_2(s) \rightarrow Mg(OH)_2(s) + CaSO_4(a)$ (16)
- $MeSO_4(a) + Ca(OH)_2(s) \rightarrow Me(OH)_2(s) + CaSO_4(a)$ (17)
- $CaSO_4(a) + \frac{1}{2}H_2O(a) \rightarrow CaSO4\cdot\frac{1}{2}H_2O(s)$ (18)

The neutralized slurry will be fed to steam stripping towers where aqueous ammonia will be stripped with steam. The ammonia bearing slurry will be pumped through heat exchange units where the high-temperature slurry from the steam stripping tower will be cooled down with an indirect heat exchange process. Lime will be added to maintain the slurry pH between 10.5 to 12.0 at the stripping tower discharge. The pH value will be required to ensure the ammonia content of the ammonia removed slurry less than 50 mg/L. Equation 19 shows the stripping reaction:

- $NH_3(a) \rightarrow NH_3(g)$ (19)

The ammonia stripping will be conducted in three stripping towers under a negative pressure. Steam will be introduced at the bottom of the towers while the preheated slurry will be fed from the upper section of the tower and flow by gravity to the bottom of the tower. One additional off-gas purification tower will be installed to further scrub the gas prior to be discharged into the air. A water jet vacuum system will be installed for each of the stripping towers to direct the stripped ammonia/steam gases to an ammonia absorption tower where the ammonia/steam gases will be cooled and condensed to absorb the ammonia to the aqueous phase (Equation 20). The expected ammonia concentration of the ammonia solution is higher than 15%.

- $NH_3(g) \rightarrow NH_3(a)$ (20)

The low ammonia slurry will be re-acidified with sulphuric acid in a mixing tank to convert the volatile aqueous ammonium hydroxide to non-volatile ammonium sulphate (Equation 21). The slurry will be filtered by dedicated filter presses. The filter cakes containing mainly gypsum will be stored on the site prior to being shipped off-site for sale. The filtrate will be used as process makeup water, mainly for LR filter cake washing water.

- $2NH_3(a) + H_2SO_4(a) \rightarrow (NH4)_2SO_4(a)$ (21)

The recovered aqueous ammonia solution will be recycled to the purification and refinery circuits to act as a neutralizing reagent. According to the METSIM™ simulation, it is expected that the recovered ammonia should meet project requirements or be slightly deficient.

The ammonia recovery facility will be equipped with sufficient ventilation to maintain a healthy work environment. Both the lime boil reactor and the lime treated solution stock tank will be equipped with exhaust fans which will direct the off-gas to the ammonia adsorbing system.

17.2.1.9 Magnesium Level Control

A bleed treatment has been incorporated into the design to control the magnesium level of the electrowinning solution to lower than 10 g/L. Several magnesium control methods have been reviewed and tested, including fluoride precipitation, crystallization removal, and a proprietary magnesium removal treatment. The proposed magnesium level control process will treat approximately 50% of the anolyte solution in order to maintain the qualified solution feeding to the electrowinning circuit at a lower threshold than what may cause a detrimental impact on electrowinning. The treatment will produce a magnesium waste product which will be handled by professional and commercial waste handling companies or be used as an agricultural fertilizer. The magnesium depleted solution will be recycled to the magnetic concentrate leaching circuit.

Further optimization investigations using the proprietary magnesium removal technology to control the magnesium level in electrolyte are planned during the demonstration plant campaigns. A market study for the magnesium waste product should be conducted based on the product quality produced from demonstration plant testing.

17.2.2 HPMSM Production

As proposed for the project, approximately two-thirds of the HPEMM produced from the electrowinning circuit will be converted to HPMSM. The processes proposed for the HPMSM production is described in the following sections.

17.2.2.1 HPEMM Dissolution

The HPEMM flakes produced from the HPEMM production facility will be packed in inter-facility containers and then transported to the HPEMM dissolution facility. The HPEMM will be leached by high-purity sulphuric acid in six 5.0 m diameter by 6.0 m high leach tanks at a temperature higher than 60°C. The dissolution includes acid dissolution and solution neutralization. The estimated leach cycle time will be approximately 22 hours, including the loading time of HPEMM into the reactors and solution neutralization. Equation 22 shows the main chemical reaction:

- $Mn(s) + H_2SO_4(a) \rightarrow MnSO_4(a) + H_2(g)$ (22)

The manganese pregnant solution containing approximately 110 to 120 g/L manganese will be treated by deep purification to further remove residual heavy metals, iron, and other impurities.

Hydrogen gas will be generated from the dissolution process. The gas will be properly collected and used for generating steam for the project, including its use for the manganese dissolution from the raw tailings. Sufficient ventilation will be provided in the metal dissolution facility to ensure the hydrogen level in the facility is lower than the safe threshold. Hydrogen detection and alarm systems will be installed for safe operation and protect operators and the facility.

17.2.2.2 Solution Deep Purification

The pregnant solution will be subjected to two stages of purification to further remove trace residual impurities carried by the HPEMM flakes, including heavy metals and iron. Stage 1 will reduce residual heavy metal contents by sulphurization and Stage 2 will remove the residual iron by oxidation treatment using hydrogen peroxide. Both purification treatments will be conducted at 60°C or higher in two separate reactors.

The treated solutions will be pressure filtered separately to separate the precipitates and pregnant solution.

The precipitate slimes produced will be sent to the dedicated heavy metal slime storage areas prior to being shipped to offsite professional/commercial waste handling facilities for treatment and reuse/disposal.

17.2.2.3 HPMSM Crystallization

The purified solution or mother solution will be concentrated in an MVR system. With the concentration, the manganese sulphate monohydrate will be crystallized from the mother solution. The crystallization process will be conducted at a temperature of 95 to 100°C. The vapour from the MVR evaporation will be condensed and reused as process water.

The sludge from the MVR process will be dewatered by six centrifugal separators to separate the crystals from the sludge. The produced solution will be recycled back to the feed of the MVR process and mother solution purification circuit. The solid product which contains HPMSM will be further dewatering by drying.

17.2.2.4 HPMSM Product Drying and Product Handling

The dewatered crystals from the centrifugal separators will be dried using six disc-type dryers at approximately 130 to 140°C to produce the final HPMSM powder. The dryers will be directly heated by steam. The final dried product is expected to contain higher than 32.3% manganese. According to the analysis results from various test work, the chemical and physical properties of the HPMSM product are anticipated to meet the specifications required by most of the potential users.

The dried HPMSM powder product will be packed by automatic packing lines and the packed HPMSM product will be stored in a dedicated product warehouse prior to being shipped to customers worldwide. As required by users, the HPMSM may be transported to customer’s site in bulk or the high-purity manganese sulphate product can be directly transported to the users in solution form without crystallization. The manganese sulphate content of the solution can be based on user’s requirements. For this study, the manganese sulphate product is based on HPMSM powder.

17.3 Waste Production and Management

The NMT (approximately 58% of the plant feed) and washed LR (approximately 46% of the plant feed) will be transported by a tubular conveyor from the south plant site to the CMP tailings site located north of the plant site. The reprocessed tailings/residue material will be conveyed by an overland conveyor and then temporarily stored in the residue storage area, which is part of the CMP raw tailings pulping facility. The residue materials will be backhauled by the trucks which deliver the extracted CMP tailings to the pulping facility to the lined storage facility at the CMP site where the CMP tailings has been excavated. The reprocessed tailings/residue materials will be levelled by post-deposition bulldozing and pressed by compaction. The dry stacked tailings pad will be covered with progressive reclamation during the operational life. Section 18.11 further discusses tailings/residue management details.

As planned, the gypsum residue (approximately 6% of the plant feed) from the ammonia recovery circuit will be sold to the local gypsum markets as construction materials. A preliminary market for the gypsum demand and supply in the Czech's market has been conducted by Mangan. The magnesium removal treatment will produce a magnesium waste product, magnesium carbonate, which is expected to be able to be used as a fertilizer suitable for agriculture. Further studies into the material characters and its handling and applications, including marketing studies, should be conducted.

The slimes from the heavy metal removal treatments and the anodic reaction stream, estimated to be approximately 0.4% of the plant feed, will be stored in dedicated areas prior to being shipped to professional and commercial waste recycling and handling companies.

The used cathodes and anodes will be transported back to suppliers or local metal handling companies for recycling.

17.4 Reagent Handling and Storage

The main reagents used for the project will include sulphuric acid (H_2SO_4) and lime (CaO), together with other less amount reagents, including barium sulphide (BaS), ammonium bisulphite, ammonium sulphate ($(NH_4)_2SO_4$) (initial use only), organic chelating agent, ammonia water ($NH_3.H_2O$), hydrogen peroxide (H_2O_2), and flocculants. The sulphuric acid and lime will be transported to the site by railcars. The deep purification by activated carbon is currently not included in the base design, but may be added in the future if required. All the liquid reagents will be dosed into the addition points using metering pumps at control rates.

To ensure containment in the event of an accidental spill, all the reagent preparation and storage facility will be located within a containment area designed to accommodate 110% of the volume of the largest tank. For the liquid chemicals, the storage tanks will be equipped with level indicators and instrumentation to ensure that spills do not occur during normal operation. Smaller reagent containers such as drums and/or 1-m^3 plastic steel-caged containers will be stored in their respective containment areas. Appropriate ventilation, fire and safety protection, and Material Safety Data Sheet (MSDS) stations will be provided at the various reagent storage and preparation areas. Each reagent line and addition point will be labelled in accordance with Workplace Hazardous Materials Information Systems (WHMIS) standards or equivalent. All operational personnel will receive WHMIS or equivalent training, along with additional training for the safe handling and use of the reagents.

17.4.1 Sulfuric Acid

- Mode of delivery: Bulk rail-car
- Form of delivery: Liquid

- On-site bulk storage: Three tanks, each 1,150 m^3, total capacity 3,450 m^3. Bulk on-site storage capacity represents approximately 10 days regular production.

Sulfuric Acid will be delivered by rail-cars to the site. From the rail-cars, the acid will be pumped into three (3) on-site bulk storage tanks, which will be installed within a secondary containment. Two tanks will be used for storage regular grade sulphuric acid and one tank will be used for storing the higher-grade sulphuric acid.

Annual railway traffic is expected to be 80 to 120 trains per year, with each train carrying 1,000 t. The three bulk storage tanks are adjacent to the rail facilities.

The acid will then be pumped to smaller day-tanks for process use.

17.4.2 Lime

- Mode of delivery: Bulk rail-car
- Form of delivery: Powder
- On-site bulk storage: Seven silos, each 318 m^3, total capacity 2,226 m^3. Bulk on-site storage capacity represents approximately 10 days regular production.

Lime will be delivered by rail-cars to the site. From the rail-cars, the lime will be pneumatically conveyed into seven on-site bulk storage silos located adjacent to the rail facilities. Each silo will be equipped with a dust collector to prevent dust from escaping the silo.

Annual rail traffic is expected to be 60 trains per year, with each train carrying 1,250 to 1,320 t.

The lime will then be pneumatically conveyed to smaller day-silos/tanks for process use. The lime will be slaked as lime milk slurry and delivered to the use points via a pressurized loop, excluding the lime used for the neutralization treatment in the CMP tailings leach circuit which will be added as received powder form.

17.4.3 Barium Sulphide

- Mode of delivery: Bulk silo-truck
- Form of delivery: Powder
- On-site bulk storage: One silo, 28 m^3 capacity (approximately 82 t storage).

Barium sulphide will be delivered by trucks to the site. From the trucks, the BaS will be pneumatically conveyed into the on-site bulk storage silo. The BaS powder will then be conveyed via screw conveyor to smaller day-silos/tanks for preparing the barium sulphide solution for process use.

Annual truck traffic is expected to be 45 trucks per year, with each truck carrying 24 t.

For dust-control, the BaS silo will be equipped with dust collector to prevent dust from escaping to the exterior.

17.4.4 Organic Chelating Agent

- Mode of delivery: Bulk tanker-truck
- Form of delivery: Liquid

- On-site bulk storage: 1 tank, 56 m^3 capacity.

Organic chelating agent will be delivered by trucks to the site. From the trucks, the reagent will be pumped into the on-site bulk storage tank, which will be installed inside the pregnant solution purification building within a secondary containment. The reagent will be pumped from the storage tank to smaller day-tanks for process use.

Annual truck traffic is expected to be 32 trucks per year, with each truck carrying approximately 27 t.

17.4.5 Ammonium Bisulphite (65%)

- Mode of delivery: Bulk tanker truck
- Form of delivery: Liquid
- On-site bulk storage: Two tanks, each 38.5 m^3, total storage capacity of approximately 77 m^3.

Ammonium bisulphite will be delivered by trucks to the site in liquid form. From the trucks, the reagent will be pumped into the two on-site bulk storage tanks. The tanks will be installed within a secondary containment.

Annual truck traffic is expected to be 130 trucks per year, with each truck carrying 24 t (approximately 18 m^3). The Ammonium bisulphite will then be pumped to smaller day-tanks for process use.

17.4.6 25% Ammonia Water (25% $NH_3.H_2O$)

- Mode of delivery: Bulk tanker truck
- Form of delivery: Liquid
- On-site bulk storage: One tank with a capacity of 100 m^3.

Ammonia water will be delivered by trucks to the site. From the trucks, the liquid will be pumped into the on-site bulk storage tank, which will be installed in the ammonia recovery area, within a secondary containment. The ammonium water will then be pumped to smaller day-tanks for process use.

Annual truck traffic is expected to be 65 trucks per year, with each truck carrying approximately 24 t.

17.4.7 Hydrogen Peroxide

- Mode of delivery: Truck
- Form of delivery: Liquid; 1 m^3 (IBC) plastic containers encased in steel frame.
- On-site storage: Two 1 m^3 plastic containers will be stored at the site in the HPMSM purification area.

Hydrogen Peroxide will be delivered by trucks to the site. The containers will be placed within a dedicated secondary containment. The hydrogen peroxide will then be diluted and pumped to other downstream tanks for further process use.

17.4.8 Flocculant

- Mode of delivery: Truck
- Form of delivery: Powder, in 700 kg big bags on pallets
- On-site storage: The process will use different types of flocculants. They will be stored onsite in the dedicated areas.

Flocculants will be locally prepared in separate wetting and mixing systems, diluted to 0.5% strength and stored separately in holding tanks. The flocculant solutions will then be further diluted to approximately 0.1 to 0.2% strength and fed to the thickener feed wells by metering pumps.

17.4.9 Glass Water ($SiO_2(Na_2O)x$)

Glass water will be delivered to the site by trucks in 1-m^3 IBC tanks encased in steel frame. The reagent will be placed within a secondary containment and pumped to serving points via metering pumps.

17.4.10 Cooling Towers and Water Treatment Chemicals

Several chemicals will be required for protecting cooling water systems and treatment wastewater. The main chemicals to be used include:

1. Bactericide (10%)
2. Corrosion and scale inhibitors
3. Reducing agent for reverse osmosis water treatment
4. Alkali agent (40%) – for reverse osmosis water treatment

All the chemicals will be transported to the site by trucks. Like the other chemicals, the reagents will be stored in designated storage areas and contained inside secondary containment areas. They will be added as undiluted or diluted solution and dosed into the addition points by metering pumps.

17.4.11 Ammonium Sulfate – For One-Time Initial Use Only

- Mode of delivery: Truck
- Form of delivery: Powder, in 1,000-kg big bags on pallets, one bag per pallet.
- On-site storage: A total of approximately 750 t for one-time initial use only for the magnetic concentrate leaching. The chemical in solid form will be dissolved and diluted with water to the desired solution strength in a mixing tank and stored in a holding tank before being pumped to the addition points by metering pumps.

17.5 Water Supply

Water supply systems to support the operations will include fresh make-up water, process water, 130°C hot water, demineralized water, and high-purity water.

17.5.1 Fresh Water Supply System

Fresh make-up water will be supplied from the adjacent power plant and supplemented with treated contact rainwater as required. Fresh water will be used primarily for the following:

- Firewater for emergency use
- Reagent preparation
- Dust suppression
- Cooling water make-up
- Process make-up water

The freshwater tank by design will be full at all times and will provide at least two hours of firewater in an emergency. Fresh water supply system is detailed in Section 18.5

17.5.2 Process Water

Process water will consist primarily of recovered water from the magnetic concentrate and NMT thickener overflows, the water recovered from ammonium recovery system, and the water from the contact water treatment plant. Fresh and recovered water will be directed to a process water storage tank, from where the water will be pumped to the processing areas. The recovered water from the magnetic separation circuit will be mainly reused in preparing slurry for the magnetic separation feed.

17.5.3 High-purity Water

High-purity water will be from:

- The condensed water from the HPMSM production circuit
- The water produced from a dedicated pure water treatment plant

The demineralized water from the adjacent power plant will be used as feed to produce the pure water. The pure water treatment plant will incorporate two-stage reverse osmosis treatment. The water will mainly be used in HPMSM production circuits, harvested manganese cathode washing, and rectifier cooling water systems.

17.5.4 Demineralized Water

Demineralized water will be made available from the adjacent power plant and will be used mainly for the in-house production of steam, and also as feed for generating pure water.

17.6 Air Supply

A central plant air service systems will supply air to the various process areas, including:

- Iron removal circuit: high pressure air by dedicated air compressors
- Filtration circuits: high pressure air for filter pressing and drying of various filtration cakes
- Electrowinning plant service air: high pressure air for various services
- HPMSM plant service air: high pressure air for various services
- Instrumentation: plant site instrument air will come from the central plant air supply system and the air will be dried, de-oiled, and stored in dedicated air receivers prior to being used to service plant control systems.

17.7 Steam Supply

Steam will be produced in-house using two 20 t/hr natural-gas fuelled steam generators, and one 6 t/hr hydrogen-fuelled steam generator.

17.8 Assay and Metallurgical Laboratory

A central assay laboratory will be constructed to support overall production. The laboratory will be equipped with necessary analytical instruments to provide routine assays for the CMP tailings extraction, various processes, and environmental departments. The instrumentation will be capable of providing routine assay for various products and supply materials and QA/QC. The assay will include chemical and physical characteristic analysis for high-purity products. The central assay laboratory will be located at the central area of the process site.

A metallurgical laboratory with laboratory equipment and instruments will be constructed to undertake all necessary test work to monitor metallurgical performance and to improve the process flowsheet and efficiency.

Overall site process control centre will be located in the building as well.

17.9 Process Control and Instrumentation

The CMP will utilize an advanced and integrated a Distributed Control System (DCS) for process control. The central control room will be located within the Technical and Engineering Services central where the assay and metallurgical testing laboratories will be housed as well.

The DCS is configured as a three-tiered pyramid network. The lowest tier comprises the field instrumentation and control equipment. The middle tier is process control level which includes monitoring computer, operator station, and engineer station. At this level, all the information of each station is integrated, and the operation, control loop configuration, parameter modification, and optimization process processing are shown centrally. The top tier is the plant integrated management system, it can coordinate and control overall operations, starting from the CMP tailings extraction through the final product production. The automatic controls will be completed by the software programs developed for the CMP. Data logging system will be integrated into the control system for various data inputs.

The DCS should provide continuous control of the plant. The control system includes operator interface workstations, system administration consoles, application-level servers, networks, and field level controls. It also includes security firewall function to facilitate remote accesses to the control system. The functions performed by the DCS include operator interface for control and monitoring using graphical display screens, alarm information screens, and trend screens. All network communications and controllers shall be redundant.

The DCS will collect, store, and present online and historical information and generate reports. DCS also performs the control functions. The DCS will perform communication functions to vendor control packages through Profibus-DP or Ethernet. The DCS communication to vendor control packages will allow the operator to directly monitor and control the equipment even if the actual control logic is performed within the vendor control system.

Motor controls for starting and stopping of drives at local control stations are via the DCS or hardwired, depending on the drive classification. All drives can be stopped from the local station at all times. Local and remote starting is dependent on the drive class and control mode. Control loops work via the DCS except where exceptional circumstances apply.

The system will be able to monitor all operation relevant conditions and record and select information for data logging or trending. There are individual programmable logic controllers (PLC) for various sections of the plant or individual equipment that are supplied as complete vendor packages. These will communicate via a data link, alarm, and status information to the plant DCS for recording and monitoring purposes.

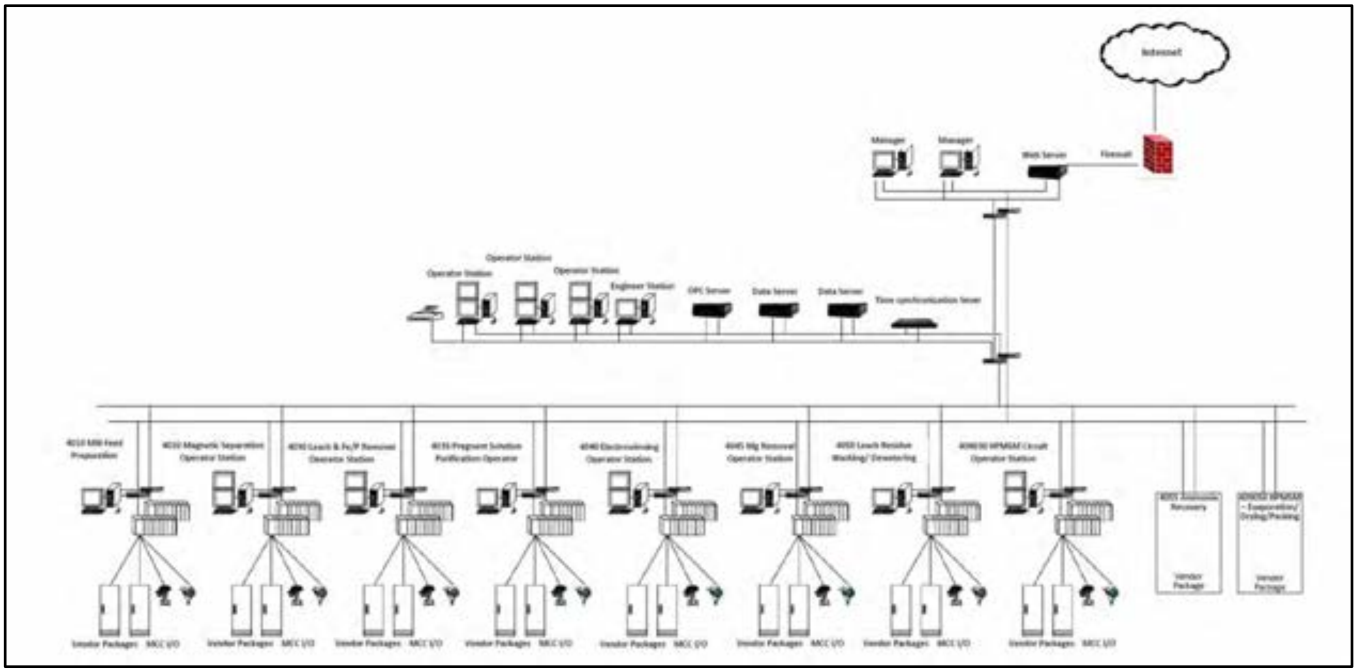
Major equipment is interlocked to the subsequent downstream equipment, e.g., a feeder cannot be started unless the downstream process unit is running and is at a healthy automated state. These process interlocks are managed only by the DCS system.

The system will be hard wired interlocks for personnel safety.

The control system will provide a comprehensive suite of graphics configuration tools including templates for operating graphics, graphic windows and pop-up windows, face plates and pop-up face plates, detail pages, alarm summaries, trend displays, overview displays, etc. Standard libraries of graphic symbols and icons will be available.

Figure 17-2 shows PC-based operator interface stations (OIS) located in various local control rooms.

Figure 17-2: PC-Based Operator Interface Stations



Source: BGRIMM (2022)

The plant central control room will be staffed by trained personnel 24 hours per day. The operation system can realize centralized control of various “domains” operations; meanwhile, respective local operations at each domain can be conducted in respective sub-systems to keep relative independence and real-time performance. The control software can realize real-time control of the production process parameters and ensure the operations at target performance.

Alarm systems, including process data alarm, equipment failure, and system failure alarm, will be able to provide both display alarm and audio alarm based on different alarm information. The alarm can be canceled after the failures are identified or resolved.

Production report can be generated automatically (shift/day/month) for production management. The production report can include operation parameters, process analysis, on-line performance calculation, and economic analysis. Historical operation data and various parameters will be recorded according to production management requirements.

Closed-circuit television (CCTV) cameras shall be installed at required key process and security points. The CCTV cameras shall be analogue format and be connected to the communications box for transmission to the Central Control Room. The cameras shall be web enabled with direct Ethernet node connectivity.

Cameras shall be located to provide adequate coverage of plant operations for access and control. Critical areas will be adequately illuminated so that vision with sufficient clarity will be obtained at night. The cameras will be monitored from local control rooms and central control room.

Process control will be facilitated with the installation of automatic samplers. The metallurgical accounting system will include the collection of samples from various streams for online analysis and the daily metallurgical balance.

For the protection of operating staff, monitor/alarm systems for various gases, including ammonia, sulphur dioxide, carbon dioxide, and hydrogen gases, will monitor the various operation areas. Portable personal monitors will also be provided for operators.

17.9.1 Metal Production Projection

According to the metallurgical performance projections developed from the test work and the proposed CMP tailings extraction plan, the metal production on an annual basis is projected as shown in Table 17-2.

Table 17-2: Annual HPEMM and HPMSM Production Projection

Year	CMP Tailings (Plant Feed)		Product			Manganese Recovery to Final Product (% tMn)
			Intermediate	Final		
	Dry Tonnes Extracted (kt/a)	Grade (% tMn)	HPEMM (kt/a)	HPEMM (kt/a)	HPMSM (kt/a)	
1	718	7.98	32.1	10.4	65.0	55.0
2	1,113	7.41	50.1	16.7	100.0	59.6
3	1,107	7.44	50.1	16.7	100.0	59.6
4	1,070	7.63	50.1	16.7	100.0	60.2
5	1,012	7.96	50.1	16.7	100.0	61.0
6	1,040	7.81	50.2	16.8	100.0	60.6
7	1,080	7.61	50.3	17.0	100.0	60.1
8	1,097	7.43	49.5	16.1	100.0	59.6
9	1,016	7.96	50.3	17.0	100.0	61.1
10	1,010	7.97	50.1	16.7	100.0	61.1
11	1,016	7.89	49.7	16.3	100.0	60.8
12	1,017	7.91	49.9	16.5	100.0	60.9
13	907	8.17	46.5	13.1	100.0	61.5
14	834	8.72	46.6	13.2	100.0	62.9
15	1,056	7.40	47.3	14.0	100.0	59.4
16	1,085	7.24	47.3	13.9	100.0	59.0
17	1,130	7.04	47.4	14.1	100.0	58.4
18	1,168	6.84	47.1	13.7	100.0	57.8
19	1,237	6.60	47.5	14.1	100.0	57.1
20	1,196	6.75	47.4	14.0	100.0	57.5
21	1,184	6.80	47.3	14.0	100.0	57.7
22	1,236	6.58	47.3	13.9	100.0	57.0
23	1,183	6.81	47.4	14.1	100.0	57.7
24	1,137	6.92	46.6	13.2	100.0	58.0

table continues…

Year	CMP Tailings (Plant Feed)		Product			Manganese Recovery to Final Product (% tMn)
			Intermediate	Final		
	Dry Tonnes Extracted (kt/a)	Grade (% tMn)	HPEMM (kt/a)	HPEMM (kt/a)	HPMSM (kt/a)	
25	997	7.64	46.7	13.3	100.0	60.1
Total	**26,644**	**7.41**	**1,194.5**	**372.3**	**2,465.0**	**59.4**

18.0 PROJECT INFRASTRUCTURE

The CMP is located in the western area of the Pardubice region of the Czech Republic, approximately 89 km by road east of Prague, on the southern shore of the Labe River. The CMP is a comprehensive brownfield development that will reprocess fine-grained tailings material from the three tailings cells, produced from historical open pit mining operations and processing of pyrite from 1951 to 1975, to produce HPEMM and HPMSM. The proposed CMP project site is immediately adjacent to existing infrastructure which includes an 820 MW coal-fired power station operated by Severní Energetická a.s. (Severní), a pre-cast concrete plant operated by TIBA Chvaletice s.r.o., a main railway, and railway spur lines. A new cast iron foundry by KASI spol.s r.o. and a new asphalt plant by Obalovna Chvaletice a.s. were recently constructed immediately adjacent to the proposed CMP plant site. Highway #322 connects to Prague via Kolin and Highway #12. The railway acts as a main transportation line from Prague to communities in Eastern Czech Republic. Train traffic is frequent, every 2 to 3 minutes.

Figure 18-1: CMP Tailings Site and Proposed Processing Plant Site

Source: Google Maps

The proposed metallurgical refinery is planned to be located immediately south of Highway #322, which is to the south of the tailings cells (a rail line is located between the highway and the CMP tailings facility). The proposed metallurgical process plant site will be partially located at the industrial park, which is the site of the former processing facilities that produced the CMP tailings. Existing railway spurs enter the proposed plant site at the northeast edge and extend west and south along the middle of the proposed process plant site. Figure 16-1 shows the CMP tailings site, proposed process plant site, and main existing infrastructure.

18.1 Site Layout

The plant feed will be extracted from the CMP tailings cells, starting with Cell #3. The tailings will be trucked to a pulping facility located at the south edge of the CMP tailings deposit between Cells #2 and #3. The tailings slurry will be pumped via an overhead bridge gallery which crosses the existing railway and Highway #322. The tailings will be upgraded via magnetic separation and the magnetic concentrate containing manganese will be leached by sulphuric acid. The pregnant solution produced from the acid leaching will be purified to remove iron, phosphorous, heavy metals, and other minor impurities. The resulting qualified solution will be processed to HPEMM metal using electrowinning. Magnesium will be partially removed from electrolyte solution to mitigate the potential effect of magnesium on HPEMM production. Two-thirds of the HPEMM metal will further be processed to produce HPMSM powder. The NMT and washed LR will be conveyed back to the CMP tailings site and then hauled by trucks to the excavated tailings areas where the residue blend will be dry stacked in a geomembrane lined facility. Gypsum produced from the ammonia recovery circuit will be trucked off site for sale. Magnesium carbonate, anode slime, and other waste materials will be sent to professional material handling companies for recycling or disposal. Figure 18-2 shows the general site layout. The proposed on-site infrastructure for the CMP will include:

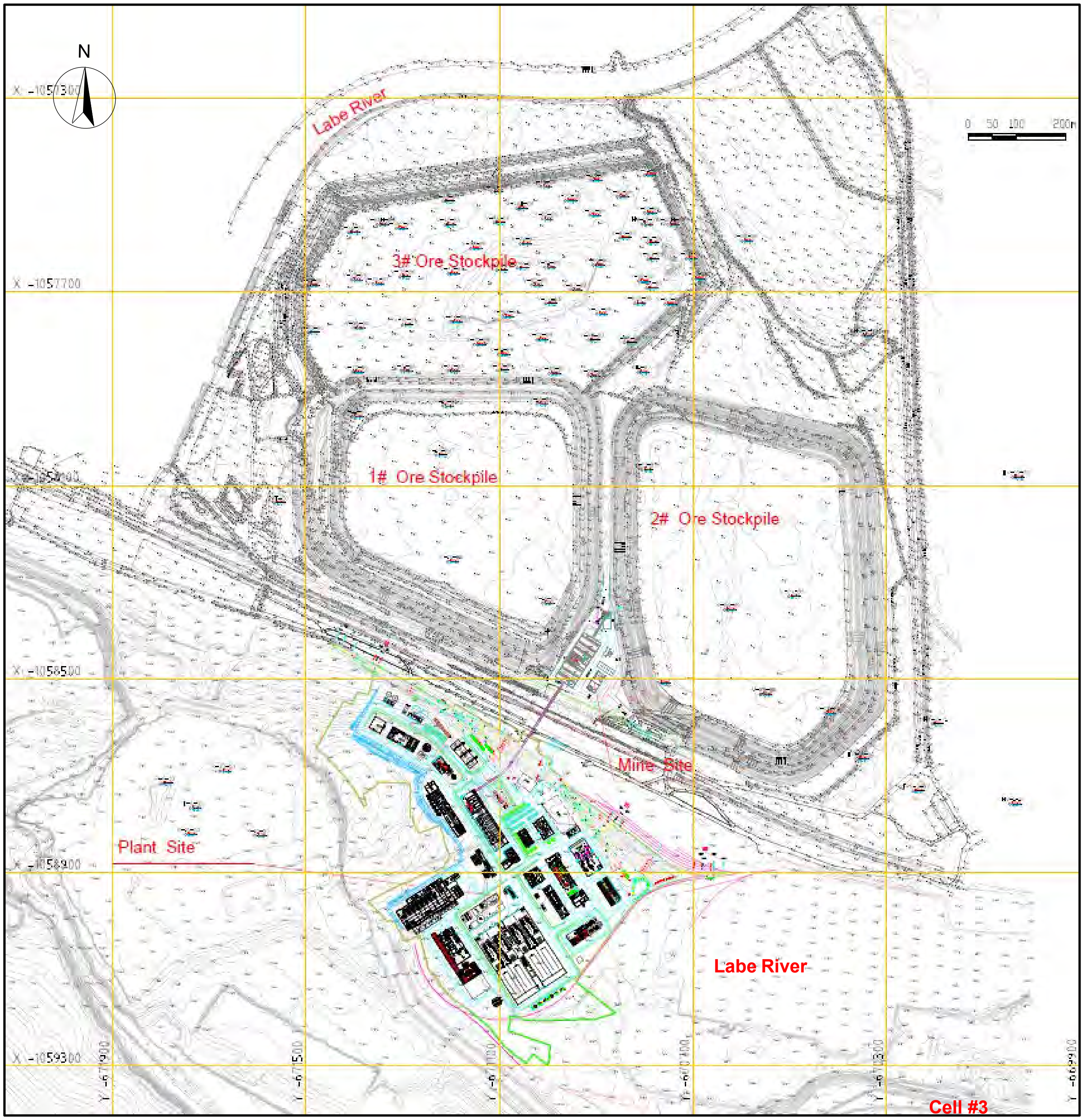
- CMP Mining Area:
  - Extracted tailings storage and residue stockpiles, and pulping facility
  - Mining maintenance workshop complex, including maintenance workshop, spare parts storage, showers and worker change rooms, dining room, offices, and meeting rooms
  - Tire washing system
  - Fuel and lubricant storage facility and fuel dispatch system
  - Parking lot for mining haul trucks, excavators, and other mobile equipment as well as a dedicated employee parking area
  - Mining area water management system including drainage channels, collection ponds, and water pumping system to pump the collected water for use as process makeup water or to the contact water collection pond for treatment at the plant site
  - Lined dry stacking storage facility for the residue blend
  - Sewage Treatment Plant (for entire site including the mining and process plant areas)
  - Temporary storage area within the Labe triangle for earthworks material excavated from the plant site preparation which shall be used for rehabilitation during dry stacking of the residue
- Conveyor/pipeline overhead gallery (bridge) connecting the north and south sites. The section above the highway and rail lines will be covered
- Security Gate control – for both Mine area and Process Plant area

- Process plant Area:
  - Process complex
  - Two 400-kV step-down transformers, including GIS switchgear in a dedicated substation; four 350 VDC, 36 kA (2 x 18 kA) rectifier transformers and local step-down transformers for site power distribution
  - Emergency generator
  - Steam plant, including hydrogen storage and handling
  - Process equipment maintenance workshop
  - Spare parts and maintenance supply warehouse
  - Water supply and management system, including a dedicated fire water system and cooling towers,
  - Water treatment facilities, including run-off water collection and treatment, storm water pond, process water treatment, and cooling water blowdown treatment
  - Assay and metallurgical test laboratories
  - Central process control room
  - General administrative and management office complex
  - Change rooms and dining facility
  - General storage yards
  - Parking areas
  - Upgraded railway spur system and related loading and unloading facilities, including sulphuric acid storage tanks and lime storage silos
  - Onsite road and pipe rack network
  - Temporary waste storage, including anode slimes for offsite recycling or disposal.
  - Scrubbers / wash towers for scrubbing of off-gases prior to discharge to atmosphere.

According to the topography, some of the process facilities are planned to be located on the sloped hillside at the southwest corner of the plant site. These facilities will be constructed on elevated pads which will be protected with retaining walls to minimize cut. The total estimated cut was 460,900 m^3 while the total fill was 75,500 m^3.

The infrastructure for the mining, process, residue storage and operations support were designed based on the information available. The design for the FS is expected to meet project requirements and local design standards.

Figure 18-2: General Project Facility Layout



As planned, all plant site facilities will be connected via a paved internal road network. Diversion channels along the roads will be constructed to direct the contact water to the site contact water pond located at the north side of the plant site. The collected water will be treated at the water treatment plant adjacent to the water collection pond. The mine haul road will be constructed on the tailings site to support the tailings extraction and the residue dry stacking operations.

18.2 Internal Roads, Pads and Railway Spurs

Internal site roads will connect various on-site facility pads. Internal site roads at the process plant site will be paved 7 m wide to accommodate two opposing lanes for unconstrained two-way traffic, while the secondary roads will be 4 to 6 m wide. The entrance to the plant site will be located at the north end of the facility, close to the highway, and will include a 100 t truck weight scale for weighing incoming and outgoing trucks. Two separate parking lots, one for commercial trucks and one for personal cars, have been included. Vehicle traffic will not be allowed to enter the plant site without permits.

There are existing railway spurs at the north edge of the proposed plant site that will be used to transport supply materials, mainly sulphuric acid, lime, spare parts, and the HPEMM and HPMSM products. The annual reagent consumables are estimated to be approximately 270,000 t. The annual manganese product production is estimated to be approximately 115,000 t of both HPEMM and HPMSM.

The on-site storage facilities will be capable of storing approximately 10 days worth of the main reagents of sulphuric acid and lime.

The roads within the mining area will be 11.4 to 12.4 m wide gravel roads to accommodate two opposing lanes for unconstrained two-way traffic, or 7.0 to 7.6 m wide single lane gravel roads. The internal roads will be sprayed with water to suppress fugitive dust that may be generated during the operation. A tire washing system will be constructed at the gate of the north CMP tailings site for incoming and outgoing trucks.

18.3 Process Plant Layout

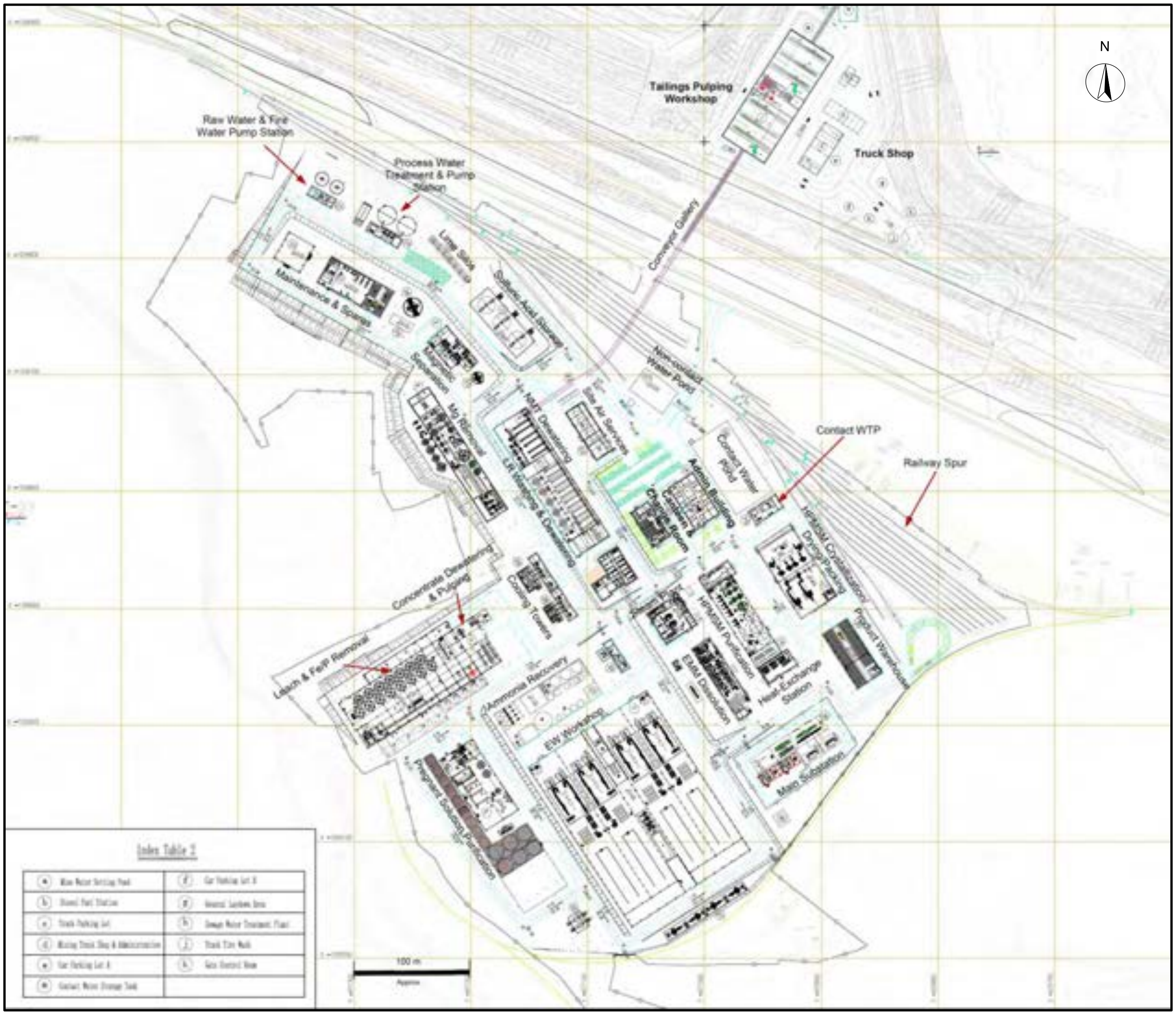
The process plant facilities will include:

- Magnetic separation facility, including NMT dewatering circuit
- Magnetic concentrate dewatering and concentrate re-pulping facility
- Concentrate leaching using sulphuric acid and iron and phosphorus removal facility
- LR dewatering with LR washing and residual manganese recovery (from LR washing water solution) facilities
- Ammonia recovery facility
- Pregnant solution purification facility
- HPEMM electrowinning, washing, stripping, packing, and storage facility
- Magnesium removal facility
- HPMSM production facilities, including HPEMM dissolution, hydrogen gas collection, solution purification, crystallization, HPMSM crystal dewatering and drying, and product handling facilities.

All the process circuits/facilities which may generate dust and off-gases will be equipped with dust and/or off-gases control systems. The off-gases will be scrubbed prior to being discharged into the air.

Figure 18-3 and Figure 18-4 show the general arrangement for process facilities, service facilities, water handling systems, and the updated railway spur. Figure 18-5 to Figure 18-8 illustrate select general arrangements.

Figure 18-3: Plant Site General Layout



TETRA TECH

Figure 18-4: Plant Site General Layout (3D Format)

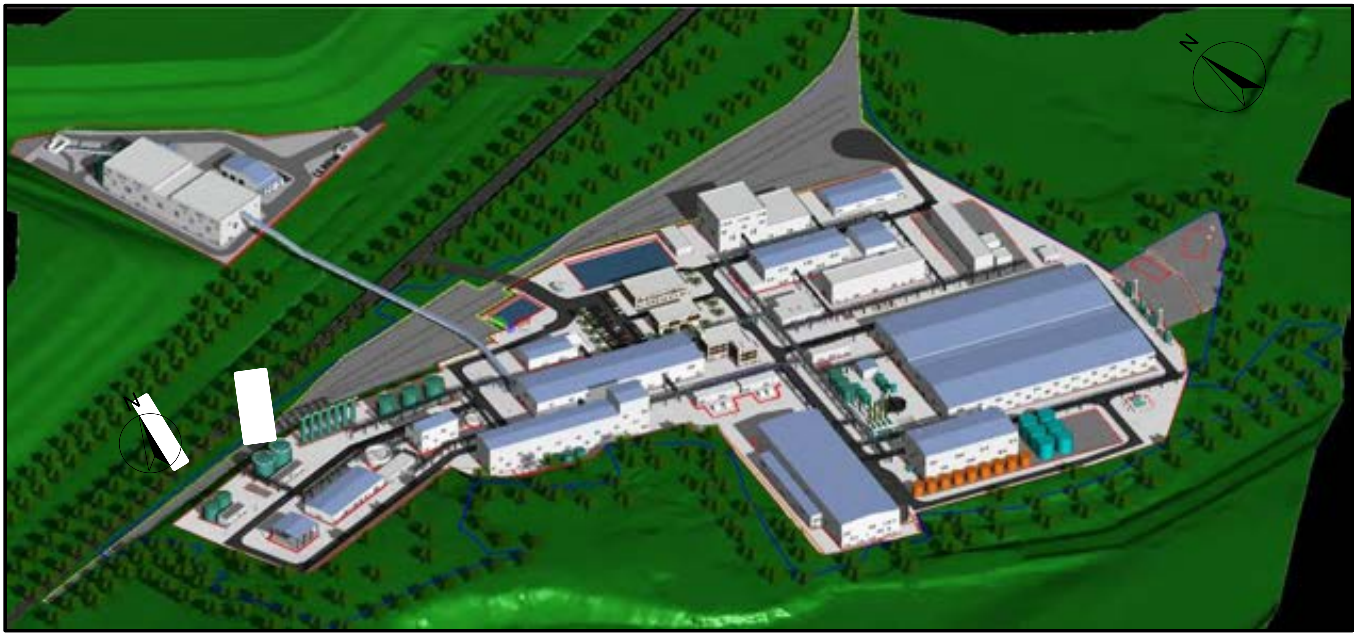
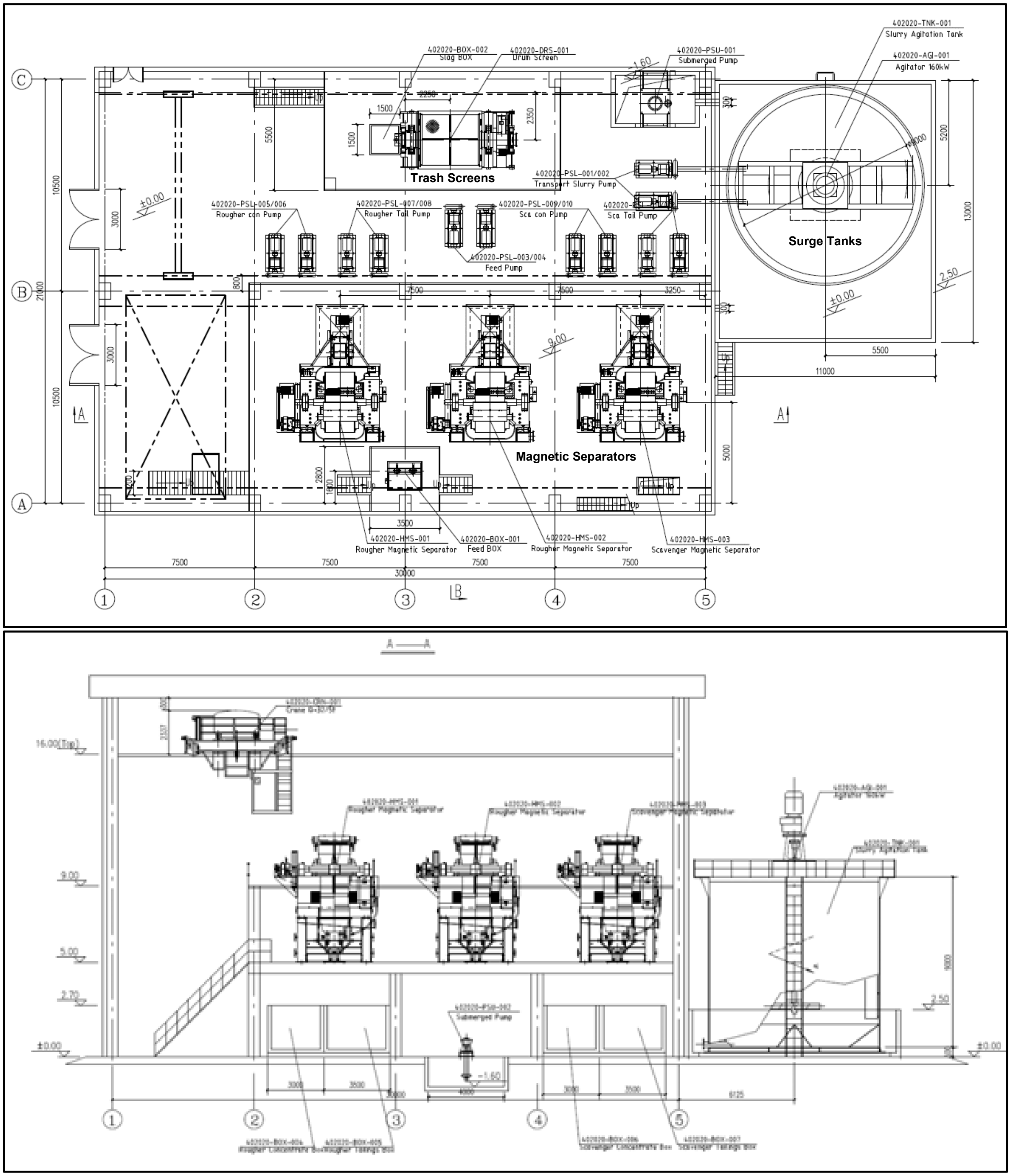


Figure 18-5: Magnetic Separation Facility General Layout



TETRA TECH

Figure 18-6: General Layout – Acid Leaching and Iron and Phosphorous Removal Facility

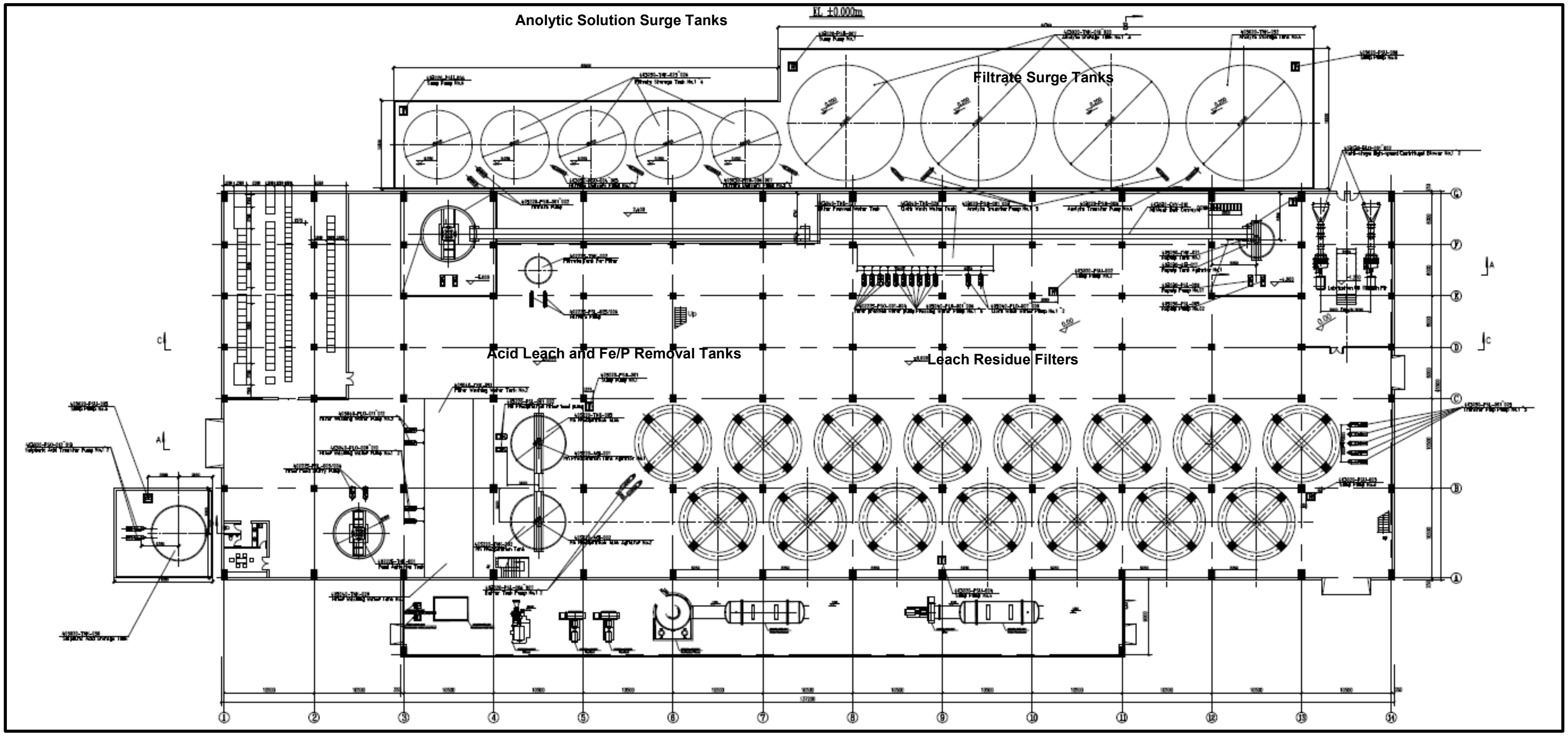
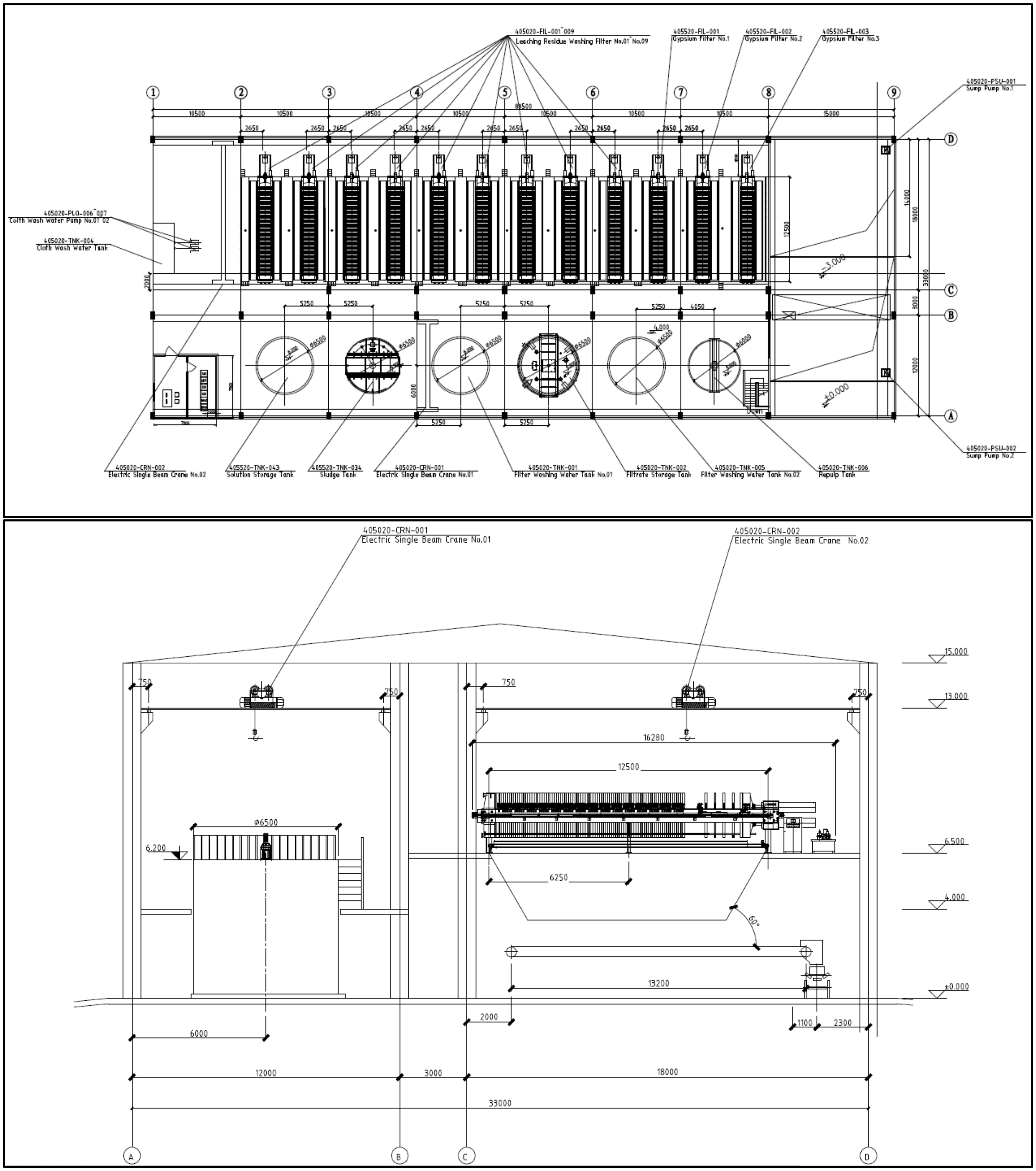
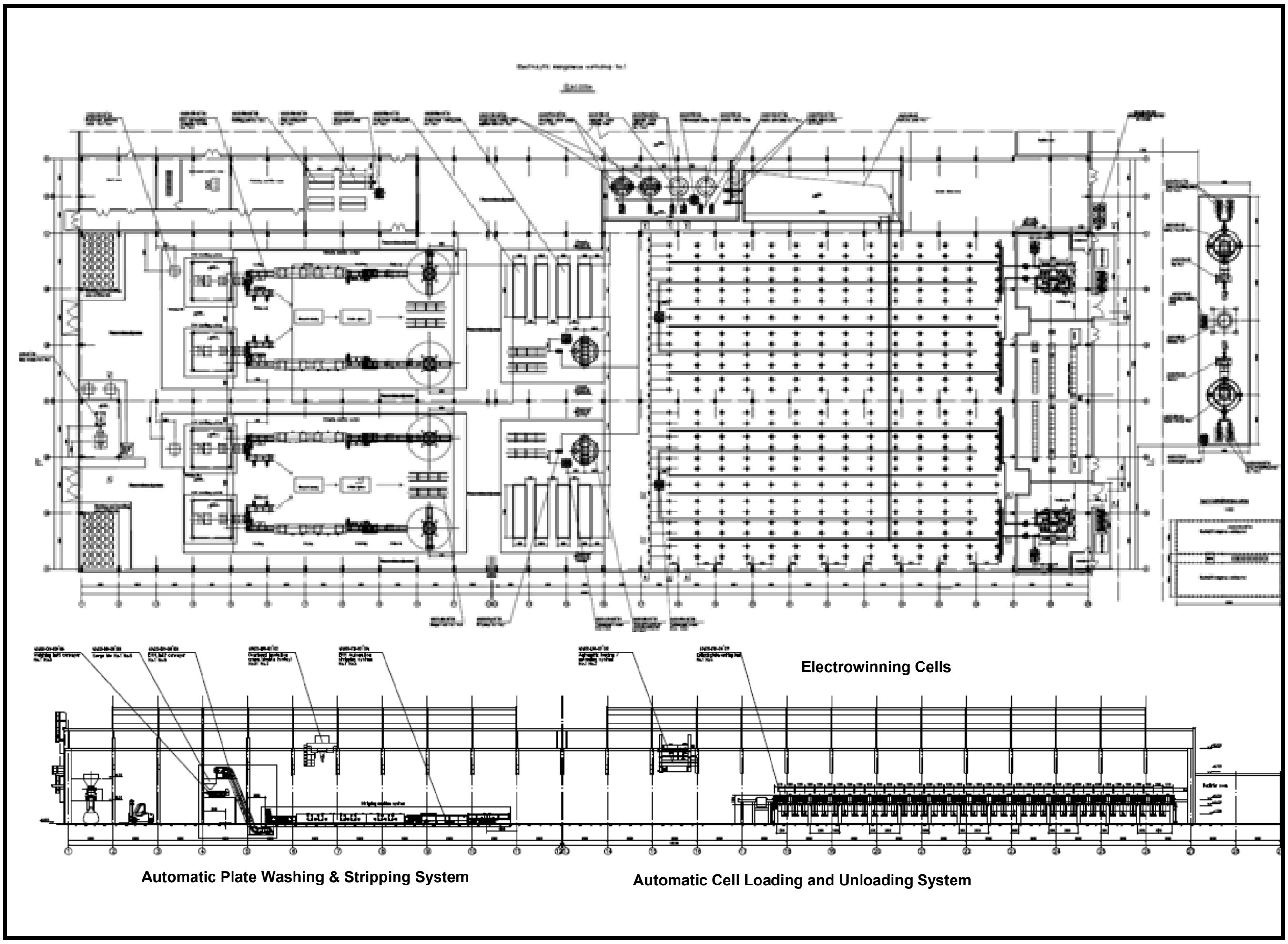


Figure 18-7: General Layout - Leach Residue Washing/Dewatering Facility



TETRA TECH

Figure 18-8: General Layout – Electrowinning Facility



18.4 Power Supply

Electrical power for the facility will be supplied via the 400 kV transmission network (owned and operated by CEPS) and will connect at the existing 400 kV Severni substation. A new substation bay, independent of the power plant, will be constructed and a 400 kV underground high voltage power cable installed and connected to the Chvaletice plant site substation. Figure 18-9 illustrates the proposed 400 kV power connection arrangement.

Figure 18-9: Proposed 400 kV Power Supply Connection Arrangement (Illustration Only)

Source: Photo from Google Maps (2022)

The 400 kV supply power will feed to two 80 MVA, 400 kV/37.5 kV/10.5 kV three-winding step-down transformers for a three-phase alternating current power supply. The main power consumers will be four electrolytic manganese rectifier transformers, which will be supplied from the 37.5 kV windings of the main transformers. The estimated running power load is approximately 75 MVA, with a power factor of 0.95 or greater after correction. The main step-down substation will be located at the east side of the plant site, adjacent to the electrowinning workshop which will be main power consumer of the CMP. Annual electrical energy consumption is 490 GWhr/year, two-thirds of which is consumed by the electrowinning process with a base load consumption profile.

The main step-down substation is equipped with a 400 kV gas insulated substation (GIS) housed in the power distribution building which also contains the main control room, a 35 kV (nominal) power distribution, and a 10 kV (nominal) power distribution. The main step-down substation is unmanned and will be equipped with an automated control system with integrated microcomputers for collecting all switching quantities and analog quantities and providing microcomputer relay protection. The 400 kV single line diagram showing the GIS and main substation 400 kV transformers are detailed in Figure 18-10. Transformer oil containment pits will be provided for the main 400 kV transformers.

The plant area electrical distribution system will be at 10 kV, which will be used to supply local substations based on the load and process requirements. The distribution of the local substations and the capacity of the transformers are detailed in the 10 kV single line diagram in Figure 18-10.

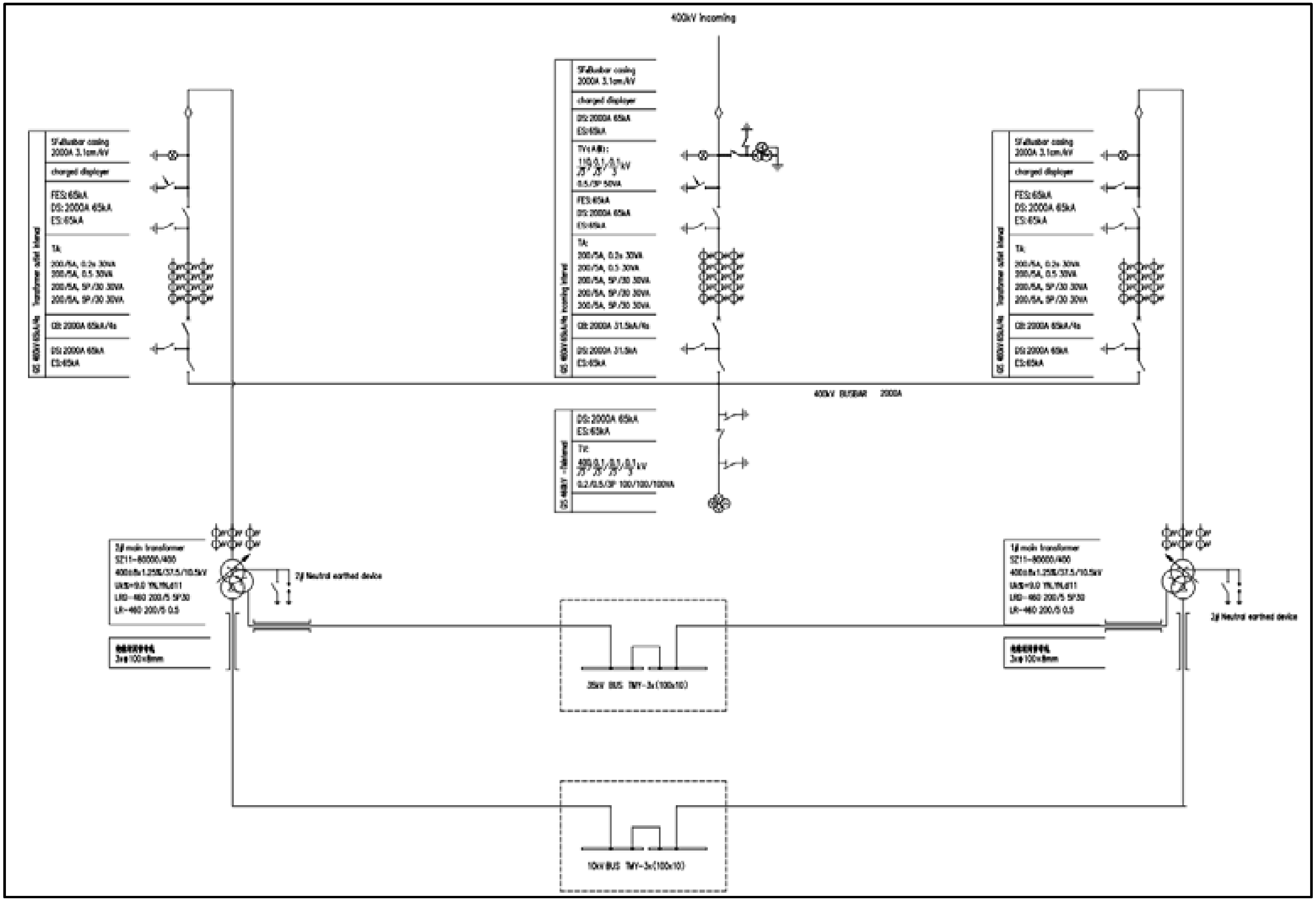
Electric equipment enclosures, metallic frameworks, electricity cable pipes and trays, and neutral points of the transformers will be grounded. The ground resistances shall be less than 0.5 ohms (Ω) for the main step-down substation and less than 4 Ω for the 35 kV and 10 kV distribution and local substations. An AC substation ground study will determine the required ground grid resistance for safe step and touch voltages.

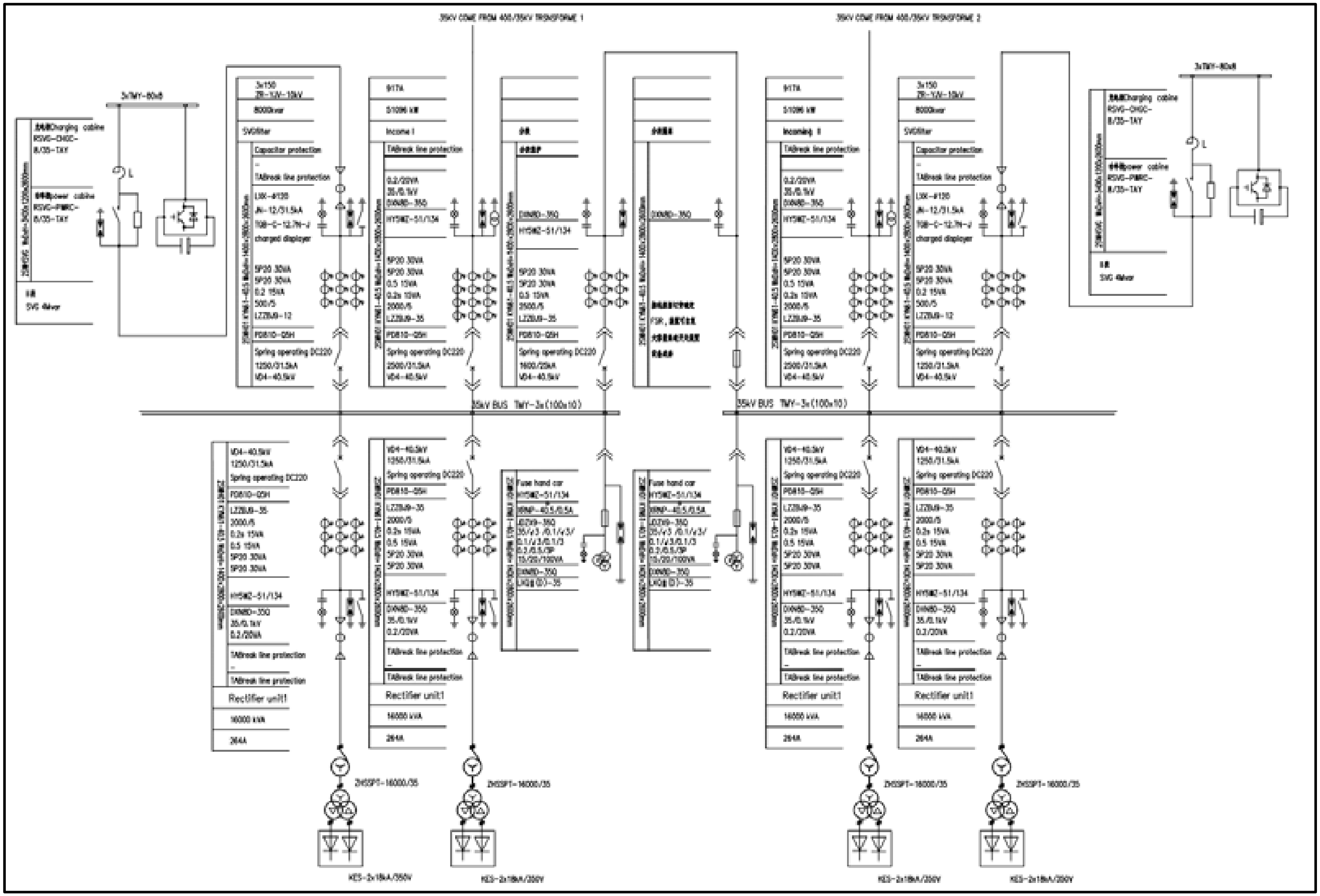
The main step-down substation will be equipped with ohms (Ω) independent lightning rods with a ground resistance of less than 10 Ω and independent of the main grounding systems for protection from direct lightning strikes.

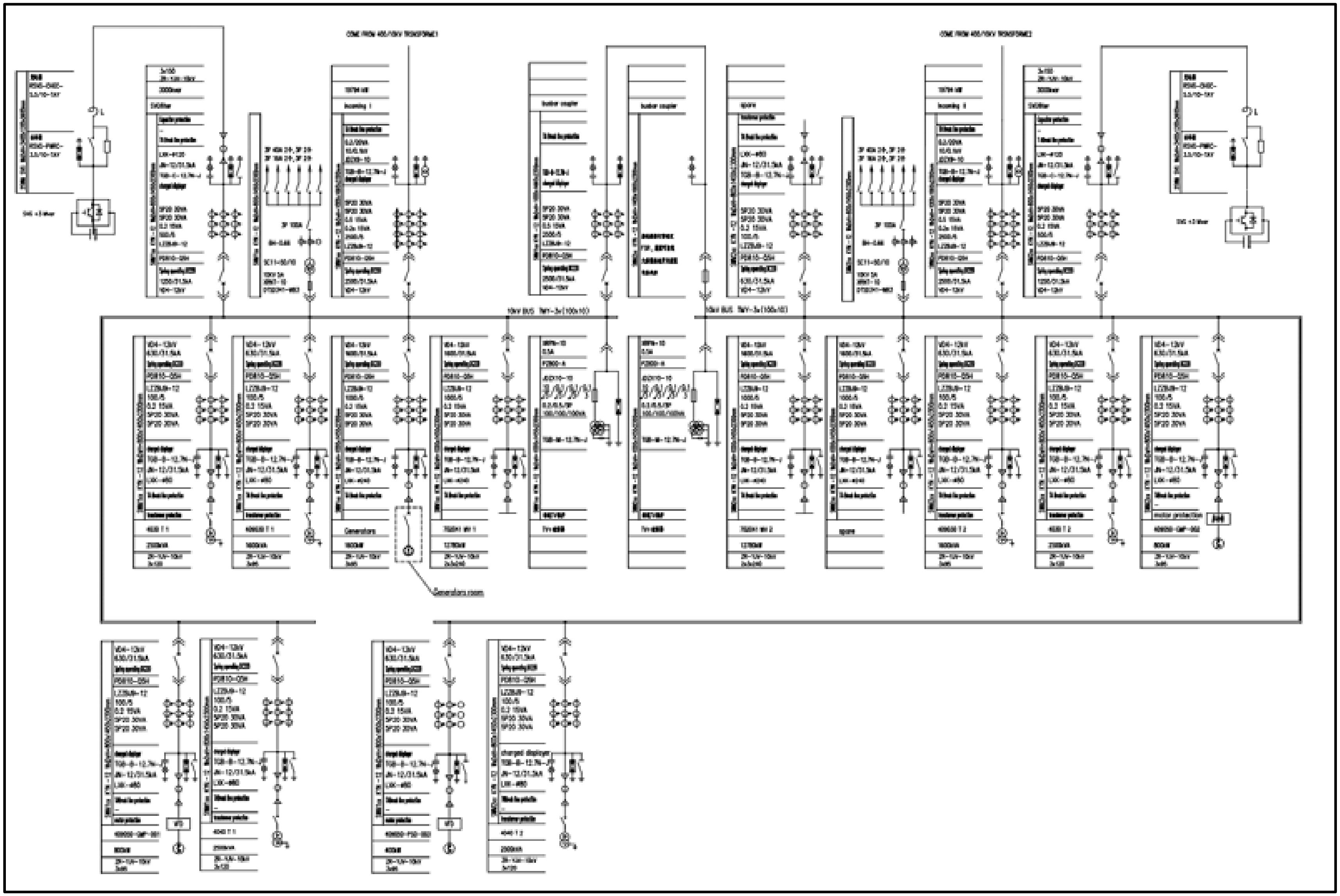
400 V is the main utilization voltage within the plant stepped down from 10 kV at the local substation. The 400 V system is solidly grounded. Automatic stepped shunt capacitors will be installed centrally at the 400 V utilization voltage at the local distribution to provide reactive power compensation.

Two site lighting systems are planned: one regular lighting and emergency lighting based on the requirements of different places. Power supply for lighting will be from 230 V low voltage power. Emergency, battery-powered lighting will be installed site wide to provide necessary lighting in case of power loss.

Figure 18-10: Electrical Single Line Diagrams




35kV BUS TMY-3x(100x10)
Capacitor protection
Spring operating DC220
Rectifier unit1
16000 kVA


Generators
Generators room

18.5 Emergency Power Supply

The estimated emergency load for the plant is 1,315 kW with a demand load of 1,198 kW. A 1,600 kW, 10 kV indoor generator will be installed in a generator room near the main step-down substation. Refer to the 10 kV single line diagram, Figure 18-10 showing the generator connection to the 10 kV bus.

Upon loss of power, the 10 kV bus will be isolated from the main transformers. The 10 kV bus tie circuit breaker will close to allow the generator to provide emergency power for the entire 10 kV bus. Load shedding will be performed at the local distribution level to prevent overloading the generator.

Key emergency loads connected to the generator are mostly for agitators and thickeners servicing for various areas, as well as other key equipment such as HVAC ventilation fans and hydrogen compressors for HPEMM dissolution.

18.6 Water Supply and Management

Two separate water management systems are planned to manage CMP water. At the plant site, collection channels along the roads will be constructed to direct the contact water to the plant site contact water collection pond located at the north side of the plant site. The collected water will be treated at the water treatment plant adjacent to the water collection pond. As a part of the plant site water control system, a separate water division system will direct the non-contact water to a storm water pond located at the north end of the plant site prior to being released to the environment at a controlled rate.

Gravel roads will be constructed on the CMP tailings site to support the tailings extraction and the residue dry stacking operations. Similar to the plant site water management, two separate site water division systems will be constructed: the water control system will direct the contact water to a collection pond where an oil-water separator will be supplied to separate contaminated oils from the water. Then the water will be pumped to two contact water surge tanks located at northside of the raw tailings storage facility. The water will be used for the preparation of the pulped slurry. Excessive contact water collected during heavy storm events will be pumped to the contact water collection pond located at the plant site and then be treated prior to use or release. Non-contact/storm water from the undisturbed areas will be directed away from the operation and discharged into the environment, while the non-contact water from the reclaimed residue dry stack area will be directed to collection ponds prior to being released to the environment at a controlled rate.

The water supply system will consist of process make-up water, cooling circulation water, potable water, demineralized water (for steam generation), 130°C hot water (for process heat loads and building heating), and fire water supply systems.

All water used in the process circuits will be re-used or treated and re-used as process make-up water. Contact water from direct runoff from the plant and mine site areas will be collected and treated at a dedicated water treatment plant at the north-east site. The treated water may either be used as process water, or be discharged into the environment. The waste process water collected from processing activities will be collected and sent to manganese and ammonia recovery circuits for treatment prior to being reused as process water. Apart from the process water treatment plant and the site run-off water treatment plant, a separate sewage water treatment plant for the waste-water generated from human activities has also been designed for the CMP. The sewage treatment plant will be located adjacent to the mining facilities. An existing underground sewage pipeline will be utilized to transfer sewage from the plant site area to the sewage treatment facility.

TETRA TECH

18.6.1 Fresh Water and Fire Water Supply

Fresh make up water will be supplied from the blowdown water ("green water") from the adjacent power plant and will be pumped to two (2) 800 m^3 water tanks. The tanks will be equipped with a standpipe, which will ensure at least a two-hour to three-hour supply of fire water (or approximately 486 m^3) is maintained. Two separate booster pumping systems will be installed, one for the process water system and one for the fire water system. Both the water supply systems will be connected to an uninterrupted power supply to ensure the water supply will not be affected by potential power outage interruptions. A dedicated fire water distribution network, including outdoor/indoor hydrants and fire sprinkler system, will be built. A diesel-operated fire pump will be included in the system, for increased reliability during a power outage.

18.6.2 Process Water

The process water required for the process is estimated to be approximately 2,080 m^3/d.

The water balance (in and out of the plant) is summarized below:

- Total water input to the plant:
  - Fresh make-up water (from adjacent power plant): 86.8 m^3/h
  - Water present in feed material/mine site: 36.8 m^3/h
  - Water present in reagents: 1.1 m^3/h
  - Water from steam (absorbed by process): 31.5 m^3/h
  - Water generated from chemical reactions: 5.8 m^3/h
  - **Total water in: approximately 162 m^3/h**
- Total water consumed by plant:
  - Cooling tower evaporation losses & process consumption: 111.4 m^3/h
  - Treated water discharge: 1.3 m^3/h
  - Moisture in product/residue/other waste materials: 49.3 m^3/h
  - **Total water consumed: approximately 162 m^3/h**
- Total cooling water in circulation: 4,338 m^3/h

The process water treatment plant will be constructed to treat the waste process water. The treated water will be re-used in process circuits, or discharged into the environment if the treated water meets local water discharge criteria.

18.6.3 Water Treatment

18.6.3.1 A. Cooling Towers Blowdown Water Treatment Plant

The cooling water generated by cooling tower will be used for magnetic separation circuit, leach circuit, electrowinning circuit and air compressors cooling.

Blowdown streams from cooling towers will be collected into the cooling circulating drainage collection tank. The pollutants in the water contain calcium and magnesium ions, calcium and magnesium crystalline suspended solids, corrosion and scale inhibitors and other components. The total blowdown flow is 22.03 m3/hr. The blowdown water will be pumped to a high efficiency automatic precipitation device where flocculant will be dosed into the water prior to its entry into the precipitation device. Sludge separated in the precipitation device will fall into the V-shaped sludge area and then is sent to the NMT dewatering circuit. The overflow which is treated water will be fed to an intermediate water tank. The overflow will be pumped through a sand filter and subsequently recycled back to the process plant as process make-up water with the excessive water (1.33 m^3/h) being discharged to the environment.

18.6.3.2 B. Contact Water Treatment Plant

The contact water will be separately collected from the mine site and the plant site. The contact collected from the mine site will be directed as makeup water for pulping the extracted raw tailings. Any excessive water due to heavy storms will be pumped to the contact water collection pond located at the plant site which will collect all the contact water generated from the site.

The contact water from the contact water collection pond in the plant site will be pumped to a surge tank and then to a high efficiency precipitation device. Flocculant will be dosed into the water prior to the water entering into the settling device. Sludge separated in the settling device will be circulated back to the feed well of the settling device as seeds or be pumped to the NMT dewatering circuit, while the treated overflow water from the settling device is fed to a surge tank. The treated water may be either used for process needs, or discharged to the environment.

18.6.3.3 C. Sewage Treatment Plant

A dedicated sewage treatment is designed by Ekosystem, a Czech local fabricator. The sewage treatment plant is located at the mine site. The sewage from the plant site will be sent to the sewage treatment plant via an existing buried pipeline passing underneath the highway #322 and the railway. As designed, the plant will have a capacity for 200 persons.

The treatment technology is designed as a continuous-flow, low-load activated sludge system with nitrification, time-controlled denitrification, regeneration using the final settling tank, equalizing tank and a separate sludge collector. The sewage treatment plant will include four separate treatment units:

- Equalizing tank with an inserted pumping station
- Activated sludge tank
- Regeneration tank with an inserted final settling tank
- Sludge collector

The wastewater will gravitationally enter the mechanical pretreatment step and the equalizing tank / pumping station. The mechanical pretreatment step will be conducted by a bar screen catcher located in the inlet section of the equalizing tank/pumping station. The equalizing tank/pumping station will be equipped with medium bubble aeration elements and a couple of pumps equipped with a flow regulator (by-pass back to the equalizing tank / pumping station). Biological treatment of wastewater will be performed in the activated sludge tank in two time-controlled phases, using a heterotrophic organism culture (the so-called activated sludge). The wastewater and activated sludge mixture will gravitationally flow from the activated sludge tank to the final settling tank where the activated sludge will sediment. The sedimented sludge will be returned to the regeneration tank. The separate sludge collector will be used for storage and aerobic stabilization of sludge. Thickened and aerobically stabilized sludge will be removed from the collector on a regular basis by a sewage truck for external disposal. Sludge water from the sludge collector will be pumped using a submersible pump back into the activated sludge tank. The treated and disinfected water will be re-used for watering plants and controlling road dust. Any excessive treated water will be discharged into the local drainage system.

18.6.4 Potable Water

Potable water will be supplied from the local water supply system. It is estimated that, on average, approximately 75 m^3/d of the potable water will be required for the CMP. The water will be provided from a local municipal pipeline network. Bottled water will be used for drinking water at the CMP tailings site.

18.6.5 Heat Utilities

18.6.5.1 Hot Water

Hot water at 1.0 MPag and 130°C will be provided by the neighbouring Severní power plant.

This hot water will be strictly used as a heating medium, in a closed loop, and shall be returned in full to the power plant after utilizing its heat value as required. No portion of this water is allowed to be consumed within the Chvaletice Manganese Plant. Return water temperature is not restricted and can be as low as 40 to 45°C.

The hot water will also be utilized as an indirect heat source for process heating in the process plant, as well as for space heating in industrial and office buildings. Leaching and iron/phosphorus removal will be the main heat loads for the hot water.

When used for space heating in industrial buildings, the hot water shall be used as the primary heating fluid to transfer heat through heat exchangers to glycol-water mixture (glycol). This glycol heating system is then to be pumped to the industrial buildings that require space heating. Forced-air unit heaters and make-up air units shall be used in the industrial and process buildings for transferring heat from the glycol water loop to the indoor space.

For office buildings, the temperature of the primary heating fluid will need to be reduced from 130°C to a range of 82 – 87°C. Baseboard heaters may be used for providing heat to the offices.

Flow-metering and temperature recording shall be installed at the battery limit of the CMP plant, both for the hot water entering and leaving the plant.

18.6.5.2 Steam

Steam will be supplied from an onsite steam generation plant using natural gas and recovered hydrogen gas as fuels separately. Natural gas will be available from the local utility company and will be used as fuel for the boilers to produce the steam. The produced steam will service various processes, mainly for ammonia recovery, start-up of ammonium sulphate evaporative crystallization circuit, HPMSM evaporative crystallization, and HPMSM crystal drying.

Two natural gas fired steam generators, each with a rated capacity of 20 t/h steam and one hydrogen fired steam generator with a capacity of 6 t/h steam are proposed for the project, to supply steam at a working pressure of 0.6 MPa. Hydrogen will be generated from the HPEMM dissolution process.

Demineralized water available from the power plant will used as feed water for the above-mentioned boilers. The water consumed within the process plant is not required to be returned to the power plant. The demineralized water may also be used as feed for the production of pure water, thus potentially reducing the overall cost of producing the pure water.

Flow-metering shall be required at the battery limit of the Chvaletice Plant as both demineralized and hot water will be purchased from the power plant.

Table 18-1 to Table 18-3 show the building space heat loads, process heat loads, and design steam consumption.

Table 18-1: Heat Load List for Buildings

Sub-Item Name	Temp. (°C)	Total Heat Load (kW)	Heat Source	Water Temp. (°C)
Total Buildings Space Heating Load	5/20	7,410	Hot Water / Glycol / Heat Exchange Station	85/60

Table 18-2: Heating Water Usage Statistics

Sub-Item No.	Sub-Item Name	Water Flow (t/h）	Heat Source	Water Temp (°C)	Remarks
4030	Leaching and Fe&P Removal	189	Thermal power plant	130/70	Anolyte heating
		9	Thermal power plant	130/70	Fe removal (supplement)
701011	Canteen and Change Room	8.1	Thermal power plant	130/70	Bathroom heat exchanger
702018	Heat Exchange Station	106.2	Thermal power plant	130/70	Heating heat exchanger
Total	**312.3 t/h**				

Table 18-3: Steam Usage Statistics

No.	Item	Steam Flow（t/h)	Heating mode	Steam parameters
1	Ammonia recovery	26.0	direct	0.4MPa，152 ºC
2	$(NH_4)_2SO_4$ evaporative crystallization (Initial）	3.3	indirect	0.4MPa，152 ºC
3	$MnSO_4$ evaporative crystallization	2.1	direct	0.4MPa，152 ºC
4	Dry	3.4	indirect	0.4MPa，152 ºC
5	Boiler deaerator	7.7	direct	-
6	**Total**		**42.5**	

18.7 Air Supply

Compressed air will be required site wide to service various process circuits, mainly iron/phosphorus removal circuit and filtration circuits, maintenance, and instrumentation systems. The compressed air will be mainly supplied from a centralized compressor station.

Plant air service systems will supply air to the various process areas, including:

- Iron purification circuits – high-pressure air by dedicated air compressors
- Filtration circuits – high-pressure air for filter pressing and drying of various filtration cakes
- Electrowinning plant service air – high-pressure air for various services
- HPMSM plant service air – high-pressure air for various services
- Instrumentation – plant site instrument air will come from the plant air compressors and will be dried and stored in dedicated air receivers prior to being used to service plant control systems

A dedicated compressed air system will be provided for the CMP tailings site for mobile equipment maintenance.

18.8 Railway Services

An existing railway spur connecting to the Czech national railway network is located immediately to the northside of the process plant. The railway spur will be upgraded and its services dedicated to the Chvaletice operation. Sudop Praha a.s. (Sudop), a local infrastructure engineering firm, designed the rail spur upgrading which is illustrated in Figure 18-3. The railway spur will be used for delivering reagents, especially sulphuric acid and lime, and spare parts from suppliers or transfer stations to the CMP site and dispatching products to customers who prefer to receive the HPEMM or HPMSM via railway transport. Dedicated loading and unloading systems and separate platforms have been designed, including dedicated sulphuric acid and lime unloading systems. Sulphuric acid storage tanks and lime storage silos will be constructed adjacent to the railway spur. The railway spur will have its own signal and control system which will be interlocked with the central control system. The CMP will operate the rail spur system and will own a shunting engine for the rail spur operation. Site Wide Water Management Plan

Water management for the mine site and plant site will follow basic principals of keeping clean water clean and managing surface water flows using conveyances such as collection ditches, ponds, and surge tanks, reducing surficial inflow from neighbouring properties, and use of liners to reduce infiltration into groundwater. Excessive contact water from the mine site will be pumped to the repulping facility or treatment as required.

18.9 Site Water Management

The surface and groundwater drainage from the existing Chvaletice mine area currently enters the natural environment as seepage to groundwater and as runoff to the Labe River.

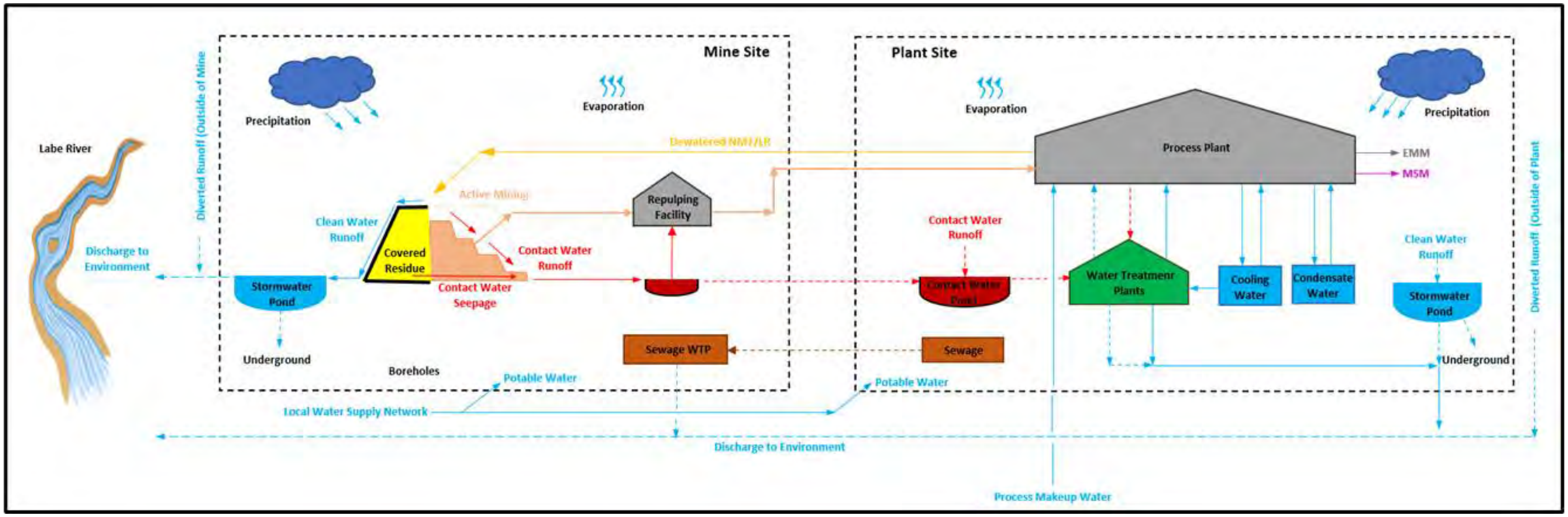
During the mining activity period, the contact runoff and seepage from the active mining area will be collected through collection ditches and then routed into a collection pond and surge tanks at the mine site. The water will be used as process makeup water for the tailings repulping process. Flows from any storm event exceeding the capacity of this contact water storage (event) will be diverted towards the main collection pond in the plant site. The water in the collection pond at the plant site will be treated and either used as process makeup water or discharged to the environment. The collection ponds and ditches will be lined to control seepage.

Once the existing tailings from each cell are processed, the residue material will be placed within a geomembrane lined residue storage facility (RSF) designed to mitigate release of contact water seepage. The surface of the RSF will be progressively covered during the mine operation and clean surface runoff will be collected and managed. The potential seepage contact water from the RSF will be collected through a central internal sump and then sent to the collection pond/surge tanks. The seepage is expected to reduce to a relatively insignificant volume a few years following the completion of mining and installation of the final cover. Until then and through the closure phase, the collected contact water shall be monitored and treated as required prior to being discharged to the environment.

The quality of the water that will be discharged into the surrounding environment, including Labe River, is expected to be significantly improved throughout the life of the project, as mine contact water will be collected and managed.

The proposed water management strategy schematic for the CMP project is shown in Figure 18-11.

Figure 18-11: Surface Water Management Concept for the Chvaletice Manganese Project Site



TETRA TECH

18.9.1 Site Water Management

The proposed process plant will be constructed south of the mine site within an existing industrial park. All the water within the plant site will be managed to mitigate potential contamination of the surface and seepage water.

The primary water sources used by the process plant for manganese extraction and upgrading include:

- General process makeup water which will be sourced from:
  - the in-situ water present in the mined tailings;
  - the contact runoff collected from the mine and plant site;
  - the recovered/treated water from various process circuits;
  - the cooling tower blow down wastewater from the nearby Seven power plant which is currently discharged into the Labe River.
- Process makeup water, which will be used for reagent preparation and specific process uses, will be sourced from:
  - the recovered clean water from various process circuits, such as condensates;
  - the treated water from water treatment plant; and
  - the cooling tower blowdown wastewater from the nearby Seven power plant.

The contact water from the mining and residue storage areas will first be collected at the mine site area in collection pond/tanks and then pumped to the Plant Feed Storage and Pulping area for pulping of the run-of-mine materials. Any surcharge/additional water from the mine site area collection pond shall be pumped to the plant site area collection pond, including flows from storm events larger than the capacity of this contact water storage (up to 1:200 year event). The water management concept for overall project site, including the plant site, is illustrated in Figure 18-11. All the ponds and ditches that are used to manage contact water will be lined to mitigate seepage.

Non-contact/storm run-off water from outside of the process plant site will be diverted to the environment. All the non-contact water, including the water from building roofs, will be collected and directed to the site stormwater control pond prior to being released to the environment. The collected clean runoff in the plant stormwater pond may be used as a makeup water source for process use.

Based on the local water authorities guide, a clean stormwater pond shall be sized such that the peak flow from the clean runoff for the post development condition is reduced to the peak flow from the clean runoff for the predevelopment condition during a 1:10 year, 1-hour storm event.

The contact water from the mine site as well as process water will be collected separately and used as process makeup water or sent to a water treatment plant. Table 18-4 shows some of main acceptable environmental discharge criteria for treated water. Further details are shown in General Site Conditions Rev 1 (Document # 1720-003010-G-DBM-001).

Table 18-4: Treated Water Quality Requirements Prior to Being Discharged

Indicator	Discharge Standards		Maximum Released Amount (kg/year)
	Acceptable value	Unit	
pH	6 – 9	-	-
NL	40	mg/l	1,200
C_{10} - C_{40}	3	mg/l	<10
Arsenic	0,5	mg/l	<5
Copper	1	mg/l	<10
Lead	0,5	mg/l	<5
Zinc	3	mg/l	100
Iron	3	mg/l	100
RAS	3,500	mg/l	50,000

Note: NL = insoluble compounds; RAS = soluble inorganic salts
Source: EIA Notification

Sewage water produced from the mine site and plant site will be collected and sent to a central sewage water treatment plant located at the mine site. The water will be treated to meet the water quality requirements prior to being discharged to the environment. The details of treated sewage discharge criteria are detailed in General Site Conditions Rev 0 (Document # 1720-003010-G-DBM-001). Chvaletice Mine Climate Data Analysis

The CMP site is located in a Warm Climatic Region T2, where it is characterized by a warm and dry summer, a relatively short transition from a slightly warm spring to summer, and from summer to a warm to moderately warm autumn. Winter is usually dry, short, with a very short period of continuous snow cover.

Daily climate data was purchased from Czech Hydrometeorological Institute for the Chotusice Airport Station located less than 10 km from the project site. Table 18-5 through Table 18-9 summarise the monthly averages for precipitation, air temperature, relative humidity, wind speed, and sunshine hours from the Chotusice Airport Station, respectively, and Figure 18-12 through Figure 18-15 summarise the annual averages for the aforementioned climate parameters.

The average annual precipitation for the Chotusice Airport Station, Prague Station, and Pardubicky were estimated to be approximately 500 mm, 535 mm, and 568 mm, respectively.

Table 18-5: Monthly Averages for Precipitation – Chotusice Airport Station

	Precipitation Depth (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Sum
2004	43.4	22.3	48.6	30.1	39.5	50.1	91.3	43.4	34.3	23.1	39.6	12.7	478.4
2005	33.4	39.2	9.2	29.2	47.9	19.3	109.9	105.7	33.9	4.4	14.1	30.5	476.7
2006	21.2	16.5	51.7	38.1	61.4	70.4	11.8	102.7	3.0	43.7	18.0	16.9	455.4
2007	36.1	38.7	34.3	1.3	36.4	75.2	77.0	62.6	74.3	17.6	52.8	16.1	522.4
2008	18.5	14.4	32.0	31.7	34.3	51.8	59.2	61.6	20.3	38.5	38.0	17.9	418.2
2009	9.3	37.7	45.0	4.9	55.8	103.3	85.9	35.8	20.7	41.0	18.0	50.7	508.1
2010	40.3	11.5	16.6	42.6	92.7	41.0	100.6	160.5	84.7	4.8	35.7	29.7	660.7
2011	25.5	6.2	14.7	10.9	51.6	126.8	105.1	49.5	36.9	32.9	0.3	27.5	487.9
2012	47.1	15.5	9.2	30.2	38.3	55.4	148.1	64.8	25.5	44.9	17.2	38.6	534.8
2013	33.7	35.4	17.4	16.8	102.5	126.0	39.9	53.3	55.0	39.7	16.5	6.1	542.3
2014	24.8	1.8	37.5	52.2	123.8	33.0	67.1	60.9	102.7	37.8	9.8	43.9	595.3
2015	29.3	4.9	30.2	16.0	52.4	52.5	18.0	69.1	13.3	39.7	57.4	15.7	398.5
2016	16.7	27.5	28.8	21.2	44.3	68.2	68.0	27.4	7.2	49.2	20.5	10.8	389.8
2017	13.9	12.6	32.0	92.2	38.2	83.8	137.3	72.9	47.5	68.4	26.0	17.8	642.6
2018	20.5	10.9	25.7	25.3	29.6	65.4	22.5	29.7	44.2	23.3	9.3	66.0	372.4
Average	27.6	19.7	28.9	29.5	56.6	68.1	76.1	66.7	40.2	33.9	24.9	26.7	498.9

Table 18-6: Monthly Averages for Air Temperature – Chotusice Airport Station

	Air Temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2004	-3.2	2.1	4.0	10.1	12.7	16.5	18.4	19.6	14.3	10.3	4.7	0.8
2005	1.3	-2.1	2.5	10.6	14.8	17.5	19.3	17.1	15.7	10.5	3.4	0.3
2006	-5.3	-1.8	1.9	9.7	14.1	18.4	22.7	16.6	17.0	11.4	7.2	3.7
2007	5.0	4.2	6.5	11.3	15.9	19.2	19.7	19.2	13.1	8.7	2.7	0.7
2008	2.7	3.7	4.5	9.3	14.9	18.8	19.4	19.1	13.8	9.4	5.5	2.1
2009	-3.6	0.5	4.9	13.6	14.9	16.2	19.6	20.0	16.2	8.5	7.0	0.3
2010	-4.3	-0.7	4.4	9.3	12.9	18.0	21.7	18.7	12.9	7.4	6.2	-4.1
2011	0.1	-0.7	5.2	11.8	15.1	18.3	18.0	19.5	16.1	9.4	3.8	4.1
2012	2.1	-3.7	6.7	10.1	16.3	18.4	19.6	19.8	14.7	8.4	6.4	0.3
2013	-0.7	0.1	0.6	9.7	13.7	17.5	21.2	19.2	13.5	10.6	5.8	2.9
2014	2.0	4.0	7.9	11.5	13.9	17.7	21.4	17.8	15.7	11.5	8.1	3.7

table continues…

	Air Temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2015	2.7	2.2	6.0	9.7	14.4	17.8	22.0	23.4	15.0	9.7	7.9	6.3
2016	0.6	5.0	4.6	9.3	15.3	19.1	20.2	18.6	17.8	8.9	3.7	0.7
2017	-4.7	1.9	7.2	8.4	15.3	19.3	20.0	20.2	13.0	10.8	5.0	2.4
2018	3.3	-2.0	2.1	14.1	17.9	19.1	21.8	22.9	16.2	11.4	5.4	2.6
Average	-0.1	0.9	4.6	10.6	14.8	18.1	20.3	19.4	15.0	9.8	5.5	1.8

Table 18-7: Monthly Averages for Relative Humidity – Chotusice Airport Station

	Relative Humidity (%)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2004	86.2	77.9	77.9	71.0	72.2	76.8	75.0	70.7	72.6	83.7	88.6	88.4
2005	82.6	81.8	74.9	65.2	67.5	66.7	74.3	76.6	75.2	76.9	87.6	86.7
2006	83.4	82.4	80.4	71.8	67.8	68.7	64.8	78.9	73.0	80.4	85.2	89.5
2007	79.4	84.4	75.0	56.8	64.1	70.6	65.8	69.0	76.8	82.8	87.7	84.6
2008	83.6	74.0	74.8	76.3	76.7	75.5	74.0	72.1	79.1	87.8	90.3	88.0
2009	91.7	90.6	83.2	61.0	68.6	75.5	71.9	68.4	73.1	83.7	82.3	85.8
2010	87.1	81.8	70.2	69.1	80.5	68.8	65.4	75.7	77.7	76.9	85.3	86.4
2011	87.1	76.3	66.3	64.8	62.1	70.2	71.8	71.4	75.4	80.1	84.4	80.7
2012	78.9	76.3	70.0	63.8	61.1	69.1	72.1	66.7	75.5	85.3	87.5	87.0
2013	86.4	87.9	77.2	74.5	78.7	76.6	65.8	72.8	82.3	81.9	86.6	87.0
2014	87.0	80.3	71.1	75.9	77.0	67.3	69.3	76.9	85.5	89.2	89.5	86.9
2015	83.8	78.5	70.3	65.0	66.7	68.4	56.0	57.3	69.6	81.4	79.4	82.3
2016	82.4	79.3	82.2	69.9	66.4	69.5	68.3	67.5	66.0	82.4	83.3	85.4
2017	81.7	77.8	71.7	71.7	66.9	63.4	67.7	66.9	79.0	80.8	83.9	80.0
2018	81.3	75.7	72.7	61.5	61.4	67.3	54.3	51.9	67.8	70.5	80.5	83.1
Average	84.2	80.3	74.5	67.9	69.2	70.3	67.8	69.5	75.3	81.6	85.5	85.5

Table 18-8: Monthly Averages for Wind Speed – Chotusice Airport Station

	Wind Speed (m/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2004	3.0	4.1	3.7	3.1	3.1	2.5	2.5	2.4	2.6	2.8	3.5	2.7
2005	4.1	3.2	3.1	2.0	2.5	2.7	2.4	2.1	2.1	2.3	2.4	3.5
2006	2.4	2.9	2.9	2.5	3.1	2.4	1.9	3.3	2.8	2.7	3.6	2.9
2007	5.5	3.7	3.6	2.6	3.0	2.7	3.3	2.4	3.8	2.4	4.0	3.2

table continues…

	Wind Speed (m/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2008	4.2	3.5	4.7	3.1	2.1	2.2	3.0	3.0	2.4	2.5	4.0	4.0
2009	2.1	4.3	4.7	3.0	3.1	3.2	2.7	2.5	2.6	2.9	3.4	2.7
2010	2.6	3.0	4.1	2.6	3.0	2.8	2.5	3.0	3.1	2.7	3.2	3.6
2011	3.0	2.8	3.0	3.4	2.6	2.7	3.2	2.3	2.0	2.7	2.4	4.5
2012	4.8	3.3	3.3	3.6	3.0	2.7	2.8	2.2	2.2	2.4	3.2	2.7
2013	3.3	2.7	3.2	2.7	3.3	2.8	2.5	2.1	3.3	2.8	3.5	3.8
2014	3.1	3.7	3.3	2.6	3.3	2.4	2.2	2.5	2.4	2.5	2.9	3.8
2015	4.5	2.7	3.6	3.4	2.8	2.4	3.0	2.4	3.0	2.3	3.8	2.9
2016	2.8	4.0	2.8	2.7	3.0	2.4	2.7	2.6	2.5	3.2	3.4	3.6
2017	3.6	3.0	3.6	4.1	3.3	3.2	3.2	3.0	3.2	4.3	3.6	4.4
2018	4.4	2.7	3.5	3.9	3.0	3.0	2.8	2.9	2.6	3.9	3.2	4.5
Average	3.6	3.3	3.5	3.0	3.0	2.7	2.7	2.6	2.7	2.8	3.3	3.5

Table 18-9: Monthly Averages for Sunshine – Chotusice Airport Station

	Sunshine (Hour)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2004	1.4	2.3	3.6	6.2	6.5	7.0	7.2	7.8	6.1	4.2	1.5	1.0
2005	2.3	2.0	4.4	6.6	8.6	8.2	6.9	6.5	6.3	5.0	1.0	0.6
2006	2.1	2.6	2.8	5.6	7.2	8.8	11.1	5.2	6.8	4.3	1.8	1.7
2007	1.6	2.4	4.2	9.2	7.7	8.3	8.3	7.6	5.2	2.9	1.2	1.0
2008	1.2	3.6	3.8	5.0	7.6	8.3	7.2	7.6	4.5	3.4	1.2	1.5
2009	1.1	0.7	2.0	9.1	6.6	5.9	7.6	8.6	6.1	1.8	2.7	1.1
2010	0.9	1.8	4.1	7.6	3.0	8.4	9.0	5.6	5.3	4.5	1.8	0.7
2011	1.4	3.3	5.4	6.5	9.1	8.8	6.4	7.5	6.6	3.9	2.0	1.7
2012	1.9	3.2	5.3	6.1	9.5	7.1	7.1	8.6	5.8	2.8	1.6	1.4
2013	0.5	0.9	2.8	4.5	5.6	6.9	10.7	8.3	3.9	4.4	1.2	1.6
2014	1.6	3.2	5.2	6.2	6.6	8.4	8.2	6.0	4.7	2.1	0.8	0.7
2015	1.0	2.4	4.4	6.5	6.5	7.4	9.5	8.7	5.8	2.8	2.7	3.0
2016	1.9	2.3	2.8	5.2	7.0	6.8	6.7	8.1	7.9	1.6	2.4	1.4
2017	2.7	2.7	4.5	3.5	8.4	9.6	7.5	8.2	3.5	2.9	1.1	1.5
2018	1.0	4.0	2.7	8.3	9.2	7.0	8.9	8.9	6.9	5.5	2.7	1.0
Average	1.5	2.5	3.9	6.4	7.3	7.8	8.2	7.5	5.7	3.5	1.7	1.3

Figure 18-12: Daily Average Precipitation (Averaged Over 15 Years for a Period Between 2004 and 2018)

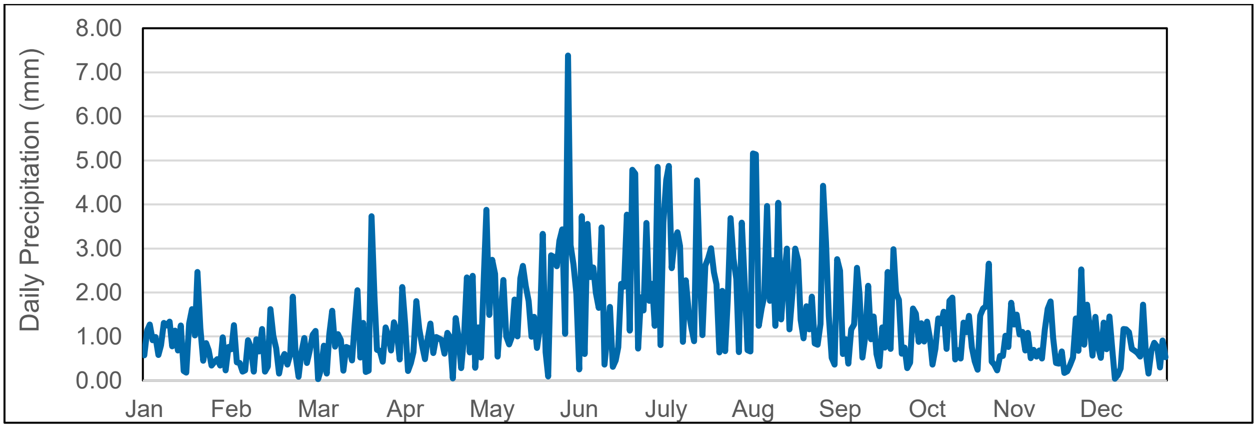


Figure 18-13: Daily Average Air Temperature (Averaged Over 15 Years for a Period Between 2004 and 2018)

Figure 18-14: Daily Average Relative Humidity (Averaged Over 15 Years for a Period Between 2004 and 2018)

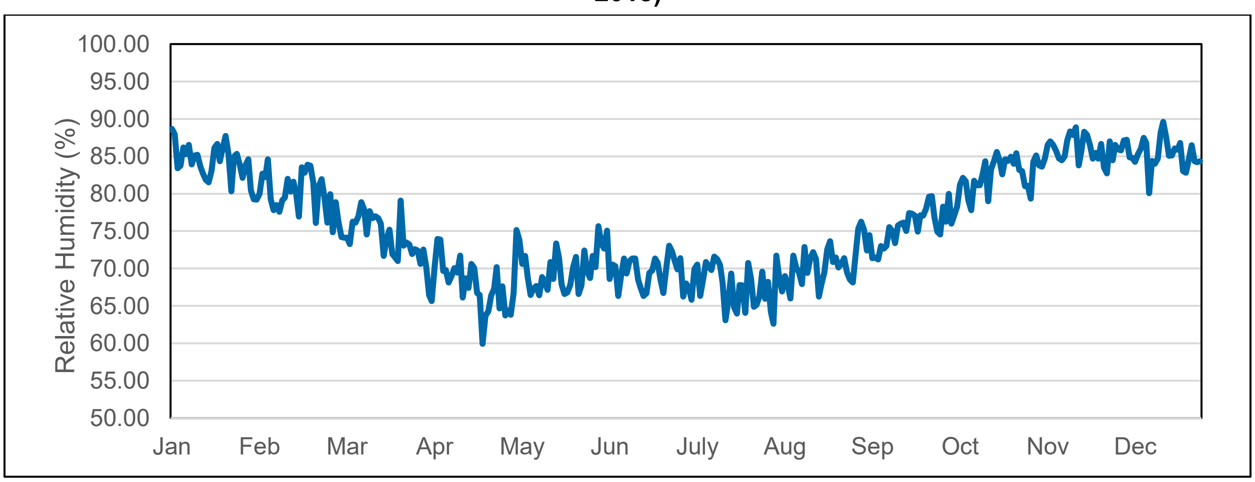


Figure 18-15: Daily Average Wind Speed (Averaged Over 15 Years for a Period Between 2004 and 2018)

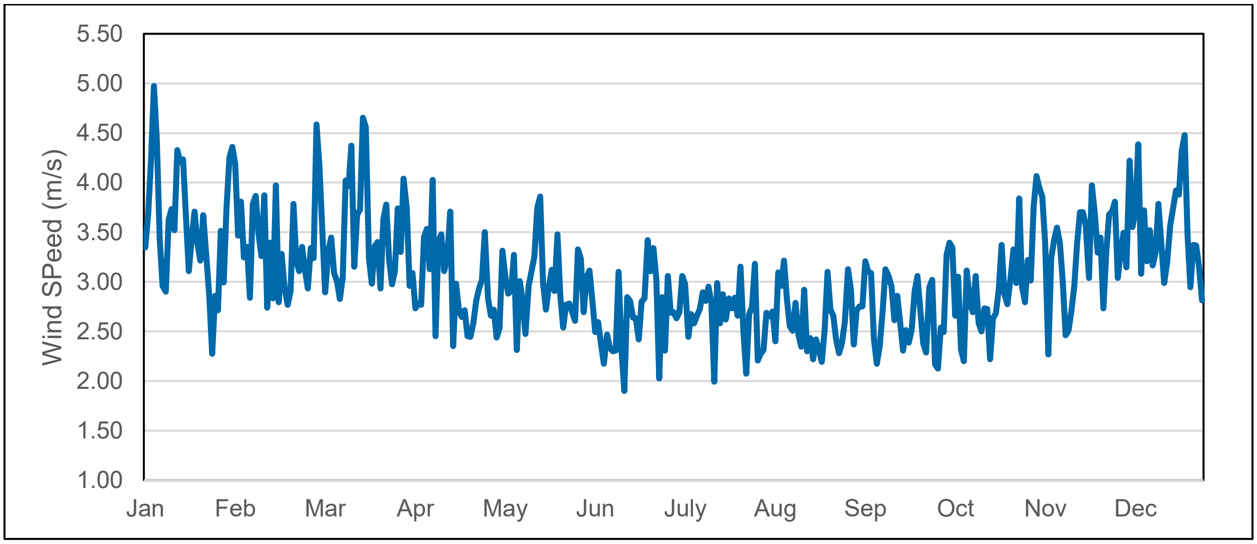
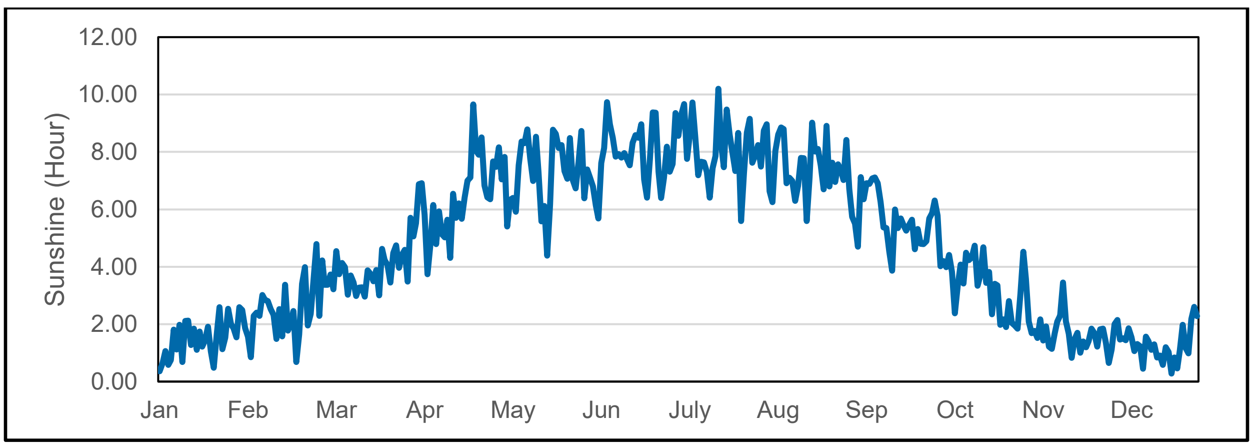


Figure 18-16: Daily Average Sunshine (Averaged Over 15 Years for a Period Between 2004 and 2018)

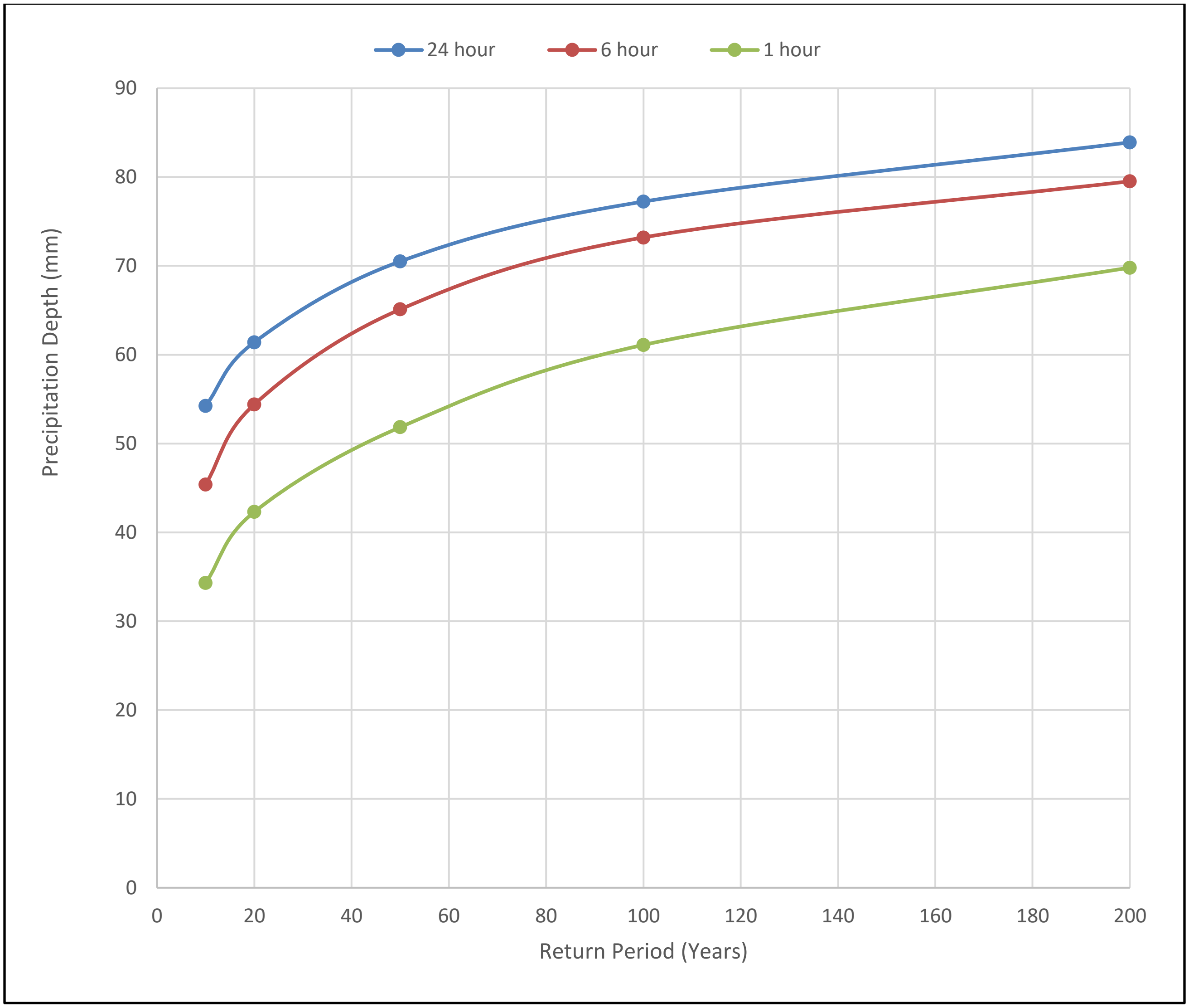


To estimate the extreme precipitation depths for the CMP Project, HyfranPlus software was used to develop statistical distributions including, but not limited to, Extreme Value, Lognormal, and Log Pearson III. Using the available precipitation data from 2004 to 2018, the annual maximum rainfalls were first specified. The annual maximums were then used in the HyfranPlus to develop extreme values at various return period. Table 18-10 and Figure 18-16 summarize the results of storm frequency analysis for various storm return periods. The extreme storm data were later used in design of the water management system and infrastructure, such as ponds and ditches.

Table 18-10: Storm Events at Various Return Periods

Return Period	Rainfall Depth (mm)		
	24 hour	6 hour	1 hour
200	83.9	79.5	69.8
100	77.2	73.2	61.1
50	70.5	65.1	51.8
20	61.4	54.4	42.3
10	54.2	45.4	34.3

Figure 18-17: Comparison of Storm Events at Various Return Periods



The stormwater at the CMP project shall be managed during both normal seasonal weather conditions and extreme storm events. To assess the normal seasonal stormwater, a sitewide water balance analysis using GoldSIM software was developed. To assess the extreme storm peak flows and volumes used to design the structures, numerical rainfall runoff models were developed using HEC-HMS software.

18.9.2 Sitewide Water balance

A sitewide water balance analysis for the CMP was completed by evaluating the balance between the inflows, outflows, and storages associated to the system. The components used in the water balance analysis of CMP are summarized in a flowchart shown in Figure 18-18.

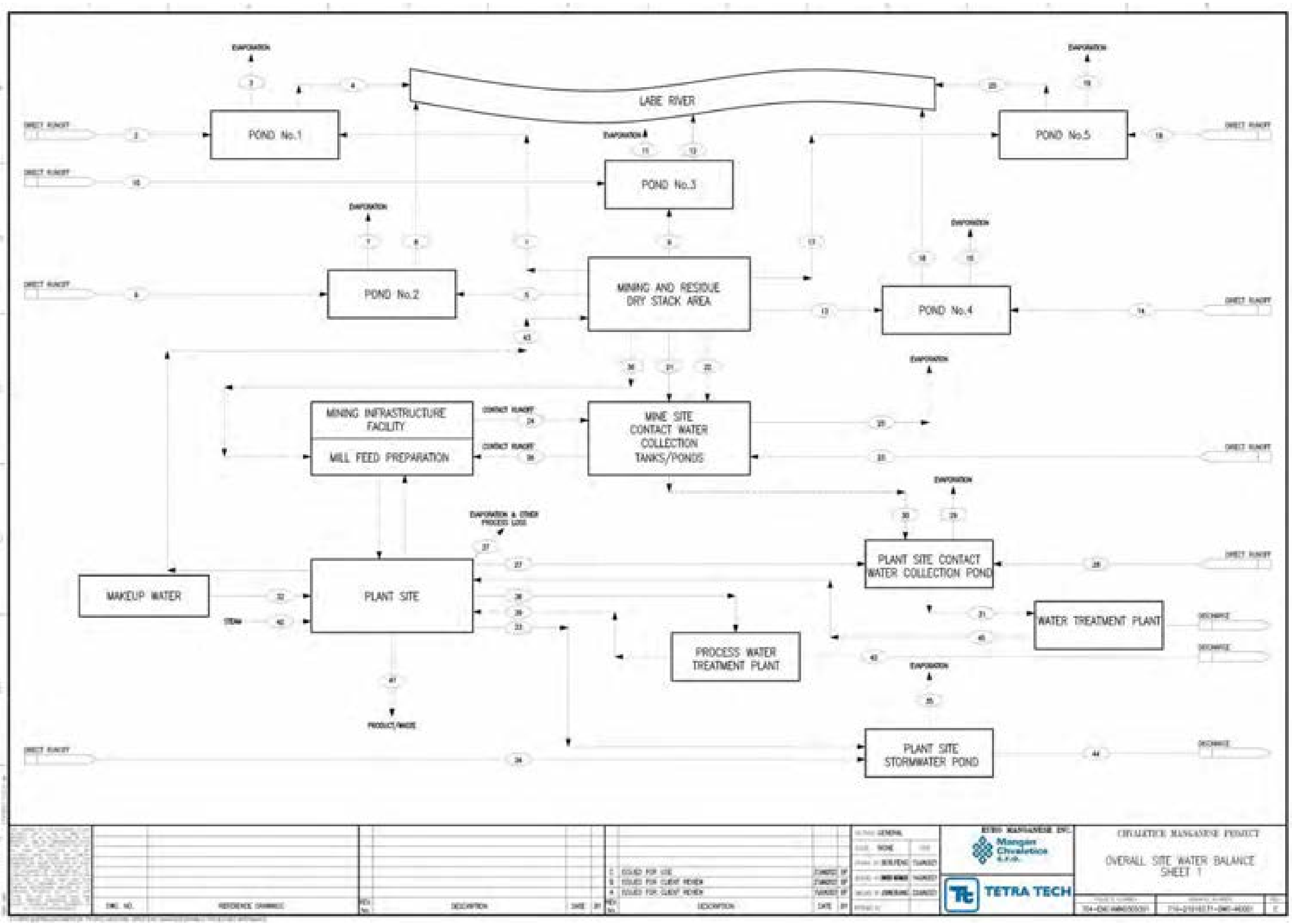
The water balance model was used to estimate:

- The amount of contact water available for process use from both the mine and plant site areas,
- The makeup water requirement; and
- Annual discharge rates from the stormwater ponds to the Labe River.

The water balance for the CMP RSF was completed over a period of 25 years based on monthly averages of the variables using the GoldSIM model, i.e., daily flows within each month were averaged over the months averaging the instantaneous daily highs and lows. Any diurnal variations of the CMP water balance components will not be covered within the current modeling scope.

GoldSIM is a globally known software used for detailed water balance modeling for mining projects. GoldSIM is a Monte Carlo simulation software that permits modeling of complex water systems. GoldSIM supports decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks.

Figure 18-18: CMP Overall Site Water Balance Flowchart



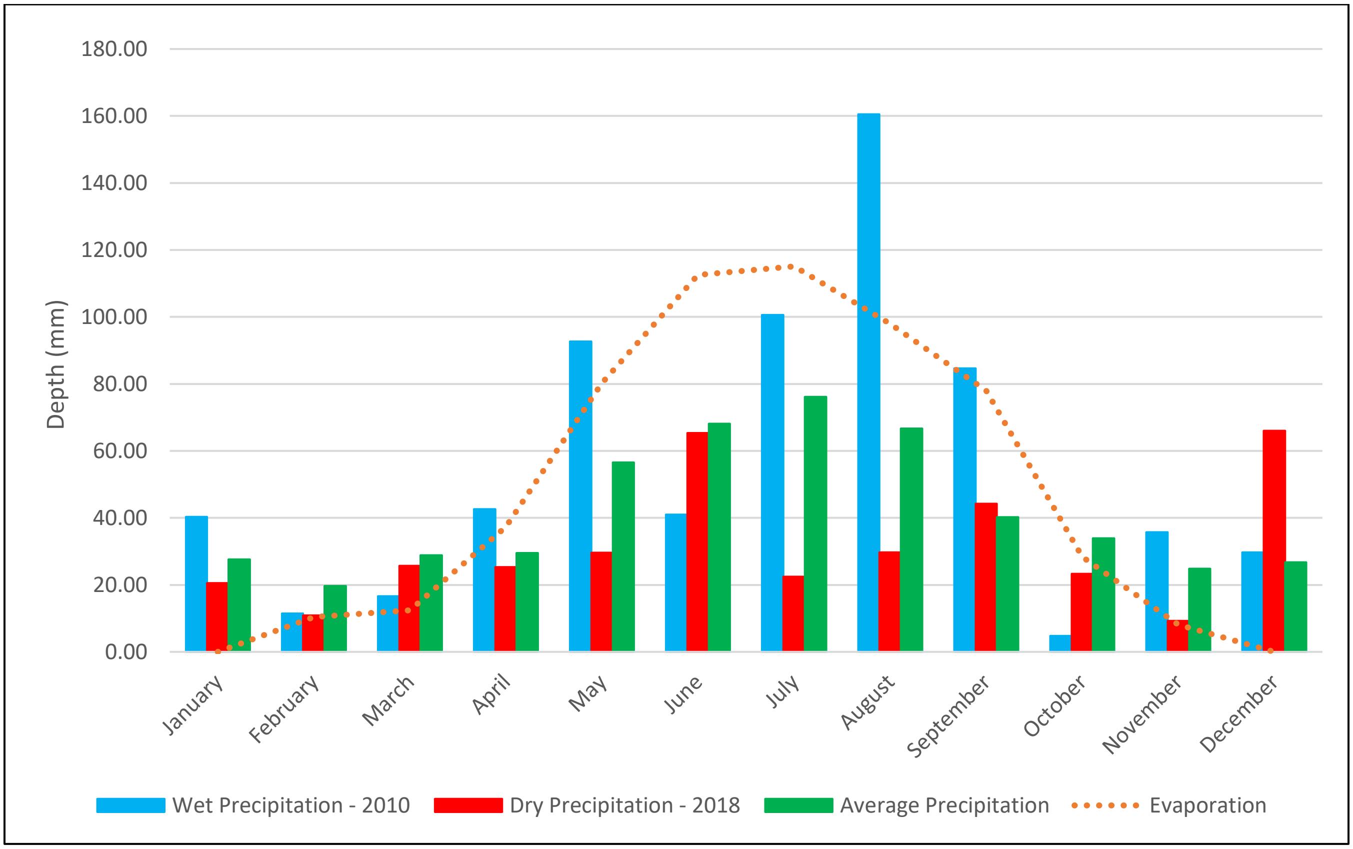
TETRA TECH

18.9.2.1 Water Balance Inputs

The hydrologic parameters contributed to the water balance model included precipitation, runoff coefficients, and catchment areas.

The water balance analysis involved the review of three weather scenarios including average weather, wet weather, and dry whether. The precipitation data was from Czech Hydrometeorological Institute for the Chotusice Airport Station (2004 - 2018) located less than 10 km from the project site, and the evaporation data was taken from the GET (2020) Mining and Dry Stacking Technical Study Report. 19 compares the precipitation and evaporation depths for various climate scenarios.

Figure 18-19: Monthly Precipitation and Evaporation Depths used in GoldSIM Water Balance Analysis



The average year was estimated based on the monthly averaging of climate data available from 2004-2018. The wet year and dry year were estimated based on the total amount of precipitation from these 15 years of data. The climate data analysis showed that the wettest year was 2010 with a total precipitation amount of 660 mm and the driest year was 2018 with a total precipitation amount of 370 mm (Table 18-5).

The runoff coefficients used for the mining area were based on the results of unsaturated modeling on the existing RSF dry stack using Vadose/W model. The Vadose/W model was used to simulate the RSF dry stack water balance under climate forcing such as precipitation, wind speed, air temperature, relative humidity, and solar radiation. Based on the estimated runoff, infiltration, and evaporated volumes of water, monthly runoff coefficients were developed for the RSF dry stack which were then used in the GoldSIM sitewide water balance model to estimate the contact and clean water runoff.

The estimated runoff coefficients of the model results for the existing tailings cells were similar to CMP staff observations from the field. The results of the Vadose/W modeling showed that the runoff coefficients for the tailings cells during normal seasonal weather are low, however the runoff coefficients could increase significantly under extreme storm events.

The runoff coefficients for specific areas and features of the CMP are summarized in Table 18-11.

Table 18-11: Runoff Coefficients

Surface Feature Description	*Runoff Coefficient
Paved/Impervious/Concrete Areas	0.95
Concrete, Asphalt	0.95
Granular Surfaces (e.g., roads)	0.65
Undeveloped areas with Vegetation	0.40

As mentioned under the mine water management methodology, the surface of the RSF will be progressively covered during the mine operation (Figure 18-20). The area of covered RSF and active mining which contribute to runoff and seepage would then change as the mining progresses through the LOM. A time series of the covered RSF and active mining area was developed and input to the GoldSIM model.

To have a more accurate estimate of pond evaporation and direct runoff, i.e., runoff over pond surface, the GoldSIM model was dynamically setup such that surface area of all the ponds and the corresponding water elevations were estimated on a daily time step. The runoff and evaporation functions then use the ponds surface area to dynamically calculate the runoff and evaporation at the subsequent time step.

Figure 18-20: Chvaletice RSF Progressive Mine Plan

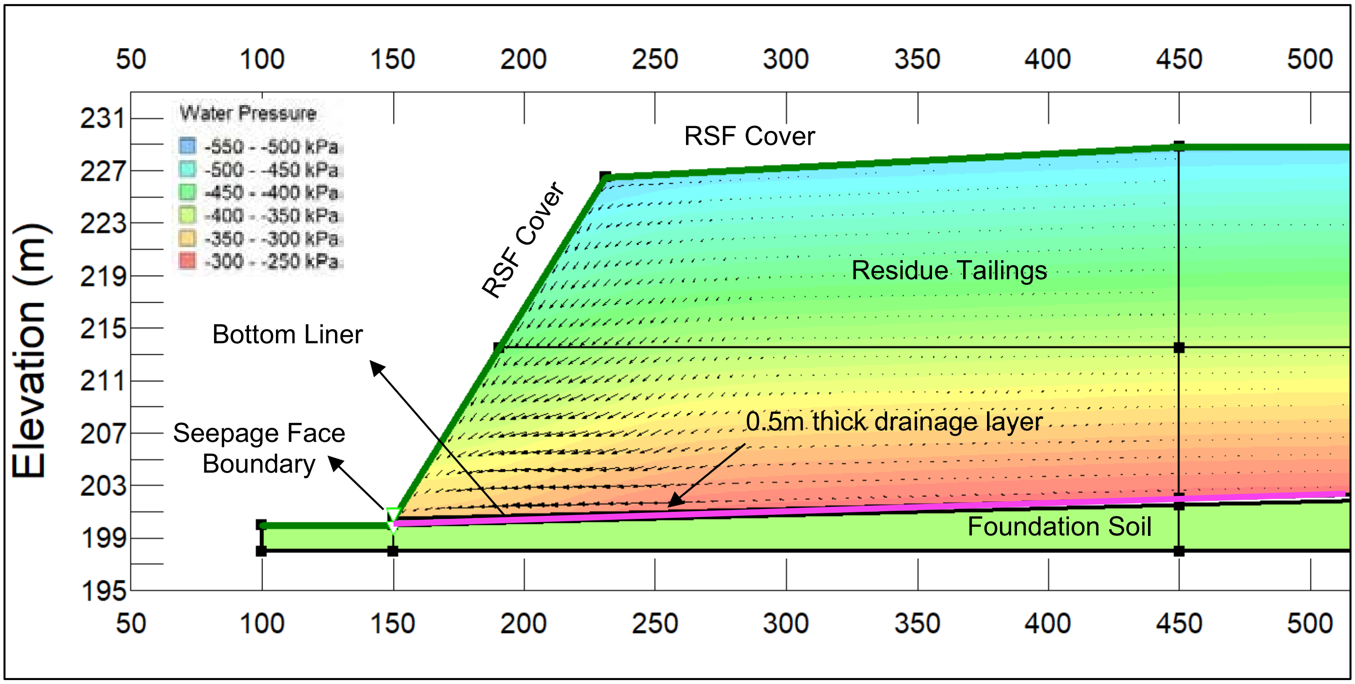
The seepage from the covered RSF was estimated using Seep/W software. A schematic of the transient (not steady state) 2D finite element model developed using for the covered RSF is shown in Figure 18-21. The material properties, Volumetric Water Content function, and Hydraulic Conductivity (HC) functions used in the model were based off the laboratory test results and the Soil Water Characteristic Curve for the residue tailings.

The laboratory test results used for setting up the model were:

- Hydraulic conductivity test to define the HC function;
- Index Testing, including Particle Size Analysis, Hydrometer Testing and Atterberg Limits to establish the soil matrix identification and expected behaviour type;

- Capillary moisture retention tests to establish Soil Water Characteristic Curve (SWCC) test which then defines the residue VWC function; and
- A detailed explanation of all the laboratory tests presented above is summarized in the Residue Storage Facility Design Report by Tetra Tech (2021).

Figure 18-21: A Schematic of the RSF Seepage Model



Some of the key model assumptions are summarized below:

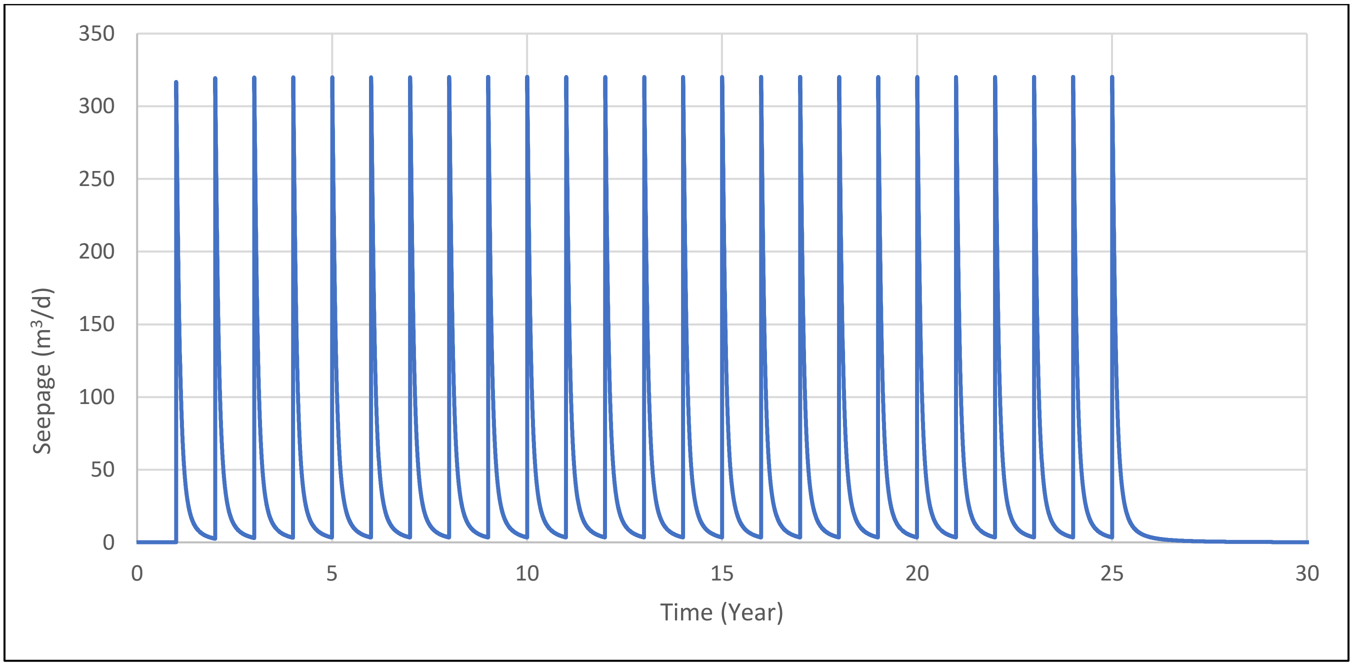
- The RSF is covered at the surface with rough and loose material and is lined at the bottom. A very low hydraulic conductivity was assumed for these impervious linear layers.
- A 0.5 m thick underdrain layer with approximate hydraulic conductivity of 5 x 10^{-6} m/s was considered at the bottom of the RSF and the top of the liner to promote seepage at the earlier years following the deposition.
- The initial moisture content within the newly placed RSF was assumed to be 23.3% gravimetric and 35.8% volumetric at 400 kpa matric suction. The volumetric water content is the volume of water per unit volume of soil, expressed as a percentage of the volume. The gravimetric water content is the mass of water per unit mass of dry (or wet) soil. The RSF saturated volumetric water content was measured to be 33.6% gravimetric and 48% volumetric based on capillary moisture retention tests. The Seep/W software would require the soil moisture data in a volumetric format.
- Volumetric Water Content Function and Hydraulic Conductivity Functions are used in the model.
- The seepage modeling was developed for a period of 30 years from the beginning of the mining which covers 25 years of active mining and an allowance for a 5-year closure period. It was assumed that at each mining year a slice of dry stack, as shown in Figure 18-20, will be covered and adds to the total seepage.

Using the assumptions summarized above a transient seepage model was developed and the results were extracted and summarized in Figure 18-22.

As shown, the seepage was relatively high once a new section of dry stack was placed, and it decreased to a relatively small amount at the end of the year before the subsequent year stacking.

The seepage values can be very sensitive to various parameters. As such, the actual seepage flows could differ from the estimated values shown in Figure 18-22 depending upon various field conditions. The results showed that the seepage during an average weather year could be in the order of 350 m^3/day. Also, the results showed that the seepage from the entire facility five years after closure could be in the order of 0.34 to 0.84 m^3/day depending on level of compaction, amount of precipitation before covering, thickness of underdrain layer, etc.

Figure 18-22: Temporal Variation of Seepage from Covered RSF – Average Weather Year



18.9.2.2 Water Balance Modeling

Using all the assumptions described above, a sitewide water balance model was developed using the GoldSIM model. The GoldSIM model was used to estimate:

- The amount of contact water available for process use from both the mine and plant site areas;
- The makeup water requirement; and
- Annual discharge rates from the stormwater ponds to the Labe River.

Figure 18-23 shows the available contact water from mine and plant site collection ponds on a daily basis for wet, average, and dry years.

Table 18-12 through Table 18-14 summarize the available runoff water during a dry year, average year, and wet year, on a monthly basis, respectively. Each table considers two scenarios: one assumes the water from the plant site clean stormwater pond is used as process makeup water, and another assumes it is discharged directly to the environment. The tables also include estimated monthly process requirement. The practicality of these scenarios must be reviewed during mine operation, when the GoldSIM model should be calibrated with actual numbers from the mine operation and annual discharge plans are developed. Table 18-12 to Table 18-14 summarize the overall mine site water balance during dry, average, and wet weather conditions.

Figure 18-24 shows the total available contact runoff from the mine and plant site collection ponds during wet, average, and dry years on an annual basis throughout the LOP.

Table 18-12: Dry Year Makeup Water Requirement

	DRY YEAR						
Month	Available Contact Water (m^3/Month)			Available Clean Storm Water (m^3/Month)	Total plant Water Requirement	Makeup Water Requirement (m^3/Month)	
	Mine Site	Plant Site	Total	Plant Site	(m^3/Month)	Without Plant Site Clean Stormwater	With Plant Site Clean Stormwater
1	3,332	4,136	7,468	4,575	67,298	59,830	55,256
2	6,710	1,393	8,102	1,550	67,298	59,196	57,647
3	3,181	1,356	4,537	1,528	67,298	62,762	61,234
4	1,826	2,045	3,871	2,316	67,298	63,427	61,111
5	1,018	2,053	3,071	2,406	67,298	64,227	61,821
6	711	3,144	3,855	3,709	67,298	63,443	59,734
7	557	3,864	4,420	4,562	67,298	62,878	58,316
8	49	1,688	1,737	2,148	67,298	65,562	63,414
9	220	2,480	2,700	2,979	67,298	64,598	61,619
10	432	2,989	3,421	3,469	67,298	63,878	60,408
11	344	1,582	1,926	1,809	67,298	65,373	63,564
12	520	2,026	2,546	2,256	67,298	64,753	62,496
Year Total (m^3/year)	18,899	28,754	47,654	33,309	807,581	759,927	726,618
Monthly Average (m^3/Month)	1,575	2,396	3,971	2,776	67,298	63,327	60,552
Daily Average (m^3/d)	52.5	79.9	132.4	92.5	2,243.3	2,110.9	2,018.4

TETRA TECH

Table 18-13: Average Year Makeup Water Requirement

Month	Average Year						
	Available Contact Water (m^3/Month)			Available Clean Storm Water (m^3/Month)	Total plant Water Requirement	Makeup Water Requirement (m^3/Month)	
	Mine Site	Plant Site	Total	Plant Site	(m^3/Month)	Without Plant Site Clean Stormwater	With Plant Site Clean Stormwater
1	3,166	2,313	5,479	2,558	67,298	61,819	59,262
2	7,022	1,994	9,016	2,215	67,298	58,283	56,067
3	3,459	1,838	5,297	2,061	67,298	62,001	59,940
4	2,122	2,338	4,460	2,641	67,298	62,838	60,198
5	1,555	3,092	4,646	3,556	67,298	62,652	59,097
6	1,526	4,707	6,233	5,439	67,298	61,065	55,626
7	1,469	5,494	6,963	6,365	67,298	60,336	53,971
8	1,444	5,710	7,155	6,595	67,298	60,144	53,549
9	1,142	4,636	5,778	5,363	67,298	61,520	56,157
10	744	2,982	3,726	3,462	67,298	63,573	60,110
11	803	2,557	3,360	2,887	67,298	63,938	61,052
12	752	2,148	2,899	2,391	67,298	64,399	62,008
Year Total (m^3/year)	25,204	39,808	65,012	45,532	807,581	742,569	697,037
Monthly Average (m^3/Month)	2,100	3,317	5,418	3,794	67,298	61,881	58,086
Daily Average (m^3/d)	70.0	110.6	180.6	126.5	2,243.3	2,062.7	1,936.2

Table 18-14: Wet Year Makeup Water Requirement

	Wet Year						
Month	Available Contact Water (m^3/Month)			Available Clean Storm Water (m3/Month)	Total plant Water Requirement	Makeup Water Requirement (m^3/Month)	
	Mine Site	Plant Site	Total	Plant Site	(m^3/Month)	Without Plant Site Clean Stormwater	With Plant Site Clean Stormwater
1	3,629	2,889	6,519	3,196	67,298	60,780	57,584
2	7,405	2,448	9,852	2,717	67,298	57,446	54,729
3	3,343	1,084	4,427	1,228	67,298	62,871	61,644
4	2,264	2,093	4,357	2,370	67,298	62,942	60,572
5	2,597	4,874	7,471	5,525	67,298	59,828	54,302
6	2,526	5,950	8,476	6,813	67,298	58,822	52,009
7	1,723	4,671	6,394	5,456	67,298	60,904	55,448
8	3,558	9,167	12,725	10,739	67,298	54,574	43,835
9	4,321	11,650	15,971	12,742	67,298	51,327	38,585
10	1,890	5,036	6,926	5,735	67,298	60,373	54,638
11	407	918	1,325	1,075	67,298	65,974	64,899
12	1,271	2,900	4,170	3,222	67,298	63,128	59,906
Year Total (m^3/year)	34,933	53,679	88,612	60,818	807,581	718,969	658,151
Monthly Average (m^3/Month)	2,911	4,473	7,384	5,068	67,298	59,914	54,846
Daily Average (m^3/d)	97.0	149.1	246.1	168.9	2,243.3	1,997.1	1,828.2

Figure 18-23: Total Contact Runoff Flow Rate for Wet, Average, and Dry Weather Conditions – Life of Mine

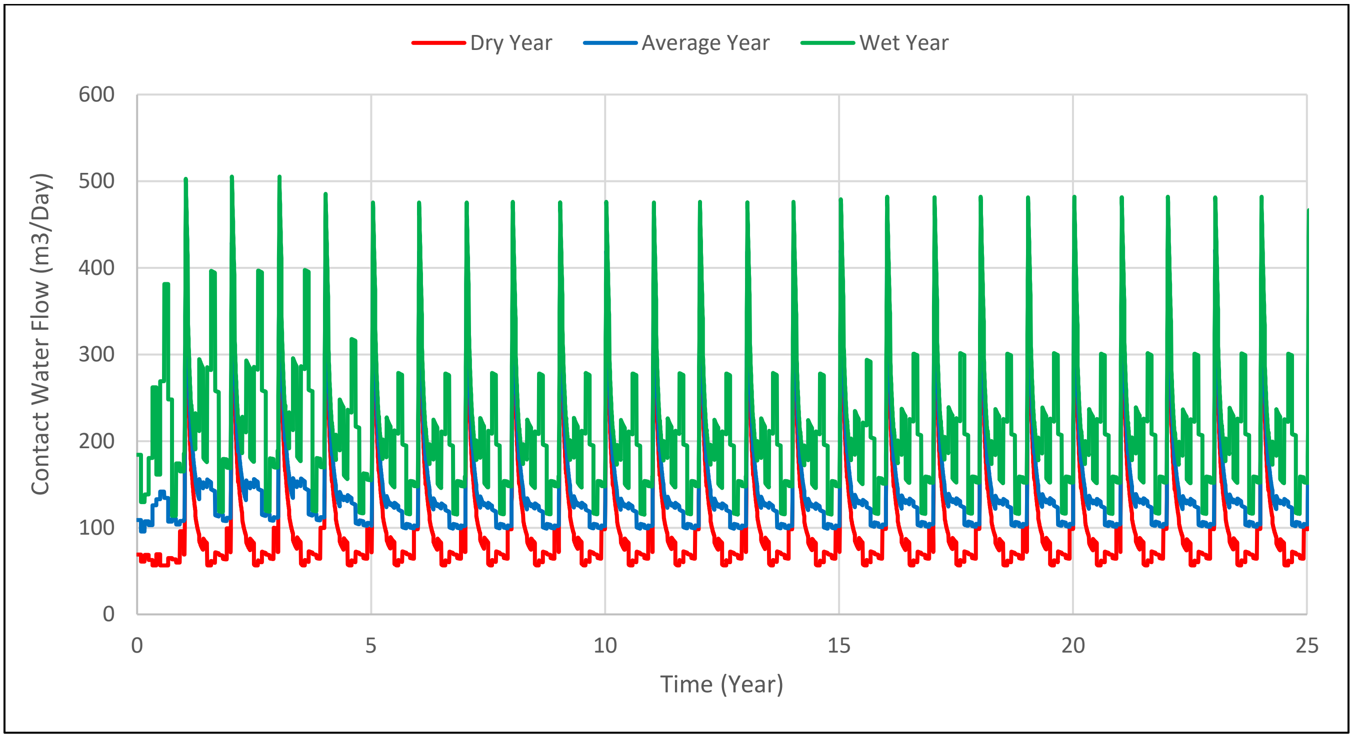


Figure 18-24: Annual Contact Water from Mine and Plant Sites

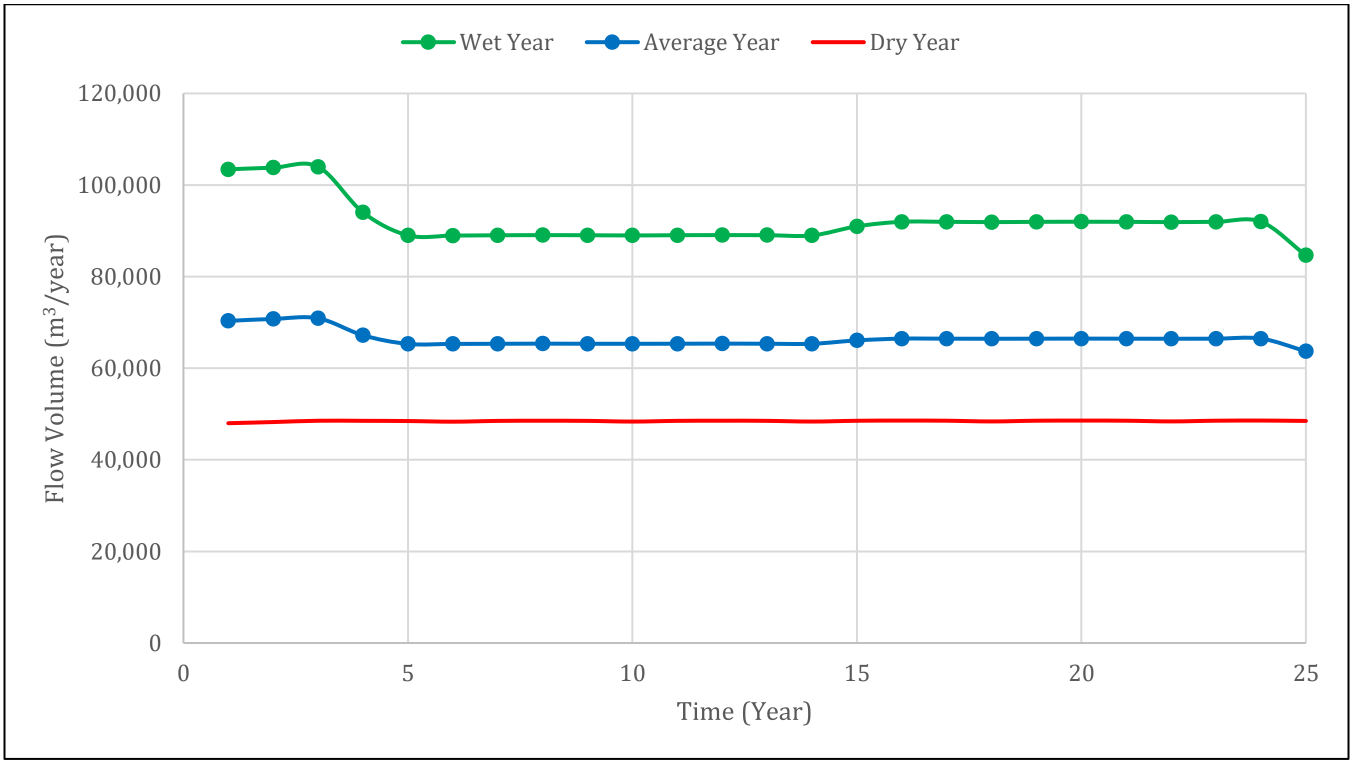


Table 18-15: Overall Mine Site Water Balance

Stream ID	Stream Description	Flow (m^3/d) - Wet Year			Flow (m^3/d) - Average Year			Flow (m^3/d) - Dry Year			Design Criteria
		Min	Average	Max	Min	Average	Max	Min	Average	Max	
1	Runoff - Pond 1	0.0	45.4	139.2	0.0	17.1	33.0	0.0	0.4	2.1	1,250 m^3
2	Direct Runoff - Pond 1	0.2	2.3	6.6	0.8	1.7	3.1	0.4	1.3	2.7	
3	Evaporation - Pond 1	0.0	2.0	4.7	0.0	2.0	4.7	0.0	2.0	4.7	-
4	Discharge - Pond 1	0.0	179.3	4,439.0	0.0	40.2	1,063.0	0.0	0.0	0.0	0.0537 m^3/s
5	Runoff - Pond 2	0.0	45.4	139.2	0.0	17.1	33.0	0.0	0.4	2.1	1,250 m^3
6	Direct Runoff - Pond 2	0.2	2.3	6.6	0.8	1.7	3.1	0.4	1.3	2.7	
7	Evaporation - Pond 2	0.0	2.0	4.7	0.0	2.0	4.7	0.0	2.0	4.7	-
8	Discharge - Pond 2	0.0	179.3	4,439.0	0.0	40.2	1,063.0	0.0	0.0	0.0	0.0537 m^3/s
9	Runoff - Pond 3	0.0	56.1	278.4	0.0	21.1	66.0	0.0	0.5	4.1	2,500 m^3
10	Direct Runoff - Pond 3	0.4	4.6	13.2	1.5	3.4	6.3	0.8	2.6	5.4	
11	Evaporation - Pond 3	0.0	4.0	9.5	0.0	4.0	9.5	0.0	2.0	4.7	-
12	Discharge - Pond 3	0.0	188.4	4,468.0	0.0	48.2	1,067.0	0.0	0.0	0.0	0.1 m^3/s
13	Runoff - Pond 4	0.0	45.4	139.2	0.0	17.1	33.0	0.0	0.4	2.1	1,250 m^3
14	Direct Runoff - Pond 4	0.2	2.3	6.6	0.8	1.7	3.1	0.4	1.3	2.7	
15	Evaporation - Pond 4	0.0	2.0	4.7	0.0	2.0	4.7	0.0	2.0	4.7	-
16	Discharge - Pond 4	0.0	179.3	4,439.0	0.0	40.2	1,063.0	0.0	0.0	0.0	0.0537 m^3/s
17	Runoff - Pond 5	0.0	375.1	1,588.0	0.0	141.0	376.6	0.0	3.2	23.5	17,000 m^3
18	Direct Runoff - Pond 5	0.8	11.1	39.6	3.0	8.1	16.5	1.5	5.6	13.3	
19	Evaporation - Pond 5	0.0	9.7	26.9	0.0	9.5	25.0	0.0	8.6	21.9	-
20	Discharge - Pond 5	0.0	1,429.1	22,202.0	0.0	352.8	7,374.0	0.0	1.6	232.4	0.73 m^3/s
21	Seepage - RSF	0.0	55.6	416.7	0.0	47.1	352.6	0.0	42.8	320.5	4,167 m^3/d
22	Contact Runoff - Active Mining	1.0	25.1	155.7	2.0	9.4	36.9	0.0	0.2	2.0	6,500 m^3
23	Direct Runoff - Mine Site Collection Pond	1.0	11.8	34.3	4.0	8.9	16.3	2.0	6.6	14.1	
24	Contact Runoff - Mining Facility	0.3	8.4	51.9	0.7	3.1	12.3	0.0	0.1	0.7	
25	Evaporation - Mine Site Collection Pond	0.0	10.4	24.6	0.0	10.4	24.6	0.0	10.4	24.6	-
26	pumping- Mine Site Collection Pond	0.0	85.3	394.3	10.8	56.7	352.9	0.0	38.9	332.5	6,500 m^3/d
27	Contact Runoff - Plant Site	12.7	141.9	425.4	49.1	108.5	201.8	24.7	81.1	174.9	7054 m^3
28	Direct Runoff - Plant Site Collection Pond	0.5	5.9	17.1	2.0	4.4	8.1	1.0	3.3	7.0	
29	Evaporation - Plant Site Collection Pond	0.0	5.2	12.3	0.0	5.2	12.3	0.0	5.2	12.3	-
30	Mine Site Collection Pond Overflow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,500 m^3/d

table continues…

TETRA TECH

Stream ID	Stream Description	Flow (m^3/d) - Wet Year			Flow (m^3/d) - Average Year			Flow (m^3/d) - Dry Year			Design Criteria
		Min	Average	Max	Min	Average	Max	Min	Average	Max	
31	Pumping - Plant Site Collection Pond	10.2	147.8	400.0	49.9	109.7	197.6	24.8	80.7	182.0	7,054 m^3/d
32	Makeup water	1,557.0	2,010.2	2,233.0	1,814.0	2,076.9	2,183.0	1,854.0	2,123.7	2,215.0	2,250 m^3/d
33	Runoff - Plant Site Stormwater Pond	14.5	167.2	484.2	55.9	125.7	229.6	29.9	100.2	212.4	3,205 m^3
34	Direct Runoff - Plant Site Stormwater Pond	0.2	1.8	5.3	0.6	1.4	2.5	0.3	1.0	2.2	-
35	Evaporation - Plant Site Stormwater Pond	0.0	1.6	3.8	0.0	1.6	3.8	0.0	1.6	3.8	-
36	Moisture from Raw Mill Feed	0.0	45.4	139.2	0.0	17.1	33.0	0.0	0.4	2.1	810.3 m^3/d
37	Evaporation and Other Process Loss	2,686.3	2,686.3	2,686.3	2,686.3	2,686.3	2,686.3	2,686.3	2,686.3	2,686.3	2,686.2 m^3/d
38	Discharge to Process Water Treatment Plant	516.0	516.0	516.0	516.0	516.0	516.0	516.0	516.0	516.0	516.0 m^3/d
39	Recycled Water from Process Water Treatment	490.8	490.8	490.8	490.8	490.8	490.8	490.8	490.8	490.8	490.8 m^3/d
40	Steam to Plant Site	674.6	674.6	674.6	674.6	674.6	674.6	674.6	674.6	674.6	674.6 m^3/d
41	Product/Waste	233.3	233.3	233.3	233.3	233.3	233.3	233.3	233.3	233.3	233.3 m^3/d
42	Discharge from Process Water Treatment Plant	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2 m^3/d
43	Residue Water - Plant Site to RSF	949.9	949.9	949.9	949.9	949.9	949.9	949.9	949.9	949.9	949.9 m^3/d
44	Discharge from Plant Site Stormwater Pond	14.7	167.4	485.7	56.5	125.5	228.3	30.2	99.6	210.8	-
45	Treated Plant Site Contact Water	10.2	147.8	400.0	49.9	109.7	197.6	24.8	80.7	182.0	2,250 m^3/d

18.9.3 Water Management Infrastructure Design

The sections below summarize the design criteria used for the design of CMP water management structures as well as the proposed design and geometries for the mine site water management structures.

The design layout for the RSF and the water management structures are summarized in Filtered Residue Storage Facility Design, Interim Report (704-ENG.VMIN03093-01-REP-T0002-A), Chvaletice Manganese Project Feasibility Study (Tetra Tech, 2021).

18.9.3.1 Open Channel Drains

Open channel drains are either ditches or newly graded swales. Channels will normally be a trapezoidal cross section or V-shaped and shall comply with the parameters listed in Table 18-16. Swales are V-shaped shallow ditches used for small flows and have lengths not exceeding 150 m. The roughness coefficients to be used for the design of drainage ditches are summarized in Table 18-17.

Unless otherwise specified, the design flow for sizing open channels and culverts (hydraulic structures) is based on a 1:10-year, 1-hour return period (Table 18-10).

The clean water ditches and swales, when designed for 1:10 year, 1-hour return period, shall be capable of handling the peak discharge for a 1:100 year, 1-hr return period when flowing full.

Table 18-16: Open Channel Design Parameters

Item	Value	Unit	Source/Comments
Minimum Base Width	0.6	m	Construction consideration
Minimum Channel Depth	0.6	m	Engineering criteria
Minimum Swale Depth	0.3	m	Engineering Criteria
Minimum Freeboard	0.1	m	Engineering criteria
Side slopes	1:2	(V:H)	Construction consideration
Minimum Longitudinal Slope	0.005	m/m	Engineering criteria
Manning’s Roughness	Varies	Varies	NRCS Practice Standard 486 (Robinson 1998) and Open-Channel Hydraulics by Ven Te Chow, Table 5-6
Riprap Minimum Depth	2×d50	mm	Surface Mining Water Diversion Design Manual (OSM 1982)

Table 18-17: Roughness Coefficients

Material/Surface Conditions	n
Unlined Ditch	0.025
Unlined Swale	0.030
Lined Ditch / Swale	0.015

table continues…

Material/Surface Conditions	n
Riprapped ditch	0.06
Corrugated Steel Pipe	0.024
Concrete Pipe	0.013
PVC and HDPE pipe smooth interior	0.010

Using the design criteria described above, the clean stormwater ditches and contact water collection ditches were sized based on the geometries summarized in Table 18-18 and Table 18-19. These tables show the required ditch depth and bottom width for various ditch bottom slopes of 0.1%, 0.3%, and 0.5%. The clean stormwater ditches were also sized for a half catchment scenario, where the ditch length is less than half of the entire length of the ditch.

Table 18-18: Design Geometry for Clean Stormwater Ditch

Ditch Bottom grade (%)	Side slopes	Bottom Width (m)	Ditch Depth (m)
0.5	2H:1V	1	0.5
0.3	2H:1V	1	0.6
0.1	2H:1V	1	0.7

Table 18-19: Design Geometry for Contact Collection Ditch

Ditch bottom grade (%)	Side slopes	Bottom Width (m)	Ditch Depth (m)
0.5	2H:1V	1	0.9
0.3	2H:1V	1	1.0
0.1	2H:1V	1	1.2
0.5	2H:1V	2	0.7
0.3	2H:1V	2	0.8
0.1	2H:1V	2	1.0

18.9.3.2 Seepage Collection Sump

The bottom of the RSF slopes from the outer perimeter towards the center. Seepage from the RSF will be collected into one central seepage collection sump.

The maximum seepage is attributed to the seepage just after each annual RSF placement. The seepage collected within the sump will then be pumped to the mine site collection pond. Following Year 30, which is five years post closure of the mine, the sump will be plugged/cemented, and the residual moisture will no longer seep out of the RSF.

An approximate maximum pumping rate of 13.5 L/s is required for the sump pump. The actual seepage rates will likely be smaller than this maximum amount. However, the proposed pumping rate considers a wet condition where a heavy rainfall (i.e., wet year x 2) infiltrates the dry stack just before it is covered. During operation, an RSF emergency preparedness plan shall be developed to account for emergency conditions. Mitigation plans such as immediate capping of the sump just after the extreme storm events should be considered in such plan.

18.9.3.3 Ponds

Two types of water management ponds will be needed in this project: Collection Ponds/Tanks and Stormwater Ponds.

While the design geometry of the stormwater and collection ponds and ditches are summarized in this report, the relevant design drawings are included in the Residue Storage Facility Design, Interim Report (Tetra Tech, 2021).

18.9.3.4 Mine Site Collection Facility

Collection pond at the mine site is designed to collect contact runoffs from the mining and RSF area. The collection ponds/tanks are sized to contain the volume of the 1:200 year, 24-hour duration storm event.

To estimate the volume of contact runoff, a hydrology rainfall runoff model using HEC-HMS model was developed for the RSF maximum active mining area under 1:200-year 24-hour storm event. Table 18-20 summarizes the results of runoff volume estimated for the contact runoff from the mining area. Two 14 m diameter by 14 m height contact water surge tanks with an approximate capacity of 3,500 m^3 have been designed to collect the contact water.

Table 18-20: Hydrology Model Results for Contact Runoff from Active Mining Area

Scenario ID	SCS Curve Number	Runoff Volume (m^3/day)	Peak Flow (m^3/s)	Runoff Coefficient
Mining Area – 1:200 Year, 24 hour	80	6,500	1.6	0.45

In addition to the runoff from the active mining area, seepage from the collection sump will also be collected into the mine site collection tanks. The contact water from the mining area must be pumped to a contact water conveying ditch in which water will gravity flow to a sump where a water-oil separator will be installed. Then the water will be pumped towards the storage tanks adjacent to the repulping facility. The storage tanks will have approximately 3,500 m^3 capacity, and the excess flow of 3,000 m^3, which may occur during an extreme event such as a 1:200 year, 24-hour storm event, shall be pumped towards the plant site collection pond. The mine site collection sump pump should have a total maximum capacity of 90 L/s.

18.9.3.5 Mine Site Stormwater Ponds

Five stormwater ponds are located within the Mine site area. Pond 1 through Pond 4 are to manage outside slope runoff from the RSF, and Pond 5 (centre pond) is designed to collect runoff from RSF surface area and internal slopes. These are designed to collect the clean runoff from the mining and covered RSF area with the goal to dampen peak flows. The stormwater pond(s) are sized to reduce the post development peak flows to the pre-development peak flows for a 1:10 year, 1-hour storm event.

A hydrology rainfall runoff model using HEC-HMS model was developed for the RSF at existing and future conditions under the 1:10 year, 1-hour storm event. For the future scenario (post-development), a conservatively high SCS curve number was used in the model. The runoff volume under this conservative scenario for the mine site is shown in Table 18-21.

Table 18-21: Hydrology Model Results for Clean Stormwater Pond _ Mine Site

Scenario ID	SCS Curve Number	Runoff Volume (m^3)	Peak Flow (m^3/s)	Runoff Coefficient
Post Development	97	21,500	10.3	0.62
Pre-Development - Existing Condition	73	1,800	1.25	0.09

Five stormwater ponds within the mining area with geometries summarized in Table 18-22 were considered to manage the RSF clean stormwater. The stormwater ponds have a minimum side slope of 2.5H:1V.

Table 18-22: Design Geometry – Clean Stormwater Ponds _ Mine Site

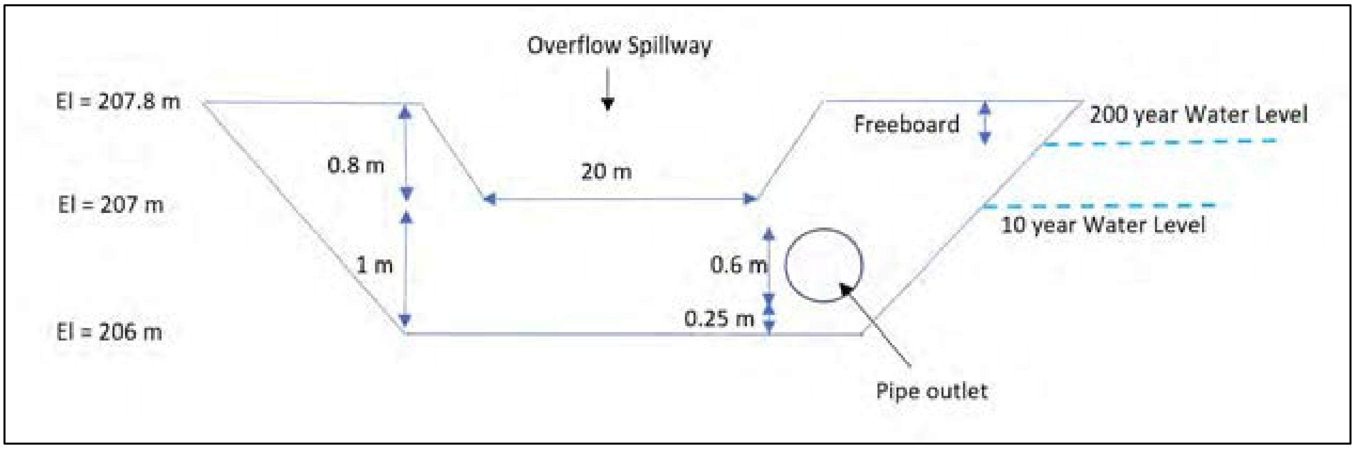
Pond ID	Storage Volume (m^3)	Depth (m)	Side Slopes (H:V)	Length to Width (Ratio)
Pond 1	1,250	1.8	2.5:1	> 5 to 1
Pond 2	1,250	1.8	2.5:1	> 5 to 1
Pond 3	2,500	1.8	2.5:1	> 5 to 1
Pond 4	1,250	1.8	2.5:1	> 5 to 1
Pond 5	17,000	1.8	2.5:1	> 5 to 1

Each pond has been designed with an emergency overflow spillway to allow storm drainage to safely exit the facility in the event that the outlet fails to function or the storm event is greater than the facility's designed capacity. The spillway is designed to convey the Inflow Design Flood, while maintaining a minimum 0.3 m freeboard around the perimeter of the facility.

Each pond includes a Low Level Outlet (LLO) to empty the pond after each storm. As shown in Figure 18-25, the spillway for the Pond 5 should be 20 m wide to adequately pass the 1:200 year flood, and the LLO should be a 0.6 m pipe with an invert 0.25 m above the bottom of the pond. The spillway for Pond 3 should be 15 m wide and those for Pond 1, Pond 2, and Pond 4 should be 8 m wide. The LLO for the Pond 1 through 4 are 0.45 m pipe.

During closure, the valve on each stormwater LLO has to remain open to empty the pond at a controlled rate.

Figure 18-25: Spillway and Low Level Outlet Design for Pond 5

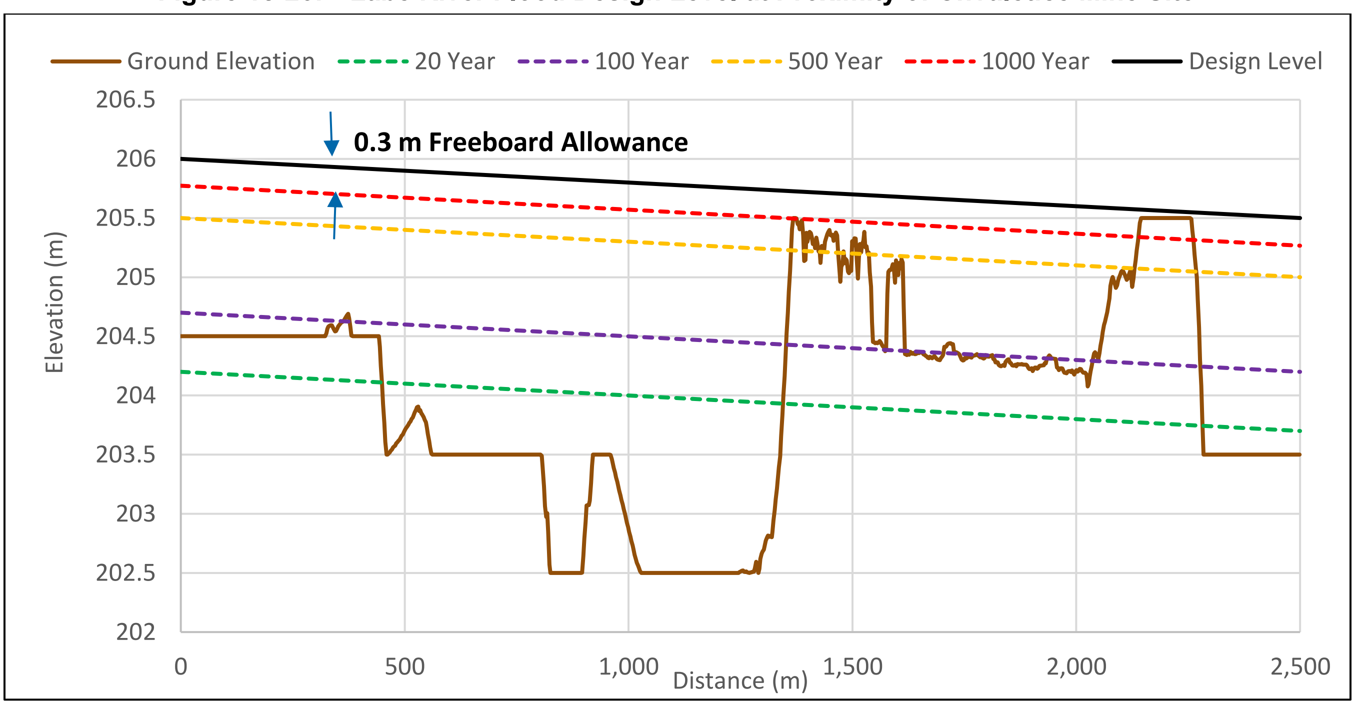


18.9.3.6 RSF Flood Protection Berm

The mining and RSF areas shall be protected using dikes against Labe River flooding. The dike crest elevation is higher than the 1:1000 year flood peak elevation plus 0.3 m freeboard.

The Labe River flood levels for various return period were collected from the Labe River Flood Protection Authority and were plotted against the 2.5 km distance along the CMP mine site property perimeter as shown in Figure 18-26. The brown line represents the natural ground along the CMP site, while the black line represents the Flood Construction Level for the CMP site. Considering a maximum 1:1000 year flood level of 205.7 m, a maximum dike crest elevation of 206 m is required, which is approximately 4 meters above the current river elevation of 202 masl.

Figure 18-26: Labe River Flood Design Level at Proximity of Chvaletice Mine Site



TETRA TECH

The design layout for the RSF and the water management structures are summarized in Filtered Residue Storage Facility Design, Interim Report, Chvaletice Manganese Project Feasibility Study (Tetra Tech, 2021).

The berm should be riprapped to El=206 m, with a thickness of 600 mm and Stone D50 of 300 mm. Whether the existing berm can be used as an appropriate flood protection structure or not should be confirmed under a separate detailed design study.

18.10 Geotechnical Investigations

18.10.1 Plant Site

An engineering-geological and hydrogeological program was carried out by K + K průzkum, s.r.o. to support the design and construction of the proposed new processing plant site for producing high purity manganese products and provide an update on historical investigations.

The program entails:

- a field program drilling of core sampling holes and mechanical cone penetration tests
- a laboratory program to determine geotechnical properties and strength parameters of the soils and rocks.
- chemical assessment of ground water samples.

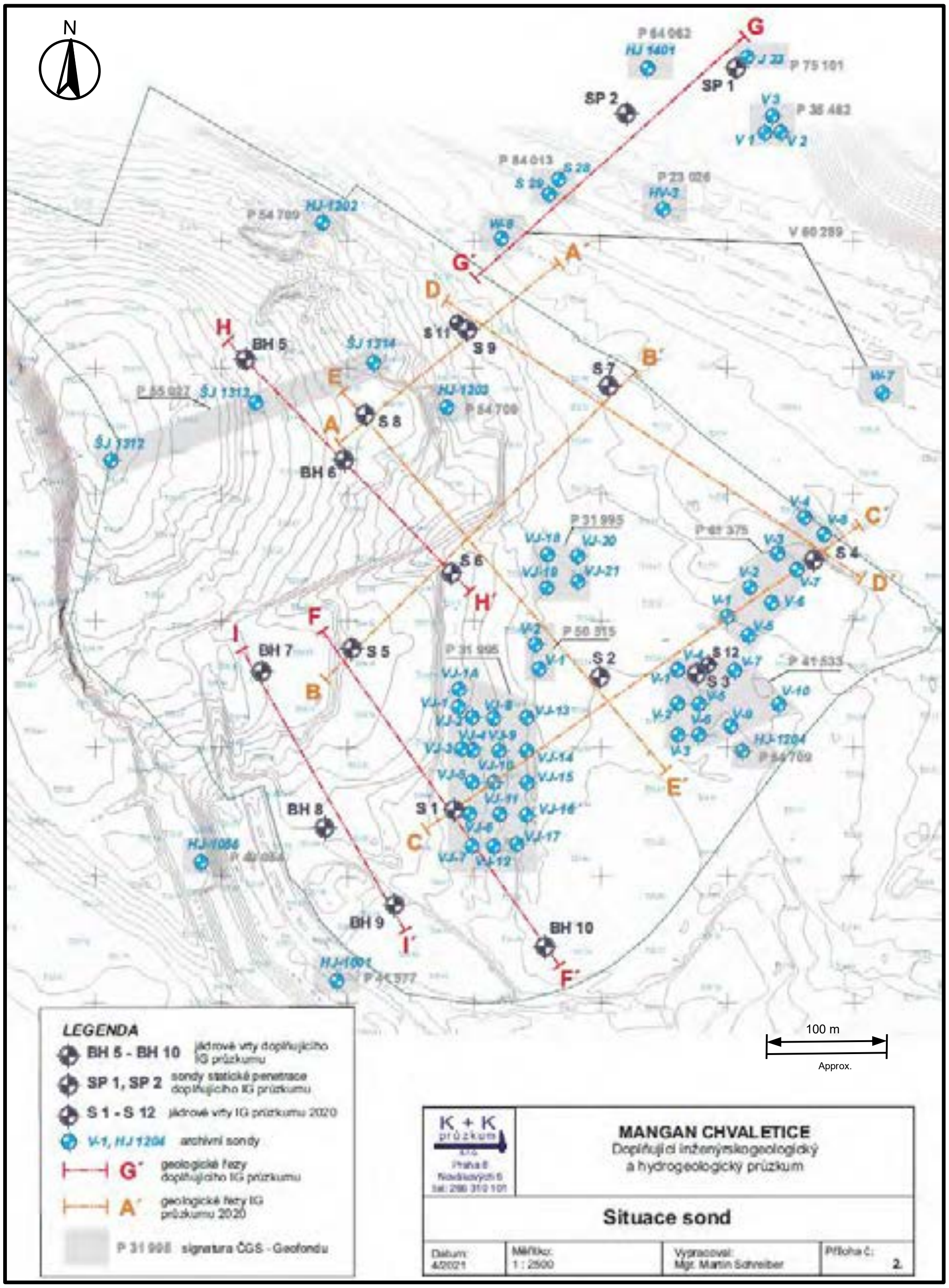
A total of 11 new core boreholes were drilled as part of the engineering and geological and hydrogeological survey in 2020, of which nine (9) deeper boreholes were used to verify the engineering and geological conditions of the site. Two (2) shallower boreholes were also drilled for hydrogeological assessment of the possibility of percolation. The nine (9) deeper boreholes, marked S 1 to S 9, reached depths of 6 to 11 m.

The geomorphological and geological setting of the site was determined through regional geomorphological classification of the area, and updated on the basis of historical and current geotechnical investigation results. Various types of foundation materials and fill materials encountered in the field program were assigned geotechnical types as follows: Fill (GT1), Deluvial, deluvial-fluvial and fluvial sediment (GT3/3a/3b), Upper Cretaceous/Turon-Bila Hora formation (GT4/5/5a), Upper Cretaceous/Cenomanian-Peruc-Korycany formation (GT6/7/8), and Upper Proterozoic-Chvaletice group (GT9/10/11/12). Figure 18-27 shows the drill hole locations.

The hydrogeological setting of the site is influenced by numerous factors including climate of the site, terrain morphology, geological structure of the area, permeability of the materials, potential sources of ground water. The ground water movement in the area, as measured through historical and current ground water levels, generally follows the direction of the terrain slope, i.e from south/southwest to north/northeast towards the Labe River. The ground water samples from current investigation are found to be highly aggressive to concrete structures as result of high sulphates concentration. The findings align with previous analysis results.

Each material type (GT1 to GT12) is evaluated on their suitability as foundation on the basis of strength parameters, geotechnical properties, and the extent of presence on site; each material is also evaluated on their suitability for pile installation for deep foundation, and as borrowed source for fill construction for parking lots and roads etc.

Figure 18-27: Geotechnical Testhole Locations at Plant Site



Source: K + K průzkum, s.r.o. 2021

The topsoil was determined as below:

- Humus loam was encountered at BH 5 and 6, the thickness is around 0.1 m to 0.2 m and very limited spreading.
- Sandy loam was encountered at BH SP1 and SP2, about 2.0-2.2 m below surface and thickness 0.8-1.6 m.

- GT1, which is a “backfill” material that is heterogenous and contains clay, sandy clay, sand and sand-clayey loam, ranged 0.4-2.2 m in the south part of the area with the deepest depth at 11 m (S8), and the average thickness is suggested to be around 2-2.2 m.

The bearing capacity for each type of material was measured and summarized in Table 18-23.

Table 18-23: Bearing Capacity for Each Type of Material

Clay and Sandy Clay with Heterogeneous Admixtures	Clay and Sandy Clay	Sand and Argillaceous Sand	Sandy Loam up to Argillaceous Sand	Loam-Sandy Gravel
GT1	GT2	GT3	GT3a	GT3b
-	120-200 kPa	150-180 kPa	150-180 kPa	450 kPa
Fully Weathered Marlite	Weakly Weathered Marlite	Strong Marlite	Highly Weathered Sandstone	Weakly Weathered Sandstone
GT4	GT5	GT5a	GT6	GT7
160-200 kPa	300-350 kPa	400-600 kPa	200-250 kPa	400 kPa
Non-Weathered Sandstone	Fully Weathered And Fossil-Weathered Slate	Weakly Weathered slate	Non-Weathered Strong Slate	Non-Weathered Strong Silicified Slate
GT8	GT9	GT10	GT11	GT12
600 kPa	250 kPa	400 kPa	800 kPa	2,000 kPa

Note: kPa = kilopascal

18.10.2 Tailings Site

The geotechnical setting of the existing tailings piles and foundation soils was determined based on the provided project information and test hole drilling programs that included cone penetration testing (CPT), sampling and laboratory analyses, and a geophysical investigation.

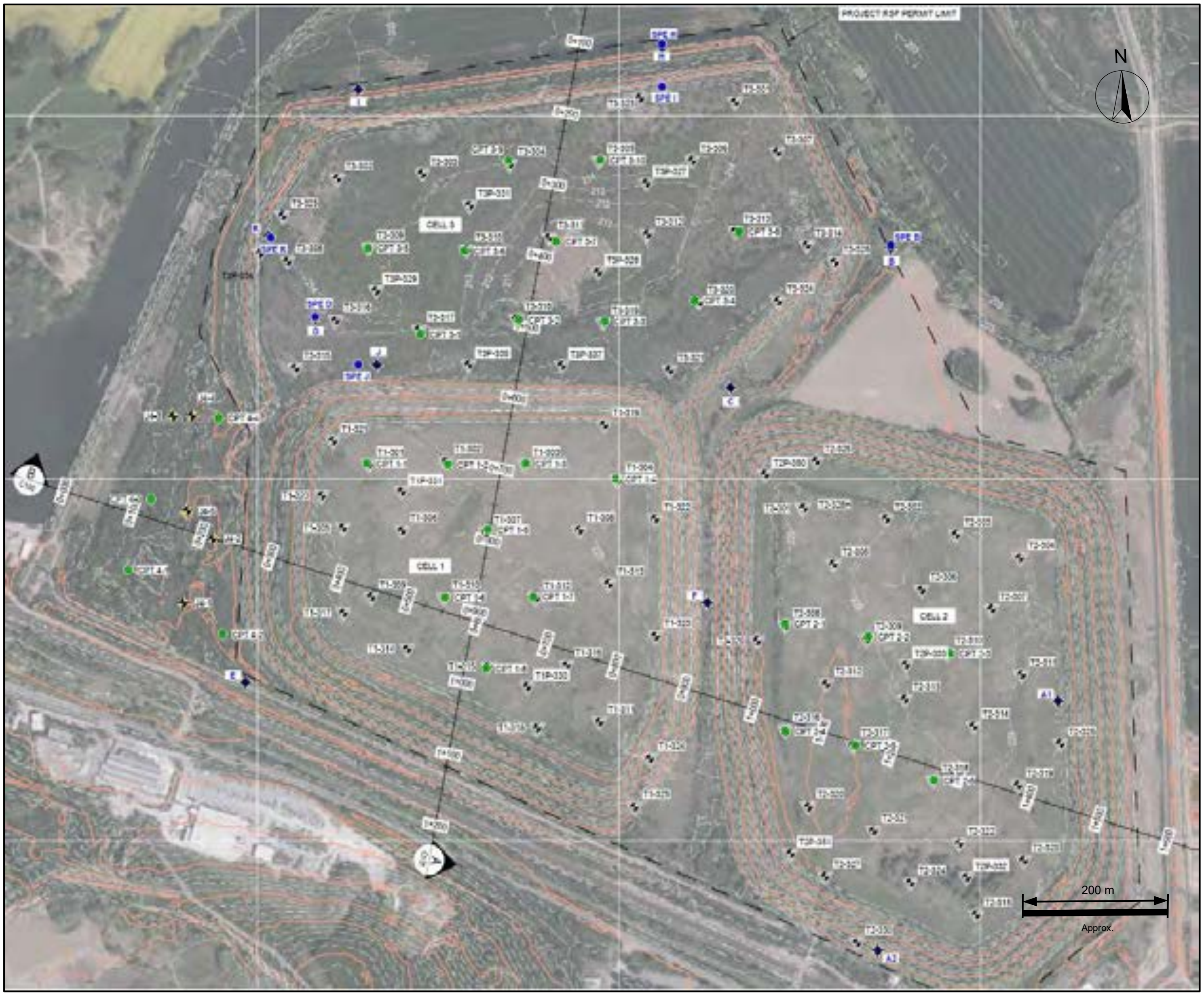
Existing and related information included the 160 test holes advanced into the 3 tailings piles using sonic and mobile percussion drilling methods in 2017 and 2018 as part of mineral resource assessment (Tetra Tech, 2019). Samples were logged, photographed, and retained for various laboratory tests that included field and laboratory moisture-content measurements, particle-size analyses, specific gravity, and chemical analyses. Hydrogeological investigations completed at the site involved drilling and testing boreholes at the site and groundwater flow modelling (Geomin, 2019 and 2021.)

A CPT investigation and a downhole seismic geophysical testing program were undertaken in 2018 to characterize existing geotechnical conditions and provide information in support of the tailings excavation plan development and the RSF conceptual design (SGS, 2018). CPT holes were targeted across all three cells to assess the variation in material properties from the perimeter (coarser-grained tailings) to the interior (finer-grained tailings) of the cells. Selected test hole depths penetrated through the tailings and into the foundation. Pore pressure measurements were collected during the cone push (CPTu) to provide continuous digital data collection of the cone sleeve friction, tip resistance, and pore pressure. Dissipation tests were undertaken at selected depths to permit determination of hydraulic characteristics of the existing tailings.

An additional geotechnical test hole and CPTu investigation program was undertaken in 2021 to support feasibility level design work (Geotest, 2021). This program included 11 boreholes and 6 CPTu holes. Selected soil and bedrock samples were retained for laboratory characterisation tests.

A site plan showing the location of test holes in the proposed mining and residue storage area is shown on Figure 18-28.

Figure 18-28: Geotechnical Testhole Locations at Existing Tailings Area



18.11 Control Philosophy

The Project will utilize an advanced and mature fieldbus control system (FCS) for process and water treatment controls. The system will integrate instrumentation, electrical management, and control. Electrical equipment on/off operation, operating status, and process control parameters can be displayed and controlled from the FCS operation station. The local control systems provided by the equipment venders will connect to the computer system through communication buses and will be operated as independent nodes of the whole plant control system.

One central control room is designed for the CMP. PC-based OIS will be located in the local control rooms.

The central control room will be the operation control center of the whole computer control system. The plant's central control room will be staffed by trained personnel 24 h/d. The operation system will realize centralized control of various operations "domains"; meanwhile, respective local operations at each domain can be conducted in respective sub-systems to ensure relative independence and real-time performance.

Control room LCD screens will display various process flowsheets and show real-time dynamic information, including process parameters, pump operating states and emergency alarms. The process control philosophy is described in more detail in Section 17.10.

The master step-down substation will be an unmanned station and equipped with the automation system integrated with microcomputers for collecting all switching quantities and analog quantities and providing microcomputer relay protection.

In addition to the plant control system, a CCTV system will be installed at various locations throughout the project site, including process facilities, water treatment plants, product loading and supply unloading facilities, railway spurs, north site operation areas (CMP tailings extraction and dry stacking areas), and main access and internal roads. The cameras can be monitored from local control rooms, central control room, and management offices.

18.12 Communication

A sitewide communication system and a premise distribution system (PDS) will be constructed with independent LAN for data communications in key processing facilities. Data exchange units, servers, fibre optical transceivers, and other equipment will be set up in the central control room and management office complex. Local telephone stations at various workshops, working sections, duty rooms, control rooms, and office buildings, will be installed. A very-high frequency (VHF) two-way radio system with several public channels will also be set up for on-site communications. The communications between the project site and external parties will be via public communication services, including internet and mobile phone services, because the project is located immediately adjacent to well-developed communities.

As indicated above, a sitewide CCTV system will monitor various key equipment, circuits, and production facilities, especially in high-risk areas where operators may be exposed to potential dust, noise, or hazardous gases.

18.13 Residue Storage Facility

The RSF design involves placement of washed and filtered process residue in an engineered containment area constructed within the same footprint as the existing tailings cells. The prepared RSF foundation will incorporate perimeter surface water diversion and a geomembrane liner for contact water collection from the filtered residue stack. The RSF will be constructed in stages to suit residue storage requirements.

18.13.1 Geotechnical Setting

The surface soil at the property is 'Holocene loam' containing silt, sand, and clay (Bateria Slany 1989 and Geomin 2019, 2021). It is typically 0.5 m to 2.0 m thick, and locally up to 5.0 m thick. Fluvial sands associated with the Labe River underlie the surface soils and are up to 10.0 m thick. These sands are connected to a shallow regional aquifer. Bedrock underlying the project site is comprised of terrestrial freshwater to marine claystones, siltstones, sandstones, and conglomerates of the Upper Cretaceous (Tetra Tech 2019).

The existing tailings can be geotechnically classified as fine-silty sand at the perimeter and silt to clayey silt at the interior. The CPT results indicate "sand-like" soil-behaviour-type tailings near the perimeter embankments and "clay-like" soil-behaviour-type tailings near the centre of each cell.

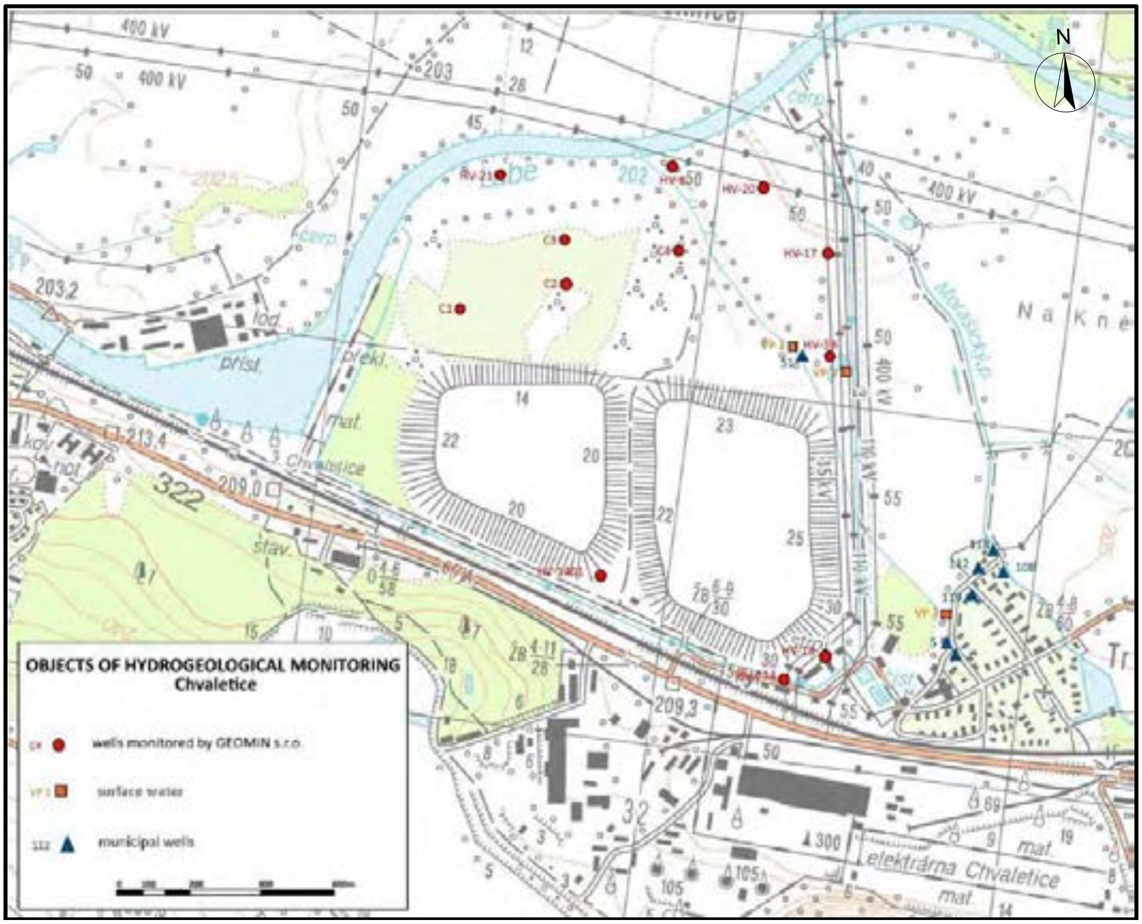
Groundwater conditions at the site are described in GET, 2017, and Geomin, 2021, 2019, and 2016. Geomin, 2019, included hydrogeological investigation undertaken in December 2018 that included eight boreholes with installation of standpipe piezometers and modelling to assess groundwater conditions.

The groundwater elevation prior to project development and below the tailings cells is near the water level of the Labe River, which is at approximately 202 masl and 1 to 3 m below original ground. Figure 18-29 provides a site plan with the location of current surface water monitoring points and groundwater monitoring wells.

The Quaternary-age terraces of the Labe River form an aquifer approximately 10 m thick and up to 2 km wide below the CMP site. The terraces are overlain by "semi-permeable Holocene loams" (Geomin 2016) that are typically less than 4 m thick. The water in this aquifer does not meet drinking water criteria due to excess sulphates, iron, nitrates, and other parameters. The water quality has likely been affected by the existing tailings cells and also by the old waste rock dumps and the fly-ash storage area at the thermal power plant upgradient (south) of existing tailings cells.

Groundwater below the tailings cells is interpreted to flow to the northwest, towards the Labe River. The river flows from east to west at the CMP site.

Figure 18-29: Surface and Groundwater Monitoring Well Locations



Source: GET (2017)

18.13.2 Residue Geotechnical Characterization

Geotechnical laboratory testing was undertaken to characterize residue behavior with test settings established based on RSF design criteria and expected geotechnical conditions. The tests were conducted on a representative sample prepared as a 54:46 blended mixture of NMT and LR obtained from metallurgical testing residue.

Residue samples were prepared to represent the expected density of residue stored as ‘track packed’ material within the interior storage zone (90% Standard Proctor Maximum Dry Density [SPMDD]) and ‘roller packed’ material in the perimeter structural zone (95% SPMDD) at various gravimetric Moisture Contents (MC). The target compaction densities were selected to establish the range of characteristics within each zone.

The laboratory test program included: Index Testing including Particle Size Analysis, Hydrometer Testing and Atterberg Limits; Standard Proctor Compaction Test (ASTM D698); Specific Gravity Test (ASTM D854); Laboratory Vane Shear Tests (ASTM D4648); Direct Simple Shear Tests (ASTM D6528); Triaxial Strength Tests under UU, CU and CD conditions; One-Dimensional Consolidation Tests (ASTM D2435); Hydraulic Conductivity Tests (ASTM D5084); Cyclic and Post-Cyclic Direct Shear Tests; and a Soil Water Characteristic Curve Test.

Results indicate that the filtered residue sample is classified as low-plasticity silt (ML) with 11% fine sand, a plastic limit of 26% and a liquid limit of 38%. The maximum dry density is 1,567 kg/m^3 at an optimum moisture content of

24.8% (mass water/mass solids) and a specific gravity of 2.98 for the blended sample. The friction angle of the residue was measured to range between 24 degrees and 29 degrees under various test settings. The residue has fairly low compressibility potential. Hydraulic conductivity test measurements ranged from $1x10^{-8}$ m/s to $1x10^{-9}$ m/s on samples prepared at 90% SPMDD and 25% MC. The post liquefied residue showed some cyclic softening and a reduction in the Shear Modulus (G) during cyclic and post-cyclic direct shear tests.

18.13.3 Tailings and Residue Geochemistry

Geochemical characterization testing was undertaken to assess potential ARD and metal leaching (ML) of the existing tailings and the re-processed tailings residue. The test results from acid base accounting, shake flask extraction and humidity cell tests are summarized in Section 20.6. The characterization results indicate that the residue blend to be backfilled is expected to be an acid generating material.

18.13.4 Design Requirements

A filtered RSF design was selected over conventional slurry tailings storage methods to mitigate environmental risks associated with seepage and to achieve the benefits of a relatively smaller storage footprint area and the potential for concurrent reclamation.

Table 18-24 presents a summary of the RSF design criteria and input data.

Table 18-24: Filtered RSF Design Criteria and Input Data

Item		Design Criteria and Input Data
1.0	**GENERAL**	
1.1	Climate	Temperate continental climate, warm summer, and cold winter. The average annual temperature is 7.9°C, varying from -2.1°C in January to 18.7°C in July (1981-2010 Pardubicky). Average annual precipitation is 650 mm and annual evaporation 700 mm (GET 2017).
1.2	Project Setting	Site is north of a coal-fired power plant, and the surrounding area is farmed for grain. Major active railway line at the south and the Labe River is to the west and north. Several small villages within a 5 km radius. Near surface groundwater contains elevated concentration of metals/contaminants. Existing tailings deposited from 1951 - 1975 in three unlined cells. Existing starter perimeter embankments appear to have been constructed using native soil, and then raised by upstream methods using tailings as a construction material. Approx. 110 ha footprint identified for excavation of existing tailings and final residue storage. Low seismic hazard, Peak Ground Acceleration of 0.2-0.8 m/s^2 for 1:475 return period (WHO, 2010, Seismic hazard distribution map).

table continues…

TETRA TECH

Item		Design Criteria and Input Data
2.0	**PLANT SITE AND PRODUCTION**	
2.1	Plant Site	South of the existing tailings area, across the highway/railway.
2.2	Excavation/Process	Extract existing tailings using excavator, 40 t haul trucks, repulp the tailings at the Plant Feed Storage and Pulping Area (Area 4010) and then pump the slurry approximately 350 m via a slurry pipeline to the main process plant at approximately 3,400 dry t per day (nominal rate). Excavation/residue placement operation 14 to 16 h/d, 5 d/k. Process plant operation 24 h/d, 7 d/w. Process plant to produce two residue streams that will be combined and conveyed to the RSF: ▪ NMT – approximately 56% of residue stream by mass. ▪ LR – approximately 44% of residue stream by mass.
2.3	Production	Total residue production: approximately 27.8 million dry t in 25 years of operation. Residue production rate (average): approximately 1.1 million dry t per year.
3.0	**RESIDUE PROPERTIES**	
3.1	General Residue Properties	NMT: relatively coarser-grained, easier to filter, target 18-20% [Mw/(Mw+Ms)] filter cake moisture content. LR: relatively finer-grained, 25% to 28% [Mw/(Mw+Ms)] filter cake moisture content, higher geochemical risk. residue blend characteristics based on laboratory testing results: ▪ Plastic limit 26, Liquid Limit 38, Plasticity Index 12. ▪ Particle size distribution: 11% fine sand, and 89% fines (4% clay). ▪ USCS – Silt (ML). ▪ Average Particle Specific Gravity 2.98. ▪ Constant head k-test: $1x10^{-8}$ m/s, sample prepared at 95% SMDD and OMC. ▪ SMDD 15.37 kN/m^3 (1567 kg/m^3) at an OMC of 25% (M_w/M_s). ▪ Friction Angle, Φ', 26° to 29°.
3.2	Acid Generating Potential	Filtered LR/NMT blend is classified as Potentially Acid Generating and with potential for Metal Leaching.
3.3	Residue Filtration	Pressure filtration tests by a manufacturer resulted in filter cake moisture content for NMT of 16% to 21% w/w [Mw/(Mw+Ms)], and for LR were approximately 24% w/w.
4.0	**RESIDUE STORAGE FACILITY**	
4.1	Residue Storage Concept	Residue to be mixed and co-disposed in the same footprint as existing tailings. External 'starter cell' required for storage during initial mining excavation activity.
4.2	General Site Subsurface Conditions	Surface sediments associated with the Labe River underlie the site and are up to 10 m thick. These sediments are connected to a regional aquifer. Sedimentary bedrock underlies the quaternary sediments, including a fine-grained calcareous sandstone (marl).
4.3	Foundation Preparation	Post-excavation area to be cleared, graded, and foundation compacted. Removal of any unsuitable foundation material required.

table continues…

Item		Design Criteria and Input Data
4.4	Containment	Seepage from the residue will be contained with a low permeability liner, collected at seepage collection sump, and pumped back to the process plant for re-use or treatment. The proposed High Density Polyethylene (HDPE) geomembrane liner shall meet the following minimum characteristics: ▪ Thickness 1.5 mm ▪ Formulated Density 0.940 g/cm^3 (min average) ▪ Tear Resistance 187 N (min average) ▪ Yield strength 22 kN/m (min average)
4.5	Residue Deposition	Rinsed and filtered residue cake will be transported to the RSF by truck, pushed out in thin lifts by bulldozer, and compacted. Perimeter structural zone shall be compacted to a minimum 95% SMDD (1,567 kg/m^3) to achieve dilatant behaviour upon shearing. The interior zone of the RSF will be compacted and will be contained by the outer structural zone. The outer structural zone shall be wider than the critical global shear failure surface as determined from geotechnical stability analyses. Any weak or out-of-specification residue shall be fully contained by both the interior zone and the outer structural zone.
4.6	Facility Geometry/Development	The design average residue dry density (in situ) is 1470 kg/m^3. This value was adopted based on the plan for 70% of the residue mass to be placed at 95% SPMDD in the perimeter structural zone and 30% of the residue mass to be placed at 90% SPMDD. 90% SPMDD is considered an achievable compaction target for residue that may be too wet due to process system upset or due to wet site conditions. Maximum 3H:1V perimeter slopes to facilitate closure cover placement and long-term stability with minimum target FoS 1.5 for static and 1.05 for pseudo-static analyses. RSF to be developed in cells that are constructed in stages to suit residue production requirements and constrained by available post-extraction space. Maximum RSF crest elevation is 229 m elevation (including final cover) related to national heritage area protection under environmental approval constraints. Minimize cut/fills of RSF foundation pad for efficiency and to limit handling of potentially contaminated foundation soils. RSF classification as 'Moderate Hazard' under system described in Hawley and Cunning, 2017.
5.0	**WATER MANAGEMENT**	
5.1	Surface Water	Divert clean (non-contact) runoff where possible and to retain non-contact runoff water up to 1:10-year, 1-hour design storm events and safely pass 1:200 year 1-hour duration storm events. Non-contact pile runoff to be directed to channel at internal location of RSF to support habitat diversity (seasonal wetland) at closure.
5.2	Contact Water	Collect residue contact water for re-use at plant or treatment/testing and release. System designed to manage peak discharge from 1:200-year return period, 24 hour duration.
5.3	Groundwater	Groundwater monitoring wells will monitor groundwater quality and flow direction.
6.0	**CLOSURE**	
6.1	General	Low permeability cover system required that incorporates a plant growth medium layer and is progressively constructed over the life of mine. Closure cover surface to incorporate variable cover thickness and elevation to promote biodiversity in surface vegetation.

18.13.5 Filtered RSF Design and Construction

A plan view drawing of the ultimate RSF shape showing key features is shown in Figure 18-30. The key elements to the design include:

- A prepared pad foundation;
- A containment system; and
- Water management features that include contact water collection sumps and stormwater management ponds.

The RSF is designed to contain the proposed nominal 27.8 Mt of residue, which is a blend of filtered NMT and rinsed LR. The ultimate RSF shape will be approximately 24 m high over an area of approximately 110 ha.

The facility will be constructed in stages when space becomes available from the mining excavation sequence shown schematically on Figure 18-31. To facilitate residue storage at the start of residue production, an external starter cell will be constructed immediately north of existing Cell #2. This area is identified as ‘RSF Starter Cell’ in Figure 18-31. Subsequent cells will be constructed sequentially within the mined-out excavation footprint of the existing tailings cells.

Figure 18-30: Residue Storage Facility Design

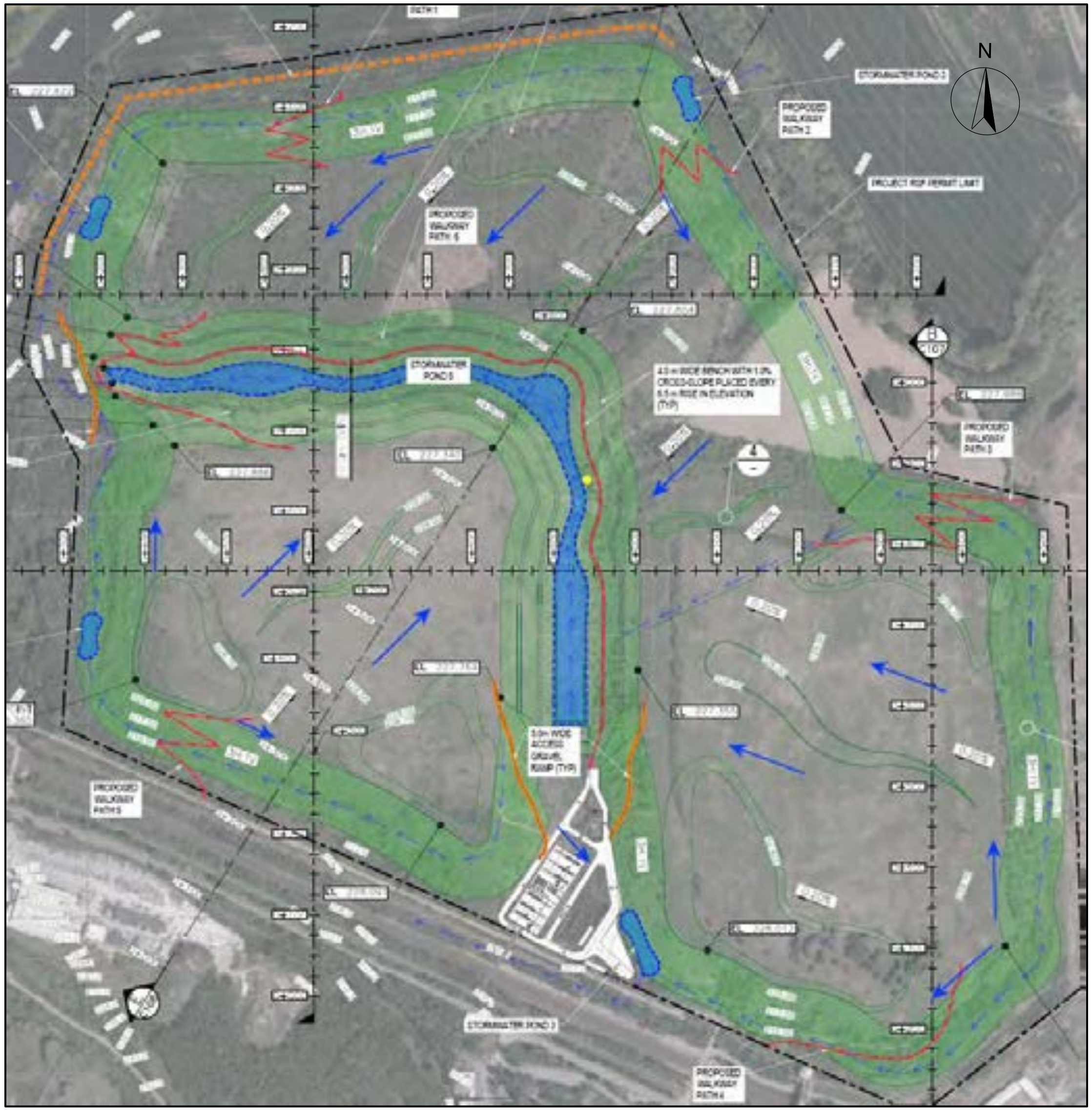


Figure 18-31: CMP Mine Plan

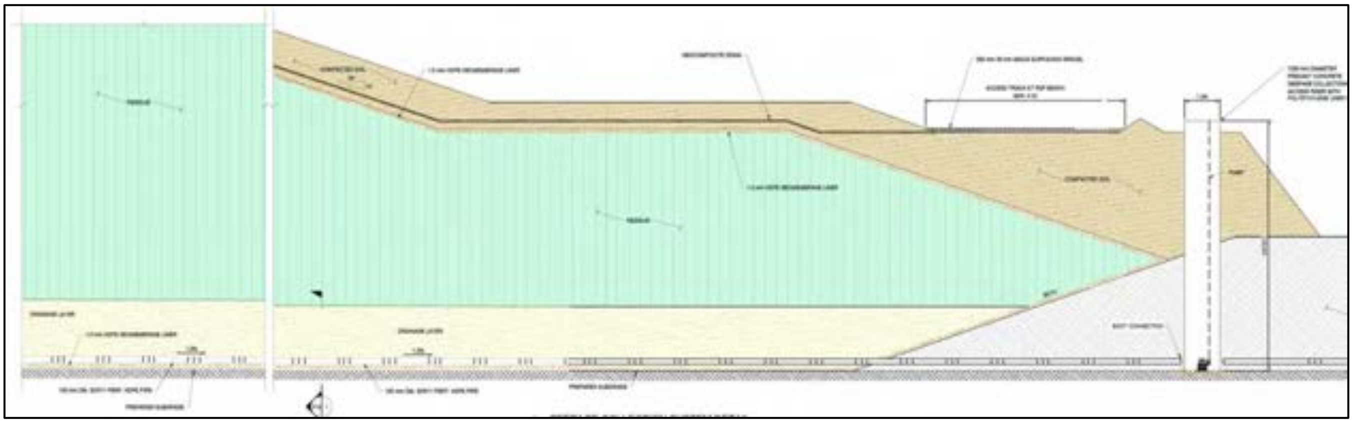
Figure 18-32: RSF Foundation Grading and Seepage Collection Layout

18.13.5.1 Filtered Residue Storage Facility Seepage Containment System

As a first step in RSF construction, a pad will be constructed in the post-mining footprint that will form the foundation of the RSF. The post-mining surface was determined based on the mine plan.

The RSF foundation pad surface will be graded towards the contact water collection sump (yellow dot) shown in plan view on Figure 18-32 and in section on Figure 18-33. Fill will be placed and compacted in the post-excavation surface to facilitate drainage to the sump.

Figure 18-33: RSF Contact Water Collection Sump Cross Section with Drainage Layer



The residue will be fully contained within the RSF liner system to mitigate the risk of environmental impact from seepage. A 1.5 mm (60 mil) thick geomembrane liner will be installed on the filtered residue foundation and connected with the low permeability cover will be installed progressively on the ultimate residue surface.

18.13.5.2 Filtered Residue Placement

The filtered residue will be transported to the RSF by haul truck from the stockpile located between existing Tailings Cells 1 and 2. At the RSF, the residue will be dumped in the active placement area and spread into trafficable lifts with a bulldozer. Residue placed in the perimeter structural zone will be compacted with a roller compactor. A method specification will be developed to determine the maximum lift thickness and the minimum number of compactor passes required.

The filtered residue perimeter slopes have currently been designed at a maximum grade of 3H:1V to suit expected geotechnical and closure construction requirements. This slope grade may be refined during the detailed design phase based on further geotechnical characterization data.

Dust management will include traffic control outside residue placement areas and the application of water and dust suppressant (if required) on the interim stack surfaces and haul roads. To further mitigate potential residue dust and erosion issues, the footprint of residue exposed to the atmosphere will be minimized and progressive cover placement will be undertaken during the operational life, as soon as reasonably possible. Residue compaction and progressive cover placement will also mitigate oxygen and moisture infiltration to reduce the risk of ARD/ML.

Surface water management to promote runoff on the uncovered and active placement areas of the filtered residue stockpile will be achieved through grading and sequencing of residue placement. Surface water management design is described in Section 18.9.3.

18.13.5.3 Filtered RSF Monitoring

The RSF monitoring program will include periodic and documented visual inspections by operators and technical specialists, geotechnical instrumentation and data collection, and measurements of surface and groundwater flow quantity and quality. Staged development of the RSF will require compilation of annual construction monitoring reports, completed by the Engineer of Record, that summarise construction methods and quality control and assurance results.

18.13.5.4 Filtered RSF Closure

The closure plan for the RSF will include placement of a low permeability geomembrane and soil cover over the filtered residue stack. The landform design (Figure 18-34) was developed to incorporate engineering features while providing enhanced habitat for biodiversity. Final land use and closure requirements will be developed in accordance with outcomes from ongoing consultations with local communities and regulators, and design constraints. The residue stack cover will consist of a 1.5 mm thick geomembrane liner to inhibit infiltration overlain by a soil growth media layer to support grass vegetation growth. The cover will be placed progressively and hydroseeded when residue crest and perimeter stockpile slopes meet design grades. The RSF will be monitored during the post-closure period to assess cover performance and environmental impact against regulatory requirements and design targets. The potential requirement for treatment of residue contact water during the post-closure period will be reviewed as part of future geochemical assessments.

Figure 18-34: RSF Closure Plan, 3D View

18.13.6 RSF Design Assessments

Engineering analyses conducted to support the RSF design were based on a geological model generated from site investigation data, laboratory test data, the expected physical and environmental properties of the residue, and the proposed operating conditions. The analyses included: mine waste storage facility hazard classification, evaluation of liquefaction potential, geotechnical slope stability analyses, seepage, and hydrotechnical analyses.

The RSF design hazard classification was determined to be 'moderate' under the Waste Dump and Stockpile Stability Rating and Hazard Classification (WSRHC) system (Hawley and Cunning, 2017) and the level of effort for investigation, analysis, and proposed monitoring and operation was developed to meet those standards.

Liquefaction analyses for the existing foundation was completed using the CPT data which indicated that the current subsurface conditions are not susceptible to liquefaction, but some degree of post-seismic strength and stiffness degradation may occur. The liquefaction potential of the residue in the proposed RSF is considered to be minimal based on laboratory cyclic testing of the residue.

Stability analyses of the proposed design were completed using two-dimensional limit equilibrium methods. The model results exceeded the target FoS of 1.50 for static conditions and 1.05 for pseudo-static conditions.

Seepage analyses were undertaken to support design of the contact water seepage collection system by determining the range of potential seepage flow volumes that may occur during 'drain down' of the residue after cover installation. Results indicate that the seepage rate from the covered profile will decrease to between 5 and 25 m^3/day from the entire facility after approximately one year.

18.13.7 Filtered RSF Construction and Operation Requirements

The main RSF construction tasks include the following items:

- Foundation preparation, earthwork, and grading
- Geomembrane liner for the foundation and the cover
- Contact and non-contact water management infrastructure
- Equipment purchase, including a roller compactor and bulldozer
- Closure soil cover placement and reclamation
- Engineering and construction management

The proposed loader and 40 t haul trucks used for residue transport and equipment required for haul road maintenance are described in Section 16.0.

The construction quantities for key construction elements are summarized in Table 18-25.

Table 18-25: RSF Construction Quantities

Mine Year	Residue Capacity Cumulative Cubic metres	Foundation Prep/Geomembrane Cumulative Square metres	Cover Geomembrane Cumulative Square metres	Cover Soil Cumulative Cubic metres
0 (Starter)	372,500	39,300	-	-
1	520,000	60,200	-	-
2	1,490,000	107,200	65,800	95,200
5	3,938,500	241,100	173,700	253,200
10	8,095,500	461,700	383,900	560,400
15	12,586,000	642,000	588,300	863,500
20	16,180,000	816,000	792,500	1,162,000
25 (Total)	22,030,500	1,058,900	1,081,900	1,588,600

The main operating costs associated with the RSF are considered under mining costs and include:

- Labour
- Owner operated equipment operation
- Dust suppression

18.13.8 Residue Storage Facility Design Future Considerations

The RSF design for the FS was developed based on available information and to meet CMP requirements and design standards. Future design considerations and uncertainty include the following:

- The actual ground conditions encountered may not be as interpreted. This geotechnical risk is associated with the need to extrapolate borehole and test pit information across a site, and the fact that ground conditions can change over time, including material properties and groundwater levels.
- If the filtered residue characteristics are significantly different to those tested/expected, particularly with respect to water content and geotechnical properties, issues associated with residue trafficability, dust generation, and geotechnical stability may arise. This risk can be mitigated by advancing the understanding of metallurgical domains and process equipment variation as part of final design.
- If the quantity of filtered tailings produced is significantly different than expected, the costs will change, and additional storage may be required if there is an increase in total production.
- There is limited space within the proposed mining and residue placement area which does not provide operational flexibility in mining plan or residue placement. This may result in periodic double-handling of material, and/or construction of the RSF cells in relatively small and inefficient steps.
- Water management: contact water quantity and quality variation from design expectations may result in additional cost and time for contact water management and treatment.

- Closure cover: the potential for damage to the cover system could lead to increased infiltration and then potentially to increased contact water treatment requirements.

RSF design alternatives that may be required in the event the design requirements change include the following:

- Additional containment measures.
- Larger than designed flood erosion protection berms or thicker than anticipated closure cover.
- Additional effort for pumping, storing, and treating residue contact water.
- Temporary storage facility for thickened but unfiltered residue to facilitate process plant maintenance or upset conditions.
- Addition of a temporary residue stockpile may be needed for additional residue drying time or if the excavation operation is unable to release adequate footprint in time for staged RSF cell construction. This temporary stockpile could potentially be placed on the existing tailings surface or an external temporary or permanent residue storage cell.

Some of the opportunities associated with the RSF design that may be realized with further work include the following:

- Optimize containment system design. The relatively low permeability of the compacted residue presents an opportunity to replace the geomembrane in the cover or base with a liner system that integrates compacted residue, compacted soil, and a growth media layer. Additional residue characterization and modelling of seepage for alternative cover options would be required to support this.
- The benefits of the proposed residue contact water drainage layer on the liner surface will depend on several factors, including the actual moisture content and density of the residue. The value of this feature can be evaluated in future design work, and assessed during the early phase of the mine life.

19.0 MARKET STUDIES AND CONTRACTS

EMN plans to produce HPEMM and HPMSM products from the CMP tailings material. The EMN management team has conducted HPEMM and HPMSM market investigations and contacted potential users to better understand market potential and product quality requirements. EMN also commissioned CPM Group to provide an HPEMM and HPMSM products market outlook study for the CMP.

CPM Group is an independent research and consultancy company based in New York. It has advised clients on precious and speciality metals markets and has worked with EMN in the past. This report was prepared by Andrew Zemek of CPM, with inputs from other members of the CPM team and selected external consultants. The CPM team has prepared a comprehensive market research report and has provided an extended executive summary of the report that summarizes market information for high purity manganese products, including market demand and supply and projected HPEMM and HPMSM prices. This extended summary from the market outlook study entitled “Market Outlook for High-Purity Manganese Products” dated July 06, 2022, is added in its entirety to this section. Any changes to the text are for formatting purposes only.

Consent has been given to EMN to use and reproduce this report in its entirety in its feasibility study of the Chvaletice Manganese Project. The following extract from the CPM study is not for reproduction, distribution, or re-transmission outside Euro Manganese Inc. and its authorized consultants without written CPM Group consent.

Electrolytic manganese metal (“Conventional” or “standard quality” EMM containing ~99.7% Mn) is used principally by comparatively small markets of steel and aluminium alloys, while manganese sulphate monohydrate (MSM, 98% $MnSO_4•H_2O$) is used mainly by the agrochemical and pharmaceutical industries. Only approximately 8-10% of all manganese mined is processed into EMM and MSM, while the vast majority is used for the production of ferroalloys: silicomanganese and ferromanganese (60-80% Mn).

The high purity versions of the products mentioned above make up an even smaller market: In 2021, the total global production of HPEMM (>99.9% Mn) was only 0.16% of the total manganese ore mined. The same figure for HPMSM (>99% $MnSO_4•H_2O$) was 0.46% (metal contained) of all manganese mined.

These niche markets behave more like high-tech product markets or specialized chemicals markets than traditional metal markets. Prices paid depend more on the purity (or lack of certain impurities) of the material rather than on the underlying manganese prices in the ferroalloys industry.

The number of high purity Mn producers is very limited: HPEMM is produced by three plants in China and one plant in South Africa (total output in 2021: 33,500 t produced by one plant in South Africa and one in China). HPMSM is produced by sixteen plants in China, one in Belgium and four small operations in Japan (total output in 2021: 296,000 t of HPMSM at 32% Mn).

Traditional applications for HPEMM are mainly in steel alloys, super alloys, aluminium alloys, and welding powders. In 2021 approximately 23% was used in the production of rechargeable batteries (through its conversion to high purity manganese sulphate solution [HPMSS] by precursor and battery makers). The use of HPEMM for the production of battery cathode precursors is expected to increase in the future in absolute numbers.

HPMSM is used primarily in the production of battery cathode materials, with small quantities also being used in the production of speciality chemicals.

Production of rechargeable lithium-ion batteries for electric vehicles is expected to dominate the market for HPEMM and HPMSM over the next two decades, dwarfing any other application for these products. Following E-Source's research into battery markets and combining it with its own research, CPM forecasts a 20-fold increase in the use of manganese in rechargeable Li-ion batteries between 2021 and 2036.

Europe will play an important part in this 'electric vehicle revolution' with 18 rechargeable battery factories already in operation and 56 expected to be operational by 2031. Europe is expected to become the second most important centre (after China) of the global electric car and battery industries. Major car makers like Volkswagen, Stellantis, Renault-Nissan, and Volvo declared their intentions to make 70%-100% of their vehicles produced in Europe electric by 2031. EMN's Chvaletice project is strategically positioned to become an important integral part of the European supply chains for these industries.

19.1 Industrial Uses of Manganese

Manganese is the twelfth most abundant element in the earth's crust and the fifth most mined metal by tonnage. The elemental form of manganese is not found in nature, in contrast to gold and sulphur. Manganese combines in nature with many compounds forming principally oxide, carbonate, and silicate minerals. The economic importance of the manganese industry is enormous, as it is a critical ingredient in virtually all types of steel. It is also an important metal in the chemical, agricultural, pharmaceutical, and energy storage industries.

Over 98% of manganese ore resources in the world occur in the form of oxides and mixed oxides (grading 30-50% Mn), with the balance occurring as carbonates (10-30% Mn content). High-grade oxide ores or selected mixed oxide ores are predominantly shipped directly to ferroalloy producers to make silico-manganese (with silicon) and ferro-manganese (with iron). Lower-grade ores are upgraded to concentrates before they can become a feedstock for the production of ferroalloys. Production of these ferroalloys accounts for more than 91% of all consumption of manganese ores

Only a small proportion of manganese ores are subject to speciality processing (8-10%) through a different route than the production of ferroalloys. The three main products in this group are Electrolytic Manganese Metal (EMM), Electrolytic Manganese Dioxide (EMD), and Manganese Sulphate Monohydrate (MSM). All three are produced in 'standard' or 'conventional purity' and 'high purity' forms. The purity of these materials varies considerably depending on their end use which is discussed in more detail later in this report. EMM, MSM and EMD are used in the production of batteries. While EMD is used largely to produce disposable alkaline batteries and LMO lithium-ion batteries, MSM is used to make the majority of manganese-containing rechargeable lithium-ion battery cathodes. Several precursor producers purchase HPEMM which is converted to manganese sulphate solution for making battery cathode precursors.

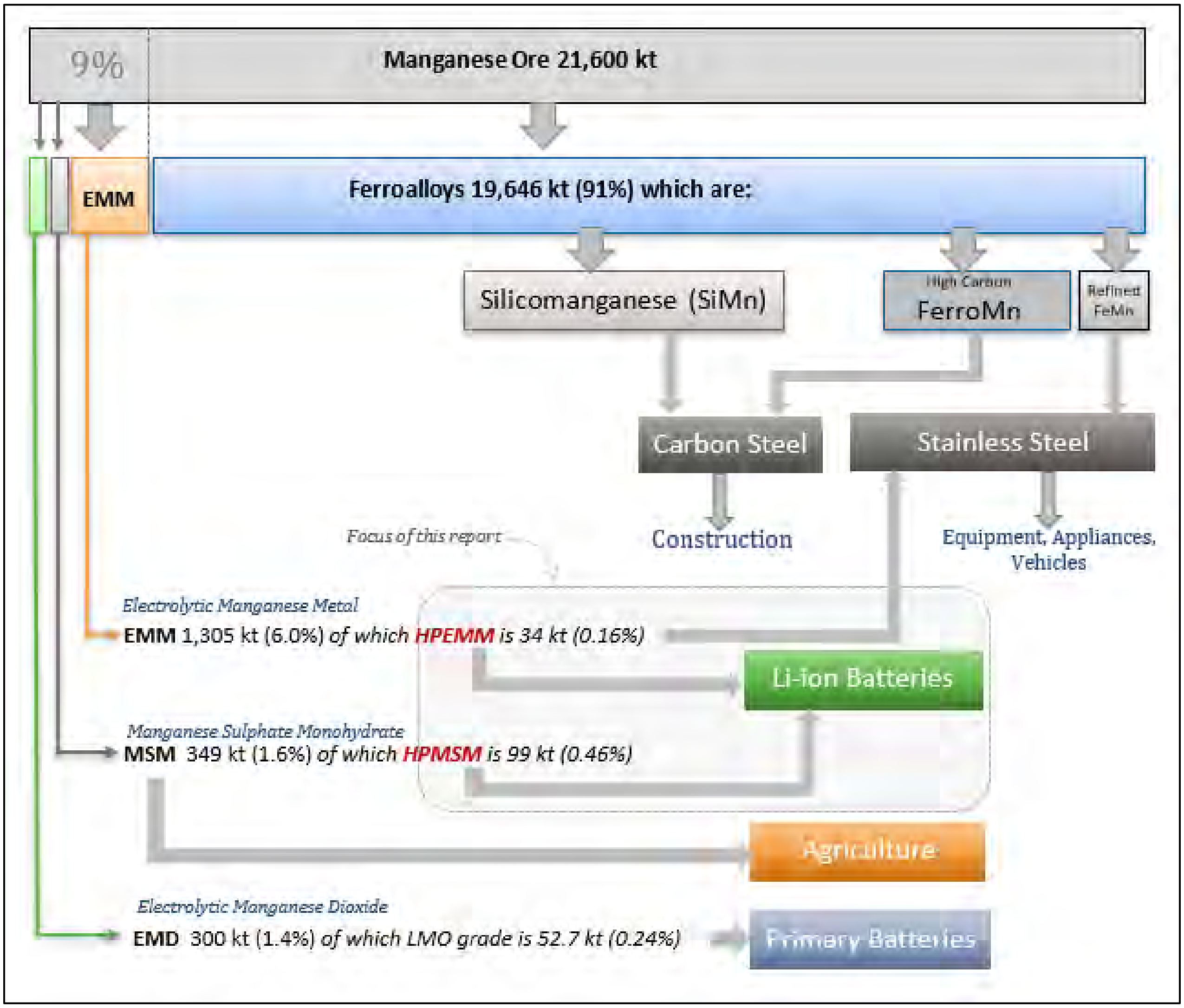
The main focus of this report is the markets for EMM, which is produced by an electrochemical process, and MSM, which can be produced in a chemical process from EMM, or directly from manganese ore.

The markets for manganese ferroalloys have entirely different characteristics from the EMM and MSM markets. The ferroalloys market behaves like a commodity metal market whose fortunes are closely tied to the fortunes of the steel industry. The ferroalloys market is price sensitive, and substitution (with alternate forms of ferroalloys) occurs when manganese ferroalloys are perceived to be too expensive.

In contrast, the market for pure manganese metal and its compounds obtained by electrolysis is more akin to the chemical products markets or high-tech markets. This market is less price-sensitive and, to a large extent, isolated from the fluctuations of the metal commodities markets. A critical factor for EMM production is the availability of the right quality of ore. Battery applications of EMM and MSM demand extraordinarily high purity products that require robust ore processing and purification methods.

The main manganese products and their end uses are shown in Figure 19-1 below.

Figure 19-1: Manganese Market and Uses (2021)



Data source: International Manganese Institute, 2021 figures;
Percentages in relation to the total tonnage of ore mined (metal contained)

19.2 Manganese Mining and Processing

19.2.1 Mn Ore Types

There are several hundred manganese minerals occurring in nature, but manganese ore is found in predominantly two groups of minerals: oxides and carbonates.

Manganese oxides are the most common manganese ores and usually contain higher concentrations of manganese (30-50% Mn). The most common manganese oxide ore minerals are Pyrolusite, Manganite, and Cryptomelane. They are described in more detail in the main report.

Carbonate deposits are far less common than oxide deposits and are generally lower in grade, typically with 10-30% Mn. With rare exceptions, high-grade carbonate deposits tend to be small. Carbonate-rich ores tend to occur as mixed oxide deposits. The most common manganese carbonates are Rhodochrosite and Kutnohorite, the latter named after Kutná Hora in the Czech Republic, where it was first found – EMN’s Chvaletice deposit is located approximately 15 km from Kutná Hora and its ore contains approximately 40% each of rhodochrosite and kutnohorite.

Oxide or mixed oxide ores are the most prevalent ores among the world’s deposits, accounting for over 90% of all known resources. ‘Manganese oxide’ deposits, such as the Kalahari manganese field in South Africa, often occur as mixed oxide ores containing carbonates and silicates. The complex mineralogy and presence of certain impurities can impact the efficiency of downstream processes, production costs and the purity of end products.

Oxide ores are principally used to make ferroalloys using pyrometallurgical processes. Due to the scarcity of high-grade, acid-soluble manganese carbonate ores, manganese oxide ores are increasingly being used to make EMM and MSM.

Carbonate ores are principally used to make EMM in China, where the contained manganese is easily dissolved in dilute sulphuric acid without the need for energy-intensive roasting prior to leaching. China is the largest consumer of manganese carbonate ore. The Daxin Mine in Guanxi Province, operated by South Manganese (formerly known as CITIC Dameng) is the largest Chinese producer. There is also a multitude of mostly small underground mines. The largest single producer of carbonate ore in the world is the Nsuta Mine in Ghana, owned by China’s Ningxia Tianyuan Manganese Industry (TMI), the world’s largest producer of EMM.

MSM is usually made directly from ore – high-grade carbonate ores are preferred, although oxides can be used as well after roasting or chemical treatment, which are expensive, energy-intensive, and/or environmentally challenging processes. HPMSM has been made from HPEMM by some Chinese HPEMM producers and several companies in Japan that convert imported HPEMM into HPMSM.

19.2.2 Mn Resources, Reserves and Production

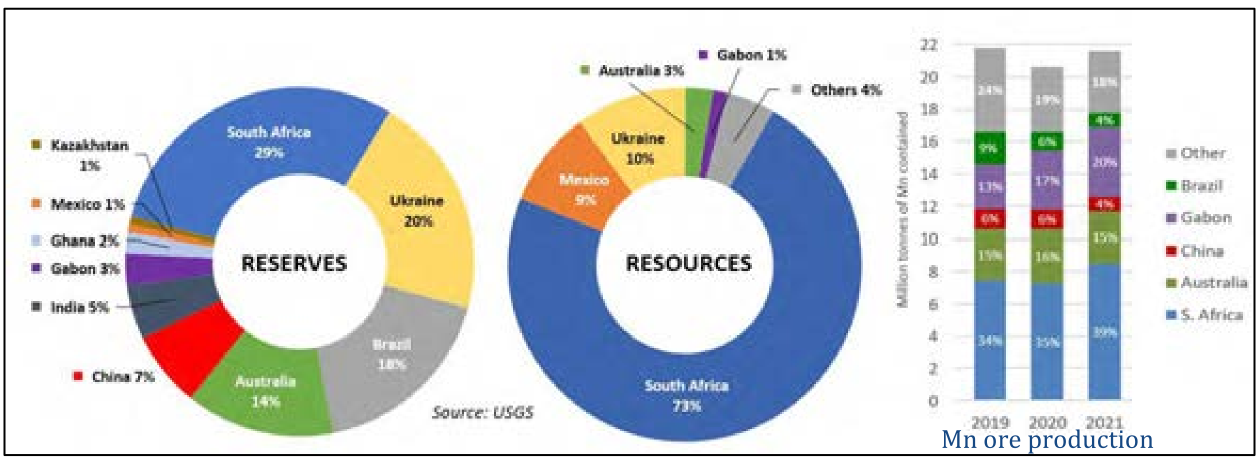
The world's resources (known deposits) of manganese ore of all types are vast. USGS estimates them at over 17.273 billion t[3]. Assuming the average grade of 35% Mn, such resources would support mining at 2021 levels for more than 300 years.

The reserves[4] are equally impressive: At 680 million metric t (metal contained), these reserves could be mined for 35 years before any further development of resources to reserves would be required.

Many countries have manganese ore deposits, but they are generally low grade. For example, Chinese carbonate ore grades are only 13% Mn on average, and its processing includes significant environmental costs (atmospheric emissions, solid waste, residual process reagents and selenium-containing tailings).

The EMN's Chvaletice manganese tailings deposit is western Europe's largest known manganese resource, with about two million t of manganese contained in the tailings. Although the 27-million-tonne mineral resource grade is only 7.33% Mn, EMN had reported that no mining or milling is required to liberate the manganese minerals and can be upgraded via high-intensity magnetic separation prior to leaching the tailings, as the primary ore from which they were made was crushed and finely milled when it was originally processed. The Chvaletice resource is hosted principally in acid-soluble manganese carbonate minerals. EMN has recently demonstrated the suitability of the Chvaletice tailings for the production of HPEMM and HPMSM in extensive bench and pilot-scale metallurgical tests.

Figure 19-2: Manganese Ore Reserve, Resource and Production Distribution by Region



Source for production figures: International Manganese Institute

Only three countries supply the EMM market at present:

- China (1,200 – 1,500 ktpy) – 98% of global supply (But only 7 kt HPEMM in 2021 – 1 out of 87 plants)
- South Africa (28-30 ktpy) (All production is HPEMM – the only HPEMM producer outside China)

[3] Chapter L of "Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply", U.S. Geological Survey, Reston, Virginia, 2017

[4] Reserves are these parts of resources, which can be mined economically at prevailing price levels at a time of estimation.

- Gabon (intended production capacity of 20 kypy, 8–12 ktpa produced previously; the plant had technical issued and has not ben in production since 2020)

Global production of MSM is approximately one million t (1,027 ktpy), of which approximately 27% is HPMSM at 32% Mn. China dominates both the agricultural MSM market (63% share) and the HPMSM market (for battery use) - 91% market share. In agro-grade MSM, India is also a producer of note (26%). Outside China, there is only one producer of HPMSM from the ore – the American company, Prince Erachem, with a production plant in Belgium. Four plants in Japan also produce HPMSM from the imported HPEMM. In 2021 their output accounted for 7.5% of all HPMSM produced globally.

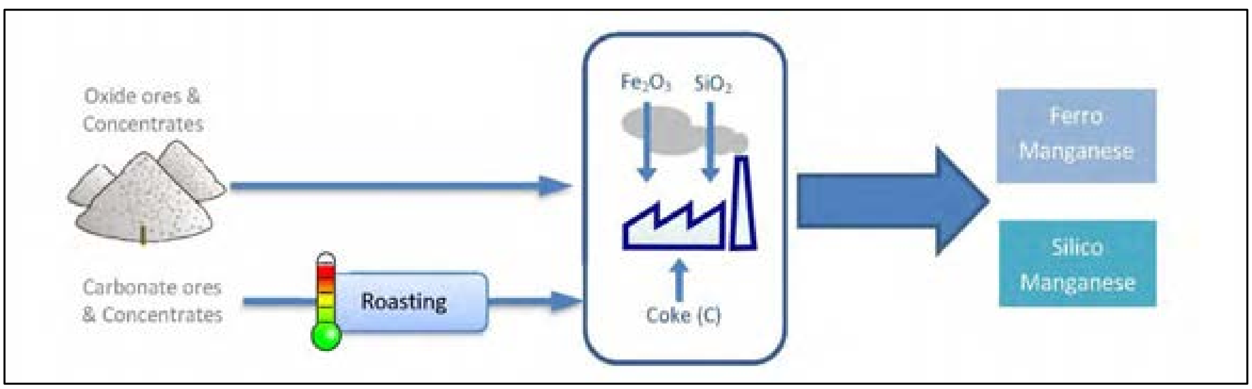
Production of HPMSM in China more than tripled between 2019 and 2021 (from 84 kt to 270 kt), and today the country claims to have 410 kt of HPMSM capacity (with a 66% utilization rate), which falls somewhat short of the 2019 announcements which added up to 920 kt by 2022-23.

The HPEMM and HPMSM project pipeline and the projected supply and demand balance are discussed in Section 19.7.

19.2.3 Manganese Ore Processing

The ferro-alloys industry, which consumes over 90% of manganese produced globally, expects an oxide ore, which can be processed with the addition of iron ore and/or silica to make ferro-manganese and silico-manganese. Carbonate ores can also be used but need to be roasted (or sintered) first, which increases the cost of production, so carbonates are usually used for the production of manganese products such as EMM and MSM.

Figure 19-3: Manganese Processing for Ferroalloys



In applications where the purity and physical characteristics of the product are very important, the preferred processing route is through electrowinning or electrolysis. This applies to EMM and EMD. Both are extracted electrolytically from solutions of manganese sulphate ($MnSO_4$) obtained as a result of leaching the ores with sulphuric acid (H_2SO_4), but there are some important differences between the two processes (see the diagram below):

19.2.4 HPEMM and HPMSM Production Process

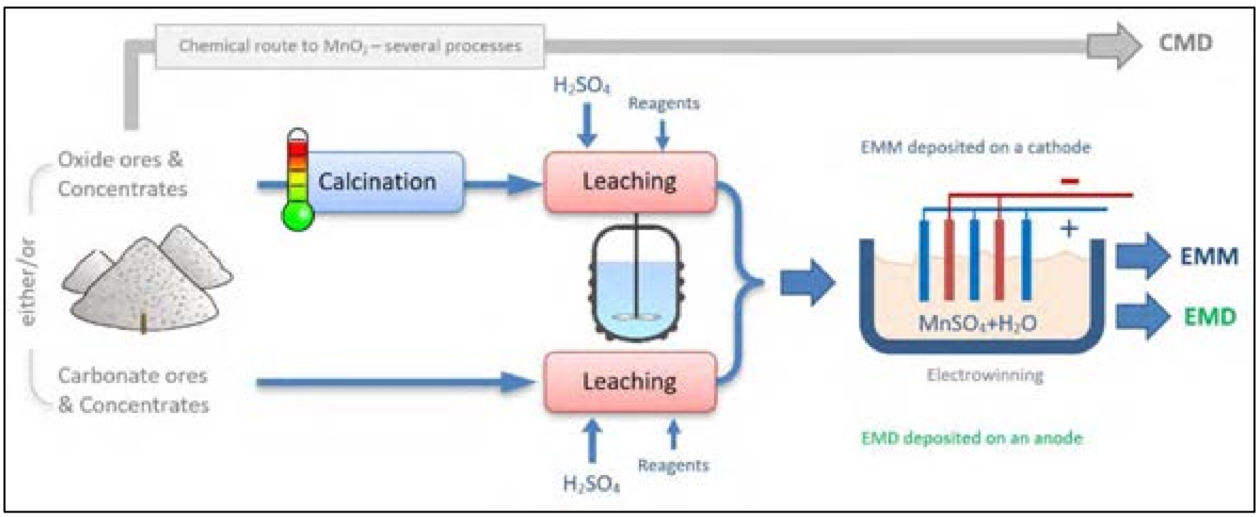
EMM is produced through an electrolytic process using manganese sulphate solutions that also contain ammonium sulphate, typically 35 g/L Mn and ~130 g/L of $(NH_4)_2SO_4$. In contrast, EMD solutions do not contain ammonium sulphate. The resulting product is a 'conventional' EMM of 99.7% purity. The remaining 0.3% impurities are either

TETRA TECH

co-deposited species such as Co, Ni, or H, remnants of the electrolysis solution or oxidation products. Depending on the final use of the EMM, these impurities may or may not be important. In metallurgical applications of EMM (in the ladle metallurgy where EMM is added directly to the molten steel), these may be of less importance than in the battery industry, where high purity is paramount. One of the very important impurities is selenium. It is added to the solution prior to electrowinning to lower the electricity consumption. The presence of this element is inconsequential most of the time for metallurgical uses of EMM, even in higher doses (800-1,800 ppm), but cathode active material makers cannot accept products with Se higher than 3-5 ppm (ideally, Se should not be present at all). That is why the 'standard quality' EMM cannot be used for battery production.

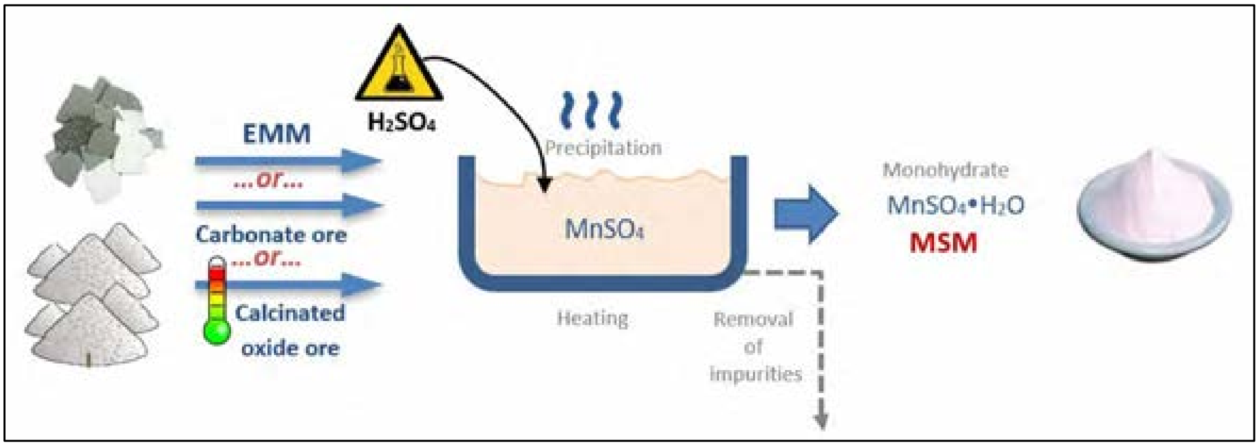
The name High Purity EMM (HPEMM) is used to describe electrolytic manganese metal containing at least 99.9% of Mn, which is made by adding sulphur dioxide (SO_2) to the electrowinning solution and eliminating the use of hazardous chromium-containing passivation reagents in the post-processing of the EMM flakes. The difference of 0.2% is significant for battery manufacturers who demand grades higher than 99.9% pure metal with stringent impurity limits on various chemical elements: The Chinese national standards identify so-called 'battery grade' of EMM, but many battery makers in China and elsewhere expect higher purity levels than the Chinese standard would allow.

Figure 19-4: Manganese Processing to Electrolytic Products



The key impurity difference between the 'conventional' and 'high purity' EMM is the absence of selenium. For this reason alone, the production cost and quality of HPEMM are higher than that of EMM.

Figure 19-5: HPMSM Production Process



HPMSM can be made by dissolving HPEMM or leaching carbonate ore with sulphuric acid. Oxide ore can also be used, which requires reducing the higher manganese oxidation states (Mn^{3+}, Mn^{4+}) in the mixed manganese minerals to the soluble form of Mn (Mn^{2+}) either pyrometallurgically or chemically by reductive leaching. This is a hazardous and energy-intensive process resulting in high operating costs. Direct production of HPMSM from manganese ore often requires using hazardous, toxic, and expensive fluorine reagents. In addition, the production of high purity MSM products is often accompanied by the production of lower grades of MSM that need to be sold to traditional low-value MSM markets.

Producing HPMSM from HPEMM leverages the inherent advantages available in the electrochemistry of EMM to prevent the carryover of impurities from the electrolysis solutions to the final product. The conversion of HPEMM to HPMSM is a relatively straightforward chemical process. After dissolving the metal and purifying the mother liquor solution, manganese sulphate monohydrate can be produced by a variety of crystallization methods using conventional crystallization equipment that is well commercialized in many industries. This processing route is used mostly in Japan, where in 2021, 19,000 t of HPMSM were produced this way (7.5% of global HPMSM production). A growing number of non-Chinese cathode producers are looking at HPEMM conversion to manganese sulphate solution (MSS) as a way of making additional cost savings. The MSS is not crystalized and is passed on to the cathode plant in its liquid form. This saves the cost of the crystallization step and also brings additional savings in the next step because there is no need to dissolve the HPMSM crystals to produce a slurry in preparation to cathode coating with ternary material. To be truly cost-effective MSS should only be transported over short distances, ideally by a pipeline.

Production directly from the ore may require more or less complex additional processes to remove impurities, hence the importance of quality feedstock.

In China, high purity MSM is increasingly being produced by a direct route from imported manganese oxide ore, largely because of the scarcity of high-quality manganese carbonate ore and also to reduce solid waste generation. Imported ore, although cleaner and higher-grade than domestic ore, comes with its own set of problems: high transport cost (international and domestic), non-refundable VAT on entry to China (13%), and the need for calcination prior to leaching (high cost). Despite these challenges, China remains the world’s largest importer of manganese ores (74% of the world’s imports in 2020) most of which is consumed by the steel industry in China.

19.3 Manganese Use in Batteries

19.3.1 Manganese Demand from Batteries

Although battery use currently accounts only for a very small fraction of overall manganese consumption (approximately 2%), this specialized sub-sector is expected to achieve a double-digit compound annual growth rate CAGR over the next two decades and should be on the radar of every manganese producer.

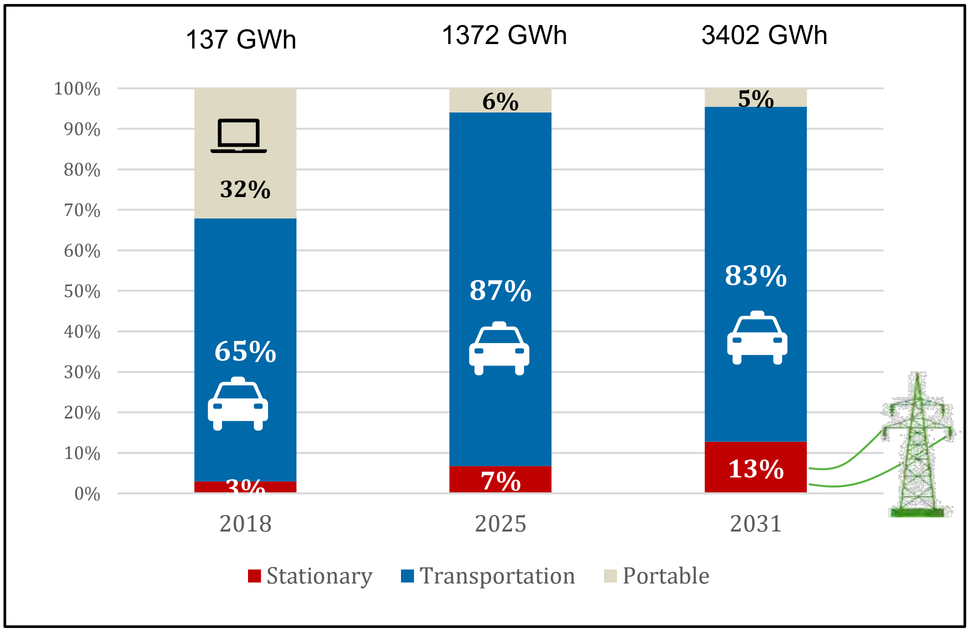
Manganese is used in the cathodes of both primary and secondary batteries. Primary batteries are also known as non-rechargeable batteries and can be used only once. A typical example is the disposable AA-style battery used widely in consumer electronics. The production process of these batteries requires EMD as an input, and the use of manganese in these batteries is not covered by this report.

Secondary batteries are also known as rechargeable batteries. One particular type of secondary battery, the lithium-ion battery (also called Li-ion or LiB), has recorded an extraordinary growth in demand: production of these batteries since 2010 grew at a rate of 25% p.a. (CAGR). One of the applications for Li-ion batteries is the propulsion of electric vehicles (EVs). Demand for batteries for EVs is expected to grow at a CAGR of 25% between 2021 and 2031 and at a slightly slower rate (around 10% CAGR) for the period 2031-2041. The majority of chemistries using manganese for secondary battery production require HPMSM as the feedstock. A very small proportion (the LMO chemistry, <1% of battery market) needs manganese in the form of the EMD, but these are likely to be discontinued after 2025.

Battery cell makers have a choice of either buying HPEMM and processing it to HPMSM or HPMSS in-house or buying a ready-made HPMSM from third parties. The trend in recent years was to buy a ready-made HPMSM, 92.5% of which has been produced directly from the ore. In 2021 only 7.5% of HPMSM required by battery makers was made "through the metal route". The HPEMM market was static or declining, and ¾ of all HPEMM produced was sold to metallurgical clients. There are signs that this trend may be reversed in the future. Growing purity demands from cathode producers make the "via the metal route" of making HPMSM preferable. The 2/3rd transport cost savings when transporting HPEMM rather than the lighter HPMSM is another factor. Potential new M2CAM (Metal to Cathode Active Material) technology of making cathode powders directly from metal powders rather than sulphates could turn out to be a "game-changer" for the industry. These aspects of HPEMM demand are discussed in greater detail in Chapter 19-8 (Price Outlook).

Our forecast for manganese use in Li-ion batteries also includes other battery applications such as Energy Storage Systems (ESS) (grid-electricity storage, or renewable sources electricity storage) and consumer electronics. However, the demand from batteries for electric vehicles is likely to dominate the battery market and is expected to claim approximately 87% market share by 2025.

Figure 19-6: Li-ion Batteries by End Use (2018, 2025p, 2031p)



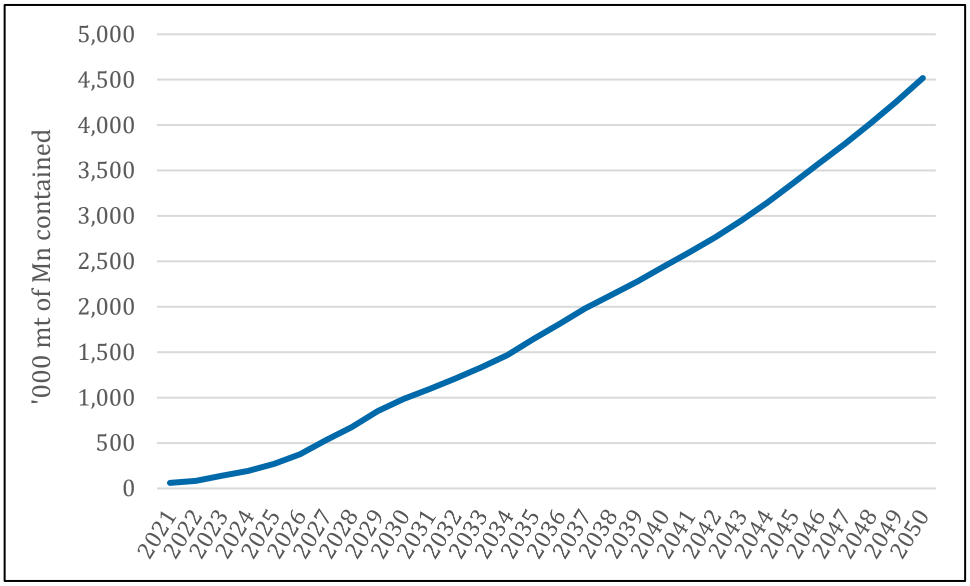
Source: E-Source, CPM

Manganese-based chemistries are likely to dominate the rechargeable battery market over the next 10-20 years, partially due to supply chain problems with cobalt, partially because of the technical merits of manganese as a battery metal, and partially due to the relatively much lower cost of manganese compared to cobalt and nickel. CPM Group and many battery experts like E-Source expect the demand for high purity manganese from the battery sector to grow nearly 30 times between 2021 and 2036, reaching 1.8 million t, i.e., the global production would need to rise 15 times to satisfy this demand. If the battery chemistry mix remains unchanged after 2035 and the demand for batteries grows 6-11% p.a., by 2050, the total demand for HP Mn from the battery industry could reach 4.5 million t. (For comparison, the 2021 global production of HP Mn was 130 kt).

It is crucial to understand that this demand can be satisfied by either HPEMM or HPMSM or, most likely, by a mix of the two products.

Figure 19-7: Manganese Demand from Li-ion Batteries to 2050 (kt)

(Thousand t NMC and LNMO battery chemistries only)



Source: E-Source, CPM
Chemistry mix shares frozen after 2031, stipulated growth beyond 2031 assumed at 11% to 6% p.a.

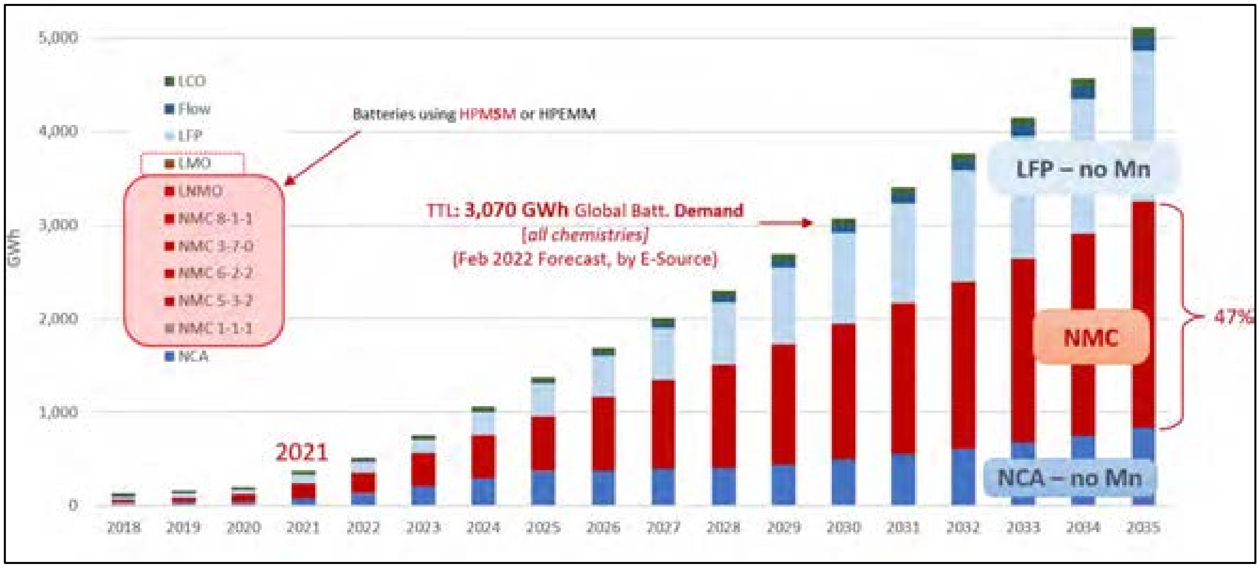
19.3.2 Battery Chemistries using HPEMM/HPMSM

At present, there are three groups of Li-ion battery chemistries that use high purity manganese for the production of their cathodes: LMO (Lithium Manganese Oxide), NMC (Lithium Nickel Manganese Cobalt), and LNMO Lithium Nickel Manganese Oxide). The LMO is a legacy battery chemistry accounting for only 0.25% of all rechargeable batteries market today and is expected to be phased out by 2025. This chemistry uses EMD as its manganese feedstock. The LNMO is a variation of the LMO chemistry and is sometimes confused with it. The crucial difference between the two is that the LNMO use HPMSM as its Mn feedstock. The production of batteries based on this chemistry is expected to grow rapidly – approximately 30 times between now and 2031, although they would still account for less than 1% of all Mn-using batteries. The LNMO is one of the most manganese-intensive battery chemistries requiring over 1 kg of Mn per kWh of battery capacity.

The NMC is currently the dominant Li-ion battery chemistry claiming approximately 44% of the rechargeable battery market (measured in kWh). It is likely to remain the dominant technology with approximately 47% - 50% of the market by 2031 and beyond.

The NMC chemistry is further subdivided into categories named after the proportion of the three metals used in the cathode: until recently, the dominant chemistry was NMC-111, in which Ni, Mn, and Co were used in equal parts (by weight). The mainstream NMC chemistries of today are NMC-622, NMC-532, while NMC-811 nicknamed 'the battery of the future', still needs some perfecting, although it is already produced on a commercial scale by some Chinese and European companies. NMC-811s promise longer-range EVs (500+ km on a single charge) but, at the same time, present many problems yet to be resolved (thermal instability and short cycle life, among others).

Figure 19-8: Global Battery Demand to 2035 by Chemistry (GWh)



Source: E-Source, CPM

One of the issues relating to the NMC chemistry is its use of cobalt. The vast majority of cobalt production, between 65% and 70% (and a large part of reserves and resources), comes from the Democratic Republic of Congo – a very unstable African country. Depending on the stage of the price cycle, the cobalt contained in the NMC-111 batteries can account for up to 80% of the cost of materials needed to make a cathode, despite being only 1/3rd of its weight. These two factors have driven the efforts of battery designers to 'engineer cobalt out' of batteries or at least significantly reduce its use. The new designs now in the mainstream, like NMC-622, NMC-532, or NMC-811, partially realize this goal. The lowest cobalt-containing designs yet are NMC-370 and NMC-271, announced in 2018 by the German chemical giant BASF (both types have expected cobalt usage <5% and manganese use of 75%). Chinese cell producers like SVOLT also developed cobalt-free batteries known as NMx. The first commercially available electric car with such a battery (Great Wall Ora Cherry Cat) was revealed in 2021. Its battery gave the vehicle a range of 600 km and didn't contain any cobalt, but instead it needed 95 kg of manganese in its cathode.

In 2020 and 2021, all major OEMs like Tesla, Volkswagen, Stellantis, Nissan-Mitsubishi-Renault, and others made announcements about developing their electrification strategies around manganese-based batteries. At the time of writing, there are approximately 30 battery chemistry variations in production or development which are using from 30% (Tesla) to 80% (BASF) of Mn in their cathodes. The "manganese intensity" of batteries currently in production is 370 g Mn/kWh. It is expected to grow to 678 g Mn/kWh by 2031 as a result of the shift to manganese described above.

The table below shows manganese use per kWh of battery capacity for the main battery chemistries. The figures include a 14% allowance for production process losses, which may or may not be recycled.

LFP (Lithium Iron Phosphate) batteries, the second-largest chemistry after NMCs (25% market share in 2021), do not use manganese at present, but this may be changing too. Several companies in China and in Europe are working on a variation of this chemistry known as LMFP (Lithium Manganese Iron Phosphate), in which up to 60% of iron is replaced by manganese. One Chinese cell maker is on the cusp of large-scale commercial production of such batteries. If all projected LFP production was replaced by LMFPs, this could further increase the demand for high purity manganese by 35% to 70% by 2031.

It is too early to say what percentage of LFPs may become LMFPs and what variation of this chemistry will become the new 'LFP mainstream'. For this reason, the demand forecast in this report assumes that LFPs do not use manganese.

Table 19-1: Manganese Use in Different Battery Chemistries

Gross Mn weight required for 1 kWh of battery capacity:

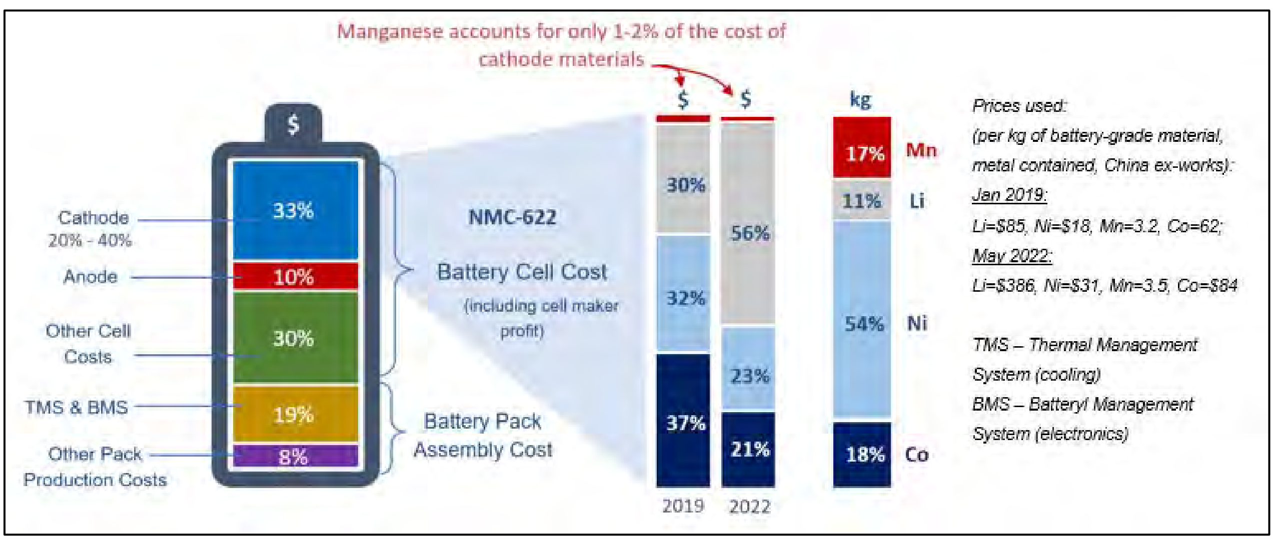
NMC-111: **0.565 kg** HPEMM, or	**1.737 kg** HPMSM
NMC-622: **0.311 kg**	**0.957 kg**
NMC-532: **0.483 kg**	**1.484 kg**
NMC-811: **0.151 kg**	**0.465 kg**
NMC-370: **1.179 kg**	**3.623 kg**
LNMO: **1.310 kg**	**4.025 kg**

Source: Cairn ERA, CPM
The above table allows for technological losses in conversion (up to 14%)

19.3.3 Manganese Price Insensitivity

Battery cells (consisting of cathode, anode, electrolyte, and a separator) are assembled together into modules and eventually into a battery pack, which is used in an electric car. Apart from battery cells, the pack contains a Battery Management System (electronics), a Thermal Management System (cooling), connecting wires, and a housing.

Figure 19-9: Cost and Weight of Cathode Materials in NMC-622 Battery Pack (2019, 2022)



Source: Cairn ERA, American Manganese Inc., Bloomberg, CPM Group

A single pack can contain several hundred to several thousand cells – in the case of Tesla Model S it is 7,104 cells (the whole pack weighs 540 kg). Depending on battery chemistry and the size of the pack, an electric car battery may need between 10 and 95 kg of manganese (more for trucks and buses). Because of the low price of manganese (~$3.0/kg) and the high value of the pack ($13,500+ for a 57-kWh pack) the demand for manganese from the battery industry is relatively insensitive to the price of manganese inputs.

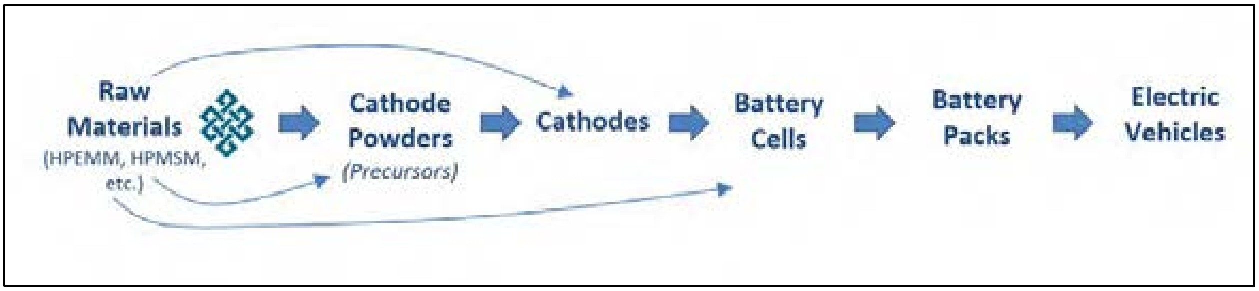
In an example shown in Figure 19-9, cathode materials' cost proportions changed significantly between January 2019 and May 2022, mainly as a result of skyrocketing prices of lithium carbonate and nickel. Manganese, however, remained stable: it accounted for 2% of the cathode cost in 2019 and 1% in 2022. This price stability (in comparison to other battery metals) and the fact that manganese mining is not monopolized by any particular country (like in the case of cobalt) makes it very unlikely that battery designers would have any reasons to try to "engineer manganese out of the batteries".

19.4 The Battery Industry

19.4.1 Global Battery Industry

The lithium-ion battery industry has its own structure and supply chain with many specialized manufacturers, as shown in the diagram below. A prospective producer of HPEMM and/or HPMSM, such as EMN, is positioned at the beginning of the chain as a supplier to the makers of precursor materials that are used in making cathodes. EMN can sell its products to different manufacturers depending on the level of supply chain integration by the various battery and EV manufacturers (Figure 19-10): some make just cathode powders or cathodes, and others (e.g., Tesla) have many stages of battery production within their manufacturing operations. The ultimate product is a battery pack sold to or made by an EV manufacturer.

Figure 19-10: Potential Users of EMN's Products



The umbrella term 'battery factories' is often used in a broad sense and can refer to manufacturers of cathode materials, battery cells, and/or battery packs. The capacity of batteries is measured in kilowatt-hours (kWh), and subsequently, the production capacities of battery factories are measured in megawatt-hours (MWh) or gigawatt-hours (GWh) or terawatt hours[5] (TWh).

Until 2018 China, Japan, and Korea accounted for almost 90% of the world's Li-ion battery cell production. Ramping up of production in the Tesla 'Gigafactory' in Nevada has brought the USA into second place, while Europe barely registered as a battery-making region. Since then, a lot has changed, and today (June 2022), Europe has 18 operating rechargeable battery factories, 7 of which are known as "gigafactories," i.e., factories with an annual production capacity greater than 1 GWh. Despite the efforts of Europe and North America (five operating plants in 2021), China still dominates battery cell production accounting for approximately 70% of global capacity.

[5] 1 TWh = 1,000 GWh = 1,000,000 MWh = 1,000,000,000 kWh

Globally, no fewer than 304 gigafactories are expected to be in operation by 2031. Their total installed capacity (according to the announcements) is to exceed 6.4 TWh – enough to power 128 million electric cars annually. Some analysts say this is already an overcapacity not justified by the expected battery demand growth. Others, like Elon Musk, the boss of Tesla, have a grander vision and claim that for full transport electrification the world needs 300 TWh of battery production capacity (but not necessarily by 2031).

The high purity manganese demand projections in this report are based on an assumption that the global demand for Li-ion batteries by 2031 will be 3.0 TWh (see Figure 19-8).

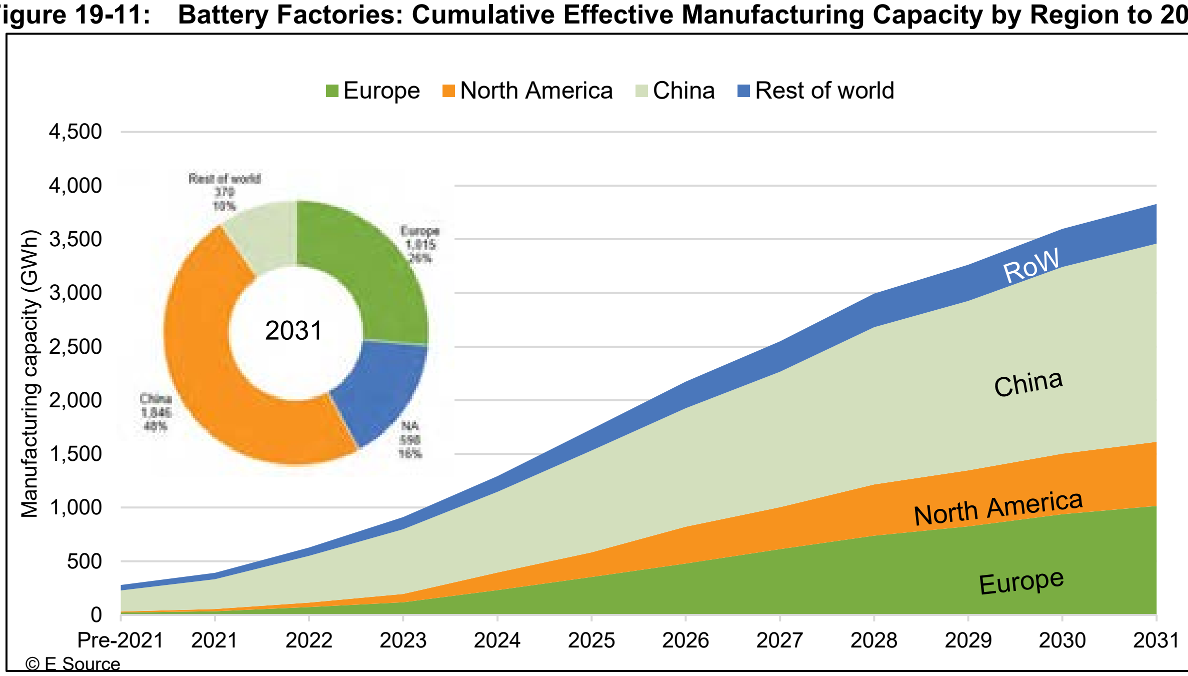
19.4.2 Battery Industry in Europe

The European Union has been slow to realize the economic potential of EVs, although it has been long aware of the necessity to combat climate change. It is now rapidly catching up.

Currently, there are 18 operating rechargeable battery factories in Europe, 7 of which are known as gigafactories. Their combined capacity is 62 GWh, which gives Europe an 8% share in the global market. European Li-ion cell production capacity should increase tenfold by 2025, with 25 gigafactories operational by that year. This translates into a total annual production capacity of around 591 GWh already in 2025.

By 2031, Europe could have as many as 56 battery cell factories, at least 8 battery pack assembly plants, 6 precursor and cathode active material plants, and 5 battery part plants (separator, electrolyte, etc.). The total announced capacity of these cell plants could be as high as 1,458 GWh, but not all may reach the nameplate capacity on time, and some may not be built or built smaller than originally planned. For this reason, E-Source and CPM Group use the measure of "effective manufacturing capacity", which takes into account possible delays, ramp-up times, and does not count doubtful projects. By this measure, Europe could have 1,015 GWh worth of battery factories by 2031, which would give the continent 26% of the world market.

Figure 19-11: Battery Factories: Cumulative Effective Manufacturing Capacity by Region to 2031



TETRA TECH

Gigafactory capacity could equate to the cathode materials demand, but in reality, no industrial plant runs at 100% capacity, so the actual demand would be lower. CPM and E-Source adopted a more conservative approach when calculating HP Mn demand from the battery sector and took into account production plans of vehicle manufacturers (and other battery customers) with corrective factors rather than the gigafactory capacity.

The Euro Manganese's Chvaletice Manganese Project, located in the Czech Republic, lies in the heart of the European battery and EV ecosystem. Our market research indicates that the growing lithium-battery sector in Europe can easily consume the entire planned output of the Chvaletice project.

A map of the most important European battery factories and a more complete table of cell factories expected to come on stream before 2031 are shown in Table 19-2 below.

Table 19-2: Major Li-ion Battery and Precursor Plants in Europe expected by 2031

No.	Company	Announced Capacity (GWh)	Likely Capacity by 2030 (GWh)	Dominant Chemistry	Location	Country
Battery Cell Plants						
1	Akasol	0.8	0.3	--	Langen n/Frankfurt	Germany
2	Akasol	5	5	--	Darmstadt n/Frankfurt Gigafactory 1	Germany
3	AMTE Power / BritishVolt	35	28	--	Blyth, England	United Kingdom
4	AMTE Power	35	5	NCA, NMC	Thurso, Scotland & Coventry, England	United Kingdom
5	Automotive Cell Company (SAFT/Stellantis)	24	34	--	Termoli	Italy
6	Automotive Cell Company (SAFT/Stellantis)	24	30	NMC	Douvrin, Hauts-de-France	France
7	Automotive Cell Company (SAFT/Stellantis)	24	25	NMC	Kaiserslautern	Germany
8	Blackstone Resources	2	0	--	Braunschweig or Eisenach	Germany
9	BasqueVolt/Nabatt	10	2	--	n/ Bilbao	Spain
10	Beyonder	20	10	--	Rogalan	Norway
11	BMZ / TerraE & others	34	2	--	Karlstein n/Frankfurt	Germany
12	Bollore	0.5	0.5	--	Ergue-Gaberic	France
13	BYD	34	0	--	?	?
14	CATL	100	59	NMC	Erfurt (Arnstadt)	Germany

No.	Company	Announced Capacity (GWh)	Likely Capacity by 2030 (GWh)	Dominant Chemistry	Location	Country
Battery Cell Plants						
15	Custom Cells	1	1	--	Itzehoe	Germany
						table continues…
16	ElevenEs / Al Pack	16	8	LFP	Subotica	Serbia
17	Envision AESC	2.5	2.5	NMC	Sunderland, England	United Kingdom
18	Envision AESC	35	29	NMC	Sunderland II	United Kingdom
19	Envision AESC (w/ Renault)	24	20	NMC	Douai	France
20	Farasis Energy	16	6	NMC	Bitterfeld-Wolfen	Germany
21	FREYR	40	25	NMC	Mo i Rana	Norway
22	GS Yuasa	?	--	NMC	Miskolc	Hungary
23	Innolith	10	1	--	Basel	Switzerland
24	Inobat	10	39.1	NMC	Voderady, Bratislava	Slovakia
25	Italvolt	70	30	--	Scarmango n/Turin	Italy
No.	Company	Announced Capacity (GWh)	Likely Capacity by 2030 (GWh)	Dominant Chemistry	Location	Country
26	Leclanche	2.3	2	NMC	Willstätt	Germany
27	Leclanche	1	1		Yverdon-les-Baines	Switzerland
28	LG Energy Solution (LG Chem)	70	70	NMC	Kobierzyce n/Wroclaw	Poland
29	Liacon	0.3	0.3	--	Ottendorf-Okrilla, n/Dresden	Germany
30	Liacon	1	1	--	Itzehoe	Germany
31	Listrom	30	0	--	North Rhine-Westphalia	Germany
32	Lithops / FAAM	15	2	LFP, NMC	Teverola, Napoli	Italy
33	Mercedes	1	2	--	?	Germany
34	MES (Magna Energy Storage)	20	10	--	Horni Sucha	Czech Republic
35	Microvast	12	0	NMC, LTO	Ludwigsfelde, (Brandenburg)	Germany

No.	Company	Announced Capacity (GWh)	Likely Capacity by 2030 (GWh)	Dominant Chemistry	Location	Country
Battery Cell Plants						
36	Morrow Batteries	32	25	NMC	Arendal	Norway

table continues…

No.	Company	Announced Capacity (GWh)	Likely Capacity by 2030 (GWh)	Dominant Chemistry	Location	Country
37	Northvolt 1	40	34	NMC, LNMO	Skelleftea	Sweden
38	Northvolt Volvo	50	20	--	Gothenburg	Sweden
39	Panasonic	5	5	NMC	?	Norway
40	SAFT	2	2	--	Bagnolet	France
41	Samsung SDI	20	10.5	--	Göd Plant 1	Hungary
42	Samsung SDI	7.5	27	--	Göd Plant 1	Hungary
43	SEAT / Iberdola	3	3	--	Barcelona	Spain
44	SK innovation	7.5	7.5	NMC	Komárom Plant 1	Hungary
45	SK innovation	16	25	NMC	Komárom Plant 2	Hungary
46	SK innovation	30	30	NMC	Iváncsa Plant 3	Hungary
47	Sunlight	1	0.5		Xanthi	Greece
48	SVOLT	24	5	NMC, LNMO	Überherrn, Saarland	Germany
49	Tesla	250	150	NCA	Grünheide	Germany
50	VARTA	10	10	--	Ellwangen	Germany
51	Verkor	50	31	--	Dunkerque	France
52	Volkswagen Group	40	24	LFP	Salzgitter (formerly Northvolt 2)	Germany
53	Volkswagen Group	40	60	--	Sagunt	Spain
54	Volkswagen Group	40	40	--	(Poland, Slovakia, or Czech Rep)	Poland
55	Volkswagen Group	40	40	--	--	Germany
56	TOGG/Farasis	25	25	NMC	Gemlik n/Bursa	Turkey

table continues…

No.	Company	Announced Capacity (GWh)	Location	Country
Precursors and Cathode Materials				
1	BASF	15	Harjavalta (Cathode Active Materials)	Finland
2	Norilsk Nickel	--	Harjavalta (Co & Ni Precursors)	Finland
3	BASF	--	Schwarzheide (Cathode Active Materials)	Germany
4	Terrafame	--	Sotkamo (Co & Ni Precursors)	Finland
5	Umicore	--	Kokkola (Co Precursors)	Finland
6	Umicore	30	Nysa (Cathode Active Materials)	Poland
7	EcoPro BM	--	Debrecen (cathodes)	Hungary

Sources: E-Source, company announcements, industry sources, CPM Group
Note: * NCA = lithium nickel cobalt aluminium oxides

As Table 19-2 above and Figure 19-12 below show, local supply chains are being built in Europe. Apart from the convenient logistics, companies within the European single market benefit from frictionless trading and strong support from the European Commission and national governments. The European Battery Alliance is a powerful body created by the EU to ensure that the EV industry in Europe secures all the regulatory approvals and funding required.

More than 260 European companies and research centres work in affiliation with the European Battery Alliance. The Chvaletice Project is at the centre of all this activity.

The Chvaletice Manganese Project is a very significant manganese deposit and currently stands to become the only primary producer of high purity manganese products for the battery industry within the European Union. We are unaware of any other known manganese production initiatives in the EU. This makes Chvaletice of significant potential strategic importance in the context of the creation of a European battery raw materials supply chain.

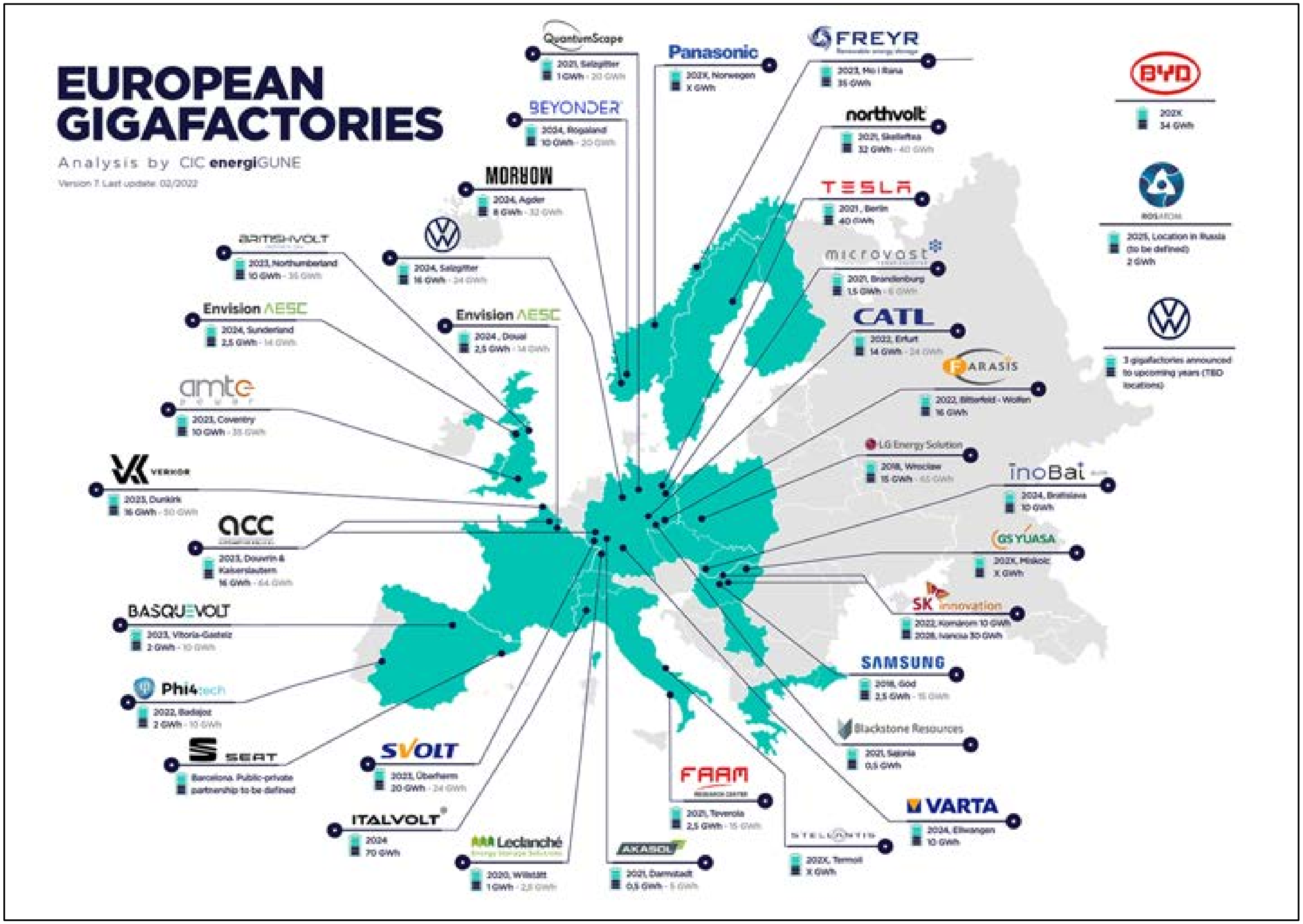
Using the figure of 1,025 GWh of European “effective capacity” from Table 19-2 above (in 2030) and assuming that 60% of batteries made in Europe will contain manganese,[6] there is likely to be 615 GWh of “Mn-bearing battery production capacity” in Europe. Making a further assumption about the capacity utilization rate of these factories at 70% and an average “manganese intensity” of 680 g/kWh, we can calculate the expected demand for high purity manganese from European battery makers to be 293 kt of HP Mn (metal units) in 2030.

The only European producer of battery-grade HP Mn at present is Prince Inc, with its plant in Belgium, which imports ore from Africa. Its maximum capacity is 3 kt of HP Mn (in metal units, assuming a 90% capacity utilization rate). Euro Manganese’s Chvaletice plant can add 48 kt when its starts production, bringing the total HP Mn supply from within Europe to 51 kt – a 17% of the expected European demand calculated above. Even if there are forecasting

[6] This is higher that the 47% expected global share on Mn-using batteries, but European battery makers tend to produce more NMCs than LFPs or NCAs.

errors on the demand side, it is clear that the European requirements for HP Mn are several times higher than the production capacity of the Chvaletice plant.

Figure 19-12: Most important Li-ion Battery Factories in Europe (2031)



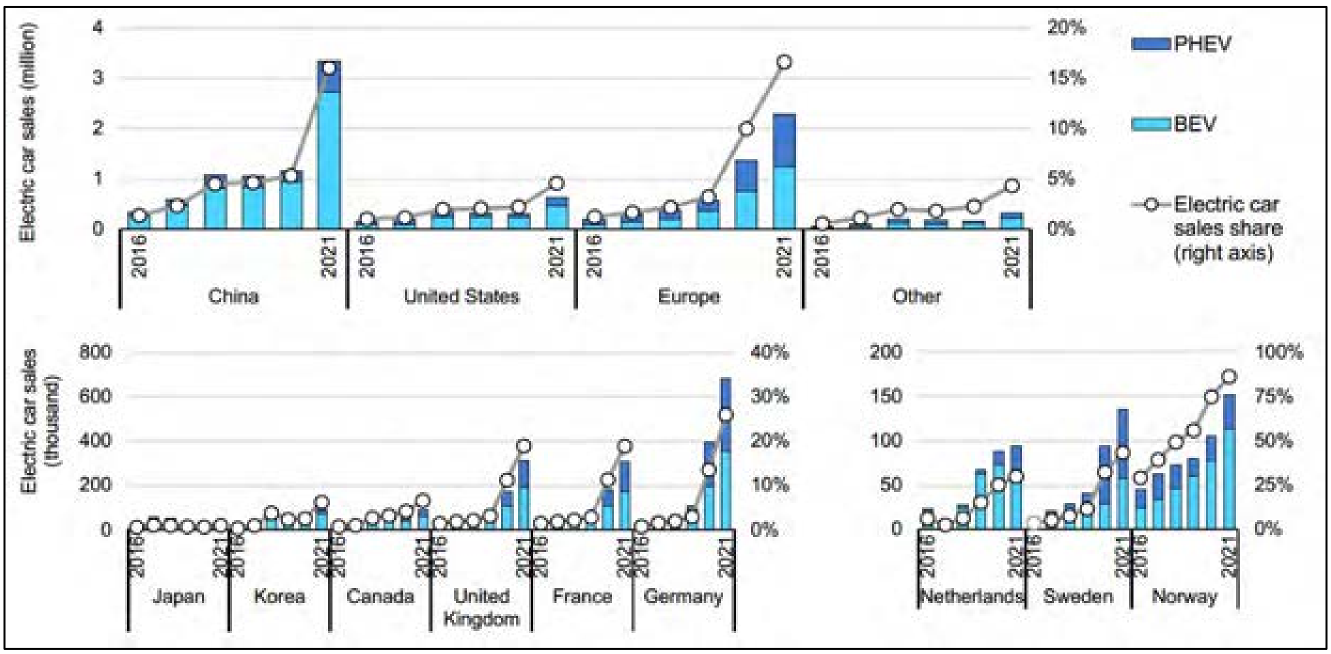
Source: CPM, June 2022

19.5 Electric Vehicles Market

According to battery industry forecasts, electric vehicles will generate 87% of rechargeable battery demand as soon as 2025. This share makes electric cars a key driver of demand for cathode materials, including manganese. The rapid growth of battery 'Gigafactories' in China, Korea, Japan, the USA, and Europe is a testimony to the healthy and growing EV market. Statistics of EV sales confirm it.

At the end of 2018, there were 4 million vehicles on the world's roads. It took more than eight years to build up this vehicle stock. At the time of writing this report (June 2022), there are 20 million – a 5-fold increase in just 3.5 years. The latest edition of "Global Electric Vehicle Outlook 2022", published by the International Energy Agency in May 2022, envisages a 10-fold increase of the current figure by 2030 – a 198 million vehicle stock, including 174.8 million cars, 17.4 million vans, 3.0 million buses, and 2.8 million trucks.

Figure 19-13: Electric Car Registrations and Sales Share (2016 – 2021)



Source: International Energy Agency, May 2022

Sales of electric cars reached another record high in 2021 despite the COVID-19 pandemic and supply chain challenges, including semiconductor chip shortages. Looking back, approximately 120,000 electric cars were sold worldwide in 2012. In 2021, that many were sold in a week.

After increasing in 2020 despite a depressed car market, sales of electric cars – battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) – nearly doubled year on year to 6.6 million in 2021. As in previous years, BEVs accounted for most of the increase (approximately 70%). This matters to the HP manganese demand, as battery packs for BEVs are typically three to nine times bigger than for PHEVs.

Electric car sales accounted for 9% of the global car market in 2021 – four times their market share in 2019. All the net growth in global car sales in 2021 (of any propulsion) came from electric cars. Sales were highest in China, where they tripled relative to 2020 to 3.3 million after several years of relative stagnation, and in Europe, where they increased by two-thirds year-on-year to 2.3 million. More electric cars were sold in China in 2021 (3.3 million) than in the entire world in 2020 (3.0 million). Together, China and Europe accounted for more than 85% of global electric car sales in 2021, followed by the United States (10%), where they more than doubled from 2020 to reach 630,000.

The so-called "penetration rate"[7] also increased. In China from 11% in 2020 to 16% in 2021 (reaching 20% in December 2021), and in Europe it reached 17% for the year. European monthly sales were highest in the last quarter of 2021, when electric cars sales reached a 27% market share and surpassed diesel vehicles for the first time. While the high penetration rates of countries like Norway (86%) and Iceland (72%) could be dismissed because of the small size of their markets, the double-digit rates in China (16%), Germany (25%), or France (19%) testify to the growing maturity of the EV markets in these countries.

The increased sales were recorded against the backdrop of the relative fall of government subsidies for EVs. Although government spending, such as through purchase subsidies and tax waivers, doubled to nearly US$30 billion globally, its share of total EV spending declined to 10% from approximately 20% only five years ago. Consumer spending doubled to almost US$250 billion, approximately eight times what was spent five years ago.

In Europe, government spending on the EV industry in 2021 increased to US$12.5 billion, a four-fold growth since 2019 but with the increased sales, a subsidy per vehicle remained flat in the range of US$5,000 – $6,000 over 2019-2021 period. The same measure in China decreased from US$5,000 to US$3,750, and in the USA, from US$4,500 to US$3,200.

Globally, there were over 450 electric car models available in 2021, an increase of more than 15% relative to 2020 offerings and more than twice the number of models available in 2018. The driving range is increasing as well. It averaged 350 km across all models sold in 2021, with premium models offering 600+ km on a single charge.

Looking into the future, the IEA's base case (the so-called STEP scenario) projects 2030 annual EV sales reaching 25.5 million units, 86% of which will be cars, and the remaining 14% vans, trucks, and buses.

19.6 Energy Storage Systems

Electric vehicles are not the only application driving the demand for Li-ion batteries. Consumer electronics demand continues to grow, but at a much slower pace; but a sector which seems to have a double-digit growth potential is known as Energy Storage Systems (ESS).

Batteries in ESS are used to store grid energy generated at times of low demand to be used later, during peak times, or to store electricity generated by renewable generators (like wind and solar) to be used when the sun is not shining or wind is not blowing. Peak shifting (which accounts for the vast majority of battery usage on the grid) is gravitating towards Li-ion because of its small footprint, low maintenance, high efficiency, and long life. The negatives of Li-ion are its high price and the requirement of a thermal management system in certain regions. Lithium batteries also have other advantages: production is becoming ubiquitous (because of the EV revolution), costs are declining, and in 5-8 years' time, there will be a surplus supply of used-EV batteries with decreased capacity[8] (due to aging/cycle life) that can be used for grid storage.

[7] Penetration rate = sales of electric vehicles as a percentage of total vehicle sales in a given year.
[8] EV batteries need replacement when they can't hold more than 80% of their original nameplate capacity.

According to the battery demand forecasts by E-Source (see Figure 19-6), the share of battery demand from ESS will grow from the current 4% of the battery market to 13% in 2031.

Historically, ESS installation used the same NMC batteries as the ones used in EVs, but they are not ideal for the demands of the electricity grid. A much more suitable alternative are so-called “flow batteries”. Vanadium Redox Flow Battery (VRB) uses a liquid electrolyte which flows across the electrodes via mechanical pumps. The need for the pumps and electrolyte tanks makes them large (building size) and only suitable for stationary applications where size and weight are not an issue. VRB technology is still considered by many as ‘in development’ despite the growing production capacity for vanadium batteries, estimated to be approximately 400 MWh. Most of this capacity is in China (83%). Flow batteries are expected to grow rapidly at a CAGR of 87% over the next 10 years, but they are likely to account for only ~20% of ESS storage by 2031.

ESS installations are more common now than several years ago, and they have also grown in size. When in December 2017, Tesla completed its ‘largest in the world’ ESS installation in Australia called Hornesdale, its combined battery storage capacity was 129 MWh. Today (2022), the largest battery-based ESS installation is in Moss Landing in California. Its batteries will eventually be able to store 1,600 MWh of energy (equivalent to 32,000 EVs). Phase 1 (1,200 MWh) was commissioned in 2020.

The battery chemistry of choice for ESS in 2022 is the LFP. These batteries offer greater safety, lower cost, and higher durability than nickel manganese cobalt chemistries, which dominate the EV market. Their lack of reliance on cobalt and nickel is also favourable from the perspective of critical minerals. What is more, the new LMFP chemistries (with manganese) currently under development are not suitable for ESS. It is expected that by 2031 NMC chemistries will account for only 10% of the ESS battery demand.

Given the above, CPM doesn’t see the ESS as a key driver for high purity manganese demand.

The energy storage market is expected to be worth US$35 billion by 2031. The top providers of ESS solutions are the well-known battery makers, including LG Chem, Samsung SDI, BYD, Panasonic, Kokam, Toshiba, Saft, Leclanché, Electrovaya, and CATL.

19.7 HP Mn Supply-Demand Balance

The HPEMM and HPMSM markets are going to be radically transformed over the coming decades as a result of the ‘electric vehicle revolution’. Most, but not all, of the lithium-ion batteries that power electric vehicles are expected to use manganese in their cathodes, and these manganese-intensive types of battery chemistries are likely to dominate the battery market for the next two decades.

As a result, the demand for high purity manganese is likely to increase 13 times between 2021 and 2031 (from 90 kt to 1.1 million t of Mn contained) and 50 times between 2021 and 2050 (to 4.5 million t).

In the case of the rechargeable battery industry, it is an “either/or” scenario between HPEMM and HPMSM. At present, HPMSM produced directly from ore dominates as a feedstock for batteries – 92.5% of demand from batteries is satisfied by this product. In the future, the role of HPEMM as a feedstock may increase, as discussed elsewhere in this report. Because of the “fluid nature” of this demand (either sulphate or metal), we discuss it as “HP Mn” and express it in metal units (metric t of HPEMM equivalent).

Such a massive demand increase requires a supply response, but the currently known expansions and new projects do not come anywhere near to satisfying this demand. What is unknown is what other market entrants and capacities may appear 15 to 20 years down the line. It is also worth remembering that the electric vehicle market is still a nascent industry, and technologies may change (to less or more manganese-intensive cathode chemistries). This, however, is not as likely in the next 10-15 years, as having made their investments, automotive and battery companies will want the return on their capital and are unlikely to make radical changes to their plants and technologies lightly.

It is important to understand how manganese is used in rechargeable batteries. The product battery makers need is an HPMSS, the soluble form of HPMSM (powder). Some cathode makers buy HPEMM (metal) to make HPMSS in-house or buy HPMSM to make the solution. The reasons for this approach are partially technological (to retain full control of the purity of the MSM) and partially commercial (there are not many reliable HPMSM suppliers capable of satisfying the very stringent purity requirements of battery makers, particularly those producing or proposing to produce batteries with lower cobalt or higher nickel content).

CPM's assessment of the industry indicates that there are very few large-capacity HPEMM projects planned at the moment, but it is difficult to say what projects might appear in 15 or 20 years' time. There are currently six non-Chinese HP Mn projects which are likely to come on stream before 2030. These projects are shown in Table 19-3. The Tsingshan project is in Indonesia, but owned by a Chinese steel maker.

Table 19-3: HP Mn Project Pipeline

	Company	Annual capacity ktpy	Comments (capacities in metal units)
1	China – announced expansions and new capacity	32+37	Expansion: 3 existing producers, 4 sites. New-builds: 4+1 new entrants.*
2	Euro Manganese, Czech Rep.	48	The only European project in the pipeline. 48 ktpy of HPEMM from 2026-27, of which 2/3 will be converted to HPMSM onsite. The only new producer of HPEMM.
3	Prince Inc., USA (expansion)	5+10	The only non-Chinese HPMSM producer with a 10 ktpy plant in Belgium. Plans additional production in two phases, both in Mexico (Tampico plant).
4	Tsingshan, Indonesia	10	Production aimed at the Chinese market. Expected to start in 2022.
6	Manganese Metal Company, South Africa	10	The only non-Chinese HPEMM producer with a 28 ktpy capacity. HPMSM demo plant expected in 2023. Full production from 2026 subject to finance.
6	Giyani Metals, Botswana	33	Demo plant expected in 2022. Full production from 2025-26 subj. to finance.
7	Element 25, Australia	(13?)	Started producing Mn ore in 2021. Feasibility Study for HPMSM planned for 2022-23. Production 2025-26?
8	Manganese-X, Canada	23	The only North American HPMSM project in the pipeline. Pre-Feasibility stage.
-	**TOTAL**	**221**	--

Note: * See notes in the text about the Ningxia TMI Project in China.

These projects add up to 221 ktpy of new supply of HP Mn. When added to the current declared (but not fully utilized) production capacity of max 180 ktpy, they bring the total capacity available in 2031 to 401 ktpy of metal contained. Meanwhile, 2031 projected HP Mn demand from the battery sector alone stands at 1,094 ktpy (1,127 ktpy when metallurgical uses are included). This creates a supply deficit of 726 kt.

The big difficult-to-answer question is what other projects might appear before 2031 which are not currently on the radar screen of market analysts. CPM has considered several projects less likely to achieve production before 2031 and, giving them the benefit of the doubt, included their potential output in the supply-demand balance calculations.

These projects included: South 32's Hermosa Project in Arizona (unannounced, but likely); Mn Energy's project in Australia (announced, but stalled); Firebird Metals in Australia (intention announced, but too early stage in CPM's view to be able to produce before 2031); Canadian Manganese Company (unlisted entity with an early-stage, low-grade project in New Brunswick).

CPM also considered new HP Mn supply from recycling old EV batteries. Assuming 50% recycling rate and 100% Mn recovery (unlikely), this supply stream could satisfy 6% of 2031 HP Mn demand.

With all the above supply corrections, the 2031 deficit comes down from 726 kt to 475 kt. If battery demand continues to grow as expected and no new projects come to the market, the deficit would increase to one million t by 2037. If this deficit is to be reduced to zero, the HP Mn industry would have to increase its capacity 11-fold (and produce at a close-to-100% utilization rate).

The question often asked is if China can rapidly increase its HP Mn capacity and bring the deficit down or even turn it into a surplus. The country has a track record of quickly developing projects and increasing production by up to 100% in a single year. But it also has a record of overoptimistic announcements and broken promises (usually resulting from the lack of finance). At the beginning of 2019, Chinese announcements regarding HPMSM capacity "in the next few years" added up to 920 ktpy. Three years later, at the beginning of 2022, the self-declared Chinese capacity stands at 356 ktpy of HPMSM, and the actual production at 270 kt. An underwhelming result compared to the 920 ktpy promise.

One of the most hotly discussed new Chinese projects is an HPMSM plant being built by TMI in the Ningxia province. TMI, a private company, is the largest global producer of 'standard quality' EMM (800 ktpy capacity) and a significant producer of Mn and Cr ferroalloys. Its "largest in the world" silicomanganese plant is close to completion.

TMI's plans to build a large (300 ktpy) HP Mn sulphate plant have been known for at least six years, but the plans kept changing; originally, the start of production was set for 2019, then for 2024, and then the project was shelved until such time "when the market conditions are right". When CPM Group visited the company in September 2019, the plant site was just an empty field. Industry insiders reported a lack of funding as the main reason for the postponement. The latest information from China is that the TMI's sulphate plant is under construction and may start production as early as 2023. Apart from this very ambitious schedule, the most hotly debated issue among industry observers is whether the final product of the plant can be called an "HP" sulphate. TMI intends to use its own 99.7% Mn 'standard quality' EMM as a feedstock. This product is made using selenium, which cannot be present in battery-grade sulphate. According to sources close to the company, it intends to hand-select EMM batches with the lowest possible selenium (~300 ppm) and, after applying various purification techniques, achieve 50-80 ppm of selenium in the sulphate. Environmental and heath and safety issues aside, such a product cannot be called "high purity sulphate" under the battery-grade specifications of the Chinese standard HG-T 4823-2015. The company says the product is intended for the domestic market, and it will have buyers for it. No European, American, Korean, or Japanese battery maker would buy such a product, as they expect no selenium in the sulphate (some will tolerate 3-5 ppm, but not 50-80 ppm).

The above poses a problem for market analysts: 1) should the potential production from the new TMI plant be taken into account in the supply-demand outlook for "true" HPMSM?; and 2) should any prices reported by the company be used in comparisons with the "selenium-free" product? In CPM's view, the answer to both questions is "no". The

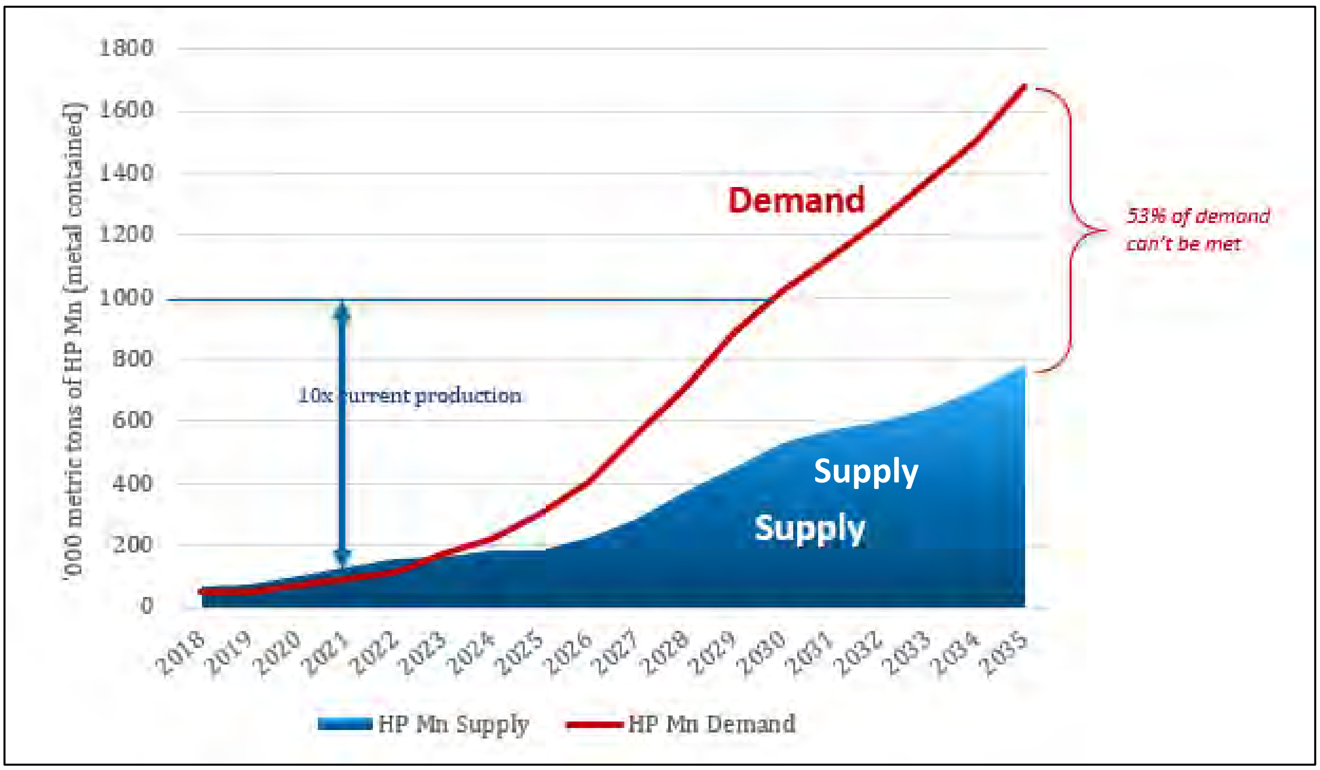
TMI project is not shown in Table 19-3, however, it was taken into account in the long-term supply-demand calculations to 2050.

The production-limiting factor in China may turn out to be the lack of good quality feedstock – Chinese domestic carbonate ores grade only 13% on average, and their purification to HPMSM comes at a great environmental and financial cost. The alternative – imported ore of higher grade – comes with its own set of problems: higher ore cost, higher transport cost (both international and domestic), and the need for calcination of imported oxide ores (cost of extra energy and the need for additional technical facilities).

The global supply-demand balance as projected by CPM Group is shown in Figure 19-14.

Figure 19-14: High Purity Manganese Demand to 2035

(in metal unts, includes HPEMM and HPMSM)



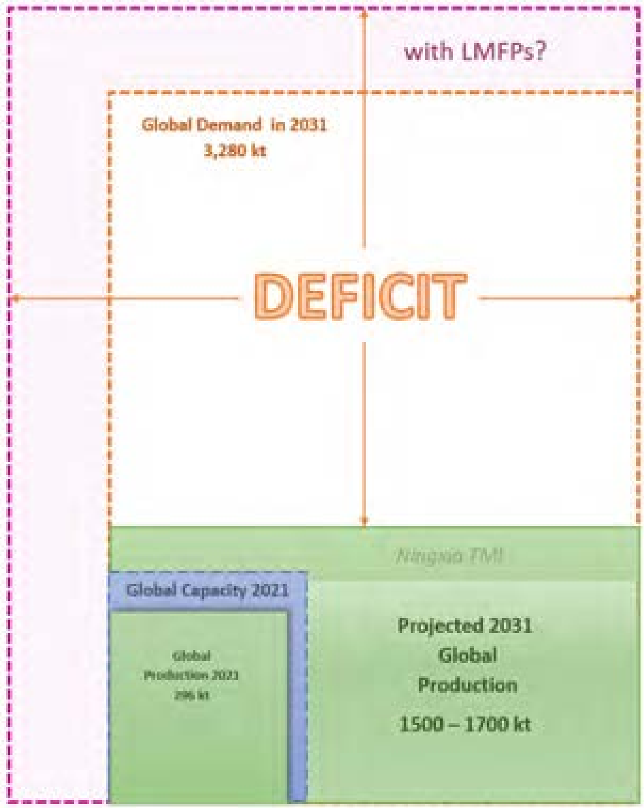
Source: E-Source, CPM Group

Figure 19-14 shows the supply and demand for HP Mn to 2035. It is likely that by then, new entrants will bring more supplies to the market, changing the market balance, but at this stage, it is impossible to say who they might be, where they are likely to be located, and how much production capacity they might add.

2035 is the year when many countries are planning bans on sales of new internal combustion engine vehicles, so we might expect a surge in demand for batteries around then, but even assuming a moderate demand growth of demand of 6%-10% p.a., by 2040 the HP Mn demand could reach 2.5 million t, and by 2050 4.5 million t (assuming no major changes in the battery chemistries mix after 2031).

At present, the key manganese feedstock for cathode powder production is HPMSM. Future technologies, like the M2CAM from Nano One, may increase the use of HPEMM, but sulphate is likely to remain the main tradeable product even then. The area chart in Figure 19-15 is a visual representation of the supply and demand situation in the HPMSM market in 2031. The chart also shows a potential new additional demand from the use of manganese in LMFP batteries. Because there is currently no large-scale commercial production of LMFPs, and it is still unclear which of the manganese variations of LFP chemistry could become mainstream, this portion of the demand was not taken into account in the rest of this report.

Figure 19-15: Supply-Demand Balance of HPMSM in 2031



Source: E-Source, IMnI, industry sources, CPM Group

Such significant deficit is very likely to have serious impact on prices of battery-grade high purity manganese products.

19.8 HPEMM and HPMSM Price Outlook

19.8.1 CPM Price Projection Assumptions

The base price modelled in this forecast is the HPMSM price "Ex Warehouse China". We subsequently add various modifying factors (cost of freight, different premiums) to arrive at the European price and a North American price, which are then plotted and shown in tables. The European price is assumed to be on a DDP basis (Delivered, Duty Paid), i.e., at the gate of a cathode plant. Berlin was used as a proxy for numerous Central and Eastern European locations of battery factories.

In the case of North America, DDP Detroit price was used, as the most active cluster of battery factories is being created around that city (both in the USA and Canada).

The following assumptions and comments should be noticed:

- We expect HPMSM prices to remain at elevated levels as a result of the developing deficit. As we commented in our previous forecasts, the prices of 'standard quality' EMM (product for the metallurgical industry, 99.7% Mn) and both the high purity product HPMSM (chemical product for batteries) and HPEMM (metallurgical and battery applications) seem to be more and more divergent. As expected, 'standard' EMM prices came off their peak of $7,750/mt in October 2021, and this product is now trading in Europe at around $2,800/mt. In contrast, HPMSM prices have been growing continuously for most of 2021 and Q1/2022, coming off their all-time highs only in May 2022 (as a result of the two-month COVID-19 lockdowns in China).
- CPM's economic forecast foresees a global recession around 2024-2025, when demand and prices may dip; however, the previous economic downturn caused by the COVID-19 epidemic was weathered well by the battery industry, and we expect the 2025 recession to have a smaller impact on EVs and batteries than on other sectors.
- Many countries in key automotive markets announced their intentions to ban sales of new internal combustion engine (ICE) vehicles around 2035. If these policies are implemented, we are likely to see a "scramble for batteries" from the car makers as they try to make up for the loss of sales of ICE vehicles with increased production of EVs. This may result in a spike in battery metals prices around 2035, including HPMSM and HPEMM.
- The project pipeline to 2030 is very thin. In CPM's opinion, only six non-Chinese HPMSM projects have a chance to come on stream before 2030: Euro Manganese, MMC, Giyani Metals, Element 25, Manganese-X, and Prince's expansion in Mexico. With all their production taken into account, we still see a significant supply gap, even assuming a 300% rise in Chinese production.
- Forecasting the supply-demand situation further in the future and in particular after 2035, is naturally less certain. New (as yet unknown) producers may come to the market, and the progress in battery technology may start changing the chemistries mix and the Mn demand patterns. Battery production may also be restricted by shortages of other battery materials like lithium, Class 1 nickel, and cobalt. To account for this uncertainty and these, as yet unknown producers, we stopped increasing the forecast prices between 2035 and 2040 and assumed they may fall (in real terms) after 2040 with more producers bringing more supply to the continually growing market forecast. The HP Mn deficit may reduce, and the market may come close to equilibrium.
- CPM believes that the position of manganese-based batteries is safe for the next 10-15 years, with higher uncertainty levels afterwards. The uncertainty doesn't necessarily mean lower demand for Mn – we may see an increase in demand if manganese-rich chemistries continue to be commercialized and if manganese finds its way to other chemistries, like LFP, which are currently Mn-free, but several battery makers work on improving their performance by adding manganese. The use of Mn in LFP batteries can potentially boost the demand for HP Mn by an additional 35% - 70% according to CPM's calculations.
- CPM's price forecast reflects the impending significant supply deficit in the HPMSM market and the differentiation between Chinese, European, and North American prices.

19.8.2 HPMSM Prices in China

Prices set in bilateral agreements between the sellers and the buyers of HPMSM are to a large extent, divorced from prices of other manganese products. The latter follows the behaviour of metals markets (the steel market in particular). The former belongs firmly in the chemicals markets. The fact that both contain manganese is almost incidental.

Table 19-4: Chinese High Purity MSM Specifications

(selected Chinese suppliers)

	Chinese Standard HG/T-4823-2015		Industry Specs	
Element or Compound	Class I (ppm)	Class II (ppm)	Huicheng (max ppm)	ISKY (max ppm)
MnSO4.H2O	≥99.0%	≥98.0%	≥99.0%	≥98.0%
Mn	≥32.0%	≥31.8%	≥32.0%	≥31.8%
As	--	--	--	10
Ca	≤100	≤200	100	50
Cd	≤5	≤10	5	10
Co	≤50	--	50	50
Cu	≤10	≤20	10	10
Fe	≤10	≤20	10	10
K	≤100	≤100	100	100
Mg	≤100	≤200	100	50
Na	≤100	≤100	100	50
Ni	≤50	--	50	50
Pb	≤10	≤15	10	10
Zn	≤10	≤20	10	10
Insoluble matter	≤100		100	--
PH (100 g/L solution, 25°C)	4.0~6.5		4.0~6.5	--
Particle Size	<400μM 100%		400 μM 100%	--

Source: China Standards.net, Dalong Huicheng, ISKY Chemical

Before 2018 no HPMSM prices were published by any pricing service. The growing importance of manganese sulphate monohydrate for the EV industry made the price reporting services turn their attention to the product. From early 2018[9] both Asian Metal (AM) and Shanghai Metal Markets (SMM) started reporting HPMSM prices in China. Now, the London-based Argus Media also reports prices of 'battery grade' manganese sulphate.

The published HPMSM prices are not a fair reflection of the real market as many different purities of the product are traded (as discussed elsewhere in this report), and most prices are set for at least six months in advance – the spot market is very limited. Before we turn our attention to price forecasting, we need to understand what the published prices refer to, as "HPMSM" is more of an umbrella term than a specific product description.

[9] The first data point reported was on 31 December 2017.

AM[10] told us that they regularly poll approximately ten HPMSM producing companies in China and ask about their recent selling prices. Then they reject the highest and the lowest price and average the rest before publication. They also said that their prices are predominantly from ISKY Chemicals Co., Ltd. and Hunan Dalong Huicheng New Materials; hence, the prices published by AM/Bloomberg reflect the material quality represented by these companies (and their location, as the prices are quoted on an "Ex Works" basis). These qualities are shown in Table 19-4.

.

Dalong Huicheng New Materials is the largest Chinese producer of HPMSM (80 kt in 2021, or 30% of the Chinese market). This company is also mentioned as a "drafting organization" for the HG/T-4823-2015 Chinese Industry Standard, so it is not surprising that its products comply with 'Class I' specification of that standard[11].

The ISKY specification is somewhat mixed – it offers lower Mn content (only 31.8% Mn or 98% MSM) but has tighter limits on most impurities, particularly calcium and magnesium. These impurities alone would make Huicheng's product unacceptable to all but one of the consumers, while the ISKY product would pass (assuming they accepted with 31.8% Mn contents). But even the "better" ISKY's product would not meet the stringent criteria of some users, who have a lower threshold for Ca and Mg than the ISKY's specification.

Another price data provider, SMM, also said that it took an average price of HPMSM from several producers but did not specify how many or who they were. It is probably safe to assume that these producers most likely reported the price for a product conforming to Class I specifications of the standard discussed above.

Usually, the HPMSM prices reported by AM and SMM are fairly close (but not identical) for the same dates, but on a number of occasions, they differed from AM up to 10%, with SMM typically quoting higher prices. The differences between AM and Argus ranged from -8% to +15% (a total range of 23%). This may reflect the different methods of calculating the average, possibly a different polling group, and the fact that the spot market for this product is relatively small and erratic. Most of the tonnage is sold under long-term contracts, with prices being negotiated periodically.

The conclusion from the above analysis is that the HPMSM prices published by AM, SMM, and Argus are *reference prices* in the broad understanding of this term. These prices refer to a mix of products of different specifications, sometimes not even reaching the 32% Mn declared in the description of the price data series (ISKY's product is only 31.8% Mn). The rejection of the highest reported prices by AM might exclude the higher-spec material.

Table 19-5: HPMSM Price Projections in China

Ex Works China; annual averages
USD per metric ton of HPMSM
Real Prices Base: 2021

HPMSM (32% Mn) Price in China, USD/mt		
Year	**Real Prices**	**% Change**
2022p	1,429	18.0%
2023p	1,600	12.0%
2024p	1,840	15.0%

[10] Asian Metal's prices are also published on Bloomberg and are the source of data for our graph on the next page

[11] The complete HG/T-4823-2015 Standard for 'battery grade' HPMSM (18 pages) can be purchased on line from ChineseStandard.net at https://www.chinesestandard.net/PDF.aspx/HGT4823-2015

HPMSM (32% Mn) Price in China, USD/mt		
Year	**Real Prices**	**% Change**
2025p	1,858	1.0%
2026p	2,230	20.0%
2027p	2,453	10.0%
2028p	2,674	9.0%
		table continues…
2029p	2,888	8.0%
2030p	3,061	6.0%
2031p	3,245	6.0%
2032p	3,472	7.0%
2033p	3,715	7.0%
2034p	3,975	7.0%
2035p	4,333	9.0%
Average 2036p – 2040p	4,333	n/a
Average 2041p – 2050p	3,490	n/a

Source: CPM Group's calculations based on supply-demand assessment and historical prices reported by Bloomberg, AM, Argus, SMM, and industry sources.

Looking forward, we see the HPMSM prices in China remaining strong and getting more and more divergent from the metallurgical quality EMM prices. The looming deficit of the 'battery grade' HPMSM described elsewhere in this report will hit China badly unless it expands its production base. In CPM's projections, we allowed for an additional 490 ktpy of new Chinese production (2.8 times the 2021 output), including 327 ktpy of as-yet-unannounced new capacity. We believe such a new capacity will be announced in the coming years under intense demand pressure.

The projected supply gap is bound to have an impact on Chinese (and global) HPMSM prices, so we see the HPMSM prices remaining firm and rising, perhaps with the exception of a period around 2025, when we envisage a global recession.

CPM's projection of HPMSM prices "Ex Works" China is shown in Table 19-5. Historical Chinese prices are shown in Figure 19-20.

19.8.3 HPMSM Prices in Europe

The prices of Chinese HPMSM published by AM and other information providers are quoted on an "Ex Works China" basis. Prices in Europe may differ significantly from the Chinese prices for reasons of cost of transportation, import duties, and a different supply-demand situation in the local market, as well as supply security, ESG (Environmental, Social, and Governance), and environmental issues.

There is no publicly available information about HPMSM prices paid by European buyers. These are only known to the buyers, Chinese exporters, and Princ Inc, the only European producer of HPMSM. All of them treat this information as commercial secrets and are unwilling to divulge it. EU customs statistics are unhelpful as they don't distinguish between the agricultural-grade MSM and battery-grade HPMSM.

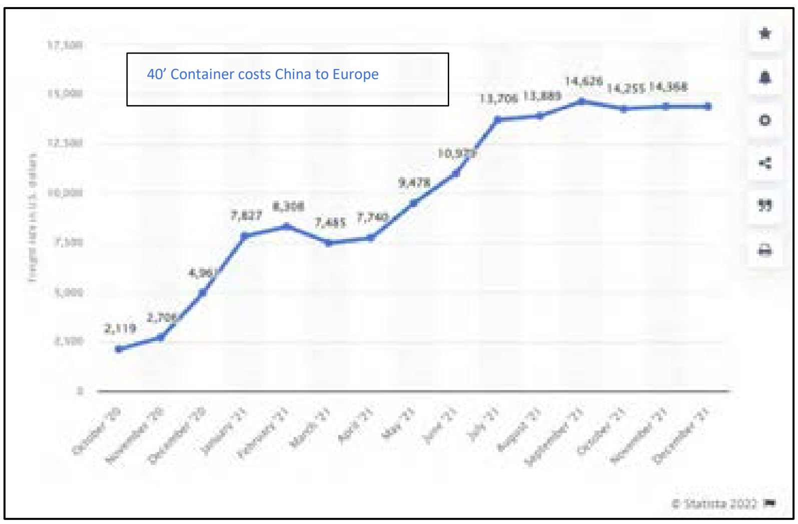
At present, China is, and will remain in the near future, the main HPMSM supplier to Europe; hence the price of Chinese materials landed in Europe is a starting point for a calculation of any European price. In this price projection, CPM calculates the theoretical European price for the material imported from China, supported by some anecdotal evidence[12]:

Publicly quoted HPMSM price "Ex Works China" plus:

- Cost of internal land transport in China and cost of customs clearance
- Sea freight to the European port and costs of customs clearance
- Cost of inland transport in Europe (to the cathode factory gate)
- EU import duty (5%, currently suspended till the end of 2023)
- Europe-specific additional premiums for:
  - Purity better than Chinese Class I
  - Non-Chinese origin (supply security)
  - Green Credentials
  - Recycled content
  - EU border carbon tax

The spreadsheet accompanying this document shows the forecast for both the "Ex Warehouse China" price and the European price calculated as described above.

Figure 19-16: 20' Container Freight Cost in Recent Years



[12] CPM is aware of a Japanese company offering a Japanese-made HPMSM in Europe in 2022 at $2,700/mt when the spot prices "ExW China" were around $1,554 (i.e. the "European Premium" = 74%). We are also aware of European buyers willing to accept prices around $3,200 for for future deliveries aroud 2026.

The cost of transport in the projection is based on the current quotes from shipping companies for transporting a 20' container from the Chinese city of Changsha (the "capital" of the HPMSM production in the Hunan Province) to Berlin (a proxy for numerous battery factories in Central Europe).

The current freights are at extraordinarily elevated levels and approximately seven times higher than a year ago (see Figure 19-16 above). In Q1/2022, the cost of freight adds $665 (or 44%) per tonne of HPMSM, but looking into the future, one has to bear in mind that:

- The current spike in container costs will pass;
- Exporters shipping a regular large number of containers would enjoy quantity discounts, while the calculation above is based on the cost of 1-10 containers.

The estimates by CPM shows the freight cost as a variable between $500 and reducing down to $200 per tonne of HPMSM by 2027

The 'Europe-specific premiums' mentioned above are estimated in aggregate based on anecdotal evidence from the industry insiders. CPM's conservative estimate puts these premiums at 15% - 25% of the Chinese "Ex Warehouse" price.

The above projection includes the cost of freight, handling, customs clearance, etc., from Changsha in China and Berlin.

Chinese material would normally be subject to a 5% import tariff upon entry to the European Union, but currently this tariff is suspended to the end of 2023 (the date of the next reviewal). In the above projection, we have assumed tariff-free access for Chinese HPMSM imports. It is likely the tariff would remain suspended or abolished until Europe has enough internal capacity to satisfy the needs of its battery industry.

Between 2035 and 2040 we projected a flat price at a 2035 level, declining after 2040. This is to account for new, as yet unknown, producers who might appear in the market attracted by high price levels and profit margins. We assumed that their production would bring more balance to the market, and the prices would stop growing as rapidly as before despite continuing growing demand and may start falling after 2040.

Table 19-6: HPMSM Price Projections in Europe

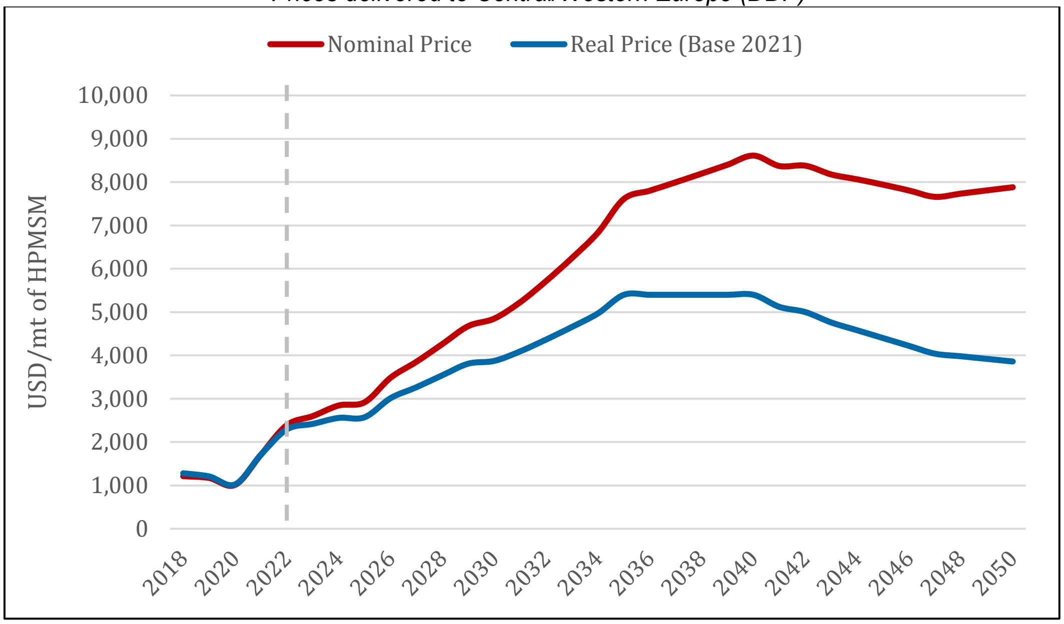
DDP Central Europe; annual averages, USD per metric ton of HPMSM
Real Prices Base: 2021
(Includes "European Premium" – see text)

HPMSM (32% Mn) Price in Europe, USD/mt		
Year	**Real Prices**	**% Change**
2022p	2,293	34.2%
2023p	2,420	5.5%
2024p	2,558	5.7%
2025p	2,573	0.6%
2026p	3,013	17.1%
2027p	3,266	8.4%

HPMSM (32% Mn) Price in Europe, USD/mt		
Year	**Real Prices**	**% Change**
2028p	3,542	8.4%
		table continues…
2029p	3,810	7.5%
2030p	3,873	1.7%
2031p	4,094	5.7%
2032p	4,366	6.7%
2033p	4,658	6.7%
2034p	4,970	6.7%
2035p	5,399	8.6%
2036p	5,399	*0%*
2037p	5,399	*0%*
2038p	5,399	*0%*
2039p	5,399	*0%*
2040p	5,399	*0%*
2041p	5,120	*-5.2%*
2042p	5,000	*-2.3%*
2043p	4,760	*-4.8%*
2044p	4,580	*-3.8%*
2045p	4,400	*-3.9%*
2046p	4,220	*-4.1%*
2047p	4,040	*-4.3%*
2048p	3,980	*-1.5%*
2049p	3,920	*-1.5%*
2050p	3,860	*-1.5%*

Figure 19-17: HPMSM Price Projection in Europe

Prices delivered to Central/Western Europe (DDP)



Source: CPM Group's calculations based on supply-demand assessment and historical prices reported by Bloomberg, AM, Argus, SMM, and industry sources.

19.8.4 HPMSM Prices in North America

The same logic applies to North American prices. There is no HPMSM production in North America at present. When Prince's Tampico plant in Mexico is converted to produce HPMSM, this will be the first North American producer of this material. Its planned output (including Phase Two) is likely to meet only 10% of the American battery industry demand for HPMSM in 2030. More plants are needed, but for the foreseeable future, most of the HPMSM needed will be imported, predominantly from China.

The DDU (Delivery Duty Unpaid) USA price could be calculated in a similar way as described above for Europe. Container shipment costs to the USA (from China) are similar to those to Europe, but the US import duty is 14%, making the Chinese HPMSM landed in the USA considerably more expensive than in Europe.

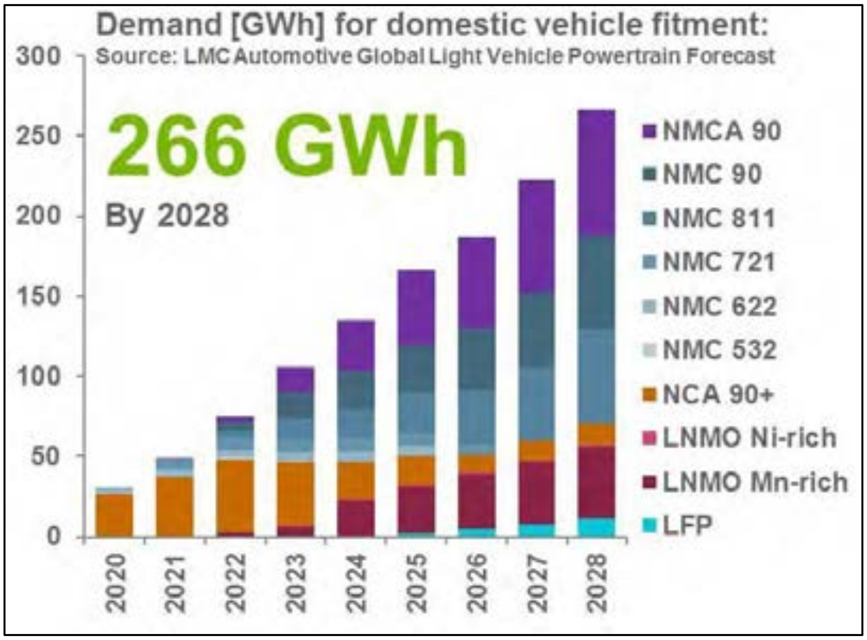
There are currently five Li-ion battery factories in the USA, but Tesla's "Gigafactory 1" at 30 GWh capacity is the only one of note, accounting for 82% share of the North American market[13].

This situation is likely to change dramatically; by 2031, there could be 26 gigafactories in the USA with an overall installed capacity of more than 700 GWh. Tesla's share is likely to shrink to just 7% of the American battery output, despite the continued expansion of its production base. At present, the Panasonic NCA batteries are produced in the Tesla factory, and they don't use manganese. This, too, is about to change when Tesla moves to Mn-based batteries from 2023 (most likely NMCA (Nickel, Manganese, Cobalt, and Aluminum)).

[13] Tesla accounts for 82% of Li-ion battery *output* in North America. The total market is much larger as many EVs are using imported batteries.

How much the American chemistry mix would differ from the European or Chinese one is being hotly debated. E-Source predicts that by 2031 67% of batteries produced in the USA will be NMCs (i.e., using manganese). Another American consultancy, LMC Automotive, goes much further, showing Mn-using batteries taking more than 90% market share by 2028 (see Figure 19-18).

Figure 19-18: Demand (GWh) for American Domestic Vehicle Fitment



Source: LMC Automotive

The demand forecast shown in Figure 19-18 (which is from mid-2021) has since changed upwards (to 396 GWh in 2028)[14] , but the chemistry mix is likely to stay the same.

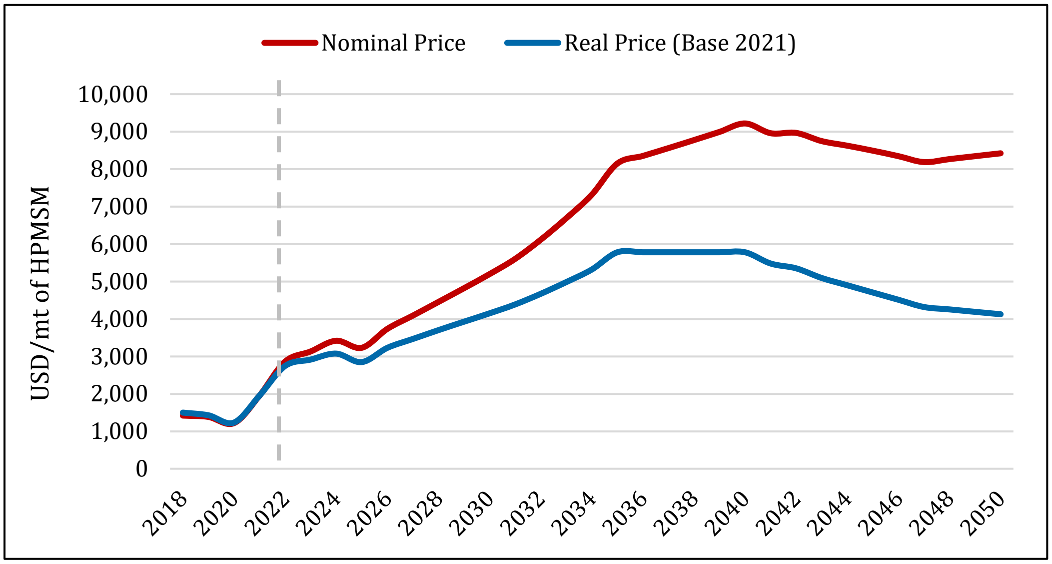
Comparing different forecasts, some calculating regional North American battery demand and others counting the announced battery factory capacities, we come to a conclusion that by 2021 North America might need between 700 kt and 1,200 kt of HPMSM annually.

On the supply side, only Prince Inc in Mexico and Manganese-X in Canada have a reasonably clear (though long) path to production, while others in the “Project Pipeline” section of this report are highly speculative entries. In May 2022, Manganese-X announced the Preliminary Economic Assessment of its Battery Hill project revealing its intention to produce 68 ktpy of HPMSM. This would be equivalent to only 10% of the North American Gigafactories capacity by 2031. So, for the foreseeable future American battery cell factories are likely to rely mostly on imports. Whether the 14% import duty would stay while the local industry shows such a significant demand rise is an open question. Probably not for the non-Chinese suppliers; probably yes, for the Chinese suppliers.

[14] Q4/2021 Battery forecast by E-Source

Figure 19-19: HPMSM Price Projection in North America

Prices delivered to Detroit, USA (DDP)



Source: CPM Group, 2022

Table 19-7: HPMSM Price Projection in North America

DDP Detroit; annual averages, USD per metric ton of HPMSM
Real Prices Base: 2021

HPMSM (32% Mn) Price in North America, USD/mt		
Year	**Real Prices**	**% Change**
2022p	2,743	40.6%
2023p	2,914	6.2%
2024p	3,074	5.5%
2025p	2,847	-7.4%
2026p	3,227	13.3%
2027p	3,464	7.4%
2028p	3,699	6.8%
2029p	3,925	6.1%
2030p	4,149	5.7%
2031p	4,386	5.7%
2032p	4,669	6.5%
2033p	4,982	6.7%
2034p	5,317	6.7%
2035p	5,779	8.7%
2036p	5,779	*0%*
2037p	5,779	*0%*

table continues…

HPMSM (32% Mn) Price in North America, USD/mt		
Year	**Real Prices**	**% Change**
2038p	5,779	*0%*
2039p	5,779	*0%*
2040p	5,779	*0%*
2041p	5,479	*-5.2%*
2042p	5,350	*-2.3%*
2043p	5,092	*-4.8%*
2044p	4,899	*-3.8%*
2045p	4,705	*-3.9%*
2046p	4,512	*-4.1%*
2047p	4,318	*-4.3%*
2048p	4,254	*-1.5%*
2049p	4,189	*-1.5%*
2050p	4,125	*-1.5%*

Source: CPM Group's calculations based on supply-demand assessment and historical prices reported by Bloomberg, AM, Argus, SMM, and industry sources.

Our American price projection includes freight from inland China (Changsha) to the battery factories cluster near Detroit as well as the 14% import duty and a likely premium for the "non-Chinese origin" and "better than Chinese product specification". Because of the limited metallurgical test work by Manganese-X and the lack of current local suppliers, it is hard to say if American buyers would be willing to pay the extra premium for "better than Chinese" quality and what tonnage of such quality from local production will be available to them. The 2035 – 2040 flatlining of the price and its decline after 2040 echoes the trend in China and Europe described above.

19.8.5 EMM and HPMSM Price Divergence

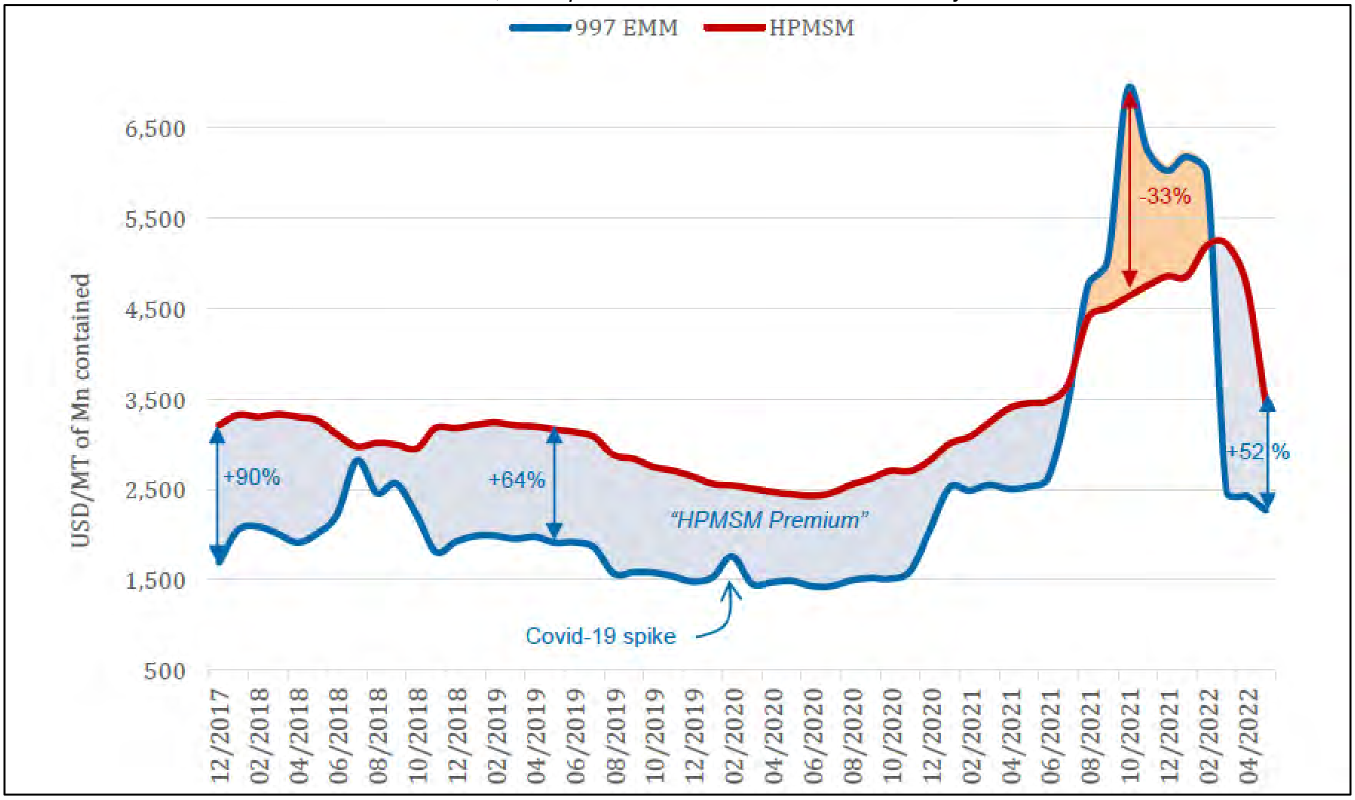
Since 2017, when Chinese prices of HPMSM were published for the first time, we have seen a continuing divergence between the 'standard quality' EMM prices (a metallurgical material) and prices of HPMSM – a chemical used mostly in Li-ion batteries.

To illustrate to what extent the HPMSM prices are divorced from the EMM price and during which periods they behaved in a similar way, it is worth looking at both prices on the same graph.

Figure 19-20 shows both prices per unit of metal contained. The graph also shows that HPMSM is a value-added product compared to EMM (most of the time – the recent price reversal is an aberration).

Figure 19-20: HMMSM and EMM 99.7% Prices in China (2017-2022)

December 2017 to May 2022
monthly averages per metric tonne of Mn contained
in warehouse China, RMB prices converted into USD at monthly FX rates



Source: Asian Metal, Bloomberg

We expect a further decoupling of standard EMM and HPMSM prices from 2022 onwards, with the former following the fortunes of the steel industry and the latter closely related to the development of the EV sector.

This decoupling of HPMSM and standard EMM prices poses a question of High Purity EMM prices – which way will they go? Will they follow the HPMSM price or the standard EMM price? As we point out in many places in this section, HPEMM can be used to produce HPMSM, although currently, only approximately 22% of global production of HPEMM is used by the battery industry (the rest goes to metallurgical applications). However, standard EMM can not be used to produce HPMSM for the battery industry.

CPM Group has grounds to believe that HPEMM will also decouple from 997 EMM, and its prices will follow HPMSM prices. This issue is discussed in more detail under the "HPEMM Prices" section of this section below.

19.8.6 HPEMM Prices

EMM prices are set on a bilateral basis between the trading parties. There is no exchange on which the material would trade and no hedging possibility[15]. It is a relatively small and opaque market compared to other metals (1.3-1.6 million t per year for 'standard quality' 99.7% Mn EMM). Prices reported by market insiders are published by information providers like Metal Bulletin (now Fastmarkets), Argus, AM, or Bloomberg. In the case of the majority of contracts, prices are set once or twice a year, and contracts tend to be long-term.

Information on standard quality 99.7% Mn EMM is readily available through the price-reporting services mentioned above[16]. However, nobody publishes prices for HPEMM (+99.9%) because it is a very small market (30-40 ktpy) with only four producers and a handful of buyers.

CPM learnt from industry insiders that historically HPEMM traded typically $500-$1,500 higher than the standard quality version of the product[17]. Unlike in the case of copper and some other non-ferrous metals, prices are **not** set on a "variable + premium" basis but rather as fixed prices in USD/mt for a period of usually six months (three months in North America). Therefore, the fixed prices are not negotiated as an "HPEMM Premium". The spot market for HPEMM is virtually non-existent; the majority of the tonnage produced is sold in annual and longer contracts. However, a price differential between the agreed half-yearly fixed price for HPEMM and a fluctuating spot price for standard quality EMM may be back-calculated.

The natural operating cost floor for the price differential between the two varieties of EMM is approximately $500/mt, which reflects the higher use of electricity (+3,000 kWh/mt) and higher cost of reagents used in the production of HPEMM. For the battery industry, however, the lower levels of impurities required by the cathode manufacturers mean that a standard EMM plant cannot be simply converted to an HPEMM plant for conversion to HPMSM for use in the battery industry without significant investment by the 997-EMM plants. The current price of for HPEMM does appear to justify this investment to target this market. In addition, given these plants are in China provides an additional barrier for these plants to make such an investment to satisfy the non-China market, as the non-China market consumers are focusing on local supply security and high ESG standards.

In 2021 78% of all HPEMM produced globally was sold to metallurgical clients and approximately 22% to battery clients (to be converted to HPMSM), and the fixed price negotiation mechanism described above was used to set the prices. A significant proportion of the contract deliveries made in June 2022 could be described as "carrying a price differential of $4,200/mt", which is a result of fixing prices (in $/mt at $7,000/mt) at the height of the EMM price spike in 2021 for the following six months. The 997-EMM spot price subsequently collapsed to levels close to $2,800 (ExW Rotterdam); hence the implied "HP premium" for the current deliveries is $4,200 ($7,000 less $2,800), but no such "premium" was agreed upon when the parties negotiated the contract. It has been historically observed that the differential between standard EMM and HPEMM increases when the standard EMM prices are low, and decrease to the natural operating cost floor when standard EMM prices are high.

In the future, CPM recognizes supply and demand market forces within the growing EV battery market may alter the pricing mechanism for high purity EMM. Today, HPEMM is very much a "metallurgical market metal", while in

---

[15] Some banks may offer over-the-counter hedging instruments, usually as part of a project financing package, and off-takers may agree to minimum and maximum prices in their contracts, but no traditional hedging through exchange futures contracts is avaialble.

[16] Bloomeberg codes for 99.7% Mn EMM prices: ExW China: MNCNEANA, ExW Rotterdam: MNCNAHZM

[17] The HPEMM "premiums" are inversly correlated to the price of the 'standard quality' EMM – when its prices are low, like $1,200/mt, the premiums could be as high as $2,000. When prices are high, as the prices were in Q4/2021 ($5,000 – $7,700), the premiums could be as low as $300 or even go to zero, as the "naked" EMM price gives HPEMM producer a big profit margin anyway.

not so the distant future, it is likely to become predominantly a "battery market metal". The use of HPEMM as a feedstock to produce HPMSM is not new, but this method of producing high purity manganese sulphate has been limited so far: in 2020, only 15% of global production of HPMSM was done through this route, and the figure for 2021 was only 7.5%.

There are signs that this situation is likely to change and that production of HPMSM "through the metal route" may be higher in the future than it is today. One reason is the quest for purity. It is much easier to produce high purity sulphate using 99.9% HPEMM as a starting point than when making it directly from the ore. Another reason is the saving on the transport cost – a ready-made sulphate contains only 32% Mn, so to have one tonne of metal contained available for cathode production, three t of sulphate need to be delivered. But perhaps the most important reason is the production process saving if the sulphate can be delivered in a liquid form (i.e., not crystallized). This saves both the producer and the buyer some steps in the production process – removing the need to crystalize a powder and also to dissolve the crystalline HPMSM to make a slurry for cathode coating. This saving works over short distances; ideally, such a liquid should be delivered by a pipeline rather than a tanker.

CAM (Cathode Active Material) makers, like BASF and Umicore, and the battery maker Northvolt have dissolution plants next to their cathode material plants to be able to convert nickel and cobalt in their metallic forms into relevant sulphates. CPM understands that the increasing demand for manganese makes such dissolution plants viable for manganese.

This approach is likely to change the trading patterns between HPEMM and HPMSM, increasing the demand for high-purity metal flakes. Another technological development likely to increase the demand for Mn in the metallic form (HPEMM) is a new method of producing cathode active materials patented by a Canadian junior company Nano One. The process known as M2CAM uses metal powders instead of sulphates as a starting point of cathode powder production. Last month, the German chemical giant BASF signed an agreement with Nano One declaring close cooperation in developing the M2CAM technology. Two weeks later, Rio Tinto invested $10 million of equity in Nan One with a similar aim. With partners like these, Nano One's technology is much more likely to succeed commercially and take away a noticeable part of market share from the sulphate-based CAM production methods.

All of the above developments lead us to believe that post-2025, the demand for HPEMM may significantly increase, leading to strong competition for supplies between metallurgical users and battery industry users of HPEMM. The latter is likely to be able to bear higher prices and exert more 'gravitational force' on the pricing, and as a result, the HPEMM pricing is forecast to be derived from the Mn sulphate price rather than the price of the "metallurgical only" 997 EMM. Therefore, the price of HPEMM would be established at a discount to HPMSM price[18] rather than at a "back-calculated" premium to the 997-EMM price. Despite the increased demand for HPEMM, we still see HPMSM as a dominant product on the market and hence a benchmark for pricing of high purity manganese products used in the battery industry.

The price differential between HPEMM and HPMSM would essentially equate to the cost of conversion of metal into sulphate, the profit of the converter, and an element of amortization of the converter's capital expenditure incurred when building the dissolution plant. We estimate that the conversion cost alone is around $800 per tonne of metal (HPEMM), and we allowed another $1,200/mt for other components mentioned above, bringing the price differential to approximately $2,000/mt of metal. Because it is based on information from European consumers of

[18] Per unit of metal contained

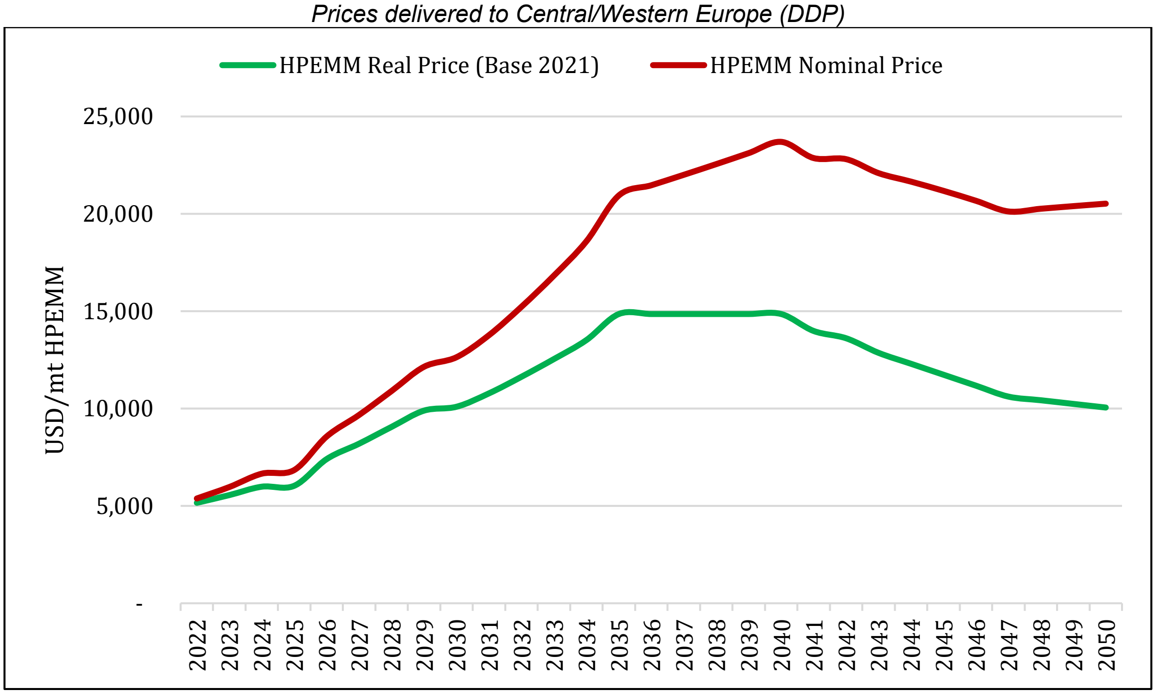
battery-grade manganese (mentioned above), this price differential is applicable to Europe (and to the European price of HPMSM, on a metal basis, from which the discount would be subtracted).

It is likely that between now and 2025 to 2026, it is expected that the transitional period where metallurgical buyers will still be pricing their purchases based on a fixed HPEMM price, while battery customers would treat HPEMM as an HPMSM alternative and would see its price as a function of the sulphate price. This would create arbitrage possibilities, which will eventually bring the prices of HPEMM to HPMSM levels (on a metal basis) less the cost of conversion paid by battery customers discussed above. The flatlining of the HPEMM price between 2035 and 2040 and its decline after 2040 reflects the situation in the HPMSM market discussed previously.

The purpose of this market study is to assist Euro Manganese Inc. in their Feasibility Study assessment of the economic viability of the Chvaletice project in the Czech Republic. Our HPEMM price projection takes into account the specific aspects of this project, including its location (Europe), its target market (Europe), its likely production start date (2026-27), and its products (super-high purity EMM and MSM). The projected HPEMM prices in Table 19-8 were calculated by subtracting $2,000/mt of metal contained from our projected prices of HPMSM discussed elsewhere in this report.

Figure 19-21: HPEMM Price Projections in Europe

Prices delivered to Central/Western Europe (DDP)



Source: CPM Group, 2022

Table 19-8: HPEMM Price Projection in Europe

DDP Central/Western Europe; annual averages; USD per metric ton of HPEMM 99.9% Mn
Real Prices Base: 2021
(Includes "European Premium" – see text)

HPEMM (99.9 Mn) Price in Europe, USD/mt		
Year	Real Prices	% Change
2022p	5,158	--

HPEMM (99.9 Mn) Price in Europe, USD/mt		
Year	Real Prices	% Change
2023p	5,555	7.7%
2024p	5,986	7.8%
2025p	6,032	0.8%
2026p	7,405	22.7%
2027p	8,197	10.7%
2028p	9,058	10.5%
2029p	9,893	9.2%
2030p	10,091	2.0%
2031p	10,780	6.8%
		table continues…
2032p	11,630	7.9%
2033p	12,541	7.8%
2034p	13,515	7.8%
2035p	14,855	9.9%
2036p	14,855	0%
2037p	14,855	0%
2038p	14,855	0%
2039p	14,855	0%
2040p	14,855	0%
2041p	13,984	-5.9%
2042p	13,609	-2.7%
2043p	12,860	-5.5%
2044p	12,298	-4.4%
2045p	11,736	-4.6%
2046p	11,174	-4.8%
2047p	10,612	-5.0%
2048p	10,425	-1.8%
2049p	10,238	-1.8%
2050p	10,050	-1.8%

Source: CPM Group's calculations based on supply-demand assessment and historical prices reported by Bloomberg, Asian Meta, Argus, SMM, and industry sources.

20.0 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT

20.1 Introduction

The CMP entails the reprocessing of mine tailings deposited in close proximity to several communities, farms, light and heavy industrial operations, recreation areas, forested and rural fauna and flora habitats, as well the Labe River. The tailings cells and proposed process plant area are brownfield sites that have been substantially altered by past industrial activities. The tailings have been placed directly on former farm fields in the alluvial plain of the Labe Valley without any underlying containment or lining system. These tailings have been leaching metals and minerals into the underlying sediments and aquifer for decades and continue to do so. The proposed plant site contains numerous buildings and infrastructure in various states of disrepair, when the site was used for the production of sulphuric acid, dating back to 1951-1975. Numerous buildings on this site continue to be occupied by small, light industrial businesses.

The environmental footprint of the CMP and EMN's plan of operations is expected to consist of:

- A tailings extraction operation that will relocate approximately 1 Mt/a of the tailings from the current cells to an adjacent processing facility
- A hydrometallurgical processing facility located on an industrial site to the south of the tailings cells, where manganese will be extracted from the tailings
- A pipeline to deliver tailings and water slurry that will cross the railway and highway corridor that separates the tailings piles from the proposed plant site, coupled with a return water pipeline and a tube conveyor that will deliver washed, neutralized, and dewatered post-processing tailings for dry stacking on the final tailings storage site
- A lined and capped final tailings storage facility located within the original tailings footprint, which will be fully reclaimed and restored to a natural state, bringing it in compliance with applicable modern environmental standards and regulations.

The construction of the CMP facilities is expected to last approximately 30 to 36 months. The productive life of the project is planned to be 25 years. Reclamation and restoration activities at the site to facilitate the return to a natural, productive state is expected to take a further one to two years. The vast majority of the reclamation is scheduled to be conducted progressively beginning shortly after commercial operations commence. While extensive efforts have been made to design a world-class manganese operation, applying best international practices and cleanest available technologies, there are numerous site-specific and local sensitivities that still need to be addressed by the CMP development and operations plan, and potential impacts that must still be avoided or mitigated. Many of these have already been addressed and assessed within the initial environmental and social impact assessment (EIA Notification) and will be further identified in the context of an extensive community, stakeholder, and regulatory agency consultation process.

Mangan, as operator of the CMP, has initiated extensive environmental and social baseline studies; evaluated the applicable environmental, health, and safety regulatory requirements; and sought to apply standards, measures, technologies, and practices aimed at bringing the proposed design and operation of the CMP into full compliance with applicable laws and regulations of the Czech Republic and the European Union, as well as in keeping with local community land use plans.

20.2 Environmental and Social Baseline Conditions

Environmental and social baseline programs for the CMP have been ongoing since the summer of 2016 together with work in support of an EIA Notification. Preliminary results are presented for air quality, noise, hydrology, hydrogeology, fisheries and aquatics, ecosystems, vegetation and soils, wildlife and wildlife habitat, and socioeconomics. Local features of interest were identified and recorded, including sensitive and protected areas, vegetation, landscape elements, and areas or sites of historical, cultural, archaeological, or geological importance. Climate; air; water; soil; natural resources; fauna, flora, and ecosystems; landscape; and population of the area were inventoried.

The crucial point of the project is to participate in the environmental and social impact assessment process and receive a binding statement from the applicable authorities, in this case, the Ministry of Environment (MoE). The EIA permit is the most critical milestone to start project implementation because EIA appropriation is a trigger point for equipment, material and works supply contracts, land planning request, and construction permit initiation.

Several strategies for the EIA process were considered initially and the following strategy for the EIA process was assessed as being the most efficient. A consolidated EIA would be prepared for tailings extraction, dry-stacking, and the process plant, and two-staged process would be pursued for submission to authorities. Stage 1 includes the full scope (beyond the legislative requirements) of the EIA Notification together with expert studies and surveys with a full assessment of the project's anticipated impacts and proposed mitigation measures. Stage 2 includes EIA documentation according to the legislative requirements taking into consideration the requirements arising from the EIA Notification and comments from the authorities which were addressed in project design. The EIA Notification was prepared based on the Preliminary Economic Assessment (PEA) issued in March 2019.

The following studies and surveys were prepared as part of the EIA Notification:

- Acoustics Study together with on-site Noise Monitoring
- Air dispersion modelling study
- Impact assessment on public health
- Hydrogeological Assessment
- Biological Assessment
- Dendrological Assessment
- Traffic Assessment
- Landscape Impact Assessment
- Comprehensive Plan for Remediation and Reclamation.

In August 2020, the screening procedure for EIA Notification was initiated by distributing the EIA Notification to the affected local self-governing units and other affected authorities. The MoE received a number of statements and requirements from 13 entities and persons. The Screening decision summarizing all received comments pertaining to the EIA Notification was published by the MoE in December 2020.

TETRA TECH

The conclusions of the EIA screening procedure did not result in any unexpected requirements. In general, it can be stated that within the first phase of the project's environmental impact assessment (screening procedure), no crucial objections and comments were raised which would make the second phase of the project assessment (EIA Documentation) or the realization of the project impossible.

Above all, the conclusions pointed out the insufficient detail of some data (many of the necessary data were either not available in time for the PEA or were not sufficiently detailed). This confirmed the expected assumption and intention to prepare an EIA Notification to the extent beyond the legislative requirements and thus obtain beneficial recommendations and inputs for the next stage of the project. While considering these requirements and recommendations in the FS and Project design, risks in the next phase of EIA assessment and release of the final EIA statement can be reduced.

The EIA Notification provides an overall assessment of the current environmental conditions that prevail in the CMP area of interest (Figure 20-1), including the assessment of project impacts on the environment and social issues together with the proposal of mitigation measures. Those issues and conclusions are addressed in each section of this text.

Figure 20-1: Area of Interest

Note: Red outline is existing tailings cells; yellow outline is the proposed location for the process facility

20.3 Air Quality

The CMP area is located in one of the hottest, driest locations in the Czech Republic.

According to maps presenting average annual maximum and minimum air temperatures in the publication Climate Atlas of the Czech Republic, the locality of Trnávka falls between a higher range of the maximum values (33 – 34°C) and a lower middle range of the minimum values (-19 to -18°C). In terms of the total annual hours of sunlight, the area of interest falls in a zone with a higher value, from 1,600 to 1,700 h/year.

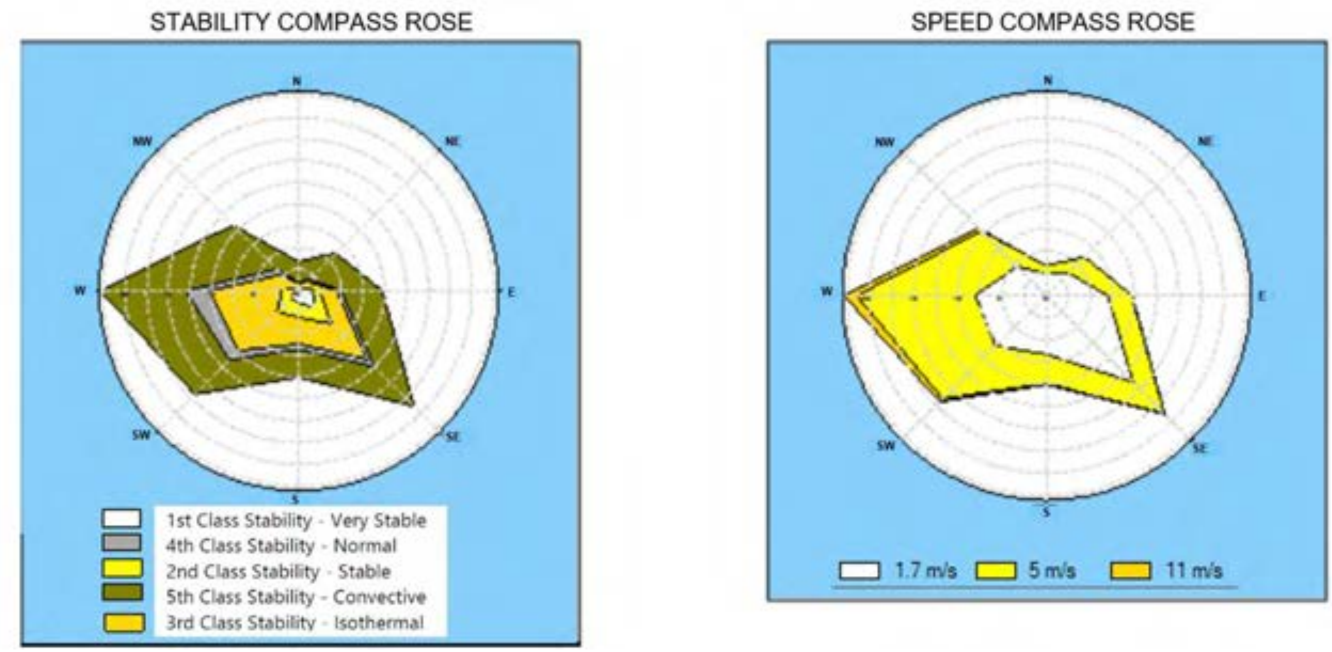
Based on the average total annual precipitations, the locality falls in the reported middle range (approximately 650 – 700 mm).

According to the information above, in the scale of the Czech Republic the area of interest can be characterized as a moderately exposed area with rather average climatic characteristics.

20.3.1 Wind Rose

According to the wind rose (Figure 20-2), the wind blows mostly in the western and south-western direction (period of January 1, 2008, to December 31, 2017, set in 10 m above ground, source: Czech Hydrometeorological Institute).

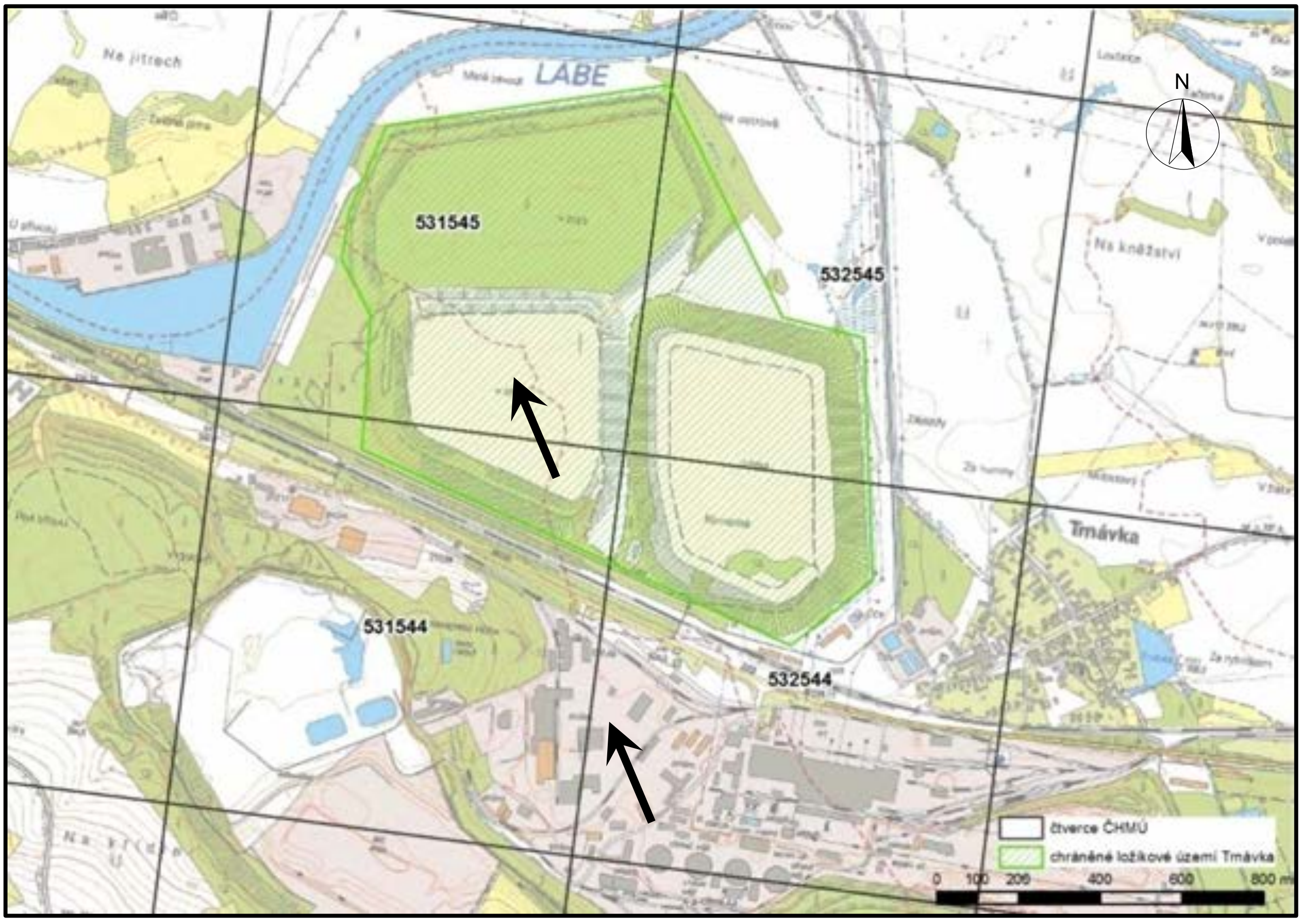
Figure 20-2: Wind Rose



20.3.2 Air Pollution

The assessment of the current level of pollution in the area of interest is based on maps of pollution levels constructed in the 1 x 1 km network, currently published on the website of the Czech Hydrometeorological Institute (www.chmi.cz). These maps show in each square the value of the moving average concentration over the previous five calendar years for pollutants which have an annual limit of air pollution.

Figure 20-3: Project Location and 1 km² Data Collection Areas



Source: Five-year average concentration (www.chmi.cz, 2017)

The following tables shows the concentrations of harmful substances in the pollution background of the area (emissions) of interest and their comparison with valid emissions limits (meaning acceptable legal air pollution limit).

Table 20-1: Harmful Substance Concentrations in the Emissions Background and their Comparison with Applicable Limits

Pollutant	Year	Map of air pollution 2014 - 2018	Air Pollution Limit	Share Air Pollution Limit (%)
SO_2 (µg/m^3)	4th highest daily air pollution	14.7 – 24.4	125	14.7 – 19.5
SO_2 (µg/m^3)	Annual Average	4.8 – 6.5	20	24.0 – 32.5
SO_2 (µg/m^3)	Winter Average	6.0 – 7.8	20	30.0 – 39.0
SO_2 (µg/m^3)	Max. hourly air pollution	< 200 (Estimate)	350	57.1
PM_{10} (µg/m^3)	36th highest daily air pollution	38.0 – 40.3	50	76.0 - 80.6
	Average annual air pollution	23.3 – 24.1	40	58.3 – 60.3
$PM_{2.5}$ (µg/m^3)	Average annual air pollution	16.9 – 17.9	25	67.6 – 71.6
NO_2 (µg/m^3)	Average annual air pollution	11.9 – 15.0	40	29.8/37.5
	Max. hourly air pollution	< 150 (Estimate)	200	<75
Petrol (µg/m^3)	Average annual air pollution	1.0 – 1.1	5	20 – 22
Benzo(a)pyren (ng/m^3)	Average annual air pollution	0.9 – 1.1	1	90 – **110**
Arsenic (ng/m^3)	Average annual air pollution	1.4 – 1.7	6	23.3 – 28.3
Lead (ng/m^3)	Average annual air pollution	5.3 – 6.2	500	1.1 – 1.2
Nickel (ng/m^3)	Average annual air pollution	0.7 – 0.8	20	3.5 – 4.0
Cadmium (ng/m^3)	Average annual air pollution	0.4 – 0.5	1	40.0 – 50.0
Ammonia	Maximum daily air pollution	12.9 – 13.5 (Pardubice Dukla air pollution station)	100*)	12.9 - 13.5

Note: *) The original emission limit for ammonia as stated in the cancelled Government Regulation No. 350/2002 Coll. (2005 amendment); now no limit is defined

As follows from the table, emissions limits in the area of interest are satisfied for mean annual concentrations of all harmful substances that have an emission limit defined for the annual mean, except benzo(a)pyrene. In this case, it is not an adverse local situation but a reality over a considerable part of the Czech Republic territory.

20.3.3 Dispersion Modelling

Dispersion modelling was conducted during the initial phase of EIA process in 2020 (EIA Notification) based on the PEA data. The subject of the dispersion study was the assessment of the potential impact of the CMP including tailings extraction and its processing, including the generated transport on the air quality in the vicinity of the tailings area and the new processing plant. Activities in the tailings area included not only the extraction of material and its partial processing, but also the final rehabilitation.

This assessment calculated the values of the air pollution contribution from the operation of the planned project (PEA data), which were evaluated together with the values of the air pollution concentrations of the relevant pollutants in the air pollution background by comparison with the applicable air pollution limits. The assessment of the impact of pollutants was prepared by the SYMOS'97 program, a dispersion model with Gaussian distribution of pollutant concentrations. The SYMOS'97 program is included in the reference methods of air pollution modelling by implementing Decree 330/2012 Coll. to Act 201/2012 Coll.

20.3.4 Emission Inventory

The results of the calculations based on the PEA data showed that the air pollution contributions of the project under consideration involving the extraction of the material and its processing in the new plant combined with the increased unrelated background automotive transport in the location under consideration to the average annual concentrations of nitrogen dioxide, PM_{10} and $PM_{2.5}$ particles and benzene will not cause the exceedance of the relevant applicable air pollution limits for the annual average of these pollutants.

The process of material extraction and its preparation within the tailings area will be associated in particular with emissions of nitrogen oxides from mining machinery engines along with the production of dust particles. The total annual emission flow of nitrogen oxides from mining machinery engines is approximately 11.3 t/year. These relatively high emissions of nitrogen oxides from diesel engines are associated with the high combustion temperature of these sources. The total expected annual PM_{10} dust particles mass flow is 0.9 t/year and $PM_{2.5}$ particles emission flow is approximately 0.55 t/year. These relatively favourable low emission values result from the high moisture content of the material extracted and are mainly attributable to dust produced by overburden disturbance and reclamation activities. Emissions of benzene and benzo(a)pyrene from generated transport can be described as relatively very low.

The operation of the new process plant is associated with the emergence of new technological sources of emissions with emissions of nitrogen oxides, PM_{10} particles emission, $PM_{2.5}$ fraction particles, emissions of sulphuric acid and ammonia. With the highest emission flow of approximately 29.2 t/year, nitrogen oxides will be emitted from the operation of the process plant. The dominant source of emissions is rail transport. PM_{10} particles emission flow is expected at a level of approximately 728 kg/year, $PM_{2.5}$ fraction particles at a level of approximately 683 kg/year. Emission flows of sulphuric acid (86.8 kg/year) and ammonia (42,7 kg/year) are expected to be relatively low due to the installation of scrubbers. Emissions of benzene and benzo(a)pyrene from generated automotive transport will be negligible.

Table 20-2: Allowable Emission Limits

Pollutant	Averaging Period	Emission Limit ($ug.m^{-3}$)	Maximum Number of Overruns
Benzene	1 year	5	0
Particles PM_{10}	1 year	40	0
Particles PM_{10}	24 hours	50	35
Particle $PM_{2.5}$	1 year	25	0
Nitrogen Dioxide	1 hours	200	18
Nitrogen Dioxide	1 year	40 $\mu g.m^{-3}$	0

Note: In Annex No. 1 to Act No. 201/2012 Coll., an emission limit is also given for the overall content of benzo(a) pyrene in particles of size PM10 declared for protection of human health, which is 1 ng/m^3.
Source: Annex 1 to Act No. 201/2012 Coll. (2017)

Table 20-3 evaluates the cumulative air pollution contributions from the operation of the tailings and the operation of the process plant to the average annual concentrations of basic pollutants cumulatively with air pollution background values. Results are compared to applicable air pollution limits. In the following table, in the row “Total with the project – maximum” the value of the highest air pollution contribution is added to the highest value of the air pollution background according to the air pollution map processed for five-year averages of monitored pollutants.

Table 20-3: Summary and Evaluation of Cumulative Air Pollution Contributions to Average Annual Concentrations

	NO_2 ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2,5}$ ($\mu g/m^3$)	Benzen ($\mu g/m^3$)	BaP (ng/m^3)
Air pollution background	max. 15.0	max. 24.1	max. 17.9	max. 1.1	0.9 – 1.1
Highest air pollution contribution	1.0	1.0	0.4	0.0018	0.0015
Total with the project – maximum	16.0	25.1	18.3	1.1018	1.1015
Air pollution limit	40	40	20	5	1.0
Share of air pollution limit (%)	**40.0**	**62.8**	**91.5**	**22.0**	**90.1 - 110.15**

The table shows that the cumulative operation of the tailings and the process plant will not cause the limit values for the average annual concentrations of nitrogen dioxide, airborne dust particles of the PM10 or PM2.5 fractions, or benzene to be exceeded. In the air pollution background, on the basis of the map of air pollution processed for five-year moving averages, it can be expected that the applicable air pollution limits for the annual average of all these pollutants will be met reliably.

For H_2SO_4, NH_3 and Mn, there are no values of air pollution limits or recommended concentrations in the Czech Republic to protect public health. An assessment of the values of air pollution contributions of these pollutants is carried out in a separate study of effects on public health.

The Dispersion Study concluded that overall, from the point of view of air effects, the CMP, as well as in the cumulation with the increased unrelated automotive transport in the addressed location can be considered acceptable.

20.4 Acoustics

Currently the noise levels in the area are considered unsatisfactory, with noise values just below or exceeding established legislative limits. Several significant noise sources in the area of interest contribute to noise pollution in particular the transport sources (vehicle and railway transport) and stationary noise sources as well. Both sources operate within the Chvaletice industrial zone.

The dominant sources of noise are communications and rail traffic:

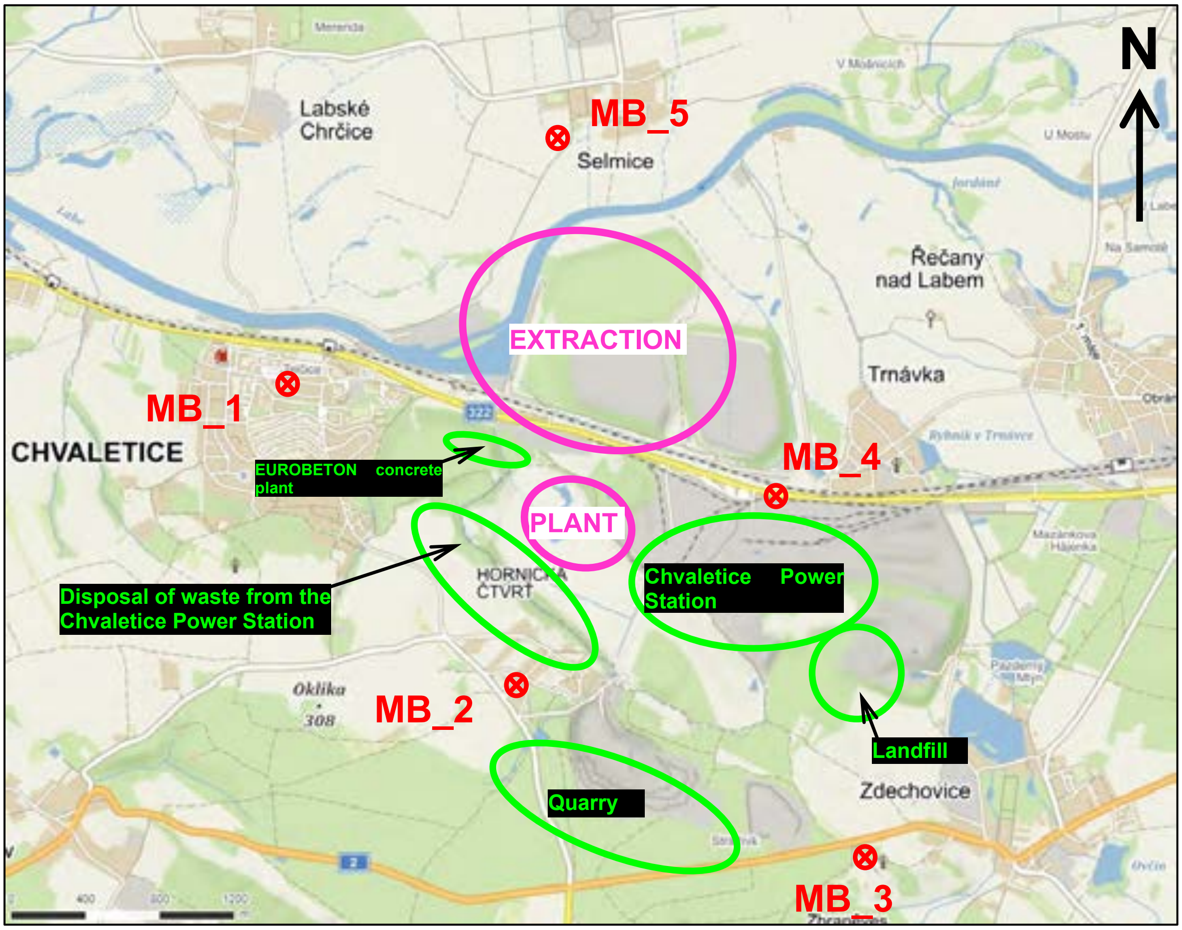
- Road No.322/II (Chvaletice – Řečany nad Labem), Road No.2/I (from road No.322 – Bernardov, via Zdechovice)
- Rail line No.010 Kolín – Přelouč

Additional sources of stationary noise include the Chvaletice Power Plant, the Concrete Mixing Plant Chvaletice, Foundry KASI, Asphalt Mixtures Coating Plant, and Stone Quarry.

The existing noise loading in the area of interest has been verified by 24-hours-noise-monitoring at five selected measuring points (5 MB) by an authorised laboratory according to Act No. 258/2000 Coll. on public health protection. Noise monitoring was carried out in 2019. The measured noise values within the 24-hours noise monitoring at measuring points No. 1 to 5 include traffic intensity and activities in the neighbouring industrial areas and have been used for the preparation of a noise model as a part of Acoustic study (part of EIA Notification).

The following figures show the location of existing significant noise sources in the area of interest, along with the noise monitoring points.

Figure 20-4: Situation of Wider Relations



Note: Figure marking measuring points MB_1 to 5, location of the Project (purple circle) and significant sources of noise in the area (green circle)

Table 20-4 presents the current existing measured and calculated total noise values within the Acoustic Study.

Table 20-4: Total Noise Values and Values from Industrial Areas Operation – Existing Conditions (Year 2020)

Monitored Point	Comparison of Equivalent Sound Pressure Levels A					
	Whole Night and Day $L_{Aeq,T}$ (dB)				Operation of Surrounding Industrial Premises Only $L_{Aeq,T}$ (dB)	
	Calculation		Measurement		Calculation	
	Day $L_{Aeq,16h}$	Night $L_{Aeq,8h}$	Day $L_{Aeq,16h}$	Night $L_{Aeq,8h}$	Day $L_{Aeq,8h}$	Night $L_{Aeq,1h}$
Point MB 1 East part of Chvaletice	61.5	57.3	60.1	58.2	33.1	29.5
Point MB 2 Hornická čtvrť	47.9	46.4	47.8	39.9	45.6	41.4
Point MB 3 Zdechovice	70.0	63.7	70.5	62.9	43.5	35.2
Point MB 4 Trnávka	58.2	57.0	57.3	57.5	54.6	54.5
Point MB 5 Selmice	43.8	43.7	42.7	42.6	37.3	36.4

According to the government Directive No. 272/2011 Coll., the hygienic limits in an equivalent noise pressure level and in the external protected environment of structures are as follows:

- Hygienic noise limit for noise from industrial areas operation – from operation of stationary noise sources and from transport on non-public purpose-built roads and parking areas within the relevant premises:
- **$L_{Aeq,\ 8h}$ = 50 dB** at daytime (6:00 – 22:00) for the eight successive noisiest hours
- **$L_{Aeq,\ 1h}$ = 40 dB** at night time (22:00 – 6:00) – for the noisiest hour

The above table shows that hygienic noise limits are being exceeded in the area of interest, in particular with regard to the Trnávka residential area, at night as well as during the day. As such, it is possible to state that from the noise pollution viewpoint, it is a territory already loaded above the bearable limits. The noise hygienic limits are being exceeded, above all, by the Chvaletice Power Plant noise sources operation. The Chvaletice Power Plant currently operates under a permit provided by the Regional Authority of Pardubice. Noise levels that do not comply with established noise hygienic limits are to be conditioned by acoustic measures according to a prescribed time schedule. Realization of the acoustic measures might improve the noise situation within the area.

The Acoustic modelling and study (2020) was prepared based on the PEA data by an authorized company. This modelling was guided by Government Regulation No. 272/2011 on the protection of health from adverse effects of noise and vibration and evaluated the noise contributions of extraction within the tailings area, processing plant activities, and other connected activities in the surrounding areas. Based on the outcomes from the acoustic modelling it can be stated that the Project will not increase the noise level above the legislative limits under the condition that following acoustic modifications and mitigation measures are implemented:

- Limit the railway siding operation in the processing plant area, loading and unloading to daytime hours only, i.e., 6 a.m. to 10 p.m.
- Take construction noise parameters into consideration during project designing

- Limit tailings extraction hours to 16 h/d, 5 d/wk with no scheduled work on weekends and holidays
- Implementation of anti-noise measures on the Chvaletice Power Station Premises
- Implementation of a noise barrier along the Road 322 in Chvaletice (if relevant)

On-site noise monitoring was updated in 2021 and additional monitoring is planned in 2022. Based on the precise and more detailed data from the FS where proposed mitigation measures were included and data received from updated noise monitoring, new noise modelling and calculations will be carried out in 2022 to specify the potential impacts of the CMP Project on noise within the area of interest.

20.5 Surface Hydrology

In the Czech Republic, the system of hydrological zoning is stipulated by the Ministry of Agriculture Decree No. 292/2002 Coll. The hydrological number, or the hydrological sequence number of the basin is the basic ranking of the flows connected to the basin, presented as an eight-digit number that designates the various basins present.

Figure 20-5: CMP Location in Relation to Hydrological Watersheds

Source: Map service Water management and protection (http://heis.vuv.cz, 2017)

The area of interest is located in the partial basin of the Labe from the Chrudimka to Doubrava No. 1–03–04–076 with a total area of 19.21 km² (Figure 20-5).

TETRA TECH

The most important watercourse in the area of interest is the Labe River, which passes around the tailings along the north and west edge. At its nearest points, the Labe Rive is approximately 100 m from the tailings. The mean annual flow of the Labe River is about 59.2 m^3/s in the area of interest and the minimum flow drops to 17.2 m^3/s. Basic hydrological data related to the profile of the Labe River for the river at km 941.532 is summarized in the table below.

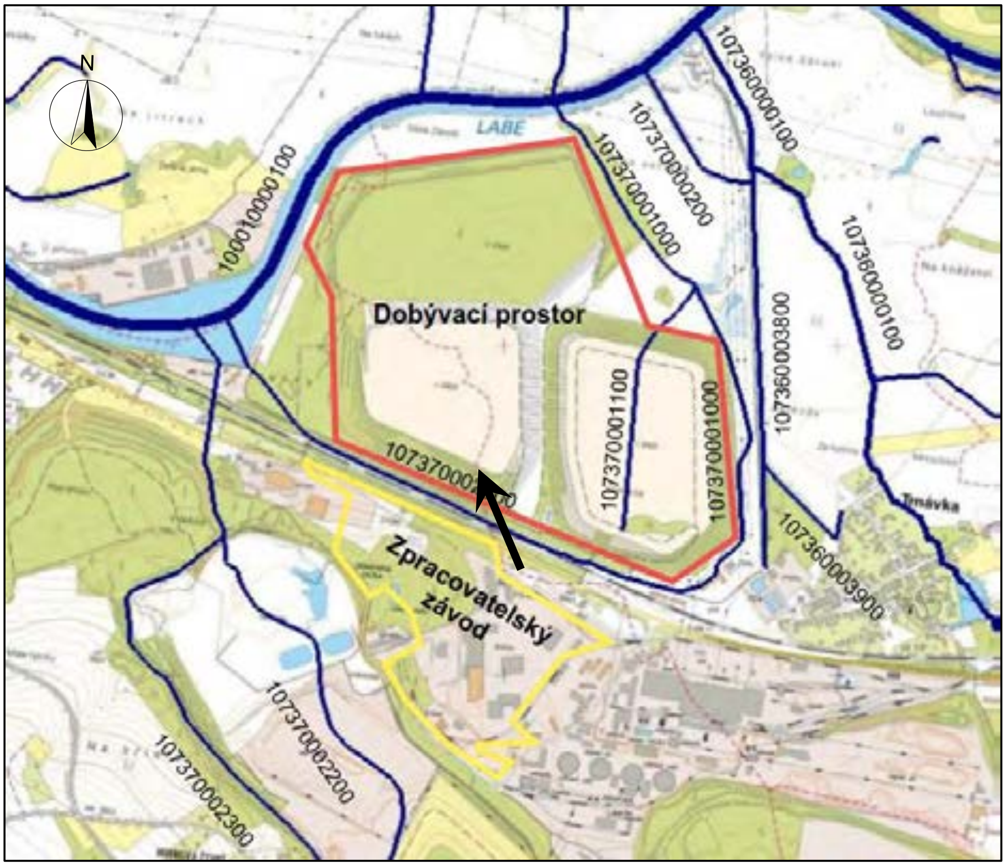
Table 20-5: Labe River, River km 941.532 – Hydrological Data (ČHMÚ)

Parameter	Flow (m^3/s)	Level Height (masl)
Q_{355}	17	--
Qmean	59,2	--
Q_1	285	202.618
Q_5	502	204.200
Q_{20}	705	204.810
Q_{100}	956	205.207
Q_{extr}	1243	205.681

Several minor watercourses are present in the area of interest and its close surroundings. Watercourses in the immediate vicinity of the project area consist primarily of trenches of anthropogenic origin or modified by anthropogenic activity, some with little to no water present; alternatively, they serve to carry treated water away from the ČOV (wastewater treatment plant).

As shown in Figure 20-6, in the area of interest and its vicinity, there are several smaller water flows that subsequently pass into the Labe River, which is of European significance.

Figure 20-6: CMP Location in Relation to Watercourses

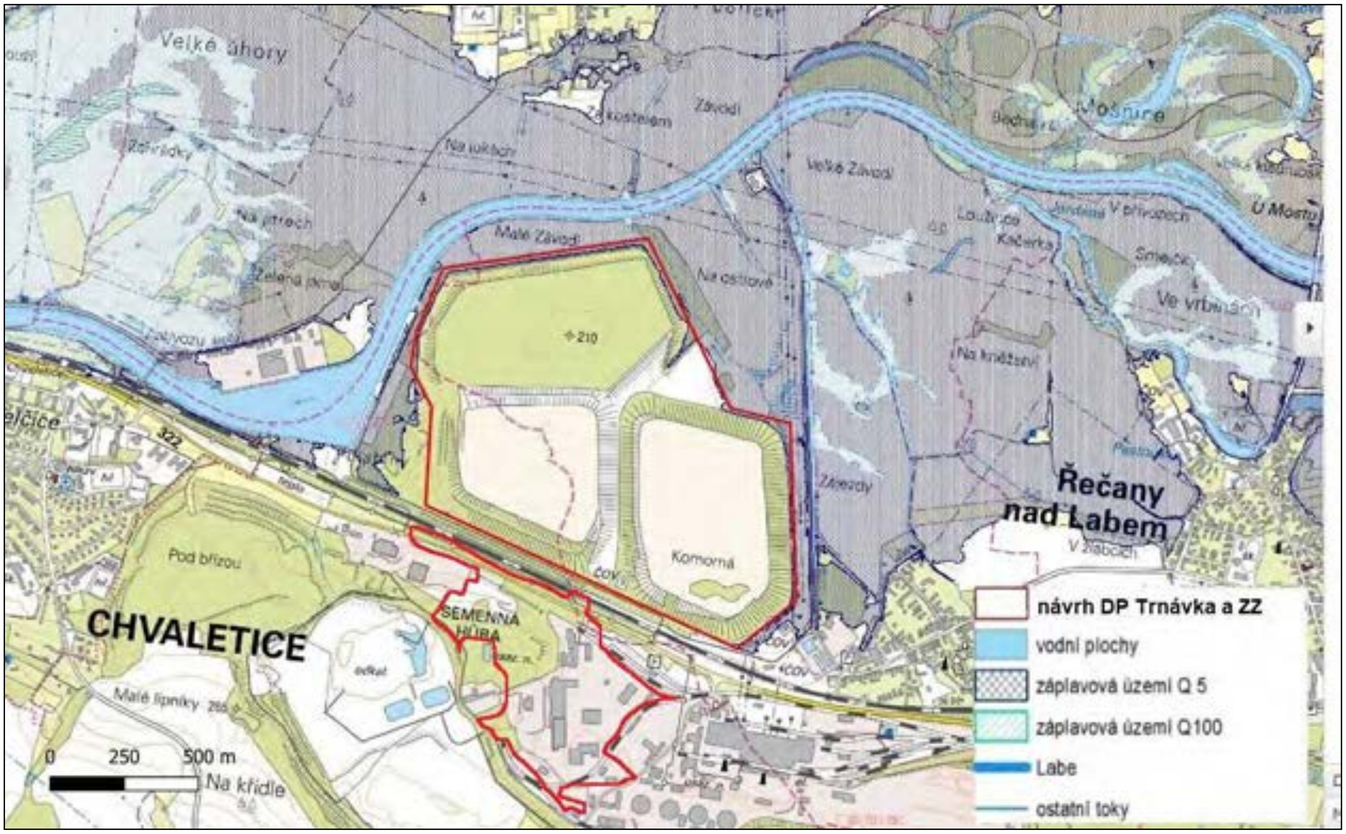


Source: Map service Water management and protection (http://heis.vuv.cz, 2017)

20.5.1 Flood Plains

The flood plains are administratively designated areas that may be flooded with water if a flood occurs. According to official water management service (HEIS, VUV), flood plains Q_5 and Q_{100}, the edge of the tailings piles are in direct contact with flood plains for 5-year and 100-year flows. The tailings piles themselves are protected against flooding due to their elevated position on the landscape and the presence of an existing flood berm.

Figure 20-7: Localization of CMP According to the Flood Plain Map



Source: HEIS, 2020

20.5.2 Chemistry of Surface Water

The chemical composition of surface water is included in the complex water and groundwater monitoring program that was initiated in 2017. The results of surface water chemistry were compared to Decree No. 401/2015 Coll. Surface water quality in the proposed development area is tied to precipitation and runoff, with elevated levels of manganese, magnesium, iron, calcium, and sulphate evident during precipitation events due to runoff from the tailings cells. Elevated concentrations of manganese (Mn concentration reaching units up to the lower tens of mg/L, 194 mg/L max.), sulphates (SO42- concentration reaching the lower units of g/L, 4,080 mg/L max.) and iron (Fe concentration reaching the tens of units of mg/L, 85.3 mg/L max.) were found. As the tailings piles currently support a cover of vegetation, elevated concentrations of such pollutants in surface water suggest that water flowing beneath the tailings piles and away from the footings of the tailings piles are drained into nearby watercourses.

Currently, the Middle Labe River is classified as a Class IV waterway (heavily polluted surface water that has been affected by human activity with water quality values indicative of an unbalanced ecosystem). During operations all contact water will be collected and treated for reuse as process water and/or discharged. Three water treatment plants (WTP) have been included in the design:

- Run-off/contact water, including rainwater, will be treated in a dedicated WTP and reused as process water or discharged into environment after the water quality meets the local discharge requirements.
- Sewage will be treated in a dedicated Sewage WTP, the treated water will be discharged into the Labe River.

- Cooling Towers blowdown water will be treated in a dedicated WTP and mostly reused as process makeup water or discharged into the environment after the water quality meets the local discharge requirements.

The quality of wastewater treated at the sewage water treatment plant and subsequently discharged to the Labe River must comply with parameters as per Government Regulation No. 401/2015 Coll. concerning wastewater discharged into watercourses (according to Annex 1 Table 1a – wastewater treatment plants up to 500 equivalent inhabitants).

Table 20-6: Quality of Purified Waste Water from the ČOV, Released into the Labe River

Indicator	Emission Standards		Maximum Released Amount [kg/year]
	Permissible Value [mg/l]	Maximum Value [mg/l]	
$CHSK_{Cr}$	150	220	1,920
BSK_5	40	80	512
NL	50	80	640

The process wastewater must be treated to the extent that the output parameters will comply with the legislation limits for wastewater drainage into watercourses according to NV 401/2015 Coll. (according to Appendix 1, Table 2). Wastewater effluent discharge criteria will be developed as part of the regulatory process for the CMP.

Table 20-7: Quality of Purified Process Wastewater from the PČOV, Released into the Labe River

CZ-NACE*	Indicator	Emission Standards		Maximum Released Amount [kg/year]
		Acceptable value	Unit	
7.00 7.10 7.29	pH	6 – 9	--	--
	NL	40	[mg/l]	1,200
	$C_{10} – C_{40}$	3	[mg/l]	<10
	Arsenic	0,5	[mg/l]	<5
	Copper	1	[mg/l]	<10
	Lead	0,5	[mg/l]	<5
	Zinc	3	[mg/l]	100
	Iron	3	[mg/l]	100
20.12	RAS	3500	[mg/l]	50 000

Note: 7.00 – mining and ores processing
7.10 and 7.29 - mining and processing of iron and other non-ferrous ores
20.12 - production of chemical substances

Outcomes of initial EIA assessment (EIA Notification) and comments from authorities are summarized as follows:

- The area of interest of the proposed Trnávka mining lease is found in immediate vicinity of an area where moderate, or respectively, high flood risk is defined by the Flood Risk Management Plan. This risk was already taken into consideration in project design.
- Tailings also contain heavy metals (Zn, Cu, Co, Ni, and Pb), which are classified as dangerous, harmful substances according to the Water Act. The Project realization must not result in an increase of the relevant contaminants content in surface water or ground water. Potential effects of the Labe River water quality through surface outflow is reduced by the designed drainage method during the extraction time, as well as after the reclamation and rehabilitation. The contaminated water from the current extraction area will be drained separately by the drainage system and used in the raw material flushing process.
- Discharged waste waters will not negatively affect the surface water quality (including sediments quality) in the Labe River – this requirement was addressed in project design through the inclusion of various water treatment plants.

20.6 Raw Tailings and NMT/LR Characteristics

Preliminary geochemical characterization to assess the potential for acid rock drainage and metal leaching of the existing tailings and the reprocessed tailings residue was completed as part of the PEA study (Tetra Tech, 2019a). Further geochemical characterization of the residue has since been conducted as part of the FS.

20.6.1 Existing Tailings Geochemistry

There are four samples of the source tailings material which have undergone geochemical characterization for ABA and Shake Flask Extraction (SFE) as part of the evaluation of ARD and ML characterization. Sample MA-200 (Head) was analyzed in December 2015, and Sample No.216 was analyzed in January 2016. Both samples are characterized as acid generating with the potential for metals leaching. In July 2017, Tetra Tech collected two additional samples from moisture saturated and unoxidized material in Cell #1 from Test Holes T1-312 (22-23 m, sample CT1312) and T1-313 (18-19 m, CT1313). These samples were classified as non-potentially acid generating and uncertain for acid generation, respectively, based on the Sobek neutralization potential ration method and classification scheme presented in Mine Environmental Neutral Drainage (MEND) report 1.20.1 (Price, 2009). Using a carbonate neutralization potential ratio, both samples would be classified as non-potentially acid generating. A multi-element sequential leach extraction test was performed on these samples.

20.6.2 Filtered Residue (Reprocessed Tailings) Geochemistry

20.6.2.1 Test Work Before 2019

Preliminary geochemical characterization of one sample of representative final residue has been completed. The original tailings (magnetic separation feed) sample, identified as the P2 composite, was relatively fine particle-size tailings material, and the reprocessed tailings sample was a blended mixture of the washed LR cake and the NMT material. ABA and SFE tests were undertaken on a prepared mixture of NMT and LR obtained from metallurgical testing.

The results indicate that the sample classifies as potentially acid generating (PAG), based on neutralization potential ratio (NPR) values less than 1. Table 20-9 provides a summary of NPR values based on different calculation methods.

TETRA TECH

Table 20-8: Sample Classification Based on NPR Value

Sobek NPR		Carbonate NPR		Sample Classification
Sobek NP/MPA	Sobek NP/AP	Carbonate NP/MPA	Carbonate NP/AP	
0.27	0.71	0.14	0.35	PAG

Notes: NP – neutralization potential; MPA – maximum potential acidity; AP – acid production potential

The paste pH is 6.6 indicating near neutral conditions at the time of testing. Neutral paste pH values indicate either that acid generation has not occurred or that it has been sufficiently buffered to remain as a neutral leachate.

Total sulphur content is 4.79%. The sulphide sulphur content is 1.86% while the sulphate sulphur content is 2.90% sulphur. Sulphide and sulphate sulphur are the dominant forms of sulphur in the system, the remaining 0.03% of total sulphur content may be elemental or organic sulphur. The ratio of sulphide to sulphate sulphur indicates that a majority of sulphide oxidation may have already occurred and produced sulphates.

The carbonate neutralization potential value of 20.5 kg of calcium carbonate ($CaCO_3$) per tonne is about one half of the Sobek NP value of 41 kg of calcium carbonate per tonne. This indicates that the neutralization potential in the sample is provided from both carbonate and non-carbonate sources. The mineralogy of the sample is unknown, but the non-carbonate sources are likely hydroxide and silicate minerals. Carbonate minerals provide the most readily available and fastest reacting source of neutralization potential. Other forms of neutralization potential may not be available to provide effective buffering under natural conditions. The effective neutralization potential of the system is likely somewhere in between the Sobek and Carbonate neutralization potential values.

The detection limits of analysis applied during SFE testing had to be increased due to the high amounts of dissolved solids in the sample, particularly with respect to calcium, manganese, hardness, and sulphate.

Further geochemical characterization of the residue was completed during the FS.

20.6.2.2 Test Work During 2020 to 2022

Three residue samples were generated from the 2019-2021 metallurgical test program for further geochemical characterization. These samples were tested by ALS Environmental and ALS Metallurgy, accredited laboratories in Canada, and include non-magnetic tailings, washed leach residue, and a blend from the non-magnetic tailings and the washed leach residue. The LR sample was washed five times to simulate the planned leach residue washing procedure which will involve on-stream filter cake washing. The tailings and leaching residue sample chemical and mineralogical characteristics, metal leachability, and acid generation potential were determined as part of the work. The test results show:

- LR is classified as potentially acid generating (PAG) with a very low net potential ratio (NPR) value. The sample has very low (below detection limit) carbonate content, as well as very little neutralization potential (NP) contributed from non-carbonate minerals. Paste pH value is 6.3, which is mildly acidic, and is expected in the first few weeks of Humidity Cell results. Total sulphur is high with a value of 9.78% and sulphide sulphur makes up 2.05% of the total sulphur.
- NMT is classified as uncertain PAG potential with NPR values slightly over 1.0 and with a paste pH of 7.0. This sample has some carbonate content and slightly less sulphide content than the LR sample at 1.58%.
- SFE analysis results indicated that one leachable metal, manganese (Mn), is measured to exceed more than one magnitude greater than the CCME (Canadian Council of Ministers of the Environment) and/or BCAWQG-

FST (BC Approved Water Quality Guidelines - Freshwater Short Term) guidelines (8.0 mg/L) in both the LR (41.2 mg/L) and NMT (21.3 mg/L) samples. Leachable phosphorus (P) measured is below detection limit values. Measured pH values of 6.95 and 7.76 are neutral pH within the guidelines (pH 6.5 – 9.0) for LR and NMT respectively.

The non-magnetic tailings and washed leach residue blend was tested by humidity cell procedure to determine the rate of acid generation and variation over time in leachate water quality. The testing period lasted 40 weeks (starting in September 2021 and ending in June 2022). The test results are summarized below:

- pH continues to decrease towards 40 weeks to pH 3.49
- Acidity gradually increased from approximately Week 21 to 40 with a spike at Week 33
- Alkalinity continually dropped from Week 1 to 19, then remained below detection limit <2.0 mg/L from Week 19 to 40
- Sulphate remains relatively consistent throughout the 40 weeks with no apparent trend
- Sulphate production and carbonate consumption are consistently variable along a continual trend for the 40 weeks after an initial 'flush' from Week 1-3
- Dissolved aluminium remained below detection limit to Week 23, followed by a significant and consistent increase from Week 23-40. The measured aluminium content is approximately 1.7 mg/L at Week 40.
- Dissolved copper remained below detection to Week 23, followed by an increase to Week 40, but measured copper content is below 1.0 mg/L at Week 40
- Dissolved zinc increases from Week 1-25 then decreases to Week 40. Values remain below 3.0 mg/L
- Dissolved manganese increased initially from Week 1-7 then remained variable along a relatively consistent trend at 250 mg/L to Week 40
- Dissolved cobalt and nickel follow relatively similar trends with an increase initially to Week 16 (nickel) and Week 26 (cobalt), followed by a decrease to approximately 0.2 mg/L for the metals at Week 40
- Dissolved cadmium increased overall to Week 26, then decreased to approximately 0.003 mg/L at Week 40

The humidity cell test results confirm that the non-magnetic tailings and washed leach residue blend is expected to be a potentially acid generating material. The material should be stored in a lined storage facility.

20.7 Hydrogeology

The underground water flow is directed northward to the drainage base formed by the Labe River. Underground water of the shallow Quaternary as well as deeper Cretaceous circulation is drained into this river.

Within some of the areas proposed for development, groundwater levels have been shown to fluctuate substantially, to the point of being completely dry at times. Groundwater quality in the area often does not meet drinking water criteria, potentially due to the leaching of metals and other ions from the existing tailings cells, waste rock from the original open pit mining operation that generated the CMP tailings, and the local geology that is rich in sulphide minerals. Elevated levels of manganese, magnesium, iron, calcium, and sulphate are most notable.

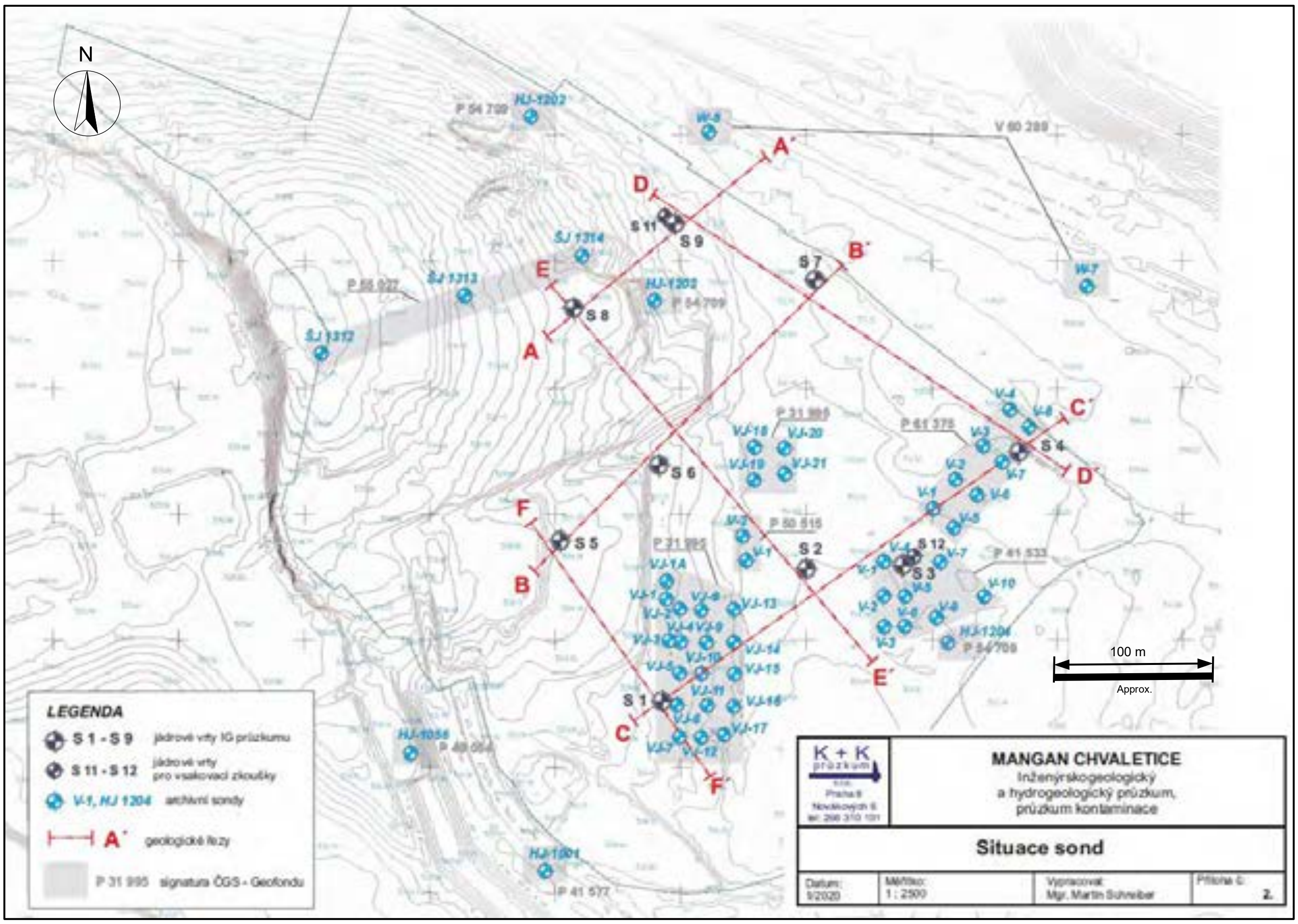
Hydrogeological and environmental studies and monitoring have been carried out in the proposed process plant area as well as in the tailings cells areas.

20.7.1 Process Plant Area

Hydrogeological surveys and monitoring have been carried out in the proposed process plant area in 2018 (OPV, 2018) and in 2020 (K+K, 2020).

A total of 11 new core boreholes were drilled as part of the engineering and geological and hydrogeological survey in 2020, of which nine (9) deeper boreholes were used to verify the engineering and geological conditions of the site. Two (2) shallower boreholes were also drilled for hydrogeological assessment of the possibility of percolation. The nine (9) deeper boreholes, marked S 1 to S 9, reached depths of 6 – 11 m.

Figure 20-8: Reconnaissance Probe Localization (K+K, 2020)



Source: K + K průzkum, s.r.o. 2021

In the area of interest, the groundwater level in new boreholes was found at a depth of 2.16–7.64 m below the ground, at the point of 207.61–216.86 masl. Groundwater is present in both Quaternary clays, which have limited intergranular permeability, and Cretaceous sandstones with relatively higher intergranular and fissure permeability, as well as marlstones and shales with limited permeability.

As part of the hydrogeological survey (K+K, 01/2020) the possibility of rainwater infiltration was verified to determine the indicative hydraulic parameters, namely the percolation coefficient.

The percolation coefficient kv = 1.01·10-6 m/s was determined from the percolation test result in borehole S11 for clay soils environment. The percolation coefficient kv = 1.45·10-5 m/s was determined from the percolation test result in borehole S12 for Quaternary sands bedrock with Cretaceous sandstones.

Given the relatively shallow groundwater level and taking into account the occurrence of backfills in the upper zone of the geological profile, the infiltration of rainwater at the site is undesirable.

A contamination survey was carried out in the area of interest to determine whether pollution had affected the geological environment. Groundwater samples were collected and subjected to a complete chemical analysis supplemented with the determination of concentration of C10–C40 hydrocarbons, trace metals, chlorinated aliphatic hydrocarbons, monocyclic aromatic hydrocarbons (BTEX), polycyclic aromatic hydrocarbons (PAH) and polychlorinated biphenyls (PCB). The determined concentrations of the analysed elements were compared with the criteria according to the Methodological Instruction of the Ministry of the Environment Pollution Indicators (2014). Based on the performed analyses, groundwater pollution was not detected, with the exception of an increase in nickel concentration, which was found in well S4 in the amount of 0.45 mg/L (while the limit is set at 0.02 mg/L according to the Methodological Instruction of the Ministry of the Environment). This finding is not considered to be a major contamination, however, it does serve to document industrial activities that have been carried out in the area of interest in the past.

Another monitoring event was carried out in 2018. A total of 12 survey boreholes were drilled in the proposed process plant area to a depth of 3 m to establish a baseline of the existing state of the soil and rock, including potential contaminants in the area of interest. Figure 20-9 shows the borehole locations. Soil samples were taken as a composite mix at depths ranging from 1 to 3 m. Table 20-9 shows the results. The samples were analyzed for the contents of selected toxicologically relevant metals, polycyclic aromatic compounds and petroleum substances determined as hydrocarbons C10–C40. The analyzed values were compared with the "Pollution Indicators" referenced in the MoE 1/2014. The maximum permissible contents in wastes that can be stored freely on the terrain, as stated in Decree No. 294/2005 Coll., as amended, were used as an additional reference.

Figure 20-9: Soil and Ground Water Sample Locations at Process Plant Area

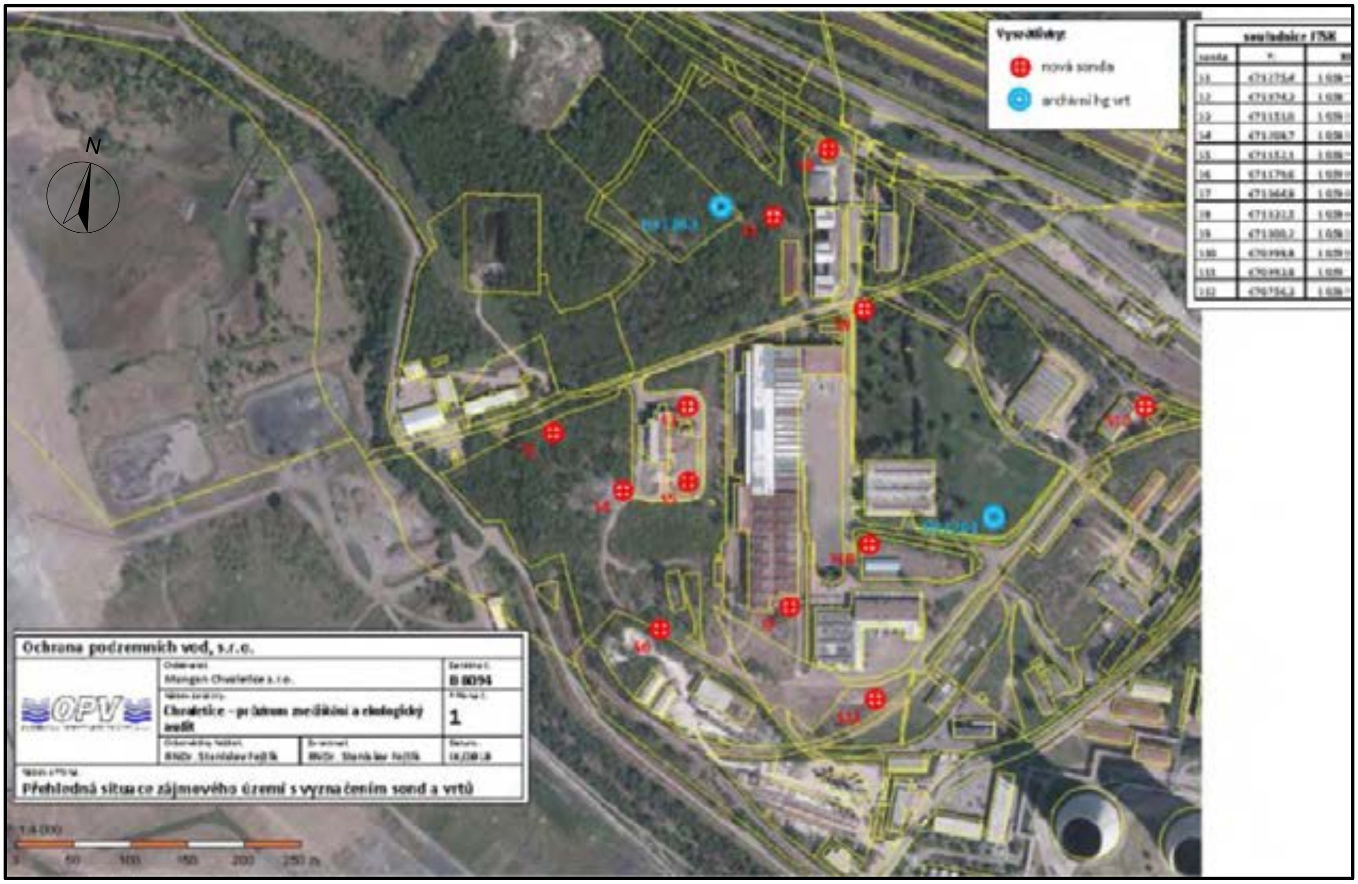


Table 20-9: Soil Samples[1], in mg/kg of Dry Matter [2]

Borehole	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	PI 3	294/2005 Sb.4
Arsenic, As	170	48	54	17	24	8,4	40	36	49	27	57	53	2.4	10
Cadmium, Cd	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0 .5	<0.5	800	1
Chromium, Cr	46	25	20	12	16	12	61	25	17	14	18	13	N/A	200
Copper, Cu	34	29	140	24	35	17	120	110	31	50	94	50	41,000	N/A
Mercury, Hg	0.31	0.24	0.34	0.78	0.36	<0.1	0.27	0..13	0.20	0.17	0.22	0..32	43	0.8
Nickel, Ni	25	34	180	<10	19	52	69	22	24	29	18	51	20,000	N/A
Lead, Pb	<20	<20	<20	<20	<20	<20	64	<20	<20	<20	52	<20	800	100
Vanadium, V	77	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	5,100	180
Zinc, Zn	70	88	110	62	75	68	310	87	58	68	130	95	310,000	N/A
Hydrocarbons C10–C40	89	< 30	94	290	73	< 30	220	< 30	52	66	35	250	1,500	300
Naphthalene	0.15	0.13	0.13	0.11	0.13	0.12	0.15	0.11	0.15	0.12	0.13	0.15	18	N/A
Phenanthrene	0.66	0.044	0.092	0.046	0.061	0.038	0.29	0.045	0.54	0.13	0.13	0.29	N/A	N/A
Anthracene	0.12	<0.01	<0.01	<0.01	<0.01	<0.01	0.065	<0.01	0.14	0.022	0.027	0.029	170,000	N/A
Fluoranthene	0.76	0.025	0.12	0.041	0.063	0.029	0.58	0.041	0.82	0.28	0.3	0.39	22,000	N/A
Pyrene	0.47	0.018	0.1	0.037	0.52	0.027	0.55	0.035	0.61	0.24	0.26	0.3	17,000	N/A
Benzo(a)anthracene	0.28	0.01	0.036	0.018	0.23	0.014	0.23	0.018	0.32	0.16	0.17	0.11	2.1	N/A
Chrysene	0.38	0.015	0.041	0.03	0.34	0.016	0.33	0.028	0.39	0.14	0.15	0.12	210	N/A
Benzo(b)fluoranthene	0.19	0.01	0.093	0.024	0.24	0.016	0.34	<0.01	0.22	0.23	0.19	0.11	2.1	N/A
Benzo(k)fluoranthene	0.077	<0.01	0.032	0.012	<0.01	<0.01	0.35	<0.01	0.11	0.099	0.091	0.038	21	N/A
Benzo(a)pyrene	0.14	<0.01	0.052	0.015	0.17	0.012	0.38	<0.01	0.16	0.17	0.12	0.052	0.21	N/A
Ideno(1,2,3-cd)pyrene	0.14	<0.01	0.029	<0.01	<0.01	0.014	0.31	<0.01	0.19	0.13	0.097	0.027	2.1	N/A
Benzo(ghi)perylene	0.062	<0.01	0.041	0.013	<0.01	<0.01	0.37	<0.01	0.082	0.12	0.076	0.024	N/A	N/A
Σ PAH [5]	3.43	0.252	0.766	0.346	1.75	0.0289	3.95	0.295	3.73	1.84	1.74	1.64	N/A	6

Notes: [1] Sampling Depth: 1 to 3 m ; [2] Unit: mg/kg of matter, excluding sampling depth in meter ; [3] PI: Pollution Indicators ; [4] 294/2005 Sb.: Decree No. 294/2005 Coll ; [5] ΣPAH: Polycyclic Aromatic Hydrocarbons

TETRA TECH

According to the MoE, the indicator value for arsenic is exceeded in all samples. However, it should be noted that the pollution indicator for arsenic is a disproportionately low value, particularly when compared to other values for arsenic that provide additional context, as presented below:

- The Clarke values in the upper part of the earth's crust (4.5 mg of arsenic per kilogram of dry matter)
- And the limit values according to the general regulations for surface waste (10 mg of arsenic per kilogram of dry matter according to Decree No. 294/2005 Coll.)
- Or in agricultural land soils (30 mg of arsenic per kilogram of dry matter according to Decree No. 13/1994 Coll., as amended—in particular, Decree No. 153/2016 Coll.)

However, in accordance with the recommendations of the MoE 1/2014 "Pollution Indicators", it is necessary to determine the local background value of the pollutant including consideration of the geological structure and previous pyrite mining activity where higher contents of arsenic can be expected. As such, a value of 40 to 50 mg per kilogram of dry matter for arsenic is considered more appropriate for the area. From this point of view, only arsenic content in the borehole S1, exceeds this value.

In the Czech Republic, arsenic in elevated concentrations is a common phenomenon, particularly in rocks containing sulphides such as slate. These rocks are found in a number of locations in the Bohemian Massif, e.g., in Barrandien, Nizky Jesenik, and generally in the bedrock of large parts of Cretaceous sediments, surrounding Chvaletice.

Most of the arsenic is present in the Kutna Hora region, where arsenopyrite minerals are strongly present. Arsenic concentrations in the Kank area are several thousand times higher (thousands to tens of thousands of milligrams of arsenic per kilogram of dry matter) than in the rest of the Czech Republic. These concentrations are considered as local background.

In the case of petroleum hydrocarbons, low levels not exceeding the pollution indicator were found in all boreholes. The content of polycyclic aromatic hydrocarbon (PAH) substances can also be evaluated similarly, as the indicator value was only slightly exceeded in case of benzo(a)pyrene in borehole S7, located in front of the industrial hall.

The quality of groundwater was verified by sampling from two archived boreholes, HJ 1203, which is located in the forested northern area, and HJ 1204 in the east of the area of interest. No anomalies were detected from the viewpoint of metal content in the water. The measured values are very low and within the detection limit level. The groundwater chemistry for both samples is mineralized, mainly due to the presence of sulphate. The groundwater sample from borehole HJ 1204 is strongly acidic (pH = 3.6) with a high content of sulphates and iron and free carbon dioxide. This is due to the rock chemistry near the borehole which is in close proximity with layers of oxidized pyrite.

20.7.2 Tailings Area

Monitoring of the groundwater table has been underway in the area of the tailings cells and the surrounding area since 2015 (Figure 20-10). Chemical analysis of the water was conducted by the Jihlava office of Ostrava-based Health Institute. It is assumed that groundwater monitoring will continue throughout all phases of the project, including during reclamation after the activities are finished.

Figure 20-10: Hydrogeological Monitoring Locations in Relation to Area of Interest

Source: Hydro geological monitoring (Geomin 2017)

In late 2018 detailed hydrogeological exploration commenced which included an extensive hydrogeological drilling and monitoring program. This assessment of the tailings piles should significantly contribute to the monitoring of changes in flow and chemistry of tailing's water over time. This detailed analysis will help determine the following: the sorption of tailing's material and quaternary collectors; hydraulic characteristics (storativity, transmissivity, filtration coefficient) in the body of the tailings piles and of the surrounding area; assess the infiltration effect of the water from tailings piles to the surrounding quaternary collector; and assess the dynamics and chemical changes of the groundwater water transiting in and out of the tailings piles. The resulting data will be used to create a complex transport and geochemical model using the Modflow mathematical modelling code (GMS software). The collected data will be used as part of the risk analysis and mitigation strategy required for the EIA permitting process.

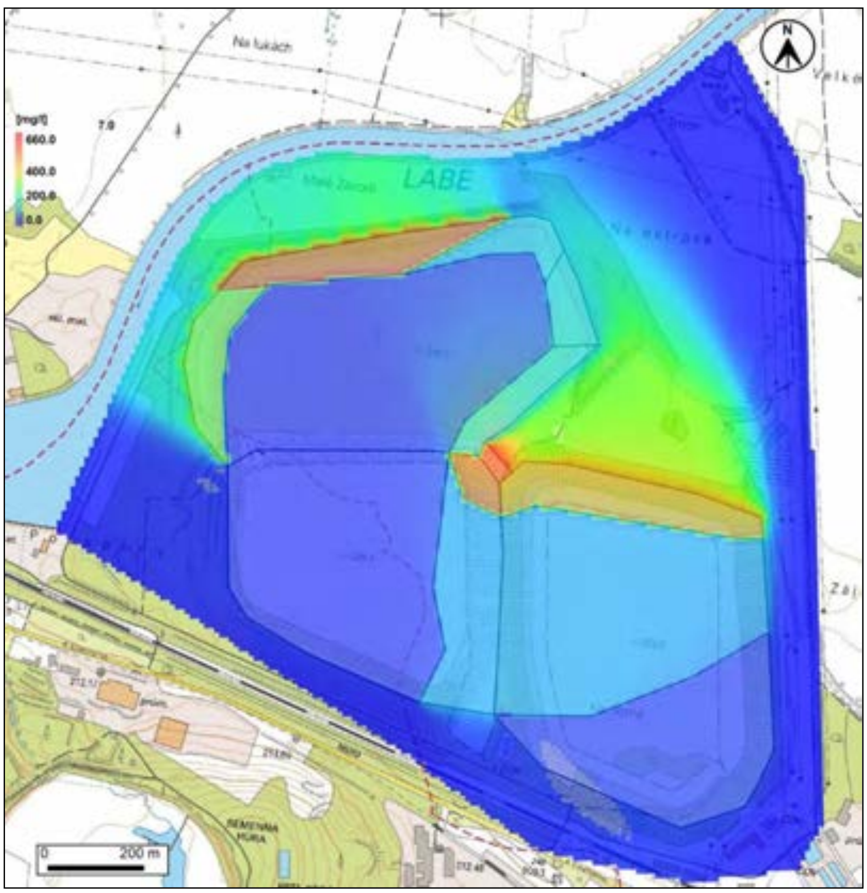
The hydrogeological drilling program ran from December 5 to 13, 2018. The drilling contractor was Intermarket Company using a SOILMEC 65 piloting rig. A total of eight new hydrogeological boreholes were drilled. Drilled material was logged on site and samples were collected into plastic buckets every 3 m for chemical analyses. A total of 47 samples were collected. In addition, 10 samples were collected for the Institute of Geological Sciences of Masaryk University in Brno for the purpose of specimen processing for models of water element spreading.

The impact on groundwater and surface water was evaluated summarily in the hydrogeologic evaluation and assessment within the EIA Notification process. The evaluation used other professional studies based on drill works, hydro-geologic monitoring, determination of groundwater and surface water quality and groundwater flowing modelling from the year 2015 – 2020.

Chemical composition of the underground water at the tailings piles and in their vicinity, as well as in the wider surroundings, is considerably affected by anthropogenic activity. In addition to the original mining activity in the locality that generated dumps of waste material and tailings piles, other sources of contamination affecting underground and surface water in the area include inter-deposits of coal, the ash from the power plant and the TKO (municipal solid waste) landfill.

Groundwater samples from the tailings piles and their immediate surroundings show distinctly higher concentrations of some parameters, particularly manganese (Mn concentrations reaching tens up to lower hundreds of mg/L, 658 mg/L max.), sulphates (SO_4^{2-} concentrations reaching lower units of g/L, 9,200 mg/L max.), iron (Fe concentrations reaching tens up to lower hundreds of mg/L, 979 mg/L max.), and aluminium (Al concentrations reaching tenths up to lower units of mg/L, 22.9 mg/L max.). Other observed parameters also show an increase more or less compared to, for example, hygienic limits for potable water; however, they are far from reaching the values of the indicators above. Increased concentrations of the observed indicators are directly related to the deposited materials at the tailings piles. According to the transport model results, up to 45.5 kg of Mn, 37.6 kg of Fe and 234 kg of S (and thus 701.6 kg of sulphates) could be released daily into the Labe River through underground water.

Figure 20-11: Scope of Contamination of Shallow Mn Aquifier



Source: EIA Notification

Home wells in surrounding municipalities (Trnávka, Chvaletice-Telčice) are less affected by the chemical composition of underground water. When compared to hygienic limits for potable water, the analyzed samples showed elevated concentrations of manganese (Mn concentration up to the lower hundredths of mg/L, 0.35 mg/L max.) iron (Fe concentration usually reaching the lower tenths of mg/L, 1.31 mg/L max.) and nitrates (NO3- concentration in the higher tens of mg/L, 188 mg/L max.). However, the tailings piles have no direct impact on the quality of underground water in these wells as they are found downstream of the flow of underground water.

Assessment of the impacts on surface water and groundwater within the EIA Notification process concluded the following: With respect to the identified contamination of surface and groundwater in the tailings, where the proven source of contamination is material coming from former mining activities, the effect of the planned tailings processing can be considered as a positive activity. The proposed process of remediation and reclamation will lead to a substantial decrease of surface water seepage into the stacked material and, as a result, to substantial decrease of leaching of pollutants from the tailings into the groundwater and surface water.

Ultimately the tailings remediation and reclamation is expected to stop one of the source of surface and groundwater contamination in the area and the consequent polluted run-off into Labe River.

20.8 Health Impacts Assessment

The Project is acceptable from the point of view of possible impact to public health, as it is unlikely to unbearably worsen the burden of the affected population by spreading above-limit noise emission or assessed air pollutants compared to current conditions. In conclusion of the Health Impact Assessment, based on a summary of the findings, it can be stated that the implementation of the CMP brings virtually unchanged exposure scenarios regarding noise emissions and air pollutants, and therefore its implementation can be expected to not change the level of risks to public health in the concerned area. There is even a positive aspect of the Project implementation of the noise mitigation actions, which will reduce the noise emission from traffic in the surrounding village, which will significantly contribute to reducing the intensity of nuisance and attributive risk of cardiovascular disorders in exposed populations.

20.9 Ecosystems and Vegetation

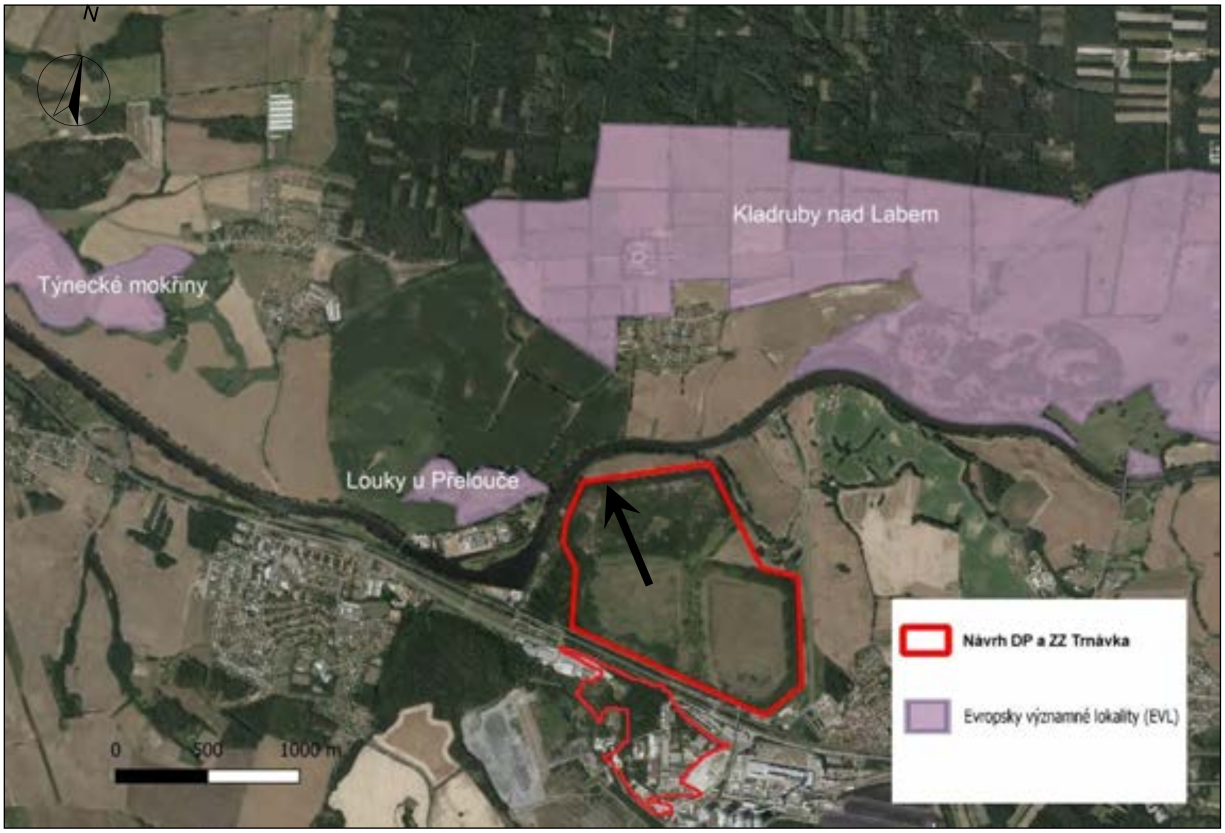
The area of interest supports a mix of ecosystems including woodland (including riparian woodland adjacent to the Labe River), farmland/agricultural, shrubby vegetation, and industrialized areas.

Natura 2000 is a network of protected areas created by the individual European Union member states on their territories according to uniform principles. The objective of the system is to protect the species of animals, plants, and types of natural sites, which are the most important, endangered, rare or limited only to a certain area. Creation and protection of the Natura 2000 locations system is defined in two legal regulations concerning nature protection: Directive No. 2009/147/ES On the protection of free-living birds ("the Bird Directive") and the Directive No. 92/43/EHS, On protection of natural sites, free-living animals and wildly growing plants ("the Sites Directive").The directives are implemented in legislation under Act No. 114/1992 Coll., on nature and landscape conservation.

None of the Natura 2000 system elements reach into the area of interest and all that are relatively near are north of (i.e., separated by) the Labe River. The EVL Louky u Přelouče (code: CZ 0537011) approximately 170 m to the west, EVL Kladruby nad Labem (code: CZ 0533698) approximately 1 km to the north and EVL Týnecké mokřiny (code: CZ 0213061) approximately 2.4 km to the northwest are found near the area of interest. No bird areas are found near the area of interest.

According to the character of the project and to the distance of Natura 2000 sites from the area of interest, no influences of the project on the Natura 2000 sites are present (concluded in Regional Authority Statement).

Figure 20-12: Location of Project According to Map of Natura 2000 Sites



Source: Nature Conservancy Central Register (www.nature.cz 2017)

There are no protected parts of nature in the area of the project or in its immediate vicinity in the sense of Act no. No. 114/92 Coll. Specially protected areas do not occur in the vicinity of the proposed construction.

The nearest small-scale specially protected areas in the vicinity of the area of interest are:

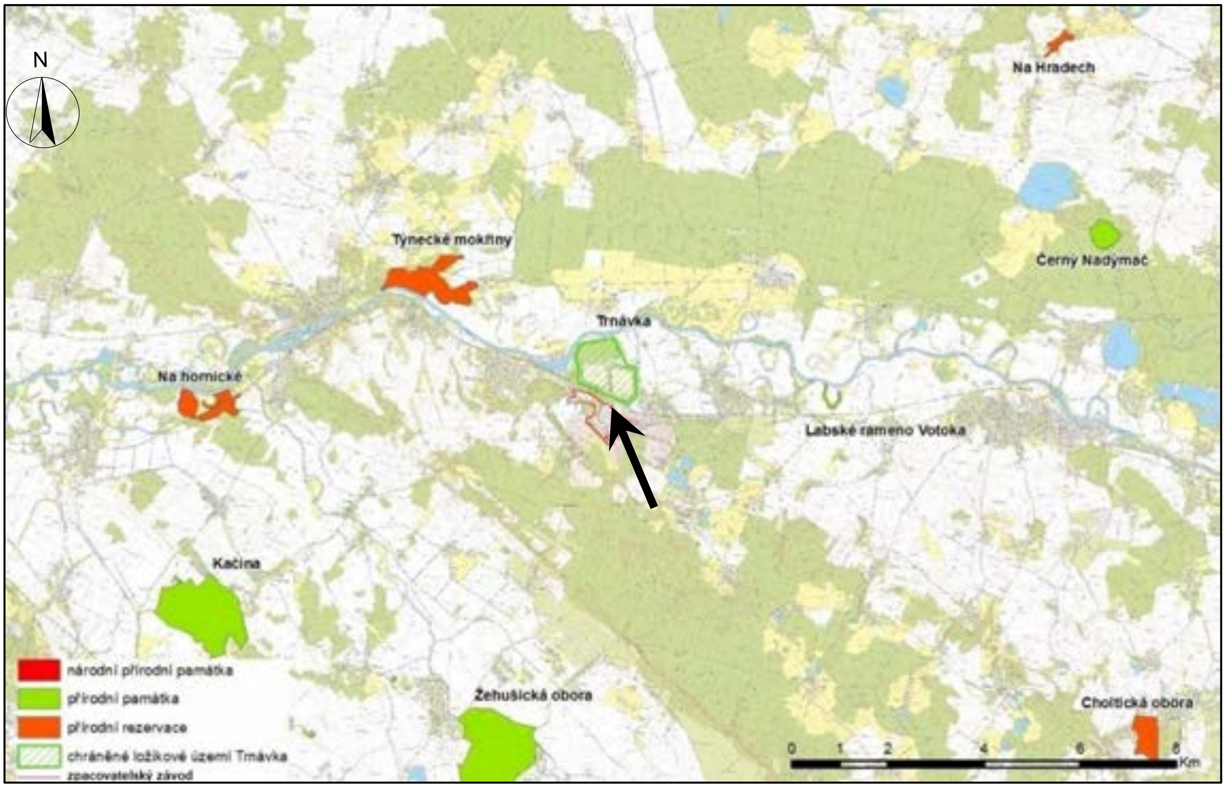
- Nature Reserve Týnecké mokřiny found approximately 2.5 km to the northwest,
- Natural Monument Labské rameno found approximately 4.0 km to the southeast,
- Nature Reserve Na Hornické found approximately 7.0 km to the southwest of the area of interest.

No natural park exists in the immediate vicinity of the assessed objective location.

The closest national park is over 15 km away from the objective area (e.g., the national park Heřmanův Městec, Doubrava).

Figure 20-13 illustrates the relation between the area of interest and the areas specially protected areas.

Figure 20-13: Area of Interest in Relation to Specially Protected Areas



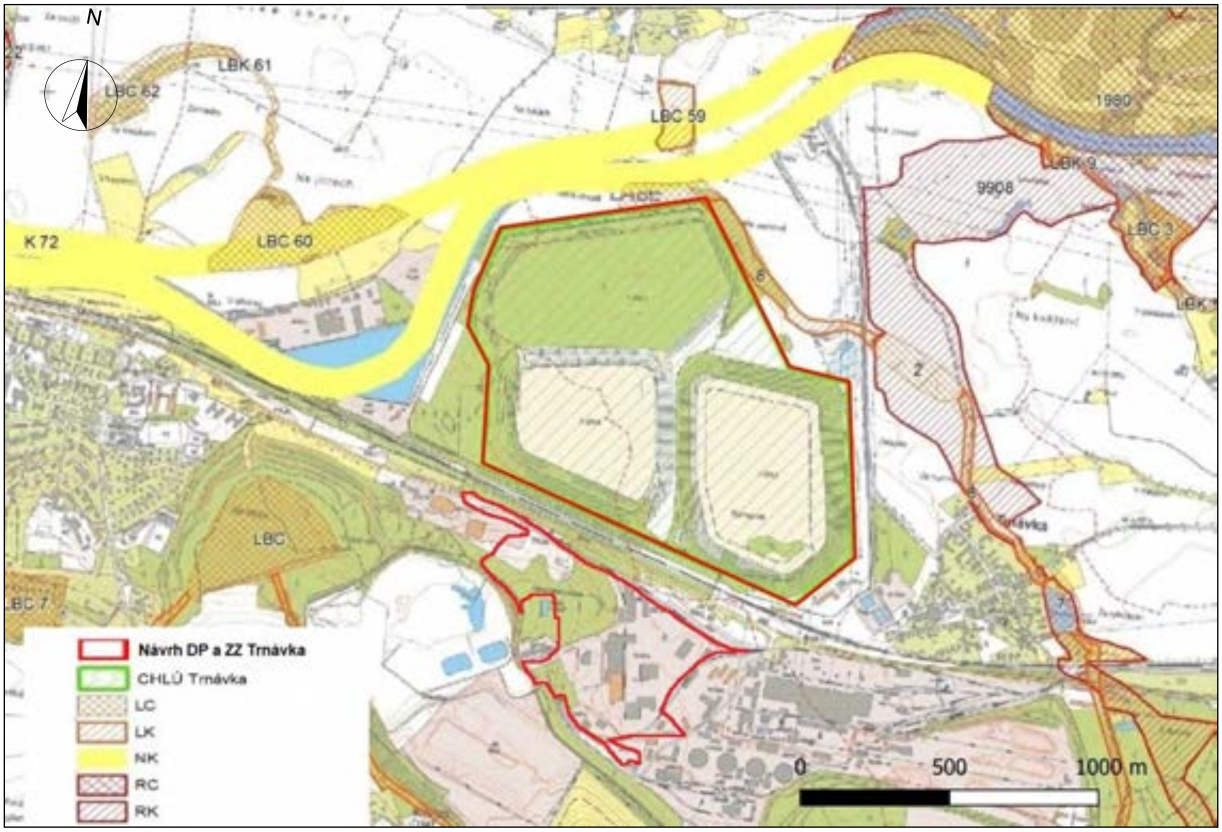
Source: Nature Conservancy Central Register (www.nature.cz, 2017)

Act No. 114/1992 Coll. defines the territorial ecological stability system as an interconnected set of natural ecosystems and modified ecosystems but close to nature that maintain natural balance. ÚSES (Territorial System of Landscape Ecological Stability) is designed to create a network of biocentres and biocorridors that interconnect them. ÚSES assists with the preservation or expansion of the gene pool of plants and animals of natural communities and enables them to move throughout the area.

No ÚSES elements are within the project area; however, the following are in itsrelatively close proximity:

- Axis of the supraregional biocorridor NK72 (Polabský luh – Bohdaneč) approximately 100 m north of the project area.
- Regional biocorridor RK 1327 (Oklika – Litošice) approximately 400 m west of the project area and the regional biocorridor 9908 (Řečany – RK 1327) approximately 100 m west of the project area.
- Local biocentre (LK) and the local biocorridor (LC) at the north-east boundary of the project area; this is predominantly a dry bed of a nameless watercourse with accompanying vegetation.

Figure 20-14: Localization of the Project and ÚSES According to ÚAP ORP Přelouč – 4th Update 2016



Source: mestoprelouc.cz

20.9.1 UNESCO

The landscape for breeding and training of ceremonial carriage horses in Kladruby nad Labem, approximately 200 m to the north of the area of interest, is the nearest monument of UNESCO World Heritage. The stud farm is protected as an NKP (national cultural monument). The entirety of the planned extraction area is part of the buffer zone around this national cultural monument.

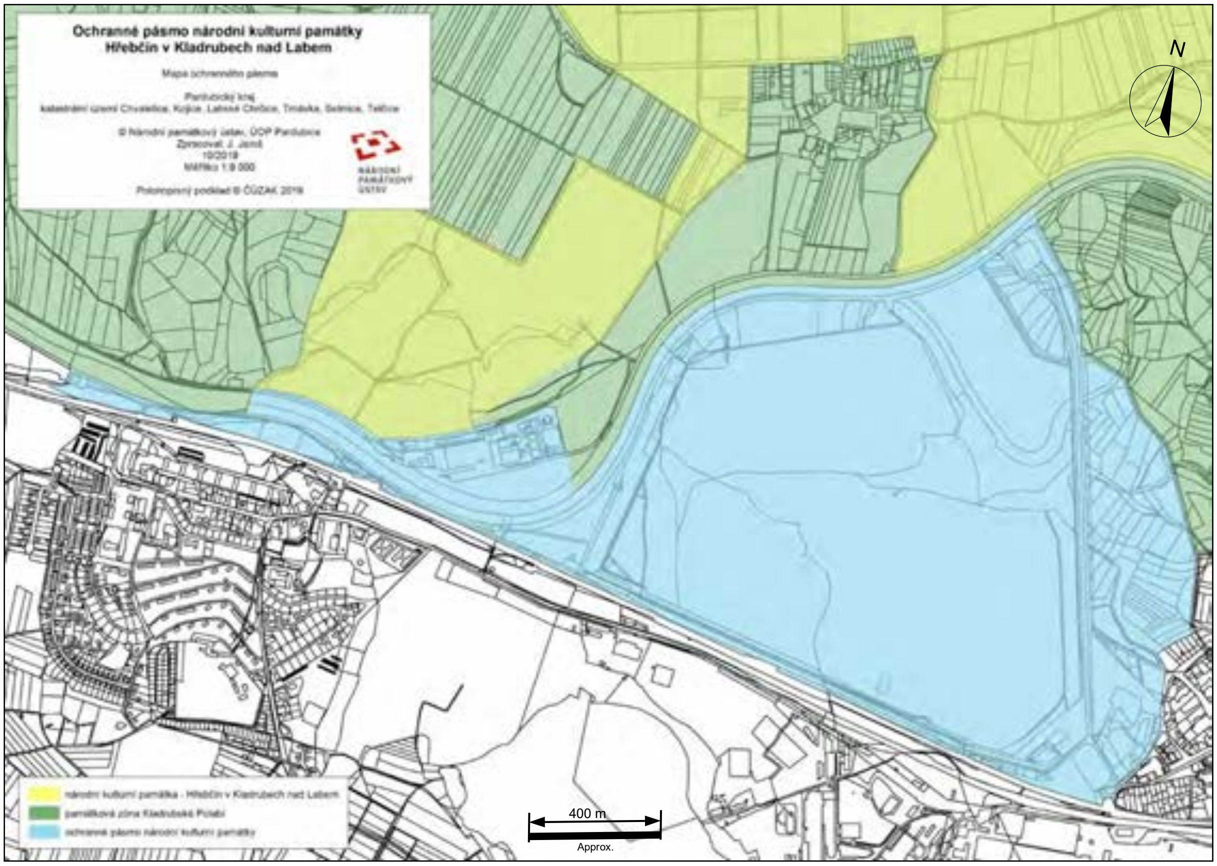
The objective is to ensure sufficient historic preservation of the relevant territory through the establishment of a protective zone around a National Cultural Monument. In the protective zone, emphasis is given to maintaining the view and composition links to urban and landscape values of the National Cultural Monument Hřebčín in Kladruby nad Labem, particularly with respect to:

- Maintaining the existing silhouette and panorama
- Maintaining the basic characteristic views and perspectives on the NKP
- Maintaining and controlling the surrounding structures height that would limit the views of the NKP
- Maintaining the suitable utilization functions and rehabilitation of unsuitably utilized areas
- All constructions, terrain modifications and arrangements whose overall height is less than 10 m and whose highest point does not exceed 229 masl

In all other cases, an application has to be filed with the competent state monument preservation authority for issuance of a binding opinion pursuant to Section 14(2) of the State Monument Preservation Act.

The entire proposed mining lease is within the territory of the protected zone of UNESCO monument.

Figure 20-15: Protected Zone of UNESCO Landscape for Breeding and Training of Ceremonial Carriage Horses in Kladruby and Labem



Source: NPU, 2020

20.9.1.1 Mining Area

A total of 215 plant taxa were documented in the area. No rare or endangered plant species protected by law according to Decree 395/1992 Coll. were identified within the location or in its close surroundings. From the taxa specified in the IUCN Red List of Plants the following species have been found*: Chenopodium bonus-henricus* (C4a), *Carex curvata* (C3), C*ucubalus baccifer* (C3), and *Filago arvensis* (C3). Mitigation measures (e.g., avoidance or targeted transfers of the relevant plants) have not been suggested in this stage of the environmental assessment.

20.9.1.2 Dendrological Survey

A dendrological survey was performed using the method of trial areas. In the scope of the survey, the project area was divided in 22 zones of groups homogeneous in terms of taxonomy and size, and furthermore, 2 zones of continuous brush vegetation were distinguished. In total, a vegetated area approximately 56.6 ha in size was assessed.

The occurrence of 134,357 trees was confirmed in the area of Tailings area. A relatively narrow composition of woody plants in terms of species is found in the area of interest. They include predominantly *Betula pendula* and *Populus tremula, Acer platanoides*, *Pinus sylvestris*, *Betula pendula*, other poplar species (*Populus* spp.), and oak (*Quercus* spp.) trees.

Two areas of continuous shrub vegetation are present in the area of interest. The first one is found in the southwest part of the area of interest and is approximately 2.24 ha in size. This shrub vegetation is composed predominantly of *Amorpha fruticosa* and *Crataegus monogyna*. The second shrubby area is found at the east tailings pile, its size is 0.64 ha and is composed predominantly of *Crataegus monogyna*.

A separate dendrological survey was carried out as a part of biological survey in 2019. About 200 items were recorded in the area and are subject to a felling permit (trees over 80 cm (inclusive) of girth and closed stands over 40 m^2) pursuant to Act No. 114/1992 Coll., on Nature and Landscape Protection.

In regard to the felling of woody plants, the imposition of substitute planting according to Section 9 of Act No. 114/1992 Coll. will be required. This substitute planting will be predominantly performed in the remediated area within the Tailings area. In order to compensate the environmental damage, additional substitute planting will be performed at a place designated by the local municipality.

Although a relatively high number of specially protected species were identified it can be stated that none are endemic to the proposed project site. Specially protected species are plentiful in the Czech Republic and some specimens are relatively common. Such species are present in many territories including heavily urbanized areas; in economic forests; or on agricultural lands.

20.9.1.3 Processing Area

The Processing plant area is formed with two main parts:

- Built-up area with production halls, warehouses, power supply accessories, utility roads, etc.
- Forested area with trees and vegetation created mainly by human activity.

20.9.1.4 Biological Survey

The location can be described as a habitat clearly dominated by common (widespread), seeded or planted species, supplemented by spontaneous weed and ruderal species.

The botanical survey recorded about 151 taxa of vascular plants, none of them specially protected.

No specially protected species, protected under Decree No. 395/1992 Coll., have been found in the Processing plant area.

More significant species include two in the category near threatened taxa (Act No. 114/1992 Coll., on the Conservation of Nature and Landscape), which require attention:

- Broad-leaved helleborine (*Epipactis helleborine)*
- Green spurge (*Euphorbia waldsteinii)*

Mitigation measures are proposed for broad-leaved helleborine, which include transplanting to a suitable location. No mitigation is required, or proposed, for green spurge.

20.10 Wildlife and Wildlife Habitat

A biological and dendrological assessment of the project was performed in 2019 and updated in 2020 in the Tailings and Processing Plant areas. The surveys focused on determining the current biological condition of the area and the occurrence of specially protected plant and animal species as listed in Decree No. 395/1992 Coll. of the Ministry of the Environment, as amended, with respect to Act No. 114/1992 Coll. on the conservation of nature and landscape, as amended. Other important species in terms of conservation were also documented if/when encountered during the conduct of the surveys.

20.10.1 Mining Area

A biological survey has been performed for the entire area of interest, designed for establishment of the mining lease.

The survey has confirmed the presence of 53 vertebrate species: 4 amphibian species, 3 reptile species, 35 bird species and 11 mammal species. During the inventory surveys, 19 specially protected animal species were found. Their list and categories of conservation according to Decree No. 395/1992 Coll. to Act No. 114/1992 Coll. are listed in Table 20-10.

Table 20-10: List of the Animal Species Found

Latin name	Czech Name	Protection
Anguis fragilis	slepýš křehký	SO
Bombus sp.	čmelák	O
Bufo bufo	ropucha obecná	O
Coturnix coturnix	křepelka polní	SO
Emberiza calandra	strnad luční	KO
Eptesicus serotinus	netopýr večerní	SO
Formica sp.	mravenec	O
Hirundo rustica	vlaštovka obecná	O
Lacerta agilis	ještěrka obecná	SO
Lanius collurio	ťuhýk obecný	O
Luscinia megarhynchos	slavík obecný	O
Natrix natrix	užovka obojková	O
Oriolus oriolus	žluva hajní	KO
Oxyhyrea funesta	zlatohlávek tmavý	O
Perdix perdix	koroptev polní	O
Rana dalmatina	skokan štíhlý	SO
Rana esculenta	skokan zelený	SO
Saxicola rubetra	bramborníček hnědý	O
Sciurus vulgaris	veverka obecná	O

Note: O – threatened species; SO – endangered species; KO – critically endangered species

TETRA TECH

20.10.1.1 Proposed Mitigation Measures

Bombus sp. Bumblebees

Support (e.g., by sowing) the presence of nutrient plants (e.g., plumeless thistle, thistle, dandelion, clover, thyme, comfrey, goat willow, dead nettle, vetchling).

Formica sp. Ants

At least one year before disturbance of the overburden, survey the area for the presence of meadow ants (ants occasionally move, disappear, or create new nests).

Edible Frog, Agile Frog, Common Toad, Sand Lizard, Slowworm, Grass Snake

Before commencing overburden disturbance, make transfers of present individuals to similar habitat areas in the vicinity.

Grey Partridge, Common Quail

Disturbance to overburdening should be carried out outside the time of breeding and weaning. In parts of the territory where heavy presence of people is not expected, it is recommended to maintain the rubble site character of the habitat, or to ensure the presence of shrubs and extensive cultivation (small-scale mowing no sooner than late summer).

Red-Backed Shrike

Planting of replacement solitary thorny shrubs (hawthorn, brier, sloe), which shrikes can use for nesting and shelter. This measure can reduce the negative effects associated with site disturbance, including vegetation removal.

Whinchat

Leave areas with unmown vegetation at the unused edges of the territory

Corn Bunting

In advance (before removal of the existing habitat), plant replacement shrubs (hawthorn, brier, sloe) in areas of similar character to ensure the continuous availability of a suitable habitat.

Common Nightingale, Golden Oriole, Red Squirrel

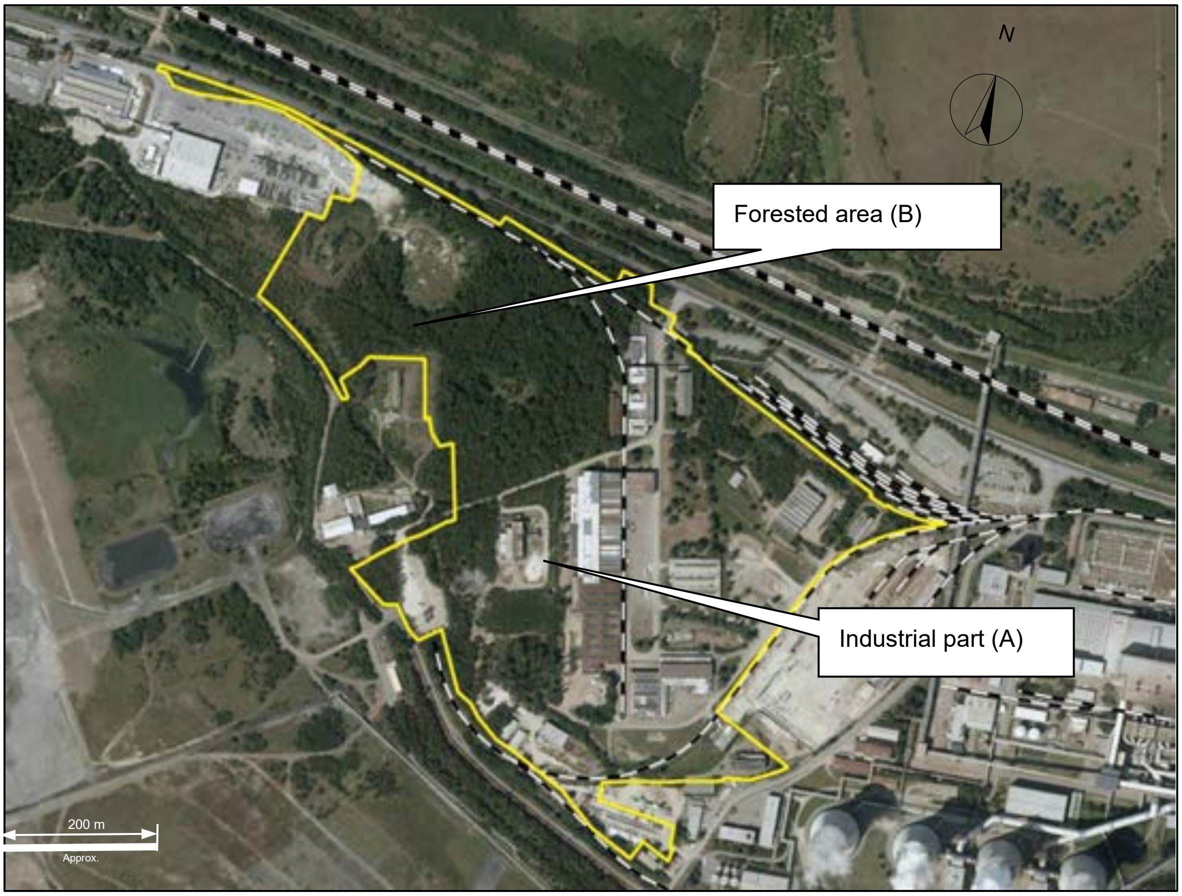
Felling should be carried out outside the time of breeding and weaning.

20.10.2 Processing Area

The Processing plant area is formed with two main parts:

- Built-up area with production halls, warehouses, power supply accessories, utility roads, etc.
- Forested area with trees and vegetation created mainly by human activity.

Figure 20-16: The Areas in Terms of Biological Diversity (source: ČUZK)



At least 43 taxa of vertebrate animals were found, including one amphibian species, 2 species of reptiles, 27 species of birds and 13 species of mammals, 3 of them are among the specially protected ones (European green toad, slowworm, sand lizard).

Specially protected species of animals, Decree of the MoE No. 395/1992 Coll., implementing certain provisions of Act No. 114/1992 Coll., on the Conservation of Nature and Landscape, as amended, were found in the area. Following species were identified:

Table 20-11: List of the Animal Species Found

Latin name	Czech name	Protection
Bombus spp	Bumblebee	SO
Formica spp	Black-backed meadow ant	SO
Bufotes viridis	European green toad	SO
Anguis fragilis	Slowworm	SO
Lacerta agilis	Sand lizard	SO

Note: O – threatened species; SO – endangered species; KO – critically endangered species

20.10.2.1 Proposed Mitigation and Compensation Measures

Conclusions of the Biological surveys specified the measures to prevent, reduce, and compensate for, the negative effects of the project in Processing plant area; the conslusions are listed below:

1. In advance of the first field (ground) work, green (trees) will be removed from the work site. This will reduce the physical presence of animals. The felling of trees shall be done in the dormancy period.
2. All excavating and ground work should be carried out in the time outside the main period of reproduction, laying eggs and hatching young sand lizards, i.e., not from May to June. Winter period is also less appropriate, as the animals can hibernate here.
3. To protect the selected species, mitigation (protection) and compensatory measures are proposed for the selected species in terms of needs of the nature conservation authority.

Black-Backed Meadow Ant

The nests of meadow ants generally have a short duration and the nesting material is not compact, thus, their transfer is complicated or rather impossible. Therefore, it is not recommended.

European Green Toad

Preventing the emergence or subsequent occupation of puddles, excavations and similar depressions in the terrain before and during the construction.

20.11 Socioeconomics

Socioeconomic studies were prepared by the Faculty of Social Geography at Charles University to evaluate how the CMP might affect population movements and commuting patterns for work. It is anticipated that labour for the CMP could be drawn from the Chvaletice area and broader Pardubice Region, which has an educated, skilled labour pool. The anticipated socioeconomic effects are expected to be modest at a regional scale, but positive and valuable for local communities. Problems such as social polarization, segregation, and other phenomena related to moving or housing are not anticipated to be significant.

Another study was prepared to evaluate the effects of the CMP on employment structure, business, and commerce in the area, and the general perception of the CMP by local residents. In 2017, there were 626 companies (i.e., 0.9%) with more than 50 employees and only 13 enterprises creating more than 1000 jobs in the whole region (Business Register RES 2018). From this point of view, the planned manganese production plant will be among the employers of medium significance in the region. There are about 5,600 economic units in the administrative district of municipalities with extended powers, 20% of which is active in industry. According to data from 2019, only 17 companies employ 50–250 employees and there are only 3 companies with more than 250 employees operating in the (micro-)region. In this context, it is clear that the future plant will become a significant employer in this micro-region.

In the phase of full operation, the direct impact will be the creation of approximately 400 jobs in the new plant, and potential additional (secondary) jobs will be created in the field of transport, logistics, and also outsourced services necessary for the normal operation of the plant. Hypothetical impacts can be expected in case of potential suppliers of selected raw materials.

The notifier will invest considerable funds in the construction and purchase of best available technologies, which can also be a promise of a high standard of care for employees and a guarantee of their permanent social security.

Mandatory financial fees to municipalities, in the cadastre of which the reclamation will be done (Trnávka and Chvaletice), will also have a significant impetus for the local economy. These include payments for the mining area and payments for extracted minerals, as follows from Act No. 44/1988 Coll., on the Protection and Utilization of Mineral Resources (Mining Act). Municipalities will be able to use these fees for a wide range of investment development activities. The investment will have a positive impact on the revenue, and partly on the expenditure, part of the public finance system. Compulsory social and health insurance payments can be expected depending on the size of statutory payments in the year of the commencement of operation.

20.12 Permitting

The CMP will require numerous permits and authorizations in order to proceed. Initial exploration and mining permits have already been secured; these and the permits/authorizations that are likely to be required are listed in Table 20-12.

Table 20-11: Permits and Authorizations

	Name of Permit / Opinion	Legislation	Requirement
	Obtained Permits		
Baseline Phase	Permit to Carry Out Mining Activities	Act No. 61/1988 Coll., on Mining Activities, Explosives and the State Mining Administration	Mining activities and activities done by the method of mining may only be carried out by organizations which have been granted permit by the State Mining Administration for these activities.
Baseline Phase	Establishment of an Exploration Area for Deposit Exploration	Act No. 62/1988 Coll., on Geological Works and the Czech Geological Survey	Geological work for the prospecting for and exploration of reserved mineral deposits and exploration of exclusive non-reserved mineral deposits may be carried out solely in an exploration area established for a legal person or natural person who is authorized to engage in mining activities.
Baseline Phase	Official certificate of the Exclusive Deposit	Act No. 44/1988 Coll., on the Protection and Utilization of Mineral Resources (Mining Act)	If a reserved mineral is found in quantity and quality that can reasonably be expected to accumulate, the Ministry of the Environment issues a certificate of exclusive deposit
Baseline Phase	Delimitation of a Protected Deposit Area	Act No. 44/1988 Coll., on the Protection and Utilization of Mineral Resources (Mining Act)	The protected area is designated by the Ministry of the Environment in consultation with the regional authority in the delegated competence of the Czech Republic by a decision issued in cooperation with the Ministry of Industry and Trade of the Czech Republic, the District Mining Authority and in agreement with the Zoning authority Office and Building Office.
Baseline Phase	Prior consent to the establishment of the mining-lease district	Act No. 44/1988 Coll., on the Protection and Utilization of Mineral Resources (Mining Act)	An organization has to have a predecessor approval from the Ministry of the Environment of the Czech Republic before submitting a proposal for the delimitation of a mining space. An organization on whose behalf exploration of the deposit was carried out or which contributed financially to the exploration of the deposit has a first claim in obtaining a predecessor approval for the delimitation of a mining space for a period of 1 year from the end of validity of the exploration area.

table continues…

TETRA TECH

	Name of Permit / Opinion	Legislation	Requirement
Preparation Phase	**Preparation Phase**		
	Change of the Zoning plan	Act No. 183/2006 Coll., on Town and Country Planning and Building Code (Building Act)	The municipal council decides on the change of the local plan and its content. The planned project (intent) must be in accordance with the zoning plan.
	Environmental Impact Assessment	Act No. 100/2001 Coll., on Environmental Impact Assessment	Environmental impact assessment must be carried out for the projects stated within this Act and realization of the project must be assessed with respect to its impact on the environment, social area and human health.
Land Planning Proceeding	**Land Planning Proceeding**		
	Coherent Stamp	Act No. 100/2001 Coll., on Environmental Impact Assessment	The process verifying that the project assessed in the EIA process for which the EIA Statement has been issued is the same as that one for which a follow-up decision (Zoning Permit) is requested. If there are discrepancies that could have a significant negative impact on the environment, a disagreeing binding opinion is issued and either the project must be modified or the project has to be assessed in the new EIA process.
	Permit for tree felling	Act No. 114/1992 Coll., on the Conservation of Nature and Landscape	The municipal authority of the affected municipalities (Chvaletice, Trnavka) issues an opinion on the felling of trees growing outside the forest, including the imposition of an obligation to implement substitute planting. Without a binding opinion it is not possible to place a building; zoning permit cannot be issued.
	Permit for exemption from the conservation conditions of specially protected species	Act No. 114/1992 Coll., on the Conservation of Nature and Landscape	Exemptions from the prohibitions for monumental trees and specially protected plant and animal species pursuant to Section 46 (2), Sections 49 and 50 in cases where other public interest outweighs the interest of nature protection, or in the interest of nature protection, authorizes a nature protection authority.
	Opinion on the Location of the Source of Air Pollution	Act No. 201/2012 Coll., on the Protection of Air	According to Section 11 (1) (b) and Section 11 (2) (b), a zoning decision, a joint permit locating and permitting a structure, or a decision on the delimitation of a mining space under other legislation may not be issued without a binding opinion.
	Permit for Affecting a Significant Landscape Component	Act No. 114/1992 Coll., on the Conservation of Nature and Landscape	Who intends to carry out any intervention that might lead to the damaging or destruction of a significant landscape component, or could endanger or weaken its ecologically stabilising function, must receive a binding statement from the nature conservation authorities. The Nature Conservation Authority issues an opinion in the context of the proceeding on the location of the building.
	Permit for Affecting Landscape Character	Act No. 114/1992 Coll., on the Conservation of Nature and Landscape	The approval of the nature conservation authorities shall be required for the approval and placement of structures and other activities that could impair or alter the character of the landscape.
	Land Planning Permit	Act No. 183/2006 Coll., on Town and Country Planning and Building Code (Building Act)	To locate the structures or facilities, their alterations, to alter their impacts on the use of the area, to alter the use of the area, and protect the significant interests within the area is possible only on the basis of the zoning decision.

table continues…

TETRA TECH

	Name of Permit / Opinion	Legislation	Requirement
	Delimitation of a Mining-Lease		
	Decision on the Delimitation of a mining area	Act No. 44/1988 Coll., on the Protection and Utilization of Mineral Resources (Mining Act)	The organization's authority for mining a reserved deposit come into an existence of the delimitation of a Mining-Lease.
	Classification into mining waste category	Act No. 157/2009 Coll., on mining waste management	Storage sites are classified in categories I or II in terms of potential effects on life, human health, and the environment. The District Mining Authority will decide on the categorization of the storage place and on the change of the category.
Construction Proceeding	**Construction Proceeding**		
	Coherent Stamp	Act No. 100/2001 Coll., on Environmental Impact Assessment	The process of verifying that the project assessed in the EIA process for which the EIA Statement has been issued is the same as that one for which a follow-up decision (Construction Permit) is requested. If changes are identified that could have a significant negative impact on the environment, the project must be modified or the project must be assessed in the new EIA process.
	Opinion on the Realization of a Construction of the Source of Air Pollution	Act No. 201/2012 Coll., on the Protection of Air	Pursuant to Section 12 (6) of Act No. 201/2012 Coll., on the Protection of Air – According to Section 11 (2) (c), a building permit, a joint permit locating and permitting a structure, or a mining activity permit under other legislation may not be issued without a binding opinion.
	Construction Permit	Act No. 183/2006 Coll., on Town and Country Planning and Building Code (Building Act)	In case of structures of any type, a building permit is necessary for any construction activities.
	Mining Activities Permit		
	Settled property rights (conflicts of interest)	Act No. 61/1988 Coll., on Mining Activities, Explosives and the State Mining Administration	If objects and interests protected by law are endangered by mining activities, the documents on the resolution of conflicts of interest must be submitted with the application.
	Mining Activities Permit	Act No. 61/1988 Coll., on Mining Activities, Explosives, and the State Mining Administration	The opening, preparation and mining of reserved deposits is permitted by the District Mining Office. Opening, preparation and mining may not be commenced without the permission of the District Mining Authority.
	Decision on the construction of storage of mining waste	Act No. 157/2009 Coll., on mining waste management	The operator must establish a storage for the mining waste. The location of the construction of a storage place within the boundaries of the mining area, as well as its modification and use, is authorized or its removal is permitted by the District Mining Office.

table continues…

TETRA TECH

	Name of Permit / Opinion	Legislation	Requirement
Operation Phase	Operation Phase		
	Permit to Use Surface Water or Groundwater	Act No. 254/2001 Coll., on Water and Amendment to Some Acts (Water Act)	The permission for the use of surface water or groundwater is required in the case of surface water for withdrawal, for impounding or accumulation, etc. Furthermore, for the discharge of waste water into surface water and groundwater is required Water Authority Permit.
	Integrated Permit (Processing Plant)	Act No. 76/2002 Coll., on Integrated Pollution Prevention and Control, on the Integrated Pollution Register and on Amendment to Some Acts (Act on Integrated Prevention)	For the operation of the Processing Plant, integrated permit must be granted by the Regional Authority. Integrated permit defines the conditions and limitation for Plant operations such as emission limits etc.
	Permit to Operate a Stationary Source of Air Pollution	Act No. 201/2012 Coll., on the Protection of Air	According to Section 11 (1) (d), a permit for early use of a structure, a permit for trial operation, or a final inspection approval under the Building Act may not be issued without a permit of operation.
	Operating permit storage of mining waste	Act No. 157/2009 Coll., on mining waste management	The construction of a storage site can only be operated with a permit. Operation of the storage site and its changes are authorized by the district mining office in accordance with its location and authorization.

20.13 Reclamation and Restoration Objectives

The existing Chvaletice tailings were deposited in unlined piles between 1951 and 1975. The piles are permeable and rainwater percolates through them, leaching metals and minerals. Cells #1 and #2 were covered by a thin cover of crushed rock from a neighbouring quarry and waste from the excavation of the Prague subway system. Cell #3 was abandoned and left without a rock or soil cover. There is visual and anecdotal, but otherwise undocumented evidence that the embankments of cells #1 and #2 were partially replanted with trees for slope stabilization purposes. The slopes of these piles have been reported to erode and have failed in the past, but generally appear to be fairly stable today. The top of the piles supports a sparse tree cover and now mostly host grasses, some shrubs and bushes, and few trees. The lack of organic matter, the poor crushed rock substrate and the harsh chemical composition of the tailings (particularly the presence of sulphates), combined with frequent desiccation of the pile tops all likely contribute to the prevention of a denser tree cover from developing. Cell #3 is thinner than the other two and was abandoned without being revegetated. Instead, natural revegetation of pioneer grasses, shrubs and deciduous tree species have created a forest composed largely of birch trees. The toxicity and metal contamination of grasses, plants, mushrooms, and trees growing on the surface of the tailings cells have been well documented. The life span of the trees on Cell #3 tends to be quite short as a result of the current harsh growing conditions.

The CMP has initiated the planning and design of a comprehensive reclamation and restoration plan with the following objectives initially identified as priorities. These objectives reflect the conclusions of the EIA Notification and authorities' and public comments:

- Restoring the site to a stable, more natural condition that will create healthy and valuable habitat for flora and fauna, with expectation of stopping ongoing leaching of metals and minerals into the underlying aquifer.

- Phased extraction of the tailings, followed by progressive reclamation of the post-processing tailings surface, in order to reduce the footprint of tailings exposed to the air, limit airborne dust, and gradually restore a healthier more natural setting.
- Placing washed, dewatered and neutralized post-manganese extraction tailings using dry-stacking methods on an impermeable high-density polyethylene liner, with suitable drainage to capture and facilitate treatment of remnant moisture contained in these tailings,
- Covering tailings with an impermeable geomembrane cap and a stable, clean soil cover that will facilitate natural revegetation and restoration of the site.
- Development of a long-term reclamation and restoration action plan in close consultation and collaboration with adjoining communities, local stakeholders and regulatory agencies. Some preliminary reclamation concepts include:
  - shaping the resulting tailings into natural-looking shapes (hills), maintaining stable, gentle slopes that blend well visually with adjoining topography and the nearby UNESCO protected area and create opportunities for the visual enjoyment of the site,
  - revegetating the site with a variety of suitable, native grass, plant, and tree local species that can support healthy biodiversity, and
  - developing infrastructure that can provide relaxation and recreation.
- Complete removal of all industrial infrastructure, buildings, and facilities from the tailings and process plant site area, other than those that can be put to productive and beneficial use by local residents and communities.

20.14 Impact Mitigation and Project Design Approach

The CMP process plant is being designed to reliably and cost-effectively produce HPEMM and HPMSM products that are destined for advanced lithium ion battery cathode formulations, while complying with the stringent Czech Republic and European Union health, safety and environmental standards

The technologies for recycling manganese from the Chvaletice tailings waste have been selected from the cleanest, practical, processing technologies available. The design approach includes close integration of the design of the process plant, the excavation areas and the final residue storage according to the requirements of each stakeholder in the Project that are bench marked against leading industry practices. This approach ensures that the quality of products includes verifiable provenance, a small environmental footprint and safe, sustainable future operations.

The CMP includes the remediation of a polluted site, where metals and other compounds currently leach into both ground and surface waters. It is expected that attempts to remediate the negative impacts of this environmental legacy would be a significant long term financial and administrative burden on local authorities and communities. As extraction, reprocessing and proper disposal of the Chvaletice tailings is carried out, the site will be progressively rehabilitated to be in compliance with Czech and European environmental requirements and returned to productive or recreational use by the community.

The process design measures that have been identified during this FS include the following:

- Washing of leach residues, recovery of manganese and reagents, residue storage placement methods that reduce the further oxidation and leaching of heavy metals.

- The final residue will be dry stacked in lined containments with comprehensive water management systems to capture and recycle runoffs and leachate from the excavation and processing areas. A range of changing climatic conditions that are expected to prevail during operation have been considered and incorporated into the associated design. Three WTPs will also be installed to effectively treat and re-use the wide range of water qualities that are expected on site.
- Limiting the duration and extent of open excavated areas of tailings and the areas for dry stacking operations; applying effective dust suppression methods, such as water misting on exposed tailings and vehicle tire wash facilities, where required.
- Visual and acoustic barriers will be installed where reasonable to reduce noise-related impacts. CMP tailings extractions will be limited to daytime weekday periods to minimize noise and traffic.
- Process plant building design will include aesthetic architectural features to blend these with the local surroundings.
- The use of toxic (such as selenium, chromium, and fluorine), hazardous reagents and chemicals has been eliminated or minimized.
- The haulage and transport of materials within the processing areas as well as to the project will be designed to minimize traffic, largely by using rail rather than road trucks whenever possible.
- Mist fumes and odours will be controlled using appropriate ventilation and scrubbing systems. Electrolytic cells will be properly vented.
- Tanks and bunded areas will be designed to ensure safe adequate storage for process reagents, chemicals and solutions.
- Waste products will be recycled or safely disposed in appropriate facilities.
- Access to site, layouts of buildings and plant working areas taken into consideration the safety and health of employees.
- Minimizing manual handling of processing equipment and the use of process control systems that facilitate robust control of processes.
- Mechanization and automation will be optimized to favour safe, healthy, and ergonomic handling of equipment, supplies and materials.

It is planned to extend these design features as the level of design definition is increased in the next phase of engineering.

20.15 Health, Safety, and Environmental Standards

In order to secure the necessary permits the project must fully comply with all health, safety and environmental protection standards as defined in Annex #4 of Law 100/2001 Sb and other legislation. The Czech EIA system is very descriptive and prescriptive and addresses all technical and non-technical parameters that may have any significant impact on health, safety, and the environment as well as on the cultural heritage or ecological functions of the area.

The typical content of the EIA is summarized below:

- Project description:

  - Detailed technical description of the project (location, capacities, project justification, schedule, start date, etc.).
  - Description and details pertaining to consumables (materials, energy, water, etc.) as well as land usage, impact on biological variety and impact on infrastructure and transportation.
  - Detailed analysis of the project outputs, risks, mitigation of negative impacts/sources and protective measures, and risk prevention. The following areas require specific assessment:
  - Pollution of air, water and soil (pollutant sources, list of contaminants, means of containment and treatment, emergency procedures etc.)
    - Wastewater (sources, amounts, pollutants, methodology of water treatment, wastewater treatment technology – type and efficiency)
    - Wastes (types, amounts, categorization, collection, treatment, disposal)
    - All other emissions, residual noise, vibration, radiation, odour, etc., the respective characterization and methods of minimization/treatment/disposal
    - Other information – e.g., landscaping or terrain modification.
- Characterization of the environment:
  - Description of the area and establishing a detailed baseline (environment, hydrogeology, geomorphology, fauna, flora, ecological systems and functions, protected areas, archaeological and cultural aspects). The CMP has already advanced significantly in this area.
  - Estimated impact of the project on the above parameters concurrent with the respective mitigation strategy for each risk.
- Impact assessment:
  - Characterization and evaluation of expected direct and indirect, primary and secondary, short-term, long-term and cumulative impacts related to construction and operation. Additional consideration is given to the materials of construction/operation, technology employed, legal compliance, natural sources usage and sustainable development of the area. These major areas will be further assessed:
    - Impacts on inhabitants and public health
    - Impact on air and climate (emission, greenhouse gas effects, etc.)
    - Impact of noise, vibration, and radiation (if applicable)
    - Impact on surface and ground water
    - Impact on soil
    - Impact on natural resources
    - Impact on biological variability (fauna, flora, ecosystems)
    - Impact on ecological functions of the area
    - Impact on cultural heritage, archaeology, and architecture.

- Risk analysis; potential failure modes; natural disasters and the respective mitigation.

The first stage of environmental and social assessment was carried out in 2019 – 2020 and finished in December 2020 with the issuance of an EIA Notification Statement.

The 2nd stage of environmental and social assessment is called EIA Documentation and the content is predefined by Annex 4 of Act No. 100/2001. EIA Documentation together with expert studies will be finished in summer 2022 and submitted to the authorities. All affected authorities and also the public can provide comments and objections. Then expert opinion on the EIA documentation is prepared by an independent authorized person on behalf of the competent authority and afterwards the public hearing follows. All negative remarks have to be taken into account and then the competent authority issues a binding EIA statement, which might include binding conditions for project realization, if any.

Table 20-12 shows the detailed listing of the requisite environmental and health and safety standards mandated for the CMP.

Table 20-12: Listing of Environmental and Health and Safety Standards

Mangan Chvaletice s.r.o. - Register of Environmental Standards		
AREA	**Standard**	**Short Description**
Environmental Protection	Act No. 17/1992, on the environment	The Act defines the basic concepts and sets out the basic principles of environmental protection; and the obligations of legal and natural persons in protecting and improving the environment; and use of natural resources; it is based on the principle of sustainable development.
Nature and Landscape	Act no. 114/1992 Coll., on Nature and landscape protection as amended,	Nature and landscape protection divided into general nature and land landscape protection (protection of landscape, species diversity, natural values and aesthetic values of nature, as well as conservation and considerate use of natural resources) and special nature and landscape protection (the Act specify protected areas as an important instrument in site protection)
Environmental Impact Assessment	Act No. 100/2001 Coll., on environmental impact assessment	The Act states the principles of the assessment of environmental impacts and impacts on public health and the procedures to be adhered to by individuals, legal entities, administrative authorities and self-governed territorial units (municipalities and regions) in the course of such assessments. The objects of compulsory assessment consist of plans (projects) for construction, activities and technologies listed in Annex No. 1 of Act No. 100/2001
Landscape planning	Act no. 183/2006 on landscape planning and constructions order	The act defines the principles of the landscape planning, principles of new constructions permitting.
Waste management	Act no. 541/2020 Coll, Waste act	Act emphasizes waste prevention, defines the hierarchy of waste handling, and promotes the fundamental principles of environmental and health protection in waste handling. Defines obligations on how to handle generated waste, how to dispose of the waste, obligations on handling of selected products, waste types and appliances.
Water Handling	Act no 274/2001 Coll, on water pipelines and sewage systems for public use	The fundamental legal regulation covering air quality assessment and management defining obligations for air emission sources operation

table continues…

TETRA TECH

Mangan Chvaletice s.r.o. - Register of Environmental Standards		
AREA	**Standard**	**Short Description**
Air and climate protection	Act no. 73/2012 Coll., on substance that deplete the ozone layer and on fluorinated greenhouse gases	Legislation defining restriction on the use of substances which are classified as harmful for ozone layer
Air and climate protection	Regulation (EU) No 517/2014 on fluorinated greenhouse gases	Legislation defining restriction on the use of substances which are classified as harmful for ozone layer
Air and climate protection	Regulation (EC) No 1005/2009 on substances that deplete the ozone layer	Legislation defining restriction on the use of substances which are classified as harmful for ozone layer
Water protection	Act no. 254/2001 Coll., on Waters and Amendments to some acts (the Water Act)	defining obligations for water protection, water use and water rights. The Act states the obligations for water use (ground water and surface water), obligations regarding water disposal and treatment of wastewater, obligations regarding water structures such as wastewater treatment plant etc. and obligations on water hazardous substances management.
Water protection	Regulation no. 401/2015 Coll., on indicators and values of acceptable pollution of surface water and wastewater	Specifying obligations on wastewater discharge
Water protection	Act no 274/2001 Coll, on water pipelines and sewage systems for public use	defines obligations water pipeline operator serving for public use and operator of sewage system
Chemicals and Health and Safety	Act no. 350/2011 on Chemical Substances and Chemical Preparations	National act regulating the whole area of chemical substances management-
Chemicals and Health and Safety	Act no. 224/2015 on Prevention of Serious Industrial Accidents caused by hazardous chemicals handling	prevention of serious accidents caused by selected hazardous chemicals and preparations is covered by the Ministry of the Environment as part of civilian emergency planning. The aim of the act is to state obligations for industrial facilities where hazardous chemicals are handled in large quantity
Chemicals and Health and Safety	Act no. 258/2000 Coll., on public health protection	The act states obligations regarding chemical substances handling and mainly, requirements regarding health and safety protections (public, workers)
Chemicals and Health and Safety	Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)	European regulations stating obligations regarding registration of substances, newly produces substances, authorization and restrictions on substances of very high concern
Chemicals and Health and Safety	Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures,	European regulation defining obligations regarding chemicals labelling and packaging, requirements for chemicals downstream users

table continues…

TETRA TECH

Mangan Chvaletice s.r.o. - Register of Environmental Standards		
AREA	**Standard**	**Short Description**
Integrated Pollution Prevention and Control	Act no. 76/2002 Coll., on Integrated Prevention	A practical application of the IPPC principle is the integrated permitting of industrial and agricultural installations. To obtain an integrated permit, a legal or natural person doing business in industry or agriculture as defined in Annex 1 to Act no. 76/2002 Coll., on Integrated Prevention, has to file a respective application with the regional authority in charge of issuing the permit
Integrated Pollution Prevention and Control	Act no 25/2008 Coll., on integrated pollution register of the Environment	The act defines the obligations for industrial and agricultural facilities on selected substances release to the air, water, soil and in off-site transfer in waste.
Regional and local legislation	Regional and local legislation issued by local and regional authorities	--
Health and Safety	Act no. 262/2006 Coll., the Labour Code	Act regulates legal relations arising in connection with the performance of dependent work between employees and their employers; such relations are referred to as “labour relations” (or “labour relationships”, or “industrial relations” or “employment relations”;
Health and Safety	Act no. 89/2012 Coll., the Civil Code	--
Health and Safety	Act no. 309/2006 Coll.,	Act to amend other requirements of safety and health at work in labour relations and to ensure the safety and health activities or providing service outside labour relations (Act on securing other conditions for safety and health at work)

21.0 CAPITAL AND OPERATING COST ESTIMATES

21.1 Capital Cost Estimate

Tetra Tech prepared the FS capital cost estimate, which includes tailings extraction, all manganese recovery processing, infrastructure, and residue backfill dry stacking costs to recover manganese and produce high-purity manganese products by re-processing the three CMP tailings cells. The capital cost estimate was developed based on inputs from EMN and the following consultants:

- CMP tailings extraction/excavation and related infrastructure – Tetra Tech
- HPEMM and HPMSM process and infrastructure (material take-offs [MTOs] and costs) – BGRIMM/Tetra Tech/EMN technical team
- Overall site service infrastructure (MTOs and costs) – BGRIMM/Tetra Tech/EMN technical team
- Railway siding and related infrastructure – SUDOP PRAHA a.s. (SUDOP)
- Tailings/residue management – Tetra Tech
- Spare parts – BGRIMM/Tetra Tech
- First fills priced as a factor of equiment supply costs based on BGRIMM's and Tetra Tech's in-house benchmarks – BGRIMM/Tetra Tech
- Owner's costs – EMN/Tetra Tech
- Construction Field Indirects – Tetra Tech
- Engineering, Procurement, and Construction Management (EPCM) – Tetra Tech.

The capital cost estimate produced for the CMP is classified as a Class 3, FS Estimate, with an expected accuracy of -10% to +20% according to the AACE. The capital cost estimate is based on an FS completed by Tetra Tech and BGRIMM in Q2 2022 and is a bottoms-up and first principles basis of estimate.

The capital cost estimates are summarized at the levels indicated by the following tables and stated in United States Dollars (USD) with a base date of Q1/Q2-2022 with no provision for forward escalation. This estimate collectively presents the entire costs for the project including all third-party estimates, Owner's scope, and Tetra Tech's scope.

The estimate has been established using a combination of equipment vendor-solicited budgetary quotations, local Czech materials, labour, and construction costs, in-house cost data for equipment and bulk material pricing for similar projects, detailed estimating for most parts of the project, and capacity factor or equipment factor allowance for some components of the project. Building construction and equipment installation-related costs have been compared with the budgetary quotations provided by three potential general local contractors. The cost estimate has been prepared using the project work breakdown structure (WBS).

The primary responsibility for the capital cost estimate preparation lies with the project services group, and principally with the lead project estimator and the active participation of the engineering leads, Project Management, and Project Owner's team.

The preparation of the capital cost estimate is the responsibility of the whole project team. Engineering is responsible for the development of MTOs, and for ensuring that the design, scope of work, and quantities for each discipline are fully understood. The responsibility for the design and scope lies solely with the lead discipline engineers.

Base estimate data (labour rates, unit rates, etc.) has been progressively reviewed with the project team and EMN/Mangan to keep the team informed and progress constructively on the building blocks of the estimate.

The total estimated initial capital cost for the design, construction, installation, and commissioning of the CMP is USD$757.4 million. Table 21-1 shows a summary breakdown of the initial capital cost.

Table 21-1: Capital Cost Summary - WBS Level 1

WBS Level 1	Description	Cost (US$'000)
10	Overall Site	57.5
30	Tailings Extraction	4.6
35 and 40	Process	352.8
50	Residue Management	5.6
55	Closure Costs	-
60	Environmental	-
70	On-site Infrastructure	82.9
-	Total Direct Costs	503.4
90	Indirect Costs	128.4
98	Owner's Costs (EMI)	47.2
-	Total Indirect/Owners Costs	175.6
99	Contingency	78.4
-	**Project Total**	**757.4**

Table 21-2: Capital Cost Summary - WBS Level 2

WBS Level 2	Description	Cost (US$'000)
1010	Overall Site - General	16.4
1020	Overall Site - Electrical/Water/Steam	33.9
1030	Overall Site - Controls and Communications	7.2
3030	Tailings Extraction Infrastructure	4.6
4010	Mill Feed Preparation	24.3
4020	Magnetic Separation	8.6
4022	Magnetic Separation Concentrate Dewatering	9.9
4022	Magnetic Separation Tailings Dewatering	11.3
4030	Leaching and Fe&P Removal	49.6
4035	Pregnant Solution Purification	28.3

table continues…

WBS Level 2	Description	Cost (US$'000)
4040	Mn Electrowinning	94.3
4045	Mg Removal	28.7
4050	Leach Residue Washing/Dewatering	19.0
4052	Manganese Recovery	3.6
4055	Ammonia Recovery	15.5
4080	Reagents	5.9
4085	Technical and Engineering Services Building	8.7
4090	HPMSM Process - From 99.9% EMM	45.1
5020	Residues Storage Facility (RSF)	5.6
7010	Ancillary Buildings	12.2
7020	Site Services and Utilities	70.7
-	Total Direct Costs	503.4
9010	Project Indirects	61.1
9020	Engineering and Project Management	67.3
9810	Owner's Costs	47.2
-	Total Indirect/Owners Costs	175.6
9910	Contingency	78.4
-	**Project Total**	**757.4**

The base currency of the estimate is USD. As shown in Table 21 2, Tetra Tech used the three-year average foreign currency exchange rates, up to 31st May 2022, for the estimate, where applicable. The foreign exchange rates are based on three-year average foreign exchange rates.

Table 21-2: Foreign Exchange Rates

Base Currency (USD$)	Foreign Currency
1.00	CAD $1.30
1.00	CZK 22.43 Kč
1.00	EUR €0.87
1.00	RMB ¥6.71

Note: Average exchange rates; some equipment prices were converted from local currency to USD based on Q1/Q2 exchange rates

21.1.1 Estimate Base Date and Validity Period

The capital cost estimate was prepared with a based date of Q1/Q2 2022. No escalation beyond Q2 2022 was applied to the estimate.

21.1.2 Measurement System

The metric system of measurement has been used in this estimate.

21.1.3 Estimate Structure

The estimate is broken out into direct, indirect, Owner's, and contingency costs.

Direct costs are those costs that pertain to the permanent equipment, materials, and labour associated with the physical construction of the process facility, infrastructure, utilities, and buildings. The direct costs are a build-up of the current project quantities; this includes the installation/construction hours, unit labour rates, contractor indirects, bulk and miscellaneous material and equipment costs, sub-contractor costs, freight, and growth.

Construction contractor's indirect costs are priced in the indirects as a separate line item for contractor profit, insurance, overheads, construction equipment, transportation, etc. The cost item is based on a factor of total labour costs which was suggested by three local contractors in the Czech Republic. Based on current projects recently completed, cost data was analyzed and confirmed against Tetra Tech's in-house benchmarks and deemed appropriate.

Indirect costs include all costs associated with implementation of the plant and incurred by the Owner, engineers, or consultants in the design, procurement, construction, and commissioning of the project.

Contingency costs have been included for each major area of the cost estimate.

21.1.4 Work Breakdown Structure (WBS)

The estimate is assembled according to the following hierarchical structure:

- Level 1 = Major Area
- Level 2 = Area
- Level 3 = Sub-Area

Each sub-area has been further broken down into disciplines such as earthworks, civil, concrete, steel, platework, mechanical, piping, electrical, instrumentation, and fire protection. Each discipline line item is defined into resources such as labour, materials, equipment, and sub-contract so that each line comprises all the elements required in each task.

The WBS has been developed in sufficient detail to provide the required level of confidence and accuracy and also to provide the basis for further development as the project moves into execution phase.

21.1.5 Direct Costs

21.1.5.1 CMP Tailings Extraction Capital Cost

The tailings extraction LOM capital cost totals USD$11.3 million, including USD$4.6 million initial capital cost and includes costs for tailings extraction equipment and related infrastructure:

- USD$6.58 million for purchase of excavation equipment

- USD$0.64 million for haul road construction
- USD$2.64 million for capitalized pre-stripping cost
- USD$1.5 million for contingency

21.1.5.2 Process and Overall Site Infrastructure Capital Cost

The overall process plant circuit design, infrastructure, and various service facilities at the plant site are designed by BGRIMM, excluding the railway spur system which was completed by Sodup, a local Czech engineering firm, and the 400 kV incoming power transformer station which was completed by Tetra Tech.

Major process-related mechanical and electrical cost estimates are based on quotations from potential equipment manufacturers in China that were provided to Tetra Tech after being reviewed and consolidated by BGRIMM, Tetra Tech, and the Owner’s technical team. The 400 kV incoming power transformer station costs were estimated by Tetra Tech based on the budgetary quotations, while the cost for the railway spur upgrading was estimated by Sodup.

The total direct cost for the process plant and related infrastructures at the plant site was estimated to be USD$493.2 million.

Process

The process includes the raw tailings transport from the dump pocket by conveying to the raw tailings storage facility, the raw tailings pulping and pumping to the plant site, magnetic separation, magnetic concentrate leaching, leach solution purification, manganese electrowinning (including cathode harvesting, washing, stripping, and preparation and HPEMM storage and packing), magnesium removal from analytic solution, ammonia recovery, leach residue washing, HPMSM production from HPEMM, non-magnetic tailings and washed leach residue dewatering, dewatered residue transport from the plant site to the mine site, residue temporal storage in the raw tailings pulping facility at the mine site, reagent handling and storage and product handling. Various process buildings, product handling and reagent storage and handling facilities, area electrical distribution, piping, and instrumentation are included in these areas. The processing plant and related infrastructures include the preparation of MTO and cost estimate.

Site Services and Utilities

Site services and utilities include the preparation of MTO and cost estimate for water management (contact and non-contact and storm water), water supply and distribution, cooling water systems, wastewater treatment, power supply and distribution, steam generation and distribution, waste management, process controls and communications, air supply and distribution, fire suppression, and railway spur systems.

Site Infrastructures

Site infrastructure includes the preparation of MTOs and cost estimates for the following buildings:

- Extracted tailings storage and pulping and washed LR/NMT storage tailings storage facility
- Plant site and mine site connection gallery for LR/NMT transport conveyor, tailings slurry pipeline, and utilities
- Magnetic separation and related concentrate and non-magnetic tailings dewatering facilities
- Leaching and iron/phosphorous removal circuits

- Leach solution purification
- Manganese electrowinning for producing HPEMM
- Magnesium removal
- Leach residue washing and dewatering
- Ammonia recovery
- Electrolytic manganese metal flake dissolution to prepare manganese sulphate solution and solution purification
- HPMSM crystallization and crystal drying and packing
- Reagent storage/preparation
- Steam generation
- Administration building
- Canteen and change room building
- Spares parts storage building
- Emergency power plant building
- Product warehouse
- Maintenance workshop and spares parts storage building
- Technical and engineering services building
- Cooling water systems
- Site water management system, including wastewater treatment plant
- Railway spur system

21.1.5.3 Equipment and Bulk Material Take-offs

Mechanical Equipment and Bulks

The quantities of mechanical equipment and bulks requirements for platework, chute work, shop fabricated tanks, and field fabricated tanks are based on following:

- Process flow diagrams
- Equipment list
- Equipment datasheets
- Layouts and general arrangement drawings.

The mechanical equipment list provides equipment tag numbers, equipment names, descriptions, sizes, and power.

Ex-works pricing was sought for the major mechanical equipment packages using competitive pricing submissions from equipment suppliers. Where budget quotes were not obtained, existing BGRIMM and Tetra Tech database pricing has been used; for minor equipment, in-house historical pricing and estimates have been used. The mechanical bulk requirements have been priced by potential vendors and included in the consolidated bill of quantities (BOQ) as part of the mechanical equipment list.

Installation labour hours have been included for each equipment item based on Tetra Tech's in-house data for the required specification and size.

The value of equipment priced from current or recent inquiries represents 99.0% of the total equipment supply value, not including platework. The remainder consists of low-cost equipment that was priced from budget quotations or purchase orders from other recent estimates and projects.

Piping

Process pipes, fittings, and valves quantities have been based on P&IDs. Piping MTOs include material type, service, specification, schedule, and diameter size requirements. Piping racks and supports have been included in the structural steel MTO, all in which have been included in the consolidated BOQI. Supply costs for pipe, fittings, and valves are based on Tetra Tech's historical data for recently completed projects in the same region. Installation hours are based on in-house typical installation hours for each size and specification of pipe, fitting, and valve.

Electrical Bulks and Equipment

The quantities for the supply and installation of all new electrical equipment for the process plant, substation, and relative on-site facilities are based on the following:

- Single line drawings
- Mechanical equipment list
- Equipment datasheets
- Layouts and general arrangement drawings

The engineering design has determined the main power distribution system materials. Electrical motors have been included with the mechanical equipment list, including VFDs. The electrical equipment list provides equipment tag numbers, equipment names, descriptions, sizes, and power. MTOs for electrical bulks were developed by engineering and included in the consolidated BOQ. A backup genset system was also included in the cost estimates.

Ex-works pricing was sought for the major electrical equipment packages using competitive pricing submissions from equipment suppliers. Where budget quotes were not obtained, existing BGRIMM and Tetra Tech database pricing has been used; for minor equipment, in-house historical pricing and estimates were used. Installation labour hours have been included for each equipment item based on Tetra Tech's in-house data for the required specification and size.

Supply costs for cable, cable tray, terminations, lighting, wiring, terminal boxes, and distribution boxes are based on Tetra Tech's historical data for recently completed projects in the same region. Installation hours are based on in-house typical installation hours for each size and specification of cable, cable tray, terminations, lighting, wiring, terminal boxes, and distribution boxes.

The value of equipment priced from current or recent inquiries represents 99.5% of the total equipment supply value. The remainder consists of low-cost equipment that was priced from budget quotations or purchase orders from other recent estimates and projects.

Instrumentation and Control

Instrumentation has been developed by factoring from the supply costs of the mechanical equipment. A factor of 4.5% has been carried in the estimate and aligns with Tetra Tech's in-house benchmarks from construction of recent projects. The central control system was based on the quotation from a potential supplier.

Civil and Detailed Earthworks, Concrete, Structure Steel, Architectural, and Sevices

All earthworks, concrete, structure steel, and architectural quantities have been provided by BGRIMM's MTOs calculated from drawings based on designed foundations, steel framing, and architectural elements, specifically for this project. Quantities have been calculated "neat" without allowances for wastage, over-pour, and other variables. Allowances for these items have been included in the unit rates. Budget pricing has been sourced from the market for supply, fabrication, shop detailing, installation, and delivery of all materials. The returned pricing schedule included for the direct and indirect costs to supply and install the agreed scope. The returned rates were compared and evaluated by Tetra Tech for completeness and inputted into the estimate. Any special coatings or paint are also be included in the MTOs. Quantities have been included in the consolidated BOQ.

Design Growth Allowance

Each line item of the estimate is developed initially at a bare quantity and cost. A growth allowance has then been allocated to each element of those line items costs to reflect the level of definition of Design Growth (Quantity Maturity) and Pricing Growth (Cost Maturity). Due to the robustness of project engineering definition and pricing quality, on average a growth allowance of 5.6% of the total direct cost was estimated and applied for the capital cost estimates.

Estimate growth is:

- Intended to account for items that cannot be quantified based on the current engineering status but empirically known to appear, essentially bridging the gap from study to constructed quantities/costs.
- Accuracy of quantity take-offs and engineering lists based on the level of engineering and design undertaken at FS level.
- Pricing growth for the likely increase in cost due to development and refinement of specifications as well as re-pricing after initial budget quotations and after finalisation of commercial terms and conditions to be used on the project.

Such growth allowances are an integral part of the capital cost estimate. Without the inclusion of these, the estimate is incomplete. The project team has reviewed the growth and collectively formed a view based on the level of design and pricing basis at a discipline level.

Design growth percentages have been applied based on historical benchmarks on the level of project definition and engineering progress for detailed equipment lists, MTOs, and minimal factoring. Pricing growth percentages have been applied based historical benchmarks on the level of pricing definition, e.g., budgetary pricing, contractor unit rates, historical unit rates for recently completed projects in the region, allowances, and factoring.

21.1.5.4 Residue Management Capital Cost

Tetra Tech developed the tailings/residue management capital cost, which is based on local construction labour rates and material costs. The cost of earthworks, foundation preparation, and piping were determined using MTOs from preliminary design drawings. The cost estimate totals USD$89.5 million, including USD$5.6 million initial capital cost, and includes:

- Mobilization/demobilization, insurance, accommodation, overheads, supervision
- Stripping and stockpile of topsoil in external starter cell footprint
- Foundation preparation
- HDPE geomembrane liner supply and installation, including overliner protection/drainage layer
- Surface water diversion/perimeter collection ditches, including contact water management pipes/pumps
- Pad roller compactor and dozer (loaders will be shared with the CMP tailings extraction; cost for the NMT/LR residue cake delivery to the RSF site is included with extraction costs above)
- Construction QC/QA and environmental/geotechnical monitoring
- Contingency of USD$14.9 million

21.1.6 Indirect Costs

21.1.6.1 Construction Indirects

The cost of construction field indirects have been based on construction execution plan and schedule as well as input from Client to account for the cost of temporary buildings, facilities, services, and utilities for the duration of the construction. The list includes, but is not limited to, the following:

- Temporary construction warehouses and service facilities for Chvaletice Manganese team
- Construction utilities
- Waste handling
- Construction communications
- Construction management and owner’s office equipment and supplies
- Temporary construction power and distribution
- Construction equipment rental and craneage over 100 t
- Site maintenance
- Medical services
- Material offloading
- Pre-site access drug testing, as required

- Scaffolding
- Lay-down areas
- Site security services
- Site surveying
- Janitorial services
- Site bussing services
- Safety training
- Heating and hoarding
- Soils and concrete testing.

Construction field indirect costs have been calculated at 3.25% of total direct costs based on Tetra Tech's in-house benchmarks for similar industrial projects.

21.1.6.2 Contractor's Indirects

Contractor's indirects are related to the contractor's direct costs but cannot easily be allocated to any part of them. For the purpose of this estimate these costs have been added and allocated by percentage per discipline based on Tetra Tech's historical data for concrete, structural, mechanical, piping, electrical, architectural and instrumentation, whilst earthworks tasks have been based on subcontract rates.

Contractor's indirects are typically inclusive of but not limited to:

- Salaries, allowances for indirect labour, supervisory and management staff
- Mobilization and demobilization of materials and personnel
- Site offices and utilities
- Construction equipment
  - equipment service and repair labour
  - materials and supplies i.e. oil, other consumable supplies and service equipment
  - fuel
  - major repair and overhaul
  - ownership cost, e.g., equipment depreciation, interest on outstanding investment value, leasing cost, registration and insurance costs, etc.
  - outside equipment hire
  - mobilization/demobilization costs.
- Staff recruitment and travel expenses
- Workshop equipment and supplies

- Small tools and consumables
- Site office overheads and associated services
- Allowance for business risk
- Head office costs/contribution
- Financing and insurances charges
- Profit.

Contractor indirects have been calculated at 5.0% of total direct costs or 20.4% of total direct labour costs.

21.1.6.3 Construction Camp, Housekeeping and Catering

No construction camp has been included in the estimate for construction. After conversations with local contractors, Tetra Tech has been advised that the region has an abundance of local skilled labour. Therefore, it has been assumed that staffing can be primarily local with a small percentage of out of town workers. The estimate allows for transportation costs along with a catering cost of $12/man-day which is based on the estimated on-site man-hours, both costs are covered under the contractor's indirects allowance.

21.1.6.4 Spares

Major mechanical and electrical spares for commissioning, capital/insurance and operating spares have been included in the estimate from supplier quotations provided to BRIMM, total spares equate to 4.2% of total equipment supply cost.

21.1.6.5 Freight and Logistics

All bulk materials, process equipment and infrastructure within the direct costs are based on, delivered to store on-site. Freight costs are deemed to inland transportation, export packing, all forwarder costs, ocean freight and air freight where required, insurance, receiving port custom agent fees, local inland freight to the project site.

The estimated freight costs have been developed from first principles for all major equipment, bulk materials, and infrastructure based on a detailed analysis of total equipment and material weights and volumes in order to determine the number of required containers. Rates per container were provided by a freight forwarder out of China and cross checked against Tetra Tech's in-house benchmarks. Bulk freight rates were reviewed in detail by Pinnacle Logistics who provided a unit rate per t based on current market costs and recently completed projects. Rates were applied to the total material and equipment quantities after detailed analysis for a total freight cost. Once calculated, the total freight cost was divided by the total material and equipment supply price, this equates to 9.4% which has been applied to all project direct costs by line item. The blended freight percentage carried in the estimate has been evaluated and compared against Tetra Tech's and BGRIMM in-house data and deemed appropriate for the project based on in-house benchmarks and current market pricing.

21.1.6.6 Initial Fills

First fills include the costs for the initial construction first fills for installed equipment and process first fills, these consist of chemicals, fuels, and lubricants etc.

First fills have been calculated from the mechanical and electrical equipment supply costs; total first fills equate to 1.0% for construction first fills and 1.5% for commissioning first fills which are based on BGRIMM's estimate and Tetra Tech's in-house benchmarks for similar industrial projects in the region.

21.1.6.7 Commissioning and Startup

The cost of commissioning and Startup Costs have been calculated from the mechanical and electrical equipment supply costs, total to 1.0% for support labour.

21.1.6.8 Engineering, Procurement, and Construction Management

The cost of EPCM has been calculated by the EPCM organization which will cover all home office-based engineering and procurement services and site-based construction management services. The EPCM budget for the estimated scope of work equates to 14.0% of total direct costs. The EPCM cost is made up of 6.5% for engineering and procurement and 7.5% for construction management, which is based on Tetra Tech's in-house benchmarks for similar industrial projects in the region.

The EP estimate includes the following:

- Project management and administration
- Engineering management and design team
- Project services including project controls, document control, and estimating
- Home office health, safety, and environmental
- Home office human resources, accounting, and business services
- Home office computers and information technology services
- Home office procurement and contract administration team
- Vendor inspection and expediting
- Home office reproduction and communications
- Travel costs for home-office staff and inspection and expediting staff
- Assignment or policy costs based on current industry standards for staff assigned to home office
- Specialist consultant reports and facilitators.

The CM estimate includes the following:

- Project management
- Field engineering
- Site document control
- Construction management
- Construction supervision to general superintendent level

- Site administration
- Field human resources
- Site quality assurance and control
- Site project controls
- Field accounting
- Site procurement
- Field warehousing
- Field contract administration
- Site safety and training
- Travel costs for field staff once assigned to site
- Travel costs for field expediting

Third Party EPCM costs are built-into the direct/indirect costs.

21.1.6.9 Vendor Representation

Costs for vendor representatives have been calculated from the mechanical and electrical equipment supply costs, which equates to 1.0% for construction vendor representatives and 1.0% for commissioning vendor representatives based on Tetra Tech's in-house benchmarks for similar industrial projects in the region.

21.1.6.10 Owner's Capital Cost

A detailed Owner's capital cost estimate was conducted, mainly by EMN, and includes:

- Labour and expenses
- Transportation and travel
- Recruitment
- Catering and meal services for staff
- Demolition (brownfield works)
- Consulting services
- External assays and testing
- Furniture and fit-out
- IT and communications
- Safety and training – owners team
- Medical service/first aid

- Security services (by contract)
- Office supplies and rent
- Technical team – head office
- Community improvements/support
- Right-of-way (ROW) and land acquisition
- Permtting
- Regulatory compliance/permits
- Legal and fees
- Accounting services and audit
- Environmental monitoring expenses
- Environmental bonding
- Rail shunting engine
- Construction insurance

21.1.7 Contingency

Contingency is a provision of funds for unforeseen or inestimable costs within the defined project scope relating to the level of engineering effort undertaken and estimate/engineering accuracy and applied to provide an overall level of confidence in costs and schedule outcomes. The contingency is meant to cover events or incidents that occur during the Project which cannot be quantified during the estimate preparation; it does not include any allowance for Project risk.

Contingency excludes:

- Major scope changes, such as changes in end-product specification, capacities, building sizes, or location of the asset or project
- Extraordinary events, such as major strikes and natural disasters
- Management reserves
- Escalation and currency effects

21.1.8 Taxes and Duties and Escalation

The following documents have been used in the preparation of the capital cost estimate.

21.1.8.1 Taxes and Duties

Taxes and duties are not included in the estimate.

21.1.8.2 Escalation

No allowance for escalation has been included beyond Q1/Q2-2022.

21.1.9 Assumptions and Exclusions

21.1.9.1 Assumptions

The following items are assumed for this capital cost estimate:

- All design is to BGRMM and Tetra Tech standard specifications.
- Competent rock is assumed to be 2.5 m below grade in areas lacking geotechnical test work, with a minimum average allowable bearing capacity of 200 kPa.
- Topsoil is assumed to be 2.2 m deep on average.
- Concrete unit rates based on concrete ready-mix plant located nearby project site.
- Concrete pours to occur in the spring/summer/fall season, additional costs will be required for winterization.
- Steel supply and fabrication pricing based on Q1/Q2-2022 pricing, no additional costs added for future escalation.
- All process assumptions are detailed in the Process Design Criteria.
- Czech Fire Code requirements are assumed to be sufficient for Euro Manganese insurance.
- All process equipment and materials will be purchased new from China.
- Contracts awarded for construction work packages will be based on competitive bids.
- Routing for off-plot piping and overhead power distribution line have been assumed based on available topography and understanding of the terrain.
- All process plant piping is painted, unless galvanized, stainless, or insulated.

21.1.9.2 Exclusions

The following items are excluded from this capital cost estimate:

- Working or deferred capital
- Financing costs
- Refundable taxes and duties
- Currency fluctuations
- Lost time due to severe weather conditions
- Lost time due to force majeure
- Lost time due to pandemic

- Changes to design criteria
- Additional costs for accelerated or decelerated deliveries of materials
- Services resultant from a change in project schedule
- Warehouse inventories, other than those supplied in initial fills, and critical spares as included in the vendor equipment budgetary quotations
- Any project sunk costs (test work, studies, exploration programs, etc.)
- Escalation costs
- Accommodation camp
- Operating costs
- Sustaining capital costs
- Force majeure issues
- Scope changes
- Aggregate crushing plant on site
- Concrete batch plant on site
- Demolition and salvage of any existing on-site structures
- Special incentives (schedule, safety, other)
- Community relations

21.1.10 Sustaining Capital Estimates

The sustaining capital cost for the LOP is estimated at approximately USD$117.0 million. The cost is assumed to be used for major equipment replacements for the CMP tailings extraction and process plant. The costs for routine equipment maintenance, including small equipment replacements and spare parts, are included in operating costs.

21.2 Operating Cost Estimate

On average, the on-site operating costs are estimated as USD$194.79/t of CMP tailings reprocessed, or USD$4.43/kg manganese metal produced (equivalent). The on-site operating costs are defined as the direct operating costs including CMP tailings extraction, processing, water treatment, NMT/LR (residue) dry stacking, site servicing, and G&A costs and exclude offsite costs such as product freight costs, sales related costs, government, and third-party royalties, which are included in the economic analysis (Section 22.0).

The estimates are based on an average annual plant feed rate of approximately 1.1 Mt of the CMP tailings, or an average annual manganese metal production of 47.5 kt (total manganese equivalent in HPEMM and HPMSM, ranging from 45,582 to 49,428 t/a of manganese), excluding the first ramp-up year. Table 21-3 shows the cost breakdown for various areas and Figure 21-1 shows the cost distribution. The major cost for the CMP is the HPEMM

TETRA TECH

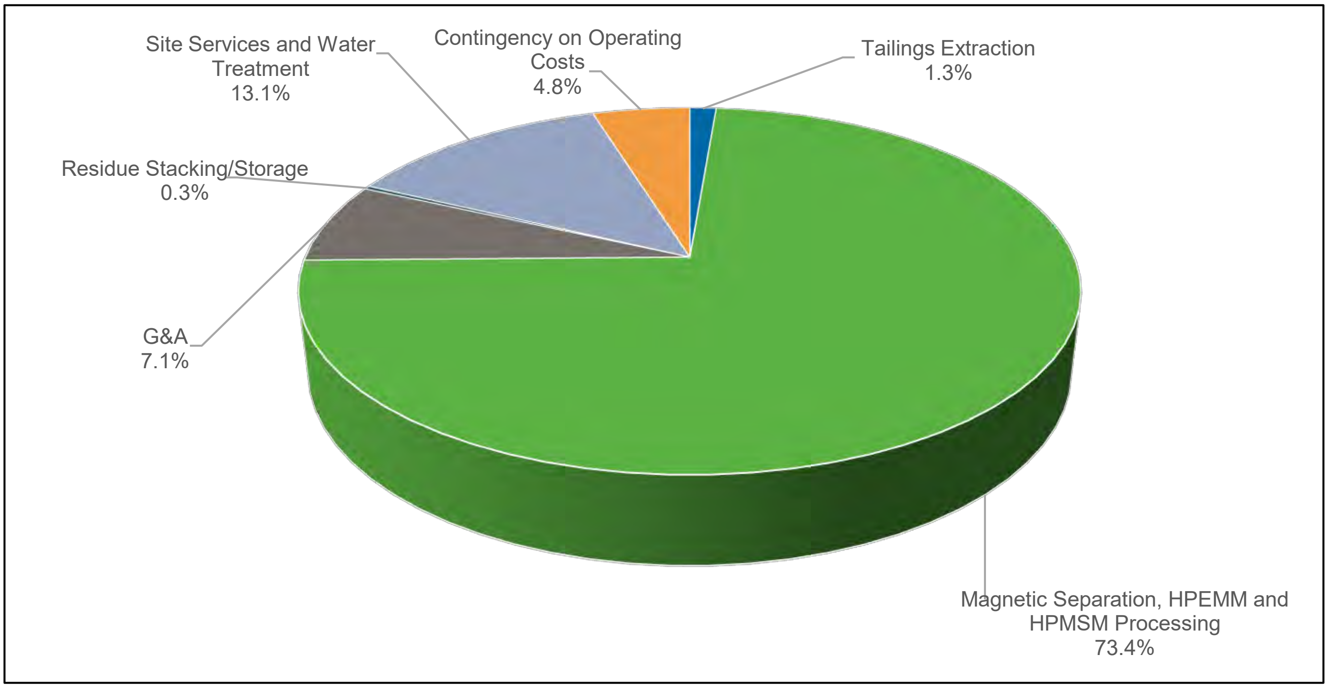
and HPMSM processing cost, which accounts for approximately 87.6% of the total cost. A contingency of 5% is included in the estimate.

Table 21-3: LOM Average Operating Cost Summary

Area	Unit Operating Cost	
	(USD$/t processed)	(USD$/kg Mn)*
Tailings Extraction	2.44	0.05
Magnetic Separation, HPEMM and HPMSM Processing	143.18	3.26
Site Services and Water Treatment	25.46	0.58
Tailings Stacking/Storage	0.66	0.02
G&A	13.78	0.31
Contingency on Operating Costs	9.28	0.21
Total Operating Cost	**194.79**	**4.43**

Note: *Unit cost per kilogram manganese metal produced (equivalent).

Figure 21-1: Overall Operating Cost Distribution by Area



The operating cost estimates are based on the consumable prices and labour salaries/wages from Q1/Q2 2022, or information from Tetra Tech's in-house database. The estimates do not include any escalation past this date. The expected accuracy range of the operating cost estimate is ±15%. All the costs are estimated in US dollars, unless specified. The foreign exchange rates used for the estimates are shown in Table 21-1.

It is assumed that operation personnel will reside in towns or villages nearby. There will be no accommodation provided at site. The CMP will provide one meal catering services for on-shift operators. Personnel will commute to the site at their own expense.

The operating costs exclude shipping charges, insurance, and sales costs for the manganese products, as well as government and third-party royalties, which are included in the economic analysis (Section 22.0).

All operating cost estimates exclude taxes unless otherwise specified.

21.2.1 CMP Tailings Extraction

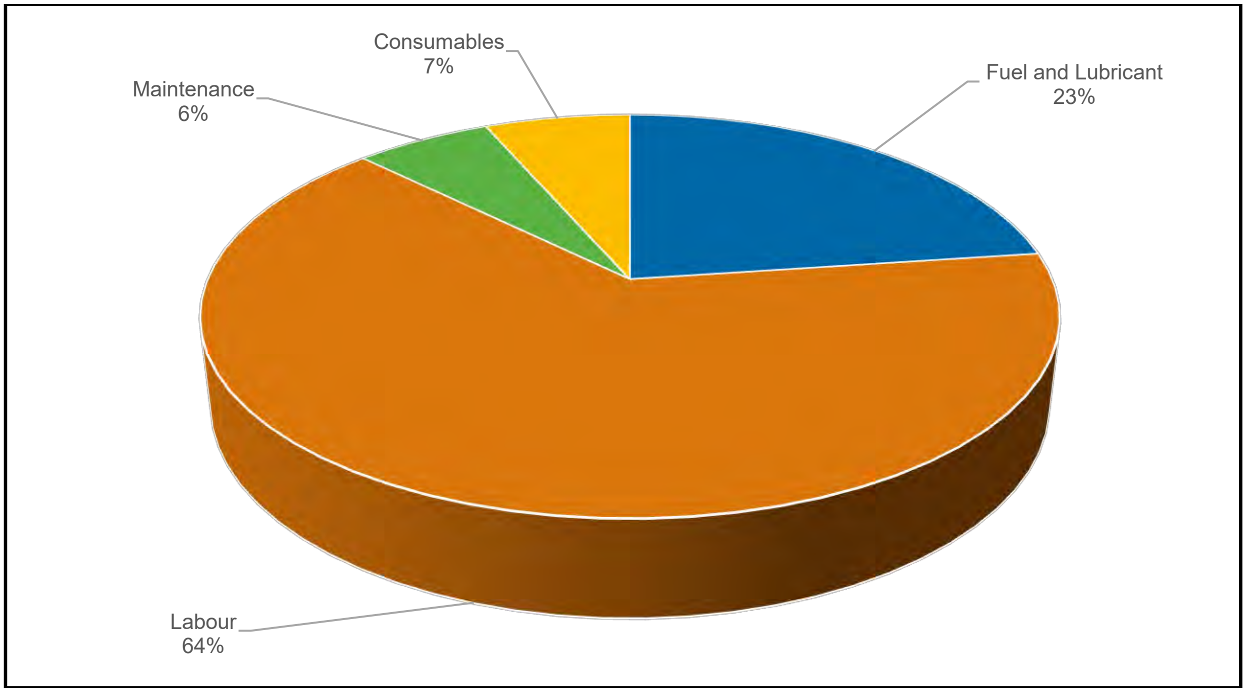
The CMP tailings extraction operating costs have been estimated on an annual basis. The extraction operation will operate 14 hours per day, 5 days per week, excluding weekends and public holidays. A temporary stockpile is planned to be located adjacent to the CMP tailings pulping facility to meet the operating requirement of the hydrometallurgical processing plant, which will operate 24 hours per day, 7 days per week.

The tailings extraction estimate includes labour, fuel, lubricant, consumables, maintenance, and mining-related G&A costs. Table 21-4 summarizes the average tailings extraction costs over the project life and Figure 21-2 illustrates the cost distribution by category. An average unit cost of USD$2.44/t of plant feed was estimated, excluding contingency. The major cost for the tailing extraction is the labour-related cost. The extraction costs vary for each year based on the scheduled throughput for each year and on haul distances from the extraction site to the plant feed pulping facility.

Table 21-4: Tailings Extraction Operating Costs

Area	Unit Operating Cost (USD$/t processed)
Fuel and Lubricant	0.56
Labour	1.58
Maintenance	0.15
Consumables	0.16
Total Tailings Extraction Operating Cost	**2.44**

Figure 21-2: Tailings Extraction Operating Cost Distribution by Category



21.2.2 Process Operating Costs

The unit process operating cost for the CMP is estimated as USD$150.34/t plant feed at the LOM average plant feed rate including the process related contingency of USD$7.19/t plant feed. The contingency allowance is estimated to cover items of cost which are not known exactly at the time of the estimate. The estimate is based on 12-hour shifts, 24 hours per day, 365 days per year at a plant availability of 90.4% and an average annual pant feed processing rate of approximately 1.1 Mt of the CMP tailings, or an average annual manganese metal production of 47,500 t. Approximately two-thirds of the HPEMM produced is planned to be converted to HPMSM.

Table 21-5 summarizes the estimated process operating costs by processing area and Table 21-6 summarizes the costs by process category. Figure 21-3 and Figure 21-4 show the cost distributions by processing area and by category, respectively.

Table 21-5: Process Operating Cost Summary by Area

Area	Unit Operating Cost (USD$/t processed)*
Magnetic Separation and NMT Dewatering	3.36
Leaching and Fe/P Purification	45.30
Solution Purification	6.17
Electrowinning	49.87
Residue Washing and Dewatering	2.47
Manganese Recovery	0.85
Magnesium Removal	7.37
Ammonia Recovery	7.71
HPMSM Production	19.37
Product Handling/Packing	0.06
Testing and QA/QC	1.23
Subtotal	143.76
Contingency	7.19
Total Process Operating Cost	**150.95**

* at nominal plant rate

Table 21-6: Process Operating Cost Summary by Category

Area	Unit Operating Cost (USD$/t processed)
Labour	6.99
Reagent	58.48
Maintenance/Operation Supply	11.81
Electricity	43.88
Other Consumables	22.60
Contingency	7.19
Total Process Operating Cost	**150.95**

* at nominal plant rate

Figure 21-3: Process Operating Cost Distribution by Area

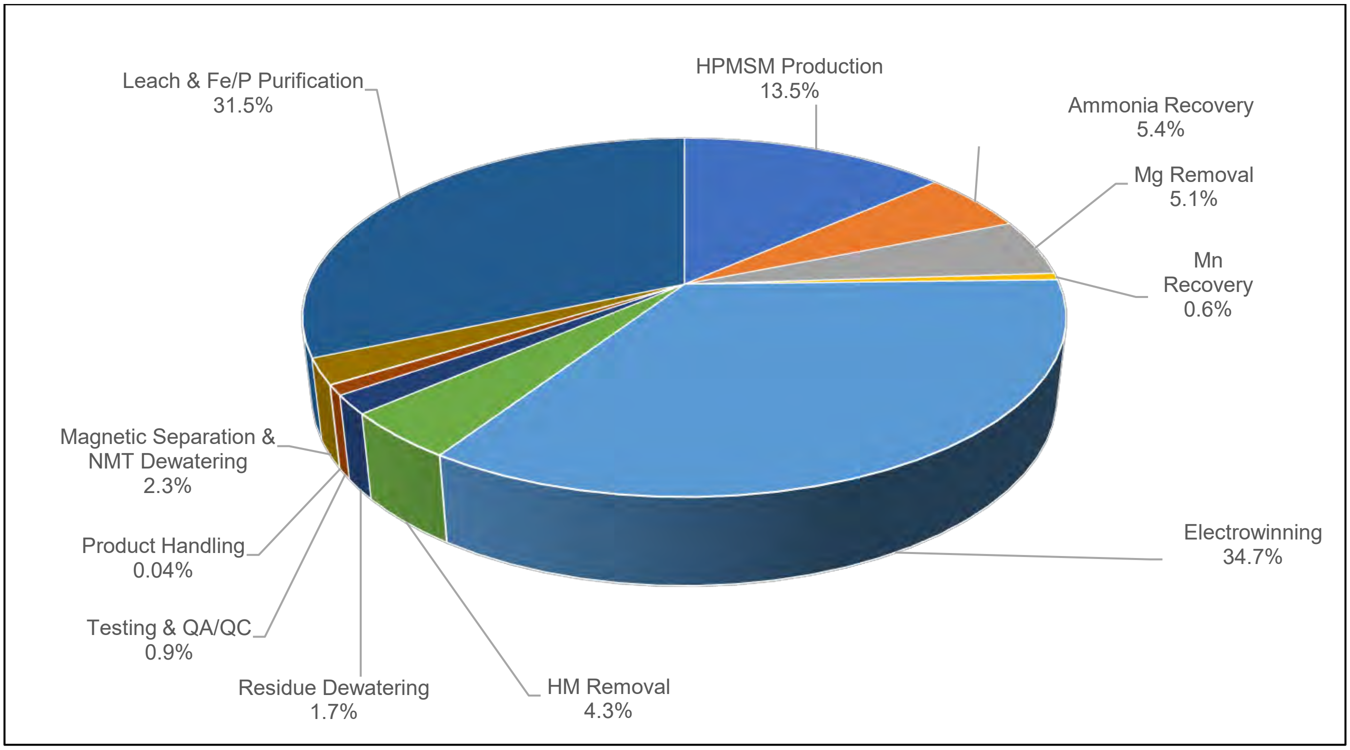
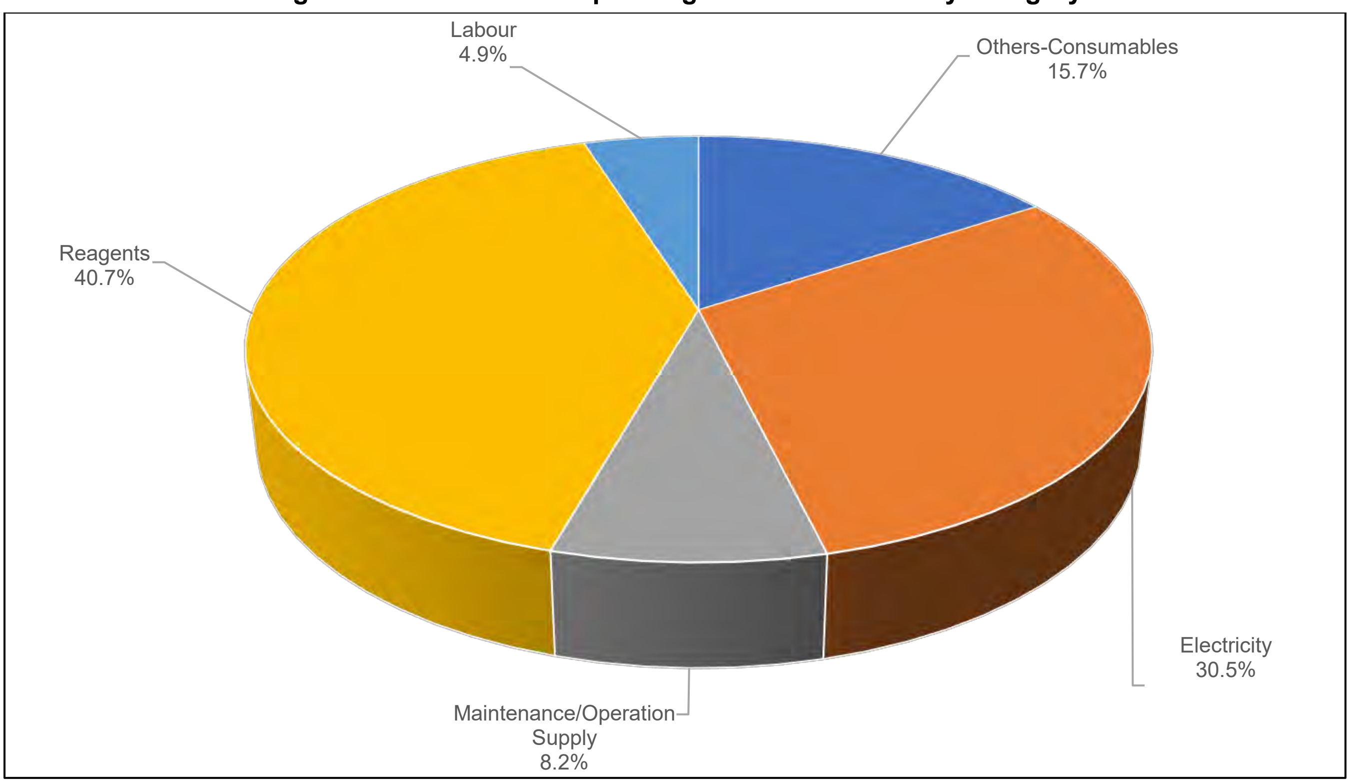


Figure 21-4: Process Operating Cost Distribution by Category



An average unit operating cost of approximately USD$129.25/t plant feed with a contingency of 5% was estimated for HPEMM production, excluding testing and QA/QC-related costing. The major costs for HPEMM production are electrowinning-related costs and acid leaching, iron, and phosphorous removal-related costs, which account for 34.7% and 31.5% of the total processing cost, respectively.

The cost for converting HPEMM to HPMSM is estimated as USD$20.34/t plant feed with a contingency of 5%. This cost is equal to 13.5% of the total process operating cost.

The cost for testing and QA/QC control is estimated as USD$1.29/t plant feed, including the contingency.

The major processing costs by category are the costs related to reagents and electricity power, accounting for approximately 40.7% and 30.5%, respectively.

The process operating cost estimate breakdowns by category are detailed in the following subsections.

21.2.2.1 Personnel

Personnel requirements include supervision, operation, and maintenance. Salary/wage levels include various benefit burdens, based on the estimated Q1/Q2 2022 labour rates in the Czech Republic. Two burden rates were estimated for the employees: 34% for management team and technical supporting personnel and 52% for general operators. The benefit burdens for the workers include retirement savings plans, various life and accident insurances, medical benefits, unemployment insurance, tool allowance, and other benefits. Mangan estimated the labour and burden rates according to local market data.

The preliminary estimates show that approximately 289 workers, including management, technical support, and maintenance will be required for the process plant, excluding CMP tailings extraction, residue dry stacking, overall site G&A, site services, and water treatment operations. The projected process personnel requirement includes:

- 40 staff for management and technical support, including personnel at laboratories for quality control, process optimization and assaying
- 198 operators servicing overall operations from CMP tailings pulping to the HPEMM and HPMSM product loadout and control room operators
- 51 personnel for equipment maintenance, including the maintenance management team.

21.2.2.2 Power

Electrical Power consumption is one of the largest operating costs for the CMP, driven by the electrowinning circuit which operates primarily on a baseload profile throughout the year and responsible for approximately 66% of total electrical energy consumed. The total estimated electrical energy consumption is approximately 490 GW/a, with a nominal operating capacity of approximately 75 MW, and installed capacity of approximately 85 MW. In April 2021, EMN solicited the services of Baringa Partners LLP (‘Baringa’), a United Kingdom based consultancy, serving the European power supply market, for strategic guidance including power supply contract structures and wholesale and retail power price forecasts within the Czech Republic and greater European Union (EU). Phase 1 of the work provided by Baringa included an overview of the European and Czech power supply markets along with both current and expected trends and the various contract structures for power purchase agreements (PPA’s) relevant to the EU market. Phase 2 of the work involved the preparation and issuing of a market sounding questionnaire to several power suppliers within the EU for the purpose of contracting long term power for the project, with initial focus on non-binding memorandum of understanding (MOU). Since that time EMN has been in active discussions with several parties with respect to securing long term power supply for the project.

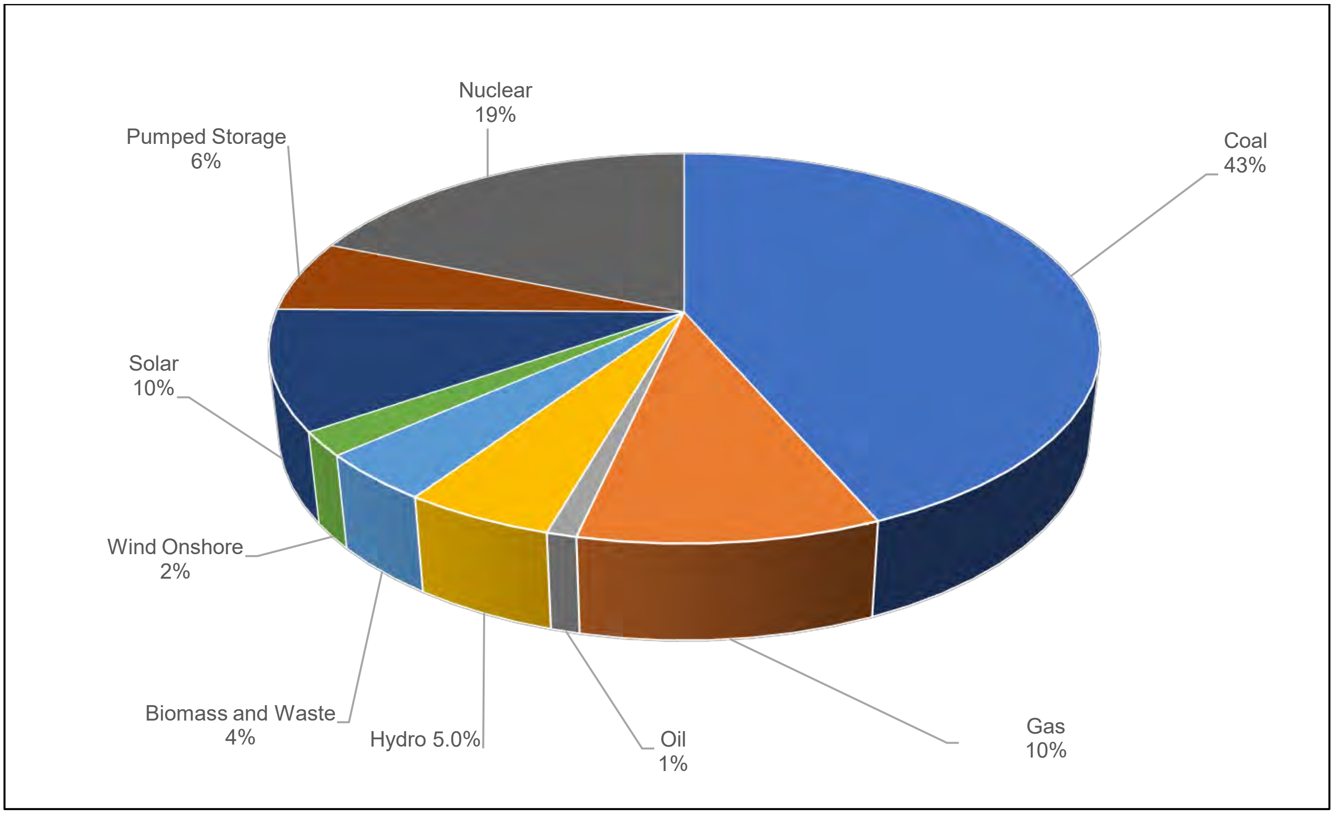
Baringa – Phase 1 Work Summary

The Czech Republic is one of the largest net electricity exporters in the EU and the power market is currently dominated by coal and nuclear generation. The National Energy and Climate Action Plan (NECP) targets 22% of final energy consumption from renewable sources by 2030. Initially, the Czech Coal Commission voted for 2038 as the recommended date for coal phase-out date; however, in January 2022, the Czech government has introduced the coal phase-out by 2033, and nuclear as well as gas followed by renewables will be key technologies in supporting the country's energy transition. Total installed capacity has remained relatively stable in recent years at around 22 GW, however a minor decline was witnessed in 2021 due to some coal units being phased out. As of 2021, the capacity mixture is composed by 9 GW of coal (brown and hard coal), 3.9 GW of nuclear, and 2 GW of gas. In terms of renewables, as of 2021, there are 2 GW of solar, 339 MW of wind, 2.3 GW of hydro (including 1.2 GW pumped storage).

The Czech power market is dominated by three players across generation, distribution, and supply. As mentioned, the Czech Republic generation mixture is dominated by nuclear and coal power plants; together, these sources represented c.a. 75% of total domestic electricity production in 2021. Natural gas, biofuels, and hydropower represent most of the remaining share, with solar and onshore wind contributing approximately only 3.5% combined.

The Transmission System Operator (TSO), ČEPS, and three Distribution System Operators (DSOs) are regulated by the Energy Regulatory Office (ERU). Supply to end users is liberalized though three main players (ČEZ, E.ON, and PREdistribuce) who continue to make up the vast majority of the market, as successors of unbundling through privatization in the 1990s. Germany is a key market for Czech wholesale power prices, with a strong correlation historically between prices in the two markets. Trading occurs on the European Energy Exchange (EEX) through OTC contracts and spot markets organized by the Czech market operator (OTE). The Czech Republic became a part of the EU cross-border intraday electricity market (Single Intra-Day Coupling or SIDC) in November 2019.

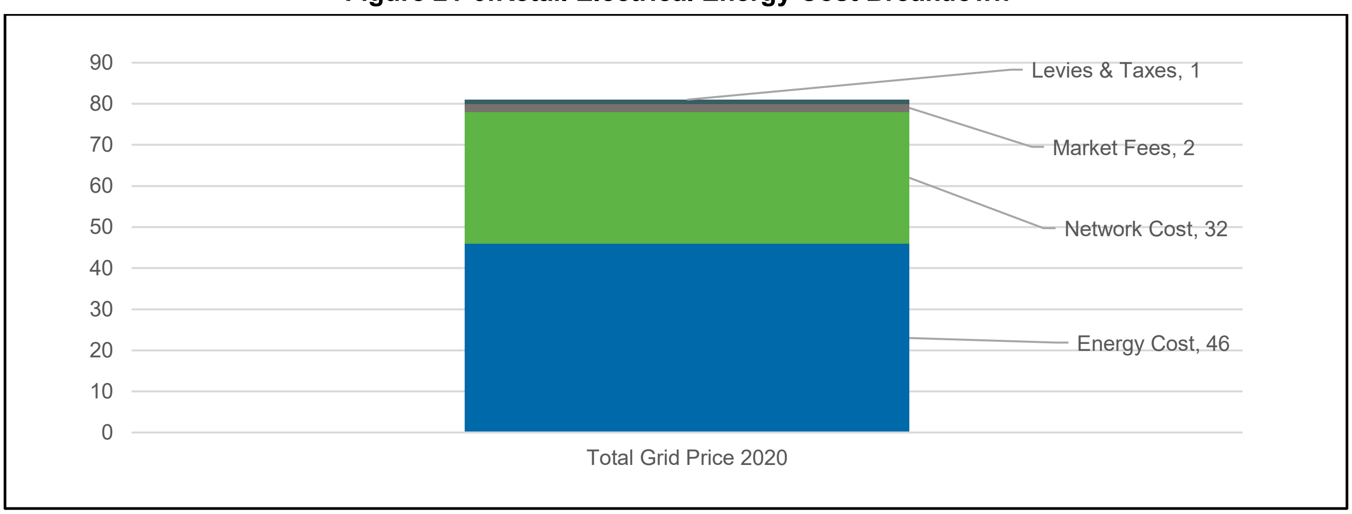
Figure 21-5:Czech Power Installed Capacity by Technology Type in 2021



Source: Baringa Partners LLP (Reproduced)

The retail tariff for non-domestic (industrial) users has historically been low relative to other markets in the region at approximately 75 to 80 €/MWh prior to the increase in commodity and power prices in 2021/2022. The total retail price is made up of actual energy costs, transportation costs to site, levies, taxes, and supplier margin. The chart below shows breakdown of retail electrical energy costs.

Figure 21-6:Retail Electrical Energy Cost Breakdown



Source: Baringa Partners LLP (Reproduced)

The CMP committed to environmental excellence and sourcing of green, renewable, carbon-free power is therefore critically important within the framework of economic and technical viability. The current Czech energy mixture consists largely of carbon-based power (coal) with some nuclear and renewables.

Baringa – Phase 2 Work Summary

In November 2021, and on behalf of EMN, Baringa prepared a market sounding questionnaire (MSQ) and reached out to a number of power suppliers/generators within the EU for the purpose of sourcing long term, renewable energy for the CMP. The ultimate objective of the MSQ was to source credible power supply partners with which to initially engage via a MOU. As a result, EMN are currently in power supply negotiations with potential power suppliers for the CMP.

In spite of the broad market test, the MSQ has shown that only limited renewable supply options are currently available in the Czech Republic. This is linked to a limited build out of renewables and the relatively high market share of CEZ as incumbent supplier in the Czech Republic. Going forward, opportunities for solar and onshore projects should improve, and the Czech Republic's policy target is also supportive of this development. As such, there might be more opportunities with local suppliers emerging across the next several years. However, one should note that energy market prices and development costs haven been increasing across Europe more recently.

Given these circumstances, the most practical way to achieve a long-term green supply is via a virtual cross-border PPA with Germany or Poland. There are significant project pipelines in Poland, and growing pipelines in Germany available from 2025 onwards. A cross-border PPA supports the decarbonization objective as it provides Guarantees of Origin (GoO), based on Poland and Germany. A fix-price contractual structure can help to fix the cost of energy to a certain level. However, this type of PPA will not protect against all energy price risks a domestic PPA could achieve. This in particular refers to the basis risk (correlation between the price paid domestically, and the price index fixed in the PPA based on the location of the generator), as well as FX and interest rate spread risks. Based on this a potential contract approach is a Contract for Difference (CfD) between EMN and the power supplier, whilst maintaining company's Energy Supply Agreement with potential suppliers. If signed, the contract for difference provides EMN with a cash flow based on a fixed price and the market price level: in a high price environment, EMN is paid the difference. If the (monthly) market price level is below the fixed price in the contract, EMN will be paying the generator (based on the market correlation between DE/PL and CZ, it is assumed that the retail cost would be lower as well). This is a relatively new structure in Europe, but popular in the U.S. as it allows contracts across markets that are not physically connected (e.g., between a developer in Texas and an off-taker in New England). Furthermore, a baseload PPA is typically settled against day-ahead indices. While EMN's consumption is very close to this type of profile and hence the volume risk is assumed low, EMN is still be exposed to imbalance price levels.

The current conflict in eastern Europe between Ukraine and Russia, along with a post-COVID-19 inflationary climate, has led to unprecedented high power prices across the entire EU. One of the main objectives of securing long term power for the CMP is to ensure long term price stability for the operation, particularly during the payback period in order to de-risk the project. Electrical energy represents approximately 30% of the total process operating costs of the CMP and is therefore a significant contributor to the economic viability of the project.

Power pricing assumptions for the FS are based on long term forecasts as prepared by Baringa, spanning the time period 2022 to 2050. The current inflationary market is represented in this forecast in the form of significantly inflated prices, with the expectation that a downward trend should be realized from 2027 onward during which time it is anticipated that the Russia/Ukraine conflict settles and technology maturation continues to evolve and be realized through lower power costs. Current wholesale average forecast power price over this time period (2022 - 2050) across the three markets (Czech, Germany, Poland) is anticipated to be approximately €75/MWhr with an average expected network costs of approximately €20/MWhr. Therefore the total assumed power price for the CMP is €95/MWhr (2022 real price).

21.2.2.3 Reagent Consumables

The cost-related operation consumables are estimated to be the largest operating cost, compared to the other costs. It accounts for 40.7% of the total process operating costs, or USD$58.48/t plant feed, excluding contingency. Reagent consumptions were estimated based on test results, METSIM™ simulation, and BGRIMM, Tetra Tech, and EMN technical teams' experience. The reagent costs are based on prices from Q1/Q2 2022 from the quotations conducted by the Mangan local logistic team, mainly from the local suppliers.

Sulphuric acid, hydrated lime, and ammonium bicarbonate are the main reagents expected to be consumed in HPEMM and HPMSM production. Approximately 185,000 t of sulphuric acid and 75,000 t of lime are estimated to be consumed per year, respectively.

21.2.2.4 Other Operation Consumables

Consumptions for other major consumables such as filter clothes, cathode, and anode plates are based on potential suppliers' data and BGRIMM, Tetra Tech, and EMN technical teams' experience; unit prices are based on quotations by potential suppliers or for minor items by BGRIMM and Tetra Tech's in-house database. The steam consumption for acid leaching, ammonia stripping, and crystallization circuits was estimated by BGRIMM design and METSIM™ simulation. Steam will be generated onsite by recovered hydrogen off-gas from HPMSM production and nature gas from local natural gas network.

21.2.2.5 Maintenance/Operation Supplies

The cost for maintenance/operation supplies is estimated as USD$11.81/t plant feed without a contingency. Maintenance supplies were estimated based on approximately 10% of major equipment capital costs based on Tetra Tech's experience.

21.2.2.6 Contingency

A contingency of 5% of the estimated operating cost is included in the operating cost estimate.

21.2.3 Residue Dry Stacking

Tetra Tech developed the tailings/residue management operating cost, which includes equipment operating and annual surface preparation costs. For the life of the project, the average annual residue dry stacking operating cost is estimated as approximately USD$0.66/t plant feed. The costs associated with the RSF closure are excluded from the estimate and were estimated separately as closure sustaining capital costs and included in the CMP economic analysis. The operating cost estimate includes:

- Strip and stockpile topsoil in external starter cell footprint annually
- Clearing and surface preparation of residue placement area
- Bulk fill of material to level residue placement area for drainage
- Operation of one loader for material handling and placement of residue

- Pad levelling by a roller compactor

21.2.4 General and Administrative and Site Services

21.2.4.1 General and Administrative Related Cost

The G&A cost at the nominal process rate is estimated as USD$12.41/t plant feed. Table 21-7 summarizes the G&A cost estimates. The cost for management personnel is estimated as USD$1.63/t plant feed. The general expense is estimated as USD$10.78/t plant feed.

Table 21-7: G&A Cost Estimates

Area	Manpower	Annual Cost (USD$/a)	Unit Operating Cost (USD$/t processed)
Labour	37	1,796,000	1.63
General Expenses	-	11,883,000	10.78
Subtotal	37	13,679,000	12.41

Personnel

Personnel includes a general manager and staffing for accounting, purchasing, environmental, sales, and other G&A departments. The total employee number for G&A is estimated as 37. Only personnel working at the CMP site were included.

Salaries and wages are based on the Q1/Q2 2022 Czech Republic labour rates and include a benefit burden of 34% for employees to cover retirement savings plans, various life and accident insurances, medical benefits, unemployment insurance, and other benefits. Mangan estimated the labour and burden rates according to local market data.

General Expenses

General expenses include general administration, contractor services, insurance, security, medical services, legal services, human resources, travel, communication services/supports, external assay/testing, engineering consulting, catering/meal services for onsite workers, land lease, and sustainability, including an environment and community liaison.

21.2.4.2 Site Services

The overall site service cost at nominal process rate, including the tailings extraction site and the plant site, water treatment and handling and railway spur operation, is estimated as USD$25.30/t plant feed, including USD$22.63/t plant feed for general site services, USD$1.47/t plant feed for site water treatment, and USD$1.20/t plant feed for railway spur operations (Table 21-8).

Table 21-8: Site Service Cost Estimates

Area	Staffing	Annual Cost (USD$/year)	Unit Operating Cost (USD$/t processed)
General Site Services			
Labour	51	1,204,000	1.09
General Expenses	-	23,740,000	21.54
Subtotal	**51**	**24,944,000**	**22.63**
Water Treatment			
Labour	6	165,000	0.15
General Expenses	-	1,458,000	1.32
Subtotal	**6**	**1,623,000**	**1.47**
Railway Spur Operation			
Labour	19	537,000	0.15
General Expenses	-	787,000	0.71
Subtotal	**19**	**1,324,000**	**1.20**

Personnel

A total of 70 employees are expected to be needed for general site services, which cover general service management and operations. The operations will include general yard services, supply unloading, product loading, site water management, small mobile machine operation, steam generation plant, railway spur system operation (including engine operators), and general maintenances.

Six workers are estimated to be required for the water treatment operation, including reagent preparation. Water treatment equipment maintenance will be conducted by a joined maintenance force from general site service and plant service teams.

Salaries and wages are based on the Q1/Q2 2022 Czech Republic labour rates and two burden rates were estimated for the site service workers: 34% for management team and maintenance personnel and 52% for general operators. The benefit burdens for the workers will cover retirement savings plans, various life and accident insurances, medical benefits, unemployment insurance, tool allowance, and other benefits. Mangan estimated the labour and burden rates according to local market data.

General Expenses

Operating expenses for general site services include small vehicle equipment operations, potable water supply, process makeup water supply, hot water and demineralized water supplies, waste management, building maintenance, road maintenance, power line maintenance, railway spur operation, steam operation, office power supply and service office/workshop heating.

Process water makeup water and hot water will be supplied from Severní power plant. The industrial water or so-called “green water” from the power plant will be used as process makeup water. The hot water will be used for building heating and process heating for the concentrate acid leach and iron/phosphorous removal circuits.

TETRA TECH

Demineralisation water will be used for producing steam, mainly for ammonia recovery, HPMSM evaporative crystallization, and HPMSM crystal drying, and generating pure water for HPMSM production. Mangan has established an agreement with Severní for the hot water supply and process makeup water (“green water”) supply.

Steam will be generated on site using hydrogen gas recovered from HPMSM production circuit and natural gas from the local natural gas pipeline network immediately adjacent to the CMP’s plant site. The demineralization water will be used for the steam generation.

Operating expenses for the water treatment plant, including cooling system operation, will mainly cover water treatment reagent, electricity power and maintenance and operation supplies.

22.0 ECONOMIC ANALYSIS

Tetra Tech completed a pre-tax economic analysis based on estimated costs and revenues for extracting and reprocessing the tailings from the Chvaletice deposit. The economic analysis is based on the sale of two products: HPEMM and HPMSM. The economic analysis concluded the following pre-tax financial results:

- Pre-tax NPV of USD$1,750 million at an 8% discount rate
- Pre-tax IRR of 24.9%
- Pre-tax payback period of 3.6 years

Grant Thornton Tax & Accounting s.r.o. (Grant Thornton), based in the Czech Republic, prepared both the Czech tax depreciation calculations based on the capital expenditure information and the allocation of such expenditures into the Czech tax depreciation groups. The Czech corporate income taxes payable for the CMP economic analysis are based on existing income tax legislation in the Czech Republic.

The post-tax economic analysis for the life of the project yielded the following financial results:

- Post-tax NPV of USD$1,342 million at an 8% real discount rate
- Post tax IRR of 21.9%
- Post-tax payback period of 4.1 years

The FS economic evaluation shows that the project is most sensitive to product prices followed by operating costs.

Key inputs into the financial model include:

- HPEMM pricing, as shown in Table 19-9 and HPMSM pricing as shown in Table 19-10
- Project start-up (construction commences) in 2023
- Operations start-up in 2027
- Plant capacity of 65% in the first year of production (2027)
- Average production of approximately 47,800 t/a of HPEMM over the 25-year LOP, of which approximately two-thirds is converted into 98,600 t/a of HPMSM
- Maximum production of 100,000 t/a of HPMSM
- Life-of-project saleable product includes 372,000 t of HPEMM and 2.46 Mt of HPMSM, focusing principally on Europe's rapidly emerging electric vehicle battery industry
- Czech Koruna to United States Dollar: 22.43 CZK to USD$1.00
- Czech royalty of 2,308 CZK per t of saleable manganese produced
- Average shipping cost of USD$116/t of HPEMM and HPMSM product sold based on the assumption that HPMSM and HPEMM products will be sold in Europe.

- Insurance on saleable products of 0.04% of the product value
- Selling costs of 0.5% of the product value
- Overall manganese recovery of 59.4% with recovery of manganese metal from HPEMM to HPMSM of 97%
- HPEMM purity of 99.9% and HPMSM Mn content of 32.34%.

In addition to the key inputs, the following estimated inputs have been used in the financial model:

- Life-of-project average price for HPEMM of USD$10.56/kg and LOM average price for HPMSM of USD$4.03/kg
- Life-of-project average tailings excavation rate and mill feed rate, of 1,066 kt/a (1,080 kt/a post ramp up)
- Pre-production capital costs of USD$757.4 million, sustaining capital of USD$117.0 million and initial working capital of USD$78.7 million
- Salvage value of USD$37.9 million (5% of initial capital) and reclamation costs of USD$2.0 million at the end of LOP.

Table 21-1 shows a summary of the financial modelling results. Figure 22-1 shows a summary of the financial modelling results in graphical form.

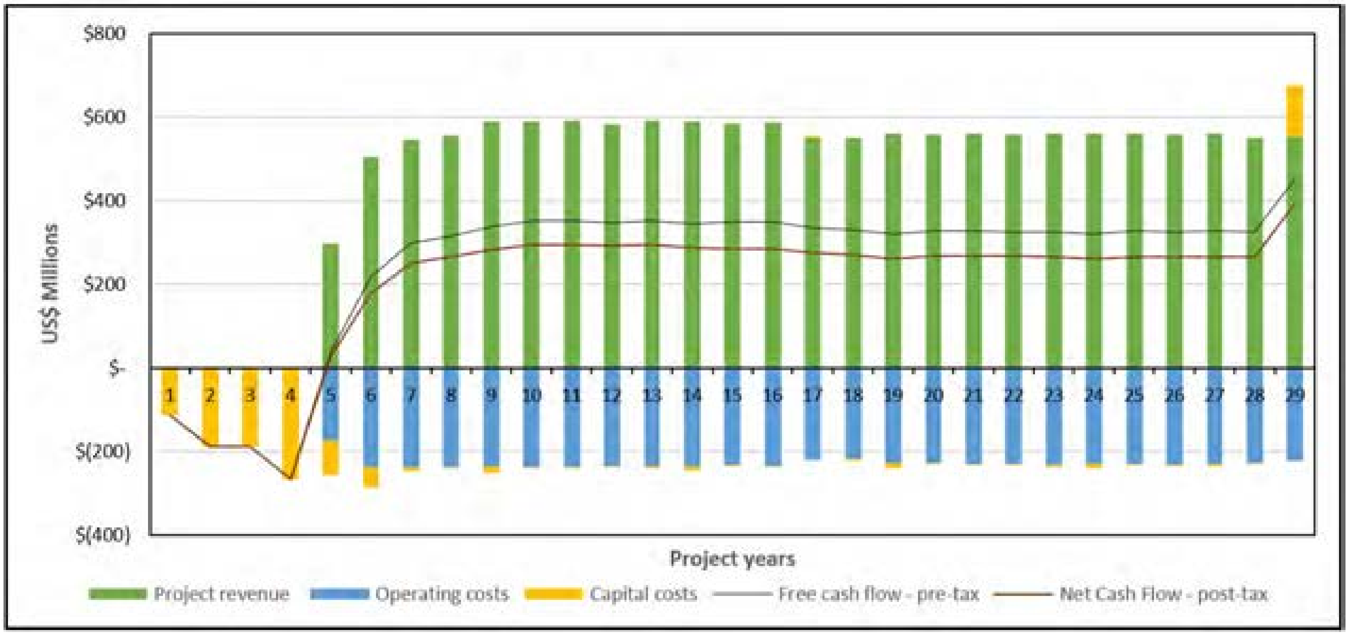
Table 22-1: Summary of Financial Results

Financial Summary	Units	Value
Tailings Extraction and Processing Information		
Life-of-project	years	25
Annual Tonnage Processed (Life-of-project Average)	kt	1,066.0
Manganese Grade (Average)	%	7.41
Contained Manganese (Life-of-project)	kt	1,973.5
HPEMM produced	kt	1,194.5
Net HPEMM produced/sold	kt	372.2
HPMSM produced/sold	kt	2,465.0
Revenue		
Revenue from HPEMM	USD$ millions	3,930.9
Revenue from HPMSM	USD$ millions	9,931.2
Total Revenue	**USD$ millions**	**13,862.1**
Selling and Distribution Costs		
Freight costs, USD$116/t	USD$ millions	330.8
Insurance costs, 0.04%	USD$ millions	5.5
Selling costs, 0.5%	USD$ millions	69.3
Total Selling & Distribution Costs	**USD$ millions**	**405.6**

table continues…

Financial Summary	Units	Value
Life-of-Project Operating Costs		
Tailings Extraction	USD$ millions	64.9
Process – Magnetic Separation	USD$ millions	89.7
Processing to HPEMM	USD$ millions	3,196.9
Processing of HPEMM to HPMSM	USD$ millions	528.4
Tailings Stacking/Storage	USD$ millions	17.6
Site Services	USD$ millions	641.6
Water Treatment and Handling	USD$ millions	36.8
G&A	USD$ millions	367.0
Contingency on Operating Costs	USD$ millions	247.2
Total Life-of-Project Operating Costs	**USD$ millions**	**5,190.0**
Other Costs		
Czech Government Royalty	USD$ millions	120.6
Total Life of Project Costs, incl. Selling & Distribution	USD$ millions	5,716.3
Capital Costs & Other Costs		
Pre-production Capital Costs	USD$ millions	757.4
Life of Project Sustaining Costs	USD$ millions	117.0
Working Capital in the First Year	USD$ millions	78.7
Reclamation Costs Recovered from Bonding Fund	USD$ millions	2.0
Salvage Value	USD$ millions	(37.9)
Total Capital Costs, net of end of Project Salvage Costs	USD$ millions	836.5
Life-of-Project Pre-Tax Undiscounted Cashflow	USD$ millions	7,309.3
Czech Corporate Taxes Payable	USD$ millions	1,397.1
Life-of-Project Post-Tax Undiscounted Cashflow	USD$ millions	5,912.2
Pre-tax NPV at 8% Real Discount Rate	USD$ millions	1,749.6
Pre-tax IRR	%	24.9
Pre-tax Payback Period	years	3.6
Post-tax NPV at 8% Real Discount Rate	USD$ millions	1,341.6
Post-tax IRR	%	21.9
Post-tax Payback Period	years	4.1

Figure 22-1: Summary of Financial Results



22.1 Basis of Financial Evaluations

The production schedule was incorporated into the 100% equity pre-tax financial model to develop annual recovered metal production from the relationships of t processed, head grades, and recoveries.

Cash flows are discounted to an assumed decision point, which is currently assumed to be the completion of an FS and securing of funding for construction four years prior to commercial production.

HPEMM and HPMSM selling values are based on a price outlook included in an independent marketing study completed for this FS by the CPM Group. Revenues were estimated by subtracting transportation, insurance, and selling costs. Operating costs for tailings extraction, processing, G&A, and other site-wide operating costs were deducted from revenues to derive annual operating cash flows.

Initial and sustaining capital costs, as well as working capital, were incorporated on a year-by-year basis over the life-of-project. Demolition and site reclamation costs were applied to the capital expenditure proceeding the last production year with an add back from the plant salvage value. Capital expenditures were then deducted from the operating cash flow to determine the net cash flow before taxes.

Initial capital expenditures include costs accumulated prior to first production of concentrate. Sustaining capital includes any capital expenditures required during the production period.

Working capital is assumed to be two months change in the annual operating cost (inventory) and two months change in revenues (receivables). Working capital required fluctuates from year to year based on the annual cash flows. The working capital is recovered at the end of the project.

22.2 Corporate Income Tax Calculations and Assumptions

EMN commissioned Grant Thornton to prepare: (i) the Czech tax depreciation calculations based on the capital expenditure information and the allocation of such expenditures into the Czech tax depreciation groups, (ii) the Czech corporate income taxes payable for the CMP economic analysis based on existing income tax legislation in the Czech Republic. The taxes are based on the pre-tax cash flows.

The following subsections outline the assumptions for tax estimation purposes used in the FS.

22.2.1 Financing

It is assumed the Project will be 100% funded by equity. As a result, no interest or principal repayments with respect to any debt will be included in the analysis. There is no special transaction (merger/acquisition/purchase or sale of shares/enterprise), consequently, no transfer pricing impacts/adjustments were taken into account. The Model assumes no interest-bearing debt financing, and no interest has been taken into account. The Model assumes no payment of dividends. Please note that transfer of Company's profit to shareholder would generally be a subject to the Czech withholding tax.

22.2.2 Taxation Authorities

The applicable tax jurisdictions of the Project for purposes of the tax model will be the Czech Republic. The Model assumes that all Project profits of the Company are to be taxed under the laws of the Czech Republic, whereas no foreign taxation is applicable, no transfer pricing impacts/adjustments were taken into account.

22.2.3 Tax Rates

The corporate income tax rate of 19% for all the years of the Project was used. The 19% rate will be used under the assumption the currently enacted income tax rate will remain in effect for the life-of-project.

22.2.4 Tax Relief Incentives

The CMP has been conservatively modelled from a tax perspective, with a full tax burden, based on the Czech legislated tax rates as described above. Other than the standard tax depreciation of capital assets starting from 2027, no investment incentives or tax credits were considered in the determination of taxable income. As such, no corporate income tax relief was included in the financial model that might otherwise be available from these investment incentives or tax credits.

A business entity may receive an investment incentive if they prove that they are able to comply with the general conditions set out in the Czech *Investment Incentives Act* and/or the specific conditions set out in the regulations of the applicable legislation of the European Union.

22.2.5 Corporate Tax Calculations

All costs/assets are intended to be incurred/used to achieve, secure, and maintain taxable income and therefore, there are no non-tax-deductible costs which have been taken into account.

The costs/revenues in the Model do not contain:

- The creation or release of the accounting or other reserves

- The creation or release of the adjustment to assets, to stocks of materials, goods, work in progress, semi-finished products, and finished products, to receivables, etc.
- The creation or release of the estimated items for employees' bonuses
- Any financial leasing
- Any debt forgiveness or any write-off of receivables (the proper settlement/payment of all receivables/liabilities is assumed)
- Any contractual fines, default charges, default interest, penalties, and other sanctions from contractual and non-contractual obligations
- Any shares/equity certificates, securities, or any derivative securities
- Any income received for free

There are no deductible items for:

- Any Research and Development activities
- Any charitable gifts
- Any Professional Education activities

There is no tax relief for disabled employees.

While a number of opportunities exist in the Czech Republic in the form or tax relief and/or tax credits on qualified investments and expenditures, no investment tax credits or other reliefs were considered in the preparation of the tax calculations in the Model.

Tetra Tech has determined the following tax results for the Project based on the tax assessment by BDO.

Table 22-2: Tax Results

Item	Units	Amount
Project Revenue	USD$ millions	13,862.1
Less Total Operating Costs	USD$ millions	5,716.3
Less Tax Depreciation on Capital Assets	USD$ millions	770.4
Less net of losses of other years carried forward	USD$ millions	22.4
Taxable Income	USD$ millions	7,353.0
Corporate Taxes	USD$ millions	1,397.1
After-tax Operating Cash flow	USD$ millions	5,874.3

22.3 Cash Flows

Tetra Tech calculated cash flows based on revenue from sale of HPEMM and HPMSM. Tetra Tech deducted off-site costs from revenue prior to deduction of operating costs to estimate operating income.

Initial, sustaining capital costs, working capital, and reclamation costs were deducted from the operating income to derive an estimate of pre-tax cash flow.

A summary of pre-tax and post-tax cashflows is show in Table 22-3.

Table 22-3: Pre- and Post-Tax Cashflow

Cash flow			<<Construction				<<Production							
TIMELINE	Units	Total/average												
Year	Calendar year	30	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Plant Year	Production year	25	-4	-3	-2	-1	1	2	3	4	5	6	7	8
Project Year	Project year	30	1	2	3	4	5	6	7	8	9	10	11	12
METAL PRICES														
Mn - HPEMM 99.9%	US$/kg	10.560					8.20	9.06	9.89	10.09	10.78	10.78	10.78	10.78
Mn -Manganese Sulphate (HPMSM)	US$/kg	4.029					3.27	3.54	3.81	3.87	4.09	4.09	4.09	4.09
PRODUCTION SUMMARY														
Tailings Processed (dry tonnes)	Ktonnes	26,644					718	1,113	1,107	1,070	1,012	1,040	1,080	1,097
Mn Grade	%	7.41%					7.98%	7.41%	7.44%	7.63%	7.96%	7.81%	7.61%	7.43%
Contained Mn	Tonnes	1,973,470					57,285	82,489	82,384	81,675	80,516	81,202	82,212	81,516
Mn Recovery - HPEMM	%	60.5%					56.0%	60.6%	60.7%	61.2%	62.1%	61.7%	61.2%	60.7%
Mn Recovery - HPMSM		58.9%					54%	59.0%	59.1%	59.6%	60.5%	60.1%	59.6%	59.1%
HPEMM Production	tonnes	372,259					10,402	16,694	16,696	16,701	16,702	16,801	16,990	16,141
HPMSM Production	tonnes	2,465,000					65,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Total Mn metal production	Tonnes	1,171,911					31,488	49,132	49,134	49,139	49,141	49,240	49,428	48,581
Overall Mn recovery		59.4%					55.0%	59.6%	59.6%	60.2%	61.0%	60.6%	60.1%	59.6%
OPERATING COSTS														
Mining	Million US$	$64.9					$2.10	$2.62	$2.69	$2.61	$2.58	$2.61	$2.72	$2.72
Process - MS	Million US$	$89.7					$2.68	$3.73	$3.71	$3.59	$3.40	$3.49	$3.62	$3.68
Process - HPEMM	Million US$	$3,196.9					$95.13	$133.55	$133.56	$133.57	$133.58	$133.84	$134.34	$132.08
Process - HPMSM	Million US$	$528.4					$15.79	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36
Tailings Stacking/Storage	Million US$	$17.61					$0.43	$0.71	$0.77	$0.75	$0.74	$0.74	$0.75	$0.75
General & Administrative Costs	Million US$	$340.80					$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63
Land Rental	Million US$	$26.24					$1.55	$1.55	$1.55	$1.55	$1.55	$1.55	$1.13	$1.13
Site services, including Railway	Million US$	$641.60					$20.76	$26.45	$26.35	$25.69	$24.64	$25.15	$25.86	$26.17
Water Treatment	Million US$	$36.77					$1.12	$1.53	$1.52	$1.47	$1.40	$1.43	$1.48	$1.51
Contingency	Million US$	$247.15					$7.66	$10.26	$10.26	$10.21	$10.14	$10.19	$10.24	$10.15
Total Operating Costs	Million US$	$5,190.08					$160.86	$215.39	$215.40	$214.44	$213.02	$213.99	$215.14	$213.18
Selling and Distribution Costs	Million US$	$330.8					$8.79	$13.60	$13.60	$13.60	$13.61	$13.62	$13.64	$13.54
Transportation Insurance	Million US$	$5.5					$0.12	$0.20	$0.22	$0.22	$0.24	$0.24	$0.24	$0.23
Selling and Distribution Costs	Million US$	$69.3					$1.49	$2.53	$2.73	$2.78	$2.95	$2.95	$2.96	$2.92
Royalties														
Royalties - Czech Government	Million US$	$120.6					$3.2	$5.1	$5.1	$5.1	$5.1	$5.1	$5.1	$5.0
Total Cost of Sales	Million US$	$5,716.3					$174.50	$236.78	$237.01	$236.10	$234.86	$235.86	$237.07	$234.87
Operating cost per tonne mill feed	US$/tonne ore	$214.5					242.99	212.84	214.12	220.60	232.05	226.73	219.56	214.12
Operating cost per kg EMM equivalent	USD/kg Mn Equ	$4.43					5.11	4.38	4.38	4.36	4.33	4.35	4.35	4.39
CASH FLOW														
EMM Gross Revenue	Million US$	$3,930.9					$85	$151	$165	$169	$180	$181	$183	$174
HPMSM Gross Revenue	Million US$	$9,931.2					$212	$354	$381	$387	$409	$409	$409	$409
Total Operating Costs	Million US$	$5,716.3					$175	$237	$237	$236	$235	$236	$237	$235
Operating Profit	Million US$	$8,145.8					$123	$269	$309	$320	$355	$355	$355	$348
Operating Margin, % of sales	%	59%					41%	53%	57%	58%	60%	60%	60%	60%
CAPITAL COSTS														
Initial capital	Million US$	$757.4	$114	$189	$189	$265								
Sustaining Capital - Mining	Million US$	$6.1					$2.3	$1.1	$0.2	$0.2	$0.5	$0.1	$0.1	$0.1
Sustaining Capital - RSF	Million US$	$82.9					$1.2	$3.9	$2.8	$2.9	$3.4	$2.8	$2.8	$2.9
Sustaining Capital - Process & Others	Million US$	$28.0									$7.0			
Total Capital Expenditure	Million US$	$874.4	$114	$189	$189	$265	$3.6	$5.0	$3.0	$3.0	$10.9	$2.9	$2.9	$2.9
Other Expenses														
Environmental Bond (incl. in Initial Capex)	Million US$	-$2.0												
Reclamation	Million US$	$2.0												
Process plant salvage value	Million US$	-$37.9	$0	$0	$0	$0								
Working Capital														
Change in Inventory	Million US$	$0					$29.1	$10.4	$0.0	-$0.2	-$0.2	$0.2	$0.2	-$0.4
Change in Receivables	Million US$	$0					$49.6	$34.6	$6.8	$1.6	$5.6	$0.2	$0.3	-$1.5
Total Working Capital changes	Million US$	$78.7					$78.7	$45.0	$6.8	$1.5	$5.4	$0.3	$0.5	-$1.9
Pre-tax Cashflow (EBITDA)	Million US$	$7,309	-$114	-$189	-$189	-$265	$41	$219	$299	$315	$338	$351	$352	$347
Cumulative pre-tax cash flow	Million US$	$7,309	-$114	-$303	-$492	-$757	-$717	-$498	-$199	$117	$455	$806	$1,158	$1,506
Pre-tax results														
Net Present Value	8%	$1,750												
Internal rate of return	24.9%													
Pre-tax payback period	3.63													
Tax Assessment														
Assets														
Depreciated Capex	Million US$	$857.0	$0.00	$0.00	$0.00	$0.00	$743.51	$5.01	$3.04	$3.01	$10.94	$2.92	$2.90	$2.94
Annual Depreciation	Million US$	$857.0	$0.00	$0.00	$0.00	$0.00	$28.11	$56.18	$56.42	$56.41	$56.99	$55.92	$56.08	$56.25
Taxes														
Revenue	Million US$	$13,862.1	$0	$0	$0	$0	$297.6	$505.4	$546.1	$555.8	$589.4	$590.5	$592.5	$583.3
Operating Costs	Million US$	$5,716.3	$0	$0	$0	$0	$174.5	$236.8	$237.0	$236.1	$234.9	$235.9	$237.1	$234.9
Capital Depreciation	Million US$	$770.4	$0	$0	$0	$0	$28.1	$56.2	$56.4	$56.4	$57.0	$55.9	$56.1	$56.3
Taxable Income	Million US$	$7,375.4	$0	$0	$0	$0	$95.0	$212.5	$252.7	$263.3	$297.5	$298.7	$299.3	$292.2
Losses Carried Forward	Million US$	-$22.4	$0	$0	$0	$0	-$21.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Net Taxable Income	Million US$	$7,353.0	$0	$0	$0	$0	$73.9	$212.5	$252.7	$263.3	$297.5	$298.7	$299.3	$292.2
Corporate Tax Rate	%		19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Corporate Tax Obligation Before Tax Relief	Million US$	$1,397.1	$0.0	$0.0	$0.0	$0.0	$14.0	$40.4	$48.0	$50.0	$56.5	$56.8	$56.9	$55.5
Corporate Tax Due	Million US$	$1,397.1	$0.0	$0.0	$0.0	$0.0	$14.0	$40.4	$48.0	$50.0	$56.5	$56.8	$56.9	$55.5
After-Tax Operating Cash Flow	Million US$	$5,874.3	-$114	-$189	-$189	-$265	$105.5	$223.3	$258.1	$266.7	$287.1	$294.9	$295.7	$290.0
Net Cash Flow														
Net Cash Flow, excluding debt	Million US$	$5,912.2	-$114	-$189	-$189	-$265	$26.78	$178.25	$251.25	$265.24	$281.68	$294.59	$295.11	$291.91
Total Cash, excluding debt	Million US$	$5,912.2	-$114	-$303	-$492	-$757	-$730.64	-$552.4	-$301.1	-$35.9	$245.8	$540.4	$835.5	$1,127.4
After-tax results (excluding debt)														
Taxes payable		$1,397.1												
Net Present Value	8%	$1,341.6												
Internal rate of return	21.9%													
Post-tax payback period	4.13													

Cash flow										
TIMELINE										
Year	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Plant Year	9	10	11	12	13	14	15	16	17	18
Project Year	13	14	15	16	17	18	19	20	21	22
METAL PRICES										
Mn - HPEMM 99.9%	10.78	10.78	10.78	10.78	10.78	10.78	10.78	10.78	10.78	10.78
Mn -Manganese Sulphate (HPMSM)	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09
PRODUCTION SUMMARY										
Tailings Processed (dry tonnes)	1,016	1,010	1,016	1,017	907	834	1,056	1,085	1,130	1,168
Mn Grade	7.96%	7.97%	7.89%	7.91%	8.17%	8.72%	7.40%	7.24%	7.04%	6.84%
Contained Mn	80,914	80,467	80,143	80,376	74,104	72,662	78,080	78,542	79,582	79,880
Mn Recovery - HPEMM	62.1%	62.1%	61.9%	62.0%	62.7%	64.1%	60.6%	60.1%	59.5%	58.9%
Mn Recovery - HPMSM	60.5%	60.5%	60.3%	60.4%	61.0%	62.4%	59.0%	58.5%	58.0%	57.4%
HPEMM Production	16,966	16,697	16,324	16,508	13,140	13,233	13,974	13,895	14,062	13,739
HPMSM Production	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Total Mn metal production	49,404	49,136	48,763	48,947	45,582	45,675	46,416	46,337	46,503	46,180
Overall Mn recovery	61.1%	61.1%	60.8%	60.9%	61.5%	62.9%	59.4%	59.0%	58.4%	57.8%
OPERATING COSTS										
Mining	$2.56	$2.56	$2.51	$2.49	$2.28	$2.22	$2.49	$2.69	$2.72	$2.74
Process - MS	$3.41	$3.39	$3.41	$3.41	$3.04	$2.80	$3.54	$3.64	$3.79	$3.92
Process - HPEMM	$134.28	$133.56	$132.57	$133.06	$124.07	$124.32	$126.30	$126.09	$126.53	$125.67
Process - HPMSM	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36
Tailings Stacking/Storage	$0.72	$0.71	$0.65	$0.64	$0.56	$0.54	$0.64	$0.72	$0.73	$0.74
General & Administrative Costs	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63
Land Rental	$1.13	$1.13	$1.13	$1.13	$1.13	$0.75	$0.75	$0.75	$0.75	$0.75
Site services, including Railway	$24.71	$24.60	$24.71	$24.72	$22.73	$21.41	$25.43	$25.96	$26.76	$27.45
Water Treatment	$1.40	$1.40	$1.40	$1.40	$1.26	$1.17	$1.45	$1.49	$1.55	$1.60
Contingency	$10.16	$10.12	$10.07	$10.09	$9.50	$9.41	$9.78	$9.82	$9.89	$9.89
Total Operating Costs	$213.37	$212.46	$211.44	$211.94	$199.57	$197.60	$205.38	$206.14	$207.71	$207.75
Selling and Distribution Costs	$13.64	$13.60	$13.56	$13.58	$13.19	$13.20	$13.29	$13.28	$13.30	$13.26
Transportation Insurance	$0.24	$0.24	$0.23	$0.23	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22
Selling and Distribution Costs	$2.96	$2.95	$2.93	$2.94	$2.75	$2.76	$2.80	$2.80	$2.80	$2.79
Royalties										
Royalties - Czech Government	$5.1	$5.1	$5.0	$5.0	$4.7	$4.7	$4.8	$4.8	$4.8	$4.8
Total Cost of Sales	$235.29	$234.30	$233.18	$233.73	$220.43	$218.48	$226.46	$227.21	$228.82	$228.77
Operating cost per tonne mill feed	231.54	231.98	229.47	229.89	243.06	262.08	214.48	209.38	202.55	195.89
Operating cost per kg EMM equivalent	4.32	4.32	4.34	4.33	4.38	4.33	4.42	4.45	4.47	4.50
CASH FLOW										
EMM Gross Revenue	$183	$180	$176	$178	$142	$143	$151	$150	$152	$148
HPMSM Gross Revenue	$409	$409	$409	$409	$409	$409	$409	$409	$409	$409
Total Operating Costs	$235	$234	$233	$234	$220	$218	$226	$227	$229	$229
Operating Profit	$357	$355	$352	$354	$331	$334	$334	$332	$332	$329
Operating Margin, % of sales	60%	60%	60%	60%	60%	60%	60%	59%	59%	59%
CAPITAL COSTS										
Initial capital										
Sustaining Capital - Mining	$0.1	$0.1	$0.1	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1
Sustaining Capital - RSF	$2.8	$3.8	$3.1	$3.1	$3.0	$3.1	$3.6	$3.4	$3.3	$3.3
Sustaining Capital - Process & Others		$7.0					$7.0			
Total Capital Expenditure	$2.9	$10.9	$3.2	$3.1	$3.0	$3.1	$10.7	$3.5	$3.4	$3.4
Other Expenses										
Environmental Bond (incl. in Initial Capex)										
Reclamation										
Process plant salvage value										
Working Capital										
Change in Inventory	$0.1	-$0.2	-$0.2	$0.1	-$2.2	-$0.3	$1.3	$0.1	$0.3	$0.0
Change in Receivables	$1.5	-$0.5	-$0.7	$0.3	-$6.1	$0.2	$1.3	-$0.1	$0.3	-$0.6
Total Working Capital changes	$1.6	-$0.6	-$0.9	$0.4	-$8.3	-$0.2	$2.7	$0.0	$0.6	-$0.6
Pre-tax Cashflow (EBITDA)	$353	$345	$350	$350	$336	$331	$320	$328	$328	$326
Cumulative pre-tax cash flow	$1,858	$2,203	$2,553	$2,903	$3,239	$3,569	$3,889	$4,218	$4,546	$4,872
Tax Assessment										
Assets										
Depreciated Capex	$2.88	$10.87	$3.18	$3.12	$3.05	$3.12	$10.71	$3.48	$3.44	$3.38
Annual Depreciation	$56.42	$56.99	$17.04	$17.01	$17.07	$17.14	$16.87	$17.32	$17.41	$17.50
Taxes										
Revenue	$592.2	$589.3	$585.3	$587.3	$551.0	$552.0	$560.0	$559.1	$560.9	$557.4
Operating Costs	$235.3	$234.3	$233.2	$233.7	$220.4	$218.5	$226.5	$227.2	$228.8	$228.8
Capital Depreciation	$56.4	$57.0	$17.0	$17.0	$17.1	$17.1	$16.9	$17.3	$17.4	$17.5
Taxable Income	$300.5	$298.1	$335.1	$336.6	$313.5	$316.4	$316.7	$314.6	$314.7	$311.2
Losses Carried Forward	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Net Taxable Income	$300.5	$298.1	$335.1	$336.6	$313.5	$316.4	$316.7	$314.6	$314.7	$311.2
Corporate Tax Rate	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Corporate Tax Obligation Before Tax Relief	$57.1	$56.6	$63.7	$63.9	$59.6	$60.1	$60.2	$59.8	$59.8	$59.1
Corporate Tax Due	$57.1	$56.6	$63.7	$63.9	$59.6	$60.1	$60.2	$59.8	$59.8	$59.1
After-Tax Operating Cash Flow	$297.0	$287.5	$285.3	$286.5	$268.0	$270.3	$262.7	$268.7	$268.9	$266.2
Net Cash Flow										
Net Cash Flow, excluding debt	$295.42	$288.19	$286.15	$286.09	$276.23	$270.44	$259.99	$268.69	$268.31	$266.76
Total Cash, excluding debt	$1,422.8	$1,711.0	$1,997.1	$2,283.2	$2,559.5	$2,829.9	$3,089.9	$3,358.6	$3,626.9	$3,893.7

Cash flow							End>>	Reclamation
TIMELINE								
Year	2045	2046	2047	2048	2049	2050	2051	2052
Plant Year	19	20	21	22	23	24	25	26
Project Year	23	24	25	26	27	28	29	30
METAL PRICES								
Mn - HPEMM 99.9%	10.78	10.78	10.78	10.78	10.78	10.78	10.78	
Mn -Manganese Sulphate (HPMSM)	4.09	4.09	4.09	4.09	4.09	4.09	4.09	
PRODUCTION SUMMARY								
Tailings Processed (dry tonnes)	1,237	1,196	1,184	1,236	1,183	1,137	997	
Mn Grade	6.60%	6.75%	6.80%	6.58%	6.81%	6.92%	7.64%	
Contained Mn	81,562	80,735	80,479	81,302	80,561	78,672	76,130	
Mn Recovery - HPEMM	58.1%	58.6%	58.8%	58.1%	58.8%	59.2%	61.2%	
Mn Recovery - HPMSM	56.6%	57.1%	57.2%	56.6%	57.3%	57.6%	59.6%	
HPEMM Production	14,096	14,017	13,979	13,903	14,060	13,225	13,312	
HPMSM Production	100,000	100,000	100,000	100,000	100,000	100,000	100,000	
Total Mn metal production	46,538	46,459	46,420	46,345	46,501	45,668	45,754	
Overall Mn recovery	57.1%	57.5%	57.7%	57.0%	57.7%	58.0%	60.1%	
OPERATING COSTS								
Mining	$2.80	$2.74	$2.75	$2.79	$2.74	$2.71	$2.51	
Process - MS	$4.15	$4.01	$3.97	$4.15	$3.97	$3.81	$3.35	
Process - HPEMM	$126.62	$126.41	$126.31	$126.11	$126.53	$124.30	$124.53	
Process - HPMSM	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36	$21.36	
Tailings Stacking/Storage	$0.76	$0.74	$0.78	$0.80	$0.78	$0.78	$0.68	
General & Administrative Costs	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	$13.63	
Land Rental	$0.75	$0.75	$0.75	$0.75	$0.75	$0.75	$0.75	
Site services, including Railway	$28.70	$27.96	$27.75	$28.68	$27.73	$26.89	$24.36	
Water Treatment	$1.69	$1.63	$1.62	$1.68	$1.62	$1.56	$1.38	
Contingency	$10.02	$9.96	$9.95	$10.00	$9.95	$9.79	$9.63	
Total Operating Costs	$210.48	$209.19	$208.87	$209.95	$209.05	$205.57	$202.18	
Selling and Distribution Costs	$13.30	$13.29	$13.29	$13.28	$13.30	$13.20	$13.21	
Transportation Insurance	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22	
Selling and Distribution Costs	$2.81	$2.80	$2.80	$2.80	$2.80	$2.76	$2.76	
Royalties								
Royalties - Czech Government	$4.8	$4.8	$4.8	$4.8	$4.8	$4.7	$4.7	
Total Cost of Sales	$231.60	$230.29	$229.96	$231.01	$230.16	$226.45	$223.08	
Operating cost per tonne mill feed	187.27	192.57	194.17	186.94	194.51	199.24	223.76	
Operating cost per kg EMM equivalent	4.52	4.50	4.50	4.53	4.50	4.50	4.42	
CASH FLOW								
EMM Gross Revenue	$152	$151	$151	$150	$152	$143	$143	
HPMSM Gross Revenue	$409	$409	$409	$409	$409	$409	$409	
Total Operating Costs	$232	$230	$230	$231	$230	$226	$223	
Operating Profit	$330	$330	$330	$328	$331	$325	$330	
Operating Margin, % of sales	59%	59%	59%	59%	59%	59%	60%	
CAPITAL COSTS								
Initial capital								
Sustaining Capital - Mining	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.0	
Sustaining Capital - RSF	$3.2	$3.6	$3.4	$3.4	$3.5	$3.5	$7.2	
Sustaining Capital - Process & Others		$7.0						
Total Capital Expenditure	$3.3	$10.7	$3.5	$3.5	$3.6	$3.6	$7.3	
Other Expenses								
Environmental Bond (incl. in Initial Capex)								-$0.40
Reclamation								$0.40
Process plant salvage value								-$38
Working Capital								
Change in Inventory	$0.5	-$0.2	-$0.1	$0.2	-$0.1	-$0.6	-$37.7	
Change in Receivables	$0.6	-$0.1	-$0.1	-$0.1	$0.3	-$1.5	-$92.0	
Total Working Capital changes	$1.1	-$0.4	-$0.1	$0.0	$0.1	-$2.1	-$129.7	
Pre-tax Cashflow (EBITDA)	$325	$320	$327	$325	$327	$324	$452	$38
Cumulative pre-tax cash flow	$5,197	$5,517	$5,844	$6,168	$6,495	$6,819	$7,271	$7,309
Tax Assessment								
Assets								
Depreciated Capex	$3.33	$10.68	$3.48	$3.53	$3.58	$3.60	$7.28	$0.00
Annual Depreciation	$17.59	$17.31	$12.40	$12.50	$12.61	$12.73	$12.17	$86.51
Taxes								
Revenue	$561.3	$560.5	$560.0	$559.2	$560.9	$551.9	$552.8	$37.9
Operating Costs	$231.6	$230.3	$230.0	$231.0	$230.2	$226.4	$223.1	$0.0
Capital Depreciation	$17.6	$17.3	$12.4	$12.5	$12.6	$12.7	$12.2	$90.2
Taxable Income	$312.1	$312.9	$317.7	$315.7	$318.1	$312.7	$317.6	-$52.3
Losses Carried Forward	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	-$1.3	$0.0
Net Taxable Income	$312.1	$312.9	$317.7	$315.7	$318.1	$312.7	$316.3	$0.0
Corporate Tax Rate	19%	19%	19%	19%	19%	19%	19%	19%
Corporate Tax Obligation Before Tax Relief	$59.3	$59.4	$60.4	$60.0	$60.4	$59.4	$60.1	$0.0
Corporate Tax Due	$59.3	$59.4	$60.4	$60.0	$60.4	$59.4	$60.1	$0.0
After-Tax Operating Cash Flow	$267.1	$260.0	$266.2	$264.7	$266.7	$262.5	$262.4	$0.0
Net Cash Flow								
Net Cash Flow, excluding debt	$265.96	$260.40	$266.37	$264.66	$266.59	$264.57	$392.12	$37.87
Total Cash, excluding debt	$4,159.6	$4,420.0	$4,686.4	$4,951.1	$5,217.6	$5,482.2	$5,874.3	$5,912.2

TETRA TECH

22.4 Sensitivity Analysis

Tetra Tech evaluated the sensitivity of the Project economics to capital costs and operating costs. Tetra Tech also evaluated the sensitivity of the Project economics to manganese recovery and manganese product prices.

The analysis indicates that the project is most sensitivity to the manganese product prices. Table 22-4 compares potential upside price and downside price cases:

- Upside price case: unaltered forecast by CPM Group
- Downside price case: a risk-adjusted, short-term forecast of CPM Group's pricing for the base case; downside prices are -12.3% from the base case for HPMSM and -14.9% for HPEMM, which are in the reverse direction and the same average price differences, compared to the upside price case.

To evaluate Project economic risks, Tetra Tech conducted sensitivity analysis on the post-tax financial performance. Figure 22-2 to Figure 22-4 show the Project economic sensitivities.

Table 22-4: Selected Financial Analysis Parameter Comparison for Different Product Prices

Metrics	Downside Price Case	Base Price Case	Upside Price Case	Unit
Metal Price - HPMSM	3,524	4,019	4,509	$/t
HPEMM	8,974	10,545	12,075	$/t
Total project revenue	12,055	13,862	15,674	$ million
Site operating costs	5,190	5,190	5,190	$ million
Selling and distribution costs	396	406	415	$ million
Royalties	121	121	121	$ million
Total cost of sales	5,707	5,716	5,726	$ million
Operating income	6,348	8,146	9,948	$ million
Total capital costs	947	953	953	$ million
Project cash flow	5,474	7,272	9,073	$ million
Pre-tax net present value 8%	1,204	1,750	2,296	$ million
Pre-tax IRR	20.5	24.9	27.2	%
Pre-tax payback period	4.45	3.63	3.63	Years
Post-tax net present value 8%	901	1,342	1,783	$ million
Post-tax IRR	18.1	21.9	24.1	%
Post-tax payback period	5.02	4.13	4.13	Years

Figure 22-2: Sensitivity of NPV to Changes in Costs

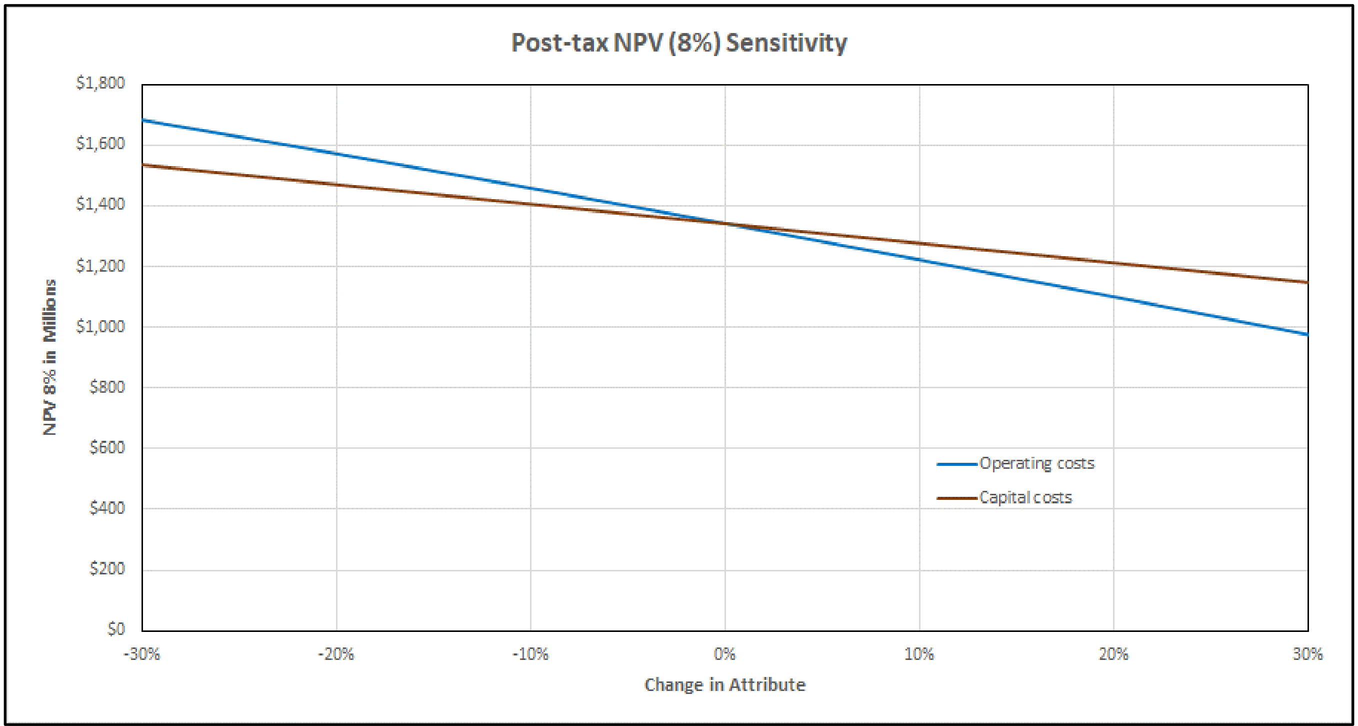


Figure 22-3: Sensitivity of NPV to Changes Metal Prices

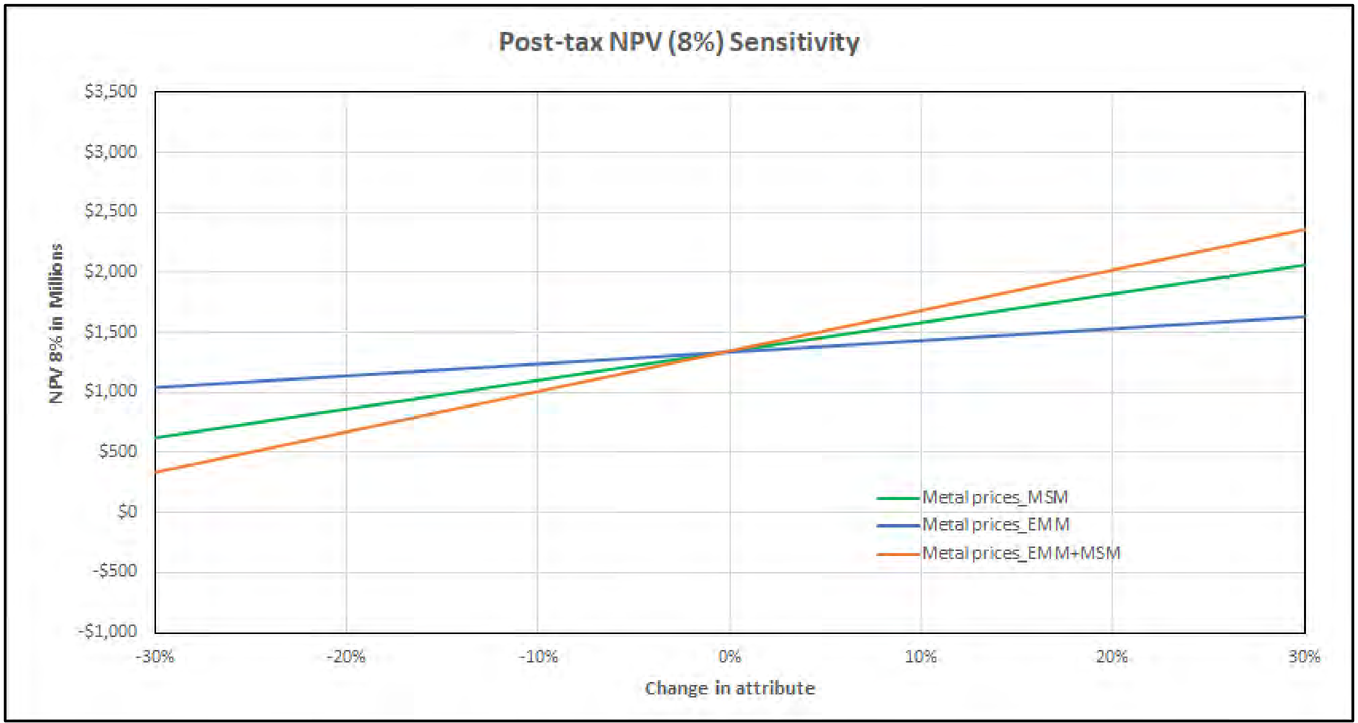
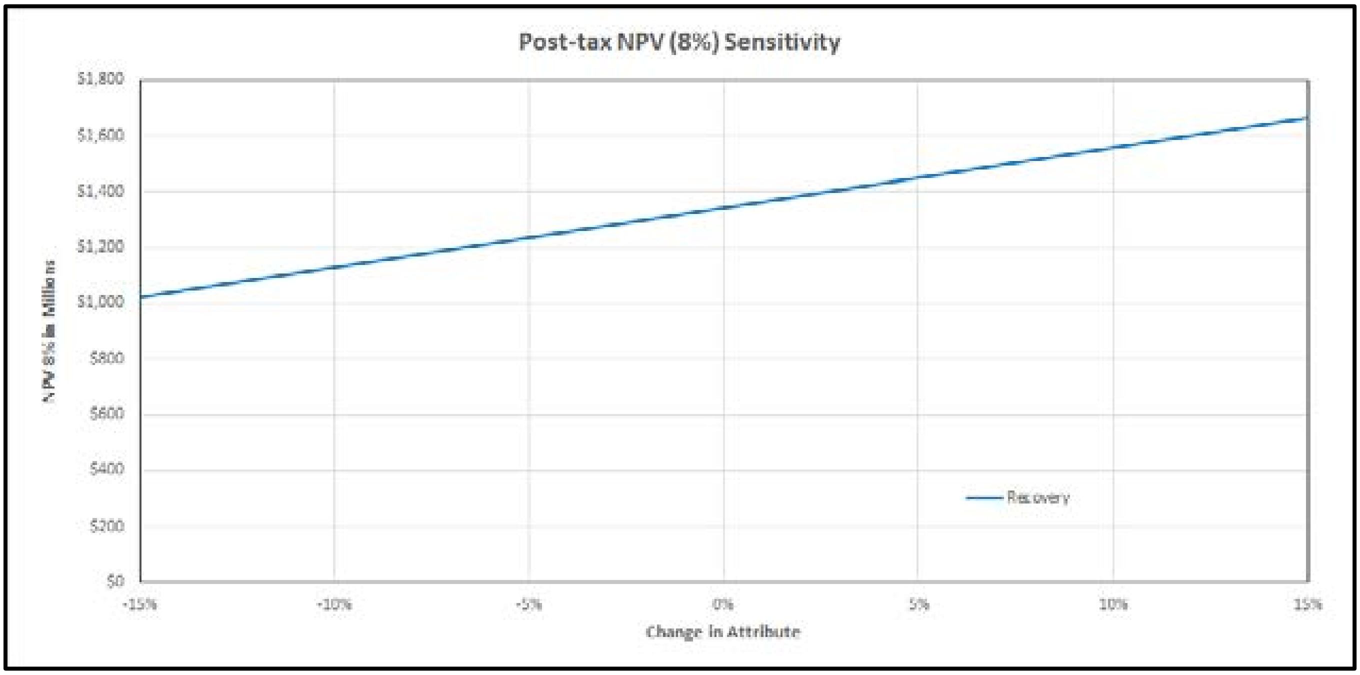


Figure 22-4: Sensitivity of NPV to Changes in Recovery



23.0 ADJACENT PROPERTIES

Adjacent to the Chvaletice manganese deposit (tailings deposit) is an 820 MW coal-fired power station, a pre-cast concrete plant, an asphalt plant, and a newly constructed cast iron foundry, with an infrastructure of highways and railways running through the centre of these properties. These industrial plants are opposite of the Chvaletice deposit, separated by highway and most frequent railway in the Czech Republic. The rest of the area, especially on the other side of the river, belongs to agriculture use including horse breeding.

Additionally, two small granite bedrock crush quarries are located to the south of the power plant.

24.0 OTHER RELEVANT DATA AND INFORMATION

24.1 Project Execution Plan

24.1.1 General

The purpose of this Project Execution Plan (PEP) is to describe the activities to be completed during the execution of the EPCM phase of the project.

The CMP consists of the following facilities at two primary locations, the process plant site (south site) and raw tailings and residue storage site (north site). The following list is based on the project WBS:

- Area 10 – Overall Site (includes railway spur and substation)
- Area 30 – Raw Tailings Extraction (north site)
- Area 35 – Mill Feed Transport, Storage and Pulping (north site)
- Area 40 – Process Plant (south site)
- Area 50 – Residue Management (RSF, north site)
- Area 70 – On-site Infrastructure

24.1.2 Codes and Standards

The project will abide by and implement Czech and EU design, environmental, regulatory, health, and safety codes and standards. These codes and standards have been incorporated into the design criteria and design basis documents prepared for the FS.

24.1.3 Scope

In order to achieve a commencement of commercial production by Q1 2027, an aggressive front-end initiative must be established. The project will transition from the FS Phase to EPCM in the first quarter of 2023, at which point the company expects to award an EPCM contract. Tender preparations are currently underway and expect to be issued in mid-September 2022. The project is anticipated to move forward in the following phases:

- **Phase 1** – Upon award of EPCM contract, initial work will involve a basic engineering design phase with the main objective of finalizing and freezing the design in addition to assess further value engineering opportunities for the primary purpose of CAPEX cost reductions and process improvements. During the basic engineering phase, major long lead equipment will be identified and tendered, with vendor selection, in order to immediately place orders for long lead equipment which will be incorporated into the detailed design. Additionally, project permitting will be underway during this time with all major permits for construction anticipated by Q1, 2024. Site preparation shall also commence including demolition of existing buildings and construction of the utility bridge (connecting the process plant area to the mine site area) for the purpose of moving bulk earthworks from the plant site area to a temporary storage area in the Labe Triangle for use during construction of mining haul roads and other plant/mine site fill requirements. This demolition and preliminary site preparation is critical in order to maintain the overall project schedule. Other critical permitting and design work during this phase includes permitting for the high voltage grid connection, railway spur, and order of long lead substation primary transformers.

- **Phase 2** – Full Project Execution following receipt of project financing and investment decision by the company, concurrent with receipt of major permits, and will include a continuation of detailed design, procurement, construction team mobilization, construction, and commissioning.

24.1.4 Objectives

The following key objectives shall be established for the Project:

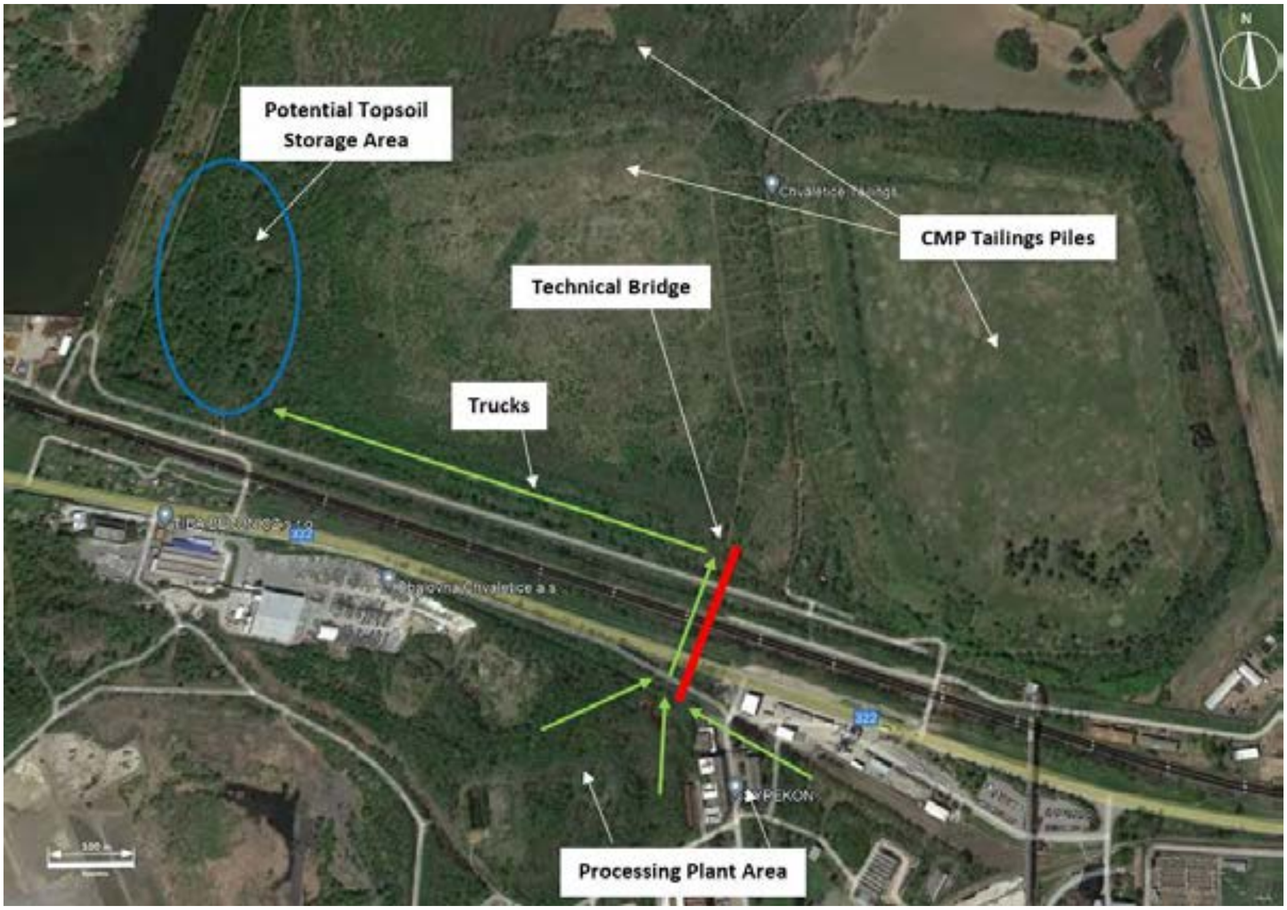
- Seamless transition from the study phase to the execution phase
- Nurture a strong Health, Safety, Environment and Community (HSEC) culture
- Work closely with the local regulatory entities to ensure a seamless and successful permitting process,
- Create a "one team" culture of mutual trust and respect with common project goals between the EPCM consultant and the Owner's project development team
- Agree and achieve quantifiable Key Performance Indicators (KPIs) for the project
- Utilize front end work activities to secure the execution phase schedule and execution plan
- Procure equipment and materials and award contracts to organizations that will deliver to meet the project's objectives
- Construct and pre-commission the facility safely and effectively (including Hazard and Operability Assessment [HAZOP])
- Meet the critical milestone dates and capital cost budgets
- Deliver a facility to meet the design throughput to achieve customer product specifications on a consistent basis for HPEMM and HPMSM
- Comply with applicable laws and codes

24.1.5 Constraints and Dependencies

This is a brownfield development site located within a rural populated area where particular attention will need to be placed on minimizing disruptions to the local communities, particularly noise and traffic. Planning for access and site logistics and construction activities will need to consider the following:

- Site preparation must be coordinated to commence with demolition of existing buildings and infrastructure and its respective impact to the local businesses. Removal of trees (October to March only) and pre-stripping (July to August only) must be coordinated with the environmental authorities so as not to disrupt existing flora/fauna, some of which will require relocation/rehabilitation.
- Access between the plant and raw tailings site areas will need to accommodate both rail and road traffic as these areas are separated by a national railway and local road. In order to minimize disruption to this local transportation corridor, the utility bridge (technological bridge) connecting the plant and CMP tailings site areas should be constructed in the early stages to assist with earthworks and site demolition of the plant site area. Figure 24-1 shows the proposed technical bridge location and stripped topsoil transport plan.

Figure 24-1: Technical Bridge Location and Stripped Topsoil Transport (Illustration Only)



Note: Green Arrow: Material transport;
Source: Mangan, 2022; Google Maps

Scheduling and logistics associated with transfer of equipment and materials to site will need to be planned to minimize delays in construction and disruption to the local community and other operating businesses. The intent is to have the plant railway spur (at least one track) available for delivery of major equipment during construction.

- Early establishment of site roads for heavy construction equipment.
- To minimize stick build on site where possible, equipment packages will be modular and/or skid mounted but sized to meet the footprint and weights capable of road/rail transportation.
- Where possible, pre-assembly of pipe bridges, field erected tanks, structural steel, conveyors, etc., shall be delivered to site in sections. Consider use of the local manufacturing facility (E.P. Chvaletice) on the plant site area for steel/conveyor fabrication.
- For the purposes of economical placement of concrete, foundations will need to be poured before winter weather periods.
- The power grid interconnection must be in place for commissioning the project site power distribution system.
- All construction related permitting to be in place for start of construction.

- Because of limited laydown areas, delivery of equipment will be scheduled for delivery on site just in time to meet the required at site date. Construction laydown areas will need to be coordinated directly on the project site as there is limited external/available space.
- Identifying suitable and available temporary laydown and logistics areas for staging of materials, equipment, and supplies may be difficult given lack of available land space. Construction sequencing and therefore material/equipment procurement and staging will be critical.

24.1.6 Key Milestones

Key project milestones include:

- FS completion
- EPCM award
- Financial Investment Decision (FID) by the Company, combined with a financing plan
- Final decision by authorities and approval of the EIA
- Basic design and Detailed Engineering Completion
- Approval of Land Planning Permit
- Receipt of Construction Permit
- Order of long lead equipment
- Site demolition/early infrastructure construction works
- Start of plant and tailings extraction site areas construction
- Completion of railway spur
- Completion of grid Interconnection/Substation
- Plant and tailings extraction site commissioning completion
- Start of initial production

24.1.7 Risks and Opportunities

The PEP will focus on seeking to mitigate risks or exploit opportunities identified at various stages in the project lifecycle. At the start of the EPCM phase, a formal risk assessment will be carried out to identify risks and develop mitigation strategies.

The risk assessment will address risks and of opportunities in the following areas:

- Safety
- Environmental
- Scope

- Supply Chain
- Production
- Technology
- Transportation and Logistics
- Product Marketing
- Construction
- Commercial

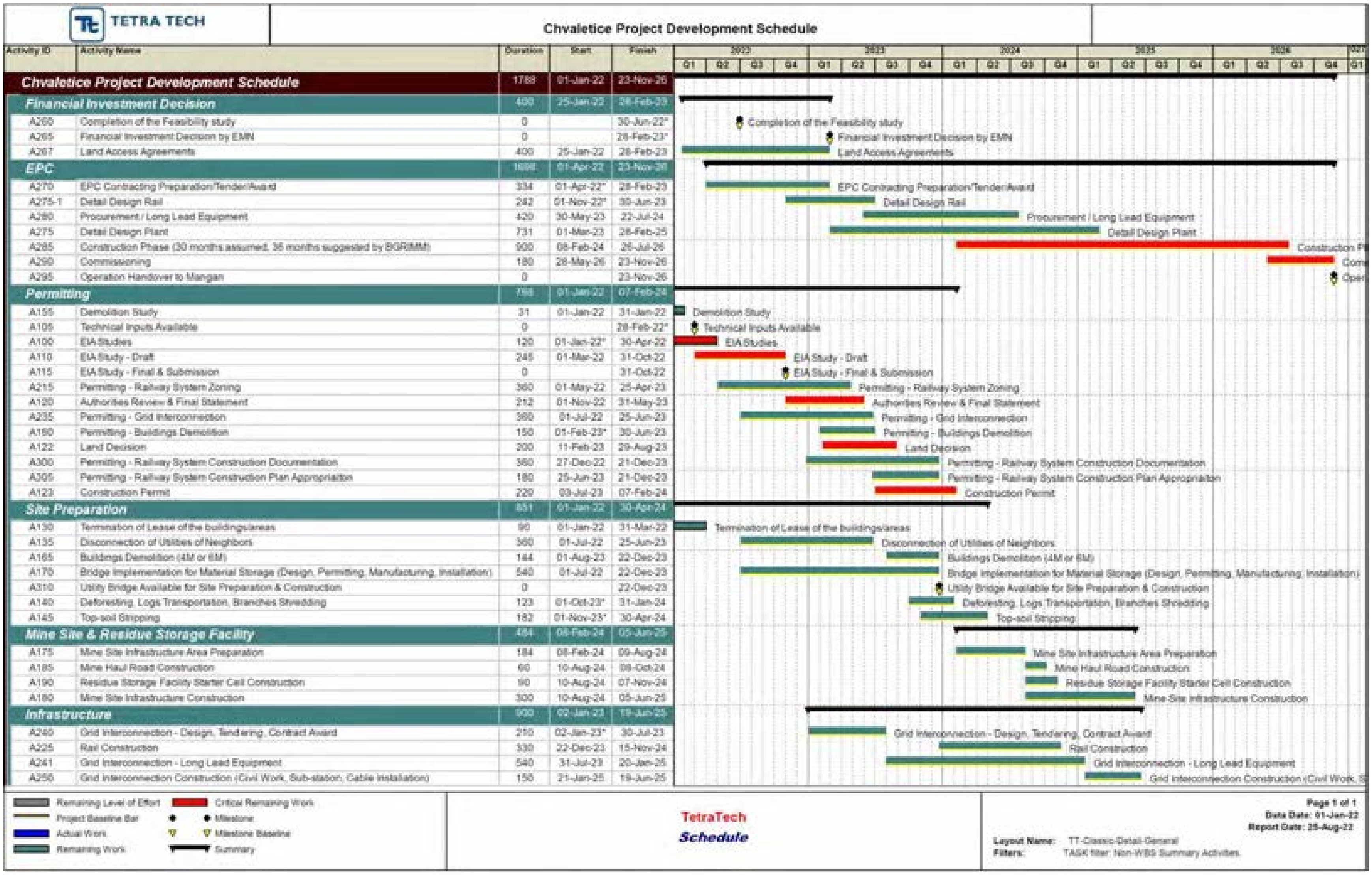
This risk assessment will be an important and integral part of project start-up planning and at all stages of design and project management. It is imperative that the project attempts to minimize risk and achieve the commitments established. A risk management register will be prepared and managed by the EPCM contractor.

24.1.8 Project Development Schedule

A Level 1, Project Development Schedule (Figure 24-2) was prepared during the FS in order to outline the overall timeline and key constraints. The critical path of the project currently falls through the EIA, detailed engineering, construction, and commissioning phases.

Based on preliminary guidance by BGRIMM along with quotes received from local construction companies, the detailed design phase is estimated to be 18 months (inclusive of basic design), during which time long lead equipment is identified and ordered. Construction duration of 30 months has been advised due to the small and restricted plant site working area, process complexity, careful interface required with the local community, and labour work hour restrictions in the Czech Republic.

Figure 24-2: Project Development Schedule – Level 1



Activity ID	Activity Name	Duration	Start	Finish
	Chvaletice Project Development Schedule	1788	01-Jan-22	23-Nov-26
	Financial Investment Decision	400	25-Jan-22	28-Feb-23
A260	Completion of the Feasibility study	0		30-Jun-22*
A265	Financial Investment Decision by EMN	0		28-Feb-23*
A267	Land Access Agreements	400	25-Jan-22	28-Feb-23
	EPC	1698	01-Apr-22	23-Nov-26
A270	EPC Contracting Preparation/Tender/Award	334	01-Apr-22*	28-Feb-23
A275-1	Detail Design Rail	242	01-Nov-22*	30-Jun-23
A280	Procurement / Long Lead Equipment	420	30-May-23	22-Jul-24
A275	Detail Design Plant	731	01-Mar-23	28-Feb-25
A285	Construction Phase (30 months assumed, 36 months suggested by BGRIMM)	900	08-Feb-24	26-Jul-26
A290	Commissioning	180	28-May-26	23-Nov-26
A295	Operation Handover to Mangan	0		23-Nov-26
	Permitting	768	01-Jan-22	07-Feb-24
A155	Demolition Study	31	01-Jan-22	31-Jan-22
A105	Technical Inputs Available	0		28-Feb-22*
A100	EIA Studies	120	01-Jan-22*	30-Apr-22
A110	EIA Study - Draft	245	01-Mar-22	31-Oct-22
A115	EIA Study - Final & Submission	0		31-Oct-22
A215	Permitting - Railway System Zoning	360	01-May-22	25-Apr-23
A120	Authorities Review & Final Statement	212	01-Nov-22	31-May-23
A235	Permitting - Grid Interconnection	360	01-Jul-22	25-Jun-23
A160	Permitting - Buildings Demolition	150	01-Feb-23*	30-Jun-23
A122	Land Decision	200	11-Feb-23	29-Aug-23
A300	Permitting - Railway System Construction Documentation	360	27-Dec-22	21-Dec-23
A305	Permitting - Railway System Construction Plan Appropriaiton	180	25-Jun-23	21-Dec-23
A123	Construction Permit	220	03-Jul-23	07-Feb-24
	Site Preparation	851	01-Jan-22	30-Apr-24
A130	Termination of Lease of the buildings/areas	90	01-Jan-22	31-Mar-22
A135	Disconnection of Utilities of Neighbors	360	01-Jul-22	25-Jun-23
A165	Buildings Demolition (4M or 6M)	144	01-Aug-23	22-Dec-23
A170	Bridge Implementation for Material Storage (Design, Permitting, Manufacturing, Installation)	540	01-Jul-22	22-Dec-23
A310	Utility Bridge Available for Site Preparation & Construction	0		22-Dec-23
A140	Deforesting, Logs Transportation, Branches Shredding	123	01-Oct-23*	31-Jan-24
A145	Top-soil Stripping	182	01-Nov-23*	30-Apr-24
	Mine Site & Residue Storage Facility	484	08-Feb-24	05-Jun-25
A175	Mine Site Infrastructure Area Preparation	184	08-Feb-24	09-Aug-24
A185	Mine Haul Road Construction	60	10-Aug-24	08-Oct-24
A190	Residue Storage Facility Starter Cell Construction	90	10-Aug-24	07-Nov-24
A180	Mine Site Infrastructure Construction	300	10-Aug-24	05-Jun-25
	Infrastructure	900	02-Jan-23	19-Jun-25
A240	Grid Interconnection - Design, Tendaring, Contract Award	210	02-Jan-23*	30-Jul-23
A225	Rail Construction	330	22-Dec-23	15-Nov-24
A241	Grid Interconnection - Long Lead Equipment	540	31-Jul-23	20-Jan-25
A250	Grid Interconnection Construction (Civil Work, Sub-station, Cable Installation)	150	21-Jan-25	19-Jun-25

Source: Tetra Tech

24.1.9 Project Execution

24.1.9.1 Execution Strategy

Project execution will be the overall responsibility of the EPCM consultant who will prepare a detailed PEP, manage the project on behalf of the company, and will be responsible for:

- Interface management with mining, process, geotechnical, environmental, power, utilities, equipment vendors, railway, and infrastructure consultants and contractors to ensure the timely execution of the project
- Execution of the scope of work and change management of the control budget and execution schedule for the project with agreed KPIs
- Administration and management of all project design, procurement, and site activities

The EPCM consultant will implement the following initiatives as part of the PEP:

- Clear focus on common project objectives
- Adequate definition of project scope, project organizational structure, and KPIs to ensure clear understanding of the team responsibilities
- Management commitment to elimination of waste, timely decision making, clear and effective communication and the promotion of a Can-Do-Culture
- Creating conditions to motivate the team and maximizing team performance
- Aligning the EPCM team with the Owner's team to promote positive working relationships
- Contract work packages will be developed with respect to size and structure to attract construction contractors with due regard to the competitiveness in the market for skilled and qualified contractors and labour

The Owner's goal is to have the CMP operational as soon as possible given the strong demand within the EU for the strategic supply of EV battery raw materials. Physical workspace at the project site is constrained along with the need to accommodate environmental sequencing of flora/fauna rescue/removal along with coordinating site demolition of existing buildings and infrastructure. In order to mitigate these risks focus will need to be given to the planning of the following key areas:

- Engineering will be completed as early as possible to ensure that the procurement of major equipment items can be delivered to meet the desired construction schedule
- Identifying Engineering Work Packages (EWPs) with the focus on modularization and preassembly of equipment to limit on site stick build and to work within the constraints of the local transportation logistics and limits
- Developing a Procurement Plan that will identify long lead procurement items to meet the execution schedule and consider upfront procurement of supplier data to fast track procurement and ensure timely completion of detail design where necessary
- Ensuring the Procurement Plan includes early logistics planning

- Identifying Construction Work Packages (CWPs) that will align with the execution schedule and be sized for the availability of local/EU qualified contractors and skilled labour
- Develop a Contract Strategy that will meet the needs of the construction environment within the Czech Republic
- Ensuring power supply infrastructure is in place as early as possible should opportunity exist to expedite the commissioning schedule

On award of the EPCM contract, the consultant will develop a detailed execution strategy and schedule for the purposes of:

- Understanding the project duration from award to production
- Developing appropriate approaches to the engineering
- Developing an appropriate project contracting and execution strategy

The execution strategy will be developed in consultation with EMN to optimize the project objectives including cost, schedule, quality, scope, and HSEC.

24.1.10 Engineering

- Engineering will be scheduled for first pass engineering where possible.
- Engineering will ensure that the design incorporates as much as practical a regard to modularization and pre-assembly to satisfy schedule, constructability, logistics, and contracting strategies.
- Design will be prioritized to provide deliverables to support permitting and to allow earliest tendering of long lead time equipment and services, and for earliest receipt of key supplier data required to allow further design development.

24.1.11 Material Management and Contracts

- The EPCM Contractor will examine the latest technology suppliers, to ensure Best Available Technology (BAT), but be guided by preferred or nominated equipment types and suppliers where commonality of operations, maintenance, or spares holdings is appropriate.
- Selection of suppliers and contractors will be guided by agreed selection criteria including adherence to the technical specifications, capital cost, delivery periods (as determined by the schedule), reliability and quality of supply, hidden or supplementary costs associated with logistics, service agreements, and consumables amongst others.
- Delivery of equipment will preferably be FOB Chvaletice Project site.
- Preference will be given to local suppliers and local content where practical, cost effective, and available.
- Prequalification of construction contractors will be conducted in order to assess safety management systems, qualification, experience, proximity to the site for logistics, mobilization, and familiarity with the Czech regulatory requirements and local industry requirements.
- Staging areas will be established and are yet to be determined.
- Staging points and laydown for the power line construction are yet be decided.

24.1.12 Construction

- The EPCM consultant shall establish a resident construction team on site supported by the project management and design teams in conjunction with the Owner's project development team.
- The construction team will provide management of vendors and contractors on site including:
  - Contractor project inductions, kickoff meetings
  - Management of site safety practices, site polices and codes of conduct
  - Site industrial relations
  - Management of quality of construction and adherence to the design (including non-conformance report, concession requests, and formalizing Technical Queries).
  - Site Change Management and Field Engineering
  - Site Contract management including progress claim progress measurement and agreement
  - Contractor periodic reporting
  - Managing the interfaces between and neighboring contractors at the tailings extraction site and offsite infrastructure contractors

24.1.13 Project Management Strategy/Battery Limits

The EPCM scope for the process plant and tailings extraction infrastructure facilities will be managed by the EPCM consultant, while the tailings extraction operations and pre-stripping/preparations of the residue storage facility will be managed by the owner. The grid power connection and railway spur will also be managed by the EPCM consultant.

It is vital that a well-integrated team is formed from the outset of the project. Key members of the entire project team will assemble for a project kickoff meeting to co-ordinate procedures, and to develop guidelines for the work effort. Agreements developed in these meetings will be documented and incorporated into the Execution Plan, the master schedule, and the project procedures. The project will be managed by a blended management team consisting of the EPCM team leaders and the Owner's team. The EPCM consultant will provide coordination of the Execution Plan, master schedule, control budget, project procedures and project reporting. Table 24-1 shows current battery limits.

Table 24-1: Battery Limits:

Item #	Scope of work	Scope of EPCM service	EMN/Mangan scope
1	Site preparation/Demolition/recycling of waste materials for use during construction (*starting summer 2023*)	YES	NO
2	Cutting down trees - deforesting - plant (*Oct to March, 2022/2023*)	NO	YES
3	Earth work - plant site preparation	YES	NO
4	Labe Triangle - site preparation for earthworks material storage	YES	NO
5	Temporary conveyor/utility bridge (*Q2/23 to Q3/23*)	NO	YES
6	Railway infrastructure - railway	YES	NO
7	Incoming Power supply connection/infrastructure - 400kV	YES	NO
8	Utility connection - water, steam, gas, road - outsite of the "plant" plot	YES	NO
9	Industrial waste water treatment plant, outlet to Labe River	YES	NO
10	Sewage waste water treatment plant, outlet to Labe River	YES	NO
11	Sewage and rain water pipes from processing plant to mining area - revamping	YES	NO
12	Relocation of the utilities	YES	NO
13	Process Plant	YES	NO
14	Cutting down trees - deforesting, prestripping - mine site (*Oct to March 2023/2024*)	NO	YES
15	Mining area infrastructure,mine site infrastructure civil works, all infrastructure/buildings in mining area (receving hopper, fuel, material storage, ore pulping etc.)	YES	NO
16	Mining area, mining roads (*inluding mining road*), including purchase of mining equipment	NO	YES
17	Residue Storage Facility starter cell construction earthworks/geomembrane/compaction/preparation/water management infrastructure	NO	YES
18	Temporary earth works material storage area (Labe Triangle), Process Plant, Demolition material, and Mine Site infrastructure	YES	NO
19	Temporary earth works material storage area (Labe Triangle) mining/RSF pre-strip	NO	YES

Note: Battery limits outlined in Table 24-1 may be modified upon final contract negotiations with the selected EPCM company

24.1.14 Interface Management

Interface Management is essential to ensure project success. Interfaces will need to be managed, documented, and reported, as would other key project activities. Throughout the project, information will need to be shared between various contractors that may not be identified as specific deliverables.

Such items will be listed in a series of interface control matrices identifying the item and responsible party on each side of the interface. An interface register will be developed to regulate and document the decision process.

The status of information required by one party from another will be addressed in the discipline's weekly Progress Meetings to be held regularly for discussing interface issues. Project team members will involve representatives from all key areas affected by the decision-making process to ensure successful cooperation between the various parties involved in the project.

The project will develop an Interface and Communications Plan to ensure that boundaries/battery limits for each entity involved in the implementation of the project are clearly defined, and that required technical data is interfaced/shared in a consistent and timely fashion between them.

24.1.15 Project Plans

The following project plans will govern the project functional processes

- Safety Management Plan
  - The Safety Management Plan details the strategy, systems, process, procedures, and standards which are used on the project and the mechanisms for recording, analyzing, and reporting HSEC performance.

  - All project personnel shall be aligned to commitment to zero harm. Ensuring appropriate HSEC behaviors is key to success of the project and reflected in the project KPIs.
- Quality Management Plan
  - Developing and following appropriate quality processes will lead to dependable outcomes for the project. The Quality Management Plan identifies management processes, review and audit programs and procedures to assure the quality requirements of the Project.
- Risk Management Plan
  - Developing and following appropriate risk management processes will lead to dependable outcomes for the project. The goal of the risk management process is to uncover new opportunities while preserving value for the project (anticipating and mitigating areas of risk).
  - The Risk Management Plan details the structure and method by which project risks will be identified and plans implemented to eliminate or mitigate the risks.
- Interface and Communications Plan
  - The Interface and Communications plan details the processes which will be used on the project to ensure smooth operation of the project and effective and efficient communication with all project stakeholders (internal and external). Critical issues addressed are:
    - Document control
    - Interface responsibilities
    - Interface battery limits
    - Work package battery limits
    - Multiple offices in different countries and time zones
    - Project language is different to local dialect
    - Multiple currencies in use.
- Project Controls Plan
  - The Project Controls Plan details the systems and processes which are used to monitor, analyze, control, review, and report on the progress of the project as well as manage the accounting and invoicing of the project. Successful project controls are key to addressing the following KPIs:
    - Timely schedule updates
    - Timely monthly reporting
    - Project milestone target delivery management
    - Variance to works budget forecasting
    - Adherence to the change management process
    - Critical path float management

- Engineering Plan
  - The purpose of engineering is to provide engineering deliverables to enable procurement, construction, and commissioning, while meeting the quality (including HSEC), cost, and time requirements of the contract.
  - The Engineering Management Plan outlines overall design and revision processes for project activities. It sets out specification and flow diagram standards, and references all engineering procedures, systems, and forms to be used.
  - Engineering will provide technical advice when required, to procurement, construction management, commissioning, and quality departments throughout the project. Resources for ongoing field support during construction and commissioning phases will be drawn from the Engineering teams.
- Procurement Plan
  - The procurement plan will detail the approach used to purchase equipment and bulk materials for the project. The approach will include:
    - Procurement packaging approach, sole sourcing, range of suppliers available
    - Lead times for key items of equipment
    - Countries of origin and preference for local content
    - Special transportation and packaging requirements
    - Modularization, pre-fabrication, and pre-assembly
- Contracting Plan
  - The Contracting Plan details the strategy which has been developed for the identification and engagement of construction contractors for the project and the processes and systems which will be used for the delivery of the project.
  - The Contracting Plan explains the management basis of the Contracts Formation and Contracts Administration procedure to be applied on the project along with an explanation of the tools, operational controls and earned value performance monitoring techniques to be applied.
  - The Contracting Plan will identify all work packages and clearly identify those packages where management responsibility for packages already awarded will be retained by and those packages to be managed by the EPCM Contractor.
  - Construction Contracts may be contemplated as follows:
    - Plant site and Tailings Extraction site Civil Earthworks Contract
    - Structural/Mechanical/Piping Construction Contract
    - Electrical/Instrumentation Construction Contract
    - Design/Supply and/or Construct Contracts (haul road, fuel depot, fire protection, electrical substation, sewage treatment plant, lime slaker/silos)
    - Vendor support as required for installation supervision and commissioning assistance

- Construction Execution Plan
  - The purpose of Construction is to ensure that the Plant and Tailings Extraction sites are built as intended within the contracted cost, schedule, and quality requirements. In delivering this project, the overriding responsibility of construction management is to achieve a project with zero harm.
  - The Construction Execution Plan details the processes to be used for the management of construction onsite. Particular challenges for construction on this project include:
    - The semi-urban location leading to noise and traffic sensitivity to the local communities
    - Construction planning and sequencing with respect to availability of laydown areas, timely arrival of equipment and materials, and transportation logistics, in particular availability of the railway spur for use during construction/equipment installation
    - Working within restricted allowable labour work hours/days per week, particularly in the tailings extraction and residue storage facilities where work hours are restricted to daytime only, Monday to Friday (with special exceptions only)
    - The safety and industrial relations behaviour of the construction contractors are key to successful delivery of the project and establishing the cultural work climate for on-going operations
    - Preference to hire locally and use first-tier contractors with consolidated work packages
- Commissioning Plan
  - The purpose of commissioning is to achieve safe and efficient completion (handover to Owner) in accordance with the contract. The Commissioning Plan details the methodology and processes used to plan for, prepare and commission the works, including the involvement of the owner's operations team.
  - The EPCM Consultant will be responsible for full Commissioning, including oversight of vendor representatives, and Performance Verification after which the Owner's operations team will take lead responsibility with the EPCM Contractor providing assistance. The EPCM and owner's teams will work jointly to assure a smooth and successful commissioning and handover.
  - Planning for commissioning will commence at project inception. Mobilization of the dedicated team will occur during the final weeks of construction and include key personnel from the engineering phase as well as key vendor support for critical equipment.
  - The Commissioning Plan will include the following phases:
    - Verification of Plant and Equipment
    - Cold-Commissioning
    - Commissioning
    - Commissioning with Ore
    - Performance Verification
    - Area Handover
    - Commissioning Closeout

24.2 Logistics

Pinnacle Logistics Solutions was contracted by EMN to conduct a logistic study for the CMP, in particle, for the equipment and construction material transport to the site worldwide. Below is the extraction from the study report.

24.2.1 Logistics Context

The CMP is located on the south bank of the Labe River, approximately 100 km east of Prague via road. Port facilities exist at Chvaletice and there is evidence of abandoned wharfage on the property. Rail service main-line parallels the properties' southern border with opportunity to build a spur line directly to the property. Regional passenger air services are available at Pardubice with international passenger and cargo services at Prague.

Figure 24-3: CMP Project Location and Adjacent Major Cities

Source: Google Maps, 2022

The CMP project site is well located to take advantage of a substantial highway/road network for delivery of goods from regional, national, and international points of origin.

Rail offers potential for heavy cargoes but would require a siding to be developed on or adjacent to the project site.

As part of the EU's Trans-European Transport Network, the Baltic-Adriatic corridor (trans-European railway and road axes, European Commission, CEF Report, February 2018) will serve to further enhance transportation options and availability to the project region.

Ocean ports in northern Europe and the north Adriatic provide multiple opportunities for delivery of overseas origin goods with direct connections to major highways and/or rails.

While current conditions indicate little benefit or opportunity, barge service does exist on the Labe River and could be considered during a cost/benefit examination or risk assessment exercise.

24.2.2 Logistics Infrastructure Overview

The existing road and rail infrastructure in the region is extensive with multiple highway access options and modest rail services.

Barge services via the Labe River operate approximately 345 days per year into Prague (Vltava River at Melnik) but services beyond Melnik are limited with several ports between Melnik and Chvaletice listed as closed.

The proposed intermodal development at Pardubice might enhance barge service to the region; however, discussions are ongoing and said port is not likely to be constructed in time to support the project. Site proximity to Prague and the extensive port facilities there will preclude the likely cost effectiveness or feasibility of river delivery beyond Prague.

24.2.3 Logistics Programs

24.2.3.1 Rail

While road will provide the most effective access to the project for cargo, rail from primary locations in Europe or internationally may provide economies of scale.

24.2.3.2 Overview

The Czech Republic operates standard gauge (1,435 mm) track meaning that there is no transload requirement between rail services from European origin or China via the recently launched China Express Train from Xi'an to Prague (Figure 24-4). This is an important advance in rail freight from China but at this time is limited to containerized cargo only.

Figure 24-4: China Express Train Routine from Xi'an to Prague

Source: Pinnacle Logistics Solutions, 2022

The historic routing alternative requires passage through Russia which operates a wider track gauge of 1,520 mm. This requires all cargo entering Russia for shipment via rail to be offloaded and reloaded (transload) to appropriate gauge railcars. The additional handling and inherent risk of damage as well as costly delays make the transload option less appealing but with oversize, non-containerized cargoes, it remains the required option.

24.2.3.3 Railway Delivery Constraints

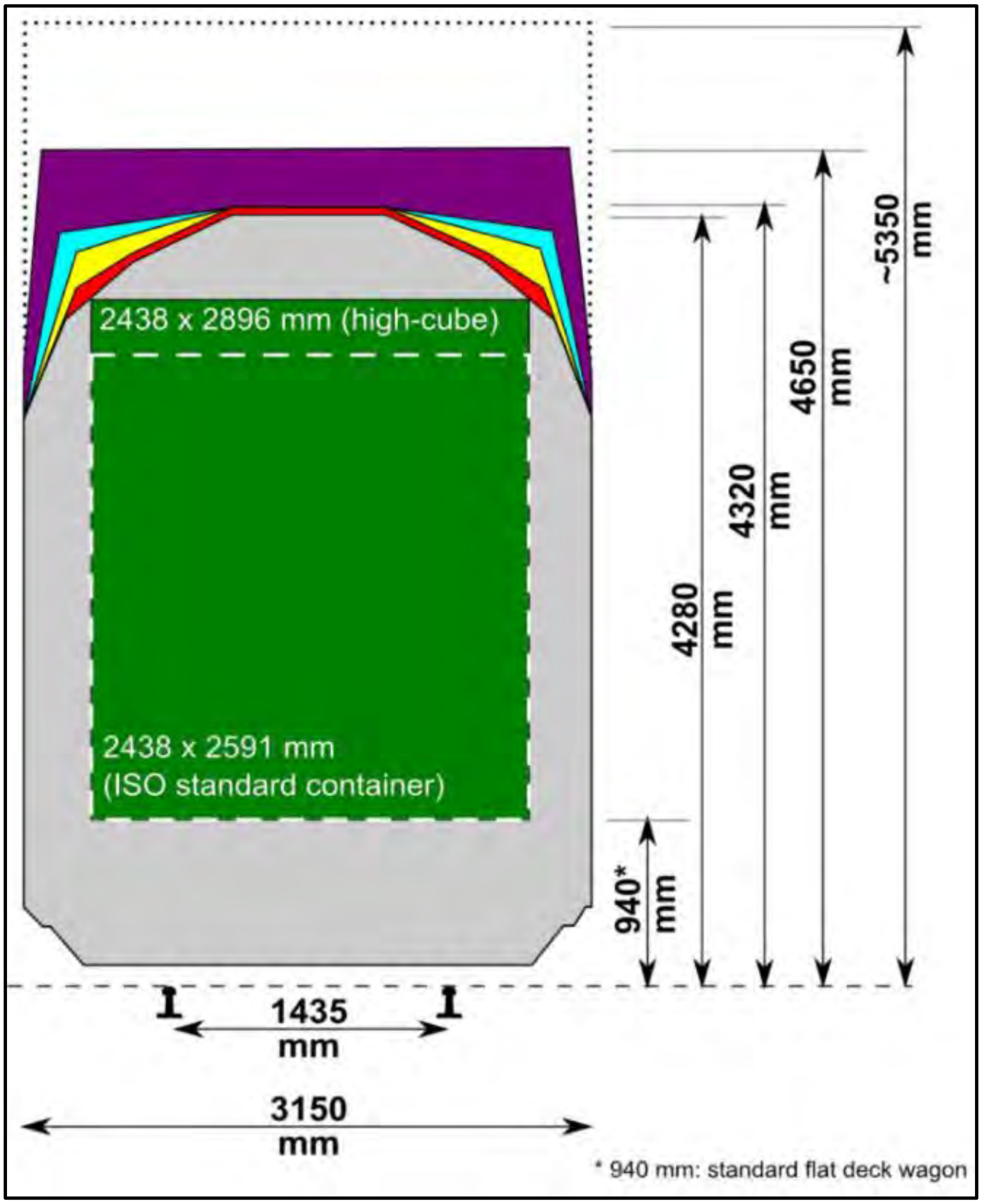
The primary constraint for cargo delivery to EMP by rail, are the dimensional constraints imposed by the various operating authorities. Cargo weight, utilizing specialty railcars, can be as much as 120 t. Thus, while a cost factor, excess weight is rarely a constraint.

Whenever practical/possible, cargo shall be designed to fit within the standard rail envelopes. Rail clearance standards in Europe are most commonly governed by the Gabarit International de Chargement (GIC). Equipment or cargo mounted on 1,305 mm (51.4") railcars, within the limits of the GIC diagram, can move virtually unrestricted on standard gauge rail lines.

Out of gauge cargo can be shipped by rail, but will attract significant premiums to the transport cost, and will require advance planning to support the use of specialty cars. The International Union of Railways (UIC) developed a standard set of loading gauges as shown below. These gauges have been further refined across Europe to harmonize train systems and they provide approximation to Russian and Chinese standards. Multiple factors apply in determining acceptability of cargo shipping envelopes and a qualified freight forwarder should be retained for this purpose.

Generally, a width of 3.15 m and height of 4.5 m are considered maximum limits (Figure 24-5). As noted previously, exceeding these dimensions can be achieved, but does require accurate general arrangement drawings submitted by CPs. Length and weight constraints are calculated based on the proposed routing and vary according to curves on the route, parallel tracks, and overall train length restrictions.

Figure 24-5: Dimension Limits – Rail Transport



Source: Pinnacle Logistics Solutions, 2022

24.2.3.4 Rail Transit Times

Transit times reflect scheduled service for in-gauge cargo. Out of gauge or over dimensional freight services may require additional transit time, adding one to two days for trainload and delivery to site. Table 24-2 shows transit days by rail.

Table 24-2: Transit Days by Rail

Route	Service Type	Transit Days
Xi'an – Prague	Standard	18
Port of Rotterdam – Prague	Standard	6-7
Port of Rotterdam - Prague	Express	3-4
Port of Trieste - Prague	Standard	6-7

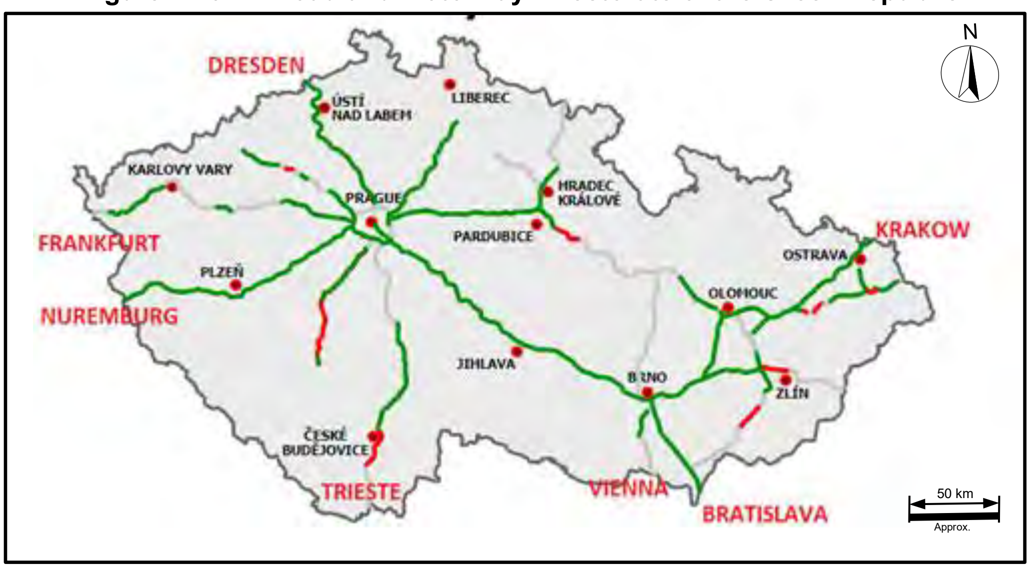
24.2.4 Ground Transportation

Over-The-Road (OTR) or Ground transportation would be the preferred method for shipping cargo to the region.

24.2.4.1 Overview

The road system is managed by the Road and Motorway Directorate of the Czech Republic. Figure 24-6 illustrates the road system.

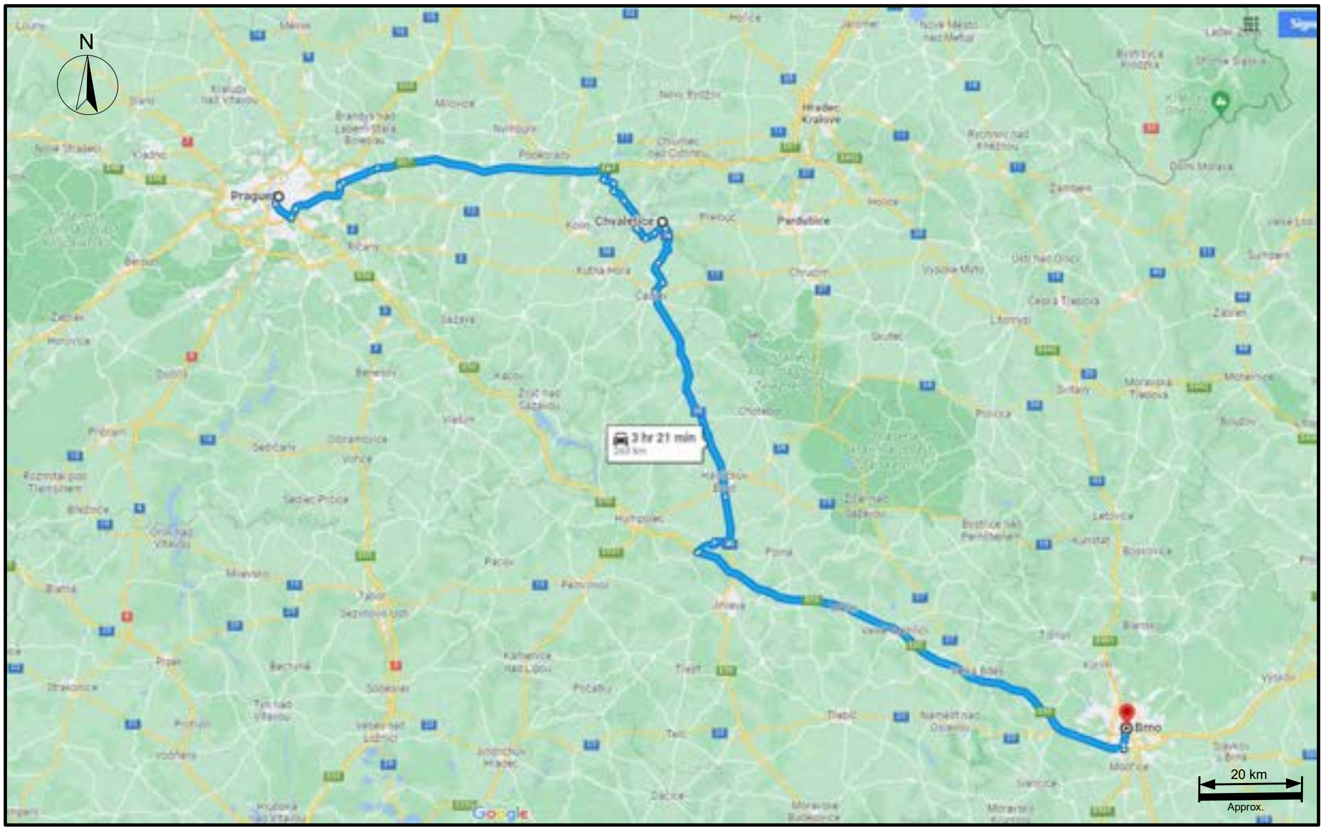
Figure 24-6: Road and Motorway Directorate of the Czech Republic



Source: Pinnacle Logistics Solutions, 2022

E series motorways above reflect direct connection with key supply points: Krakow, Poland; Dresden and Nuremberg, Germany; Vienna, Austria; Budapest, Hungary and Bratislava, Slovakia. Ocean ports Trieste and Venice would be serviced over the road via Vienna or Bratislava and future expansion of E55 as noted. Road access to site is direct via E series motorways from either Prague or Bmo with no impediments to delivery of standard or oversize cargo. Table 24-3 shows the distances the CMP site and some of manufacture centres and ocean ports.

Figure 24-7: E Series Motorways Between Prague and Brno



Source: Google Maps, 2022

Table 24-3: Distances Between CMP and Manufacturing Centres and Ocean Ports.

Origin City	Distance (km)
Amsterdam (ocean port)	1,059
Bratislava (manufacturing center)	231
Budapest (transportation hub)	461
Dresden (manufacturing center)	238
Krakow (manufacturing center)	445
Nuremberg (transportation hub)	374
Trieste (ocean port)	717
Vienna (transportation hub)	211

Note: Via E series (major routes) avoiding city centers and inherent infrastructure challenges such as tunnels and overhead power lines (transit).

24.2.4.2 Road Delivery Constraints

The Czech Republic subscribes to EU maximum permissible load regulations (Table 24-4).

TETRA TECH

Table 24-4: European Union Maximum Permissible Load Regulations.

Parameter	Maximum Permissible
Length	18.75 m
Width	2.55 m
Height	4.0 m
Weight (general cargo)	40 t (gross weight)
Weight (40’ container)	44 t (gross weight)

EU countries recognize that oversize/overweight or abnormal loads constitute an economically important segment of commercial road haulage and as such, have adopted similar permitting regulations (Directive 96/53/EC) to provide for contiguous carriage of abnormal loads across multiple countries.

Abnormal load permits generally allow up to 5 m in width, 30 m in length and height of 4.95 m. Axle loading varies between countries and permittable loading (up to 150 t) would be calculated on a per load basis. In all cases of abnormal load permitting, one or all of transport unit signage, indicator lights and escort vehicles may be required. Czech Republic specific limitations can only be confirmed with actual cargo plan and general arrangement drawings.

Widths exceeding 5 m are possible throughout much of Europe, but each load is subject to a route survey and permit application process and may require addition of police assistance or escort. Payload restrictions can only be calculated against actual cargo dimensions, assessment of reducible load consideration, general arrangement drawings and allowable transport axle spread, configuration and quantity.

A desktop review of all major highways entering the Czech Republic indicated no physical constraints to passage such as tunnels or bridges and as noted, European regulations allow substantial latitude in load dimensions and weight.

In general, road transport delivers greater flexibility than rail for both general and oversized cargo. In 2019, road freight transport accounted for 76.3% of total inland freight as opposed to 17.6% via rail and 6.1% via inland waterway (Eurostat, 2019). These values have not altered substantially over the prior five-year period and reflect a broad average, which can be considered analogue as measured against the reporting metrics provided.

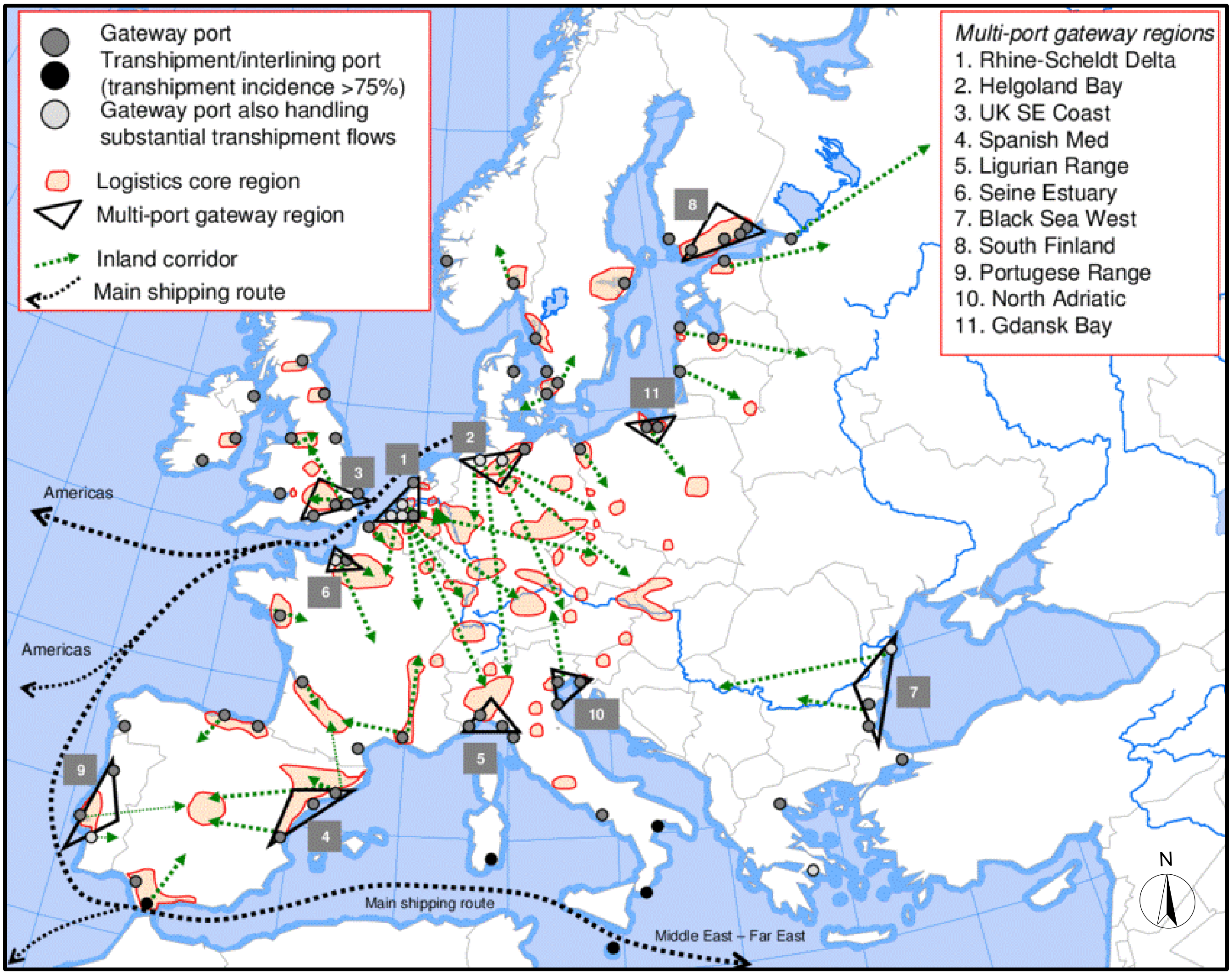
24.2.4.3 Ocean-River Transportation

Project cargo originating from overseas origins can be landed at several ports for furtherance to Chvaletice.

Key ports for project consideration would include Rotterdam, Amsterdam, Hamburg, Bremerhaven, Vienna, and Trieste (Figure 24-8). All of these ports have direct motorway and rail access for delivery to Prague and/or Chvaletice direct. Transfer to barge for delivery by river is possible from North Sea ports only. There is no effective river connection between Adriatic ports and Prague.

All listed ports provide full container and breakbulk (none containerized, typically crated deck or hold stowed cargo) handling and transload. Port selection for project cargo would be predicated on scheduled service from various origins and required on site date of specific cargoes. Table 24-5 shows sample transit days from worldwide sea ports to the key European sea ports.

Figure 24-8: Key Ports for the CMP



Specific Port Notes:
1. Rhine-Scheldt Delta includes Amsterdam, Antwerp, and Rotterdam ports
2. Helgoland Bay represents the mouth of the Elbe River which, in the Czech Republic is the Labe River
10. Port of Trieste
Source: Pinnacle Logistics Solutions, 2022

Table 24-5: Sample Transit Days from Worldwide Sea Ports to Key European Sea Ports

Los Angeles, USA	Amsterdam	43
Los Angeles, USA	Trieste	29
New York, USA	Trieste	16
New York, USA	Amsterdam	11
Bilbao, Spain	Trieste	12
Bilbao, Spain	Amsterdam	3
Shaoxing, China	Trieste	41

As evidenced in Table 24-4, there are multiple port opportunities to accommodate delivery schedules.

24.2.4.4 River Constraints

There are two main constraints to barging on the Labe River: inland port services and water depth.

Port services exist at Melnik, Prague and Pradubice. 1,000t barges can reach only as far as Prague from Baltic or northern ports, limiting the effective cargo movement directly to Chvaletice. Lighter barge services are available from Melnik to Chvaletice; however, limited shore services suggest that there is little opportunity to economically barge to site.

Navigation of the Labe remains a critical constraint to effective transportation of goods. Flooding and resulting sediment deposits have rendered the river unnavigable for extended periods and existing dams cannot effectively regulate water depth. In a 2006 report, construction of locks to maintain fixed navigability of 160 cm water level for 345 days annually has been identified as the only solution to maintaining viable services, but little advancement of the proposition has been achieved.

Further evidence of the challenges to navigation on the Labe is the fact that cruise ships have to be purpose built for use on the Labe and, departing from Hamburg, only travel as far as Prague, via the Vltava (or Moldova) river.

24.2.4.5 Air Services

Vaclav Havel Airport Prague (PRG) is an international airport providing passenger and cargo services. PRG is a hub for Czech Airlines and Smartwings and as a base for Ryanair but also services multiple carriers with global reach. Cargo airlines operating at PRG include Qatar Airways Cargo, Turkish Cargo, and UPS Airlines. With two concrete runways (3,250 m and 3,715 m), PRG can accommodate most widebody aircraft.

Pardubice (PED) is an international airport providing passenger and cargo services. With a 2,500 m concrete runway, the airport can accommodate aircraft such as 737 or A320. As PRG has increased services and capacity, PED has seen substantial reduction in passenger and cargo volumes, indicating a likelihood of limited support services.

Brno-Turany (BRQ) is an international airport providing passenger and cargo services. With a 2,650 m concrete runway, the airport can accommodate aircraft such as 737 or A320. With similar capacity to PED, BRQ offers reasonable proximity to site for air cargo or passenger services.

25.0 INTERPRETATIONS AND CONCLUSIONS

25.1 Mineralogy and Mineral Resources

The CMP is located in the Pardubice region of the Czech Republic approximately 89 km east of Prague by road. A long history of mining has occurred in the area, with continued industrial activity from the adjacent 820 MW coal-fired power generation plant and several other industrial operations now located on and around the former plant site that produced the CMP tailings.

The CMP tailings deposits are located within easy access of road, rail and river transportation, energy, power, and a plentiful workforce that resides in numerous local communities. The tailings deposits were constructed above ground using dried and compacted manganiferous tailings as the perimeter dams to hold the slurries that were deposited from the historical pyrite flotation plant.

Recent delineation drilling completed by EMN in 2017 and 2018 resulted in the completion of 160 drill holes, totaling 3,188.8 m, spaced at approximately 75 m throughout each of Cells #1, #2, and #3, and which have allowed for continuous sampling through the full vertical profile of the tailings material. A resultant 1,484 samples were sent for analysis of geochemistry, particle size analysis, specific gravity, and in situ bulk density measurements, and original pore moisture content determination. Economic concentrations of manganese were confirmed within the materials forming the outer perimeter embankments by 2018 drilling investigation and sampling. The full drilling database makes for a comprehensive and robust foundation for high-confidence Mineral Resource estimation.

Sample digestion using aqua regia has been used as a proxy for the soluble manganese mineral components of the materials, however, actual solubility may vary relative to the solvents and processes determined from the metallurgical test work. Total manganese concentrations were determined using lithium borate fusion and XRF analysis, which has provided consistent results between drill programs and between laboratories. Elevated concentration of manganese was measured in all samples collected from the tailings material with laboratory reported ranges for total manganese between 1.16 to 12.32% tMn with average of 7.33%, soluble manganese between 0.66 to 10.50% sMn with average of 5.86%, and an average of 79% of the total manganese measured to be soluble, occurring predominantly as the manganese carbonate minerals rhodochrosite and kutnohorite. The manganese concentrations were well-distributed throughout each cell, however, a slight decrease in average grade is observed towards the center of each cell. The upper portion of Cell #2 shows a consistently slightly lower concentration of manganese compared to the lower portion of the cell. A similar, but less pronounced trend is observed for Cell #1. This may reflect changes to mining or processing methods, increased dilution, or removal of materials with less manganese during the historical pyrite mining activities.

Preliminary inspection of the grain size distribution analysis indicates that the dominant particle size is silt-sized. Overall, approximately 6.2% of the material is clay-sized (less than 2 µm), approximately 56.6% of the material is silt-sized (greater than 2 µm, less than 63 µm), 37.2% is sand-sized (greater than 63 µm, less than 2 mm), and less than 1% is gravel-sized (greater than 2 mm) based on the European ISO TS 17892-4 standard. A general trend in all three cells is observed whereby particle size grades from coarse to fine towards the center of each cell. This is evidently related to particle size sorting in a playa-like environment, due to the hydraulic placement of the tailings material from spigots located on the periphery of the tailings piles and direction of flow towards the center of the piles, where decantation of liquid overflow took place using a perforated decantation tower at the center of each pile that fed a pipeline situated below the tailings which flowed into the adjoining Labe River.

Moisture content measured from each sample ranges from approximately 1.2 to 39.3% and averaging 21.1% overall. As with particle size distributions, moisture shows a strong zonation towards the center of each cell where the material is observed to be saturated with above average moisture contents. This is attributed to the moisture retention capacity and low permeability of the fine silt and clay-sized materials predominant around the center of each cell. Measurement of conductivity and pH in moisture recovered from the tailings samples at the laboratory was conducted to estimate in situ pore water quality. Conductivity values ranged from 0.77 ms/cm to 7.91 ms/cm with an average of 3.94 ms/cm, and pH ranged from 4.1 to 7.6 with an average of 5.99. These measurements indicate waters were moderately acidic to circumneutral, with elevated conductivity indicating moderate dissolved solids in solution.

In situ dry bulk density has been calculated for each sample based on estimated core recovery volumes in the field and measured sample mass and moisture content in the laboratory. The in situ dry bulk density variable is considered critical for the accurate estimation of total tonnages with the deposit. Immeasurable moisture loss in the field and visual estimation of core recovery influences the range of in situ dry bulk density. The calculated values ranged from 0.35 to 3.15 t/m^3, with 95% probability interval of 0.87 to 2.01 t/m^3, and average of 1.49 t/m^3 ±0.017 t/m^3 (95% chlorine). The in situ dry bulk density is a function of the composite mineral densities in addition to the degree of compaction in the tailings.

The Mineral Resource Estimate was classified as Measured and Indicated based on sample spacing and variance assessment. The MREs are shown in Table 1-1 with an effective date of July 1, 2022. QA procedures were prepared by EMN and Tetra Tech and implemented by EMN during the site investigation. Implementation was verified by CP James Barr, P.Geo., during two separate two-day site visits to the Property (2017 and 2018). Quality control was undertaken by the CP following receipt of the laboratory data. The MRE was prepared and validated by the CP using guidelines set forth by the JORC Code and the NI 43-101 and the CIM Best Practices resulting in Measured and Indicated MREs for each of the cells. The CP is satisfied that integrity of samples has been preserved during handling, preparation, and analysis and believes that the resulting mineral resource model to accurately represents the in situ material.

25.2 Mineral Reserve

Mineral Reserves are based on the Measured and Indicated Resources. Material economic modifying factors were applied to each block in the block model including mined grade, contained metal, recovery rates for HPEMM and HPMSM, mining operating cost, processing cost, (including EMM to MSM conversion cost), residue placement cost, general and administrative costs, site service costs, water treatment, shipping cost, product insurance, and royalties. Minimal dilution and losses of material are expected to occur at the bottom of the tailings cells and original ground. This dilution accounts for a Resource to Reserve conversion of 98.8%. No Inferred resources are included in the Reserve.

Reserve pricing for HPMSM and HPEMM was based on price projection assumptions developed by CPM Group. Tetra Tech used CPM's price forecast to 2031 and then held prices flat over the remaining LOP. The Reserve is not sensitive to metal pricing or operating costs, and the CP is not aware of any other modifying factors not discussed in this report that could materially affect the Mineral Reserve estimate. The Mineral Reserve estimation for the Project conforms to industry-accepted practices, and is reported using the 2014 CIM Definition Standards.

The Project's combined Proven and Probable Mineral Reserve amount to 26,644,000 t, grading an average 7.41% total manganese with an effective data of July 14, 2022. Approximately 99% of the Mineral Resource was converted to a Mineral Reserve.

25.3 Mineral Processing and Metallurgical Testing

Comprehensive metallurgical test programs were completed by CRIMM with an independent verification test program conducted by BGRIMM. The process mineralogical study verified the previous findings, indicating that manganese mainly occurs in the form of manganese carbonates, including rhodochrosite and kutnohorite, both of which are soluble in diluted acid. The manganese carbonates account for approximately 80% of the total manganese. The second main manganese mineral group, approximately 19% of the manganese, is in the form of manganese silicate minerals, which are refractory to acid dissolution. The main gangue minerals are quartz, feldspar, sericite/muscovite, pyrite, apatite, and others. Pyrite is the primary sulphide mineral present in the samples tested. Particle sizing of the samples tested varies substantially within the tailings storage piles, ranging from 43 to 97% passing 74 µm, averaging 74% passing 74 µm. It appears that the particle size of the material located at the edge of the tailings storage piles is coarser than the material at the center of the pile.

The test results show that the mineral materials of economic interest respond well to high-intensity magnetic separation. On average, manganese recovery to the magnetic concentrate is expected to be approximately 86% to 87%, varying from 76 to 95% tMn. The magnetic separation can improve the feed manganese content from 7.2% tMn (the MB Composite) to approximately 14% to 15% tMn, ranging from 12.0 to 16.0% tMn.

On average, sulphuric acid leaching can extract approximately 75% of the manganese from the magnetic separation concentrate, ranging from 71.9 to 82.8% tMn. When considering the downstream iron/phosphorus removal treatment, the optimized leach conditions were determined as leach temperature at approximately 90°C, with a leach retention time of five to six hours, and 0.42 acid to 1.0 feed ratio.

The test results show that with the purification treatments, the impurity contents in the pregnant solution can be reduced to the levels meeting the requirements for HPEMM production using a selenium-free process.

Three semi-continuous HPEMM pilot plant runs were conducted on the MB Composite, high-grade composite (Composite P1), and low-grade composite (Composite P2) using the conditions developed from the batch tests. With further optimized test conditions (Pilot Plant Runs 2 and 3), a higher than 63% average current efficiency was achieved. According to the assay data by CRIMM, it is anticipated that the impurity content of the HPEMM products should meet or exceed the criteria required by potential customers of HPEMM.

HPMSM generation test programs confirmed that HPMSM can be produced from the CMP Mineral Resource. CRIMM's test results indicated that the best-quality HPMSM powder was produced from the HPEMM flakes generated during the CMP HPEMM pilot plant runs. The target specifications were not achieved during the CMP test work program when using CMP magnetic separation concentrate (without electrowinning) or purchased EMM flakes produced using a selenium-addition procedure. According to the assay data by CRIMM, it is anticipated that the impurity content of the HPMSM products should meet or exceed the criteria required by potential customers of HPMSM. BGRIMM's test work verified the HPEMM to HPMSM process to be feasible.

Both the HPEMM and HPMSM manganese products produced were assayed to determine minor impurity content by CRIMM. Separate analyses on the minor element concentrations were also conducted by BGRIMM and other independent laboratories. Although standardized assay methods are still under investigation, in general, the separate assay results show that the impurity content of the HPMSM and HPEMM produced should meet or exceed the criteria required by potential customers.

The dewatering test results were conducted by various potential equipment suppliers in China. The thickening and filtration rates of the leach residue and the magnetic tailings were determined. Also, the material handling tests on the raw tailings and reside (NMT/LR blend) confirmed the materials are sticky with poor flowability, special attention is required for the material handling design, transfer points and chute angles, in particular.

25.4 Tailings Extraction Methods

The CMP mine plan is designed to produce approximately 3,000 t/day of tailings feed over a 25-year project life. The mine plan is based on truck and shovel equipment extracting the tailings in benches from the three tailings cells. The mine design criteria were based on the project and regulatory requirements. The bench designs were based on geotechnical and hydrogeological analysis and permits the tailings to be extracted at a rate that allows the residue to be placed within the existing footprint. A main haul road between the tailings cells to a plant feed storage area will provide access to all cells and temporary haul ramps will be developed in each cell as they advance.

Selected mine equipment can be sourced and maintained in close proximity to the Project, while the majority of equipment maintenance is planned to be conducted at site. The equipment fleet will be able to be used for tailings extraction and residue placement. On-site infrastructure includes a truck maintenance workshop, fuel station, truck washing facility, and temporary stockpile for tailings and residue.

25.5 Recovery Methods

The CMP process plant is designed to have a 25-year project life at a nominal name plate production rate of 50,000 t/a of HPEMM by extracting approximately 1.1 Mt/a of the CMP tailings. Two-thirds of the annual HPEMM flake production is expected to be converted into approximately 100,000 t/a of HPMSM. HPEMM product containing greater than 99.9% manganese is expected to be sold as flakes and will be produced without the use of selenium and chromium. The CMP HPMSM product will be designed to contain no less than 99.9% MSM, a minimum of 32.34% manganese, and will be sold in powder form, produced without the use of fluorine.

The proposed process flowsheet was developed by EMN, CRIMM and BGRIMM over several years of test work and is based on numerous results, including a comprehensive test work program with semi-continuous pilot plant testing, equipment vendor testing and utilization of existing/known operational technologies used by other global manganese operations. The flowsheet includes the following key process circuits:

- Tailings pulping/pumping
- Wet magnetic separation to upgrade the leach feed from 7.41% tMn to approximately 15% tMn, and on average reject approximately 57% of the feed to NMT, with an expected 86% manganese recovery.
- Sulphuric acid leach to dissolve the acid leachable manganese, mainly from the manganese carbonate minerals.
- Leach solution purification, including magnesium content management in anolyte solution, to ensure efficient electrowinning operations and high-quality products.
- Washing of LR using a combination of filter cake repulping and on-stream washing, including manganese and ammonia recovery from washing solution to minimize their losses and produce washed leach residues for dry stacking with NMT.
- Manganese electrodeposition from qualified solution to produce HPEMM product, including post-electrowinning treatments and handling, such as washing, stripping and stripped plate handling.

- Acid dissolution of HPEMM flakes, leach solution deep purification, crystallization by evaporation and crystal drying to produce HPMSM.
- Dry stacking of non-magnetic separation tailings and washed leach residues onto the lined RSF.

The flowsheet and equipment proposed for the CMP have been widely used in the manganese metal and sulphate industry and it is expected that the equipment can be operated and maintained effectively in the local environment. Further optimization of the flowsheet, equipment sizing, and layout as discussed in Section 26.0 should be conducted.

25.6 Project Infrastructure

25.6.1 General Project Infrastructure

The CMP is a brownfield project immediately adjacent to existing infrastructure which includes an 820 MW coal-fired power station operated by Severní Energetická a.s., a pre-cast concrete plant, an asphalt plant, a newly constructed cast iron foundry, a main railway, highway #322 and a railway spur. Highway #322 connects to Prague, 89 km by road, via Kolin and Highway #12. The railway acts as a main transportation line from Prague to communities in the Eastern Czech Republic. The proposed location for the high-purity manganese production plant is planned to be located at the same site of the former flotation plant that produced the CMP tailings. The infrastructure proposed for the tailings extraction, process, residue storage, and operational support were designed based on the information available. The design for the FS is expected to meet project requirements and local design standards.

Process circuits that may generate dust and off-gases will be equipped with dust and off-gases control systems. The off-gases will be scrubbed prior to being discharged into the air.

A covered utility bridge has been designed to connect the plant site to the mine site area and will include material transfer infrastructure including the CMP tailings slurry pipeline, filtered residue tube conveyor, water pipelines, electrical/communication cables, and a personnel walkway. The bridge will also provide access to both the sites for maintenance workers and operators. The residue material will be backfilled to the excavated CMP tailings area using a dry stacking storage method and will be placed progressively during operations on a geo-membrane lined containment.

The proposed upgraded railway spurs will provide more efficient material handling for large amounts of incoming and outgoing materials, as compared to trucking. This existing railway facility will benefit the CMP with cost effective material handling. Various material handling and storage facilities have been planned for the CMP, including railcar loading and unloading facilities, lime storage silos, and sulphuric acid storage tanks.

25.6.2 Power Supply

Local electrical power will be supplied via the Czech high voltage, 400kV, transmission grid which is owned and operated by CEPS. The power will feed to two (2), 400 kV/37.5 kV/10 kV step-down transformers located at the plant site substation. The main power consumers will be four electrowinning lines which required direct current which will be supplied from four 350 V/36 kA rectifier transformers. The estimated power demand of the CMP is approximately 75 MW. The plant site substation will be located at the east side of the plant site, close to the incoming power source and adjacent to the electrowinning workshop which will be main power consumer of the CMP.

25.6.3 Steam Supply

Steam, for process use, will be produced on-site by two (2) 20-t per hour, 0.6 MPa, steam generators fired by natural gas. Additionally, the steam produced will be supplemented by a 6-t per hour, 0.6 MPa, hydrogen-boiler fueled by hydrogen gas recovered from the HPEMM dissolution process. The steam will be mainly used for ammonia recovery and HPMSM crystallization and drying, as well as for magnesium removal. Total steam production is 46 tph.

25.6.4 Water Supply and Process Water Management

The water supply system will consist of fresh process make-up water, cooling circulation water, potable water, fire water supply, pure water, demineralized water, and 130°C, pressurised/hot water. The pore water from the existing CMP tailings will form part of the process makeup water. All the process water used in the process circuits will be directly re-used or treated and re-used. A cooling-tower blowdown water treatment plant, a pure water generation plant, a sewage water treatment plant for the wastewater generated from human activities, and a site run-off contact water treatment plant have been designed for the CMP. The fresh process makeup water will be sourced from the adjacent Severní power plant and will be supplemented by the treated contact water from the project, as required. . The demineralized water to be used for steam generation, pure water along with the 130°C hot water to be used for building heating and process heating will be also sourced from the power plant.

25.6.5 Air Supply

Compressed air will be required site wide to service various process circuits, mainly the iron/phosphorus removal circuit and filtration circuits, maintenance, and instrumentation systems. The compressed air will be supplied from a centralized compressor station.

A dedicated compressed air system will be provided at the mining and residue storage area for mobile equipment maintenance.

25.6.6 Site Water Management

Two separate water management systems are planned to manage site water for both the plant and mine site areas. Contact water from direct runoff from the plant site and mine site will be separately collected. The contact water from the mine site, including the seepage from the dry stack pile, will be directly used as process water with any excessive water being sent to the contact water pond located at the plant site. The contact water collected from the plant site will be treated and use d as process water. Any excessive treated contact water will be discharged into the environment. As a part of the site water control, two separate water division systems have been designed to direct the non-contact/storm water away from the plant site and the CMP tailings site. The storm water will report to the storm water surge ponds located at the plant and mine site areas, prior to being released to the environment at a controlled rate.

25.6.7 Residue Storage Facility

The RSF was designed to store the washed and filtered process residue. The geomembrane lined containment area will be constructed within the same footprint as the existing tailings cells and incorporate surface water diversion and contact water containment features. The RSF will be constructed in stages to suit residue storage requirements and the construction footprint made available from excavation of the existing tailings. The RSF slopes and surfaces will be progressively capped and reclaimed to mitigate dust generation and water infiltration.

25.7 Environmental Studies, Permitting, and Social or Community Impact

The vicinity of the CMP tailings has been significantly impacted by past mining and related heavy industrial activities. Mining activity at Chvaletice ended in 1975. Czech law exempts landowners and developers from impacts prior to 1989, when communism ended in then Czechoslovakia. Due to the location of the CMP on the shore of the Labe River and a shallow aquifer in the Labe Valley, there are significant environmental sensitivities related to ongoing tailings runoff and related impacts to local groundwater. Currently, EMN has knowledge of impacted groundwater caused by the historical mining and processing activity in the area, in particular, the ongoing leaching of metals and other pollutants from the tailings. EMN continues to regularly monitor these impacts in groundwater wells and expects that the reprocessing of the Chvaletice tailings would result in a significant reduction or elimination of ongoing groundwater pollution caused by the currently unlined tailings facility. Environmental baseline studies and other environmental studies have been in progress since the summer of 2016. These studies include a comprehensive site wide Biological Survey, a detailed Air Dispersion Model and Study, an Acoustic/Noise Impact Study, a Road and Rail Transportation Study, a site wide Hydrogeological Survey, a Health Impact Assessment, an Impact on Landscape Character study, and a Reclamation and Remediation Study. A screening decision summarizing all received comments on the Company's EIA Notification was published by the MoE in December 2020. The conclusions of the EIA screening procedure did not result in any unexpected requirements.

The second and final stage of the Project's ESIA is under preparation and is expected to be submitted to the Czech MoE in September 2022. The ESIA will include a detailed description of:

- The manganese production process and resulting environmental footprint of the Project;
- Results of baseline and other studies conducted to date;
- Health, safety, and environmental management plans;
- Impact assessment, impact mitigation and avoidance plans/measures;
- Socioeconomic impacts on local communities;
- Reclamation plans/objectives; and
- Acoustic and dispersion modeling results.

25.8 Project Execution Plan

A Level 1, Project Development Schedule has been prepared during the FS in order to outline the overall timeline and key constraints. According to the schedule, it is expected that the project should take approximately four years to develop to achieve a commencement of commercial production by Q1, 2027. The critical path of the project currently falls through the environmental impact assessment, detailed engineering, construction, and commissioning phases.

25.9 Capital and Operating Cost Estimates

25.9.1 Capital Cost Estimate

The total estimated initial capital cost for the design, construction, installation, and commissioning of the Project was estimated to be USD$757.4 million, excluding sustaining costs (USD$117.0 million), and working capital cost (USD$78.7 million). All costs are shown in US dollars and the accuracy range of the estimate is -10% +20%.

Tetra Tech established the capital cost estimate using a hierarchical WBS. Where applicable, the quotations used in this estimate were obtained in Q1/Q2, 2022. Tetra Tech used the foreign currency exchange rates shown in Table 21-2, where applicable. The foreign exchange rates are based on three-year average foreign exchange rates up to May 31, 2022.

25.9.2 Operating Cost Estimate

On average, the on-site operating costs are estimated as USD$194.79/t of CMP tailings reprocessed, or USD$4.43/kg manganese metal produced (equivalent). The on-site operating costs are defined as the direct operating costs, including CMP tailings extraction, processing, water treatment, residue dry stacking, site servicing, and G&A costs, and exclude other costs such as product freight costs, sales related costs, and government and third-party royalties, which are included in the economic analysis.

The estimates are based on an average annual plant feed rate of approximately 1.1 Mt of the CMP tailings, or an average annual manganese metal production of 47,500 t (total manganese equivalent in HPEMM and HPMSM, ranging from 45,582 to 49,428 t/a of manganese, excluding the first ramp-up year). The major cost for the CMP is the HPEMM and HPMSM processing cost, which accounts for approximately 73.4% of the total cost, excluding service costs required for water and steam supply and water treatment. A contingency of 5% is included in the estimate. The expected accuracy range of the operating cost estimate is ±15%.

25.10 Economic Analysis

Tetra Tech completed a pre-tax economic analysis based on estimated costs and revenues for extracting and reprocessing the tailings from the Chvaletice deposit. The economic analysis is based on the sale of two products: HPEMM and HPMSM. The product prices used for the analysis were based on the projection by CPM. The economic analysis summarized below shows that the project is economically viable:

- Pre-tax NPV of USD$1,750 million at an 8% discount rate
- Pre-tax IRR of 24.9%
- Pre-tax payback period of 3.6 years

GrantThornton, based in the Czech Republic, prepared both the Czech tax depreciation calculations based on the capital expenditure information and the allocation of such expenditures into the Czech tax depreciation groups, and the Czech corporate income taxes payable for the CMP economic analysis based on existing income tax legislation in the Czech Republic.

The post-tax economic analysis for the life of the project yielded the following financial results:

- Post-tax NPV of USD$1,342 million at an 8% real discount rate

- Post tax IRR of 21.9%
- Post-tax payback period of 4.1 years
- The FS economic evaluation shows that the CMP is most sensitive to product prices followed by operating costs

26.0 RECOMMENDATIONS

This FS and Public Report concludes that re-processing of the CMP deposit is expected to provide a strong economic return for shareholders. It is recommended that the Project be moved to the next phase of project development and engineering design as defined in the FS.

Full details of recommendations by discipline are outlined in the following subsections, and the cost breakdown by discipline for future recommended work is summarized in Table 26-1. The costs related to the recommended work have not been included project capital cost estimates.

Table 26-1: Recommended Costs for Future Work

Area	Estimated Cost (USD$)
Tailings Extraction	427,000
Mineral Processing and Metallurgical Testing*	460,000
Recovery Methods/Trade-off Studies	50,000
Infrastructure (Geotechnical)	200,000
Marketing and Transportation Studies	180,000
Total Cost	**1,317,000**

Note: *Excludes costs already allocated for operation of the Demonstration Plant

26.1 Mining Reserve and Mining Methods

To support the mine design and schedule, additional geotechnical and hydrogeological testing of the tailings should be undertaken.

- The in situ hydraulic properties of the tailings material needs to be verified using methods specifically designed for characterizing a saturated/unsaturated groundwater flow regime. This will include testing and/or monitoring of:
  - In situ volumetric moisture content variations.
  - In situ positive and negative pore pressure variations.
  - In situ saturated hydraulic conductivity testing at various locations and elevations in the tailings cells.
  - Development of soil-water retention curves for tailings at various locations and elevations in the tailings cells.
  - Install lysimeters to directly measure the temporal and spatial variability in tailings cell infiltration.
- An instrumented trial cut should be undertaken with the benching of the first cut and/or during the test mining phase that is planned to support ore feed to the demonstration plant. The instrumentation should be installed well in advance of the cut to allow baseline conditions and temporal variability to be assessed. Water management in the vicinity of the trial cut should mimic operational conditions and aim to minimize infiltration.

In addition to the above, geotechnical sampling of moisture content, grain size, and plasticity of finer-grained factions is proposed for each unit within all three tailings cells, both as an initial drill campaign with two holes per cell, in the central areas of the cells where the fine-grained material is located, and continued sampling at annual intervals during the life of the project during bench cutting. This data collection aims to further constrain the boundaries between the differing units within the cells and refine estimates of water levels. Through the investigative work, the locations and volumes of pressurized saturated tailings can be identified, and the mining plan adjusted to allow sufficient time for those zones to drain.

- When operating, water management should be aimed at minimizing infiltration on the top of the piles and the benches. This will include, but not necessarily be limited to, the following:
  - Maintenance of existing vegetation in place for as long as possible. The vegetation contributes to evapotranspiration effectively reducing the water available to infiltrate into the cells.
  - Grading of benches and temporary ditches to promote runoff and limit infiltration.
  - Control of water from higher benches/vegetated areas to eliminate run of onto lower slopes and benches.

Even after depressurization of the tailings, operating haul trucks in the center of the cells where the material has been previously saturated may be difficult during inclement weather. To reduce the bearing pressure of the trucks and increase mobility, the use of flotation/balloon tires for the trucks during these periods is recommended. Composite construction mats ('swamp mats') are also recommend as temporary staging areas for excavators and haul trucks as needed. These mats can be easily conveyed by the excavator to the active mining face and removed when not required.

EMN has completed an assessment of the potential of converting diesel-powered articulated trucks into diesel-hydrogen hybrids. Other opportunities include an evaluation of potential benefits of transitioning to a predominately battery electric vehicle fleet once those options become available in the selected equipment sizes.

The estimated costs associated with the recommended work are summarized in Table 26-2.

Table 26-2: Recommended Budget for Tailings Extraction

Task	Estimated Cost (USD$)
Geotechnical Sampling Program	180,000
Hydrogeological Instrumentation and Monitoring	220,000
Floatation tires and Swamp mats study	10,000
Electric fleet study	17,000
Total	**427,000**

26.2 Mineral Processing and Metallurgical Testing

Further metallurgical testing is recommended to better define metallurgical performance and optimize processing conditions, in particular, the verification testing by the planned demonstration plant campaigns. The samples to be tested should be generated from different spatial locations, including variations in mineralogy, head grade, and particle size distribution. Also effective utilization of carbon dioxide recovered from the acid leach circuit should be tested and verified. One of the demonstration plant key objectives is to generate samples for customer supply chain validation. Therefore, further product specifications should be closely reviewed with the potential users and updated based on the user's requirements. The costs associated with the demonstration plant runs and product specification update have been budgeted in the current demonstration plant campaign.

Additional tests should be conducted with equipment vendors to generate data to support the engineering design, such as determination of carbon dioxide utilization rate, as well as commercial validation of the newly available hydrogen gas steam boilers. Verification of the magnesium removal process is planned to be conducted with the planned demonstration plant runs. A total of USD$100,000 has been estimated for further testing programs with equipment vendors, excluding sample generation and shipment costs and the rental and manufacture costs for the test equipment.

Further improvements are recommended for the electrowinning tank-house. Current tank house design is based on prevailing manganese electrowinning technology in China, which leaves room for improvements in health, safety and environmental areas, operational efficiency, and productivity. Areas of concern include the following:

- Mist abatement/control/mitigation
- Electrolyte drip capture and handling
- Handling of disqualified cathodes
- Handling of anode & frame assembly,
- Cartridge & slime handling
- Capacity alignment between harvesting & stripping systems
- Layout & material flow
- Cell performance-monitoring
- Cathode & anode design.

It is recommended that the basic design of the electrowinning cell, as designed by standard Chinese technology and as incorporated by BGRIMM, be retained for most part, while leveraging off of proven design improvements validated in other mature electrowinning operations.

It is estimated that the cost of the design and testing work for these improvements will be approximately USD$360,000.

Table 26-3: Recommended Budget for Metallurgical Test Work

Task	Estimated Cost (USD$)
Bench Scale Verification and Design Data Generation Tests	200,000
Demonstration Plant Runs	included in the Company's current budget
Electrowinning Tank Shop Working Environmental Improvement	360,000
Total	**560,000**

26.3 Recovery Methods

Several trade-off studies and process optimizations have been completed during the FS. As the project is considered pioneering from the perspective of feedstock, process scale up and high purity product specification targets, the plan to produce HPEMM and HPMSM products in compliance with all applicable modern environmental standards and regulations, in conjunction with current technology developments in these areas, further trade-off studies, such as equipment sizing and type, best available technologies, including filtration technology, modern manganese electrowinning cells, emissions and dust control, material handling and slurry pumping characterization should be further conducted during the next phase of project development. The objectives should be to reduce capital and operating costs, to use automatic operations as much as possible, and to adapt larger and energy efficient equipment if possible.

Further plant visits to the EMM and MSM plants in China and South Africa should be arranged to obtain operational feedback related to the manganese production and automation, as well as other modern metal electrowinning operations. Also, the visits to potential equipment suppliers should be conducted to better understand their equipment features and performance. These costs are part of the next phase of project development.

The travel costs associated with the bench marking of other electrowinning production plant visits is estimated at USD$50,000.

The Project plans to use locally produced barium sulphide (BaS). The further work will be required to work together with the European suppliers to develop feasible solution for the reagent production, handling, and transportation. There are currently two memorandums of understanding in place with two European producers of BaS for the mutual collaboration of this product supply. These costs are reflected in the estimated material supply costs.

26.4 Marketing and Transportation Studies

Further marketing studies for high-purity manganese products are recommended to better understand the market supply and demand and their pricing. The rechargeable battery industry for electrical cars and energy storage is an emerging industry. Several battery formulations exist in the market today with many new formulations expected in future years, with the potential for high manganese content. The change in battery formulations will affect the market demand to various metals used for the battery production, including lithium, cobalt, nickel, manganese, and other metals. Further customer interaction should be pursued with the main objective of establishing off take agreements, in addition to updated market forecast studies.

A further comprehensive transportation study for various equipment, construction materials, and operation consumables and supplies should be conducted, especially the equipment and construction materials which cannot be sourced locally.

Further marketing studies for selling by-product gypsum for industrial use and magnesium carbonate by-products for agricultural use should be studied to improve project economics.

The Project is expected to consume large amounts of sulphuric acid and lime. The local sources for the reagents and other reagents required for the Project should be further investigated in the next phase of the engineering work. The investigations should include reagent sources and logistic arrangements.

The estimated cost for this work will be approximately USD$180,000.

26.5 Project Infrastructure

Additional geotechnical drilling investigations for infrastructure foundation studies are recommended for the proposed locations of the process facilities and ancillary buildings at the plant site and the mine site. The estimated cost for this work will be approximately USD$200,000.

26.5.1 Residue Storage Facility Design Work

The alignment and thickness of the proposed perimeter drainage layer should be reviewed as part of future design work and the proposed reclamation plan for the RSF site. Similarly, the geometry and compaction specification of the perimeter structural zone in the filtered stack should be developed as part of future work in the context of operational requirements, cover design requirements, and constraints with respect to stacked residue consolidation and the geotechnical stability of the stack slopes.

Plans to mitigate potential impact to protected species and habitats should be incorporated into project development and any constraints to RSF design, operation, and closure identified.

Facility closure objectives and alternatives should be evaluated, and an environmental risk assessment should be undertaken to identify contaminants of concern, source and environmental pathways, regulatory limits, potential controls and mitigation, and potential impacts to human health and the environment.

Environmental management plans should be developed for dust, contact water, groundwater, and topsoil.

The costs associated with the studies have been included in the initial capital cost estimates.

26.6 Environmental Studies, Permitting, and Social or Community Impact

EMN/Mangan has completed intensive environmental baseline studies and other environmental studies since the summer of 2016. EMN/Mangan plans to submit Project's Environmental and Social Impact Assessment in September 2022.

It is assumed that the environmental assessment work is close to completion and the work is part of the on-going report submission work. No further costs associated with the assessment work has been budgeted

27.0 REFERENCES

27.1 General

Bilfinger Tebodin Czech Republic, s.r.o., 2020, Recyklace odkaliště Chvaletice – Trnávka (EIA Notification, Version 1, Final), July 2020

CPM Group, 2022, Market Outlook for High-Purity Manganese Products, Prepared for Euro Manganese Inc., July 6, 2022

Tetra Tech Canada Inc., 2019, Public Report and Preliminary Economic Assessment for the Chvaletice Manganese Project, Chvaletice, Czech Republic. January 29, 2019.

Tetra Tech Canada Inc., 2019, Technical Report and Preliminary Economic Assessment for the Chvaletice Manganese Project, Chvaletice, Czech Republic. January 29, 2019.

Výzkumný ústav maltovin Praha, s.r.o., 2021, Gypsum availability in the Czech Republic in 2020 and its prediction for 5 – 15 years, December 2021

27.2 Mineral Resources

Bateria Slany –1986 to 1989, Various reports, a Czech state battery producer's resource, metallurgical, environmental, engineering and economic studies of Chvaletice manganese tailings.

Bateria Slany, 1989. Translated extracts of resource assessment report.

Cullen, et al. 2013, Mineral Resource Estimate Technical Report for the Plymouth Mn-Fe Deposit Woodstock Property New Brunswick, Canada. Prepared for Buchans Minerals Corporation and Centrerock Mining Limited. May 6, 2013.

Daniel Smutek, 2016, Chvaletice. Sulphur and Manganese Through Quarrying. Nature and Regional Protection Agency of Czech Republic (multi-stakeholder project for Iron Mountains Geopark with participation of European Union)

GET, 2015, Legislative Aspects Related to the Granting of a Permit for the Mining and treatment of Manganese Ore, Chvaletice – Tailing Ponds 1, 2 (3104804), Řečany – Tailing Pond 3 (3243700), prepared for Navigator Management Ltd., April 2015

Ministry of Environment of the Czech Republic, 2018, Document Reference Number MZP/2018/550/387-Hd, ZN/MZP/2018/54, April 17, 2018

Novotny J. and Husak F., 1972, Borehold slude sedimentation grain size sorting (pg. 4/6 of Chvaletice P054730_en document)

SIHAYA, 2018. Geophysical prospection of rock dynamic parameters by VSP well logging and SRS at locality: Power-station Chvaletice. Report prepared by SIHAYA for SGS Czech Republic, July 2018.

Tetra Tech Canada Inc., 2017, Public Report on Mineral Resource Estimation for the Chvaletice Manganese Project Chvaletice, Czech Republic, October 14, 2017

Tetra Tech Canada Inc., 2018, Public Report on Mineral Resource Estimation for the Chvaletice Manganese Project, Chvaletice, Czech Republic. December 8, 2018

27.3 Mining

Tetra Tech Canada Inc., 2022, Chvaletice Manganese Project Feasibility Mine Design Report. File 704-ENG.VMIN03093-01-REP-H0001, June 27, 2022

27.4 Metallurgy and Process

ALS Canada Ltd, 2014 COA_VA14199511_116227-28883357, December 30, 2014,

ALS Canada Ltd, 2015, COA_VA15005481_117190-28980198, January 13, 2015

ALS China, 2018, Data Assay Report (GZ18063000), October 2018

ALS China, 2018, Data Assay Report (GZ18223290) November 2018

ALS Metallurgy Kamloops, 2021, Mineralogical Assessment of Chvaletice Manganese Samples – KM6471, September 02, 2021

AMEC Foster Wheeler, 2016. Chvaletice EMM Project, Chvaletice, Czech Republic, Process Development Report. September 15, 2016.

AMEC Foster Wheeler, 2016. Chvaletice EMM Project, Scoping Study, Project 181632, September 15, 2016,

Beijing General Research Institute for Metallurgy and Mining, 2022, Magnetic Separation Test Work, Final Report, 1720-003010-G-TR-001, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Deep Purification Test Work, Final Report, 1720-003010-G-TR-002, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Leaching and Fe/P Removal Test Work, Final Report, 1720-003010-G-TR-003, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, MS Concentrate Press Filter Test Work, Final Report (Jingjin), 1720-003010-G-TR-004, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Press Filter Test Work, Final Report, 1720-003010-G-TR-005, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Magnetic Separation Concentrate & Tailings Settling Test, Final Report, 1720-003010-G-TR-006, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Non-Magnetic Tailings (NMT) Pressure Filter Test Work, Final Report (Jingjin), 1720-003010-G-TR-007, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Zn Removal by BaS Test Work, Final Report, 1720-003010-G-TR-008, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Solid Liquid Separation-Filtration Test Work - Leach Residue, Final Report, 1720-003010-G-TR-009, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Mg Removal Test Work, Final Report, 1720-003010-G-TR-010, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Heavy Metals Removal Test Work, Final Report, 1720-003010-G-TR-011, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, High Efficiency Thickener Test Work, Final Report, 1720-003010-G-TR-012, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Crystallization MSM Test Work, Final Report, 1720-003010-G-TR-013, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Pressure Filtration Test Work - For CCD Washed Leach Residue Thickener Underflow, Final Report, 1720-003010-G-TR-014, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Deep Purification Fe Removal Test with H_2O_2 and Air, Final Report, 1720-003010-G-TR-015, May 20, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria – General Site Conditions, 1720-003010-G-DBM-001, August 23, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Feasibility Study Report, 1720-003010-G-REP-001, August 3, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Electrical, 1720-003010-E-DBM-001, June 23, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Architectural, 1720-003010-A-DBM-001, June 3, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - HVAC, 1720-003010-B-DBM-001, June 3, 2021

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Civil, 1720-003010-C-DBM-001, June 3, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Fire Protection, 1720-003010-G-DBM-002, June 3, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Instrumentation & Telecommunication, 1720-003010-I-DBM-001, June 03, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Mechanical, 1720-003010-M-DBM-001, June 3, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Piping, 1720-003010-M-DBM-002, June 3, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Structural, 1720-003010-S-DBM-001, June 3, 2022

Beijing General Research Institute for Metallurgy and Mining, 2022, Design Criteria - Process, 1720-003010-P-DBM-001 PDC Rev.2, July 20, 2022

Changsha Research Institute of Mining and Metallurgy Co., Ltd., 2017, Exploratory Magnetic Separation Test Work Report, May 27, 2017

Changsha Research Institute of Mining and Metallurgy Co., Ltd., 2018, Compilation of EMI Chvaletice Manganese Project (CMP) Test-Work Reports, December 2018

Changsha Research Institute of Mining and Metallurgy Co., Ltd., 2018, Report of Test Program for High Purity Manganese Sulfate crystallization process of CMP's HPMSM Project, December 2018 (Updated in March 2019)

CINF Engineering Co., Ltd., 2018, Executive Summary_Pre-Feasibility Rev B (F2085SQ2-01)_Chvaletice Manganese Project, November 2018

Dept. Earth and Ocean Sciences, UBC, 2015Quantitative Phase Analysis of 2 Powder Samples Using the Rietveld Method and X-Ray Powder Diffraction Data, January 08, 2015

Jenike & Johanson, 2021, Flow Property Test Results for Manganese Ore & Ore Residue, May 27, 2021

K + K průzkum s.r.o., 2021, Supplementary Engineering-Geological and Hydrogeological Survey, April 2021

Kemetco Research Inc., 2015, Data Report KT1-5, Project #: I00301, January 2015 to February 2015

Kemetco Research Inc., 2016, Data Report – Mg Removal Using Fluoride, Project #: Eu Mn J0201, February 2016

Kemetco Research Inc., 2016, Data Report – Mg Removal Using Hydroxide, Project #: Eu Mn J0201, February 2016

Met-Solve Laboratories Inc., 2016, MS1656 Euro Manganese, Project #: MS1656, March 02, 2016

Met-Solve, 2016, project MS1656 Euro Manganese prepared for Marco Romero, President and CEO, Euro Manganese Inc., March 2, 2016

Process Mineralogical Consulting Ltd., 2015, Mineralogical Note, December 15, 2015

Process Mineralogical Consulting Ltd., 2016, Mineralogical Note, January 27, 2016

SGS Canada Inc., 2017, An Investigation into Acid Leaching and Mineralogical Characterization on Samples from the Chvaletice manganese deposit (draft report), Project 16204-001, October 06, 2017

SGS, 2018. Cone-Penetration-Test Investigation of the Existing Tailings Piles Located Near Chvaletice, Czech Republic. Report prepared by SGS Czech Republic s.r.o., January 2018

27.5 Infrastructure

Beijing General Research Institute for Metallurgy and Mining, 2022, Feasibility Study Report, 1720-003010-G-REP-001, August 03, 2022

Sudop Phaha a.s., 2021, Construction of A Branch and Tranship Facilities- Drawing No. 1, June 2021

Sudop Phaha a.s., 2021, Construction of A Branch and Tranship Facilities- Drawing No. 3, June 2021

Sudop Phaha a.s., 2021, Construction of a Siding and Transshipment Facilities for Mangan Chvaletice, June 2021

27.6 RSF Design

Canadian Dam Association (CDA), 2019. Technical Bulletin - Application of Dam Safety Guidelines to Mining Dams. 43 p.

Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions, and rules for buildings [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC].

G impuls Praha, 2017, Chvaletice Tailings Concluding Report on the Geophysical Works. September 19, 2017 Geomin s.r.o., 2016. Report on hydrogeological work performed to the date of 30 June 2016 and proposal of hydrogeological survey and modelling of Trnavka area. (Translated from Czech language original), July 2016

Geomin s.r.o., 2019, Hydrogeological exploration of tailings piles in Chvaletice (Final report), May 2019

Geomin s.r.o., 2021, Technical Report, Chvaletice – Groundwater Monitoring (Draft), February – March 2021.

Geotest, 2021. Chvaletice – MANGAN, Subsoil Survey Final Report. Report prepared for Mangan Chvaletice, June 2021.

Hawley, M., & Cunning, J. (Eds.). 2017, Guidelines for Mine Waste Dump and Stockpile Design. CSIRO Publishing.

Idriss, I.M. and Boulanger, R.W. (2008). Soil Liquefaction during Earthquakes, Earthquake Engineering Research Institute, Monograph No. 12, pp. 237.

Schenk et al., 2001, Earthquake Hazard Maps for Czech Republic, Poland, and Slovakia. Acta Geophisica Polonica. Vol XLIX, No. 3, 2021

Tetra Tech Canada Inc., 2022, Chvaletice Manganese Project Feasibility Residue Storage Facility Design Report. File 704-ENG.VMIN03093-01-REP-T0003, June 30, 2022

27.7 Water Management

Czech Hydrometeorological Institute, http://portal.chmi.cz/

Tetra Tech Canada Inc., 2022, Chvaletice Manganese Project Feasibility Site Wide Water Management Plan. File 704-ENG.VMIN03093-01-REP-H0003 (v3), June 28, 2022

27.8 Environmental

Department of Social Geography and Regional Development, Faculty of Science, Charles University, 2018, Impact of the Location of Mangan Chvaletice on the Social Environment of the Microregion – Socio-geographic Analysis, October 2018

EMI, 2018, Memorandum summarising environmental regulations related to tailings storage in Czech Republic. Unpublished internal report, September 2, 2018.

GET, 2017, Environmental Baseline Study. Chvaletice – Trnavka Tailings Pond. Report prepared for Mangan Chvaletice, s.r.o., September 2017

Global ARD Testing Services Inc., 2015, Certificate of Analysis; Project # 1523, December 19, 2015

Global ARD Testing Services Inc., 2016, Certificate of Analysis; Project # 1523, January 25, 2016

Mangan Chvaletice s.r.o., 2019, Community + Engagement (Draft, Rev 3), January 2019

Mangan Chvaletice s.r.o., 2019, Permits and Opinions, January 2019

Mangan Chvaletice s.r.o., 2019, Summary of Environmental Studies (Rev 3), January, 2019Petru, M., 2015, The Environmental and Social Conditions in the Territory Conflicts of Interest in Regard to Environmental Protection Interim Report (translated from Czech). GET s.r.o. April, 2015

Petru, M., 2017, Chvaletice – Trnavka Tailing Pond, Environmental Baseline Study, for Mangan Chvaletice sro Published by GET, September 2017

Price, W.A, 2009, Prediction Manual of Drainage Chemistry from Sulphidic Geologic Materials. Mend Report 1.20.1, December, 2009

Price, William, A, 2009, MEND Report 1.20.1. CANMET Mining and Mineral Sciences Laboratory, Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials.

PRK Partners, 2017, PRK Partners to Cannacord Genuity Corp,, confidential letter, subject: Legal Opinion on matters related to Euro Manganese Inc., April 27, 2018

Tetra Tech Canada Inc., 2021, Chvaletice NMT/LR – Review of ARD/ML, Humidity Cell and Metallurgical Tests (Interim). Memo no. 704-ENG.VMIN0309301-MEMV0001-00, November 8, 2021

Vavron, M., 2017, Localization Services for Scoping Study (Czech Republic). Prepared for Euro Manganese Inc. Published by Tebodin Czech Republic, s.r.o., March 23, 2017

APPENDIX A COMPETENT PERSONS CONSENT FORMS

Competent Person's Consent Form

Pursuant to the requirements of ASX Listing Rules 5.6, 5.22 and 5.24 and
Clause 9 of the JORC Code 2012 Edition (Written Consent Statement)

Report name

Technical Report and Feasibility Study for the Chvaletice Manganese Project, Czech Republic

(Insert name or heading of Report to be publicly released) ('Report')

Tetra Tech Canada Inc.

(Insert name of company releasing the Report)

Chvaletice Manganese Project

(Insert name of the deposit to which the Report refers)

If there is insufficient space, complete the following sheet and sign it in the same manner as this original sheet.

September 12, 2022

(Date of Report)

Statement

I/We,

Chris Johns, P.Eng.

(Insert full name(s))

confirm that I am the Competent Person for the Report and:

- I have read and understood the requirements of the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 Edition).
- I am a Competent Person as defined by the JORC Code 2012 Edition, having more than twenty years' experience that is relevant to the style of mineralization and type of deposit described in the Report, and to the activity for which I am accepting responsibility.
- I am a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a 'Recognized Professional Organization' (RPO) included in a list promulgated by ASX from time to time.
- I have reviewed the Report to which this Consent Statement applies.

I/We am a full time employee of

Tetra Tech Canada Inc.

(Insert company name)

Or

I am a consultant working for

(Insert company name)

and have been engaged by

Euro Manganese Inc.

(Insert company name)

to prepare the documentation for

Chvaletice Manganese Deposit

(Insert deposit name)

on which the Report is based, for the period ended

July 27, 2022

(Insert date of Resource/Reserve statement)

I have disclosed to the reporting company the full nature of the relationship between myself and the company, including any issue that could be perceived by investors as a conflict of interest.

I verify that the Report is based on and fairly and accurately reflects in the form and context in which it appears, the information in my supporting documentation relating to Exploration Targets, Exploration Results, Mineral Resources and/or Ore Reserves (*select as appropriate*).

Consent

I consent to the release of the Report and this Consent Statement by the directors of:

Euro Manganese Inc.
(Insert reporting company name)

"original document signed"

Signature of Competent Person

September 12, 2022
Date:

Engineers and Geoscientists of British Columbia
Professional Membership:
(insert organization name)

39423
Membership Number:

"original document signed"

Signature of Witness:

Jianhui (John) Huang, P. Eng., Vancouver, Canada
Print Witness Name and Residence:
(e.g. town/suburb)

Additional deposits covered by the Report for which the Competent Person signing this form is accepting responsibility:

None.

Additional Reports related to the deposit for which the Competent Person signing this form is accepting responsibility:

None.

"original document signed"

Signature of Competent Person
Original Signed and Sealed

September 12, 2022
Date

Engineers and Geoscientists of British Columbia
Professional Membership:
(insert organization name)

39423
Membership Number:

"original document signed"

Signature of Witness

Jianhui (John) Huang, P.Eng., Vancouver, Canada
Print Witness Name and Residence:
(eg. Town/suburb)

Competent Person's Consent Form

Pursuant to the requirements of ASX Listing Rules 5.6, 5.22 and 5.24 and
Clause 9 of the JORC Code 2012 Edition (Written Consent Statement)

Report name

Public Report and Feasibility Study for the Chvaletice Manganese Project, Czech Republic

(Insert name or heading of Report to be publicly released) ('Report')

Tetra Tech Canada Inc.

(Insert name of company releasing the Report)

Chvaletice Manganese Project

(Insert name of the deposit to which the Report refers)

If there is insufficient space, complete the following sheet and sign it in the same manner as this original sheet.

September 12, 2022

(Date of Report)

Statement

I/We,

Davood Hasanloo, M.Sc., M.A.Sc., P.Eng.,

(Insert full name(s))

confirm that I am the Competent Person for the Report and:

- I have read and understood the requirements of the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 Edition).
- I am a Competent Person as defined by the JORC Code 2012 Edition, having five years' experience that is relevant to the style of mineralization and type of deposit described in the Report, and to the activity for which I am accepting responsibility.
- I am a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a 'Recognized Professional Organization' (RPO) included in a list promulgated by ASX from time to time.
- I have reviewed the Report to which this Consent Statement applies.

I/We am a full time employee of

____

(Insert company name)

Or

I am a consultant working for

Tetra Tech Canada Inc.

(Insert company name)

and have been engaged by

Euro Manganese Inc.

(Insert company name)

to prepare the documentation for

Chvaletice Manganese Deposit

(Insert deposit name)

on which the Report is based, for the period ended

July 27, 2022

(Insert date of Resource/Reserve statement)

I have disclosed to the reporting company the full nature of the relationship between myself and the company, including any issue that could be perceived by investors as a conflict of interest.

I verify that the Report is based on and fairly and accurately reflects in the form and context in which it appears, the information in my supporting documentation relating to Exploration Targets, Exploration Results, Mineral Resources and/or Ore Reserves (*select as appropriate*).

Consent

I consent to the release of the Report and this Consent Statement by the directors of:

Euro Manganese Inc.

(Insert reporting company name)

"original document signed"

Signature of Competent Person

September 12, 2022

Date:

Engineers and Geoscientists of British Columbia

Professional Membership:

(insert organization name)

42950

Membership Number:

"original document signed"

Signature of Witness:

Jianhui (John) Huang, P.Eng., Vancouver, Canada

Print Witness Name and Residence:

(e.g. town/suburb)

Additional deposits covered by the Report for which the Competent Person signing this form is accepting responsibility:

None.

Additional Reports related to the deposit for which the Competent Person signing this form is accepting responsibility:

None.

"original document signed"

Signature of Competent Person
Original Signed and Sealed

September 12, 2022
Date

Engineers and Geoscientists of British Columbia
Professional Membership:
(insert organization name)

42950
Membership Number:

"original document signed"

Signature of Witness

Jianhui (John) Huang, P.Eng., Vancouver, Canada
Print Witness Name and Residence:
(eg. Town/suburb)

Competent Person's Consent Form

Pursuant to the requirements of ASX Listing Rules 5.6, 5.22 and 5.24 and
Clause 9 of the JORC Code 2012 Edition (Written Consent Statement)

Report name

Public Report and Feasibility Study for the Chvaletice Manganese Project, Czech Republic

(Insert name or heading of Report to be publicly released) ('Report')

Tetra Tech Canada Inc.

(Insert name of company releasing the Report)

Chvaletice Manganese Deposit

(Insert name of the deposit to which the Report refers)

If there is insufficient space, complete the following sheet and sign it in the same manner as this original sheet.

September 12, 2022

(Date of Report)

Statement

I/We,

Hassan Ghaffari, P.Eng.

(Insert full name(s))

confirm that I am the Competent Person for the Report and:

- I have read and understood the requirements of the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 Edition).
- I am a Competent Person as defined by the JORC Code 2012 Edition, having more than ten years' experience that is relevant to the style of mineralization and type of deposit described in the Report, and to the activity for which I am accepting responsibility.
- I am a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a 'Recognized Professional Organization' (RPO) included in a list promulgated by ASX from time to time.
- I have reviewed the Report to which this Consent Statement applies.

I/We am a full time employee of

Tetra Tech Canada Inc.

(Insert company name)

Or

I am a consultant working for

(Insert company name)

and have been engaged by

Euro Manganese Inc.

(Insert company name)

to prepare the documentation for

Chvaletice Manganese Deposit

(Insert deposit name)

on which the Report is based, for the period ended

July 27, 2022

(Insert date of Resource/Reserve statement)

I have disclosed to the reporting company the full nature of the relationship between myself and the company, including any issue that could be perceived by investors as a conflict of interest.

I verify that the Report is based on and fairly and accurately reflects in the form and context in which it appears, the information in my supporting documentation relating to Exploration Targets, Exploration Results, Mineral Resources and/or Ore Reserves (*select as appropriate*).

Consent

I consent to the release of the Report and this Consent Statement by the directors of:

Euro Manganese Inc.

(Insert reporting company name)

“original document signed”

Signature of Competent Person

September 12, 2022

Date:

Engineers and Geoscientists of British Columbia

Professional Membership:

(insert organization name)

30408

Membership Number:

“original document signed”

Signature of Witness:

Jianhui (John) Huang, P.Eng., Vancouver, Canada

Print Witness Name and Residence:

(e.g. town/suburb)

Additional deposits covered by the Report for which the Competent Person signing this form is accepting responsibility:

None.

Additional Reports related to the deposit for which the Competent Person signing this form is accepting responsibility:

None.

"original document signed"

Signature of Competent Person

September 12, 2022

Date

Engineers and Geoscientists of British Columbia

Professional Membership:

(insert organization name)

30408

Membership Number:

"original document signed"

Signature of Witness

Jianhui (John) Huang, P.Eng., Vancouver, Canada

Print Witness Name and Residence:

(eg. Town/suburb)

Competent Person's Consent Form

Pursuant to the requirements of ASX Listing Rules 5.6, 5.22 and 5.24 and
Clause 9 of the JORC Code 2012 Edition (Written Consent Statement)

Report name

Public Report and Feasibility Study for the Chvaletice Manganese Project, Czech Republic

(Insert name or heading of Report to be publicly released) ('Report')

Tetra Tech Canada Inc.

(Insert name of company releasing the Report)

Chvaletice Manganese Deposit

(Insert name of the deposit to which the Report refers)

If there is insufficient space, complete the following sheet and sign it in the same manner as this original sheet.

September 12, 2022

(Date of Report)

Statement

I/We,

James Barr, P.Geo.

(Insert full name(s))

confirm that I am the Competent Person for the Report and:

- I have read and understood the requirements of the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 Edition).
- I am a Competent Person as defined by the JORC Code 2012 Edition, having more than five years' experience that is relevant to the style of mineralization and type of deposit described in the Report, and to the activity for which I am accepting responsibility.
- I am a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a 'Recognized Professional Organization' (RPO) included in a list promulgated by ASX from time to time.
- I have reviewed the Report to which this Consent Statement applies.

I/We am a full time employee of

____

(Insert company name)

Or

I am a consultant working for

Tetra Tech Canada Inc.

(Insert company name)

and have been engaged by

Euro Manganese Inc.

(Insert company name)

to prepare the documentation for

Chvaletice Manganese Deposit

(Insert deposit name)

on which the Report is based, for the period ended

July 27, 2022

(Insert date of Resource/Reserve statement)

I have disclosed to the reporting company the full nature of the relationship between myself and the company, including any issue that could be perceived by investors as a conflict of interest.

I verify that the Report is based on and fairly and accurately reflects in the form and context in which it appears, the information in my supporting documentation relating to Exploration Targets, Exploration Results, Mineral Resources and/or Ore Reserves (*select as appropriate*).

Consent

I consent to the release of the Report and this Consent Statement by the directors of:

Euro Manganese Inc.

(Insert reporting company name)

"original document signed"

Signature of Competent Person

Date: September 12, 2022

Professional Membership: Engineers and Geoscientists of British Columbia
(insert organization name)

Membership Number: 35150

"original document signed"

Signature of Witness:

Print Witness Name and Residence: Jianhui (John) Huang, P.Eng., Vancouver, Canada
(e.g. town/suburb)

Additional deposits covered by the Report for which the Competent Person signing this form is accepting responsibility:

None.

Additional Reports related to the deposit for which the Competent Person signing this form is accepting responsibility:

None.

"original document signed"

September 12, 2022

Signature of Competent Person

Original Signed and Sealed

Date

Engineers and Geoscientists of British Columbia

Professional Membership:

(insert organization name)

35150

Membership Number:

"original document signed"

Signature of Witness

Jianhui (John) Huang, P.Eng., Vancouver, Canada

Print Witness Name and Residence:

(eg. Town/suburb)

Competent Person's Consent Form

Pursuant to the requirements of ASX Listing Rules 5.6, 5.22 and 5.24 and
Clause 9 of the JORC Code 2012 Edition (Written Consent Statement)

Report name

Public Report and Feasibility Study for the Chvaletice Manganese Project, Czech Republic

(Insert name or heading of Report to be publicly released) ('Report')

Tetra Tech Canada Inc.

(Insert name of company releasing the Report)

Chvaletice Manganese Deposit

(Insert name of the deposit to which the Report refers)

If there is insufficient space, complete the following sheet and sign it in the same manner as this original sheet.

September 12, 2022

(Date of Report)

Statement

I/We,

Jianhui (John) Huang, Ph.D., P.Eng.

(Insert full name(s))

confirm that I am the Competent Person for the Report and:

- I have read and understood the requirements of the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 Edition).
- I am a Competent Person as defined by the JORC Code 2012 Edition, having more 20 years' experience that is relevant to the style of mineralization and type of deposit described in the Report, and to the activity for which I am accepting responsibility.
- I am a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a 'Recognized Professional Organization' (RPO) included in a list promulgated by ASX from time to time.
- I have reviewed the Report to which this Consent Statement applies.

I/We am a full time employee of

Tetra Tech Canada Inc.

(Insert company name)

Or

I am a consultant working for

(Insert company name)

and have been engaged by

Euro Manganese Inc.

(Insert company name)

to prepare the documentation for

Chvaletice Manganese Deposit

(Insert deposit name)

on which the Report is based, for the period ended

July 27, 2022

(Insert date of Resource/Reserve statement)

I have disclosed to the reporting company the full nature of the relationship between myself and the company, including any issue that could be perceived by investors as a conflict of interest.

I verify that the Report is based on and fairly and accurately reflects in the form and context in which it appears, the information in my supporting documentation relating to Exploration Targets, Exploration Results, Mineral Resources and/or Ore Reserves (*select as appropriate*).

Consent

I consent to the release of the Report and this Consent Statement by the directors of:

Euro Manganese Inc.

(Insert reporting company name)

"original document signed"
Signature of Competent Person

September 12, 2022
Date:

Engineers and Geoscientists of British Columbia
Professional Membership:
(insert organization name)

30898
Membership Number:

"original document signed"
Signature of Witness:

Hassan Ghaffari, P. Eng., Vancouver, Canada
Print Witness Name and Residence:
(e.g. town/suburb)

Additional deposits covered by the Report for which the Competent Person signing this form is accepting responsibility:

None.

Additional Reports related to the deposit for which the Competent Person signing this form is accepting responsibility:

None.

"original document signed"

Signature of Competent Person

September 12, 2022

Date

Engineers and Geoscientists of British Columbia

Professional Membership:

(insert organization name)

30898

Membership Number:

"original document signed"

Signature of Witness

Hassan Ghaffari, P. Eng., Vancouver, Canada

Print Witness Name and Residence:

(eg. Town/suburb)

Competent Person's Consent Form

Pursuant to the requirements of ASX Listing Rules 5.6, 5.22 and 5.24 and
Clause 9 of the JORC Code 2012 Edition (Written Consent Statement)

Report name

Public Report and Feasibility Study for the Chvaletice Manganese Project, Czech Republic

(Insert name or heading of Report to be publicly released) ('Report')

Tetra Tech Canada Inc.

(Insert name of company releasing the Report)

Chvaletice Manganese Deposit

(Insert name of the deposit to which the Report refers)

If there is insufficient space, complete the following sheet and sign it in the same manner as this original sheet.

September 12, 2022

(Date of Report)

Statement

I/We,

Maureen Marks, P.Eng.,

(Insert full name(s))

confirm that I am the Competent Person for the Report and:

- I have read and understood the requirements of the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 Edition).
- I am a Competent Person as defined by the JORC Code 2012 Edition, having more than five years' experience that is relevant to the style of mineralization and type of deposit described in the Report, and to the activity for which I am accepting responsibility.
- I am a Member or Fellow of The Australasian Institute of Mining and Metallurgy or the Australian Institute of Geoscientists or a 'Recognized Professional Organization' (RPO) included in a list promulgated by ASX from time to time.
- I have reviewed the Report to which this Consent Statement applies.

I/We am a full time employee of

Tetra Tech Canada Inc.

(Insert company name)

Or

I am a consultant working for

(Insert company name)

and have been engaged by

Euro Manganese Inc.

(Insert company name)

to prepare the documentation for

Chvaletice Manganese Deposit

(Insert deposit name)

on which the Report is based, for the period ended

July 27, 2022

(Insert date of Resource/Reserve statement)

I have disclosed to the reporting company the full nature of the relationship between myself and the company, including any issue that could be perceived by investors as a conflict of interest.

I verify that the Report is based on and fairly and accurately reflects in the form and context in which it appears, the information in my supporting documentation relating to Exploration Targets, Exploration Results, Mineral Resources and/or Ore Reserves (*select as appropriate*).

Consent

I consent to the release of the Report and this Consent Statement by the directors of:

Euro Manganese Inc.

(Insert reporting company name)

"original document signed"

Signature of Competent Person

September 12, 2022

Date:

Engineers and Geoscientists of British Columbia

Professional Membership:

(insert organization name)

176335

Membership Number:

"original document signed"

Signature of Witness:

Jianhui (John) Huang, P.Eng., Vancouver, Canada

Print Witness Name and Residence:

(e.g. town/suburb)

Additional deposits covered by the Report for which the Competent Person signing this form is accepting responsibility:

None.

Additional Reports related to the deposit for which the Competent Person signing this form is accepting responsibility:

None.

"original document signed"

Signature of Competent Person

Original Signed and Sealed

September 12, 2022

Date

Engineers and Geoscientists of British Columbia

Professional Membership:

(insert organization name)

176335

Membership Number:

"original document signed"

Signature of Witness

Jianhui (John) Huang, P.Eng., Vancouver, Canada

Print Witness Name and Residence:

(eg. Town/suburb)

APPENDIX B JORC TABLE 1

SECTION 1 Sampling Techniques and Data

Criteria	Explanation
Sampling Techniques	▪ The 2018 sampling program is summarized as: ▪ Sonic rig advanced at 2 m intervals using 100mm core tube, approx. 14 kg wet weight per sample. ▪ 730 core samples (2 m) of tailings material were recovered for analysis. ▪ Samples extracted from core tube at 1 m subsamples (approx. 7 kg wet weight) for logging and physical measurements. ▪ A quarter split (approx. 3.5 kg wet weight) was extracted from the 1 m subsamples, recombined with the corresponding 1 m quarter split subsample, bagged and shipped to SGS for particle size analysis, lithogeochemistry, metals analysis and bulk density testing (approx. 7 kg for 2 m representative sample. ▪ Remaining ¾ sample was split for additional test work in Czech Republic, and for metallurgical test work in China. ▪ All samples were clearly labelled and stored in vacuum-packed and sealed plastic bags to preserve original moisture content and prevent sample deterioration. Geochemical samples were contained in plastic buckets, inventoried and stored in a locked facility in Prelouc, Czech Republic, prior to being shipped to SGS Bor.
Drilling Techniques	▪ The 2018 program completed drilling of 1,509.5 metres in 80 holes. ▪ The program included completion of 35 vertical and 19 inclined 100 mm diameter Sonic holes, totaling 1,409.5 m, and an additional 26 mobile percussion drill holes, totaling 100 m, were completed around the perimeter embankments of the tailings piles in areas which were not previously accessed for sampling. ▪ Sonic holes were placed as infill holes with approximately 75 metre spacing between 2017 holes and as inclined directed underneath the outer perimeter embankment, using 100 mm diameter size rods and sonic core barrel advance provided by Eijkelkamp SonicSampDrill B.V. and crews from Giesbeek, the Netherlands.
Drill Sample Recovery	▪ Recoveries estimated by field crew and recorded on geological logs. ▪ No casing was installed and drill rods were pulled for each core run.
Logging	▪ Logging was conducted in the field at drill side by GET sro, on hard copy paper and transcribed into digital drillhole database. ▪ Records include lithological description, wet mass, estimated recovery, and volume.
Subsampling Techniques and Sample Preparation	▪ Sampling excludes overlying topsoil, and underlying native soil substrate. ▪ Assay samples received at SGS Bor were weighed (wet) and homogenized by hand using the "Japanese slab cake method" of kneading and rolling the sample. ▪ A 500 g subsample sent to laser diffraction particle size analysis. ▪ The remaining sample was dried (105 degrees C) and homogenized. ▪ 1 kg was extracted for pulverization to 95% passing 75µm mesh. ▪ First stage of analysis was conducted SGS in Bor, Serbia, which included partial digestion using aqua regia with ICP/MS or AAS, and near total digestion using four acids (nitric, perchloric, hydrofluoric and hydrochloric) with ICP/MS or AAS from 0.5g aliquots. ▪ The second stage of analysis was conducted at SGS in Lakefield, Ontario, Canada, which included using lithium borate fusion and x-ray fluorescence (XRF) for major concentration of major cation oxide, concentration of in organic sulphur and carbon using LECO furnace, measurement of specific gravity by pycnometer, and for particle size analysis by LD-PSA. ▪ Total of 888 samples were analyzed at SGS laboratories.
Quality of Assay Data and Laboratory Tests	▪ Quality control (QC) protocol included insertion of field duplicates (5%), blank (4%) and certified reference samples (5%) in all drill holes, collection of sample preparation duplicate (5%) and pulp duplicates (2%). ▪ Three holes were drilled in 2018 to twin holes completed in 2017. ▪ A database was compiled, and various checks and measures were performed by Tetra Tech. No significant quality assurance (QA) concerns were identified by the Competent Person.
Verification of Sampling and Assaying	▪ Independent analyses were conducted by an external umpire laboratory; Activation Laboratories, located in Ancaster, Ontario, Canada. The lab received 96 representative samples (approximately 1 in 10). ▪ Independent CP sampling was conducted.
Location of Data Points	▪ Property topography was provided by GET sro in Czech projection S-JTSK using the Bpv datum. ▪ Surveying of drill hole collars was completed on-site by GET using a Trimble model R4 GNSS global positioning system (GPS) receiver equipment.
Data Spacing and Distribution	▪ Infill Sonic holes (35) were spaced at approximately 100 m, giving approximately 75m overall average spacing including the 2017 drill holes. ▪ Perimeter Sonic holes (19) were inclined at 45 degrees and spaced at two holes per side of the tailings cells. ▪ Perimeter percussion holes (26) were drilled vertically and spaced at approximately two to three holes per side of the tailings cells.

Criteria	Explanation
	▪ Downhole sampling continuous at 2 m intervals.
Orientation of Data in Relation to Geological Structure	▪ Drillholes were drilled both vertically and inclined through heterogeneous tailings mass.
Sample Security	▪ Samples stored at a field warehouse managed by Geomin in Jihlava prior to shipping to laboratory for analyses.
Audits or Reviews	▪ Independent site visit, sampling and data review completed by Tetra Tech Competent Person, James Barr, P.Geo., during the delineation drilling campaign on July 30-31st, 2018.

SECTION 2 Reporting of Exploration Results

Criteria	Explanation
Mineral Tenement and Land Tenure Status	▪ Mangan is a private company established in the Czech Republic in 1997, is 100% owned by Euro Manganese Inc., and holds 100% ownership of exploration licence number 631/550/14-Hd (which was valid until September 30, 2019, but on December 4, 2018 was renewed and extended to May 31, 2026) and exploration licence number MZP/2018/550/386-Hd (valid until May 31, 2026). ▪ Exploration licence number 631/550/14-Hd is registered to include mineral rights on a total area of 0.98 km² (98 ha) which cover the Chvaletice Manganese Project deposits, of which 0.82 km² is located within the Municipality of Trnavka, and 0.16 km² is located within the Municipality of Chvaletice. ▪ Exploration licence MZP/2018/550/386-Hd allows the company to drill on the perimeter of the tailings piles. ▪ On April 28, 2018, Mangan was issued a Preliminary Mining Permit by the Ministry of Environment, Licence No. MZP/2018/550/387-HD which covers the areas included in the Exploration Licences and secures Mangan's rights for the entire deposit area and is a prerequisite for the application for the establishment of the Mining Lease District. ▪ On July 20, 2021, Mangan was issued a new Preliminary Mining Permit, Licence No. MZP/2021/550/92-Hd, valid until May 31, 2026. ▪ At present, Mangan does not hold surface rights to the Chvaletice Manganese Project area, which are considered as those lands of original ground elevation surrounding and immediately underlying the protected area that contains tailings Cells 1, 2, and 3. The area of interest for the Chvaletice Manganese Project overlies and adjoins 18 privately owned land parcels. ▪ An aggregated land package covering 26.64 ha has been purchased, or has option agreement to be purchased, by Mangan. The parcel of land is proposed for development and construction of a high-purity manganese processing facility and related infrastructure.
Exploration Done by Other Parties	▪ Hand auger sampling in 2014, four holes ranging from 2 to 2.5 m depth. ▪ Testpit sampling in 2015, seven testpits ranging between 1.8 to 3.8 m depth.
Geology	▪ The mineralization found in tailings at the Chvaletice Manganese Project deposited by manmade processes following grinding and flotation processes of black pyritic shale and is therefore not characteristic of a traditional bedrock hosted manganese deposit. ▪ The material can be physically characterized as a compacted soil, with varying degrees of particle sizes from clay to coarse sand. ▪ Mineralogy has been quantified by limited x-ray diffraction (XRD) analyses, with resulting manganese bearing mineral phases as rhodochrosite (and other Mn-bearing carbonates), spessartine (and other Mn-silicates); quartz was the main gangue mineral, and pyrite was the main sulphide mineral.
Drill Hole Information	▪ Drillholes were collared on the surface of the tailings deposits and drilled vertically downwards to completion in the underlying native soil substrate, approximate average depth in Cell 1 = 26 metres, Cell 2 = 27 metres and Cell 3 = 11 metres.
Data Aggregation Methods	▪ Raw drillhole samples were composited to 2 metre intervals for use in mineral resource estimation.
Relationship Between Mineralization Widths and Intercept Points	▪ Downhole width is equivalent to true width.
Diagrams	▪ Diagrams, maps and cross-sections are included in the press release for reference.
Balanced Reporting	▪ All of the tailing material which has been assayed has reported elevated concentration of manganese ▪ 2018 Sample assay grades range from 0.19% to 11.69% total Manganese (by XRF analysis), with mean value of 7.29%.
Other Substantive Exploration Data	▪ A total of 6.6 km lines of high-resolution electric resistivity tomography (ERT) and seismic refraction was conducted by GImpuls Praha spol. s.r.o., on behalf of Mangan Chvaletice, in 2017.
Further Work	▪ No further exploration work is recommended or planned.

SECTION 3 Estimation and Reporting of Mineral Resources

Criteria	Explanation
Database Integrity	▪ Tetra Tech undertook verification of the data transfer and compilation process at SGS through visual comparison of the issued certificates of analysis with the digital assay records. ▪ The drillhole database was visually inspected by Tetra Tech, and corrections made prior to further inspection using digital validation tools within Leapfrog Geo modelling software.
Site Visits	▪ A site visit was conducted by Tetra Tech CP, James Barr, P.Geo., from July 1 to 3, 2017, and July 30-31, 2018, during both drilling campaigns, and a site visit was conducted by Mr. Jianhui Huang, Ph.D., P.Eng on February 5, 2018.
Geological Interpretation	▪ A mineral resource estimate has been developed for total and soluble manganese concentrations. ▪ Total manganese is based on XRF analysis, and soluble manganese is based on results of aqua regia digestion and ICP-MS or AAS analysis. ▪ Additionally, average moisture and grain size distribution indicators are reported for the deposit. ▪ Geological interpretation assumes that deposition of tailings materials was episodic over the life of the historical mining operations, and the material was deposited from processed materials with mixed particle sizes suspended in slurry with thin lateral continuity with a particle gradation from coarse to fine away from the point of discharge.
Dimensions	▪ Total surface area is approximately 1,032,800 m^2, approximate total volume (tailings) 17,528,800 m^3, approximate total volume of topsoil is 2,060,030 m^3. ▪ The resource is reported using a sub-block model with parent blocks 50x50x4 metres and sub-blocks 12.5x12.5x2 metres.
Estimation and Modelling Techniques	▪ The Mineral Resource Estimate was calculated using Aranz Leapfrog Geo v.4.4.2. ▪ Interpolation searches were 150x150x8 metres and were performed using an inverse distance (to the exponent 3) methodology. Data distribution did not conform to reliable variography assessment. ▪ The search was limited to a maximum of two samples per drill hole and required a minimum of two to a maximum of six samples in order to populate a block.
Moisture	▪ The tonnage is reported on an in situ dry material basis. ▪ Moisture loss was measured during sample handling and preparation.
Cut-off Parameters	▪ A break-even grade of 2.18% total Mn has been estimated for the Chvaletice deposit. The estimated break-even cut-off grade falls below the grade of most of the blocks (excluding 5,000 tonnes which have grades less than 2.18% total Mn, these have not been deducted from the Mineral Resource Statement). It is assumed that material segregation will not be possible during mining due to inherent difficulty of grade control and selective mining for this deposit type.
Mining Factors or Assumptions	▪ The deposit sits above ground and is candidate for traditional truck and shovel mining, or other possible surface extraction techniques following dewatering of tailings. ▪ It is assumed that material segregation will not be possible due to inherent difficulty of grade control and selective mining for this deposit type.
Metallurgical Factors or Assumptions	▪ Preliminary assumptions include pre-concentration operating costs of US$6.47/t feed, leaching and refining operating cost estimates of US$188/t feed, total recovery to HPEMM and HPMSM of approximately 60.5% and 58.9%, respectively, and metal prices of 9.60 kg/t for HPEMM and 3.72 kg/t for HPMSM (marketing study report prepared by CPM Group LLC, June 2022). The actual commodity price for these products may vary.
Environmental Factors or Assumptions	▪ The area covered by the Chvaletice tailings has been significantly impacted by past mining and other heavy industrial activities. ▪ Environmental baseline studies have been in progress since the summer of 2016. These include hydrological sampling and monitoring, as well fauna and flora surveys.
Bulk Density	▪ In situ dry bulk density is basis for tonnage estimate and was calculated from estimated core recovery along with laboratory measurements for mass and moisture. ▪ Bulk density was a variable modelled into the block model based on the calculated in situ dry bulk density for each sample. ▪ Calculated in situ dry bulk density values for individual samples range between 0.35 t/m^3 and 3.15 t/m^3, with a mean value of 1.55 t/m^3.
Classification	▪ Classification is based on the JORC Code and divides the mineral resource into Measured and Indicated categories. ▪ A variance analysis on the block model determined that blocks supported from five or more samples, within an average distance of 100 m and with the closest sample within 75 metres be classified as Measured Resources, and blocks with greater than three samples within average distance of 150 metres be classified as Indicated Resources.

Criteria	Explanation
	▪ No blocks were classified as Inferred Resources.
Audits and Reviews	▪ No external audits were performed. ▪ Internal peer and senior review audits were performed as part of Tetra Tech's quality management system.
Discussion of Relative Accuracy/Confidence	▪ The mineral resource estimate is reported as a weighted average grade and tonnage based on the search methodology and is not reported within error or confidence limits. ▪ Indicated resources are considered lower confidence with higher margin of error than Measured resources. ▪ The modelling was validated using visual comparison, declustered mean comparison, and swath plots and is considered to be representative of the input data. ▪ Reconciliation to the 2017 block model was completed to identify areas with significant changes may have occurred. ▪ Bulk density relies on estimated recovery from the field which may introduce some error into the calculation. ▪ Assumption of lateral continuity/gradation of particle size may introduce error.

SECTION 4 Estimation and Reporting of Mineral Reserves

Criteria	Explanation
Mineral Resource estimate for conversion to Ore Reserves	▪ The Mineral Resource Estimate described in Section 3 has been used to determine Ore Reserves. ▪ The Mineral Resource Estimate is reported inclusive of Ore Reserves.
Site visits	▪ A site visit was conducted by Tetra Tech CP's or QP's, Maurie Marks, P.Eng., Chris Johns, P.Eng., Hassan Ghaffari, P.Eng., and Jianhui Huang, Ph.D., P.Eng. on May 3rd,2022 and Jianhui Huang, Ph.D., P.Eng on February 5, 2018. The three tailings cells were visited as well as proposed infrastructure locations. Jianhui Huang, Ph.D., P.Eng also visited the Changsha Research Institute of Mining and Metallurgy Co. Ltd. (CRIMM) laboratory and pilot plant facility five times between January 20, 2017 and September 20, 2018 to witness sample preparation and test/assay facilities and to discuss test program and results with CRIMM's technical team. Mr. Huang visited Beijing General Research Institute for Mining and Metallurgy (BGRIMM) four times during September 03 2019 to January 25 2020 to witness test/assay facilities and to discuss test program and results with BGRIMM's technical team. Mr. Huang also visited the SGS Minerals Services (SGS) laboratory on June 29, 2017 and Slon Magnetic Separator Ltd. On December 27 2019 to witness the metallurgical testing.
Study status	▪ Preliminary Economic Assessment work completed in 2019 was used as the basis to advance the project for completion of the current Feasibility Study. ▪ As part of the Feasibility Study, an economically viable mine plan has been developed that includes material modifying factors.
Cut-off parameters	▪ To convert the Mineral Resource to an Ore Reserve, a break-even grade of 2.18% total Mn has been estimated for the resource estimate of the Chvaletice deposit. ▪ The estimated break-even grade falls below the grade of most of the blocks (excluding 5,000 tonnes which have grades less than 2.18% total Mn). Material segregation will not be possible during mining due to inherent difficulty of grade control and selective mining for this deposit type. ▪ Calculation of the cut-off parameters was undertaken using a Net Smelter Return (NSR) formula, including the following modifying factors; mined grade, contained metal, recovery rates for HPEMM and HPMSM, mining operating cost, processing cost, (including EMM to MSM conversion cost), residue placement cost, general and administrative costs, site service costs, water treatment, shipping cost, product insurance, and royalties. ▪ These parameters were applied to each block in the block model to determine the value.
Mining factors or assumptions	▪ The tailings cells are designed to be mined by excavator, loading haul trucks on 3m high benches with a 12m bench width and face angle of 45°. ▪ Geotechnical considerations were focused on bench stability and the ability to operate equipment on the benches of the tailings cells. Depressurization of the water contained within the cells is expected to occur during the cut of the first bench and continue with each subsequent advance. ▪ Mining extents used for reserve estimation extend horizontally to the limits of all three cells, and is controlled vertically by original ground, with a shallow-graded floor. This floor is designed to maximise reserve extraction whilst allowing the installation of drainage infrastructure and placement of residue immediately following mining. ▪ Pre-stripping of the topsoil will be completed one year in advance of mining on an annual basis, with material stockpiled on top of each respective cell for replacement as cover material on the residue storage facility during years 2-25 of the life of mine. Blasting of the material is not required. ▪ Minimal dilution and losses of <1% are expected to occur at the interface between the lower bounds of the tailings cells and original ground as the surface is uneven. The entirety of material to be mined is considered ore and will be processed. In turn, the entire orebody delineated in reserves is expected to be recovered.

Criteria	Explanation
	▪ Mining infrastructure designed as part of the Feasibility Study includes truck maintenance workshop and warehouse, refuel areas, equipment laydown area and admin building. A central haul road is also designed for access to each of the tailings cells throughout the life of mine. ▪ Inferred resources have not been included within the Feasibility Study.
Metallurgical factors or assumptions	▪ Several metallurgical test programs have been completed, including three semi-continuous pilot plant runs and large scale batch testing based on preliminary optimized process/test conditions. ▪ A total of 25 composite samples were constructed from the drill core interval samples representing different variation characters, including spatial location, grade variation and particle size variations, and tested. ▪ Purification technologies were tested. ▪ Se-free electrowinning processed has been developed and confirmed for the mineral material. ▪ Cr-free passivation treatment for the cathode plates has been tested and developed. ▪ The metallurgical recoveries were estimated mainly from pilot plant test results that were used to calibrate a mass balance model of the process circuits. The estimated total manganese recoveries for process circuits are shown below: - Magnetic separation: 82.1 to 90.1% tMn, averaging 86.1% tMn; - Leaching recovery: 75% tMn - Purification & Electrowinning: 93.6% tMn - HPEMM to HPMSM: 97.4% tMn. ▪ The sample products produced from the semi-continuous pilot plant tests and large scale batch tests show that high purity electrolytic manganese metal (HPEMM) and high purity manganese sulfate monohydrate (HPMSM) can be produced from the tailings material that exceed typical industry standards. ▪ Further the comprehensive metallurgical test work completed by CRIMM, BGRIMM conducted various verification tests, including magnetic separation, concentrate leaching and solution purification, EMM dissolution and solution purification, crystallization, magnetic tailings and leach residue dewatering. The metallurgical test work also conducted equipment type selection and verification tests by potential suppliers and verify suitability for some of the reagents produced by local European suppliers. ▪ Mill feed and leach residue material handling tests were conducted by Jenike & Johanson Ltd. to determine. ▪ Head sample, non-magnetic tailings and leach residue samples were submitted to accredited laboratories in both Canada and Czech Republic for determining their chemical and physical properties. ▪ Ultra-high purity assay methods for the HPEMM and HPMSM were investigated. Preliminary product specifications were developed.
Environmental	▪ Several environmental studies have been conducted, including environmental baseline studies which include ecosystem mapping, documentation of the physical and environmental characteristics of the Chvaletice Manganese Project site and an assessment of land use plans of the adjoining municipalities. Significant local features were recorded, including sensitive and protected areas, vegetation, landscape elements, and areas or sites of historical, cultural, archaeological or geological importance. Climate, air, water, soil, natural resources, fauna, flora and ecosystems, landscape and population of the area were preliminarily inventoried. The baseline studies provide an overall assessment of the environment conditions that prevail in the Project area of interest.
Infrastructure	▪ The existing infrastructure immediately adjacent to the proposed project site includes an 820 MW coal-fired power station operated by Severní Energetická a.s. and a pre-cast concrete plant operated by Eurobeton. ▪ The Property is located along paved Highway #322 which connects to Prague, approximately 89 km by road, via Kolin and Highway #12. The proposed process plant and management office are located immediately south of the highway. A rail line is located between the highway and the Chvaletice Manganese Project tailings facility, immediately to the south of the Chvaletice tailings property, which acts as main transportation line from Prague to communities of Eastern Czech Republic. Spur lines at the south of the highway are used to transport and unload coal to the 800 MW power station, and to service an adjacent industrial park which is the site of the former processing facilities that produced the Chvaletice tailings. ▪ New and refurbished infrastructures that will be built to service the Project include: - north site: one non-magnetic tailings (NMT) and washed leach residue (LR) storage facility, one extracted existing tailings pulping, various service facilities, such as truck shop, office, fuel station and parking lots; - south-north site connection overhead bridge housing one slurry pipeline and NMT/LR transport conveyor and various utility pipelines and power cables; - south site: various process facilities, maintenance workshop and spare part storage facilities, railway spurs and loading/unloading facilities, reagent storage facilities, laboratories, general office and service complex, power supply, water supply, steam supply and air supply.
Costs	▪ Capital costs were estimated based on the FS level engineering designs completed by Tetra Tech, BGRIMM and Sudop Praha a.s, with inputs contributed from Tractebel Engineering a.s and Mangan/EMN. The capital costs include direct costs (equipment, buildings, equipment installation, access and inner roads, railway spur upgrading and others). Indirect costs (shipping, construction indirect, EPCM, spare parts and initial fills), owner

Criteria	Explanation
	costs and contingency (approximately 15.6% of direct costs). The total initial capital cost was estimated to be US$757 million. ▪ Major equipment prices were based on quotations. ▪ Capital costs related to process facilities and other facilities were estimated based on workshop and building layouts prepared according to engineering designs. ▪ Equipment transport costs for capital cost estimates were based on percentage of equipment costs, including land and ocean transport costs, port handling costs and custom fees if applicable. ▪ Operating costs were estimated based on operation functions, including tailings extraction, process, lined NMT/LR dry stacking storage, G&A and site services. The categories included in the operation cost estimates include manpower requirement, various consumables (reagents and other consumables), electricity power consumption, steam consumption, hot water consumption, maintenance spare parts, office and general management related costs, including safety and training costs. The average life of project operating cost was estimated to be US$194.79/t mill feed. ▪ Operating consumable costs and related shipping costs were mainly based on the marketing study prepared by logistic team at Mangan. ▪ The foreign exchange rates used in cost estimates and economic model were based on current rates and average exchange rates of the last three years, up to 31st May 2022. ▪ A market study for high purity electrolytic manganese metals and high purity manganese sulfate monohydrate was conducted by CPM Group LLC (June 2022). ▪ Government royalty was based on 2,308 Czech Koruna (CZK) per tonne of Mn produced.
Revenue factors	▪ The products are assumed to be distributed worldwide, mainly in European countries. Preliminary transport costs for the products were estimated based on potential consumer locations and tonnages. The consumable costs and related shipping costs were mainly based on the marketing study prepared by logistic team at Mangan. ▪ Plant feed grades were based on year-by-year mine plan which was developed from ore reserve estimate. Grades throughout the life of mine plan are relatively consistent at an average of 7.4% Mn. ▪ The foreign exchange rates used in costs estimates and economic model were based on current rates and average exchange rates of the last three years up to 31st May 2022. ▪ The sale and distribution costs were included in the economic analysis. ▪ Tetra Tech relied on the market study conducted by CPM Group LLC as the basis for the pricing of the Ore Reserves.
Market assessment	▪ A market study for high purity electrolytic manganese metals and high purity manganese sulfate monohydrate was conducted by CPM Group LLC. ▪ The study includes the market demand and supply for high purity manganese products. High purity electrolytic manganese metal (HPEMM) and high purity manganese sulfate monohydrate (HPMSM) products are mostly used in the manufacture of lithium-ion batteries for electric vehicles (EVs) and energy storage systems (ESS) – the market is expected to experience significant growth over the next two decades. HPEMM is also used in a variety of steel, aluminum and other super alloys. ▪ The report analyzes consumption trends and potential factors that may affect their supply and demand over the life of the project. The report also analyzes supply market, indicating potential competitors appear to mainly be from China and South Africa. The main demand will be rapidly growing battery industry for electric vehicles and energy storage systems. ▪ The study shows that the prices of the HPMSM are likely to rise more steeply initially due to massive increase in demand from the battery industry. The price of conventional EMM will continue to be driven by the aluminum and steel alloy industry and the level of economic activity in these sectors, but the battery industry will have growing influence on the general price levels of electrolytic manganese metal and the high-purity premiums are likely to raise in the next decade. ▪ The test results show that the products produced from the semi-continuous pilot plant and large-scale batch testing would meet the specifications required by potential customers.
Economic	▪ All the capital costs, operating costs, product packing, shipping, sales as well as revenue streams were included in the financial model. ▪ The base NPV calculations were based on a discount rate of 8%. The post-tax NPV at a discount rate of 8% was US$1,342 M with a 21.9% IRR and 4.13 years payback period. ▪ Project sensitivity was analyzed to compare the key variables of discount rate, product price, capital cost, operating cost and metal recovery on pre-tax and post-tax NPV. The project is relatively less sensitive to capital costs compared to operating cost and product price.
Social	▪ EMN has initiated the social impact studies, including collection of land-use and socio-economic data, ▪ EMN has initiated pro-active and regular consultation with community stakeholders, which are expected to intensify as the Chvaletice Manganese Project evaluation and planning advances. In November 2017, the

Criteria	Explanation
	Company's subsidiary, Mangan Chvaletice s.r.o. ("Mangan"), inaugurated a Project Information Center in the Town of Chvaletice's Municipal Culture House, to provide residents with opportunities to learn about the Project, help them to develop relationships with the Company and its team, and to provide feedback and suggestions during the Project evaluation and planning stage. In November of 2018, Mangan relocated its registered office to Chvaletice. This move is intended as a first step towards ultimately basing its head office in this municipality, in close proximity to its operations. ▪ Community involvement and consultation is an ongoing process. ▪ The Company is committed to, and has commenced, the employment of local residents.
Other	▪ No naturally occurring risks have been identified that may impact the Ore Reserve. ▪ EMN has engaged with several potential customers and been in negotiations around securing contracts for the product. ▪ EMN is still working to secure the surface rights for the project.
Classification	▪ Ore reserves were classified based on resource categories defined during resource estimation. Measured ore resources were converted to Proven Reserves, and Indicated resources were converted to Probable Reserves. No Measured resources were included within Probable reserves. No Inferred resources were included within the reserve classification.
Audits or reviews	▪ There has been no external audits or reviews of the Ore Reserves. ▪ Internal peer and senior review audits were performed as part of Tetra Tech's quality management system. ▪ The process engineering design and cost estimates by BGRIMM were overseen and reviewed by Tetra Tech and EMN's technical team. ▪ The comprehensive metallurgical test work conducted by CRIMM in 2017 and 2018 and by BGRIMM and potential suppliers between 2019 and 2020 were overseen and reviewed by EMN's technical team and Tetra Tech. Randomly selected samples were assayed by independent assay laboratories. A demonstration plant to further verify and process and generate sample products for potential consumers is under installation. High purity assay procedures have been tested.
Discussion of relative accuracy/confidence	▪ The Ore Reserve estimate is reported as a weighted average grade and tonnage based on the search methodology and is not reported within error or confidence limits. ▪ Probable reserves are considered lower confidence with higher margin of error than Proven Reserves. ▪ Appropriate modifying factors were considered and applied as part of the conversion from Mineral Resource to Ore Reserve. ▪ The 2017-2021 metallurgical test programs by CRIMM, BGRIMM and other laboratories have widely assessed the variability of the various plant mill feed samples, including a total of 25 composite samples representing different variation characters, covering spatial location, grade variation and particle size variations. A demonstration plant has been planned and under construction. The semi-continuous campaigns should provide further data for future design work. ▪ The capital cost estimates were estimated according to circuit design and preliminary layout. The main equipment costs are from quotations from potential suppliers. ▪ Operating costs were estimated by various categories and on circuit and area basis. Most of consumable prices were based on a supply marketing study conducted by Mangan's logistic team. ▪ Both operating cost and capital costs are expected in line with Class 3, compared to FS level cost estimates. ▪ Some of the potential product and process technology risks are associated with the Project are: - Market changes in high-purity manganese products and their acceptance by customers - Some metallurgical responses and product assays should be confirmed. More metallurgical test work is required to verify key operating conditions, especially impurity controls. - Scale up and control of crystallization and purification processes. - Changes in supply costs.