ANNEX 5

Appendices to EIA Technical Chapters

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Annex 5A: Supporting Information to the Geomorphology, Soils and Land Use Capability Impact Assessment

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Table 1: Changes to terrain attributes due to ground disturbance cause by the Project

Terrain Attribute	Soils LSA at baseline (ha)	Project footprint (loss) (ha)	Project footprint at end of operations (ha)	Soils LSA at closure (ha)	Net change (ha)	Relative % change in the soils LSA
Elevation range (masl)						
<300	265	-20	15	260	-5	-2%
300 - 400	325	-22	11	314	-11	-4%
400 - 500	250	-66	46	230	-20	-8%
500 - 600	215	-50	79	244	29	+14%
600 - 700	224	-136	116	204	-20	-9%
700 - 800	278	-134	138	282	4	+2%
800 - 900	178	-29	53	202	24	+13%
>900	1	0	0	1	0	0%
No data[1]	0	-7	7	0	0	0%
Total	*1,735*	*464*	*464*	*1,735*	*0*	*0%*
Slope class						
Gently sloping (0 to 5%)	207	-20	87	275	68	+33%
Sloping (5 to 10%)	174	-22	41	193	19	+11%
Strongly sloping (10 to 15%)	194	-34	35	195	1	0%
Moderately steep (15 to 30%)	777	-206	146	717	-60	-8%
Steep (30 to 60%)	381	-174	117	323	-58	-15%
Very steep (>60%)	2	-1	31	32	30	+1,735%
No data[1]	0	-7	7	0	0	0%
Total	*1,735*	*-464*	*464*	*1,735*	*0*	*0%*

1. 'No data' represents area of mine access road (Option 1) that falls outside the domain of the available digital elevation model. This area is generally <300 masl, with slope gradients <5%.

Table 2: Cropland agricultural land use capability change due to ground disturbance caused by the Project

Facility Name	Cropland agricultural land use capability rating (ha)						Facility total (ha)
	Water	Permanently not suitable (N2)	Presently not suitable (N1)	Marginally suitable (S3)	Moderately suitable (S2)	Highly suitable (S1)	
Mine pit area	0	95.7	0	0	0	0	95.7
Oxide ore stockpile	0	19.5	2.7	0	0	0	22.3
Plant site, waste management facility and workshop area							
Mine workshop area	0	8.1	0.1	0	5.4	0	13.5
Upper plant site	0	28.2	0	0	0	0	28.2
Waste management facility	0	0.1	0	0	0	0	0.1
Sediment ponds	0	4.9	0	0	0	0	4.9
Plant site, waste management facility and workshop area subtotal	*0*	**41.3**	**0.1**	**0**	**5.4**	**0**	**46.7**
Roads							
Off-site access road option 1	0	3.6	0.1	0	1.9	13.6	19.1
Off-site access road option 2	0	0	0	0	0	7.5	7.5
On-site access road	0	12.1	0.1	0	0.5	0	12.7
Haul road	0	7.5	0	0	0	0	7.5
WMF/TMF access road	0	5.5	0	0	0	0.4	5.9
Roads subtotal – including access road option 1	***0***	***28.7***	***0.2***	***0***	***2.4***	***14***	***45.2***
Roads subtotal – including access road option 2	***0***	***25.1***	***0.1***	***0***	***0.5***	***7.9***	***33.6***
Conveyor belt	***0***	**1.5**	**0**	**0**	**0**	**0**	**1.5**
TMF	***0***	**233.5**	**11.2**	**0**	**0**	**0**	**244.7**
Total in project footprint (ha) - including road option 1	***0***	**420.2**	**14.2**	**0**	**7.7**	**14.0**	**456.1**
Total in project footprint (ha) - including road option 2	**0**	**416.6**	**14.1**	**0**	**5.9**	**7.9**	**444.5**
Total suitable agriculture land use area in the project footprint (road option 1)							**21.7**
Total suitable agriculture land use area in the project footprint (road option 2)							**13.8**
Total agriculture land use area in biophysical LSA (ha)[1]							**3,989**
Relative % loss of suitable resource in biophysical LSA (both road option 1 and 2)							***<1%***
Absolute % loss of suitable of biophysical LSA[2]							***<1%***

1. Based upon Corine land cover data (v6; Source: European Environment Agency).
2. The total area of the biophysical LSA is 116 km^2

Table 3: Grazing land use capability change due to ground disturbance caused by the Project

Facility name	Grazing land use capability rating (ha)						Facility total (ha)
	Water	Permanently not suitable (n2)	Presently not suitable (n1)	Marginally suitable (s3)	Moderately suitable (s2)	Highly suitable (s1)	
Mine pit area	*0*	**0**	**0**	**78.6**	**17.1**	**0**	**95.7**
Oxide ore stockpile	0	0	0	19.5	0	2.7	22.3
Plant site, waste management facility and workshop area							
Mine workshop area	0	0	0	8.1	0	5.4	13.5
Upper plant site	0	0	0	25.3	2.9	0	28.2
Waste management facility	0	0	0	0.1	0	0	0.1
Sediment ponds	0	0	0	4.6	0.3	0	4.9
Plant site, waste management facility and workshop area subtotal	*0*	**0**	**0**	**38.1**	**3.2**	**5.4**	**46.7**
Roads							
Mine access road option 1	0	0	0	3.5	0.1	15.5	19.1
Mine access road option 2	0	0	0	7.5	0	0	7.5
Access road	0	0	0	12.1	0	0.6	12.7
Haul road	0	0	0	7.5	0	0	7.5
WMF/TMF access road	0	0	0	5.5	0	0.4	5.9
Roads subtotal – including road option 1	***0***	***0***	***0***	***28.6***	***0.1***	***16.5***	***45.2***
Roads subtotal – including road option 2	***0***	***0***	***0***	***32.6***	***0***	***1***	***33.6***
Conveyor belt	***0***	**0**	**0**	**1.5**	**0**	**0.0**	**1.5**
Tailings management facility	***0***	**0**	**0**	**233.5**	**0**	**11.2**	**244.7**
Total in project footprint (ha) - including road option 1	***0***	**0**	**0**	**392.2**	**20.5**	**43.4**	**456**
Total in project footprint (ha) - including road option 2	***0***	***0***	***0***	***396.2***	***20.4***	***27.9***	**445**
Total suitable grazing land use area in the project footprint (road option 1)							***456***
Total suitable grazing land use area in the project footprint (road option 2)							***445***
Total grazing land use area in biophysical LSA (ha)[1]							***7,077***
Relative % loss of suitable resource in biophysical LSA (both road option 1 and 2)							***6%***
Absolute % loss of suitable of biophysical LSA[2]							***4%***

1. Based upon information provided by Euromax.
2. The total area of the biophysical LSA is 116 km^2

Table 4: Forestry land use capability change due to ground disturbance caused by the Project

Facility name	Forestry land use capability rating (ha)						Facility total (ha)
	Water	Permanently not suitable (n2)	Presently not suitable (n1)	Marginally suitable (s3)	Moderately suitable (s2)	Highly suitable (s1)	
Mine pit area subtotal	*0*	*0*	*0*	*28.7*	*66.9*	*0*	*95.7*
Oxide ore stockpile	0	0	2.6	10.1	9.4	0	22.3
Plant site, waste management facility and workshop area							
Mine workshop area	0	0	5.1	0	8.4	0	13.5
Upper plant site	0	0	24.9	2.3	0.9	0	28.2
Waste management facility	0	0	0	0.1	0	0	0.1
Sediment ponds	0	0	1.3	0.9	2.7	0	4.9
Plant site, waste management facility and workshop area subtotal	*0*	*0*	*31.3*	*3.3*	*12.1*	*0*	*46.7*
Roads							
Mine access road option 1	0	0	18.9	0	0.3	0	19.1
Mine access road option 2	0	0	7.5	0	0	0	7.5
Access road	0	0	0.6	1.9	10.2	0	12.7
Haul road	0	0	0	0	7.5	0	7.5
WMF/TMF access road	0	0	0	0.6	0.6	4.7	5.9
Roads subtotal – including road option 1	***0***	***0***	***19.5***	***2.5***	***18.6***	***4.7***	***45.2***
Roads subtotal – including road option 2	***0***	***0***	***8.1***	***2.5***	***18.3***	***4.7***	***33.6***
Conveyor belt	***0***	**0**	**0.5**	**0.2**	**0.8**	**0**	**1.5**
TMF	***0***	**0**	**14.5**	**52.4**	**108.1**	**69.6**	**244.7**
Total in project footprint (ha) - including road option 1	***0***	***0***	***68.5***	***97.3***	***215.9***	***74.4***	***456***
Total in project footprint (ha) - including road option 2	***0***	***0***	***57.1***	***97.3***	***215.6***	***74.4***	***444***
Total suitable forestry land use area in the project footprint (road option 1)							***388***
Total suitable forestry land use area in the project footprint (road option 2)							***387***
Total forestry land use area in biophysical LSA (ha)[1]							***6,810***
Relative % loss of suitable resource in biophysical LSA (both road option 1 and 2)							***6%***
Absolute % loss of suitable of biophysical lsa[2]							***4%***

1. Based upon Corine land cover data (v6; Source: European Environment Agency).
2. The total area of the biophysical LSA is 116 km^2

Table 5: Predicted cumulative change in metals concentrations due to dust deposition for the Project

Metals	Environmental Design Criteria (EDC)	Baseline[1]		Cumulative at end of operations[2,3]		Concentration change due to the Project		Difference from EDC[4]	
		Highlands	Lowlands	Highlands	Lowlands	Highlands	Lowlands	Highlands	Lowlands
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Antimony (Sb)	22	0.3	0.2	0.3	0.2	0.0	0.0	-21.7	-21.8
Arsenic (As)	76	6.2	3.7	6.5	4.0	0.3	0.3	-69.5	-72.0
Cadmium (Cd)	0.4	0.05	0.05	0.05	0.05	0.00	0.00	-0.35	-0.35
Chromium (Cr)	30	20.8	8.0	21.2	8.4	0.4	0.4	-8.8	-21.6
Copper (Cu)	20	29.7	10.9	30.6	12.0	1.0	1.1	***10.6***	-8.0
Lead (Pb)	40	32.5	22.7	32.7	23.0	0.3	0.3	-7.3	-17.0
Mercury (Hg)	0.1	0.02	0.01	0.02	0.01	0.00	0.00	-0.08	-0.09
Nickel (Ni)	15	12.1	4.7	12.2	4.9	0.1	0.2	-2.8	-10.1
Zinc (Zn)	60	39.9	56.1	40.1	56.3	0.2	0.1	-19.9	-3.7

1. Baseline values determined as averages of collected samples for the Geomorphology, Soils and Land Use Capability Baseline Report (Annex 3, Section 3.3).
2. Cumulative deposition assumed worst-case scenario (year of maximum operations, year 12) occurs throughout the 24.5-year Mine Life (construction plus operations), and maximum rate of deposition in the modelling domain (77.2 g/m^2/yr)
3. Deposition rates (g/m^2) incorporated into soil layer using bulk soil density of 1.6 g / cm3 and a 15 cm thick topsoil / rooting layer.
4. For difference from EDC columns, negative values mean the cumulative concentration at the end of the project are x mg/kg below the EDC and positive values are x mg/kg above the EDC.

Table 6: Impact classification matrix

Receptor	Phase of the Project	Source of impact	Magnitude	Geographic extent	Duration	Frequency	Impact classification
Agriculture land use	Construction	Spatial ground disturbance	Low	Local	Permanent	Infrequent	Moderate
		Dust deposition	Negligible	Local	Medium-term	Frequent	Negligible
	Operations	Dust deposition	Negligible	Local	Medium-term	Frequent	Negligible
		Acidifying emissions	Low	Local	Medium-term	Frequent	Low
Grazing land use	Construction	Spatial ground disturbance	Low	Local	Permanent	Infrequent	Moderate
		Dust deposition	Negligible	Local	Medium-term	Frequent	Negligible
	Operations	Spatial ground disturbance	Moderate	Local	Permanent	Infrequent	Moderate
		Dust deposition	Low	Local	Medium-term	Frequent	Low
		Acidifying emissions	Low	Local	Medium-term	Frequent	Low
	Closure	Spatial ground disturbance	Moderate	Local	Permanent	Infrequent	Moderate
	Post closure	Spatial ground disturbance	Moderate	Local	Permanent	Infrequent	Moderate
Forestry land use (fuel, timber)	Construction	Spatial ground disturbance	Low	Local	Permanent	Infrequent	Moderate
		Dust deposition	Negligible	Local	Medium-term	Frequent	Negligible
	Operations	Spatial ground disturbance	High	Local	Permanent	Infrequent	High
		Dust deposition	Low	Local	Medium-term	Frequent	Low
		Acidifying emissions	Low	Local	Medium-term	Frequent	Low
	Closure	Spatial ground disturbance	High	Local	Permanent	Infrequent	High
	Post closure	Spatial ground disturbance	High	Local	Permanent	Infrequent	High
Control of erosion / sediment loading	Construction	Spatial ground disturbance	Moderate	Local	Long-term	Frequent	Moderate
		Dust deposition	Negligible	Local	Long-term	Frequent	Negligible
	Operations	Spatial ground disturbance	Low	Local	Long-term	Frequent	Low
		Dust deposition	Negligible	Local	Long-term	Frequent	Negligible
	Closure	Spatial ground disturbance	Low	Local	Long-term	Frequent	Low
Nutrient cycling	Construction	Spatial ground disturbance	Low	Local	Long-term	Infrequent	Low
		Dust deposition	Negligible	Local	Long-term	Frequent	Negligible
	Operations	Spatial ground disturbance	Low	Local	Long-term	Infrequent	Low
		Dust deposition	Negligible	Local	Long-term	Frequent	Negligible
		Acidifying emissions	Low	Local	Long-term	Frequent	Low
	Closure	Spatial ground disturbance	Low	Local	Long-term	Infrequent	Low

Table 2: Residual impact classification matrix

Receptor	Phase of the Project	Source of impact	Impact classification before mitigation	Mitigation	Magnitude	Geographic extent	Duration	Frequency	Residual impact classification
Agriculture land use	Construction, operations, closure, post-closure	Spatial ground disturbance due to road construction	Moderate	Construction of the road will be routed to minimise loss of productive agricultural land.	Moderate	Local	Permanent	Infrequent	Low
Grazing land use	Construction, operations, closure	Spatial ground disturbance (loss of suitable grazing land use in the Shtuka Valley and Jazga Valley)	Moderate	Reclamation of the TMF to EDC and grazing land uses at and above the tailings capping layer. Long-term monitoring of soil quality, including ecological health and risk assessment post-closure (Section 6.9.3).	Low	Local	Long-term	Infrequent	Low
Forestry land use (fuel, timber)	Construction, operations, closure, post-closure	Spatial ground disturbance (loss of suitable forestry land use capability in the Shtuka Valley and mine pit area)	High	Capping of the TMF with a layer of soil or waste rock material that meets EDC. Long-term monitoring of soil quality, including ecological health and risk assessment post-closure (Section 6.9.3). Although forestry land is not returned, the magnitude of impact is low because the high magnitude due to quality is mitigated, and the low magnitude due to quantity remains.	Low	Local	Permanent	Infrequent	Moderate
Control of erosion / sediment loading	Construction	Spatial ground disturbance	Moderate	Erosion control measures incorporated into the project design during construction (Section 6.9.3; also refer to the mitigations presented in the sediment impact assessment [Section 9]).	Low	Local	Long-term	Frequent	Low

Annex 5B: Supporting Information to the Water Quantity and Water Quality Impact Assessments

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ANNEX 5B
Water Environment
Supporting Information

Schlumberger
Water Services

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ANNEX 5B
Water Environment

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APPENDICES

APPENDIX A: Waste schedule over life of mine by ARD code schedule over life of mine by ARD code

LIST OF ABBREVIATIONS AND ACRONYMS

ARD	Acid rock drainage
ANFO	Ammonium Nitrate Fuel Oil
EDC	Engineering Design Criteria
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
FAO56	Food and Agriculture Organisation Irrigation and Drainage Paper No 56
FS	Feasibility Study
HEC-HMS	The USGS Corp of Engineers Hydraulic Engineering Center Hydraulic Modelling System
HEC-RAS	The USGS Corp of Engineers Hydraulic Engineering Center River Analysis System
LOM	Life of mine
MODFLOW	USGS 3D Finite difference groundwater model
MODFLOW VKD	USGS Variable hydraulic conductivity with depth 3D groundwater model
ROM	Run of mine
SPR	Source Pathway Receptor
TMF	Tailings management facility
US SCS	United States Soil Conservation Service
WAD-CN	Weak acid dissociable cyanide
WTW	Water Treatment Works

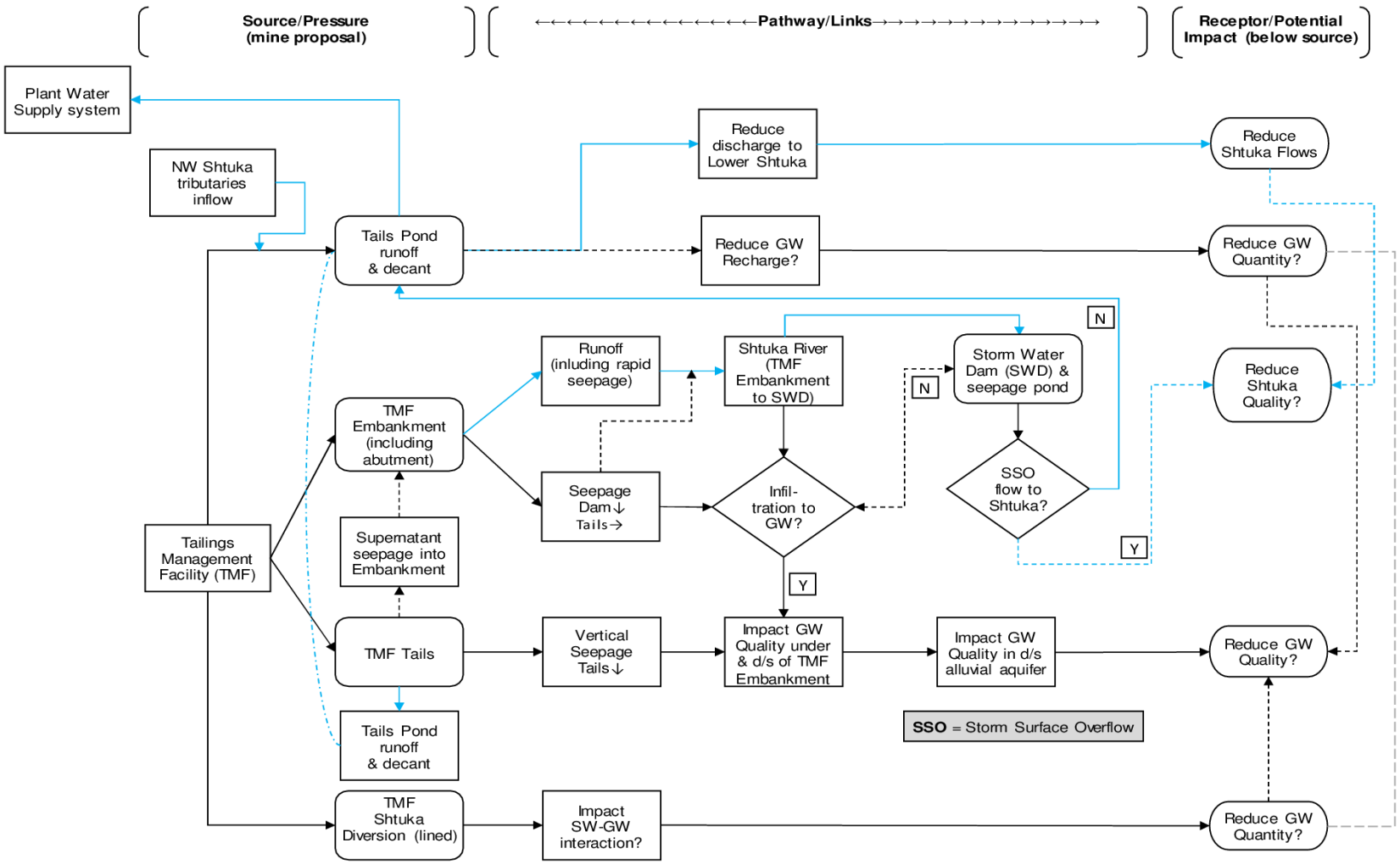
Q	Flow rate
L	Water level
Km	kilometres
m	metres
mm	millimetres
masl	metres above sea level
Mt	million tonnes
s	second

1 THE SOURCE PATHWAY RECEPTOR CONCEPT

This Annex presents supporting information to chapters 7 and 8 of the main ESIA report.

Hydrological impact assessment have been informed through the process by developing conceptual models and draw upon the source-pathway-receptor (SPR) concept. Accordingly, the following SPR diagrams have been developed to inform assessments associated with the operational phase for the project:

- Figure A1.1 covering the TMF.
- Figure A1.2 covering the oxide stockpile facility.
- Figure A1.3 covering the mine pit and ROM pad facility.
- Figure A1.4 covering the mine water supply during operations.
- Figure A1.5 covering haul road drainage management.
- Figure A1.6 covering mine plant site drainage management.



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Source Pathway Receptor diagram – operational phase for the TMF

PROJECT:	Ilovica Gold-Copper Project		FIGURE: A1.1
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT 55459_R1v2
DRAWN: APu	CHECKED: PB		DATE: January 2016

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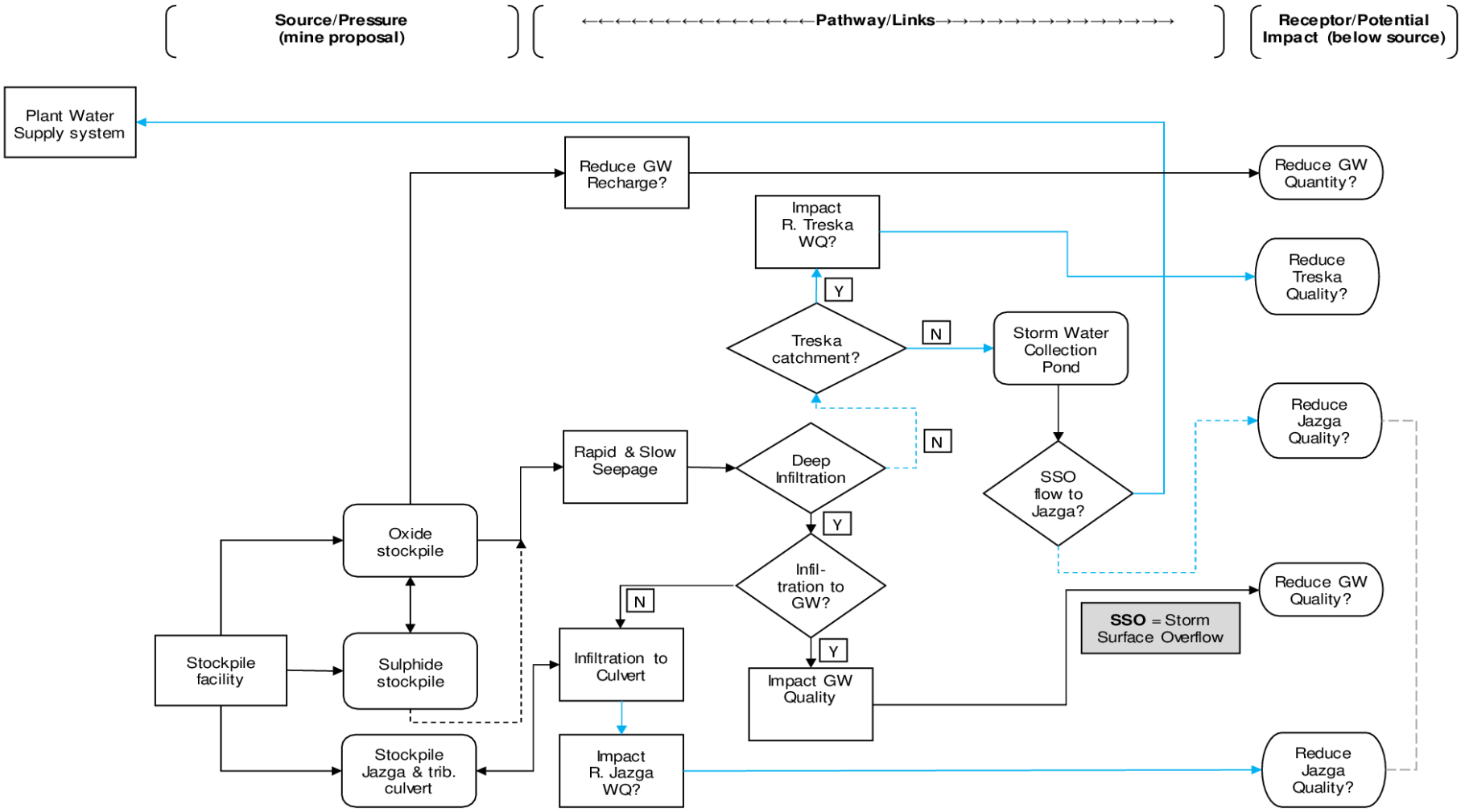

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Source Pathway Receptor diagram – operational phase for the stockpile

PROJECT:	Ilovica Gold-Copper Project		FIGURE: A1.2
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT 55459_R1v2
DRAWN: APu	CHECKED: PB		DATE: January 2016

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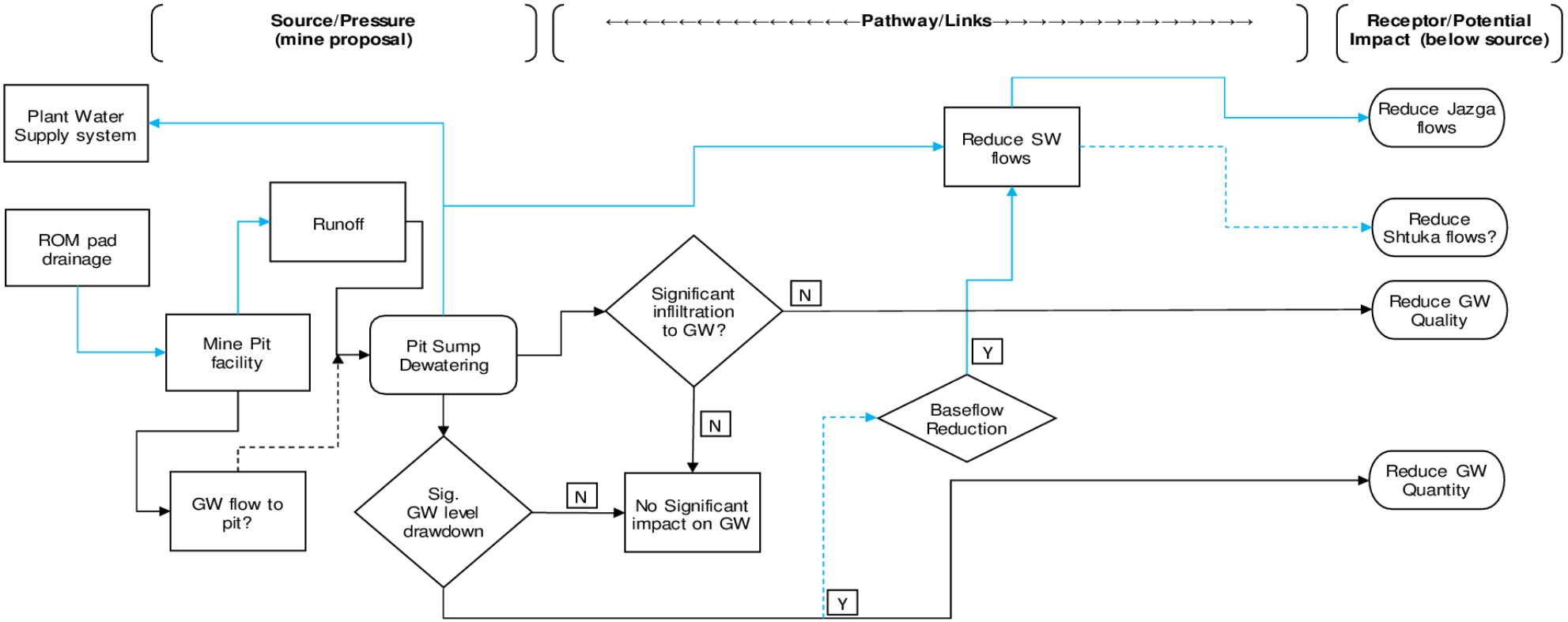

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Source Pathway Receptor diagram – operational phase for the mine pit and ROM pad

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A1.3
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT	55459_R1v2
DRAWN: APu	CHECKED: PB	DATE:	January 2016

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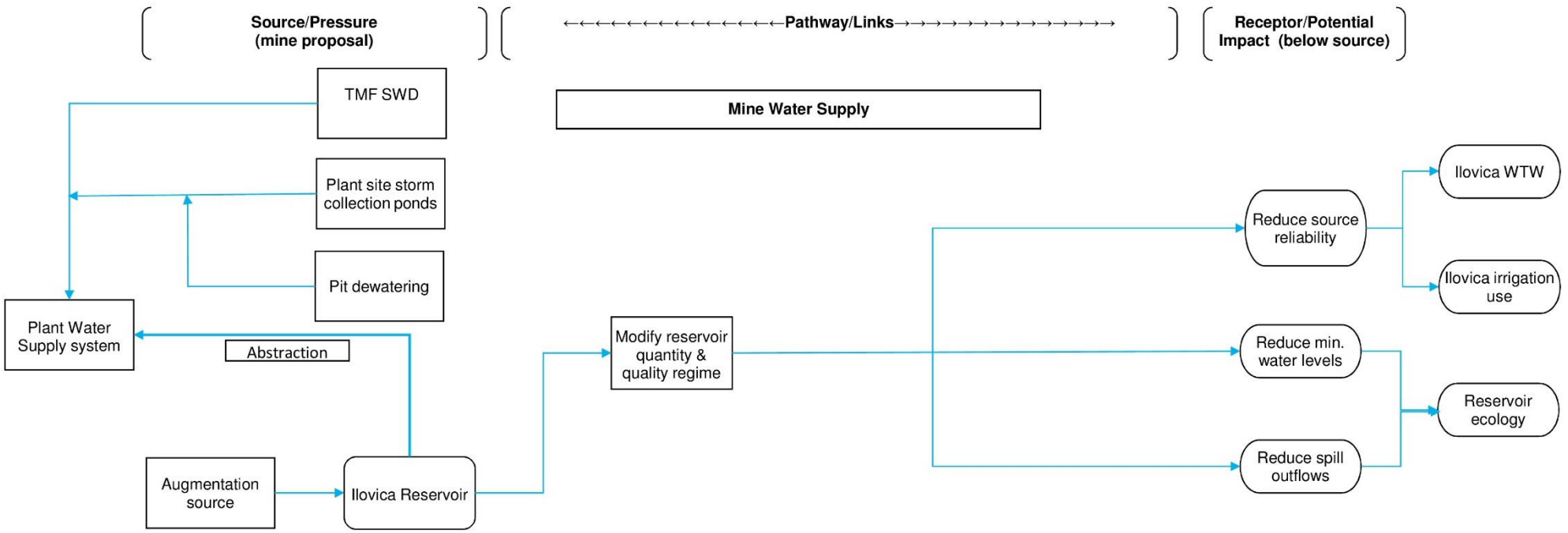

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Source Pathway Receptor diagram – operational phase for mine water supply

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A1.4
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT	55459_R1v2
DRAWN: APu	CHECKED: PB	DATE:	January 2016

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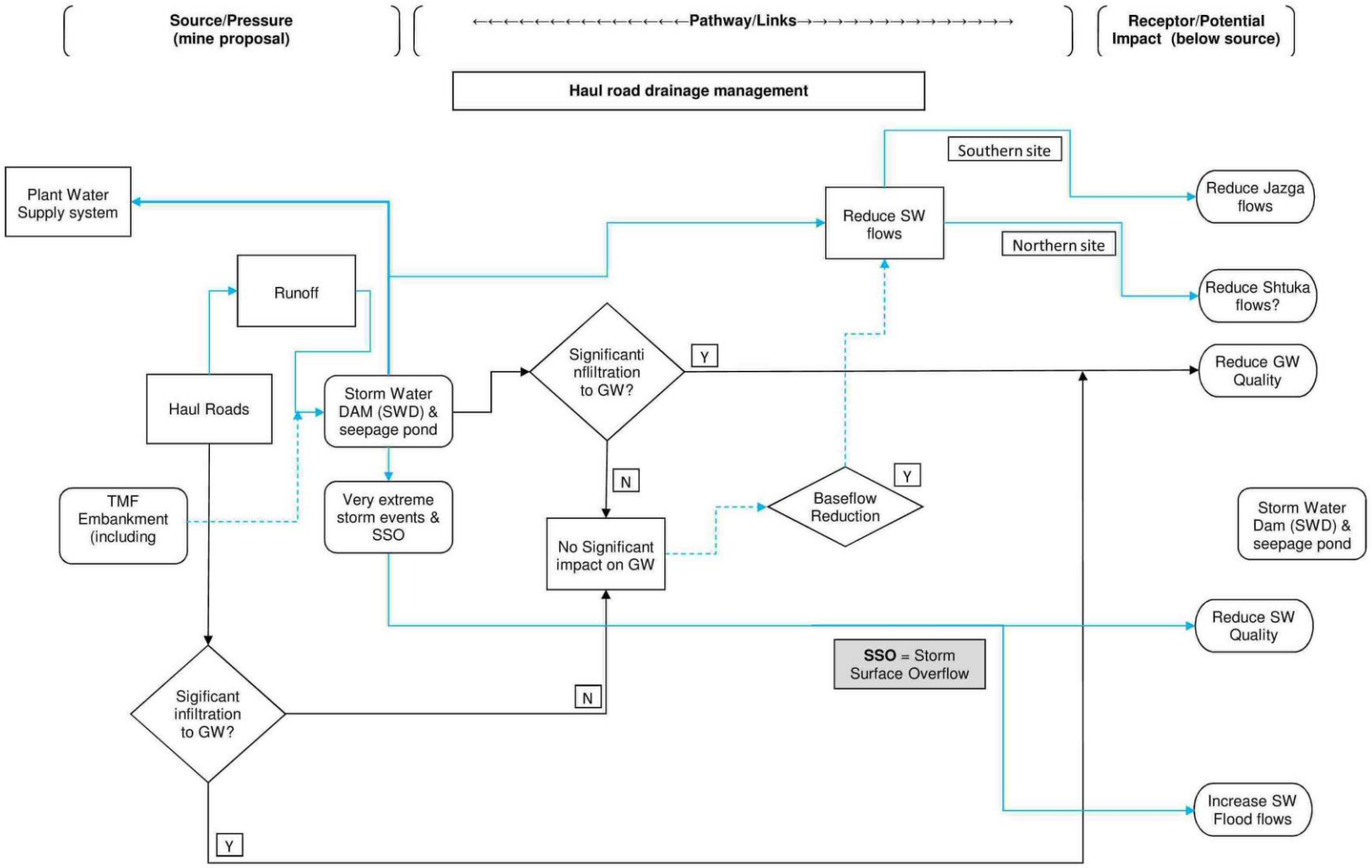

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Source Pathway Receptor diagram – operational phase for haul road drainage management

PROJECT:	Ilovica Gold-Copper Project		FIGURE: A1.5
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT 55459_R1v2
DRAWN: APu	CHECKED: PB		DATE: January 2016

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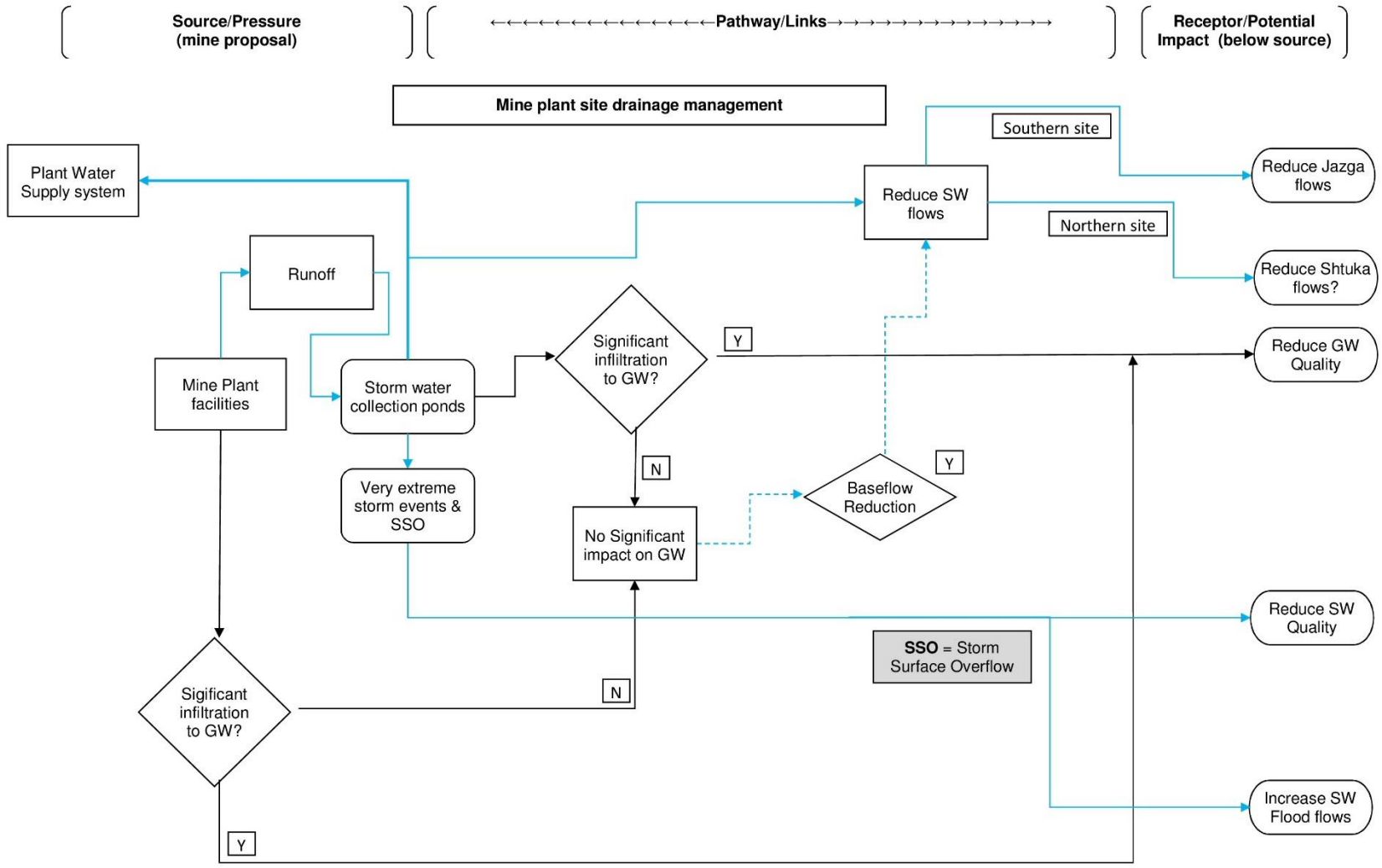

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Source Pathway Receptor diagram – operational phase for mine plant site drainage management

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A1.6
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT	55459_R1v2
DRAWN: APu	CHECKED: PB	DATE:	January 2016

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2 METHODS AND CRITERIA FOR WATER ENVIRONMENT IMPACT ASSESSMENTS

The methodologies developed and applied for undertaking the various water quantity and/or water quality evaluations of mine related changes (also referred to as preliminary effects) are described in Sections 3 to 9 of this Annex.

This section describes how assessed mine related effects are categorised to inform the first step in the impact assessment process (refer to main ESIA report).

2.1 SWS proposed criteria for defining magnitude of preliminary effects at specific receptors

In preparation for the August 2015 ESIA workshops, preliminary criteria were developed for informing definition of magnitude of preliminary effects (or changes) in respect of various water environment and water dependent receptors. These did not specifically cover impacts due to fluvial flooding. Those for surface waters are essentially as previously defined, although additional sets of criteria have been defined to cover the median flow regime (Q50) and fluvial flood regimes. Those previously defined for groundwater have subsequently been modified. The proposed criteria are covered respectively as indicated below.

2.1.1 Water bodies

Surface waters

The broad criteria proposed for assessing effects on river systems is outlined in Tables 2-1 and 2-2. This includes criteria for assessing changes to quantity and quality regimes in the river water body and an indicator parameter (wetted perimeter) used to inform effects assessments on river dependent ecology.

These criteria do not necessarily fit for specific considerations of water dependent ecological features at Ilovica Reservoir water body. Here, it is proposed to base assessments of effect on reservoir dependent ecological features in relation to a relatively simple impact on the mean water level regime in the reservoir as given in Table 2-3.

Table 2-1 Criteria for defining magnitude of change to river systems

Magnitude of change	Assessed change to quantity and quality regime in river		Impacts to security of supply (quantity) - village water supply schemes		Riverine habitat impact
	Q95 (low flow) Q50 (median flow)	Water quality	Broad definition and criteria for direct abstraction	Criteria (if augmented)	Reduction in wetted perimeter under Q95 (low flow condition)
Negligible	<10% reduction	No significant change from maximum baseline	No significant change from baseline security category Reduction (<10%)	No significant change from baseline average number of days per year village supply was augmented <5 from WTW	No significant change from baseline (<20%)
Low	10-30% reduction	Quality exceeds baseline maximum but not EDC	Increase in frequency of supply failure Reduction (10 - 30%)	Supply augmented from WTW <15 additional days per year (on average) over baseline	20-50%

Magnitude of change	Assessed change to quantity and quality regime in river		Impacts to security of supply (quantity) - village water supply schemes		Riverine habitat impact
	Q95 (low flow) Q50 (median flow)	Water quality	Broad definition and criteria for direct abstraction	Criteria (if augmented)	Reduction in wetted perimeter under Q95 (low flow condition)
Moderate	30-50% reduction	Quality exceeds EDC but not for parameters affecting human or ecological health.	Increase in frequency of supply Reduction (30 - 50%)	Supply augmented from WTW 15-30 additional days per year (on average) over baseline	50-90%
High	>50% reduction	Quality exceeds EDC for parameters affecting human and ecological health.	Increase in frequency of supply failure Reduction (>50%)	Supply augmented from WTW >30 additional days per year (on average) over baseline	>90%

Table 2-2 Criteria for defining magnitude of change associated with fluvial flooding

Magnitude of change	Flood flows/levels remain within channel		Flood flows/levels spill out of channel	
	Q_{100} flow	Q_{100} level	Q_{100} flow	Q_{100} level
Negligible	Increase ≤ 15% of baseline Q.	Increase ≤ 0.10m wrt baseline L.	Increase ≤ 10% of baseline Q.	Increase ≤ 0.05m wrt baseline L.
Low	Increase ≤ 30% of baseline Q.	Increase ≤ 0.25m wrt baseline L.	Increase ≤ 20% of baseline Q.	Increase ≤ 0.15m wrt baseline L.
Moderate	Increase ≤ 50% of baseline Q.	Increase ≤ 0.35m wrt baseline L.	Increase ≤ 35% of baseline Q.	Increase ≤ 0.25m wrt baseline L.
High	Increase > 50% of baseline Q.	Increase > 0.35m wrt baseline L.	Increase > 35% of baseline Q.	Increase > 0.25m wrt baseline L.

Table 2-3 Criteria for defining magnitude of change associated with changes to the mean water level in Ilovica Reservoir as considered pertinent to reservoir dependant ecological features

Magnitude of change	Change in mean reservoir level (m) relative to the mean baseline value
Negligible	Reduction ≤ 0.5 m
Low	Reduction ≤ 2.0 m
Moderate	Reduction ≤ 5.0 m
High	Reduction > 5.0 m

Groundwater

A groundwater model was developed and calibrated against observed groundwater level and rainfall/recharge data for the period 2014-15. This is referred to as the Calibrated Model (CM).

The calibrated model was subsequently used to develop a Baseline (B) and Predictive Model (P), which has been used to determine the likely effect of mining-related activities on groundwater levels across the project study area. The baseline and predictive model uses the same model parameters as the calibrated model, except for rainfall-

recharge which is based on data for the 54 year period 1961-2015. The baseline model has been used to define the baseline average (BAV) and dry (BDRY) conditions that form the basis for prediction of the magnitude of the mine-related effects on groundwater levels.

It is noted that 2014-15 was an exceptionally wet year, having received around 50% more rainfall-recharge than the average that was recorded over the period 1961-2015. The baseline average (BAV) and dry (BDRY) groundwater level conditions used for model prediction are therefore lower than the equivalent groundwater level conditions in the calibrated model. The relationships between groundwater levels in the calibrated model, the baseline model and the predictive model are shown schematically in Figure A2.1.

The effects analysis compares the magnitude of change in groundwater levels caused by mining with the magnitude of change that would occur naturally between average and dry conditions (Figure A2.1). The effect of mine-related activities on groundwater levels at specific groundwater-dependent receptors has been assessed under two rainfall-recharge regimes:

- Average recharge regime. In this case the predicted mine-related reduction in groundwater levels occurring under the Average recharge regime (J) is compared to the naturally occurring change between average and dry conditions under the same recharge regime (K) (Figure A2.1).
- Dry recharge scenario. In this instance the reduction in groundwater levels as a result of mining when the predictive model is run under the Dry recharge regime (Y) is compared to the naturally occurring variation in groundwater levels under the Dry regime (K) (Figure A2.1).

These relationships are defined in Table 2-4.

Table 2-4 Relationships defined for effects analysis

Recharge Regime	Natural change in groundwater level	Change due to mining
AVERAGE	$K=B_{AV}-B_{DRY}$	$J=B_{AV}-PM_{AV}$
DRY		$Y=B_{AV}-PM_{DRY}$

The broad criteria proposed for assessing impacts on groundwater bodies is outlined in Table 2-5, which includes quantity and quality impacts to the groundwater body. The quantity criteria draw upon comparisons between modelled groundwater levels for baseline and mine affected conditions. This is also represented in a schematic diagram (Figure A2.2) in order to help understand the definitions for the assessments, the possible range of changes to the groundwater level regime, and their relationship with associated assessment criteria.

Table 2-5 Criteria for defining magnitude of change to groundwater bodies

Magnitude of change	Criteria for defining change to the general quantity and quality under Average Recharge Regime		Criteria for defining change to the general quantity and quality under Dry Recharge Regime	
	Groundwater level (quantity)	Water quality	Groundwater level (quantity)	Water quality
Negligible	J≤0.25*K	No significant change from maximum baseline	Y≤1.25*Z	No significant change from maximum baseline
Low	0.25*K<J≤0.5*K	Quality exceeds baseline maximum but not EDC	1.25*Z<Y≤1.5*Z	Quality exceeds baseline maximum but not EDC
Moderate	0.5*K<J≤1.0*K	Quality exceeds EDC but not for parameters affecting human or ecological health.	1.5*Z<Y≤2.0*Z	Quality exceeds EDC but not for parameters affecting human or ecological health.

High	J>1.0*K	Quality exceeds EDC for parameters affecting human and ecological health.	Y>2.0*Z	Quality exceeds EDC for parameters affecting human and ecological health.

The most conservative outcome from these two scenarios has been used to define the magnitude of the potential impact of mining on groundwater receptors.

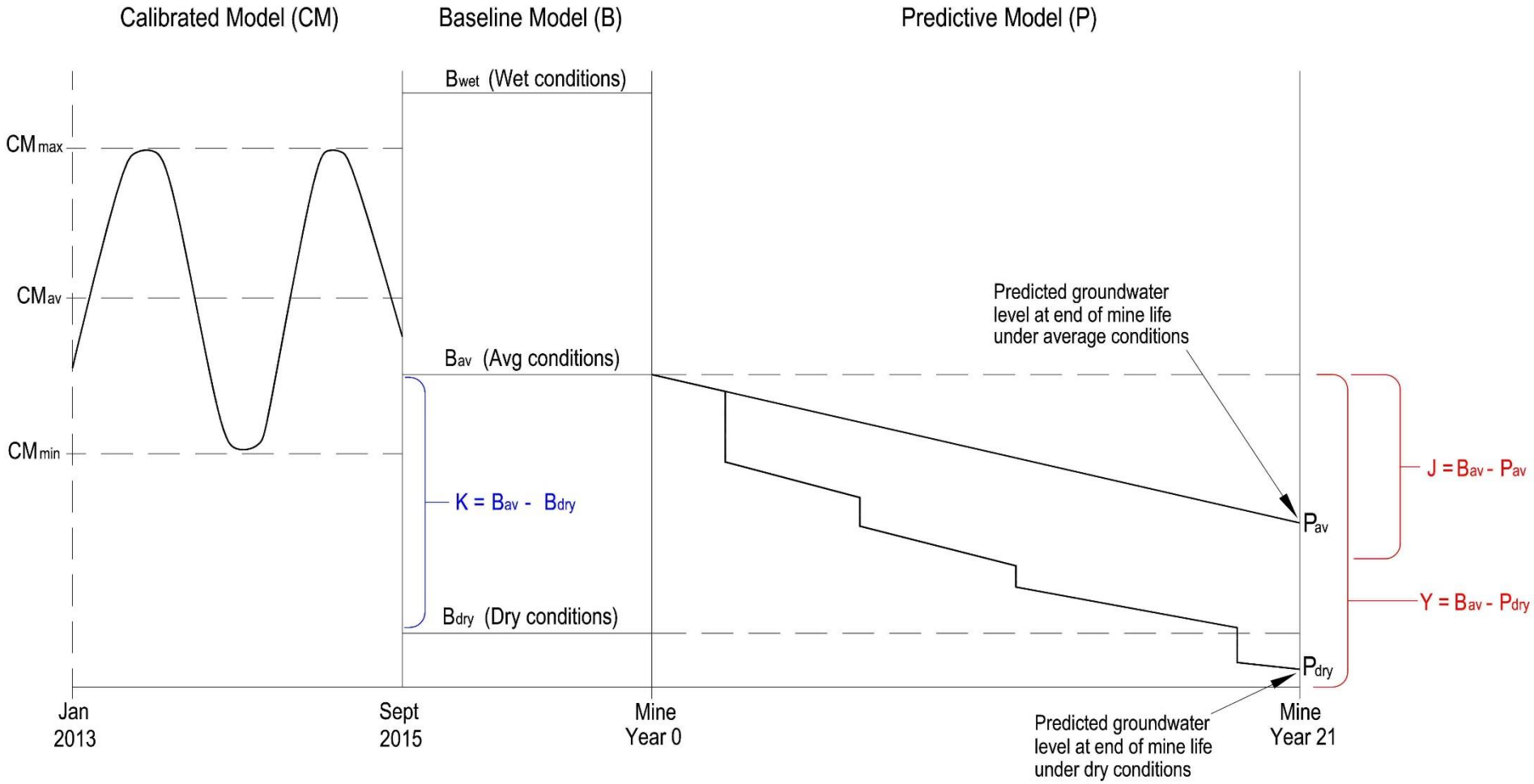
2.2 SWS proposed criteria for defining importance/sensitivity of key study receptors

SWS proposed matrix for determining the importance/sensitivity of the receptor, which is set out in Table 2-6 below.

Table 2-6 Criteria for defining importance/sensitivity of water environment (dependent) receptor

Importance/Sensitivity of Water Environment or Dependent Receptor	Broad category of water environment receptor	
	Groundwater	**Surface water**
Low	Local small scale groundwater body supporting no noteworthy water resource function, dependent surface water, ecology or any other dependent socio or environment related need.	Local small scale stream/ditch (or in line surface water) supporting no noteworthy water resource function, dependent ecology or any other dependent socio or environment related need. Flooding, from a defined event, will only affect low sensitivity receptors to an extent considered tolerable.
Medium	Local small scale groundwater body supporting a moderately noteworthy water resource function, dependent surface water, ecology or any other dependent socio or environment related need.	Local small scale stream/ditch (or in line surface water) supporting a moderately noteworthy water resource function, dependent ecology or any other dependent socio or environment related need. Flooding, from a defined event, will affect moderate or low sensitivity receptors to an extent normally considered as tolerable (and not warranting special measures).
High	Local small scale groundwater body supporting an important water resource function (village/town water supplies), dependent surface water, ecology (≥ regional designation) or any other dependent socio or environment related need of equivalent standing. Regional scale groundwater body supporting a moderately noteworthy water resource function, dependent surface water, ecology or any other dependent socio or environment related need.	Local small scale stream/ditch (or in line surface water) supporting an important water resource function (village/town water supplies), ecology (≥ regional designation) or any other dependent socio or environment related need of equivalent standing Regional scale river (or in line surface water) supporting a moderately noteworthy water resource function, dependent ecology or any other dependent socio or environment related need. Flooding, from a defined event, will affect moderate or high sensitivity receptors to an extent that may be unacceptable (and ordinarily would prompt some form of mitigation).

Very High	Local small scale groundwater body supporting a very important water resource function (town/city water supplies), dependent surface water, ecology (≥ national designation) or any other dependent socio or environment related need of equivalent standing. Regional scale groundwater body supporting an important water resource function (village/town water supplies), dependent surface water, ecology (≥ regional designation) or any other dependent socio or environment related need of equivalent standing.	Local small scale stream/ditch (or in line surface water) supporting a very important water resource function (town/city water supplies), ecology (≥ national designation) or any other dependent socio or environment related need of equivalent standing Regional scale river (or in line surface water) supporting an important water resource function (village/town water supplies), dependent surface water, ecology (≥ regional designation) or any other dependent socio or environment related need of equivalent standing. Flooding, from a defined event, will affect moderate or high sensitivity receptors to an extent that is totally unacceptable (and very likely warrants targeted mitigation).



Notes:

- Calibrated Model (CM) uses rainfall-recharge data from 2014-2015 calibration period
- Baseline (B) and Predictive (P) Models use 54 year historical rainfall-recharge data set
- Dry recharge regime was applied for key mine years being assessed, this is shown schematically as a stepped drawdown for the purposes of this figure

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Schematic representation of groundwater models used to predict preliminary effects

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A2.1
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: APu	CHECKED: PB	DATE:	January 2016

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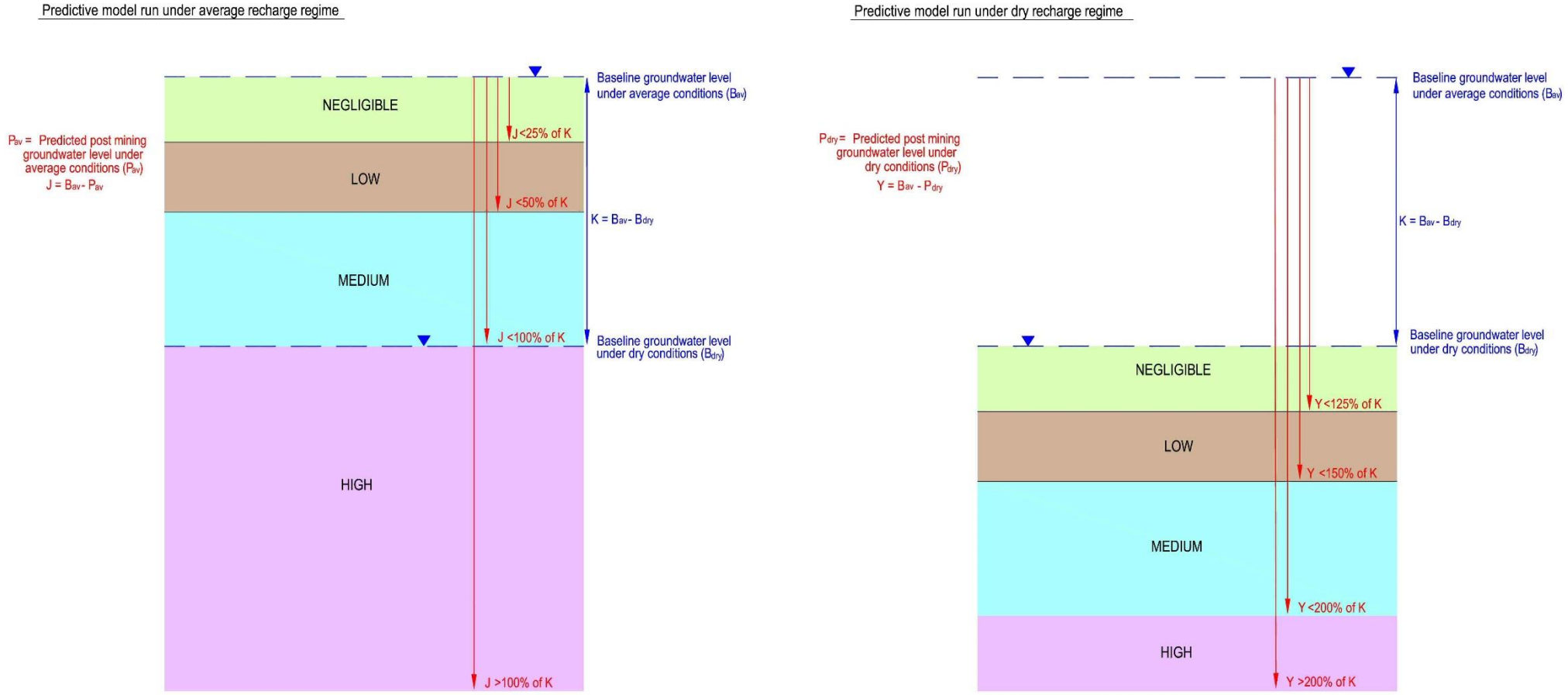

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Schematic representation of predicted groundwater level change and associated categorization of preliminary effects

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A2.2
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: APu	CHECKED: PB	DATE:	January 2016

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3 WATER BALANCE MODELLING ASSOCIATED WITH THE MINE OPERATION

3.1 Inputs provided for assessment of receptors

A site-wide water balance model was developed in GoldSim for the Ilovica FS in order to quantify reclaim and fresh (raw) water sources through LOM. The model was extended to include the construction and closure phases of the mine in order to provide the following inputs for impact assessment:

- runoff from the open pit and ROM pad;
- pit lake formation upon closure;
- seepage to ground from the oxide stockpile;
- runoff from the TMF embankment;
- seepage to ground and surface water from the tailings mass and TMF embankment; and
- Ilovica Reservoir management as fresh water supply to the mine and local villages.

Full details of the FS water balance model setup are provided in Sections 8 and 9 of the FS report (Euromax Resources, press release dated 6th January 2016).

3.2 Analytical modelling approach

3.2.1 Open pit and ROM pad

Construction and operation

For the construction and operation phases, the water balance model was used to calculate daily runoff rates from the pit walls and the ROM pad to provide inputs to the geochemical model for prediction of pit water quality (Section 6).

Runoff from the pit walls (or pre-strip area) was estimated using a unit runoff value calculated using the US SCS curve number method. This ensured that light precipitation events did not register any runoff (and were lost as evaporation) but that larger events were represented. A curve number of 76 was used which produces the following equivalent runoff coefficients which were used by Amec Foster Wheeler to size the pit sump:

- Runoff coefficient of 0.3 for a 5 year, 24 hour storm; and
- Runoff coefficient of 0.35 for a 10 year, 24 hour storm.

These runoff coefficients are based on experience of runoff generation in large open pits in similar climatic environments.

Unit evaporation loss from the pit walls was based on a soil moisture balance with a maximum evaporation rate equal to 30% of potential evapotranspiration. The balance of the precipitation (precipitation minus runoff minus evaporation) was assumed to infiltrate ("unit infiltration") into the pit wall and migrate to the pit sump over an average period of 5 days.

These unit rates were multiplied by the pit area (minus any ponded water in the sump) for that time step to produce the daily flow rates. The pit area for that time step was calculated by linearly interpolating between defined areas provided for years -1, 2, 7 and 21. This was based on the assumption that the pit area grows at a constant rate between defined areas and that all runoff generated outside of the pit was diverted to the Jazga River.

Precipitation falling directly on to the sump was assumed to have a runoff coefficient of 1 (i.e. no losses). Evaporation was lost from the sump water surface assuming an evaporation rate equal to 120% of potential evapotranspiration.

Runoff from the ROM pad was routed to the sump. This was modelled with a curve number of 89 and a surface area of 1.1 ha. The SCS land use definitions are defined for agricultural purposes, not mining. The curve number of 89 was estimated on the assumption that the ROM pad surface will be comparable to the SCS land use definition of impervious dirt area with clay-rich soils.

Groundwater seepage to the sump was simulated using the output from the 3D numerical groundwater model (Section 5 this document).

Closure

For the closure phase, the water balance model was used to calculate the proportions of inflows to the pit lake to provide inputs to the HEC-HMS rainfall runoff model for impact assessment on downstream receptors (Section 4), and to the geochemical model for water quality impact assessment on downstream receptors (section 6).

The inputs for runoff, evaporation and infiltration of precipitation in the pit were the same as for operations. Groundwater seepage to the pit lake was based on a stage-inflow rate relationship derived in the 3D numerical groundwater model (Section 5). A stage-volume-area relationship for the final pit (Figure A3.1) was used to calculate the stage, volume and surface area of the lake based on the inflows and losses (Figure A3.2).

3.2.2 Oxide stockpile

The oxide stockpile was assumed to be constructed in year 4 so no assessment was required for the construction phase. For the operation and closure phases, the water balance model was used to calculate seepage rates from the base of the oxide stockpile to provide inputs to the 3D numerical groundwater model for groundwater resource (Section 5) and water quality (Section 6) impact assessment on downstream receptors.

Numerical modelling of seepage from the oxide stockpile was undertaken using VADOSE/W, a software package which uses the finite element method to both solve the Richard's equations for groundwater flow under partial saturation conditions, and to comprehensively model soil – climate interaction. The model consisted of a 1D column of representative oxide stockpile material. The hydraulic characteristics of both the Granodiorite and Dacite oxide materials were based upon parameters obtained from laboratory testing of representative samples. Column heights of 20m and 120m were modelled, to account for the variation of stockpile material thickness. Climate data from 1971 was used, as monthly precipitation totals throughout this year showed the least departure from mean monthly rainfall calculated from the long term 54 year rainfall record. Rates of seepage by unit area were recorded from the base of the column and scaled up to account for the entire facility footprint.

The results of the VADOSE/W modelling were used to calibrate the stockpile seepage rate in the water balance model using a soil moisture balance and breakthrough curve based on a normal distribution with an average travel time of 1 day for every 10 m height, and standard deviation of 0.4 days for every 10 m height. It was assumed that the stockpile had a constant height of 120 m so the parameters used were an average travel time of 12 days and standard deviation of 4.8 days. This allowed seepage rates for LOM to be simulated.

3.2.3 TMF embankment

For all mine phases, the water balance model was used to calculate runoff and seepage rates from the TMF embankment to provide inputs to the 3D numerical groundwater model for groundwater resource (Section 5) and water quality (Section 6) impact assessment on downstream receptors.

Based on the embankment design, Golder Associates assumed that, on average, 67% of precipitation would become runoff and 33% would infiltrate into the embankment. These estimates were incorporated into the water balance model as follows:

(i) unit runoff was calculated using a curve number of 96,

(ii) unit evaporation loss uses a soil moisture balance with a maximum evaporation rate equal to 30% of potential evapotranspiration and

(iii) unit infiltration was the remaining balance.

These unit rates were multiplied by the downstream embankment area to produce the flow rates. The downstream embankment area at each time step was calculated by linearly interpolating between defined areas provided for years -1 and 21. The oxide stockpile breakthrough curve was used to translate the infiltration rate to a seepage rate because the embankment will be constructed with similar material. To simulate the increasing elevation of the embankment, its height for each time step was calculated by linearly interpolating between defined annual heights at year -1 and 21.

3.2.4 TMF tailings

The water balance model was used to simulate seepage from the deposited tailings to the ground and surface water. Tailings deposition was assumed to begin in year 1 so seepage was produced for the construction phase. Changes to recharge within the TMF footprint during the construction phase were accounted for in the 3D groundwater model (Section 5).

For the operation and closure phases, the water balance model was used to calculate seepage rates from deposited tailings to provide inputs to the 3D numerical groundwater models for groundwater resource (Section 5) and water quality (Section 6) impact assessment of downstream receptors.

Golder Associates modified the TMF component of the site-wide water balance to include details of construction, tailings properties and pond management. Full details of the TMF component are provided in Section 9 of the FS Report (Euromax Resources, press release dated 6th January 2016).

The TMF has been designed to be an unlined facility. Seepage from the deposited tailings was calculated by multiplying the area of deposited tailings by the tailings permeability. It was assumed by Golder Associates that 75% of this seepage was lost to ground and the remaining 25% seeps into the embankment. The 25% seepage to the embankment was combined with rainfall-infiltration on the embankment surface described above. The area of deposited tailings was calculated using a volume-area relationship and the total volume of (consolidated) tailings deposited in the TMF. The hydraulic conductivity of the tailings was assumed by Golder Associates to be 10^{-7} m/s in years 1 and 2, reducing linearly to 10^{-9} m/s by the end of year 21.

3.2.5 Ilovica Reservoir

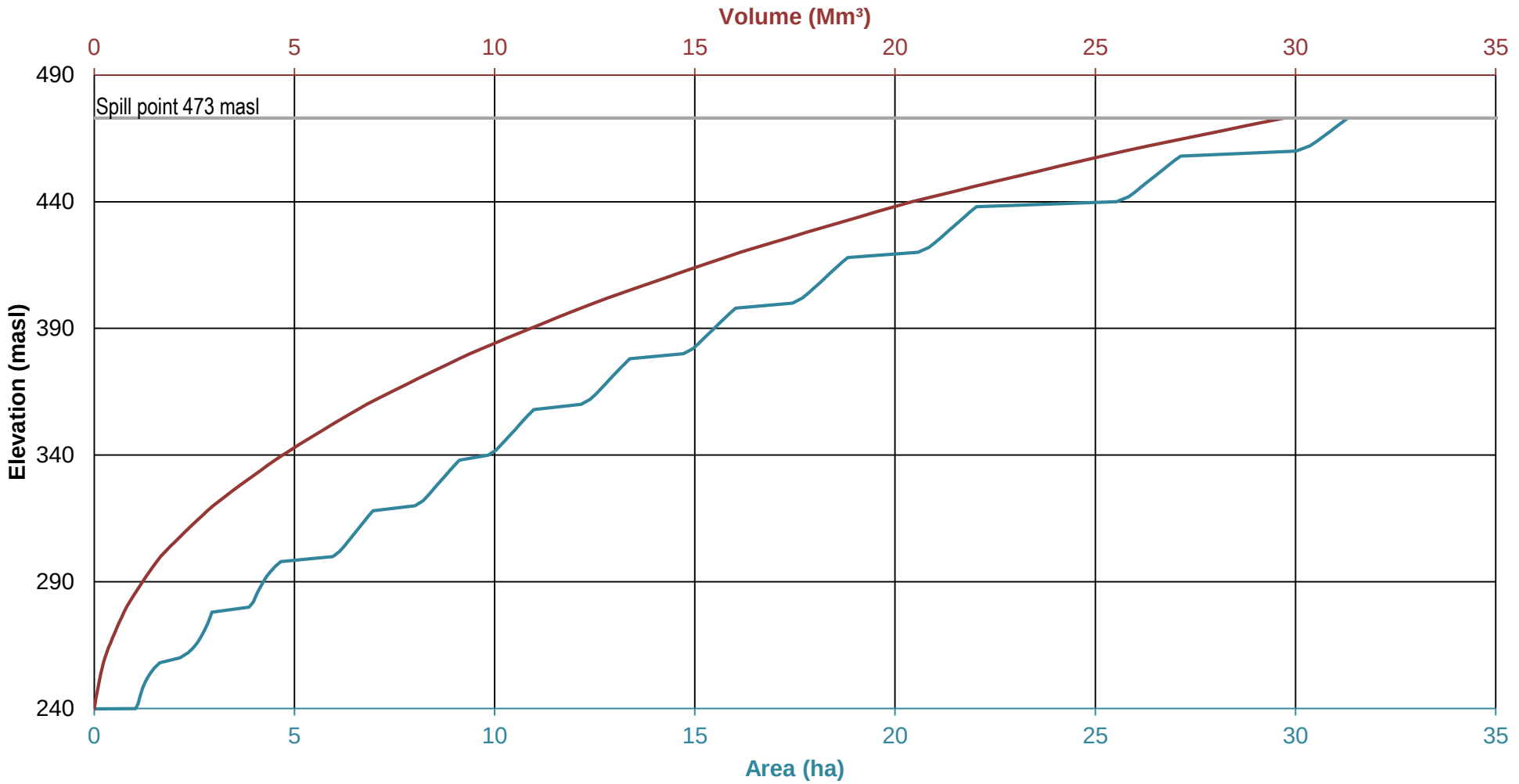
For all phases, the water balance model was used to calculate abstraction requirements (and augmentation requirements during construction and operation phases) in order to provide inputs to the HEC-HMS model for surface water resource impact assessment on downstream receptors (Section 4).

Total abstraction from Ilovica Reservoir was a combination of the following abstractions:

- mine demand – process plant and potable fresh water demand as defined by the process flow sheet and dependent upon the amount of available reclaim from the TMF;
- irrigation abstractions – 30 ha being irrigated with water demand ranging from 0 m³/d/ha from October to February to a maximum of 64.7 m³/d/ha in July (based on potato water requirements); and
- domestic water abstractions – number of household connections increasing by 33 per year, from 2053 connections at year -1 and each connection having a mean demand of 0.54 m³/d (mean actual consumption by connection in 2012).

Full details of the rules defining the abstraction rates are provided in Section 8 of the FS Report (Euromax Resources, press release dated 6th January 2016).

A reservoir storage-yield-reliability analysis was carried out based on the method of Parks and Gustard (1982) using the present capacity (356,000 m³), and an annual agriculture and public water supply abstraction of 465,794 m³/yr. The reservoir was modelled using a 54-year series of daily inflows generated using the HEC-HMS rainfall-runoff model. Two versions of the model were used: (i) with the baseline reservoir inflow series and (ii) with the closure reservoir inflow series. These were then compared to produce the impact assessment for reservoir reliability (Section 4).



Data source: EOX, December 2015, Site Layout_2015-12-07.dwg

Schlumberger Water Services

Elevation-volume-area relationships for the open pit at closure

PROJECT:	Ilovica Gold-Copper Project			FIGURE:	A3.1
CLIENT:	Euromax Resources (Macedonia) UK Ltd			PROJECT:	55459_R1v2
DRAWN:	SS	CHECKED:	PB	DATE:	January 2016

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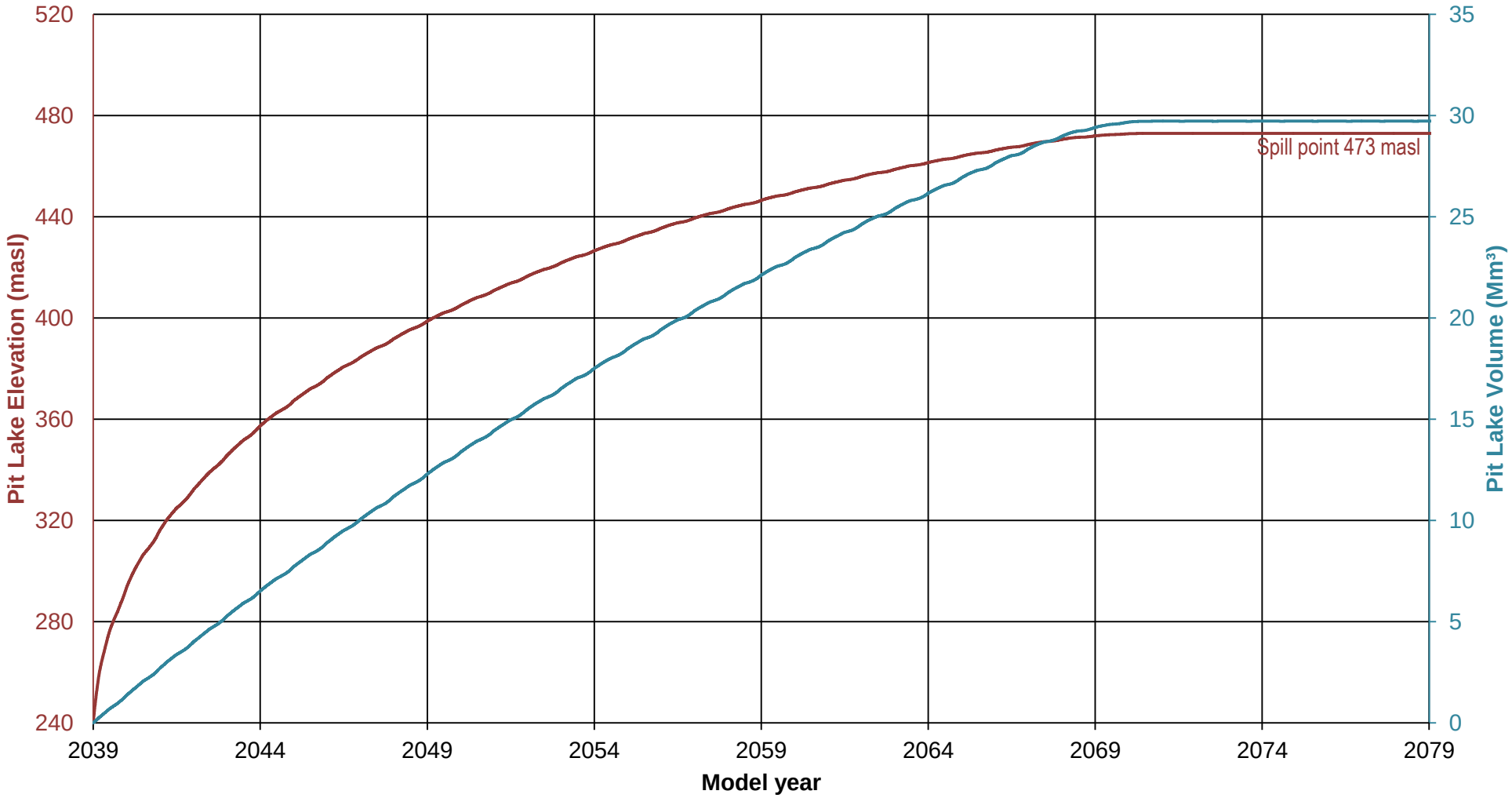

Data source: EOX, December 2015, Site Layout_2015-12-07.dwg

Schlumberger Water Services

Elevation and volume of pit lake following closure

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A3.2
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: SS	CHECKED: PB	DATE:	January 2016

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4 SURFACE WATER RESOURCE MODELLING

4.1 Introduction

The occurrence of surface water in the local and regional study areas is described in Annex 3. Estimates of baseline stream flows to be used in the impact assessment at key 'receptor' locations are presented in Section 5 of the main ESIA report. The baseline flows were estimated by fitting the HEC-HMS (soil moisture accounting) rainfall runoff model to the project catchments as described in Annex 3.

The development of the mine has the potential to affect the baseline surface water regime. Effects on flows will likely result from changes in the hydrological characteristics of the catchments. For example, changes in interception, infiltration and flows are likely to result from stripping of vegetation on the mine site and from changes in catchment area which will result from the excavation of the open pit. The sections below list the catchment changes that will occur during construction, operations, closure and post-closure phases of the mine. Although the catchment changes will be somewhat progressive over time, they are modelled in key years in the mine life that represent the culmination of the changes in order to demonstrate their effects on stream flows.

4.2 Construction Phase (Year -1)

4.2.1 Jazga & Treska [1] catchments

- Jazga catchment: The forest canopy is stripped over entire pit, ROM and oxide stockpile. Subsurface materials are excavated from part of pit footprint for construction of TMF starter dam. Haul roads and access roads are constructed with associated drainage designed to infiltrate run-off; runoff collection ponds are established at the plant site and mine services area. The forest canopy is removed along the power line and conveyor line.
- Treska catchment: The forest canopy is stripped over oxide stockpile footprint.
- Ilovica reservoir: Euromax abstraction commences to supply construction works. Augmentation of Ilovica reservoir commences from an external water supply source.

4.2.2 Shtuka catchment

- Forest canopy and soil are stripped from the footprint of the final TMF embankment and from the footprint of the pit in the Shtuka catchment. Forest canopy is stripped from the footprint of the starter dam tailings basin. The Shtuka river is diverted, including truncation of a small portion of the Suchica catchment. Haul roads and access roads are constructed with associated drainage designed to infiltrate run-off; runoff collection ponds are established at the plant site and mine services area.

4.3 Operations Phase (Year 21)

4.3.1 Jazga & Treska catchments

- Jazga catchment: The oxide stockpile, ROM, pit, roads, plant site and mine services area are fully developed and cut off from the River Jazga surface water regime by runoff collection ponds. There is no vegetation canopy along conveyor and power lines.

[1] Within the local study area there is a small tributary to the Jazga River, known locally as the Treska River, which flows directly into Ilovica Reservoir. This small river system should not be confused with the much larger Treska River located within the Vardar catchment.

- Treska catchment: The small part of the oxide stockpile located in the Treska catchment will drain into the Treska River.
- Ilovica Reservoir: Water demand is increased for operations. Ilovica reservoir is augmented from the external water supply source. The external source is likely to be Turija reservoir or groundwater abstracted in the Strumica valley, or a combination of both sources, but this has not been defined in the modelling performed to date.

4.3.2 Shtuka catchment

- The TMF catchment, roads, plant site, mine services area and the pit are all fully developed and cut off from the River Shtuka surface water regime by runoff collection ponds.

4.4 Closure Phase pre-pit lake formation (Year 27)

4.4.1 Jazga & Treska catchments

- Jazga catchment: The oxide stockpile, ROM, roads, upper plant, power line and conveyor are removed and the mine site (minus the pit) is fully restored to baseline catchment characteristics. The pit is fully developed and cut off from the River Jazga surface water regime by the topography at the pit entrance. The part of the catchment occupied by the mine services area is permanently lost to the Jazga catchment.
- Treska catchment: The oxide stockpile is removed and the footprint is fully restored to baseline characteristics.
- Ilovica reservoir: Abstraction by Euromax has ceased and the demand on the reservoir's water resource is restored to baseline water demand (village water supply and irrigation). Restoration to pre-project baseline water demand was selected in order to specifically assess the impact of abstraction for the mine, and cessation of abstraction, on the water resource.

4.4.2 Shtuka catchment

- The TMF is capped and re-vegetated. The TMF and its catchment drain to the Shtuka River. Part of the pit is permanently lost to the Shtuka catchment. The plant site and mine services area are restored. The mine services area drains to the Shtuka River.

4.5 Post-Closure post pit lake formation (Year 57)

4.5.1 Jazga & Treska catchments

- Jazga catchment: The pit lake is able to spill to the Jazga River.
- Treska: No change from Year 27.
- Ilovica reservoir: No change from Year 27.

4.5.2 Shtuka catchment

- No change from Year 27.

4.6 Approach to predictive modelling

The baseline HEC-HMS rainfall-runoff model (described in Annex 3) was modified to create the following four new models that reflect the anticipated catchment changes:

- Construction phase - Year -1: Represents the timing of maximum change in catchment characteristics.
- Operations phase - Year 21: Represents the timing of maximum change in the catchment size and maximum water resources demand.
- Closure (pre pit lake formation) - Year 27: Represents the timing of maximum change in catchment size during closure. In the case of the Shtuka catchment the model represents the Shtuka catchment that will remain in perpetuity.
- Post-closure (post pit lake formation) - Year 57: Represents the Jazga catchment that will remain in perpetuity. A model of the Shtuka catchment was not produced for Year 57 as it is assumed to be the same as for Year 27.

The changes that were made to the Jazga catchment model at each modelled year are presented in Tables 4-1 to 4-4.

The changes that were made to the Shtuka catchment model at each modelled year are presented in Tables 4-5 to 4-7.

Each model was applied to the 54-year synthesized daily areal rainfall record for the catchments (described in Annex 3) and a 54-year daily flow record was generated at the key receptor locations representing the flow regime likely to result from the respective modelled changes in land use.

4.7 Additional information required by the HEC-HMS models

The HEC-HMS models required the following to be estimated in addition to the model parameter changes in Annexes A and B:

- Monthly abstraction rates from the reservoir (for the mine, public water supply and agriculture) were provided by the GoldSim Model (Section 3 of this document).
- A record of spills from the pit lake during post-closure was obtained from a pit lake model developed in GoldSim (Section 3 of this document). The pit lake model used the same 54-year rainfall record as the HEC-HMS models.
- The loss of approximately 8 l/s or 8% of average flow in the Jazga to the pit during operations (when the pit is at its maximum extent) and during closure before the pit lake forms was estimated using the numerical groundwater flow model (Section 5 of this document)
- An estimate of construction water demand, provided by the Engineers.

4.8 Modelling levels in Ilovica Reservoir

Levels have also been modelled in Ilovica Reservoir given the reservoir inflows (from the Jazga and Treska rivers plus any assumed supplementary inputs proposed for the mine scheme) and deducting from this the proposed abstraction regime from the reservoir along with direct leak estimates through/under the dam embankment. When a positive outflow from the reservoir spillway is both predicted and preceded the spillway stage-discharge curve is utilized to directly calculate reservoir level. Otherwise a very simple continuity approach is applied in conjunction with the reservoir stage-volume curve to predict so as to predict the volumetric state in the reservoir and translate this to a corresponding stage.

4.9 Assessments

The resulting 54-year estimated daily flow series at each key surface water resources receptor were used to assess the potential effects on the flow for each phase of the project. This included an assessment of potential changes to the:

- low flow regime (Q95).
- security of water supplies to Ilovica and Shtuka via the village intakes at JZGS01 and STGS01.
- the extent of aquatic habitat as represented by the river channel wetted perimeter on the Jazga and Shtuka rivers at gauging stations JZGS01 and STGS01 respectively.
- The contribution of the Jazga and Shtuka rivers to flows in the Turija and Strumica rivers downstream.
- The level regime in Ilovica Reservoir used to consider impact on reservoir dependant ecological features.

The assessments are presented in Section 5 of the main ESIA report.

Table 4-1 Jazga catchment: HEC-HMS model parameters in Construction Phase: Year -1

				Yr -1 (Construction)			Comments
			Natural (baseline)	Natural	Modified	Removed	
Components subject to change	Catchment Areas	JZGS02 Catchment	17.9 km²	17.84 km²	0.06 km²	None	Canopy removed for new power line
		Oxide Tributary	1.98 km²	1.62 km²	0.22 km²	0.14 km²	Canopy removed for power line and conveyor. Canopy removed from pre-strip of component of pit and ROM. Plant removed from catchment
		R. Jazga/Oxide Tributary Confluence to JZGS01	1.54 km²	0.48 km²	0.77 km²	0.29 km²	Component of Pit, ROM and Oxide stockpile pre-stripped. Haul road constructed with infiltration drainage. Area of pit scavenged for starter dam material and component of Lower Plant removed from catchment
		JZGS01 to Reservoir & Treska	4.45 km²	4.37 km²	0.06 km²	0.02 km²	Canopy removed for power line. Canopy removed from pre-strip of small Oxide stockpile component. Access roads constructed with infiltration drainage. Component of Mine services area removed from catchment
	Catchment Area Inputs	Evapotranspiration	Forest Canopy	Forest Canopy	FAO56 Ref Crop	N/A	FAO56 reference crop evapotranspiration used for areas with removed canopy
	Catchment Area Parameters	Canopy Storage	30 mm	30 mm	5 mm	N/A	Canopy storage reduced from 30mm for forest cover to 5mm for brush cover
	Reaches	Jazga	No losses	No losses	No losses	N/A	No river losses
	Reservoir	Ilovica Reservoir	Village & agriculture supply	Village & agriculture supply	Euromax construction demand	N/A	Euromax construction demand 2900m3/d (Amec Foster Wheeler estimate)

Table 4-2 Jazga catchment: HEC-HMS model parameters in Operations Phase: Year 21

				Yr 21 (Operations)			Comments
			Natural (baseline)	Natural	Modified	Removed	
Components subject to change	Catchment Areas	JZGS02 Catchment	17.9 km²	17.84 km²	0.06 km²	None	Change from Yr -1 (Construction): None
		Oxide Tributary	1.98 km²	1.62 km²	0.08 km²	0.28 km²	Change from Yr -1 (Construction): Component of pit and ROM removed from catchment
		R. Jazga/Oxide Trib Confluence to JZGS01	1.54 km²	0.48 km²	None	1.06 km²	Change from Yr -1 (Construction): Bulk of pit, ROM, Oxide stockpile and Haul road removed from catchment
		JZGS01 to Reservoir & Treska	4.45 km²	4.37 km²	0.05 km²	0.03 km²	Change from Yr -1 (Construction): Small component of Oxide stockpile and access road removed from catchment
	Catchment Area Inputs	Evapotranspiration	Forest Canopy	Forest Canopy	FAO56 Ref Crop	N/A	FAO56 reference crop evapotranspiration used for areas with removed canopy
	Catchment Area Parameters	Canopy Storage	30 mm	30 mm	5 mm	N/A	Canopy storage reduced from 30mm for forest cover to 5mm for brush cover
	Reaches	Jazga	No losses	No losses	8 L/s	N/A	8 l/s loss to pit from Jazga River adjacent to pit (estimated from GW modelling)
	Reservoir	Ilovica Reservoir	Village & agriculture supply	Village & agriculture supply	Euromax operations demand	N/A	Euromax operations demand approx. 6800m^3/d (GoldSim water balance)

Table 4-3 Jazga catchment: HEC-HMS model parameters in Closure Phase: Year 27

				Yr 27 (Closure)			Comments
			Natural (baseline)	Natural	Modified	Removed	
Components subject to change	Catchment Areas	JZGS02 Catchment	17.9 km²	17.9 km²	None	None	Change from Yr 21 (Operations): Power line removed and catchment restored to baseline conditions
		Oxide Tributary	1.98 km²	1.86 km²	None	0.12 km²	Change from Yr 21 (Operations): Power line, conveyor, Upper Plant and ROM removed and catchments restored to baseline conditions. No discharge from pit to river
		R. Jazga/Oxide Trib Confluence to JZGS01	1.54 km²	0.75 km²	None	0.79 km²	Change from Yr 21 (Operations): ROM, Oxide stockpile and Haul road removed and restored to baseline conditions. Lower Plant restored but now drains to the Shtuka valley. No discharge from pit to river
		JZGS01 to Reservoir & Treska	4.45 km²	4.43 km²	None	0.02 km²	Change from Yr 21 (Operations): Power line, access road and small component of Oxide stockpile removed and restored to baseline conditions. Lower Plant restored but now drains to the Shtuka valley
	Catchment Area Inputs	Evapotranspiration	Forest Canopy	Forest Canopy	N/A	N/A	All available modified areas now restored with forest cover
	Catchment Area Parameters	Canopy Storage	30 mm	30 mm	N/A	N/A	All available modified areas now restored with forest cover
	Reaches	Jazga	No losses	No losses	8 L/s	N/A	8 l/s loss to pit from Jazga River adjacent to pit (estimated from GW modelling)
	Reservoir	Ilovica Reservoir	Village & agriculture supply	Village & agriculture supply	No demand	N/A	Return to baseline reservoir water demand

Table 4-4 Jazga catchment: HEC-HMS model parameters in post-closure phase: Year 57

				Yr 57 (Post Pit Lake)			Comments
			Natural (baseline)	Natural	Modified	Removed	
Components subject to change	Catchment Areas	JZGS02 Catchment	17.9 km²	17.9 km²	None	None	Change from Yr 27 (Closure): None
		Oxide Tributary	1.98 km²	1.86 km²	0.12 km²	None	Change from Yr 27 (Closure): Pit spilling to Jazga River - modified catchment modelled in GoldSim and removed from HEC HMS model
		R. Jazga/Oxide Trib Confluence to JZGS01	1.54 km²	0.75 km²	0.83 km²	0.03 km²	Change from Yr 27 (Closure): Pit spilling to Jazga River - modified catchment modelled in GoldSim and removed from HEC HMS model. Pit catchment area increased (component from Shtuka catchment)
		JZGS01 to Reservoir & Treska	4.45 km²	4.43 km²	None	0.02 km²	Change from Yr 27 (Closure): None
	Inputs	Evapotranspiration	Forest Canopy	Forest Canopy	None	N/A	
	Parameters	Canopy Storage	30 mm	30 mm	None	N/A	
	Reaches	Jazga	No losses	No losses	GoldSim (54yr spill record)	N/A	
	Reservoir	Ilovica Reservoir	Village & agriculture supply	Village & agriculture supply	No demand	N/A	Baseline reservoir water demand

Table 4-5 Shtuka catchment: HEC-HMS model parameters in Construction Phase: Year -1

					Yr -1 (Construction)			Comments
			Sub-divisons	Natural (baseline)	Natural Catchment	Modified Catchment	Removed Catchment	
Components subject to change	Catchment Areas	STGS03 Catchment	Diversion	4.45	3.23	None	None	Diversion in place but baseline water still reports downstream therefore no change on baseline
			Diversion South		1.03	None	None	
			Diversion North		0.19	None	None	
		STGS03 - Proposed TMF Dam	TMF North	6.62	3.98	0.09	0.24	Upper Plant removed and canopy stripped for component of pit and access road
			TMF South		1.06	None	None	
			TMF		None	0.24	None	Starter Dam tailings area stripped - canopy removed
			TMF Dam		None	1.01	None	Final embankment footprint stripped
		Sushica		None	0.034	None	None	Diversion channel truncates part of Sushica catchment
		TMF Dam - STGS01		2.64	2.5	0.14	None	Canopy removed from haul and access road with SuDS style drainage
		Shtuka Village		2.4	2.26	None	0.14	Component of Lower Plant removed from catchment
	Inputs	Evapotranspiration		Forest Canopy	Forest Canopy & FAO56 Ref	FAO56 Ref Crop	N/A	FAO56 reference crop evapotranspiration used for areas with removed canopy
	Parameters	Canopy Storage		30 mm	30 mm (canopy) & 5 mm (no canopy)	5 mm & 0 mm	N/A	Canopy storage reduced from 30mm for forest cover to 5 mm for brush cover and 0 mm for dam footprint

Table 4-6 Shtuka catchment: HEC-HMS model parameters in Operations Phase: Year 21

					Yr 21 (Operations)			Comments
			Sub-divisons	Natural (baseline)	Natural Catchment	Modified Catchment	Removed Catchment	
Components subject to change	Catchment Areas	STGS03 Catchment	Diversion	4.45	3.23	None	None	
			Diversion South		1.03	None	None	
			Diversion North		None	None	0.19	Catchment now withing TMF water management area with no release to the River Shtuka
		STGS03 - Proposed TMF Dam	TMF North	6.62	None	None	3.00	Catchment now withing TMF water management area with no release to the River Shtuka
			TMF South		1.06	None	None	
			TMF		None	None	1.96	Catchment now withing TMF water management area with no release to the River Shtuka
			TMF Dam		None	None	0.6	Catchment now withing TMF water management area with no release to the River Shtuka
		Sushica		None	0.034	None	None	
		TMF Dam - STGS01		2.64	2.21	None	0.43	Access roads and area within TMF cut-off drains removed from catchment
		Shtuka Village		2.4	2.19	None	0.21	Lower plant and access roads removed from catchment
	Inputs	Evapotranspiration		Forest Canopy	Forest Canopy & FAO56 Ref Crop	N/A	N/A	FAO56 reference crop evapotranspiration used for areas with removed canopy
	Parameters	Canopy Storage		30 mm	30 mm (canopy) & 5 mm (no canopy)	N/A	N/A	Canopy storage reduced from 30mm for forest cover to 5mm for brush cover

Table 4-7 Shtuka catchment: HEC-HMS model parameters in Closure Phase: Year 27

					Yr 27 (Closure)			Comments
			Sub-divisons	Natural (baseline)	Natural Catchment	Modified Catchment	Removed Catchment	
Components subject to change	Catchment Areas	STGS03 Catchment	Diversion	4.45	3.23	None	None	Catchment restored to baseline
			Diversion South		1.03	None	None	
			Diversion North		0.19	None	None	
		STGS03 - Proposed TMF Dam	TMF North	6.62	2.93	None	0.07	Component of pit permanently removed
			TMF South		1.06	None	None	
			TMF		None	1.96	None	Restored area contributing to the River Shtuka. Tailings results in reduced permeability
			TMF Dam		None	0.60	None	Restored area contributing to River Shtuka. Embankment with different properties when compared to baseline
		Sushica		None	0.03	None	None	
		TMF Dam - STGS01		2.64	2.64	None	None	
		Shtuka Village		2.4	2.45	None	None	Gain of catchment from restored Lower Plant in baseline Jazga catchment
	Inputs	Evapotranspiration		Forest Canopy	Forest Canopy	FAO56 Ref Crop (TMF Dam Only)	N/A	FAO56 reference crop evapotranspiration used for areas with removed canopy
	Parameters	Canopy Storage		30 mm	30 mm	5 mm (TMF Dam only)	N/A	Canopy storage reduced from 30mm for forest cover to 5mm for brush cover
		Soil Percolation		10 mm/hr	N/A	0.01 mm/hr (TMF Only)	N/A	Soil percolation rate reduced to account for restored tailings conductivity of 10-8 to 10-9 m/s

5 GROUNDWATER RESOURCE MODELLING

5.1 Introduction

A regional 3D groundwater model was developed to evaluate the potential impact of mining activities on groundwater, including:

a) Impacts of mining activities, including development of the TMF and the open pit, on groundwater receptor points in and around Ilovica and Shtuka villages and in areas of irrigated agriculture on the Strumica plain.

b) The magnitude of groundwater inflows to the open pit through mine life and potential dewatering requirements.

c) The likelihood and extent of contaminant transport from the TMF in the Shtuka valley and from the oxide stockpile in the Jazga valley.

According to the ESIA methodology as described in Section 1 of the main ESIA report, the groundwater model was designed to assess the changes to the groundwater regime caused by mining activities. Subsequently this analysis was used to predict possible effects and then impacts resulting from mining.

5.2 Key source terms to be assessed

The following key source terms, as outlined in Section 1 of this Annex, were assessed as part of the groundwater modelling:

a) The open pit and associated dewatering

b) Seepage to groundwater from the TMF and embankment

c) Seepage to groundwater from the oxide stockpile

5.3 Key receptors to be assessed

A number of groundwater receptors have been designated within the framework of the ESIA, as described in Section 5 of the main ESIA report. Modelled changes to the groundwater quantity and quality at these receptors will be used to assess the significance of mining activities on groundwater supplies used for domestic and agricultural purposes. Groundwater receptors are summarised in Table 5-1. Their locations are shown in Figure 5-6 (main ESIA report).

Table 5-1 ESIA groundwater receptors and location

Receptor name	Location
Well IB19	Ilovica Village
Well IB39	Ilovica Village
Spring ISP41	Ilovica Village
Well IB30	Ilovica Village
Shallow irrigation borehole BH347	Strumica plain, between Ilovica and Turnovo
Monitoring borehole IC15113	Strumica plain, between Ilovica and Turnovo
Well SB47	Shtuka Village
Well SB57	Shtuka Village
Spring SSP49	Shtuka Village

Changes at these receptors will be assessed at specified stages of the mine operation as outlined in Table 7.1 of the main ESIA report and summarised in Table 5-2 below:

Table 5-2 Stages of mine operation at which impact will be assessed

Scenario	Mine phase	Mine year
A	Construction (baseline)	-1
B	Early operation	2
C	Mid operation	7
D	Late operation	21
E	Post closure	27

5.4 Conceptual model

A preliminary conceptual model of the regional hydrogeological regime was established and has been used as the basis for representation of hydrogeological processes in the groundwater model. This was based on the conceptual model described in Annex 3 and was subsequently refined following acquisition of additional data from hydrogeological and geotechnical investigations conducted by Euromax between January and July 2015.

The Ilovitza deposit is an alkaline copper-gold porphyry system, 1.5 km^2 in diameter, intruded into granitic country rock, and itself intruded by dacite and granodiorite porphyry stocks that have become hydrothermally mineralized and altered. The deposit is situated up gradient of Ilovitza and Shtuka villages and on the watershed between the Jazga and Shtuka rivers, two steep mountain streams draining the southern margins of the granitic Ograzhden Mountain range. The Jazga and Shtuka rivers discharge into the Strumica valley, a fault-bounded half graben which is infilled with several hundred metres of alluvial and lacustrine deposits.

Recharge across the porphyry deposit and the surrounding granite occurs as direct infiltration of rainfall. The amount of effective recharge that is able to percolate will be limited by the steep, wooded slopes that characterize the area and high rates of interception and evapotranspiration.

Groundwater level data are available from mineral exploration boreholes within the deposit itself, and from geotechnical investigation boreholes in the area of the proposed plant site (located on the plateau area to the north and above the deposit) and within the footprint of the TMF in the Shtuka valley. Additional groundwater level data are available from existing wells and boreholes in and around Ilovica and Shtuka villages and on the Strumica plain. Groundwater monitoring data indicate the following:

a) There is a hydraulic gradient across the open pit, from approximately 620 m – 650 masl under higher ground in the northeast/east to around 475 m – 500 masl in the Jazga river valley on the western edge of the deposit;
b) Hydraulic gradients in the Jazga and Shtuka valleys are typically towards the valley bottom, where groundwater discharges as baseflow into the main river channels and larger tributary streams. These river systems drain groundwater from the mountain catchments to the Strumica Plain. It is believed that a significant volume of streamflow is transmitted within the highly fractured, high conductivity zone that occurs along the main axis of each river valley.
c) The fractured granite aquifer in the upland parts of the Jazga and Shtuka catchments is connected to and drains into alluvial deposits in the lower catchment areas, and ultimately into the Strumica plain further down gradient.

Groundwater storage and flow within both the porphyry deposit and granite is controlled almost exclusively by the degree of fracturing that occurs in each rock type. Water level data and packer testing indicate that the upper horizons of the deposit (approximately coincident with the oxide zone) are relatively highly weathered and/or fractured, and are therefore relatively well drained. Packer test data indicates that the underlying rocks (suphides) have a lower permeability and likely comprise a very inactive groundwater zone. Effective porosity in this zone is expected to be extremely low.

The granite host rocks in the upper Jazga and Shtuka catchment areas shows similar characteristics to the porphyry deposit, i.e. high degree of fracture permeability in near-surface layers reducing to low or negligible permeability with increasing depth below ground level. The thickness of the fractured, unconfined granite aquifer is likely to vary from tens of metres to over 100 m depending on the degree and distribution of weathering in the granite surface. The main axis of the Shtuka valley is highly faulted and fractured and is believed to form a highly conductive corridor that has an important role in draining the upper catchment area and in transmission of both surface water and groundwater to the alluvial deposits further down gradient. Similar conditions are likely to exist in the Jazga valley.

The Shtuka and Jazga valleys discharge to the Strumica valley which is filled with a mixture of alluvial and lacustrine material consisting of interbedded clays, silts, sands and gravels with a combined thickness of several hundreds of metres. These form an important aquifer system that is exploited for domestic and agricultural water supplies. A shallow unconfined aquifer (generally less than 10 m thick) supports numerous small irrigation boreholes. The deeper, confined aquifer is also exploited for agricultural water supplies, with artesian boreholes having piezometric heads that vary from around 1 to 6 m above ground level within the project study area.

5.5 Modelling Approach

5.5.1 Model code selection

The groundwater model was developed using the industry standard finite difference groundwater modelling code MODFLOW. A variant of the code, MODFLOW VKD, was used to represent the reduction of hydraulic conductivity and storage with depth within the orebody and surrounding country rock in order to represent the conceptual model of groundwater flow in the vicinity of the open pit and TMF.

5.5.2 Model geometry and layering

The model domain encompasses both the Jazga and Shtuka catchments. To appropriately model groundwater conditions to either side of these catchments, the model domain was extended into neighbouring catchments (Figure A5.1). To the north the model boundary follows the headwater catchment boundaries of the Jazga and Shtuka Rivers. The eastern model boundary continues to follow the Shtuka catchment divide southwards, before following the Suchica catchment divide and then neighbouring catchments south to the town of Novo Selo. The southern boundary follows the Strumica River briefly, before looping south to incorporate the area around the town of Monospitovo and Monospitovo wetland area. Monospitovo wetland has not been explicitly modelled as it was considered to be outside of the area of interest for the current ESIA. The boundary then re-joins the Strumica North of Dabilje, before heading East to just beyond Bosilovo. The western model boundary runs North along the Causica stream.

The model includes 3 distinct layers:

a) Layers 1 and 2 represent the valley floor colluvial and alluvial deposits. The upper of these layers represents the shallow aquifer system primarily used for domestic and agricultural abstraction. Layer 2 represents the deeper, artesian aquifer system and is therefore confined, with limited vertical connectivity to Layer 1.

b) Layer 3 contains both the granite host rock and the gold-copper porphyry deposit in the upper Jazga and Shtuka catchments. This layer incorporates changes to both hydraulic conductivity and storage with depth to represent the shallow weathered zone, transitioning to fresh bedrock at depth. Hydraulic properties assigned to these layers were based on available data and were refined to observed data during model calibration. Model calibration is discussed further in Section 5.6.

The model grid was refined to 20 m x 20 m within the principal areas of interest:

a) Ilovica and Shtuka villages and the Strumica plain, where the majority of groundwater receptors are situated.
b) The proposed open pit and the oxide stockpile area in the Jazga valley.
c) The proposed TMF in the Shtuka valley.

The grid size gradually increases towards the edges of the model domain to a maximum cell size of approximately 500 m x 500 m.

5.5.3 Boundary conditions

Boundary conditions were based upon the conceptualisation of hydrogeological system and nature of the model domain boundary.

Streams

The MODFLOW stream package was used to represent all riparian networks throughout the model domain. The stream package allows stream boundary condition cells to gain water from, and to lose water to, the groundwater system. It is therefore possible to model both losing and gaining streams, and for stream reaches to run dry if loss to groundwater exceeds streamflow from upstream. In addition, the stream package tracks the volume of water transmitted through the stream network and so allows the model to be calibrated against field streamflow measurements.

No flow boundaries

No flow boundaries were used to model catchment divides. In the groundwater model these are present along the external Jazga, Shtuka and Suchica catchment boundaries (Figure A5.1).

Constant heads

Constant heads were used sparingly in the groundwater model, primarily to generate the baseline natural head gradient from northwest to southeast along the Strumica plain. Constant heads were applied to short sections of the western and eastern boundaries in Layers 1 and 2 (Figure A5.1). Observed groundwater level data were used to determine the constant heads that should be applied.

Inflows to the open pit

The MODFLOW drain package was used to simulate groundwater inflows during excavation of the open pit. The pit design was provided to SWS by DMT as 4 pit shells, detailed in Table 5-3. Yearly interim pit shells were interpolated to generate a smooth transition between pit shells to improve numerical model stability.

Table 5-3 Pit Shells available for simulation of pit development

Pit shell name	Mine year
Pre-Strip	-1
Starter pit	2
First pushback	7
Final pit shell	21

5.5.4 Material properties

Initial hydraulic properties for the granite host rock and the porphyry deposit were based on the results of packer tests carried out in investigation boreholes drilled in the area of the ore body and TMF footprint. A summary of the results obtained from exploratory hydrogeological and geotechnical drilling and testing is given in the Annex 3 and in the FS report (Euromax Resources, press release dated 6th January 2016). Since a significant difference in permeability between the granite host rock and porphyry deposit was not apparent in the data the same starting hydraulic properties were used. These were then modified independently during calibration.

Limited data were available to estimate initial hydraulic properties for the alluvial valley fill in the Strumica plain. Estimates were initially made based upon literature values according to the nature of the valley fill material (e.g. as observed during drilling of investigation borehole IC15111), and were then refined during calibration to observed data.

Initial material properties are presented in Table 5-4.

Table 5-4 Initial material properties

Parameter	Representing	Parameter Value
LAYER 3 - Granite and deposit		
High hydraulic conductivity	Fractured Granite	1.00E-06 m/s
Low K (Kbase)	Fresh Granite	2.00E-08 m/s
High Specific Yield		0.05
Low Specific Yield		0.005
Thickness of high K zone	Weathered, fractured surface layer	30 m
Thickness of transition zone	Reducing fractures	120 m
LAYER 2 – Lower Strumica valley alluvium/ colluvium		
Uniform K	Lower alluvium with clay layers	1.00E-06 m/s
Specific Yield		0.02
LAYER 1 – Upper Strumica valley alluvium/ colluvium		
Uniform K	Upper Alluvium	1.00E-06 m/s
Vertical anisotropy factor	Between layer 1 and 2	1
Specific Yield		0.02

5.5.5 Recharge

Recharge rates were defined by sub-catchment using output from the baseline HEC-HMS surface water modelling (Section 4) in order to couple both surface water and groundwater models. Recharge sub catchments are shown in Figure A5.2.

The HEC-HMS model used soil moisture accounting to estimate stream baseflows for given areal rainfall data. For the Jazga and Treska catchments upstream of Ilovica reservoir and the Shtuka catchment upstream of STGS03, calibration in HEC-HMS was performed using the "linear reservoir" baseflow module which conserves mass in the model. The "GW1 percolation rate" estimated by the HEC-HMS modelling is reflective of recharge to groundwater after evaporative, surface storage and interflow (flow in the shallow sub-surface to the river) losses and was therefore used as an estimate of groundwater recharge.

Over the alluvial deposits in the Strumica plain (including the remaining Jazga catchment downstream of the reservoir) and the Shtuka catchment downstream of STGS03 there is much uncertainty as to the hydrological behavior of these catchments. Measured data suggests they are hydrologically inactive other than during prolonged wet periods (described in more detail in Annex 3). The "linear reservoir" module was not used for these catchments as interflow was not considered a significant component of flow into the streams. Therefore the modelled "soil percolation rate" was used to estimate average groundwater recharge as this reflected potential recharge after evaporative and soil storage losses.

5.6 Model calibration

5.6.1 Calibration criteria and methodology

The model was calibrated to groundwater levels and stream flow data for the period 2014 to mid-2015. Sub catchment rainfall data were available for this period.

A steady state groundwater model was developed to calibrate the groundwater model to average data and to provide initial heads for the transient model. The steady state model utilises averaged daily sub-catchment recharge rates from the 2014-2015 period. Overspill rates for the Ilovica reservoir were also averaged to generate a representative rate of flow into the Jazga. Model properties such as hydraulic conductivity and the thickness of the high hydraulic conductivity zone and transition zone in Layer 3 were adjusted to achieve a calibration to groundwater levels measured in piezometers and boreholes located in the key areas of interest:

a) The proposed open pit area
b) The proposed TMF footprint
c) Ilovica and Shtuka villages
d) Strumica plain

Once a reasonable steady state calibration was achieved for the majority of groundwater targets the transient model was set up using monthly stress periods with daily time steps. Transient recharge data from 2014-2015 were applied to the model and further refinement of the hydraulic properties was carried out. In addition to groundwater levels, computed stream flows were also compared to measured stream flow data recorded at surface water gauging stations on the Jazga River (JZGS01, JZGS02, JZGS03) and Shtuka River (STGS01, STGS02, STGS03).

5.6.2 Calibrated model properties

The final calibrated hydraulic properties are shown in Table 5-5 and include distinct zones of hydraulic properties that were added to Layer 3 of the model during calibration. These were added to improve the representation of

hydraulic properties in the area of the open pit and along the bottom of the Jazga and Shtuka river valleys as follows:

a) The hydraulic conductivity of the oxidised zone and underlying sulphide zone of the deposit was increased, reflecting both chemical alteration of the material and material deformation as a consequence of the porphyry emplacement.

b) Corridors of higher hydraulic conductivity were added along the main axes of the river valleys to simulate the highly fractured granite observed in both field packer tests, in electrical resistivity geophysical surveys and as interpreted from analysis of the surface water flow regimes in both valleys.

Table 5-5 Summary of final calibrated hydrogeological parameters used in the 3D groundwater model

Parameter	Representing	Parameter Value
LAYER 3 – GRANITE COUNTRY ROCK		
High K (Kmax)	Fractured Granite	1.00E-06 m/s
Low K (Kbase)	Fresh Granite	1.00E-08 m/s
High Specific Yield		0.02
Low Specific Yield		0.005
Thickness of high K zone	Weathered, fractured surface layer	10 m
Thickness of transition zone	Reducing fractures	70 m
LAYER 3 – HIGH K RIVER VALLEY FLOOR		
High K (Kmax)	Weathered, fractured surface layer	1.00E-04 m/s
Low K (Kbase)	Fresh bedrock	2.00E-08 m/s
High Specific Yield		0.2
Low Specific Yield		0.005
Thickness of high K zone		30 m
Thickness of transition zone	Reducing fractures	100 m
LAYER 3 – PORPHYRY DEPOSIT		
High K (Kmax)	Fractured rock	2.00E-06 m/s
Low K (Kbase)	Fresh rock	2.00E-08 m/s
High Specific Yield		0.02
Low Specific Yield		0.005
Thickness of high K zone	Weathered, fractured surface layer	50 m
Thickness of transition zone	Reducing fractures	100 m
LAYER 2 – STRUMICA PLAIN		
Uniform K	Lower Alluvium with clay layers	5.00E-06 m/s
Specific Yield		0.02
LAYER 1 – STRUMICA PLAIN		
Uniform K	Upper Alluvium	5.00E-05 m/s
Vertical anisotropy factor	Between layer 1 and 2	0.01
Specific Yield		0.02

5.6.3 Calibration to groundwater levels

The proposed pit area.

Calibration plots for targets in the open pit area are presented in Figure A5.3. Despite the steep terrain and significant groundwater gradients in this area, a reasonable calibration was achieved for most targets. The nature of the terrain and the complexity of the geology is responsible for the large residuals shown by several boreholes. For the purposes of estimating pit dewatering rates and impacts on nearby receptors, however, a reasonable calibration at the majority of boreholes was considered sufficient to ensure that the baseline modelled water levels and the hydrogeological regime are representative of general conditions.

The proposed TMF footprint

Calibration plots for targets located within the footprint of the TMF are presented in Figure A5.4. A satisfactory calibration was achieved for most targets in the TMF area, with the exception of TMF003 and TMF011, indicating that the groundwater model adequately represents baseline groundwater levels over most of the TMF footprint.

Ilovica and Shtuka villages

Calibration plots for targets located around Ilovica and Shtuka villages are presented in Figure A5.5. A good calibration was achieved for receptors in Shtuka Village (SB57 and SB47). The model overestimates water levels at receptor IB39 at Ilovica village by approximately 6 m. However, the model does show a good calibration to the up gradient Ilovica groundwater receptor IB19, which is located close to the Jazga River.

Strumica Valley

Calibration plots for targets located in the Strumica valley are presented in Figure A5.6. Modelled piezometric levels in the deeper, confined aquifer (Layer 2) are generally within 3 m of observed water levels, and the majority show a residual of less than 1 m. Computed water levels for receptors in the shallow, unconfined alluvium (Layer 1 – boreholes IC15113 and BH347) show close matches to observed groundwater levels, with residuals of 0.1 – 0.4 m and 0.25 m respectively.

5.6.4 Calibration to stream flows

Appropriate representation of the river networks was necessary to adequately model a potential pathway between the TMF source and groundwater receptors downstream in Ilovica and Shtuka villages and on the Strumica plain.

Jazga Valley

Stream flows were recorded in the calibrated model at gauging stations JZGS01, JZGS02 and JZGS03. Modelled and observed stream flows at each gauging station are presented in Figure A5.7. Modelled low flows at each station are in general slightly higher than observed, however the seasonal variation in stream flows is well represented.

Shtuka Valley

Modelled stream flows were exported from the model at the location of all of the gauging stations along the Shtuka River. Modelled and observed stream flows stream flows at each gauging station are presented in Figure A5.8. The match to observed flows is generally good with the exception of STGS01 and STGS02, located downstream of the proposed TMF facility and just upstream of the confluence between the Shtuka and Strumica Rivers respectively. In these instances, seasonal trends are well represented, as are peak flows, however baseflow is

significantly higher than that recorded at the gauging stations. This is thought to be due to the stream boundary conditions in the groundwater model picking up flows that in reality may occur within the stream bed itself, since the underlying granite is heavily fractured and capable of supporting a significant component of the catchment flow beneath ground level.

5.7 Predictive model development

5.7.1 Predictive model setup

The predictive model represents all mining activities that have the potential to affect the groundwater regime, as described in Section 5.2. The model has been used to predict changes to the groundwater regime caused by mining activities at the designated groundwater receptors.

A number of additions and modifications were made to the historical model in order to set up a predictive groundwater model representing the operational period of mining. These were as follows:

a) *The proposed open pit*. As discussed in Section 5.5.3, time variant drain boundary conditions were used to lower the groundwater level to that of the proposed and interpolated pit floor elevations through operational mine life. This was designed to represent a passive dewatering system.

b) *TMF and associated modification of the Shtuka stream network.* The TMF was introduced as a recharge boundary incorporating seepage rates defined in the TMF water balance model (Section 3) for both the embankment footprint and the tailings deposition area. Three progressively larger TMF footprints were used, corresponding to the starter dam at 645 masl, downstream raise to 720 masl and the downstream raise to 772 masl, approximately equivalent to mine years 1, 8 and 19 respectively. Total seepage by unit area was calculated such that additional seepage generated through expansion of the facility was accounted for between footprint configurations.

c) *Streams*. Streams within the footprint of the TMF were removed to simulate diversion of the Shtuka River around the TMF and the restriction on groundwater baseflow imposed by infilling stream channels with low permeability tailings. The Shtuka River diversion was simulated by routing the flow in the Shtuka from the coffer dam directly to the proposed river diversion inflow point just south of the Storm Runoff Drain. It was not necessary to represent the river diversion channel explicitly in the groundwater model since the diversion is assumed to be lined and therefore should not interact with groundwater.

d) *Oxide stockpile*. A recharge boundary was added to simulate seepage from the base of the oxide stockpile. Recharge rates were calculated using a 1D finite element seepage model of the facility. The model calculates surface recharge to a representative thickness of oxide stockpile material to generate approximate seepage rates from its base by unit area. Seepage rates in the 3D groundwater model were scaled up to account for the entire stockpile footprint. A description of the 1D oxide stockpile seepage model, is included in Section 3.2.2.

Yearly stress periods were used in the predictive model. A yearly average catchment recharge was calculated from the 54 year historical rainfall record. Sensitivity analyses were run to study the impact of variations in recharge at the receptors and are described in Section 5.7.2.

5.7.2 Predictive model results

Predicted groundwater heads

Predicted groundwater levels before mining (year -1) and at year 21 of mine life are shown in Figures A5.9 and A5.10 respectively. By the final year of pit operation (Year 21), groundwater levels will be drawn down to just below

the pit floor at 260 m amsl. This is equivalent to ground surface elevation of the Strumica plain just south of Ilovica and Shtuka villages. However, owing to the very low permeability of the surrounding granite host rock, the extent of the cone of depression caused by lowering groundwater levels within the pit is likely to be limited.

Modelled changes to groundwater receptors

The change to groundwater levels at the specified groundwater receptors resulting from mining activities is in all instances extremely limited throughout mine life. The predicted maximum change in groundwater levels within Ilovica and Shtuka villages during mine operation is approximately 0.01 m. Predicted impacts at individual receptors (locations shown in Figure 7.2 of the main ESIA report) are summarised in Table 5-6.

Table 5-6 Summary of groundwater levels (masl) at designated receptors prior to the mine operation (A) and during operational mine life (B, C and D).

Receptor name	Location	A- Mine year -1	B – Mine year 2	C-Mine year 7	D-Mine year 21
Well IB19	North Ilovica Village	301.85	301.85	301.85	301.85
Well IB39	North Ilovica Village	281.36	281.36	281.36	281.36
Spring ISP41	North Ilovica Village	273.27	273.27	273.27	273.27
Well IB30	South Ilovica Village	274.91	274.91	274.91	274.91
BH347	Ilovica and Turnovo	229.50	229.50	229.50	229.50
Monitoring borehole IC-15-113	Ilovica and Turnovo	227.25	227.25	227.25	227.25
Well SB47	Shtuka Village	306.62	306.63	306.63	306.63
Well SB57	Shtuka Village	282.69	282.69	282.69	282.69
Spring SSP49	Shtuka Village	295.40	295.39	295.39	295.39

Predicted pit inflow rates

Predicted pit inflow rates are presented in Figure A5.11. The groundwater model indicates that pit inflow rates could range from approximately 15 l/s for the starter pit (Year 2), 22 l/s at the first pushback (Year 7) and up to a maximum of approximately 32 l/s for the final pit (Year 21). Inflow rates to the pit are likely to be sufficiently low to be managed using a passive dewatering system, since the low permeability nature of the rock in and around the open pit means that the resulting cone of depression does not extend far beyond the open pit. The low permeability of the surrounding rock would also preclude the use of boreholes for dewatering. However effective runoff and seepage water management will be required to maintain a dry pit, particularly once the excavation reaches the elevation of the baseline water table. This lies at an elevation of approximately 660 masl on the eastern side of the pit and at approximately 500 masl in the centre of the proposed pit footprint.

Modelled changes to river flows

The groundwater model predicts a reduction in flow in the River Jazga at JZGS01 from 130 l/s at baseline to 119 l/s in mine year 21, i.e. a reduction of approximately 10%. This loss consists of two components:

a) The reduction in size of the pit catchment recharge entering the river due to the presence of the pit, and;

b) The loss of water flow through the stream bed in the vicinity of the mine due to drawdown of groundwater levels within the pit.

Movement of water from the stream to the pit will be controlled by the nature of the granite that separates the stream bed from the pit wall and its hydraulic connectivity. There was limited data available to inform this at the time of modelling, therefore an initial estimation was made and further investigation is recommended. It is important to note that blasting in the pit could enhance fracturing in the vicinity of the pit wall which may result in localised increases in hydraulic conductivity and connectivity, potentially leading to an increase in the volume of stream flow lost to the pit as it is mined out.

The Shtuka River downstream of the TMF at STGS01 and STGS02 is predicted to gain in total flow throughout the majority of the mine operation. The magnitude of the increase reflects the rate of seepage from TMF, which peaks in mine years 10, 11 and 12. However stream flows at both gauges return to pre-mining baseline levels, and by mine year 23, streams flows are predicted to be 15 l/s lower than at pre-mine baseline levels. This reduction in flow is due to two factors:

a) the reduction in seepage from TMF which decreases with time, and;
b) the removal of the stream network under the footprint of the TMF, which effectively reduces the size of the upstream catchment.

In parallel to this, the removal of the Shtuka River and its tributary streams beneath the tailings footprint will reduce the efficiency of the valley drainage system in the groundwater model. It was found during modelling that the corridor of elevated hydraulic conductivity along the valley floor was not sufficient to remove all the inflow from the catchment. This results in a build-up of groundwater beneath and to the sides of the TMF during mine operation and post-closure which may need to be drained to prevent increases in pore pressure within the facility and/or overtopping of the embankment along the sides of the facility. Further modelling is necessary to better and more reliably simulate the effect and impact of the TMF on the local hydrogeological regime.

Sensitivity to climate

A number of sensitivity runs were conducted to establish whether the effects of mining activities at groundwater receptors would be greater during periods of extreme weather.

The scenarios were set up to simulate a single year of extreme drought, which was represented in the model by removing all recharge. A total of 4 sensitivity models were developed, each representing a drought occurring during a requisite year for impact assessment to groundwater receptors as shown in Table 5-7.

Table 5-7 Summary of sensitivity analysis scenarios

Sensitivity analyses	Scenario	Mine phase	Drought in mine year
1	A	Construction (drought baseline)	-1
2	B	Early operation	2
3	C	Mid operation	7
4	D	Late operation	21
5	E	Post closure	27

Drought conditions induced significant reductions in baseline water levels, as demonstrated by the reduction of water levels at designated receptors during drought conditions (Table 5-8 Scenario A-drought) compared with baseline water levels (Table 5-8 Scenario A-average recharge). However even under extreme drought conditions there is predicted to be negligible additional change to groundwater levels caused by mining activities at the designated receptors, beyond that induced by the drought itself.

Table 5-8 Summary of groundwater impacts at designated receptors, sensitivity analyses groundwater levels (masl) versus predictive model baseline groundwater levels (masl).

Receptor name	Location	A: Year -1 Baseline groundwater levels	A: Year -1 Drought scenario	B: Year 2 Drought Scenario	C: Year 7 Drought Scenario	D: Year 21 Drought Scenario
Well IB19	North Ilovica Village	301.85	301.45	301.45	301.45	301.45
Well IB39	North Ilovica Village	281.36	280.27	280.27	280.27	280.27
Spring ISP41	North Ilovica Village	273.27	272.45	272.45	272.45	272.45
Well IB30	South Ilovica Village	274.91	272.86	272.86	272.86	272.86
BH347	Ilovica and Turnovo	229.50	226.96	226.96	226.96	226.96
Monitoring borehole IC-15-113	Ilovica and Turnovo	227.25	224.91	224.91	224.91	224.91
Well SB47	Shtuka Village	306.62	306.44	306.45	306.45	306.44
Well SB57	Shtuka Village	282.69	281.99	281.98	281.98	281.98
Spring SSP49	Shtuka Village	295.40	295.15	295.14	295.14	295.14

5.8 Closure model

5.8.1 Closure model setup

A closure model was developed to simulate closure of the mine and recovery of the hydrogeological regime.

The closure model runs over a duration of 100 years using yearly stress periods of average recharge, as in the predictive model. At the time of writing, SWS is not aware of any modelling that has been undertaken of post closure seepage from the TMF. Therefore, in the closure model seepage from the TMF and the TMF embankment has been maintained at closure levels for a period of 10 years, before being reduced by a factor of 10 to simulate drain-down of stored water within the facility. It is expected that additional seepage modelling will need to be undertaken to address this data gap.

Drain boundary conditions representing the pit were removed from the model, allowing groundwater levels to recover. Streams in the TMF area were kept consistent with the predictive model as it was assumed that surface water management across the TMF and Shtuka diversion channel would remain in place at closure.

5.8.2 Closure model Results

A relationship between water level within the pit area and groundwater inflow through the pit walls as the groundwater levels recover in the pit area was exported from the model and used to inform the pit filling model built using GoldSim. The GoldSim model combines groundwater inflows with surface water runoff in order to produce a pit lake filling curve (Figure A3.2).

Changes to groundwater levels at the receptors in Ilovica and Shtuka villages and the Strumica plain caused by mining activities continue to be minimal through closure, as demonstrated in Table 5-9.

Table 5-9 Summary of groundwater levels (masl) at designated receptors prior to the mine operation (A), during operational mine life (B, C and D) and post-closure (E).

Receptor name	Location	A: Year -1	B: Year 2	C: Year 7	D: Year 21	E: Year 27
Well IB19	North Ilovica Village	301.85	301.85	301.85	301.85	301.85
Well IB39	North Ilovica Village	281.36	281.36	281.36	281.36	281.36
Spring ISP41	North Ilovica Village	273.27	273.27	273.27	273.27	273.27
Well IB30	South Ilovica Village	274.91	274.91	274.91	274.91	274.91
BH347	Ilovica and Turnovo	229.50	229.50	229.50	229.50	229.50
Monitoring borehole IC-15-113	Ilovica and Turnovo	227.25	227.25	227.25	227.25	227.25
Well SB47	Shtuka Village	306.62	306.63	306.63	306.63	306.63
Well SB57	Shtuka Village	282.69	282.69	282.69	282.69	282.69
Spring SSP49	Shtuka Village	295.40	295.39	295.39	295.39	295.39

The sensitivity analysis also showed minimal impact post-closure, as shown in Table 5-10.

Table 5-10 Summary of groundwater impacts at designated receptors, sensitivity analyses groundwater levels (masl) versus predictive model baseline groundwater levels (masl) including post closure.

Receptor name	Location	A: Year -1 Baseline groundwater levels	A: Year -1 Drought scenario	B: Year 2 Drought scenario	C: Year 7 Drought scenario	D: Year 21 Drought scenario	E: Year 27 Drought scenario
Well IB19	North Ilovica Village	301.85	301.45	301.45	301.45	301.45	301.45
Well IB39	North Ilovica Village	281.36	280.27	280.27	280.27	280.27	280.27
Spring ISP41	North Ilovica Village	273.27	272.45	272.45	272.45	272.45	272.44
Well IB30	South Ilovica Village	274.91	272.86	272.86	272.86	272.86	272.86
BH347	Ilovica and Turnovo	229.50	226.96	226.96	226.96	226.96	226.96
Monitoring borehole IC-15-113	Ilovica and Turnovo	227.25	224.91	224.91	224.91	224.91	224.91
Well SB47	Shtuka Village	306.62	306.44	306.45	306.45	306.44	306.44
Well SB57	Shtuka Village	282.69	281.99	281.98	281.98	281.98	281.98
Spring SSP49	Shtuka Village	295.40	295.15	295.14	295.14	295.14	295.14

5.9 Contaminant Transport Modelling

5.9.1 Introduction

The solute transport modelling code MT3DMS was used to model contaminant transport from the TMF and oxide stockpile. Advection is considered to be the most significant form of transport for a fracture dominated flow system. For this reason, and because there is little data available with which to define parameters, diffusion and dispersion effects were not modelled.

Sulphate concentrations were modelled during the contaminant transport modelling. Sulphate was selected as it is predicted to occur at relatively high concentrations in the TMF and embankment areas. From these results the plume migration for all other contaminants could be estimated in relative proportions.

5.9.2 Model set up

Background concentrations were assumed to be zero for the purposes of the groundwater modelling, since insufficient data exists to define and calibrate to background concentrations satisfactorily. The MT3D model output was therefore used to provide a conservative indication of the magnitude of increase in concentration as a result of mining, as opposed to providing absolute concentrations.

Concentrations were assigned to the recharge rates applied to the groundwater flow model to represent seepage from the TMF, embankment and oxide stockpile. Seepage concentrations were defined based on laboratory test data and geochemical models and are described in Section 6. Annual estimates of average concentration for the three areas of interest (TMF, TMF embankment and the oxide stockpile) were used. The model was run with a daily transport time step size in order to improve model stability.

5.9.3 Operational model results

The results of the MT3D modelling are shown in Figure A5.12 for years -1, 2, 7 and 21 of mine life. The model predicts that a plume will develop due to seepage from the oxide stockpile and TMF areas. With time the main plume, emanating from the TMF, migrates southwards following the zone of higher hydraulic conductivity along the Shtuka river channel. The highest concentrations are not seen to migrate beyond the extent of the TMF during mine life, remaining within the lower conductivity material. A smaller plume also develops from the oxide stockpile.

It should be noted that it is not possible within the current model to represent fracture flow, since there is little known about the degree of fracturing within the valleys. As such plume migration is controlled in the model by the bulk hydraulic conductivity properties assigned to the model, and migration of contaminants through individual fault structures is not represented.

5.9.4 Closure model results

Predicted plume migration during closure for years 5, 10, 15, 20, 30 and 50 post closure is presented in Figure A5.13. The concentration of the plume is seen to reduce following closure due to the lower seepage rates from the TMF and embankment area and freshening from the upstream catchment groundwater flow.

5.9.5 Outputs from contaminant transport modelling

Modelled groundwater concentrations at selected points along the Jazga and Shtuka were exported from the contaminant transport model to inform geochemical analysis (Section 6). Groundwater concentrations were exported at the key groundwater receptors, plus JZGS01 and STGS01 gauging stations and selected points upstream of these gauging stations, as shown on Figure A5.14.

5.10 Sensitivity Analysis

A sensitivity analysis was conducted to evaluate confidence in model outputs. Estimated pit dewatering rates were found to be most sensitive to the hydraulic conductivity assigned to the porphyry deposit, whereas effects on groundwater levels at receptors and travel time of the contaminant plume were more sensitive to the hydraulic conductivity assigned to the granite country rock. It should be noted however that changes made to the model during sensitivity analysis took the model out of its calibrated state, therefore although results can be used to highlight uncertainties, less confidence should be applied to these model results without further re-calibration.

Sensitivity to the seepage rate from the TMF was also investigated. Increasing the rate of seepage from the TMF and embankment by 10% was found to increase the maximum concentration within the contaminant plume but there was little change to the extent of the plume in this scenario when compared to the base case.

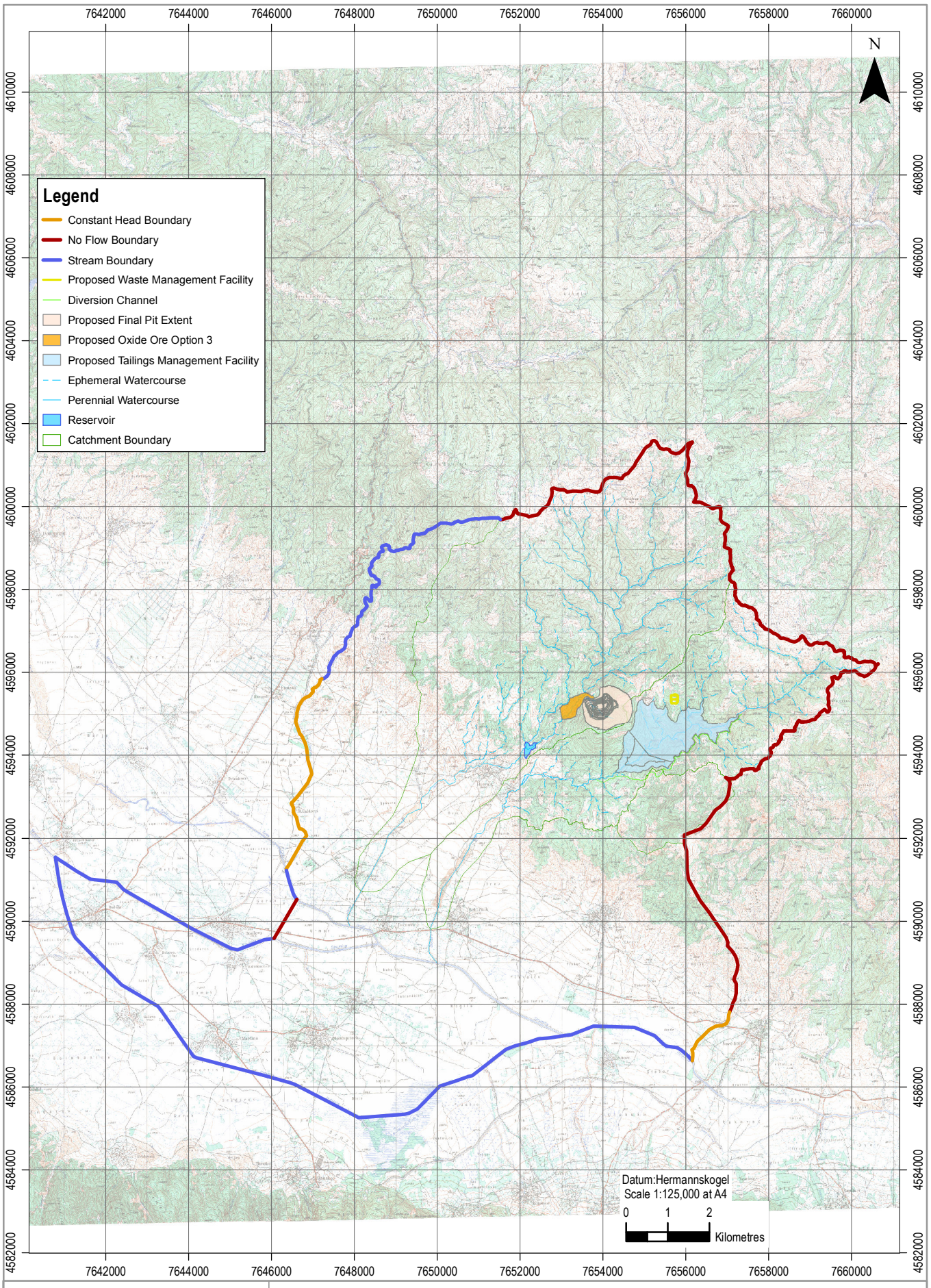
5.11 Linked considerations

As detailed in previous sections, inputs from several other aspects of the ESIA study were used to provide inputs to the 3D groundwater model. These are summarised as follows:

a) Outputs from the surface water resource modelling undertaken using HEC-HMS (Section 5) were used to define the catchment recharge zones and recharge rates used in the groundwater model
b) Results from the VADOSE/W modelling (Section 3) were used to provided estimates of seepage rate from the oxide stockpile during operational mine life
c) The GoldSim water balance model (Section 3) was used to provide the estimates of seepage rate from the TMF and TMF embankment used in the predictive groundwater model.
d) Geochemical modelling outputs (Section 6) were used to provide estimates of concentrations assigned to seepage from the oxide stockpile and TMF and embankment in the contaminant transport modelling

Results were exported from the groundwater modelling to provide input to the following aspects of the study:

a) Contaminant transport modelling was used to predict the development of the plume and associated estimates of groundwater concentrations at downstream receptors, including baseflow to streams, for input into the geochemical modelling (Section 6).



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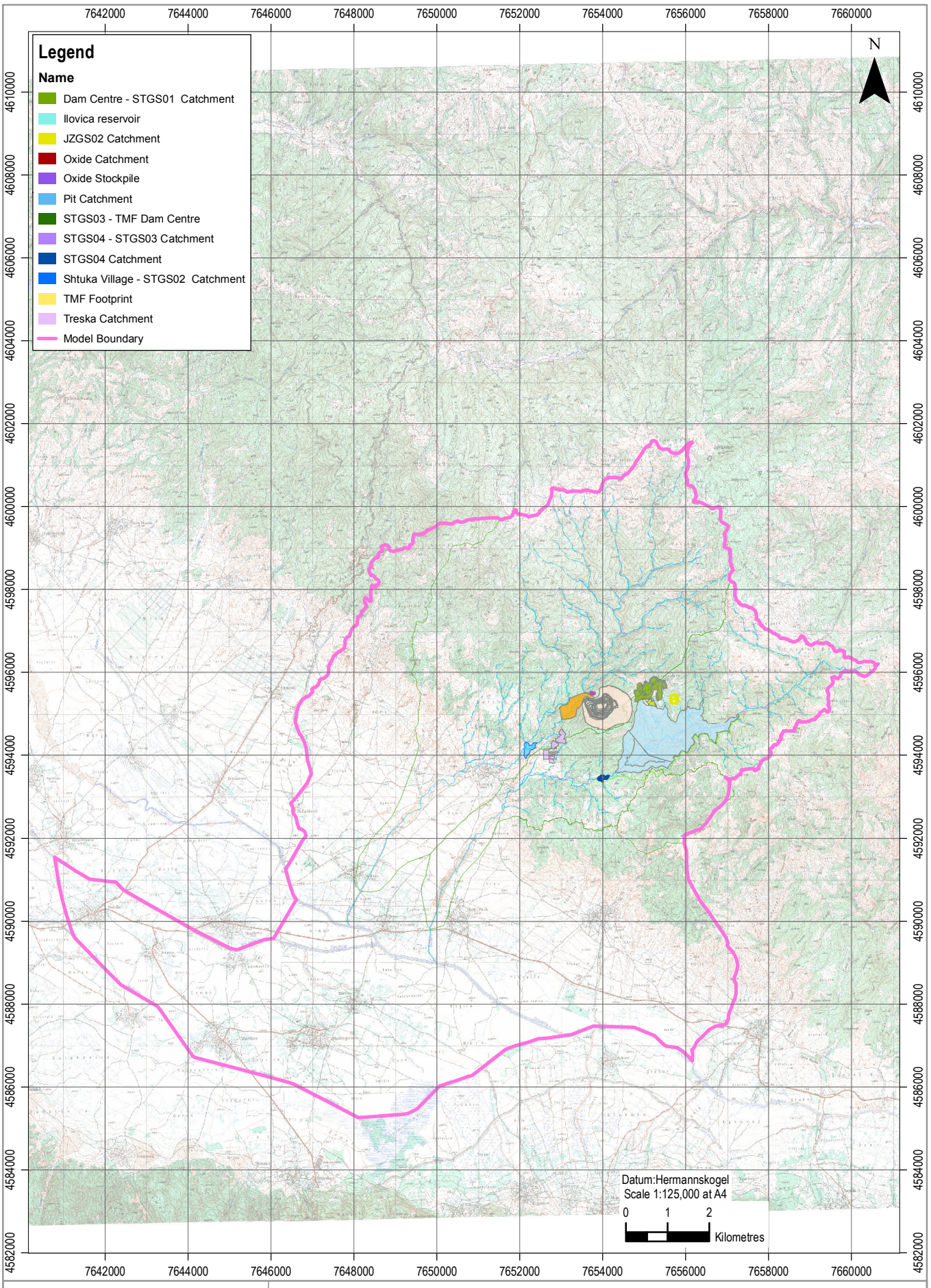
External boundary conditions to groundwater model domain by type

PROJECT:	Ilovica Gold-Copper Project	FIGURE #:	A5.1
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT #:	55459_R1v2
DRAWN: SD	CHECKED: RM	DATE:	January 2016

Document Path: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\540_Models\003_Ilovica_3D_model\7_Post_Processing_for_Deliverables\Figure_A5.1_Model_boundaries_Basemap_Site_Layout_v9_and_v6_EIA_4-11-2015.mxd

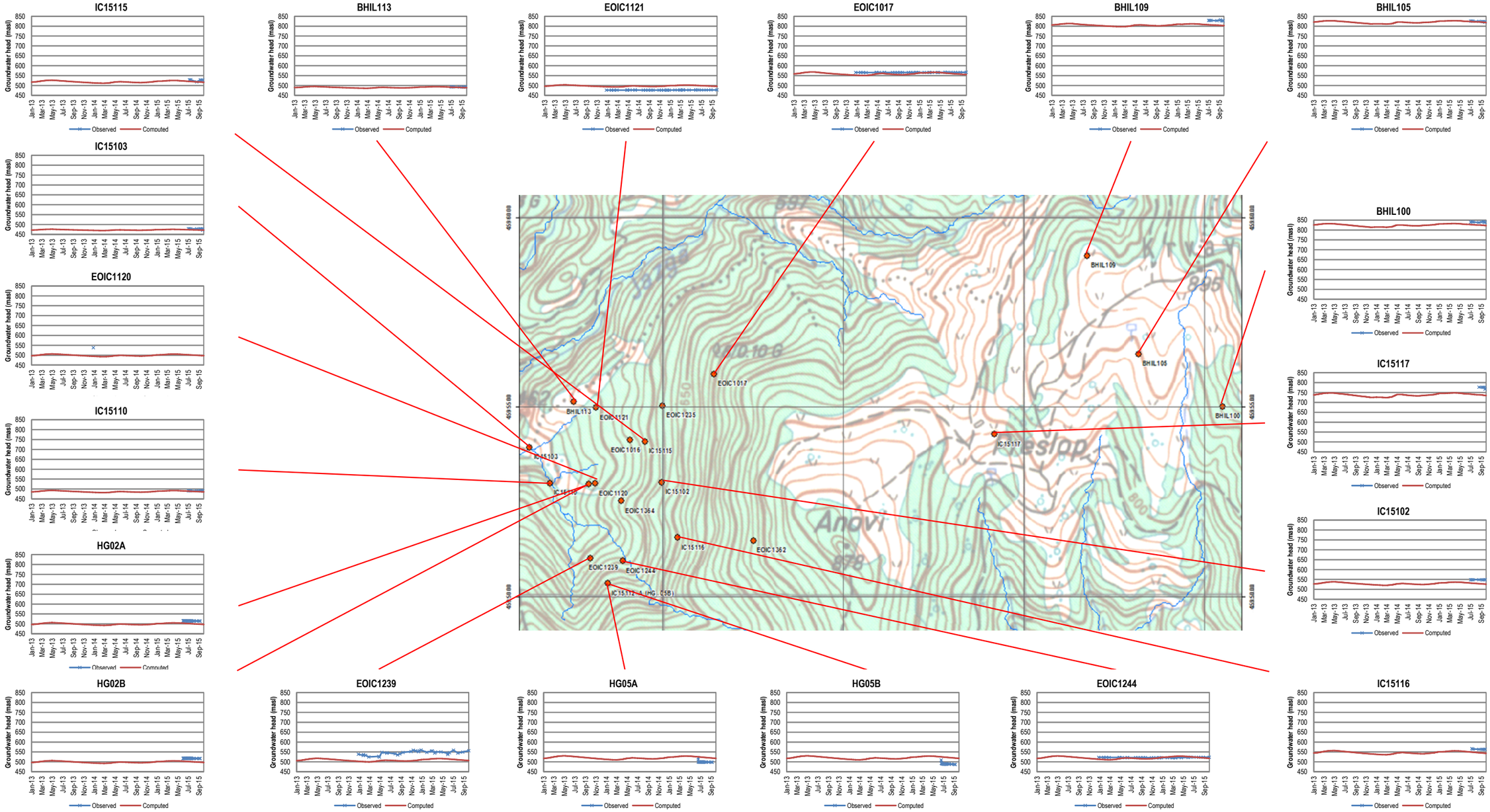


Schlumberger Water Services

Groundwater model recharge sub-catchments

PROJECT:	Ilovica Gold-Copper Project		FIGURE #: A5.2
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT #: 55459_R1v2
DRAWN: SD	CHECKED: RM		DATE: January 2016

Document Path: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\540_Models\003_Ilovica_3D_model\7_Post_Processing_for_Deliverables\Figure_A5.2_Recharge_zones_Basemap_Site_Layout_v9_and_v6_EIA_4-11-2015.mxd

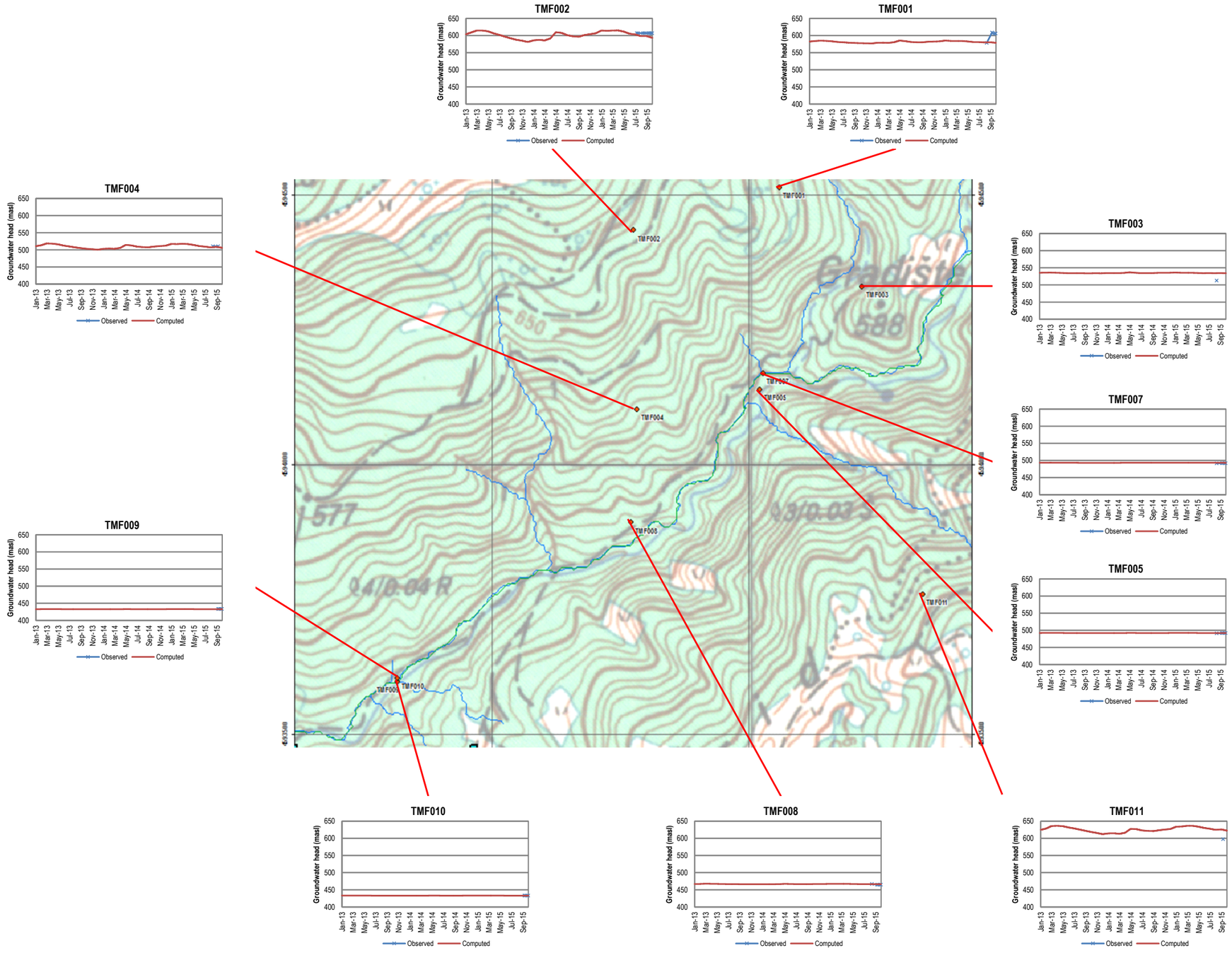


Groundwater level calibration plots, proposed pit and plant site area

PROJECT:	Ilovica Gold-Copper Project		FIGURE #: A5.3
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT #: 55459_R1v2
DRAWN: SD		CHECKED: RM	DATE: January 2016

Schlumberger Water Services

Document Path: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\540_Models\003_Ilovica_3D_model\7_Post_Processing_for_Deliverables\Figure_A5.3_Cal_Pit_area.mxd



Groundwater level calibration plots, TMF area

PROJECT:	Ilovica Gold-Copper Project		FIGURE #: A5.4
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT #: 55459_R1v2
DRAWN: SD		CHECKED: RM	DATE: January 2016

Schlumberger Water Services

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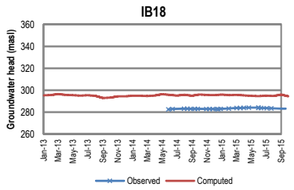

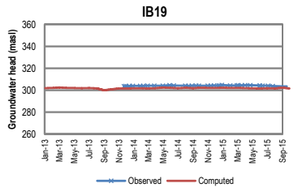

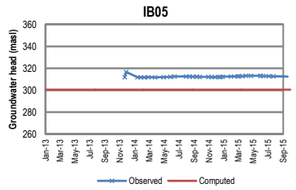

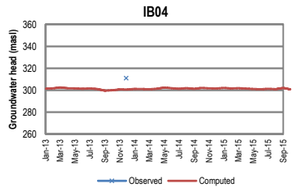

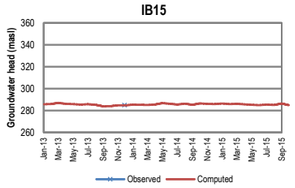

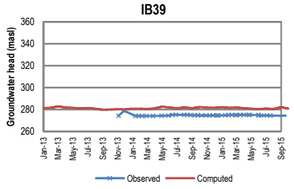

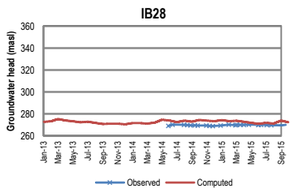

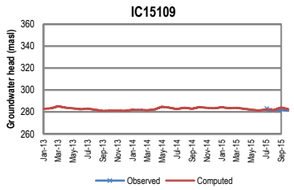

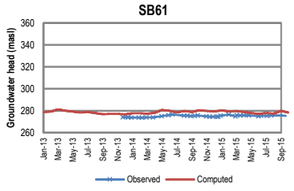

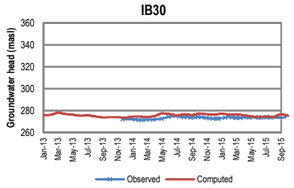

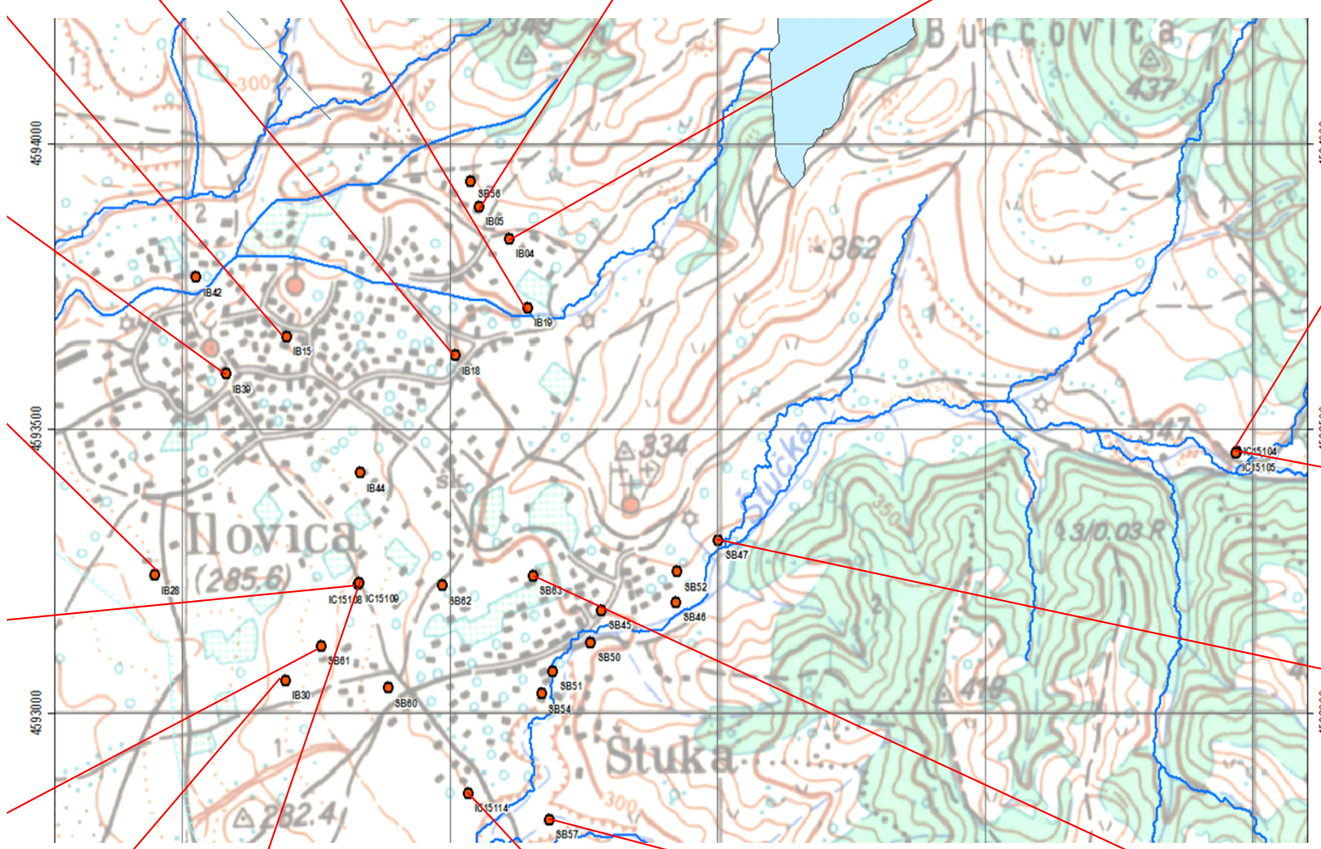

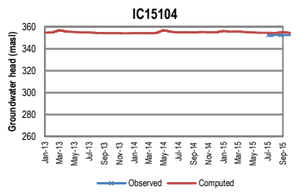

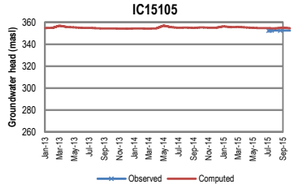

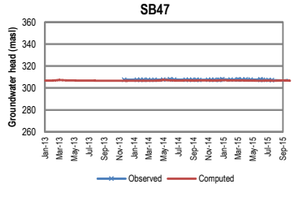

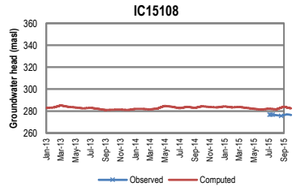

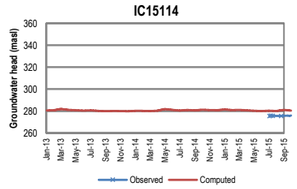

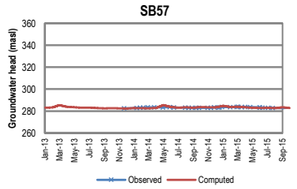

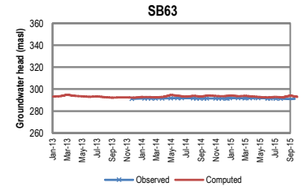

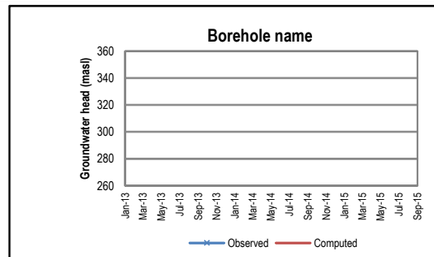

All graphs are scaled identically to example graph above

Schlumberger Water Services

Groundwater level calibration plots, Ilovica and Shtuka Villages

PROJECT:	Ilovica Gold-Copper Project		FIGURE #: A5.5
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT #: 55459_R1v2
DRAWN:	SD	CHECKED: RM	DATE: January 2016

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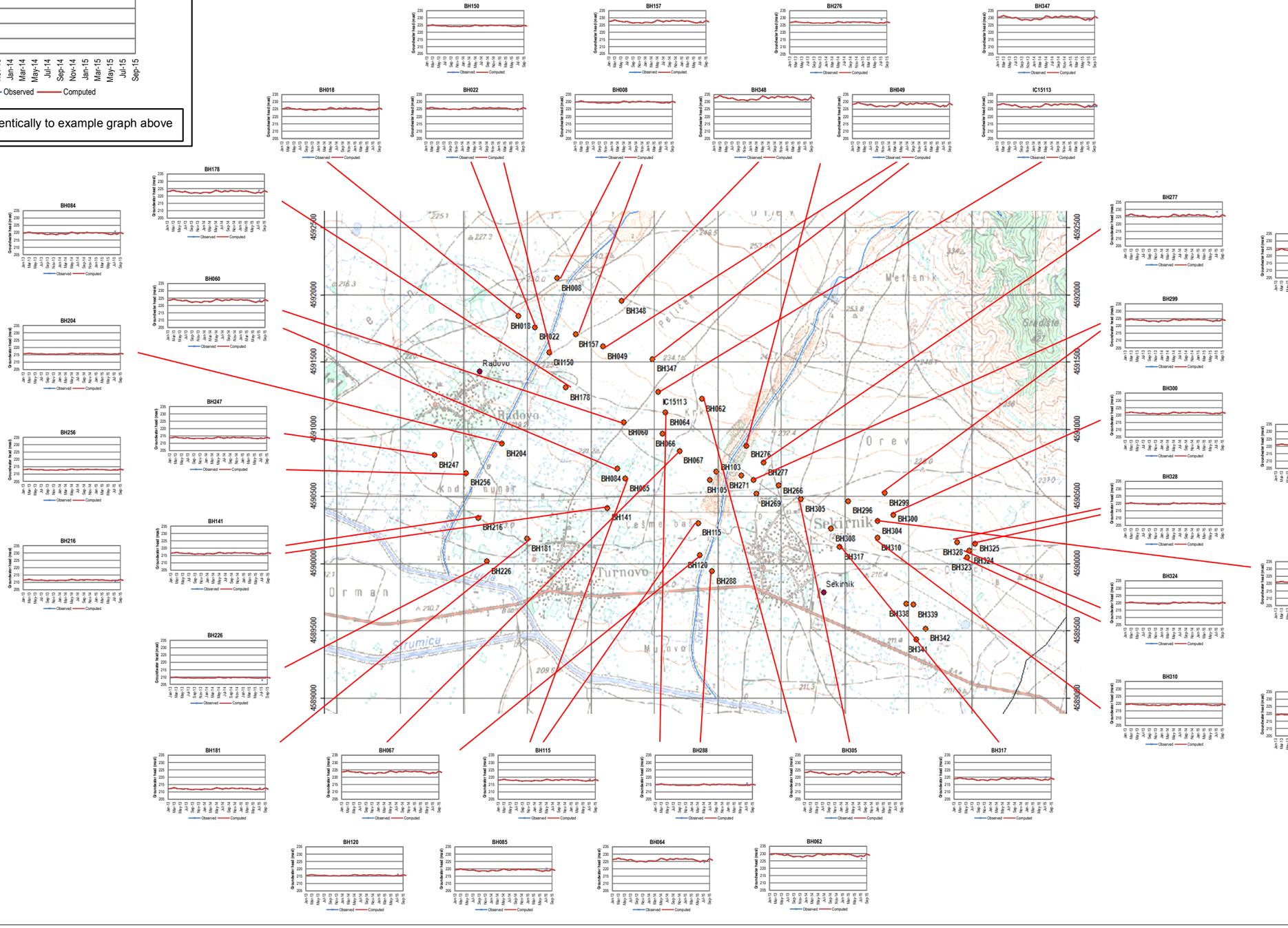
Borehole name

Groundwater head (masl)

Observed — Computed

All graphs are scaled identically to example graph above



	Schlumberger Water Services	Calibration plots, Strumica Valley	
		PROJECT: Ilovica Gold-Copper Project	FIGURE #: A5.6
		CLIENT: Euromax Resources (Macedonia) UK Ltd	PROJECT #: 55459_R1v2
		DRAWN: SD CHECKED: RM	DATE: January 2016

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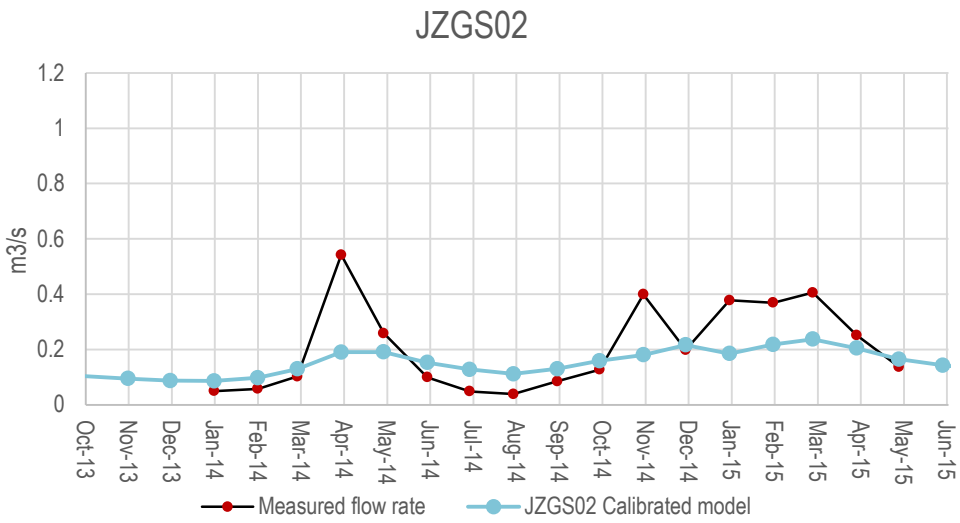

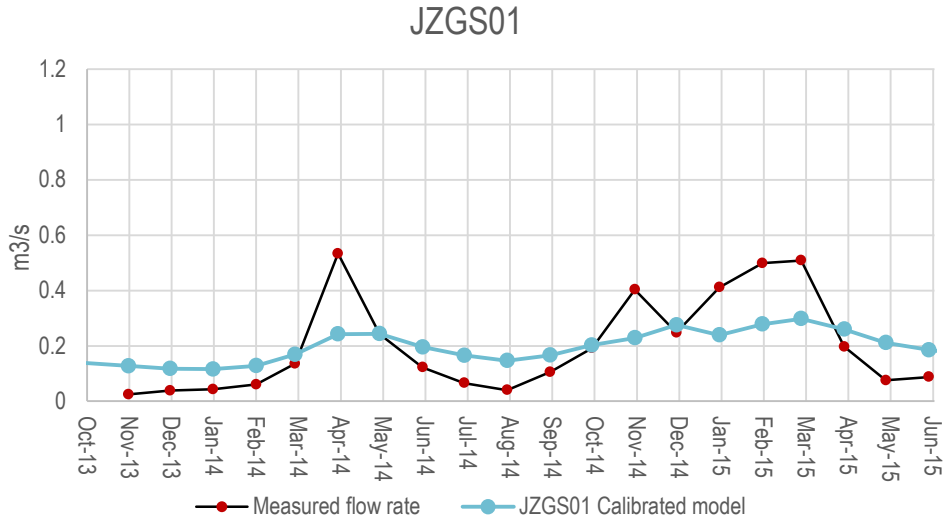

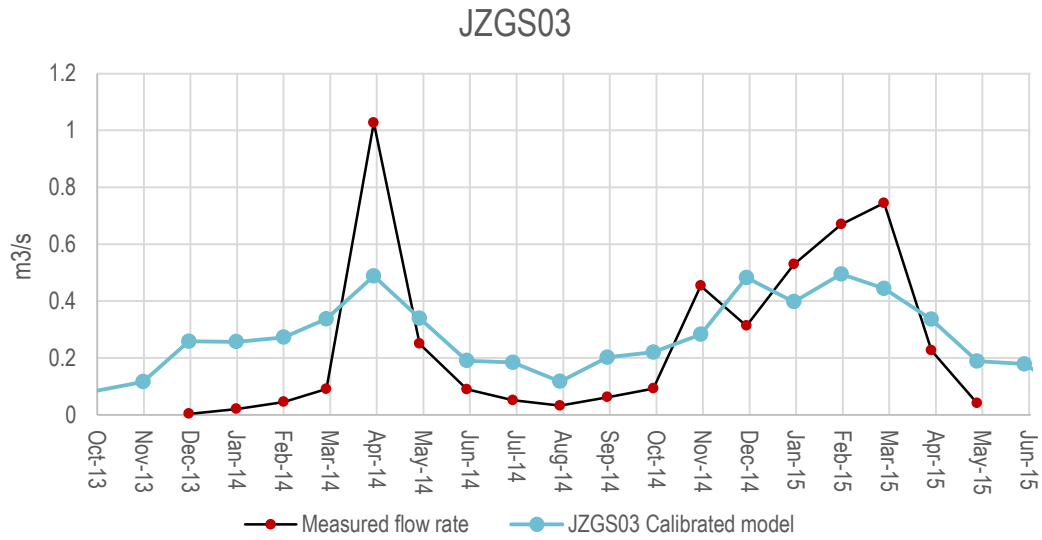

Schlumberger Water Services

Jazga valley stream flow calibration

PROJECT:	Ilovica Gold-Copper Project		FIGURE: A5.7
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT #: 55459_R1v2
DRAWN: SD	CHECKED: RM		DATE: January 2016

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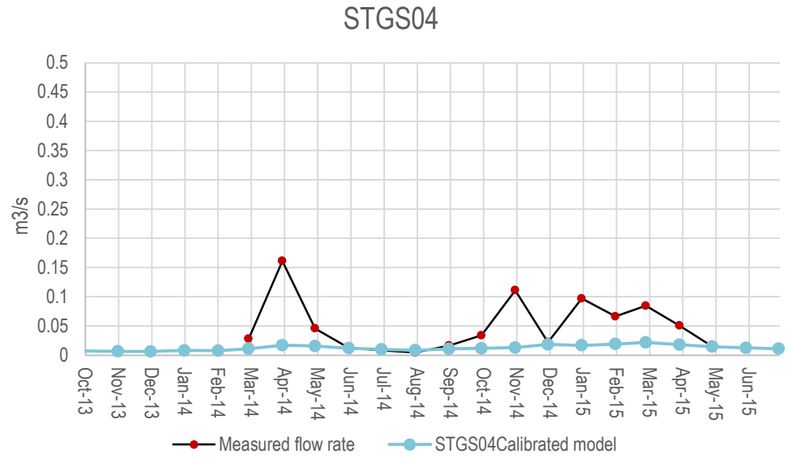

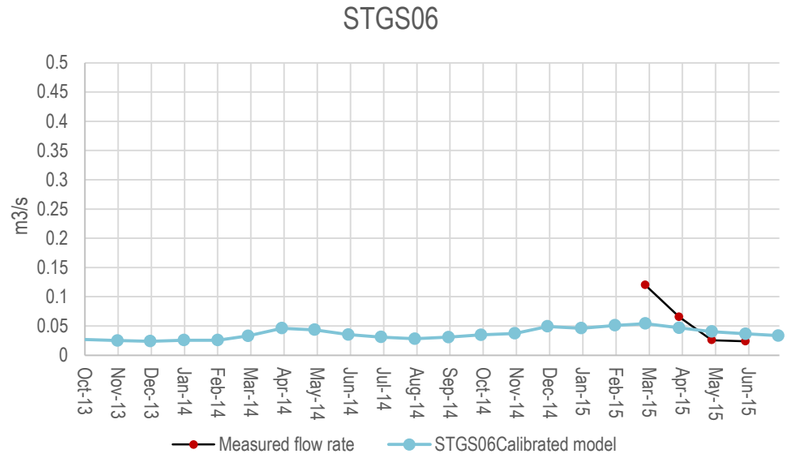

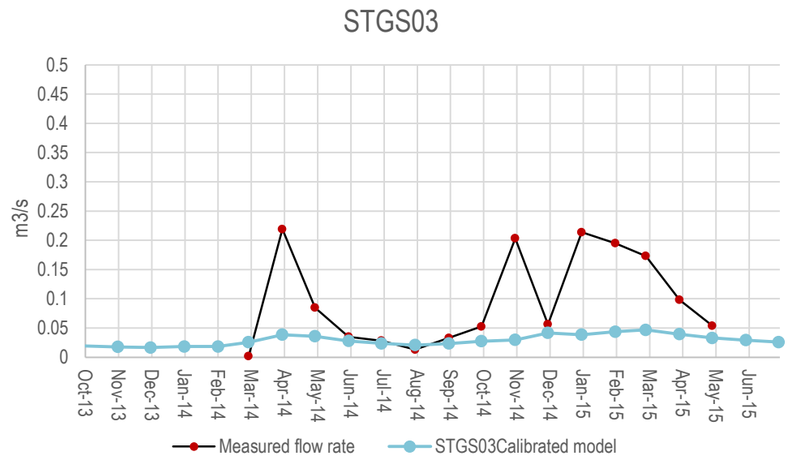

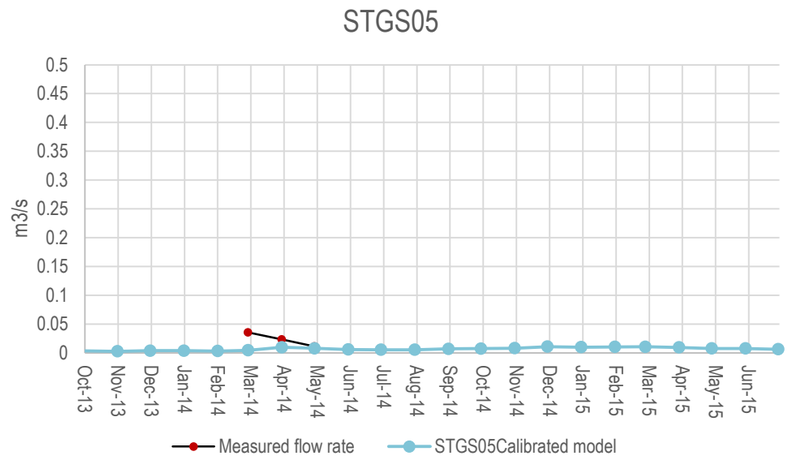

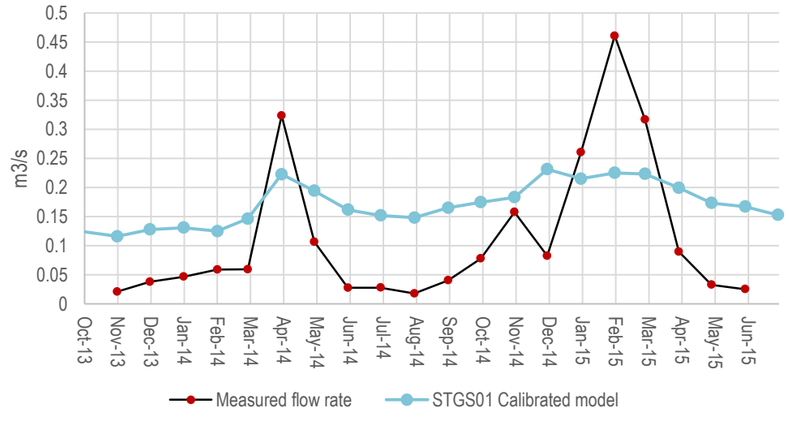

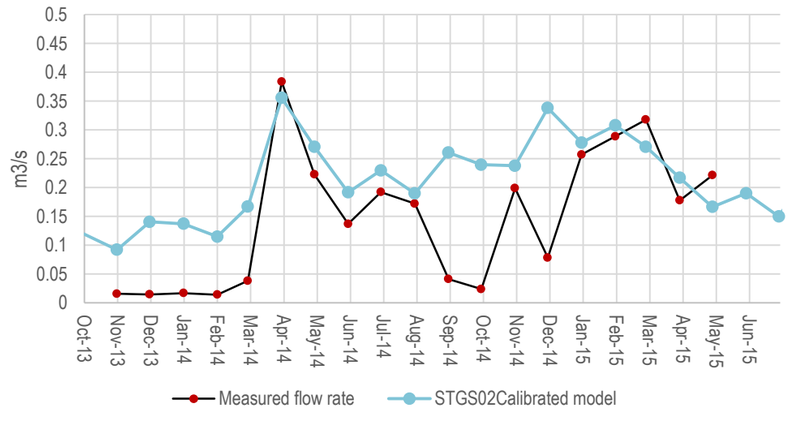

Schlumberger Water Services

Shtuka valley stream flow calibration

PROJECT:	Ilovica Gold-Copper Project		FIGURE: A5.8
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT #: 55459_R1v2
DRAWN: SD	CHECKED: RM		DATE: January 2016

P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\540_Models\003_Ilovica_3D_model\3_Calibration\Model_Versions\IL_TV_094\Ilovica_GaugingStation_Locations_094.xlsx

7648000 7652000 7656000 7660000

4596000 4592000

N

Head (masl)
1600.00
1560.00
1520.00
1480.00
1440.00
1400.00
1360.00
1320.00
1280.00
1240.00
1200.00
1160.00
1120.00
1080.00
1040.00
1000.00
960.00
920.00
880.00
840.00
800.00
760.00
720.00
680.00
640.00
600.00
560.00
520.00
480.00
440.00
400.00
360.00
320.00
280.00
240.00
200.00

Legend
- Final pit outline
- Groundwater head contours (masl)
- Turija Canal
- TMF
- Mine facilities

Datum:Hermannskogel
0 1 2 Kilometres

Schlumberger Water Services

Modelled groundwater head contours for mine year -1

PROJECT:	Ilovica Gold-Copper Project	FIGURE #:	A5.9
CLIENT:	Euromax Resources (Macedonia) UK Ltd.	PROJECT #:	55459_R1v2
DRAWN: SS	CHECKED: RM	DATE:	January 2016

Document Path: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\540_Models\003_Ilovica_3D_model\7_Post_Processing_for_Deliverables\Figure_A5.9_Modelled_GW_levels_year-1.mxd

7648000 7652000 7656000 7660000

4596000 4592000

N

Head (masl)
1600.00
1560.00
1520.00
1480.00
1440.00
1400.00
1360.00
1320.00
1280.00
1240.00
1200.00
1160.00
1120.00
1080.00
1040.00
1000.00
960.00
920.00
880.00
840.00
800.00
760.00
720.00
680.00
640.00
600.00
560.00
520.00
480.00
440.00
400.00
360.00
320.00
280.00
240.00
200.00

Legend
Final pit outline
Groundwater head contours (masl)
Turija Canal
TMF
Mine facilities

Datum:Hermannskogel
0 1 2 Kilometres

Schlumberger Water Services

Modelled groundwater head contours for mine year 21

PROJECT:	Ilovica Gold-Copper Project	FIGURE #:	A5.10
CLIENT:	Euromax Resources (Macedonia) UK Ltd.	PROJECT #:	55459_R1v2
DRAWN: SS	CHECKED: PB	DATE:	January 2016

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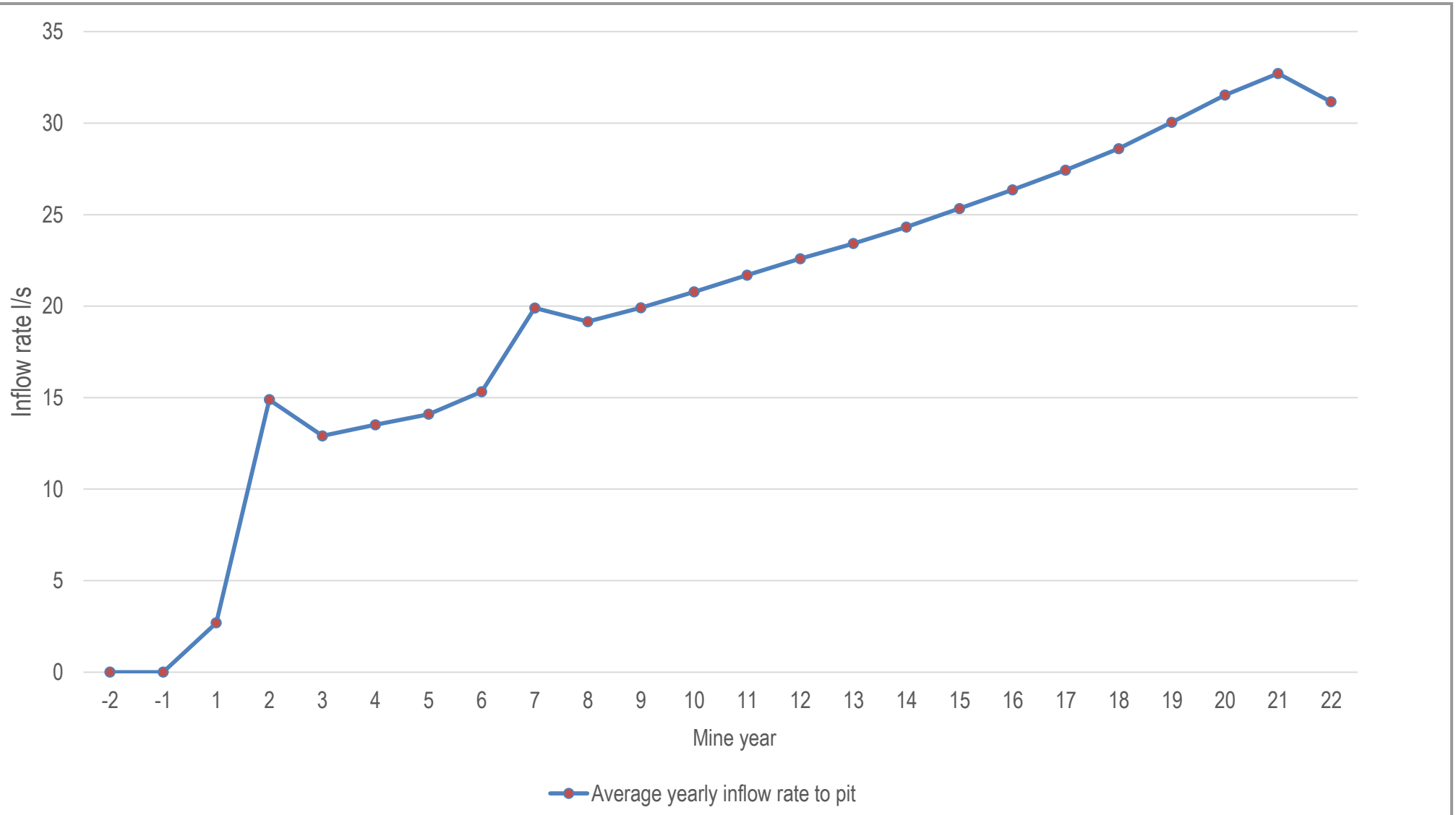

Schlumberger Water Services

Modelled groundwater inflow rates to the pit through operational mine life

PROJECT:	Ilovica Gold-Copper Project		FIGURE: A5.11
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT #: 55459_R1v2
DRAWN: SD	CHECKED: RM		DATE: January 2016

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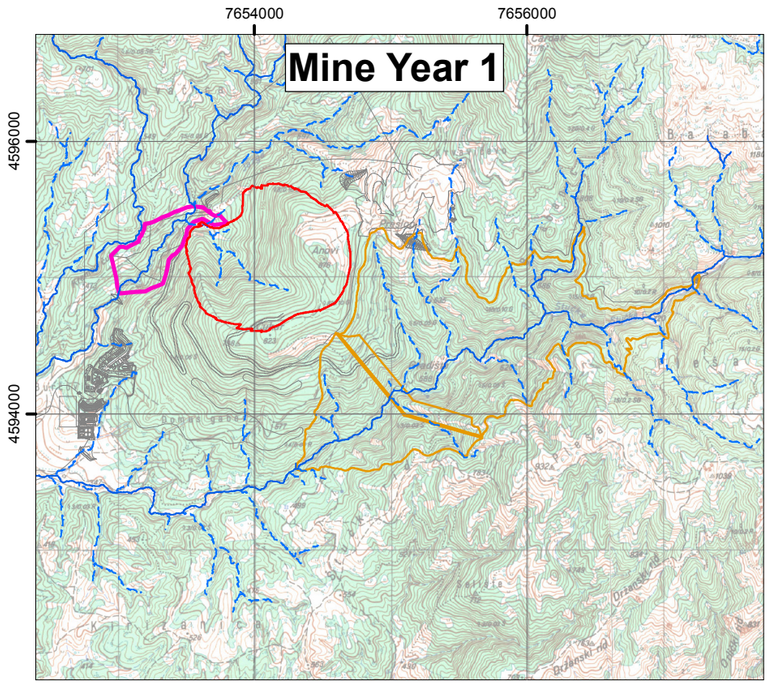

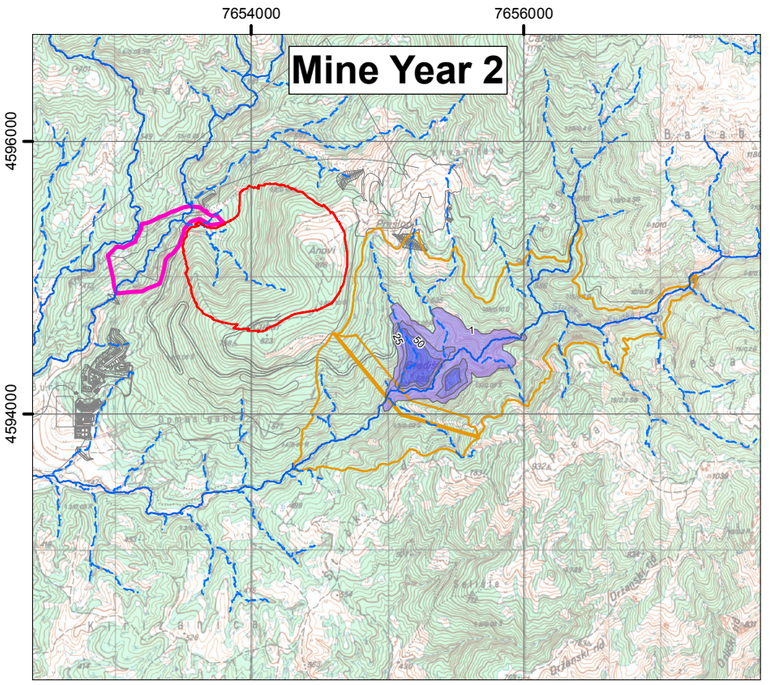

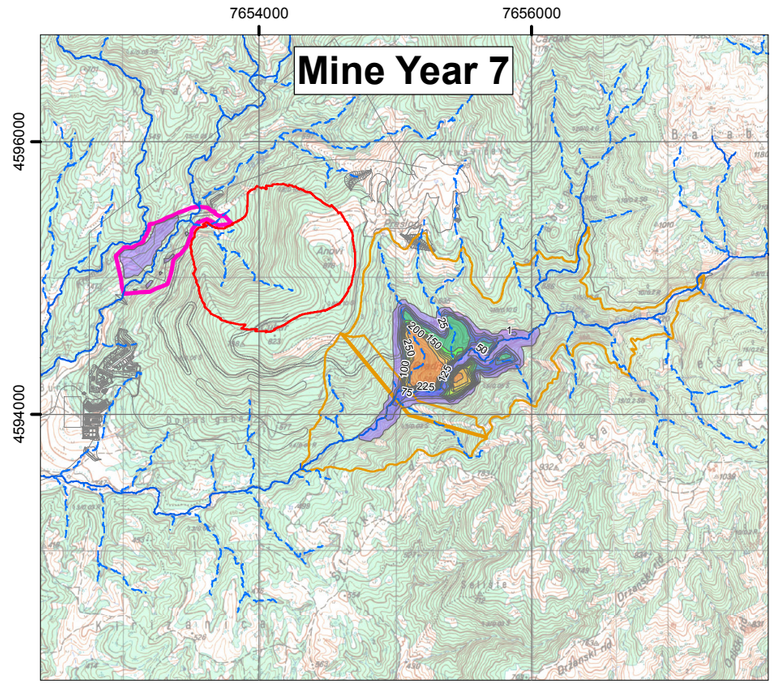

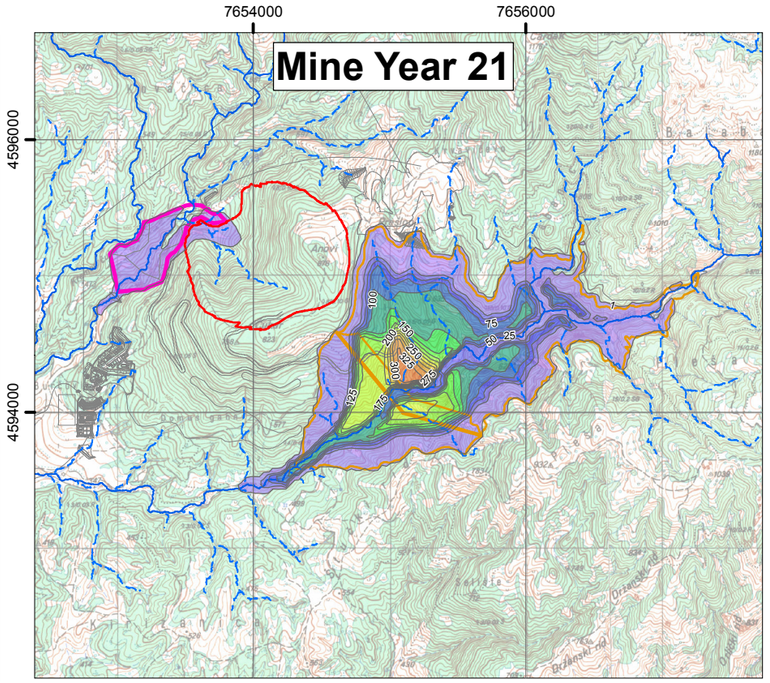

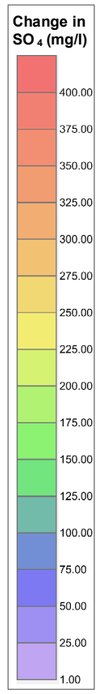

Legend

- Final pit outline
- Oxide stockpile
- TMF outline
- Mine facilities

Datum:Hermannskogel

0 1 2 Kilometres

N

Schlumberger Water Services

Change in modelled groundwater sulphate concentrations during mine operation

PROJECT:	Ilovica Gold-Copper Project		FIGURE #: A5.12
CLIENT:	Euromax Resources (Macedonia) UK Ltd.		PROJECT #: 55459_R1v2
DRAWN:	SS	CHECKED: PB	DATE: January 2016

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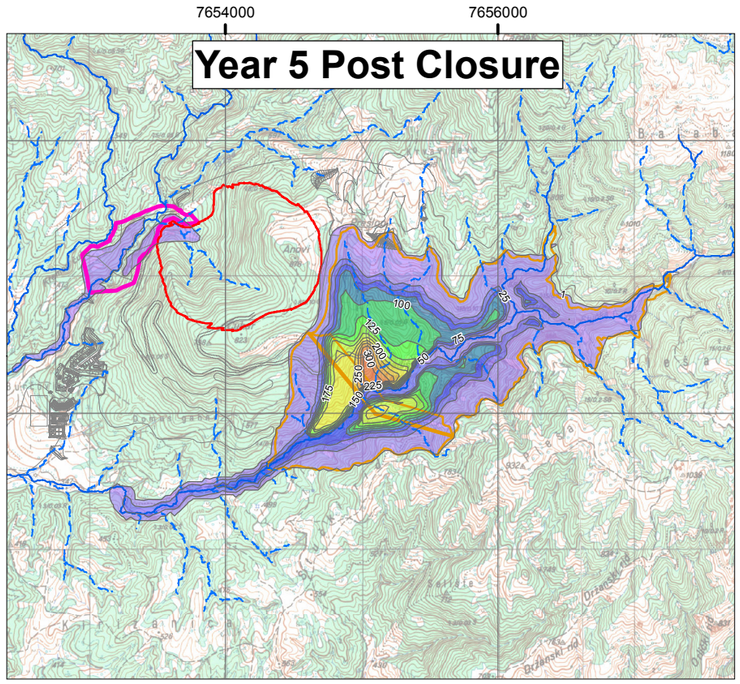
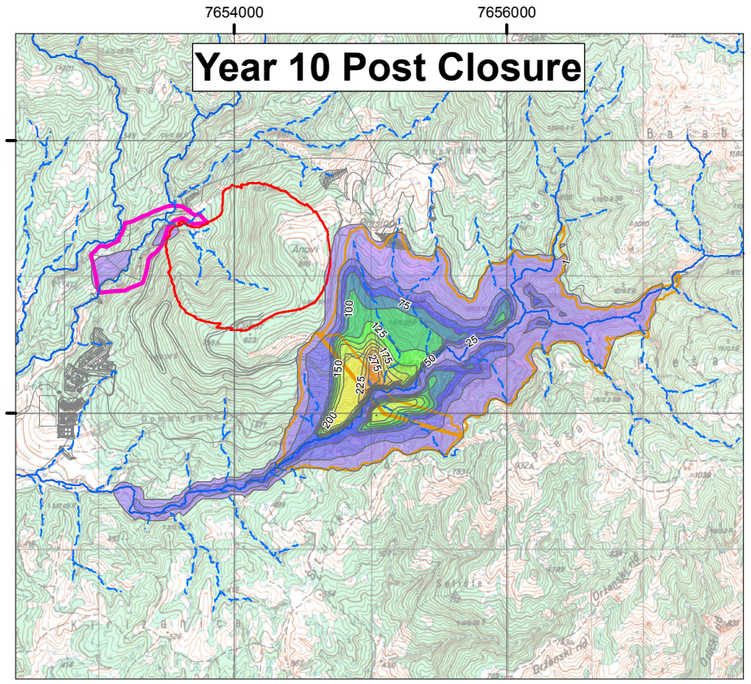
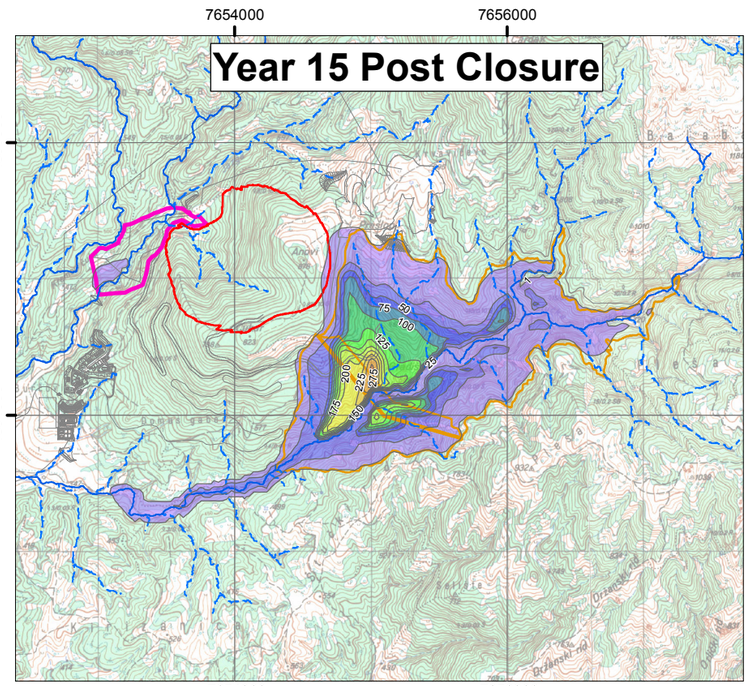
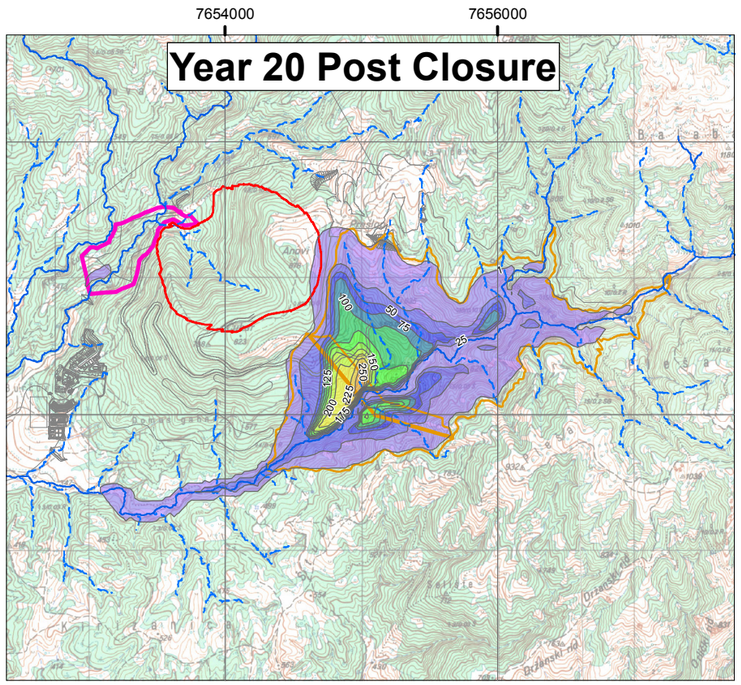
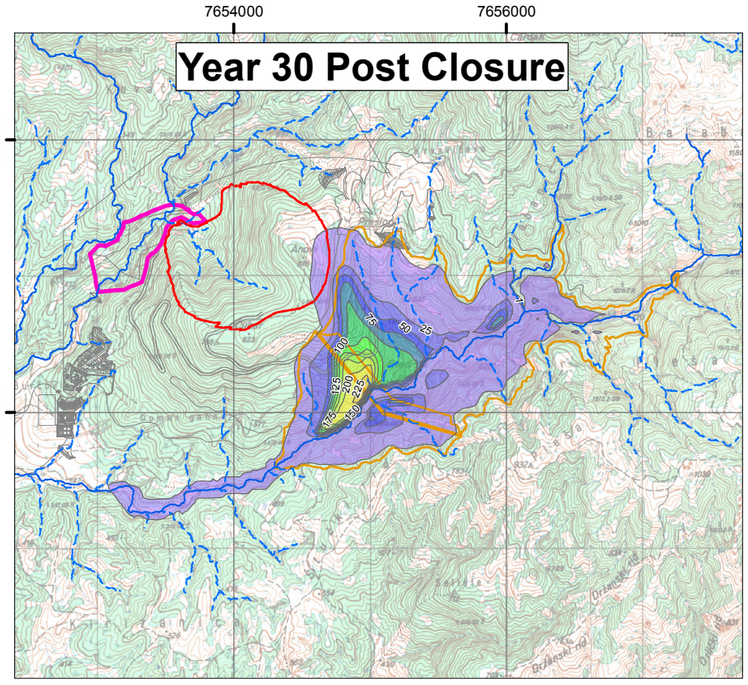
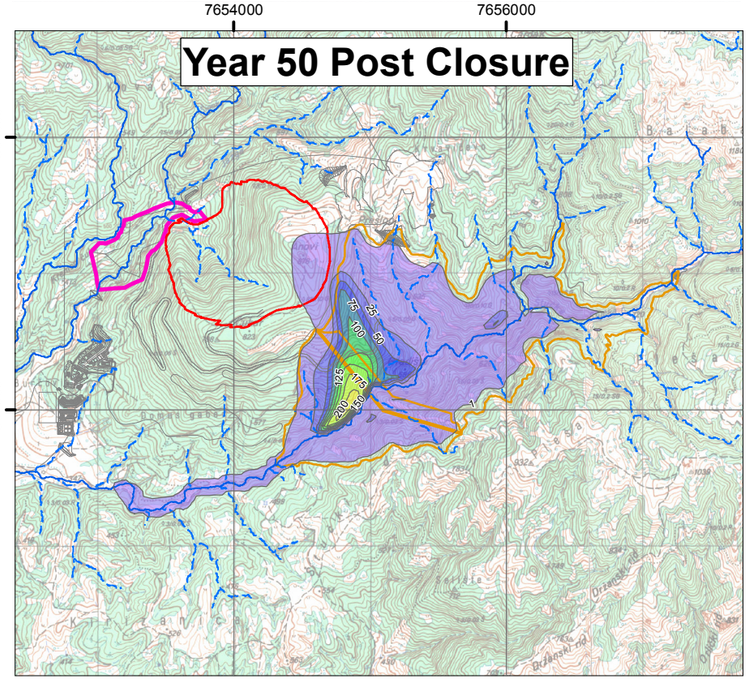


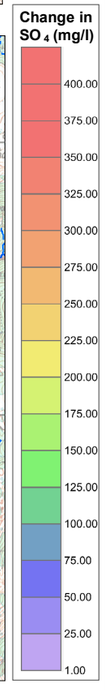












Legend

- Final pit outline
- Oxide stockpile
- TMF outline
- Mine facilities

Datum:Hermannskogel

0 1 2 Kilometres

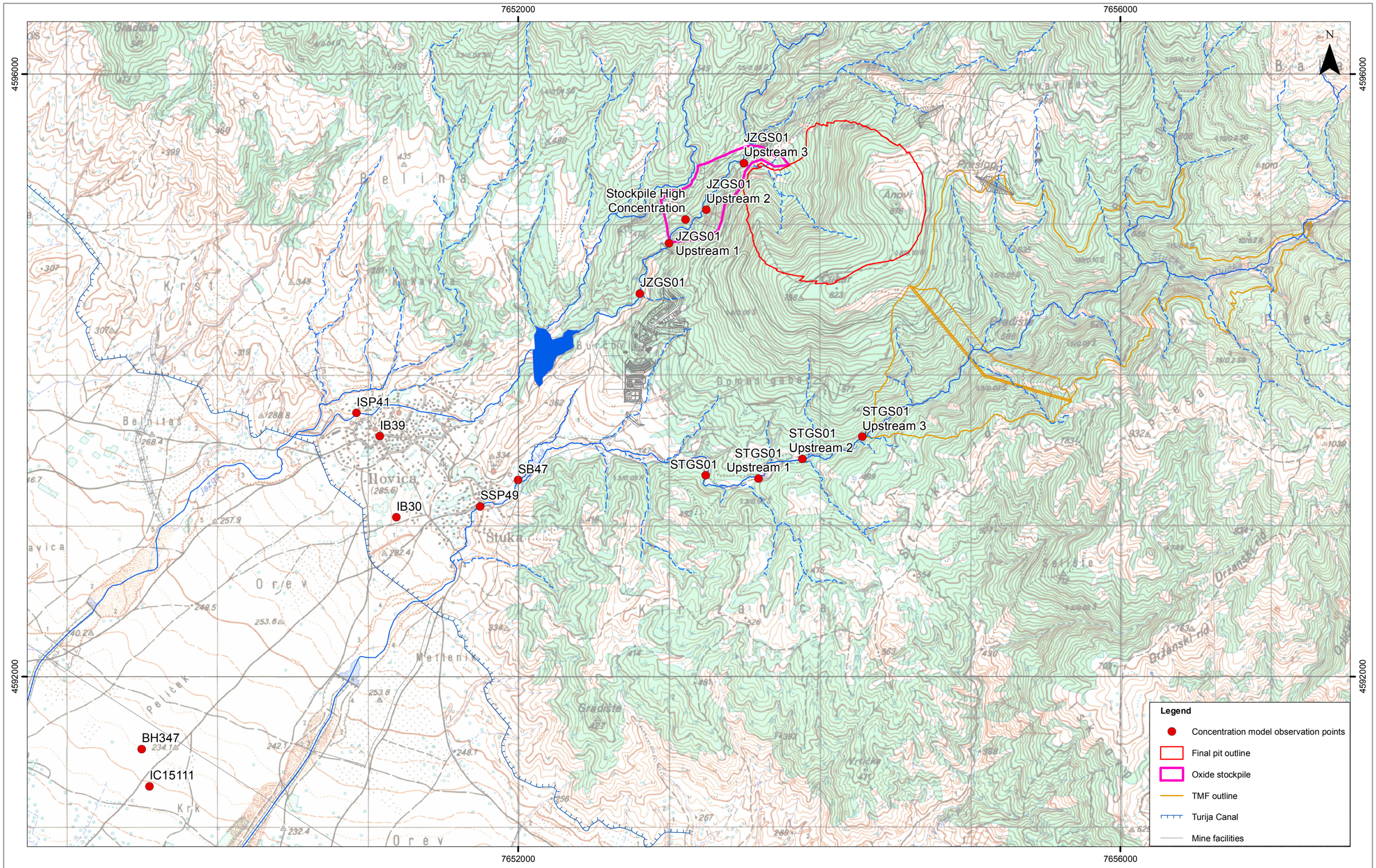
N

Schlumberger Water Services

Change in modelled groundwater sulphate concentrations post closure

PROJECT:	Ilovica Gold-Copper Project	FIGURE #:	A5.13
CLIENT:	Euromax Resources (Macedonia) UK Ltd.	PROJECT #:	55459_R1v2
DRAWN: SS	CHECKED: PB	DATE:	January 2016

Document Path: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\540_Models\003_Ilovica_3D_model\7_Post_Processing_for_Deliverables\MT3D results\Closure figure\Figure_A5.13_ClosureConcs.mxd



Datum:Hermannskogel

0 0.7 1.4 Kilometres

Schlumberger
Water Services

Concentration model observation points

PROJECT:	Ilovica Gold-Copper Project	FIGURE #:	A5.14
CLIENT:	Euromax Resources (Macedonia) UK Ltd.	PROJECT #:	55459_R1v2
DRAWN: SS	CHECKED: PB	DATE:	January 2016

Document Path: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\540_Models\003_Ilovica_3D_model\7_Post_Processing_for_Deliverables\MT3D results\Concentration observation points\Figure_A5.14_Concentration observation points.mxd

6 HYDROLOGICAL AND GEOCHEMICAL MODELLING OF MINE FACILITY SOURCE TERMS

6.1 Introduction

Modelling has been completed to assess water quality source terms for the following mine facilities:

1. Seepage from oxide stockpile in operations
2. Operational runoff and groundwater dewatering flows within the pit, including runoff from the ROM pad.
3. Formation of a pit lake in closure conditions.
4. Seepage from the tailings within the TMF to ground and into the waste rock embankment, as well as seepage and runoff emanating from the waste rock TMF embankment itself.

The modelling methodologies for the assessment of water quality from each mine facility are described below. A further potential source of poor quality water identified earlier in the project, sewage discharge, has not been modelled. The sewage discharges produced by the project will be treated and reused within the water balance, and thus should not cause any impact on water quality.

6.2 Oxide stockpile

6.2.1 Conceptualization

Construction

The oxide stockpile will not be constructed or operational during the construction period (before year 1) and thus water quality modelling has not been performed for this period.

Operations

Construction of the base of the oxide stockpile is to begin during operations. Oxide ore is to be stockpiled between life of mine (LOM) years 3 and 5. The final mass of material stockpiled is 10 Mt and the material is mainly oxidized dacite and upper oxidized granodiorite. The oxide stockpile is located in the Jazga valley, close to the open pit, and will be placed over the top of the River Jazga. The river will be culverted underneath the stockpile. The material is not expected to be acid producing. It has been assumed due to the gravelly nature of the material and the large particle sizes and pore spaces that all incident precipitation onto the oxide stockpile will infiltrate and report to the base of the facility as seepage. At this point the seepage will mostly infiltrate to ground and a small amount may report to surface water or the storm water collection dam (Figure A1.2). The effect of seepage on groundwater and surface water is discussed in Section 7. The water quality is modelled from the largest extent of the stockpile (LOM year 6) until the end of the stockpile life (LOM year 21). The chemistry of the seepage emanating from the stockpile is a function of the interaction between the stockpile material and precipitation. It is assumed that not all seepage will be in contact with the surface area of the oxide ore on the stockpile.

Closure

The oxide stockpile is expected to be fully processed and removed during the operational period, thus no modelling has been completed for the closure period. It is assumed that the footprint will be rehabilitated to baseline conditions.

6.2.2 Mine design and key project information

The oxide stockpile, as described in Section 6.2.1, will be in place only during operations. Material will be stockpiled from LOM year 3. The maximum mass and extent of the stockpile is reached in LOM year 6. The final mass stockpiled (as per the ESIA project description) is 10 Mt and the final height of the stockpile is 120 m. The composition of material to be stockpiled has been deduced from the mine schedule and geological block model, produced by DMT and Tetratech. The material breakdown for the final stockpile is presented in Table 6-1. The material codes correspond to a geological and ARD risk classification system fully described in the Geochemistry Appendix A.

Table 6-1 Oxide stockpile material breakdown

Material	Description	Proportion (%)
GRTALOX	Granite, altered, oxidised	2.1
DACOXSW	Dacite, oxidised, stockwork	5.2
DACOX	Dacite, oxidised	77.7
GNDIOOX_UPPER	Granodiorite, oxidised, upper 10 m	15.0
GNDIONONOX	Granodiorite, nontronitic, oxidised	0.1

6.2.3 Hydrological inputs

The hydrological inputs for water quality modelling of the oxide stockpile are described further in Section 3.2.2. The predicted seepage through LOM is presented in Figure A6.1. The hydraulic properties for the oxidized dacite and granodiorite were derived through laboratory investigation and seepage was numerically modelled using VADOSE/W. The seepage for the final height and footprint area was calculated using the GoldSim water balance, based on the soil moisture balance and breakthrough curve predicted using VADOSE/W. The average travel time through the stockpile is 12 days. The GoldSim model predicts a range of seepage flows and the modelled seepage flows used to predict water quality are the 25th, 50th and 75th percentile flows.

6.2.4 Geochemical inputs

The geochemical data used as inputs for the stockpile model are fully described in the Geochemical Annex 4. The geochemical inputs used to define mine facility water quality sources were based on a series of field leach tests conducted on site in Macedonia by EOX. The first set of field experiments placed material on leach pads at the site and the material weathered in response to normal climatic conditions. The leachate from interaction between material and precipitation was collected and analysed for a number of field and laboratory parameters. The series of tests comprise artificially irrigated pads. Material of ore grade was placed on leach pads indoors and irrigated on a regular basis using distilled water. The weathering period between irrigation was recorded, as well as the volume of water used in irrigation. The leachate produced from the material was collected and analysed for field and laboratory parameters.

The geochemical dataset does not fully correspond to material codes within the block model. Where field test data are missing a proxy geochemical dataset was chosen, as shown in Table 6-2. Around 85% of the stockpile material has a direct corresponding material within the geochemical kinetic dataset. The oxidized granodiorite ore is currently being tested on an irrigated leach pad, but not enough laboratory results have been collected to date to use this data in the water quality modelling.

Table 6-2 Assignment of geochemical input chemistry to mine scheduled material

Stockpile scheduled material	Description schedule material	Corresponding leach pad code	Description of leach pad material	Proportion (%)
GRTALOX	Granite, altered, oxidised	GRTALOX	Granite, altered, oxidised	2.1
DACOXSW	Dacite, oxidised, stockwork	DACOXORE	Dacite, oxidised, ore grade	5.2
DACOX	Dacite, oxidised	DACOXORE	Dacite, oxidised, ore grade	77.7
GNDIOOX_UPPER	Granodiorite, oxidised, upper 10 m	GNDIO	Granodiorite, unoxidised	15.0
GNDIONONOX	Granodiorite, nontronitic, oxidised	GNDIO	Granodiorite, unoxidised	0.1

The initial geochemical data was recorded as chemical concentrations but for use in the water quality models it was converted into mass release per kg of material per day. The mass load was calculated by normalizing the concentration for the mass of the material on the leach pad experiment, by the volume of leachate collected and the number of days between precipitation or irrigation events (weathering period). The mass loading inputs are presented in Table 6-3 for the material present in the oxide stockpile. The specific surface area for the geochemical input to the water quality model is 0.37 m2/kg, as defined by particle size distribution.

Table 6-3 Chemical mass loading inputs

Parameter	DACOXORE	GNDIO	GRTALOX
pH-F (pH units)	6.14	6.23	5.77
Model alkalinity (mg/kg/day CaCO3)	0.3061	0.1409	0.0808
Ag-D (mg/kg/day)	0.000008	0.000002	0.000002
Al-D (mg/kg/day)	0.0005	0.0005	0.0016
As-D (mg/kg/day)	0.000019	0.000004	0.000003
Ba-D (mg/kg/day)	0.00081	0.00002	0.00025
Bi-D (mg/kg/day)	0.00001	0.00003	0.00001
Ca-D (mg/kg/day)	0.13	0.07	0.02
Cd-D (mg/kg/day)	0.000003	0.000003	0.000001
Cl-ion (mg/kg/day)	0.36	0.01	0.02
Co-D (mg/kg/day)	0.00008	0.00001	0.00002
Cr-D (mg/kg/day)	0.00001	0.00001	0.00000
CrVI-D (mg/kg/day)		0.00002	0.00001
Cu-D (mg/kg/day)	0.0001	0.0001	0.0001
Fe-D (mg/kg/day)	0.0011	0.0008	0.0007
F-ion (mg/kg/day)	0.0028	0.0008	0.0012
Hg-D (mg/kg/day)		0.00000	0.00000
K-D (mg/kg/day)	0.050	0.017	0.005
Mg-D (mg/kg/day)	0.031	0.015	0.004
Mn-D (mg/kg/day)	0.00009	0.00019	0.00004
Mo-D (mg/kg/day)	0.00001	0.00002	0.00001
Na-D (mg/kg/day)	0.257	0.013	0.008
Ni-D (mg/kg/day)	0.00005	0.00001	0.00001
N-NH3 (mg/kg/day)	0.004	0.001	0.001
N-NO2 (mg/kg/day)	0.0008	0.0005	0.0003

Parameter	DACOXORE	GNDIO	GRTALOX
NO3-N (mg/kg/day)	0.031	0.006	0.005
OrthPO4-P (mg/kg/day)	0.003	0.004	0.003
Pb-D (mg/kg/day)	0.00003	0.00002	0.00002
Sb-D (mg/kg/day)	0.00001	0.00000	0.00000
Se-D (mg/kg/day)	0.00007	0.00000	0.00001
SO4-D (mg/kg/day)	0.44	0.10	0.03
Sr-D (mg/kg/day)	0.00055	0.00022	0.00008
U-D (mg/kg/day)	0.000001	0.000005	0.000012
V-D (mg/kg/day)	0.000019	0.000014	0.000009
Zn-D (mg/kg/day)	0.0014	0.0001	0.0005

6.2.5 Model set-up

The seepage rates and mass loading rates described above were used to create a mass balance model to predict seepage water quality through LOM. The mass loading rates were scaled to the mass of material on the stockpile. A scaling factor to take into account the differential surface area to mass ratio of material in the geochemical tests and that to be placed on the stockpile was applied. This was then further modified by the addition of an empirical factor to account for the extent of effective solid-solution contact during infiltration of rainwater through the stockpile. The mass load for the stockpile was then integrated into the modelled seepage volumes. Each seepage solution was thermodynamically equilibrated using the industry standard code PHREEQC, with a temperature of 15^{o}C and a *Pe* of 10 mV. The solutions were allowed to charge balance using chloride ions. Minerals that were over-saturated within the solution were allowed to precipitate if kinetically feasible. Mostly this included ferrihydrite (iron hydroxide). Any precipitated iron hydroxides were allowed to act as a surface for sorption. This appears on the basis of modelling to induce removal of a proportion of the copper introduced to the initial solution.

6.2.6 Results

Model results for a range of seepage scenarios are presented in Table 6-4. These are compared with project EDC effluent guidelines, with exceedances highlighted in red (Golder, 2015). The results are a function of the geochemical and hydrological data inputs. The water quality was mainly controlled by the chemistry and behavior of the geochemical field tests. The precipitation of iron hydroxides released additional protons and decreased the pH of the predicted solutions. The copper concentrations were decreased where iron hydroxides are precipitated, as copper ions sorb onto iron hydroxide surfaces. Iron, copper and zinc occasionally exceeded project effluent standards, however most parameters were within acceptable concentrations. The pH of the solutions was slightly depressed, although alkalinity was above zero so given a longer period the pH may equilibrate to be slightly more neutral. The hydrological inputs are very dependent on rainfall, and the model predicts that leachate production will not be continuous.

Table 6-4 Predicted oxide stockpile seepage water quality results for 25th, 50th and 75th percentile seepage flows

Parameter	Units	Project effluent standards*	25%ile seepage over LOM			50%ile seepage over LOM			75%ile seepage over LOM		
			Min	Average	Max	Min	Average	Max	Min	Average	Max
Seepage vol	m3/day		0	27	220	0	100	413	0	218	608
pH	pH	6 - 9	3.8	4.7	5.3	3.6	5.0	5.6	3.8	5.3	5.8
Ag	mg/l		0.0004	0.0025	0.0124	0.0002	0.0019	0.0216	0.0001	0.0012	0.0139
Al	mg/l		0.03	0.19	0.94	0.02	0.14	1.63	0.01	0.09	1.05
Alkalinity	mg/l		15	95	470	8	70	814	6	44	524
As	mg/l	0.1	0.001	0.006	0.030	0.001	0.005	0.053	0.000	0.003	0.034
Ba	mg/l		0.04	0.26	1.28	0.02	0.19	2.21	0.02	0.12	1.42
Ca	mg/l		7	44	217	4	32	375	3	21	242
Cd	mg/l	0.05	0.0002	0.0010	0.0052	0.0001	0.0008	0.0090	0.0001	0.0005	0.0058
Cl	mg/l		7	57	487	4	48	845	3	30	544
Co	mg/l		0.004	0.024	0.120	0.002	0.018	0.207	0.001	0.011	0.134
Cr**	mg/l	0.1	0.0005	0.0033	0.0167	0.0002	0.0025	0.0290	0.0002	0.0015	0.0187
Cu	mg/l	0.3	0.01	0.04	0.22	0.00	0.03	0.38	0.00	0.02	0.24
F	mg/l		0.2	0.9	4.7	0.1	0.7	8.1	0.1	0.4	5.2
Fe***	mg/l	2	0.03	0.27	1.93	0.02	0.22	3.35	0.01	0.14	2.16
Hg***	mg/l	0.002	0.000002	0.000011	0.000052	0.000001	0.000008	0.000091	0.000001	0.000005	0.000058
K	mg/l		3	17	83	1	12	143	1	8	92
Mg	mg/l		2	11	53	1	8	91	1	5	59
Mn	mg/l		0.006	0.038	0.188	0.003	0.028	0.325	0.002	0.018	0.209
Mo	mg/l		0.0009	0.0059	0.0291	0.0005	0.0044	0.0504	0.0003	0.0028	0.0325
NH3-N	mg/l		0.000002	0.002842	0.052799	0.000000	0.005007	0.228830	0.000000	0.002435	0.071660
NO3-N	mg/l		1	6	30	1	5	53	0	3	34
NO2-N	mg/l		1	6	27	0	4	47	0	3	31
Na	mg/l		13	81	402	7	60	697	5	38	449
Ni***	mg/l	0.5	0.00	0.02	0.08	0.00	0.01	0.13	0.00	0.01	0.09
P	mg/l		0.6	3.5	17.5	0.3	2.6	30.3	0.2	1.6	19.5
Pb	mg/l	0.2	0.002	0.010	0.050	0.001	0.007	0.087	0.001	0.005	0.056
SO4	mg/l		23	127	499	12	87	611	8	55	419
Sb	mg/l		0.0003	0.0021	0.0103	0.0002	0.0015	0.0178	0.0001	0.0010	0.0115
Se	mg/l		0.004	0.023	0.114	0.002	0.017	0.198	0.001	0.011	0.127

Parameter	Units	Project effluent standards*	25%ile seepage over LOM			50%ile seepage over LOM			75%ile seepage over LOM		
			Min	Average	Max	Min	Average	Max	Min	Average	Max
Si	mg/l		0.06	0.36	1.80	0.03	0.27	3.12	0.02	0.17	2.01
Sr	mg/l		0.03	0.18	0.91	0.02	0.14	1.58	0.01	0.09	1.02
U	mg/l		0.00001	0.00004	0.00019	0.00000	0.00003	0.00032	0.00000	0.00002	0.00021
V	mg/l		0.001	0.007	0.033	0.001	0.005	0.058	0.000	0.003	0.037
Zn* **	mg/l	0.5	0.07	0.44	2.19	0.04	0.33	3.79	0.03	0.21	2.44
*** As described in the EDC**											
****Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant**											
***** Modelled data is as dissolved concentrations, standard as totals**											

6.2.7 Conclusions and further work

The FS indicates that sulphide ore may be temporarily stockpiled on the same footprint as the oxide stockpile. No details on timing or volume of sulphide ore placement have to date been defined. It is assumed that sulphide material will be stockpiled separately and that all seepage or runoff collected. Sulphide ore contact water is likely to be more acidic (see geochemical results in Appendix A) than that from oxide ore and could potentially induce lower pH conditions and higher trace metal leaching than indicated in the model results presented for the oxide stockpile.

Any change in expected stockpiled oxide material tonnage may affect the predicted water quality. If the amount of material reduces it is likely that the mass load and seepage volumes will decrease and the potential effect on ground and surface waters would be lower.

6.3 Open pit

6.3.1 Conceptualization

Construction

The construction period for the Ilovica project corresponds to LOM year -1. At this stage there is a shallow pre-strip depression as described in Section 6.3.2. Runoff in contact with the excavated pre-strip area is expected to generate a water quality that differs from baseline conditions as precipitation will react with the freshly exposed rock surface. The runoff is not currently expected to be managed within the pre-strip pit area, and if the runoff volume is high, this could potentially reach the Jazga River. Good construction management practice would indicate that runoff will be collected from the pre-strip area, and this would also provide an additional source of water for construction water supply needs.

The current LOM -1 pre-strip pit is cut relatively shallow and no groundwater is expected to surface within the pre-strip pit shell area, thus it is not necessary to predict groundwater quality at this stage.

Operations

There are two main components of water that will report to the pit during operations, surface runoff and groundwater ingress through the pit walls. Water will be managed within a pit sump, which is likely to be moved around the pit footprint in line with operational requirements. Water in the pit sump will be pumped to the process plant for consumption. It is thus assumed that there will be no discharge to environment from the pit sump. The open pit will gradually grow during operations as more material is excavated. As the pit grows in size the flow of water into the pit is likely to increase, as both runoff increases from an increased surface area and groundwater flow may increase as the pit base is deepened.

The runoff component will mainly be accounted for by runoff generated from the footprint of the excavated pit shell. A small amount of runoff will also be generated from the ROM pad (located next to the pit). Runoff generated on the footprint of the ROM pad will drain into the pit and be collected in the pit sump. The ROM pad will store a small amount of ore material before it is transported to the processing plant. At the time of modelling, few details were available on the likely ore schedule which could be placed on the ROM pad. The runoff from the ROM pad is therefore assumed to be similar to the runoff found within the open pit, as it is likely to be storing the same material that is currently being excavated in the pit. Runoff is assumed to be generated from the entire exposed pit shell, no preferential flows over any particular area or material types. The chemistry of the runoff within the pit is controlled by the material exposed on the pit surface.

Dewatering will be managed within the pit passively. The chemistry of groundwater inflow has been derived from monitoring groundwater within the deposit area. This information was not, however, available at the time of

completing the ESIA, so a prediction of groundwater chemistry, using the likely material exposed in the inundation zone behind the pit face was completed.

Another source of contamination in the open pit during operations will be nitrate and ammonia residues from blasting operations using ANFO. This potential contamination has not been modelled as the greatest control on minimizing losses to the environment will be the efficiency of ANFO use and blasting techniques, which can be controlled using a suitably designed blasting plan.

Closure

The closure period begins at the end of operational mine life. At this point, sump pumping will cease. The groundwater is expected to rebound within the pit void to form a lake. As well as groundwater rebound, inflows to the pit will include pit runoff and interflow, ROM pad runoff and direct rainfall to the lake surface, which will all add to the volume of water within the pit. Evaporation from the lake surface will remove a small volume of water. The pit lake is expected to fill up to an elevation of approximately 473 masl, after which a pit lake outflow of around 20 l/s is expected. The chemistry of the pit lake and the pit lake spill will be dependent on chemistry of the inflows and interactions with exposed material within the pit shell. Direct rainfall will have a diluting effect on all other inflows. The groundwater inflow chemistry will be similar to that of the last year of operations. The runoff chemistry will initially be as the pit runoff in the final year of operations, but as the lake volume increases the runoff chemistry will only correspond to the chemistry produced from water-rock interactions from material above the water level. Evaporation will remove pure water but leave solute load within the pit lake, increasing the concentration load modelled in the pit lake volume. Material submerged beneath the lake surface is assumed not to add to the solute load. A conceptual diagram of the pit in closure is presented in Figure A6.2.

6.3.2 Mine design and key project information

The geochemical inputs to the pit are based on the distribution of material within the open pit. The project currently has four defined pit stages:

- a pre-strip at LOM year -1,
- a starter pit at LOM year 2,
- a first pushback at LOM year 7,
- a final pit at LOM year 21.

The mine will continue to operate until LOM year 23 but with processing of stockpile ore only during the last two years. The material exposed in the pit shell has been classified by Euromax using the ARD classification system described in the Geochemical Annex 4, based on lithology, oxidation zone and mineralization. The block model assigns to each block a specific material code from the system. The pit shells and block model were uploaded into Schlumberger 3D modelling software Petrel. The surface blocks of the resource model cut by each pit shell were isolated and the proportions of materials assigned to each pit shell surface were calculated. The proportions from the ARD classification system for each pit shell and the surface areas are presented in Table 6-5. The pit shells depicting corresponding ARD material codes (as listed in Table 6-5) are presented in Figures A6.3 to A6.6.

Table 6-5 Material proportions, surface areas and corresponding mine stages

Stage			Pre-strip	Starter Pit	First pushback	Final Pit Shell
LOM Year		**Year**	**-1**	**2**	**7**	**21**
Surface area (2D)		**m2**	**257308**	**474942**	**589774**	**941198**
DACMIX	Dacite, mixed	%	0.0	1.9	2.5	1.2
DACMIXSW	Dacite, mixed, stockwork	%	0.0	0.4	1.7	1.4
DACOX	Dacite, oxidized	%	86.0	47.0	19.2	13.9
DACOXSW	Dacite, oxidized, stockwork	%	0.0	0.1	0.2	1.5
DACUNOXSW	Dacite, unoxidised, stockwork	%	0.0	4.2	18.4	12.5
DACUNOXUD	Dacite, unoxidised, undisturbed	%	0.0	0.7	10.7	7.6
GDIONON	Granodiorite, nontronite	%	0.0	9.6	5.0	5.6
GDUNOXSW	Granodiorite, unoxidised, stockwork	%	0.0	1.1	2.1	2.6
GNDIOCA	Granodiorite, unoxidised, carbonate	%	0.0	3.4	6.0	6.8
GNDIOCAMIX	Granodiorite, mixed, carbonate	%	0.0	0.2	0.2	0.1
GNDIOMIX	Granodiorite, mixed	%	0.0	1.9	1.1	0.3
GNDIOMIXSW	Granodiorite, mixed, stockwork	%	0.0	1.5	1.2	0.1
GNDIONONMIX	Granodiorite, nontronite, mixed	%	0.0	1.6	0.4	0.3
GNDIONONSW	Granodiorite, nontronite, stockwork	%	0.0	12.1	13.0	17.2
GNDIOOX	Granodiorite, oxidised	%	0.0	4.8	2.6	0.4
GNDOUNOX	Granodiorite, unoxidised	%	0.0	3.5	2.5	1.3
GRTAL	Granite, altered, unoxidised	%	0.0	0.0	3.2	10.6
GRTALOX	Granite, altered, oxidized	%	13.9	6.0	9.1	8.5
GRTMIX	Granite, mixed	%	0.1	0.1	0.9	2.9
GRTNON	Granite, nontronite	%	0.0	0.0	0.2	5.5

During closure, management of water within the pit will cease, and the groundwater level will rebound allowing formation of a pit lake. Using the same principle as above and the water balance to be presented in Section 6.3.3 the material proportions on the pit shell surface above and below the pit lake water surface at each time step were derived using the geological and ARD block model (Table 6-6 and Table 6-7). The ARD material and ARD risk are presented with respect to the final lake elevation in Figure A6.7.

Table 6-6 Material proportions on pit shell surface (as ARD codes) below water surface during pit lake formation

Year post-closure	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 17	Year 19	Year 21	Year 23	Year 25	Year 27	Year 31
Pit filling elevation (masl)	**293.6**	**316.3**	**332.1**	**345.6**	**357.3**	**367.3**	**376.3**	**384.5**	**391.8**	**398.7**	**405**	**410.9**	**416.5**	**421.7**	**426.6**	**435**	**443**	**450**	**456**	**461**	**466**	**473**
Surface area below water (m2)	**43226**	**67622**	**86670**	**101630**	**108214**	**125828**	**131270**	**150276**	**154726**	**160392**	**177624**	**181806**	**186170**	**206474**	**210690**	**216392**	**257142**	**262964**	**267838**	**299542**	**305168**	**311060**
DACUNOXSW																		0.04	0.06	0.12	0.2	1.19
DACUNOXUD																						0.13
GDIONON	25.63	28.74	27.59	25.92	24.99	23.67	22.53	21.5	21	20.3	19.09	18.63	18.13	17.88	17.56	16.47	16.1	15.42	14.79	14.35	14.05	13.75
GDUNOXSW	22.21	15.35	13.37	11.77	10.74	9.91	9.23	8.97	8.88	8.9	8.59	8.49	8.24	8.09	8.01	7.62	7.48	7.18	6.87	6.67	6.5	6.31
GNDIOCA	47.61	36.89	33.2	30.19	28.77	28.01	26.89	26.47	26.2	25.53	25.09	24.85	24.81	24.53	24.23	23.22	22.84	22.17	21.66	21.24	20.68	20.1
GNDIONONSW	4.09	15.61	22.11	28.73	32.31	35.07	37.72	38.46	38.84	38.91	38.75	38.61	38.34	38.2	38.25	38.77	39.08	39.88	40.37	40.82	41.1	40.49
GNDOUNOX	0.45	3.31	3.52	3.02	2.65	2.39	2.19	2.11	2.09	2.27	2.36	2.39	2.48	2.47	2.45	2.28	2.2	2.07	1.98	2.04	2.24	2.4
GRTAL											0.02	0.06	0.38	0.62	0.82	2.04	2.37	3.02	3.91	4.32	4.75	4.99
GRTMIX																						0.13
GRTNON		0.09	0.21	0.38	0.54	0.94	1.43	2.5	3	4.1	6.11	6.96	7.62	8.21	8.68	9.59	9.93	10.23	10.37	10.44	10.47	10.51
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 6-7 Material proportions on pit shell surface (as ARD codes) above water surface during pit lake formation

Year post-closure	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 17	Year 19	Year 21	Year 23	Year 25	Year 27	Year 31
Pit filling elevation (masl)	**293.6**	**316.3**	**332.1**	**345.6**	**357.3**	**367.3**	**376.3**	**384.5**	**391.8**	**398.7**	**405**	**410.9**	**416.5**	**421.7**	**426.6**	**435**	**443**	**450**	**456**	**461**	**466**	**473**
Surface area above water (m2)	**897972**	**873576**	**854528**	**839568**	**832984**	**815370**	**809928**	**790922**	**786472**	**780806**	**763574**	**759392**	**755028**	**734724**	**730508**	**724806**	**684056**	**678234**	**673360**	**641656**	**636030**	**630138**
DACMIX	1.21	1.24	1.26	1.29	1.31	1.33	1.35	1.37	1.39	1.41	1.42	1.45	1.47	1.48	1.5	1.51	1.57	1.59	1.65	1.68	1.7	1.73
DACMIXSW	1.42	1.46	1.49	1.52	1.54	1.57	1.6	1.61	1.64	1.66	1.67	1.7	1.73	1.75	1.77	1.78	1.85	1.88	1.95	1.98	2	2.03
DACOX	14.44	14.88	15.13	15.44	15.69	15.92	16.21	16.35	16.62	16.84	17	17.31	17.58	17.77	17.95	18.13	18.82	19.05	19.77	20.08	20.37	20.68
DACOXSW	1.58	1.63	1.65	1.69	1.71	1.74	1.77	1.79	1.82	1.84	1.86	1.89	1.92	1.94	1.96	1.98	2.06	2.08	2.16	2.19	2.23	2.26
DACUNOXSW	13.01	13.41	13.63	13.91	14.14	14.34	14.61	14.73	14.98	15.17	15.32	15.6	15.84	16.01	16.17	16.34	16.96	17.16	17.78	18.03	18.26	18.05
DACUNOXUD	7.92	8.16	8.3	8.47	8.61	8.73	8.89	8.97	9.12	9.24	9.33	9.5	9.64	9.75	9.85	9.95	10.32	10.45	10.84	11.01	11.17	11.28
GDIONON	4.79	3.92	3.6	3.3	3.06	2.93	2.74	2.67	2.54	2.46	2.44	2.36	2.25	2.15	2.08	2.01	1.85	1.81	1.69	1.69	1.64	1.6
GDUNOXSW	1.81	1.68	1.63	1.57	1.54	1.53	1.49	1.45	1.37	1.27	1.23	1.15	1.1	1.07	1.02	0.98	0.87	0.85	0.8	0.8	0.79	0.79
GNDIOCA	5.12	4.58	4.38	4.12	3.89	3.64	3.38	3.22	2.92	2.77	2.6	2.29	1.95	1.79	1.65	1.5	1.04	0.91	0.45	0.3	0.26	0.24
GNDIOCAMIX	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11	0.11
GNDIOMIX	0.27	0.28	0.28	0.29	0.29	0.3	0.3	0.31	0.31	0.32	0.32	0.32	0.33	0.33	0.34	0.34	0.35	0.36	0.37	0.38	0.38	0.39
GNDIOMIXSW	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.1	0.1	0.1	0.1	0.1	0.1	0.11	0.11	0.11	0.11	0.11
GNDIONONMIX	0.29	0.3	0.3	0.31	0.31	0.32	0.32	0.33	0.33	0.34	0.34	0.35	0.35	0.36	0.36	0.36	0.38	0.38	0.4	0.4	0.41	0.41
GNDIONONSW	17.73	17.32	16.76	15.89	15.22	14.57	13.74	13.44	12.91	12.56	12.3	11.89	11.55	11.3	11.02	10.73	9.39	8.88	7.36	6.64	6.01	5.78
GNDIOOX	0.38	0.39	0.4	0.4	0.41	0.42	0.42	0.43	0.44	0.44	0.45	0.45	0.46	0.47	0.47	0.48	0.49	0.5	0.52	0.53	0.53	0.54
GNDOUNOX	1.29	1.11	1.05	1.06	1.08	1.09	1.1	1.1	1.09	1.04	1.02	0.98	0.93	0.92	0.91	0.9	0.92	0.93	0.95	0.91	0.8	0.7
GRTAL	10.98	11.31	11.5	11.74	11.93	12.1	12.33	12.43	12.64	12.8	12.93	13.15	13.27	13.34	13.4	13.47	13.46	13.48	13.37	13.33	13.26	13.28
GRTALOX	8.83	9.11	9.26	9.45	9.6	9.74	9.92	10.01	10.17	10.3	10.4	10.59	10.76	10.87	10.98	11.1	11.52	11.66	12.09	12.28	12.46	12.65
GRTMIX	3.05	3.14	3.19	3.26	3.31	3.36	3.42	3.45	3.51	3.55	3.59	3.66	3.71	3.75	3.79	3.83	3.97	4.02	4.17	4.24	4.3	4.3
GRTNON	5.74	5.91	6	6.1	6.17	6.19	6.21	6.16	6.02	5.82	5.61	5.16	4.96	4.76	4.59	4.41	3.95	3.8	3.46	3.32	3.2	3.07
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

6.3.3 Hydrological inputs

Runoff in construction and operations

A runoff series was generated by the site-wide water balance (GoldSim) model using the 54 year simulated historical rainfall time series currently being utilized within GoldSim and surface water modelling, based on the historical rainfall record for the site (Section 3). Runoff is based on a site-specific curve number and scaled to the corresponding pit shell surface areas, representing the pit shell LOM years -1, 2, 7 and 21. Individual runoff events were deemed appropriate for modelling. A typical year from the 54 year period was chosen to model the geochemical results reflecting both average yearly maximum runoff unit events and taking into account normal periods of lower rainfall events and longer weathering periods that produce the worst case scenario in terms of water quality. The runoff events used within the model are presented in Figure A6.8, these are based on the runoff series from the simulated year 2006, which has a runoff volume variation between 0.004 mm/day and 10.1 mm/day. The weathering period between runoff events was calculated in days; within the modelled period this was between 1 and 46 days.

Groundwater estimation in operations

Groundwater inflows to the open pit through LOM are derived using the numerical groundwater model described in Section 5. The groundwater inflows to the pit are presented in Figure A5.11.

Pit sump modelling

Runoff and groundwater inflows from within the pit will be combined and managed within a pit sump during operations. The inflows to the pit through LOM were modelled within the GoldSim water balance, and estimations of volumes within the pit sump and processing plant requirements were included (Section 3). The pit sump water balance used for geochemical modelling is presented in Table 6-8.

Table 6-8 Yearly operational pit sump water balance

	Annual Inflow					Annual Outflow		
Result:	**Direct rainfall**	**Pit runoff**	**Pit interflow**	**ROM runoff**	**Groundwater**	**Evaporation from pit sump**	**To Plant**	**Overflow**
Unit:	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr	m3/yr
Displaying:	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Year 1	73	32,603	186,944	2,344	237,325	70	457,253	0
Year 2	75	42,749	249,770	2,432	401,113	70	695,789	0
Year 3	72	45,562	271,875	2,329	411,478	70	731,473	0
Year 4	75	49,631	292,993	2,441	429,700	70	774,242	0
Year 5	73	50,514	290,150	2,364	456,521	70	799,537	0
Year 6	73	49,100	304,531	2,326	534,918	70	891,005	0
Year 7	74	54,580	321,309	2,436	595,704	70	973,240	0
Year 8	73	53,883	318,922	2,340	607,771	70	983,200	0
Year 9	73	56,171	327,958	2,344	632,516	70	1,018,496	0
Year 10	73	57,205	342,598	2,363	658,975	70	1,060,566	0
Year 11	75	61,252	362,709	2,445	686,442	70	1,113,051	0
Year 12	74	61,631	363,611	2,401	713,144	70	1,140,703	0
Year 13	72	63,095	363,166	2,347	739,878	70	1,168,691	0

	Annual Inflow					Annual Outflow		
Result:	Direct rainfall	Pit runoff	Pit interflow	ROM runoff	Groundwater	Evaporation from pit sump	To Plant	Overflow
Year 14	74	63,572	384,996	2,376	769,180	70	1,220,905	0
Year 15	75	69,720	400,472	2,477	800,594	70	1,272,908	0
Year 16	72	64,476	394,220	2,309	832,793	70	1,293,578	0
Year 17	73	68,166	405,535	2,336	866,917	70	1,342,593	0
Year 18	75	75,502	432,069	2,497	906,140	70	1,415,802	0
Year 19	74	72,102	434,181	2,400	950,178	70	1,458,268	0
Year 20	72	71,779	433,931	2,321	990,961	70	1,500,110	0
Year 21	74	78,865	450,417	2,433	995,789	70	1,527,561	0

Pit lake formation in closure

The formation of a pit lake is predicted using a module within the GoldSim Ilovica water balance model (Section 3). The inflows to the pit include:

- Runoff and interflow from exposed pit surface above the lake water level and the ROM pad area
- Rebounding groundwater inflows to the pit
- Direct precipitation to the lake surface

The main outflows from the pit are:

- Evaporation from the pit lake surface
- Overflow from the pit lake (once the lake has reached an elevation of 473 masl)

The overall water balance is shown in Figure A6.9. The lake reaches a final elevation of 473 masl (the lowest pit intersection with the natural topographic surface) between year 28 and 29 post-closure. At this point the lake will begin to spill, with subsequent an annual average flow rate of 20 l/s.

6.3.4 Geochemical inputs

Introduction

The geochemical data is fully described in the Geochemical Annex 4 and in Section 6.2.4. The geological codes within the block model were each assigned a matching or proxy data set within the kinetic geochemical tests are presented in Table 6-9.

Table 6-9 Block model ARD codes and corresponding leach pad dataset

Block model codes	Description	Corresponding leach pad	Description and comment
DACMIX	Dacite, mixed	DACUNOXUD	No corresponding testwork, dacite unoxidised, undisturbed as a conservative proxy
DACMIXSW	Dacite, mixed, stockwork	DACUNOXBR	No corresponding testwork, dacite, unoxidised, brecciated (analogous to stockwork), as a conservative proxy
DACOX	Dacite, oxidised	DACOX	Dacite, oxidised
DACOXSW	Dacite, oxidized, stockwork	DACOX	No corresponding testwork, dacite oxidized, used as a proxy

Block model codes	Description	Corresponding leach pad	Description and comment
DACUNOXSW	Dacite, unoxidised, stockwork	DACUNOXBR	Essentially the same material as brecciated is analogous to stockwork, dacite, unoxidised, brecciated
DACUNOXUD	Dacite, unoxidised, undisturbed	DACUNOXUD	Dacite, unoxidised, undisturbed
GDIONON	Granodiorite, nontronite	GDIONON	Granodiorite, nontronite
GDUNOXSW	Granodiorite, unoxidised, stockwork	GDUNOXSW	Granodiorite, unoxidised, stockwork
GNDIOCA	Granodiorite, carbonate	GNDIOCA	Granodiorite, carbonate
GNDIOCAMIX	Granodiorite, carbonate, mixed	GNDIOCA	No corresponding testwork, grandodiorite, carbonate used as a proxy
GNDIOMIX	Granodiorite, mixed	GNDIO	No corresponding testwork, grandodiorite, unoxidised used as a proxy
GNDIOMIXSW	Granodiorite, mixed, stockwork	GDUNOXSW	No corresponding testwork, granodirorite, unoxidised, stockwork used as a proxy
GNDIONONMIX	Granodiorite, nontronite, mixed	GRDIONON	No corresponding testwork, granodiorite, nontronite used as a proxy
GNDIONONSW	Granodiorite, nontronite, stockwork	GDUNOXSW	No corresponding testwork, granodiorite, unoxidised stockwork used as a conservative proxy
GNDIOOX	Granodiorite, oxiide	GNDIO	No corresponding testwork, grandodiorite, unoxidised used as a proxy
GNDOUNOX	Granodiorite, unoxidised	GNDIO	Essentially the same material, granodiorite, unoxidised
GRTAL	Granite, altered	GRTAL	Granite, altered
GRTALOX	Granite, altered, oxidised	GRTALOX	Granite, altered, oxidised
GRTMIX	Granite, mixed	GRTAL	No corresponding testwork, granite, altered used as a proxy
GRTNON	Granite, nontronite	GRTNON	Granite, nontronite

Operational runoff

Geochemical inputs for runoff within the open pit were produced from kinetic tests as previously described for the oxide stockpile model. The concentrations recorded from the kinetic tests were converted into mass released per surface area of material. The particle size distribution of the material on the field kinetic tests was used to calculate a surface area for each leach pad (Table 6-10).

Rainfall events and weathering period data were analysed for each leachate sample collected from the kinetic tests. The mass load released by surface area for each leachate sample was then divided by the weathering period of the rainfall event to produce a mass released from sample surface area per time period. The final averages of this mass load calculation are presented in Table 6-11.

Table 6-10 Surface area for field kinetic tests

Leach Pad	Surface area (m2/kg)	Surface area of entire leachpad (m2)
GNDIOCA	0.18	54.67
DACOX	0.41	124.27
GRTALOX	0.19	57.05
DACOXBR	0.15	13.25
DACUNOXBR	0.25	75.29
GRTAL	0.21	62.53
GRTALHS	0.24	19.90
GRTNON	0.18	15.43
GRDIONON	0.21	63.72
GNDIO	0.14	11.85
DACUNOXUD	0.33	27.95
GDUNOXSW	0.37	31.76

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Table 6-11 Calculated average mass load release by surface area of kinetic test

Parameter	DACOX	DACUNOXBR	DACUNOXUD	GDUNOXSW	GNDIO	GNDIOCA	GRDIONON	GRTAL	GRTALOX	GRTNON
pH-F pH units	5.39	3.51	2.78	3.07	6.23	6.03	4.73	3.42	5.77	4.72
Alkalinity (mg/m2/day CaCO3)	1.14E-01	6.04E-04	7.98E-04	0.00E+00	1.01E+00	9.61E-01	3.65E-02	0.00E+00	4.25E-01	2.47E-02
Ag-D mg/m2/day	3.53E-06	2.07E-05	4.56E-05	1.76E-05	1.70E-05	9.91E-06	7.48E-06	6.99E-06	7.91E-06	7.79E-06
Al-D mg/m2/day	1.23E-02	2.13E-01	1.01E+00	1.89E-01	3.80E-03	1.78E-03	1.96E-03	1.43E-01	8.28E-03	8.93E-03
As-D mg/m2/day	1.26E-05	7.63E-05	4.24E-03	2.76E-04	2.72E-05	5.09E-05	1.15E-05	2.24E-05	1.84E-05	1.18E-05
Ba-D mg/m2/day	3.16E-04	2.16E-04	4.63E-04	2.29E-04	1.72E-04	2.97E-04	3.61E-04	7.84E-05	1.33E-03	2.91E-04
Bi-D mg/m2/day	3.15E-05	7.52E-04	1.87E-04	1.14E-04	1.92E-04	1.04E-04	6.85E-05	6.68E-05	6.91E-05	9.66E-05
Ca-D mg/m2/day	2.59E-02	6.64E-02	1.26E-01	4.83E-01	5.03E-01	5.34E-01	5.17E-01	6.27E-02	8.89E-02	3.48E-01
Cd-D mg/m2/day	3.26E-06	6.57E-04	7.85E-03	1.63E-04	1.85E-05	8.50E-06	1.71E-04	4.25E-05	7.30E-06	1.16E-04
Cl-ion mg/m2/day	7.65E-02	2.50E-02	5.83E-02	3.26E-02	7.45E-02	4.34E-02	3.20E-02	3.00E-02	9.19E-02	3.28E-02
Co-D mg/m2/day	1.03E-05	3.10E-03	3.86E-03	2.47E-03	4.86E-05	2.83E-05	5.12E-04	2.93E-03	9.12E-05	7.56E-04
Cr-D mg/m2/day	1.09E-05	8.31E-05	2.93E-04	2.20E-04	4.86E-05	2.83E-05	2.14E-05	3.89E-05	2.36E-05	2.12E-05
CrVI-D mg/m2/day	2.33E-05	1.11E-04	2.62E-04	1.43E-04	1.10E-04	6.61E-05	4.94E-05	5.57E-05	7.54E-05	4.97E-05
Cu-D mg/m2/day	5.84E-05	1.69E+00	4.91E-01	3.53E-01	9.04E-04	1.65E-04	4.65E-02	5.24E-01	7.26E-04	3.13E-02
Fe-D mg/m2/day	3.96E-03	1.58E-01	6.68E+00	1.40E+00	5.59E-03	3.26E-03	2.72E-03	1.53E-01	3.81E-03	6.03E-03
F-ion mg/m2/day	1.27E-03	6.76E-04	4.05E-04	1.01E-03	6.04E-03	2.81E-03	2.17E-03	8.55E-04	6.46E-03	2.71E-03
Hg-D mg/m2/day	1.74E-07	4.15E-07	n/a	4.63E-07	1.26E-06	6.18E-07	3.58E-07	3.76E-07	4.05E-07	7.36E-07
K-D mg/m2/day	1.44E-02	1.23E-02	1.41E-02	4.71E-02	1.20E-01	5.26E-02	1.09E-01	9.87E-03	2.71E-02	1.01E-01
Mg-D mg/m2/day	5.86E-03	2.17E-02	4.29E-02	8.84E-01	1.07E-01	1.48E-02	2.79E-01	9.94E-03	2.08E-02	3.50E-01
Mn-D mg/m2/day	4.98E-05	1.17E-03	2.66E-03	2.24E-02	1.39E-03	4.51E-04	1.35E-01	1.38E-03	2.23E-04	1.25E-01
Mo-D mg/m2/day	1.51E-05	8.89E-05	9.39E-04	5.02E-04	1.75E-04	1.06E-04	3.20E-05	3.00E-05	3.62E-05	3.18E-05
Na-D mg/m2/day	1.81E-02	1.41E-02	2.08E-02	9.75E-03	9.29E-02	1.12E-01	3.84E-02	4.85E-03	4.04E-02	1.75E-02
Ni-D mg/m2/day	1.52E-05	2.40E-03	2.02E-03	1.98E-03	7.29E-05	4.40E-05	3.29E-04	1.69E-03	4.92E-05	7.05E-04
N-NH3 mg/m2/day	2.53E-03	1.76E-02	5.40E-03	8.14E-03	9.54E-03	4.31E-03	4.31E-03	2.04E-02	4.20E-03	8.01E-03
N-NO2 mg/m2/day	2.41E-03	2.68E-04	1.76E-04	1.88E-04	3.70E-03	2.14E-03	5.27E-04	2.81E-04	1.74E-03	2.77E-04
NO3-NO3 mg/m2/day	3.65E-02	1.79E-02	1.43E-02	1.47E-02	1.88E-01	9.34E-02	5.31E-02	2.13E-02	1.08E-01	2.94E-02
NO3-N mg/m2/day	8.24E-03	4.04E-03	3.23E-03	3.33E-03	4.24E-02	2.11E-02	1.20E-02	4.82E-03	2.43E-02	6.64E-03

Parameter	DACOX	DACUNOXBR	DACUNOXUD	GDUNOXSW	GNDIO	GNDIOCA	GRDIONON	GRTAL	GRTALOX	GRTNON
OrthPO4-P mg/m2/day	6.85E-03	1.13E-02	8.46E-03	9.01E-03	3.07E-02	1.92E-02	1.36E-02	1.35E-02	1.53E-02	1.33E-02
Pb-D mg/m2/day	7.14E-05	1.78E-04	4.08E-04	1.51E-04	1.46E-04	8.50E-05	2.26E-04	5.99E-05	9.08E-05	5.94E-04
Sb-D mg/m2/day	6.53E-06	1.13E-05	3.04E-05	8.87E-06	3.53E-05	1.98E-05	1.37E-05	1.27E-05	1.44E-05	1.40E-05
Se-D mg/m2/day	4.80E-06	3.25E-04	6.07E-04	1.70E-04	2.84E-05	1.44E-05	9.58E-05	1.15E-04	2.87E-05	9.25E-05
Si-T mg/m2/day	5.97E-02	3.93E-02	1.79E-01	1.71E-01	8.81E-02	8.65E-02	5.76E-02	3.12E-02	5.38E-02	6.00E-02
SO4-D mg/m2/day	1.12E-01	5.20E+00	3.58E+01	1.44E+01	7.10E-01	3.54E-01	2.83E+00	3.04E+00	1.65E-01	2.82E+00
Sr-D mg/m2/day	1.57E-04	1.10E-04	1.77E-04	6.95E-04	1.55E-03	7.06E-03	1.94E-03	1.32E-04	3.98E-04	4.45E-04
U-D mg/m2/day	1.55E-06	1.04E-03	1.13E-03	7.19E-04	3.45E-05	1.25E-04	1.45E-05	3.59E-04	6.52E-05	6.72E-06
V-D mg/m2/day	2.23E-05	1.22E-04	3.55E-04	1.13E-04	9.73E-05	5.66E-05	4.27E-05	4.00E-05	4.52E-05	4.23E-05
Zn-D mg/m2/day	1.99E-03	1.11E-01	3.11E-01	2.35E-01	8.30E-04	3.41E-04	4.88E-02	2.55E-02	2.56E-03	9.55E-02
n/a Data not available										

Operational groundwater inflows

Baseline groundwater quality monitoring within the deposit provides the best estimation of groundwater inflows to the pit. No suitable groundwater monitoring is available at Ilovica, as there is uncertainty relating to current depths of drill holes within the deposit due to collapses and inadequate capping of drill hole heads. As no suitable baseline data is available the geochemical inputs for the groundwater inflows will be estimated from the kinetic dataset. The geochemical input for the groundwater inflows to the pit are based on the same chemical mass load estimations as described for the runoff model. The material breakdown used to estimate groundwater quality only takes into account material below 600 masl, to take into account less or no groundwater movement through the oxide zone within the pit, as found in current water level monitoring within the deposit. The material breakdown used for the estimation is presented in Table 6-12.

Table 6-12 Material proportions for geochemical groundwater inflow estimation

Pit stage		Starter Pit	First Pushback	Final Pit
Surface area of pit (m2)		144754	273250	577030
LOM start year		2	7	21
LOM end year		6	20	23
Block model ARD code	Corresponding leach pad code	Proportion of material		
DACMIXSW	DACUNOXBR	0.3	0.2	0.3
DACOX	DACOX	0.1	0.0	0.1
DACOXSW	DACOX	0.0	0.0	0.6
DACUNOXSW	DACUNOXBR	8.2	24.0	15.1
DACUNOXUD	DACUNOXUD	1.6	7.3	4.5
GDIONON	GRDIONON	23.0	10.0	9.0
GDUNOXSW	GDUNOXSW	2.6	3.4	4.2
GNDIOCA	GNDIOCA	8.1	12.0	10.9
GNDIOCAMIX	GNDIOCA	0.4	0.3	0.1
GNDIOMIX	GNDIO	4.1	1.4	0.4
GNDIOMIXSW	GDUNOXSW	3.6	2.3	0.1
GNDIONONMIX	GRDIONON	3.8	0.9	0.5
GNDIONONSW	GDUNOXSW	29.1	25.8	27.6
GNDIOOX	GNDIO	5.5	3.1	0.6
GNDOUNOX	GNDIO	8.4	3.6	2.0
GRTAL	GRTAL	0.0	2.6	9.0
GRTALOX	GRTALOX	0.9	2.0	4.7
GRTMIX	GRTAL	0.1	0.9	1.5
GRTNON	GRTNON	0.0	0.4	8.9
Totals		100	100	100

Pit lake geochemical inputs

The runoff chemistry component in the pit lake model was produced from the same mass loading data described in the runoff section for operations above. The runoff was calculated for the material proportions above the pit lake surface described in Section 6.3.2. The groundwater inflow chemistry used within the closure pit model is the same as described above in the operational groundwater inflow section.

The solution used as a chemical input for the precipitation within the pit lake water balance is a solution with no chemical load. The solution is set with a pH of 5.5 and alkalinity of 5 mg/l $CaCO_3$ to take into account equilibration with the atmosphere. The pit lake chemistry is calculated each annual time step within the model, and the final pit lake chemistry produced each year is the used as an input to the next annual time step. This is described further in Section 6.3.6. The evaporation component of the pit lake model acts within the geochemical calculations as a

blank solution that removes water volume from the pond, but not solute load, slightly concentrating the pond chemistry. This is further described in Section 6.3.5.

6.3.5 Model set-up

Construction runoff

The geochemical mass loads and hydrological inputs described above were used to create a mass balance model. The unit runoff volumes were scaled to pit shell surface areas. The mass loads were scaled to the material proportions as described, and to the proportion of each pit shell surface area. Runoff water pH was then calculated from the molar concentration of hydrogen ions. The mass load for the entire pit area was dissolved into the total runoff event volume to produce a runoff water quality concentration. Each runoff event solution was then thermodynamically equilibrated with the industry standard code PHREEQC, using a temperature of 15^{o}C and a pe of 10 (where pe is defined to control redox). The solutions were charge balanced using calcium ions. Where ferrihydrite was supersaturated it was allowed to precipitate and the solid surface was programmed to act as surface for sorption and exchange.

Operations

The runoff chemistry models are set-up as described for the construction models above, using the operation pit shell material proportions and corresponding hydrological and geochemical inputs.

As for operational runoff, groundwater chemistry was estimated by combining the hydrological inputs with geochemical mass loads to produce a solute concentration. Groundwater inflow chemistries were modelled by assuming a contact surface area of the pit shell (material described in Section 6.3.4) where groundwater is likely to seep, plus a 10 meter inflow pathway behind the pit shell surface. It was assumed that 5% of the inflow pathway surface area is in contact with the groundwater inflow volumes. The weathering period for the groundwater inflow is estimated to be between 60 and 115 days (as per Darcy velocity calculations from the numerical groundwater model). The mass loading models were equilibrated using the thermodynamic code PHREEQC where the pe was fixed to 4, to take into account the lower redox conditions of the groundwater (this is in contrast to the collected geochemical field data, which are open to the atmosphere and leachates produced will have a more oxidating redox level). The solutions were charge balanced using calcium ions. Where ferrihydrite was supersaturated it was allowed to precipitate and the solid surface was programmed to act as surface for sorption and exchange.

Closure

The runoff chemistry component of the pit lake geochemical model is set-up as described for the construction models above, using the pit shell material proportions above the lake level (Section 6.3.4) and corresponding hydrological and geochemical inputs. An average groundwater chemistry from the groundwater inflow results for the final pit (Section 6.3.6) was used as the groundwater inflow solution to the pit lake model. The inflows for each year were mixed proportionally with respect to the pit lake water balance, and thermodynamically equilibrated using PHREEQC. The evaporation component was included as a negative component, which removes water volume but not solute load. The lake volume and chemistry from the previous year of the model was also included within the mix. The lake solution for each year was charge balanced using calcium ions. Where ferrihydrite was supersaturated it was allowed to precipitate and the solid surface was programmed to act as surface for sorption and exchange. The pit lake chemistry was also allowed to equilibrate with the atmospheric gases.

6.3.6 Results

Construction

The results for the pre-strip pit shell runoff modelling are presented in Table 6-13 with the project effluent discharge standards for comparison (results exceeding discharge standards are highlighted in red). Generally the water quality is relatively good, the runoff produced tends to be of neutral pH and low metal load. At the maxima of the predicted range, which correspond to low volumes of water and longer weathering periods, the pH drops to below project effluent standards and zinc is elevated. For most runoff events water quality is likely to be of acceptable discharge consent, however for extreme events it is advised that runoff within the construction phase pit shell be managed and reused for water supply.

Table 6-13 Results of pre-strip pit shell runoff water quality modelling

Parameter	Units	Project effluent standards**	Min	Median	Max
Runoff volume	l/day		1021	423014	1532784
Weathering period	days		1	4	46
pH*	pH	6 - 9	7.48	6.40	4.51
pe	mg/l		7	8	10
Ag	mg/l		0.000001	0.000011	0.001044
Al	mg/l		0.002	0.031	2.975
Alkalinity as CaCO3	mg/l		0.03	0.35	34.30
As	mg/l	0.1	0.000003	0.000034	0.003362
Ba	mg/l		0.0001	0.0012	0.1154
Ca	mg/l		0.02	0.29	27.74
Cd	mg/l	0.05	0.0000008	0.0000101	0.0009710
Cl	mg/l		0.02	0.21	19.80
Co	mg/l		0.000005	0.000063	0.006034
Cr* **	mg/l	0.1	0.000002	0.000019	0.003050
Cu	mg/l	0.3	0.0001	0.0015	0.1437
F	mg/l		0.0004	0.0052	0.5027
Fe** **	mg/l	2	0.0002	0.0025	0.2349
Hg** **	mg/l	0.002	0.000000	0.000001	0.000052
K	mg/l		0.003	0.042	4.067
Mg	mg/l		0.002	0.021	2.003
Mn	mg/l		0.00002	0.00020	0.01888
Mo	mg/l		0.000004	0.000047	0.004552
NO3	mg/l		0.002	0.025	2.966
NO2	mg/l		0.01	0.12	10.55
Na	mg/l		0.004	0.055	5.333
Ni** **	mg/l	0.5	0.000004	0.000056	0.005359
P	mg/l		0.005	0.063	5.978
Pb	mg/l	0.2	0.00001	0.00014	0.01844
SO4	mg/l		0.03	0.32	30.60
Sb	mg/l		0.000002	0.000020	0.001923
Se	mg/l		0.000002	0.000021	0.002070
Si	mg/l		0.006	0.072	6.936
Sr	mg/l		0.00004	0.00050	0.04804
V	mg/l		0.00001	0.00007	0.00642
Zn** **	mg/l	0.5	0.0004	0.0055	0.5258

*** pH statistics calculated from molar concentration of hydrogen ions**

**** As described in the EDC**

*****Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant**

****** Modelled data is as dissolved concentrations, standard as totals**

Operations

The results of modelled runoff water quality for the operational open pit are presented in Table 6-14. Operational groundwater inflow water quality modelling results are presented in Table 6-15. The results are compared with project effluent standards, however all water collected within the open pit will be collected and pumped to the processing plant, thus there will be no discharge of contact water from the open pit during operations.

Table 6-14 Results of operational pit runoff water quality modelling

Parameter	Units	Project effluent standards**	Starter pit			First pushback			Final pit		
			Min	Median	Max	Min	Median	Max	Min	Median	Max
Runoff volume	l/day		1885	848721	4773167	2341	1053926	5927229	2341	1053926	5927229
Weathering period	days		1	3	46	1	3	46	1	3	46
pH*	pH	6 - 9	5.92	4.57	3.23	5.48	4.12	2.90	5.55	4.19	2.95
Pe	mg/l		8	10	11	8	10	12	8	10	12
Ag	mg/l		0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001
Al	mg/l		0.007	0.177	4.153	0.021	0.541	12.664	0.018	0.447	10.460
Alkalinity as CaCO3	mg/l		0.00	0.00	10.75	0.00	0.00	8.44	0.00	0.00	6.51
As	mg/l	0.1	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.00	0.03
Ba	mg/l		0.000	0.001	0.021	0.000	0.001	0.022	0.000	0.001	0.021
Ca	mg/l		0.09	2.40	46.80	0.20	5.08	96.44	0.17	4.41	84.32
Cd	mg/l	0.05	0.000	0.001	0.017	0.000	0.003	0.071	0.000	0.002	0.049
Cl	mg/l		0.006	0.155	3.629	0.005	0.129	3.023	0.005	0.117	2.746
Co	mg/l		0.000	0.002	0.040	0.000	0.004	0.100	0.000	0.004	0.102
Cr***	mg/l	0.1	0.000	0.000	0.003	0.000	0.000	0.006	0.000	0.000	0.006
Cu	mg/l	0.3	0.01	0.37	8.67	0.05	1.22	28.49	0.04	1.06	24.86
F	mg/l		0.000	0.005	0.126	0.000	0.005	0.111	0.000	0.004	0.104
Fe****	mg/l	2	0.01	0.19	13.88	0.02	0.67	67.54	0.02	0.54	53.45
Hg****	mg/l	0.002	0.00000	0.00000	0.00002	0.00000	0.00000	0.00002	0.00000	0.00000	0.00002
K	mg/l		0.00	0.11	2.49	0.00	0.09	2.01	0.00	0.09	2.11
Mg	mg/l		0.02	0.45	10.49	0.02	0.45	10.61	0.02	0.57	13.25
Mn	mg/l		0.002	0.047	1.094	0.001	0.030	0.705	0.002	0.050	1.171
Mo	mg/l		0.000	0.000	0.008	0.000	0.000	0.015	0.000	0.000	0.013
NO3	mg/l		0.000	0.017	0.482	0.000	0.003	0.055	0.000	0.003	0.074
NO2	mg/l		0.006	0.134	1.232	0.000	0.032	0.196	0.000	0.038	0.251
Na	mg/l		0.00	0.08	1.84	0.00	0.07	1.72	0.00	0.06	1.48
Ni****	mg/l	0.5	0.000	0.001	0.030	0.000	0.003	0.069	0.000	0.003	0.071
P	mg/l		0.001	0.021	0.846	0.000	0.016	2.153	0.001	0.018	2.108
Pb	mg/l	0.2	0.000	0.000	0.007	0.000	0.000	0.010	0.000	0.000	0.010
SO4	mg/l		0.4	9.3	219.7	0.8	21.0	499.4	0.7	18.7	442.7
Sb	mg/l		0.0000	0.0000	0.0007	0.0000	0.0000	0.0009	0.0000	0.0000	0.0008
Se	mg/l		0.000	0.000	0.004	0.000	0.000	0.011	0.000	0.000	0.010
Si	mg/l		0.00	0.10	2.24	0.00	0.11	2.50	0.00	0.10	2.40
Sr	mg/l		0.000	0.002	0.049	0.000	0.002	0.051	0.000	0.002	0.053
V	mg/l		0.000	0.000	0.004	0.000	0.000	0.007	0.000	0.000	0.006
Zn****	mg/l	0.5	0.01	0.14	3.19	0.01	0.27	6.23	0.01	0.25	5.97
* pH statistics calculated from molar concentration of hydrogen ions											
** As described in the EDC											
***Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant											
**** Modelled data is as dissolved concentrations, standard as totals											

Table 6-15 Results of operational pit groundwater inflow quality modelling

Parameter	Units	Project effluent standards*	Starter pit			First pushback			Final pit		
			Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Seepage vol	m3/day		1096			1631			2763		
pH	pH	6 - 9	3.82	4.55	5.21	3.82	4.54	5.20	3.81	4.53	5.20
Ag	mg/l		0.0003	0.0004	0.0004	0.0002	0.0003	0.0003	0.0001	0.0001	0.0002
Al	mg/l		2.70	3.81	4.54	2.22	3.13	3.73	1.07	1.51	1.80
Alkalinity	mg/l		4.01	5.73	6.86	3.40	4.86	5.85	1.59	2.28	2.76
As	mg/l	0.1	0.005	0.007	0.009	0.005	0.007	0.008	0.002	0.003	0.004
Ba	mg/l		0.005	0.007	0.009	0.003	0.005	0.005	0.002	0.003	0.003
Ca	mg/l		25.8	36.4	43.4	19.6	27.7	33.0	10.3	14.5	17.2
Cd	mg/l	0.05	0.009	0.013	0.016	0.009	0.013	0.016	0.004	0.005	0.006
Cl	mg/l		0.7	0.9	1.1	0.4	0.6	0.8	0.3	0.4	0.4
Co	mg/l		0.03	0.05	0.05	0.02	0.03	0.04	0.01	0.02	0.02
Cr**	mg/l	0.1	0.002	0.003	0.003	0.001	0.002	0.002	0.001	0.001	0.001
Cu	mg/l	0.3	7.9	11.2	13.4	6.8	9.5	11.4	3.2	4.4	5.3
F	mg/l		0.03	0.04	0.05	0.02	0.03	0.03	0.01	0.02	0.02
Fe***	mg/l	2	13.8	19.4	23.2	11.4	16.0	19.1	5.5	7.7	9.2
Hg***	mg/l	0.002	0.000008	0.000012	0.000014	0.000006	0.000008	0.000010	0.000003	0.000005	0.000006
K	mg/l		0.8	1.2	1.4	0.6	0.8	0.9	0.3	0.5	0.6
Mg	mg/l		6.1	8.6	10.3	3.8	5.4	6.5	2.4	3.4	4.1
Mn	mg/l		0.5	0.8	0.9	0.3	0.4	0.4	0.2	0.3	0.4
Mo	mg/l		0.004	0.006	0.007	0.003	0.005	0.006	0.002	0.002	0.003
NH3-N	mg/l		0.3	0.5	0.6	0.2	0.3	0.4	0.1	0.2	0.2
NO3-N	mg/l		0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
NO2-N	mg/l		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Na	mg/l		0.5	0.7	0.8	0.4	0.6	0.7	0.2	0.3	0.3
Ni***	mg/l	0.5	0.02	0.03	0.04	0.02	0.02	0.03	0.01	0.01	0.02
P	mg/l		0.68	0.95	1.14	0.48	0.67	0.80	0.27	0.38	0.45
Pb	mg/l	0.2	0.003	0.005	0.006	0.002	0.003	0.003	0.001	0.002	0.002
SO4	mg/l		137.8	194.4	231.8	104.3	147.2	175.5	54.7	77.1	91.9
Sb	mg/l		0.0002	0.0003	0.0004	0.0002	0.0003	0.0003	0.0001	0.0001	0.0002
Se	mg/l		0.0029	0.0040	0.0048	0.0023	0.0032	0.0038	0.0011	0.0016	0.0019
Si	mg/l		0.79	1.12	1.34	0.56	0.79	0.94	0.32	0.44	0.53
Sr	mg/l		0.02	0.03	0.04	0.02	0.02	0.03	0.01	0.01	0.02
U	mg/l		0.0004	0.0006	0.0007	0.0003	0.0004	0.0005	0.0002	0.0002	0.0003
V	mg/l		0.0016	0.0023	0.0028	0.0013	0.0019	0.0022	0.0006	0.0009	0.0011
Zn***	mg/l	0.5	2.1	3.0	3.6	1.5	2.1	2.6	0.8	1.2	1.4
*** As described in the EDC**											
****Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant**											
***** Modelled data is as dissolved concentrations, standard as totals**											

The operational groundwater and runoff water quality presented above was combined using the hydrological conditions described in Section 6.3.3 to produce the predicted operational pit sump water quality, Table 6-16 and compared with project effluent standards for context. As stated previously, all water collected within the pit during operations will be collected and pumped to the processing plant for reuse.

Closure

The results for the pit lake water quality model are presented in time series Figures A6.10 and A6.11 and as a statistical range in Table 6-17 (compared with EDC effluent standards). The water quality is acidic and has high concentrations of trace metals and sulphate. The main geochemical component of the pit lake model is the runoff draining into the pit lake. This continues to add solute load to the pit lake after the lake level has stabilized, as the high wall of the pit is left exposed with a large surface area of sulphide material.

Table 6-16 Results of water quality modelling of operational pit sump water

Parameter	Units	Project effluent standards**	Starter pit			First pushback			Final pit		
			Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
pH*	pH	6-9	5.37	4.20	3.69	5.35	4.46	3.99	5.29	4.54	4.12
Ag	mg/l		0.0002	0.0003	0.0005	0.0001	0.0003	0.0006	0.0001	0.0002	0.0004
Al	mg/l		1.56	2.72	4.33	1.37	3.48	6.92	0.70	2.18	4.67
Alkalinity	mg/l		0.00	0.00	3 .98	0.00	0.00	3.52	0.00	0.00	1.77
As	mg/l	0.1	0.003	0.004	0.005	0.003	0.008	0.015	0.001	0.004	0.009
Ba	mg/l		0.003	0.007	0.014	0.002	0.006	0.011	0.001	0.004	0.009
Ca	mg/l		15.0	28.4	48.2	12.1	29.3	56.9	6.8	19.7	41.6
Cd	mg/l	0.05	0.005	0.010	0.016	0.006	0.017	0.036	0.002	0.009	0.021
Cl	mg/l		0.4	1.0	2.2	0.3	0.8	1.6	0.2	0.6	1.2
Co	mg/l		0.02	0.03	0.05	0.01	0.03	0.06	0.01	0.02	0.05
Cr* **	mg/l	0.1	0.001	0.002	0.003	0.001	0.002	0.004	0.000	0.001	0.002
Cu	mg/l	0.3	4.6	7.5	11.2	4.2	9.3	17.3	2.1	5.7	11.7
F	mg/l		0.02	0.04	0.08	0.01	0.03	0.06	0.01	0.02	0.05
Fe** **	mg/l	2	1.7	7.6	13.3	6.9	14.6	26.8	3.4	8.1	15.8
Hg** **	mg/l	0.002	0.000005	0.000010	0.000017	0.000003	0.000008	0.000014	0.000002	0.000006	0.000011
K	mg/l		0.5	1.0	1.9	0.3	0.7	1.3	0.2	0.5	1.1
Mg	mg/l		3.5	6.3	10.3	2.4	4.6	7.8	1.6	3.7	7.1
Mn	mg/l		0.3	0.6	1.0	0.2	0.3	0.5	0.1	0.3	0.6
Mo	mg/l		0.002	0.004	0.007	0.002	0.005	0.009	0.001	0.003	0.006
NH3-N	mg/l		0.2	0.4	0.9	0.1	0.2	0.3	0.1	0.2	0.3
NO3-N	mg/l		0.00000	0.00716	0.03236	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
NO2-N	mg/l		0.0000	0.0697	0.2960	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Na	mg/l		0.3	0.7	1.3	0.2	0.6	1.0	0.1	0.4	0.7
Ni** **	mg/l	0.5	0.01	0.02	0.04	0.01	0.02	0.04	0.01	0.02	0.03
P	mg/l		0.45	1.16	2.01	0.84	1.29	1.67	0.49	0.84	1.23
Pb	mg/l	0.2	0.002	0.004	0.006	0.001	0.003	0.005	0.001	0.002	0.005
SO4	mg/l		79.5	139.6	222.9	64.1	150.6	288.9	35.9	100.1	207.4
Sb	mg/l		0.0001	0.0003	0.0005	0.0001	0.0003	0.0005	0.0001	0.0002	0.0004
Se	mg/l		0.0017	0.0029	0.0045	0.0014	0.0033	0.0064	0.0007	0.0021	0.0044
Si	mg/l		0.21	0.44	0.79	0.16	0.37	0.70	0.10	0.26	0.54
Sr	mg/l		0.01	0.03	0.04	0.01	0.02	0.04	0.01	0.01	0.03
V	mg/l		0.0009	0.0018	0.0031	0.0008	0.0019	0.0037	0.0004	0.0012	0.0026
Zn** **	mg/l	0.5	1.2	2.1	3.4	0.9	2.1	3.8	0.6	1.4	2.9
*** pH statistics calculated from molar concentration of hydrogen ions**											
**** As described in the EDC**											
*****Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant**											
****** Modelled data is as dissolved concentrations, standard as totals**											

Table 6-17 Results range for pit lake water quality modelling

Parameter	Units	Project effluent standards**	Min	Mean	Max
pH*	pH	6 - 9	3.79	3.73	3.68
Ag	mg/l		0.00	0.00	0.00
Al	mg/l		10.2	11.5	12.7
Alkalinity	mg/l		0	0	0
As	mg/l	0.1	0.02	0.02	0.02
Ba	mg/l		0.02	0.02	0.02
Ca	mg/l		75	85	95
Cd	mg/l	0.05	0.050	0.056	0.062
Cl	mg/l		2.5	2.9	3.2
Co	mg/l		0.10	0.11	0.12
Cr***	mg/l	0.1	0.005	0.006	0.006
Cu	mg/l	0.3	25	28	31
F	mg/l		0.09	0.10	0.12
Fe****	mg/l	2	38	42	47
Hg****	mg/l	0.002	0.0000	0.0000	0.0000
K	mg/l		1.6	1.9	2.2
Mg	mg/l		10	11	13
Mn	mg/l		0.84	0.98	1.13
Mo	mg/l		0.01	0.01	0.01
NH3-N	mg/l		1.01	1.14	1.27
NO3-N	mg/l		0.0000	0.0000	0.0000
NO2-N	mg/l		0.0000	0.0000	0.0000
Na	mg/l		1.16	1.33	1.49
Ni****	mg/l	0.5	0.07	0.07	0.08
P	mg/l		0.64	0.69	0.76
Pb	mg/l	0.2	0.009	0.010	0.011
SO4	mg/l		397	451	504
Sb	mg/l		0.001	0.001	0.001
Se	mg/l		0.01	0.01	0.01
Si	mg/l		1.90	2.18	2.47
Sr	mg/l		0.03	0.04	0.04
U	mg/l		0.001	0.001	0.001
V	mg/l		0.01	0.01	0.01
Zn****	mg/l	0.5	5.19	5.93	6.67
* pH statistics calculated from molar concentration of hydrogen ions					
** As described in the EDC					
***Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant					
**** Modelled data is as dissolved concentrations, standard as totals					

6.3.7 Conclusions and further work

During operations there will be no discharge of contact water, as water collected in the pit sump should always be supplied to the processing plant. In later mine life when the pit reaches depth this will be true, however when the pit is shallower more careful management of runoff may be required to ensure no releases to the environment.

The outflow volume from the pit lake is relatively high; further work could be completed to assess the robustness of this estimate as it could have impacts on the quality and discharge from the pit as well as the mitigation measures required.

6.4 Tailings and TMF

6.4.1 Conceptualization

Construction

During the construction period (LOM year -1), no tailings will be produced. The area of the TMF will begin to be stripped and material removed from the pre-strip pit shell will be placed as a TMF starter embankment. No water management for runoff will be in place during the construction period downgradient of the TMF site. It is assumed that no seepage will occur from the initial placement of waste rock material. Runoff from the material will be generated, and the quality of the runoff water will be dependent on the interaction between waste rock material and precipitation.

Operations

The planned TMF is a cross-valley impoundment within the Shtuka valley, with a waste rock embankment at the western end. The starter dam will have a height of approximately 45 m and the final height of the dam is 276 m. Tailings will be produced at 10 Mt per year for 21 years. The tailings will be a mix of CIL and flotation tailings at a ratio of 0.075:1. The starter dam will be completed in LOM year 2 and the final dam completed in LOM year 20. Tailings are piped to the TMF and placed by spigots. The facility footprint will not be lined, but the TMF starter dam will have a 2 mm thick HDPE liner on its upstream face and a coarse and fine seepage filter and seepage underdrain below the liner, which will convey seepage under the embankment to a storm water dam at the toe of the TMF. The Shtuka River will be diverted around the footprint of the TMF.

The TMF embankment will be designed with a higher permeability rockfill toe, to assist in lowering the phreatic surface within the embankment. The selection and placement of specific material types within the TMF embankment has not yet been finalized. For purposes of preliminary geochemical modelling it was assumed that waste is to be placed homogenously. The down-gradient face of the tailings embankment will be compacted and it is assumed that most precipitation landing on the embankment will run off rather than infiltrate. Tailings will be placed as a slurry and tailings pore water is expected to seep to ground and into the embankment. Infiltration water entering the embankment will mix with tailings seepage and daylight at the toe of the TMF embankment. A conceptual diagram of the TMF, including hydrological flows, for the starter dam and final TMF design is presented in Figure A6.12.

Closure

The final dam height will be 276 m and the total mass of deposited tailings 210 Mt with a footprint surface area of 1,938,634 m^2. The detailed closure rehabilitation design for the TMF is still to be finalized. However, the design will minimize infiltration into the TMF and long term seepage impact on groundwater. A vegetation cover will also minimize erosion from the TMF surface. The facility will be capped with a 500 mm thick layer of crushed rock. Basic hydrological conceptualization in closure assumes runoff will not be in contact with waste material due to the final cap on the TMF and embankment. The seepage will continue as found for the final year of operations for 10 years post closure, then it will reduce to 10% of the final operational seepage volume to simulate drain down from the tailings.

6.4.2 Mine design and key project information

The embankment will be constructed using waste material. The waste material schedule through LOM is presented in Appendix A, exported from the geological block model and coded by ARD description. Tailings will be produced at around 10 Mt per year and the TMF heights and volumes are as described in the project conceptualization (Section 6.4.1 above). The runoff models were estimated using the surface area of the embankment through LOM,

which is presented in Table 6-18. The runoff model also assumes that the waste material produced that year will be the material which is in contact with runoff water, as the material is currently expected to be placed sequentially as it is produced. The seepage water quality through the TMF embankment for each LOM year is predicted using the cumulative waste material proportions from the initial to the current LOM year, for each model time step.

Table 6-18 Mean average embankment surface area through LOM

	Mean embankment surface area
LOM year	m2
-1	51643
1	116279
2	141062
3	165878
4	190694
5	215476
6	240258
7	265074
8	289890
9	314672
10	339454
11	364271
12	389087
13	413869
14	438651
15	463467
16	488283
17	513065
18	537847
19	562663
20	587479
21	612227

6.4.3 Hydrological inputs

The hydrological inputs for the TMF water quality model are based on the Golder's TMF module that has been incorporated into the SWS site-wide water balance model. No specific seepage modelling has been undertaken other than a simplistic estimation (Section 3). There key flows within the TMF water quality model are:

- Surface runoff from the embankment face
- Tailings pore water seepage to ground
- Tailings pore water seepage to the embankment
- Infiltrated rainfall seepage through the embankment

The results of the water balance modelling are presented in Figure A6.13. The water balance is only a preliminary model and will be updated after further laboratory testwork is completed on tailings samples. It is likely that a more sophisticated seepage model will also need to be completed. These updates should also take into account more detailed information about waste placement within the TMF embankment and which material will be in contact with the flows identified above.

6.4.4 Geochemical inputs

The geochemical data is fully described in the Geochemical Annex 4. As described in Sections 6.2.4 and 6.3.4 the waste materials defined in the schedule are linked to the block model and geochemical test results. The TMF water quality model assigned geological codes from the schedule to corresponding material within the geochemical kinetic dataset as described in Table 6-9. The geochemical input for the TMF embankment runoff were derived from the kinetic dataset as described in Section 6.3.4 for operational pit runoff. The mass released by surface area from the kinetic tests is presented in Table 6-11.

The geochemical input to the TMF water quality seepage model was based on mass loads released from kinetic tests calculated by material amount (as first described in Section 6.2.4). The initial geochemical data was recorded as chemical concentrations but for use in the tailings seepage water quality models it was converted into mass release per kg of material per day. The mass load is calculated by normalizing the concentration for the mass of the material on the leach pad experiment, by the volume of leachate collected and the number of days between precipitation or irrigation events (weathering period). The mass release loads per kg for the kinetic tests are presented in Table 6-19. The geochemical input for the solution of seepage from precipitation is modelled as a simple proportional mix of concentrations from the original kinetic leach tests (a potential underestimate of chemical load), whereas the solution for the tailings pore water seepage through the embankment is calculated from a mass loading model. This is in order not to double count mass release the material within the embankment. With further design information and updates to seepage models within the embankment this model could be refined. The original average kinetic concentrations are presented in Table 6-20.

The tailings test work completed to date was based on tailings that were produced for the PFS and then dried and stored. As such they are unlikely to fully represent the tailings as per the current project design. Analysis of tailings supernatant has been requested, and this should be available to update the water quality results in the near future. A number of geochemical analyses have been completed on older tailings samples and these are fully described in the Geochemistry Appendix A. The current most appropriate chemistry to use is the seepage chemistry derived from the industry standard static leach test EN12457-3 at a 2:1 leach. The test was performed on a blended rougher and scavenger tails sample of ratio 80:20. The results are presented in Table 6-21. The tailings blend tested had not been through a cyanide process, as the PFS did not consider this as a process option. The predicted cyanide destruction level expected in the tailings stream sent to the TMF (AMEC, 2015) was used as the WAD cyanide concentration within the water quality model. The WAD cyanide concentration will be confirmed after further tailings laboratory tests have been completed.

Table 6-19 Mass release loads by kg from kinetic leach tests

Parameter	Units	DACOXORE	DACDIST	DACOX	DACUNOXBR	DACUNOXUD	GDUNOXSW	GNDIO	GNDIOCA	GRDIONON	GRTAL	GRTALOX	GRTFROC	GRTNON
pH-F pH units	pH units	6.14	2.98	5.39	3.51	2.78	3.07	6.23	6.03	4.73	3.42	5.77	4.77	4.72
Model alkalinity	mg/kg/day CaCO3	3.06E-01	0.00E+00	4.73E-02	1.52E-04	2.63E-04	0.00E+00	1.41E-01	1.75E-01	7.75E-03	0.00E+00	8.08E-02	1.83E-02	4.48E-03
Ag-D	mg/kg/day	7.56E-06	2.74E-06	1.46E-06	5.21E-06	1.50E-05	6.59E-06	2.37E-06	1.81E-06	1.59E-06	1.46E-06	1.50E-06	1.99E-06	1.41E-06
Al-D	mg/kg/day	4.72E-04	1.69E-01	5.08E-03	5.34E-02	3.31E-01	7.07E-02	5.30E-04	3.25E-04	4.17E-04	2.98E-02	1.58E-03	6.15E-04	1.62E-03
As-D	mg/kg/day	1.89E-05	2.91E-04	5.23E-06	1.91E-05	1.39E-03	1.03E-04	3.79E-06	9.28E-06	2.45E-06	4.68E-06	3.50E-06	3.12E-06	2.15E-06
Ba-D	mg/kg/day	8.12E-04	2.74E-05	1.31E-04	5.42E-05	1.52E-04	8.54E-05	2.39E-05	5.41E-05	7.66E-05	1.64E-05	2.53E-04	1.08E-04	5.29E-05
Bi-D	mg/kg/day	9.44E-06	3.00E-05	1.31E-05	1.89E-04	6.13E-05	4.26E-05	2.68E-05	1.89E-05	1.45E-05	1.39E-05	1.31E-05	1.98E-05	1.75E-05
Ca-D	mg/kg/day	1.27E-01	2.03E-02	1.07E-02	1.67E-02	4.15E-02	1.80E-01	7.02E-02	9.72E-02	1.10E-01	1.31E-02	1.69E-02	4.05E-02	6.32E-02
Cd-D	mg/kg/day	2.83E-06	1.61E-04	1.35E-06	1.65E-04	2.58E-03	6.08E-05	2.58E-06	1.55E-06	3.64E-05	8.85E-06	1.39E-06	1.76E-06	2.10E-05
Cl-ion	mg/kg/day	3.62E-01	1.57E-02	3.17E-02	6.27E-03	1.92E-02	1.22E-02	1.04E-02	7.91E-03	6.81E-03	6.25E-03	1.75E-02	8.51E-03	5.95E-03
Co-D	mg/kg/day	7.56E-05	8.07E-04	4.29E-06	7.79E-04	1.27E-03	9.23E-04	6.78E-06	5.16E-06	1.09E-04	6.10E-04	1.73E-05	5.67E-06	1.37E-04
Cr-D	mg/kg/day	9.44E-06	3.97E-05	4.50E-06	2.09E-05	9.62E-05	8.21E-05	6.78E-06	5.16E-06	4.54E-06	8.10E-06	4.48E-06	5.67E-06	3.84E-06
CrVI-D	mg/kg/day	n/a	3.23E-05	9.65E-06	2.80E-05	8.61E-05	5.35E-05	1.53E-05	1.20E-05	1.05E-05	1.16E-05	1.43E-05	1.03E-04	9.03E-06
Cu-D	mg/kg/day	1.13E-04	5.30E-01	2.42E-05	4.24E-01	1.62E-01	1.32E-01	1.26E-04	3.00E-05	9.88E-03	1.09E-01	1.38E-04	2.68E-05	5.69E-03
Fe-D	mg/kg/day	1.09E-03	2.90E-01	1.64E-03	3.97E-02	2.20E+00	5.25E-01	7.80E-04	5.93E-04	5.78E-04	3.20E-02	7.24E-04	7.02E-04	1.09E-03
F-ion	mg/kg/day	2.83E-03	1.63E-04	5.27E-04	1.70E-04	1.33E-04	3.77E-04	8.42E-04	5.13E-04	4.60E-04	1.78E-04	1.23E-03	5.88E-04	4.91E-04
Hg-D	mg/kg/day	n/a	5.82E-08	7.19E-08	1.04E-07	n/a	1.73E-07	1.75E-07	1.13E-07	7.60E-08	7.85E-08	7.70E-08	1.48E-07	1.34E-07
K-D	mg/kg/day	5.02E-02	3.41E-03	5.96E-03	3.09E-03	4.65E-03	1.76E-02	1.67E-02	9.58E-03	2.31E-02	2.06E-03	5.15E-03	1.96E-02	1.84E-02
Mg-D	mg/kg/day	3.12E-02	3.47E-03	2.43E-03	5.44E-03	1.41E-02	3.30E-01	1.50E-02	2.70E-03	5.92E-02	2.07E-03	3.96E-03	5.41E-03	6.35E-02
Mn-D	mg/kg/day	8.50E-05	8.45E-04	2.06E-05	2.94E-04	8.74E-04	8.38E-03	1.93E-04	8.22E-05	2.86E-02	2.87E-04	4.24E-05	6.17E-04	2.26E-02
Mo-D	mg/kg/day	1.42E-05	1.95E-04	6.26E-06	2.23E-05	3.09E-04	1.88E-04	2.44E-05	1.93E-05	6.81E-06	6.25E-06	6.89E-06	1.15E-05	5.76E-06
Na-D	mg/kg/day	2.57E-01	1.33E-03	7.48E-03	3.54E-03	6.84E-03	3.64E-03	1.30E-02	2.04E-02	8.16E-03	1.01E-03	7.69E-03	3.09E-03	3.17E-03
Ni-D	mg/kg/day	4.72E-05	5.20E-04	6.29E-06	6.02E-04	6.64E-04	7.42E-04	1.02E-05	8.03E-06	7.00E-05	3.52E-04	9.35E-06	8.51E-06	1.28E-04
N-NH3	mg/kg/day	3.97E-03	8.66E-03	1.05E-03	4.42E-03	1.77E-03	3.04E-03	1.33E-03	7.86E-04	9.16E-04	4.26E-03	7.98E-04	4.61E-03	1.45E-03
N-NO2	mg/kg/day	7.56E-04	9.96E-05	1.00E-03	6.73E-05	5.79E-05	7.01E-05	5.15E-04	3.91E-04	1.12E-04	5.85E-05	3.31E-04	9.68E-05	5.03E-05
NO3-N	mg/kg/day	3.09E-02	1.71E-03	3.41E-03	1.02E-03	1.06E-03	1.24E-03	5.91E-03	3.84E-03	2.55E-03	1.00E-03	4.63E-03	4.05E-02	1.20E-03

Parameter	Units	DACOXORE	DACDIST	DACOX	DACUNOXBR	DACUNOXUD	GDUNOXSW	GNDIO	GNDIOCA	GRDIONON	GRTAL	GRTALOX	GRTFROC	GRTNON
OrthPO4-P	mg/kg/day	2.83E-03	4.78E-03	2.84E-03	2.84E-03	2.78E-03	3.37E-03	4.29E-03	3.49E-03	2.88E-03	2.81E-03	2.92E-03	3.75E-03	2.41E-03
Pb-D	mg/kg/day	2.83E-05	2.35E-05	2.96E-05	4.46E-05	1.34E-04	5.65E-05	2.03E-05	1.55E-05	4.81E-05	1.25E-05	1.73E-05	1.70E-05	1.08E-04
Sb-D	mg/kg/day	5.67E-06	4.22E-06	2.71E-06	2.84E-06	9.99E-06	3.31E-06	4.92E-06	3.61E-06	2.90E-06	2.65E-06	2.74E-06	3.68E-06	2.53E-06
Se-D	mg/kg/day	7.27E-05	1.18E-04	1.99E-06	8.16E-05	2.00E-04	6.35E-05	3.96E-06	2.63E-06	2.04E-05	2.40E-05	5.46E-06	2.83E-06	1.68E-05
Si-T	mg/kg/day	n/a	2.85E-02	2.47E-02	9.87E-03	5.90E-02	6.39E-02	1.23E-02	1.58E-02	1.22E-02	6.50E-03	1.02E-02	1.06E-02	1.09E-02
SO4-D	mg/kg/day	4.36E-01	4.07E+00	4.63E-02	1.30E+00	1.18E+01	5.40E+00	9.90E-02	6.45E-02	6.00E-01	6.34E-01	3.13E-02	2.41E-02	5.12E-01
Sr-D	mg/kg/day	5.48E-04	3.37E-05	6.51E-05	2.77E-05	5.81E-05	2.60E-04	2.17E-04	1.29E-03	4.13E-04	2.75E-05	7.56E-05	1.63E-04	8.08E-05
U-D	mg/kg/day	1.46E-06	4.53E-04	6.44E-07	2.61E-04	3.72E-04	2.69E-04	4.81E-06	2.27E-05	3.09E-06	7.49E-05	1.24E-05	1.21E-05	1.22E-06
V-D	mg/kg/day	1.89E-05	4.48E-05	9.22E-06	3.05E-05	1.17E-04	4.22E-05	1.36E-05	1.03E-05	9.08E-06	8.33E-06	8.60E-06	1.13E-05	7.69E-06
Zn-D	mg/kg/day	1.38E-03	1.19E-02	8.24E-04	2.78E-02	1.02E-01	8.79E-02	1.16E-04	6.22E-05	1.04E-02	5.31E-03	4.87E-04	2.91E-04	1.73E-02

n/a - no data available

Table 6-20 Average kinetic leach pad results by material type

Parameter	DACDIST	DACOX	DACUNOXBR	DACUNOXUD	GDUNOXSW	GNDIO	GNDIOCA	GRDIONON	GRTAL	GRTALOX	GRTFROC	GRTNON
Field pH (pH units)	2.82	5.16	3.28	2.35	2.85	6.06	5.92	4.51	3.28	5.48	4.50	4.37
Alkalinity (mg/l CaCO3)	0.0	7.5	0.1	0.3	0.0	22.3	34.9	2.7	0.0	17.8	3.2	1.5
Field conductivity (µS/cm)	834	64	431	2248	1145	125	161	240	323	75	106	259
Field dissolved oxygen (mg/L)	8	7	7	7	7	7	7	7	7	7	7	7
Field ORP (mV)	455	272	392	503	445	275	282	329	386	280	299	326
Measured TDS (mg/l)	523	24	294	1834	946	61	73	146	208	44	70	170
Measured TSS (mg/l)	79	193	26	494	40	15	7	21	33	140	6	65
Ag-D (mg/l)	0.0008	0.0004	0.0006	0.0018	0.0006	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Al-D (mg/l)	19.69	1.43	6.57	37.69	6.00	0.11	0.08	0.18	5.92	0.42	0.09	0.46
As-D (mg/l)	0.020	0.003	0.002	0.125	0.007	0.001	0.002	0.001	0.001	0.001	0.001	0.001
Ba-D (mg/l)	0.008	0.031	0.007	0.021	0.014	0.004	0.010	0.015	0.005	0.059	0.015	0.016
Bi-D (mg/l)	0.005	0.005	0.021	0.010	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Ca-D (mg/l)	4	2	3	5	30	9	18	16	4	4	6	13
Cd-D (mg/l)	0.031	0.000	0.022	0.265	0.010	0.000	0.000	0.005	0.002	0.000	0.000	0.005
Cl-ion (mg/l)	2	9	2	3	2	2	2	2	2	6	2	2
Co-D (mg/l)	0.186	0.001	0.129	0.168	0.125	0.001	0.001	0.015	0.163	0.009	0.001	0.030
Cr-D (mg/l)	0.005	0.001	0.002	0.010	0.006	0.001	0.001	0.001	0.002	0.001	0.001	0.001
CrVI-D (mg/l)	0.009	0.002	0.004	0.008	0.011	0.002	0.002	0.002	0.003	0.004	0.008	0.003
Cu-D (mg/l)	56.99	0.01	58.33	26.41	18.05	0.02	0.01	1.29	23.54	0.03	0.01	0.98
Fe-D (mg/l)	24.16	0.65	5.27	229.76	37.99	0.12	0.12	0.17	5.58	0.25	0.15	0.35
F-ion (mg/l)	0.10	0.10	0.09	0.10	0.10	0.11	0.11	0.11	0.10	0.23	0.10	0.11
Hg-D (mg/l)	0.00005	0.00005	0.00005	N/A	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
K-D (mg/l)	0.53	0.89	0.70	0.83	3.85	2.10	1.84	3.86	0.62	0.95	3.08	3.88
Mg-D (mg/l)	0.76	0.46	0.96	1.68	48.84	1.91	0.51	8.40	0.61	0.86	0.78	12.45
Mn-D (mg/l)	0.13	0.01	0.06	0.14	1.30	0.03	0.02	3.77	0.10	0.02	0.08	4.96
Mo-D (mg/l)	0.109	0.002	0.003	0.026	0.019	0.005	0.004	0.002	0.002	0.002	0.003	0.002
Na-D (mg/l)	0.46	1.56	0.47	0.73	0.63	1.75	4.76	1.52	0.37	1.94	0.65	0.74

Parameter	DACDIST	DACOX	DACUNOXBR	DACUNOXUD	GDUNOXSW	GNDIO	GNDIOCA	GRDIONON	GRTAL	GRTALOX	GRTFROC	GRTNON
Ni-D (mg/l)	0.079	0.002	0.096	0.082	0.104	0.002	0.002	0.010	0.087	0.003	0.002	0.025
N-NH3 (mg/l)	0.91	0.39	0.95	0.94	0.76	0.25	0.14	0.18	1.03	0.21	0.80	0.31
N-NO2 (mg/l)	0.01	0.13	0.02	0.01	0.01	0.08	0.07	0.02	0.01	0.07	0.02	0.01
NO3-NO3 (mg/l)	0.95	2.61	0.95	1.27	1.28	3.21	2.90	2.37	0.95	2.89	23.17	1.86
OrthPO4-P (mg/l)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Pb-D (mg/l)	0.007	0.012	0.005	0.021	0.005	0.003	0.003	0.007	0.003	0.004	0.003	0.022
Sb-D (mg/l)	0.0007	0.0008	0.0007	0.0012	0.0007	0.0008	0.0008	0.0007	0.0007	0.0007	0.0007	0.0007
Se-D (mg/l)	0.0146	0.0006	0.0118	0.0208	0.0098	0.0006	0.0006	0.0029	0.0055	0.0012	0.0006	0.0034
Si-T (mg/l)	2.89	5.47	1.46	8.02	8.85	1.88	2.77	2.39	1.15	2.47	1.47	2.28
SO4-D (mg/l)	334.8	9.4	165.8	1230.3	576.8	13.7	11.6	83.6	110.7	7.9	3.9	100.7
Sr-D (mg/l)	0.009	0.014	0.006	0.010	0.047	0.046	0.234	0.063	0.009	0.016	0.025	0.016
U-D (mg/l)	0.0556	0.0002	0.0348	0.0424	0.0311	0.0006	0.0048	0.0004	0.0157	0.0044	0.0019	0.0002
V-D (mg/l)	0.006	0.003	0.004	0.012	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Zn-D (mg/l)	3.81	0.23	4.95	10.14	14.12	0.02	0.01	1.34	1.64	0.17	0.07	3.30
N/A - no data available												

Table 6-21 Chemical input for seepage direct from tailings, derived from the EN 12457-3 2:1 leach test

Parameter	Unit	EDC effluent standards	EN 12457-3 2:1 leach
			Blended rougher and scavenger tails (80:20)
Sample weight	g		175
Volume DI water	ml		350
Initial pH	pH		8.35
Final pH	pH		8.39
Volume recovered	ml		286
pH	pH		9.08
Alkalinity	mg/l as CaCO3		87
Acidity	mg/l as CaCO4		<2
Conductivity	uS/cm		672
Chloride	mg/l		4.4
Sulphate	mg/l		220
Mercury	mg/l		0.000005
Silver	mg/l		0.000183
Aluminum	mg/l		0.016
Arsenic	mg/l	0.1	0.0038
Boron	mg/l		0.182
Barium	mg/l		0.0446
Beryllium	mg/l		0.0000035
Bismuth	mg/l		0.000012
Calcium	mg/l		61.6
Cadmium	mg/l	0.05	0.000027
Cobalt	mg/l		0.000725
Chromium	mg/l	0.1	0.00144
Copper	mg/l	0.3	0.00133
Iron	mg/l	2	0.0035
Potassium	mg/l		22.3
Lithium	mg/l		0.00346
Magnesium	mg/l		10.1
Manganese	mg/l		0.00266
Molybdenum	mg/l		0.0453
Sodium	mg/l		46.1
Nickel	mg/l	0.5	0.0008
Phosphorus	mg/l	2	0.308
Lead	mg/l	0.2	0.00002
Antimony	mg/l		0.0016
Selenium	mg/l		0.00202
Silicon	mg/l		8.8
Tin	mg/l		0.00004
Strontium	mg/l		0.176
Thorium	mg/l		0.000005
Titanium	mg/l		0.00028
Thallium	mg/l		0.000039
Uranium	mg/l		0.00144
Vanadium	mg/l		0.00184
Tungsten	mg/l		0.00211

Parameter	Unit	EDC effluent standards	EN 12457-3 2:1 leach
			Blended rougher and scavenger tails (80:20)
Yttrium	mg/l		0.000013
Zinc	mg/l	0.5	0.001
WAD cyanide	mg/l		0.0208

6.4.5 Model set-up

The model predicts the individual water chemistry for the four flows described in Section 6.4.3. The direct tailings seepage to ground is assumed to be the geochemical input described in Section 6.4.4, but this model set-up is will be revised once further tailings testwork data and seepage modelling is complete. The estimation of runoff water quality for the TMF embankment takes the mass load by surface area from the kinetic tests and scales the data to take into account the surface area of the embankment. The mass load is multiplied by the average weathering period between rainfall events; for the baseline meteorological dataset this is currently around 3 days. It is assumed that only 1% of runoff will be in contact with the TMF embankment surface material. The resulting mass load was dissolved into the average runoff volumes. The annual solutions were thermodynamically equilibrated using the industry standard code PHREEQC, with a temperature of 15°C and a pe of 10. The solutions were allowed to charge balance using chloride ions. Minerals that were over-saturated within the solution were allowed to precipitate if it was kinetically feasible, mostly this was ferrihydrite (iron hydroxide). Any precipitated iron hydroxides were programmed to act as a solid surface for sorption and exchange of ions.

The model set-up for the seepage water quality through the embankment has two key components. Firstly infiltrated precipitation that interacts with waste material in the embankment. The second is a flow of tailings pore water that seeps into the embankment from the tailings, this tailings water is further modified during interaction with the waste material in the embankment. A model was built that estimates each individual chemistry, and then in a final step mixes these proportionally with respect to the TMF embankment water balance. The chemistry of the precipitation seepage is modelled by mixing kinetic leach pad solutions at the proportions present in the cumulative waste placement schedule. The tailings pore water leachate is modified to account for the mass load from the waste material. The mass loading data is coupled with the original tailings solution, scaled to account for the mass of material within the embankment and the volume of seepage. The resulting embankment seepage solutions are then proportionally mixed in line with the water balance and thermodynamically equilibrated using the industry standard code PHREEQC, with a temperature of 15°C and a pe of 10. The solutions were allowed to charge balance using chloride ions. Minerals that were over-saturated within the solution were allowed to precipitate if it was kinetically feasible, mostly this was ferrihydrite (iron hydroxide). Any precipitated iron hydroxides were allowed to act as a solid surface for sorption and exchange of ions.

6.4.6 Results

Runoff

The predicted water quality from the TMF embankment through LOM is presented in Table 6-22 and compared with effluent discharge standards. In early mine life the predicted runoff water quality is more neutral in character, with lower concentrations of trace metals. The main metals of concern are iron, copper, cadmium and zinc. The chemistry of the runoff water is mainly controlled by the waste material exposed each year from the waste schedule. No discharge standard for sulphate has been defined, but the sulphate concentration is relatively high, greater than 500 mg/l, from LOM year 3 onwards. The drinking water quality guidelines for the project state a guidance standard of 250 mg/l for sulphate.

Seepage

Operational seepage water quality is predicted as two distinct flows. The tailings pore water is expected to seep directly to ground, beneath the tailings footprint. This is predicted to have the chemistry as described in Table 6-21. The prediction will be updated following further tailings laboratory test results.

Tailings pore water will also seep into the TMF embankment, here it will combine with infiltrated rainwater. The tailings pore water and infiltration water will both react with the waste material within the TMF embankment. The predicted water quality of seepage water from the TMF embankment is presented in Table 6-23. As for the tailings runoff the key parameters of concern within the seepage water quality are low pH (although this is buffered in early operations by tailings porewater which has a higher pH with significant alkalinity), cadmium, copper, iron and zinc.

Closure

The TMF and tailings water balance (produced by Golders) was not continued into closure conditions. SWS assumed that the chemistry will be the same as predicted for the final year of operations, but this will be updated following more detailed water balance modelling. In closure, it is assumed that the TMF embankment will be capped with a layer of clay and topsoil, and that runoff water quality will return to baseline conditions for the catchment.

6.4.7 Conclusions and future work

The water quality predictions are preliminary, based on the most current design information available. In future more detailed seepage modelling, potentially using 2D slices to look at the water balance and flow within the TMF and embankment, should be completed to produce more reliable estimates of seepage volumes and chemistries. More information on waste placement, when this is available, should also be incorporated into the models to increase the accuracy of results. The current assumption that all seepage reports to ground may also be amended in future after further investigation on the nature and fracturing of geological material below the TMF footprint is concluded.

6.5 Links to downstream effects

The mine facilities described and modelled in Section 6 will be used as source terms within the source – pathway – receptor models to assess effects and impacts of the mine project on water quality. The source term results will be fed in as key changes, and how these effect downstream receptors will be reported within the ESIA. In the Jazga the key sources that may affect downgradient surface and groundwater receptors are the open pit runoff in construction, the oxide stockpile during operations and a spill from pit lake formation in closure. In the Shtuka catchment the key sources that may affect downgradient surface and groundwater receptors are runoff from the TMF embankment in the construction phase and seepage from the TMF tailings and embankment in operations and closure.

Table 6-22 TMF embankment runoff water quality modelling results through LOM

Parameter	Unit	Project effluent standards	LOM Year																				
			-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
pH*	pH	6 - 9	5.35	5.22	3.99	3.55	3.48	3.39	4.79	3.41	3.43	3.43	3.45	3.46	3.65	3.49	3.49	3.50	3.49	3.48	3.56	3.46	3.45	3.45
Ag	mg/l		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	mg/l		1.54	2.18	3.74	15.37	30.78	23.83	2.73	11.33	10.20	10.53	8.24	10.94	6.04	9.64	10.82	8.34	9.21	6.71	9.50	10.46	10.70	10.70
Alkalinity	mg/l		17.52	13.29	0	0	0	0	8.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As	mg/l	0.1	0.002	0.005	0.005	0.031	0.069	0.040	0.004	0.015	0.013	0.013	0.008	0.014	0.006	0.009	0.015	0.010	0.011	0.006	0.014	0.012	0.013	0.013
Ba	mg/l		0.05	0.02	0.02	0.03	0.02	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03
Ca	mg/l		14.36	29.29	38.76	107.43	212.35	195.46	38.72	86.64	75.87	74.45	58.33	74.95	40.17	81.19	74.30	57.57	66.34	53.00	71.97	124.97	127.87	127.87
Cd	mg/l	0.05	0.001	0.012	0.022	0.109	0.221	0.171	0.012	0.076	0.063	0.064	0.043	0.065	0.026	0.033	0.059	0.044	0.043	0.025	0.049	0.023	0.024	0.024
Cl	mg/l		10.20	5.01	4.52	4.53	3.36	4.06	4.11	4.26	4.18	4.17	4.03	3.90	4.23	2.86	3.81	3.91	3.81	3.69	3.63	2.63	2.70	2.70
Co	mg/l		0.00	0.01	0.02	0.07	0.16	0.12	0.04	0.07	0.07	0.08	0.07	0.08	0.06	0.12	0.09	0.07	0.09	0.08	0.08	0.13	0.13	0.13
Cr* **	mg/l	0.1	0.0008	0.0003	0.0023	0.0051	0.0100	0.0097	0.0011	0.0046	0.0042	0.0041	0.0036	0.0041	0.0027	0.0061	0.0043	0.0036	0.0042	0.0038	0.0046	0.0098	0.0100	0.0100
Cu	mg/l	0.3	0.02	1.66	3.64	16.15	40.76	18.86	5.12	13.92	14.66	17.13	17.27	18.90	14.21	31.27	20.74	17.93	19.48	17.04	19.97	25.23	25.81	25.81
F	mg/l		0.23	0.23	0.18	0.10	0.11	0.21	0.28	0.19	0.18	0.18	0.20	0.17	0.19	0.14	0.15	0.13	0.14	0.15	0.11	0.12	0.12	0.12
Fe**	mg/l	2	0.03	0.04	1.06	72.35	161.58	117.51	0.12	33.43	23.97	25.53	8.12	29.54	3.24	24.31	31.53	19.11	23.35	8.22	31.34	52.99	54.19	54.19
Hg**	mg/l	0.002	0.00003	0.00004	0.00003	0.00001	0.00002	0.00004	0.00004	0.00003	0.00003	0.00002	0.00003	0.00002	0.00002	0.00003	0.00002	0.00002	0.00002	0.00002	0.00002	0.00003	0.00003	0.00003
K	mg/l		2.36	3.76	3.08	1.21	2.17	3.77	4.14	2.33	2.19	1.93	2.01	1.72	1.69	2.74	1.49	1.45	1.59	2.05	1.64	2.81	2.87	2.87
Mg	mg/l		1.25	3.99	4.58	1.39	3.43	12.17	8.19	3.69	3.05	2.49	2.80	2.40	2.07	17.65	4.31	4.18	7.00	8.97	8.53	35.73	36.56	36.56
Mn	mg/l		0.01	0.16	0.48	0.06	0.12	0.65	1.88	0.27	0.16	0.16	0.15	0.12	0.08	1.79	0.23	0.32	0.52	0.97	0.66	1.51	1.55	1.55
Mo	mg/l		0.00	0.01	0.01	0.01	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
NH3-N	mg/l		0.00	0.34	0.82	1.03	1.40	1.83	0.51	1.55	1.57	1.54	1.58	1.46	1.15	1.39	1.35	1.21	1.30	1.29	1.10	1.06	1.08	1.08
NO3-N	mg/l		0.19	0.05	0.08	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO2-N	mg/l		1.85	1.65	0.74	0.00	0.00	0.00	1.41	0.00	0.00	0.00	0.06	0.00	0.36	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Na	mg/l		2.84	3.21	2.62	1.44	2.04	2.96	3.22	2.41	2.47	2.20	2.46	1.94	1.92	1.60	1.60	1.47	1.39	1.52	1.36	1.13	1.16	1.16
Ni**	mg/l	0.5	0.003	0.009	0.015	0.043	0.097	0.071	0.024	0.040	0.042	0.046	0.046	0.050	0.039	0.086	0.056	0.045	0.058	0.052	0.055	0.099	0.101	0.101
P	mg/l		3.14	1.13	0.30	0.37	0.72	0.56	0.92	0.34	0.33	0.33	0.30	0.34	0.31	0.54	0.37	0.31	0.38	0.34	0.37	0.71	0.72	0.72
Pb	mg/l	0.2	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SO4	mg/l		17.14	87.72	148.55	518.88	1062.40	925.20	147.80	396.31	344.47	346.05	264.53	356.62	179.90	440.35	365.77	284.42	332.77	266.87	366.81	660.11	675.41	675.41
Sb	mg/l		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Se	mg/l		0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Si	mg/l		3.68	2.29	2.20	2.56	3.26	3.71	2.08	2.40	2.31	2.19	2.06	2.08	1.82	2.54	2.12	2.02	2.16	2.12	2.30	3.74	3.82	3.82
Sr	mg/l		0.03	0.05	0.05	0.01	0.03	0.05	0.08	0.05	0.06	0.05	0.07	0.04	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
U	mg/l		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	mg/l		0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Zn**	mg/l	0.5	0.3	0.8	1.6	4.9	10.3	9.2	1.8	3.9	3.4	3.4	2.8	3.6	1.9	6.6	4.0	3.3	4.0	3.7	4.6	10.5	10.7	10.7

*** pH calculated from molar concentration of hydrogen ions**

**** As described in the EDC**

*****Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant**

****** Modelled data is as dissolved concentrations, standard as totals**

Table 6-23 Predicted seepage water quality from the TMF embankment

Parameter	Units	Project effluent standards**	LOM year																				
			-1^	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
pH*	pH	6 - 9	5.07	5.19	5.40	4.99	4.45	4.20	4.27	4.22	4.17	4.08	4.09	4.03	4.03	4.00	3.95	3.89	3.85	3.80	3.71	3.44	3.36	3.24
Ag	mg/l		0.0004	0.0007	0.0009	0.0004	0.0005	0.0006	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0008	0.0007	0.0007
Al	mg/l		1.32	2.26	4.01	2.29	4.18	6.14	5.80	6.12	6.58	7.15	6.95	7.05	7.18	7.18	7.13	7.18	7.17	7.10	7.04	8.52	8.12	7.29
Alkalinity	mg/l		6.6	82.3	54.6	66.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
As	mg/l	0.1	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Ba	mg/l		0.03	0.07	0.08	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04
Ca	mg/l		7.08	73.19	83.87	72.12	83.89	94.46	93.80	94.78	96.16	97.36	96.48	95.81	95.90	95.72	94.40	93.27	92.39	90.48	87.43	87.74	79.96	63.88
Cd	mg/l	0.05	0.000	0.008	0.019	0.014	0.028	0.042	0.040	0.042	0.045	0.048	0.046	0.047	0.047	0.046	0.045	0.045	0.045	0.043	0.042	0.050	0.047	0.041
Cl	mg/l		8.72	11.92	13.11	6.48	6.17	6.40	6.39	6.47	6.63	6.82	6.75	6.73	6.87	6.83	6.76	6.78	6.76	6.73	6.62	7.02	6.67	5.94
Co	mg/l		0.002	0.008	0.019	0.011	0.021	0.030	0.030	0.032	0.035	0.039	0.039	0.040	0.042	0.043	0.044	0.045	0.047	0.048	0.049	0.061	0.060	0.057
Cr***	mg/l	0.1	0.001	0.001	0.000	0.000	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004
Cu	mg/l	0.3	0.01	1.02	2.35	1.87	4.32	5.86	5.66	6.04	6.61	7.45	7.50	7.93	8.41	8.71	8.92	9.25	9.50	9.78	10.04	12.39	12.08	11.43
F	mg/l		0.11	0.19	0.23	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.12	0.12	0.12
Fe****	mg/l	2	0.06	0.05	0.03	1.30	14.65	25.83	22.65	23.96	25.55	27.56	26.21	26.39	25.64	25.61	25.31	25.08	24.80	23.89	23.55	30.33	28.61	25.18
Hg****	mg/l	0.002	0.00000	0.00003	0.00004	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002	0.00001	0.00001	0.00002	0.00002	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
K	mg/l		0.92	21.38	23.36	21.34	21.24	21.48	21.49	21.42	21.42	21.35	21.17	20.87	20.75	20.57	20.12	19.64	19.25	18.53	17.42	16.20	13.81	8.87
Mg	mg/l		0.52	10.71	12.92	10.18	10.19	11.16	11.42	11.45	11.53	11.57	11.43	11.24	11.20	11.40	11.23	11.10	11.12	11.10	10.85	11.67	10.45	7.93
Mn	mg/l		0.01	0.08	0.25	0.06	0.05	0.10	0.18	0.18	0.19	0.19	0.19	0.18	0.18	0.20	0.19	0.20	0.20	0.23	0.24	0.32	0.31	0.29
Mo	mg/l		0.00	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02
NH3-N	mg/l		0.21	0.32	0.81	0.51	0.48	0.57	0.60	0.64	0.69	0.75	0.75	0.76	0.82	0.82	0.82	0.84	0.85	0.88	0.89	1.08	1.08	1.07
NO3-N	mg/l		0.029	0.040	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NO2-N	mg/l		0.851	1.388	1.271	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
Na	mg/l		1.59	41.90	45.11	43.44	43.27	43.52	43.39	43.22	43.15	42.94	42.62	42.02	41.74	41.33	40.43	39.43	38.62	37.06	34.76	31.89	27.00	16.88
Ni****	mg/l	0.5	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
P	mg/l		1.71	2.04	0.98	0.29	0.44	0.49	0.46	0.46	0.46	0.47	0.47	0.48	0.47	0.48	0.48	0.49	0.49	0.50	0.51	0.66	0.70	0.79
Pb	mg/l	0.2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SO4	mg/l		9.41	245.97	329.89	277.63	343.00	419.40	409.34	419.50	434.21	451.61	442.19	440.72	441.87	442.08	435.35	431.46	427.87	419.20	406.75	450.70	410.10	326.23
Sb	mg/l		0.001	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
Se	mg/l		0.001	0.003	0.004	0.003	0.005	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.007	0.006
Si	mg/l		0.00	6.26	7.22	4.64	4.65	4.93	4.90	4.94	5.01	5.09	5.01	4.94	4.96	4.93	4.80	4.71	4.63	4.46	4.19	4.18	3.51	2.12
Sr	mg/l		0.02	0.18	0.20	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.16	0.16	0.15	0.14	0.12	0.09
U	mg/l		0.0000	0.0002	0.0003	0.0002	0.0003	0.0005	0.0004	0.0005	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0007	0.0007	0.0006
V	mg/l		0.0025	0.0050	0.0062	0.0033	0.0038	0.0047	0.0046	0.0048	0.0050	0.0053	0.0052	0.0052	0.0053	0.0053	0.0052	0.0052	0.0052	0.0051	0.0050	0.0057	0.0054	0.0046
Zn****	mg/l	0.5	0.22	0.66	1.43	0.74	1.37	2.14	2.08	2.19	2.34	2.53	2.45	2.47	2.51	2.57	2.57	2.60	2.64	2.69	2.74	3.49	3.35	3.05
WAD Cyanide	mg/l	0.5	0.000	0.018	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.018	0.017	0.017	0.016	0.015	0.014	0.012	0.007

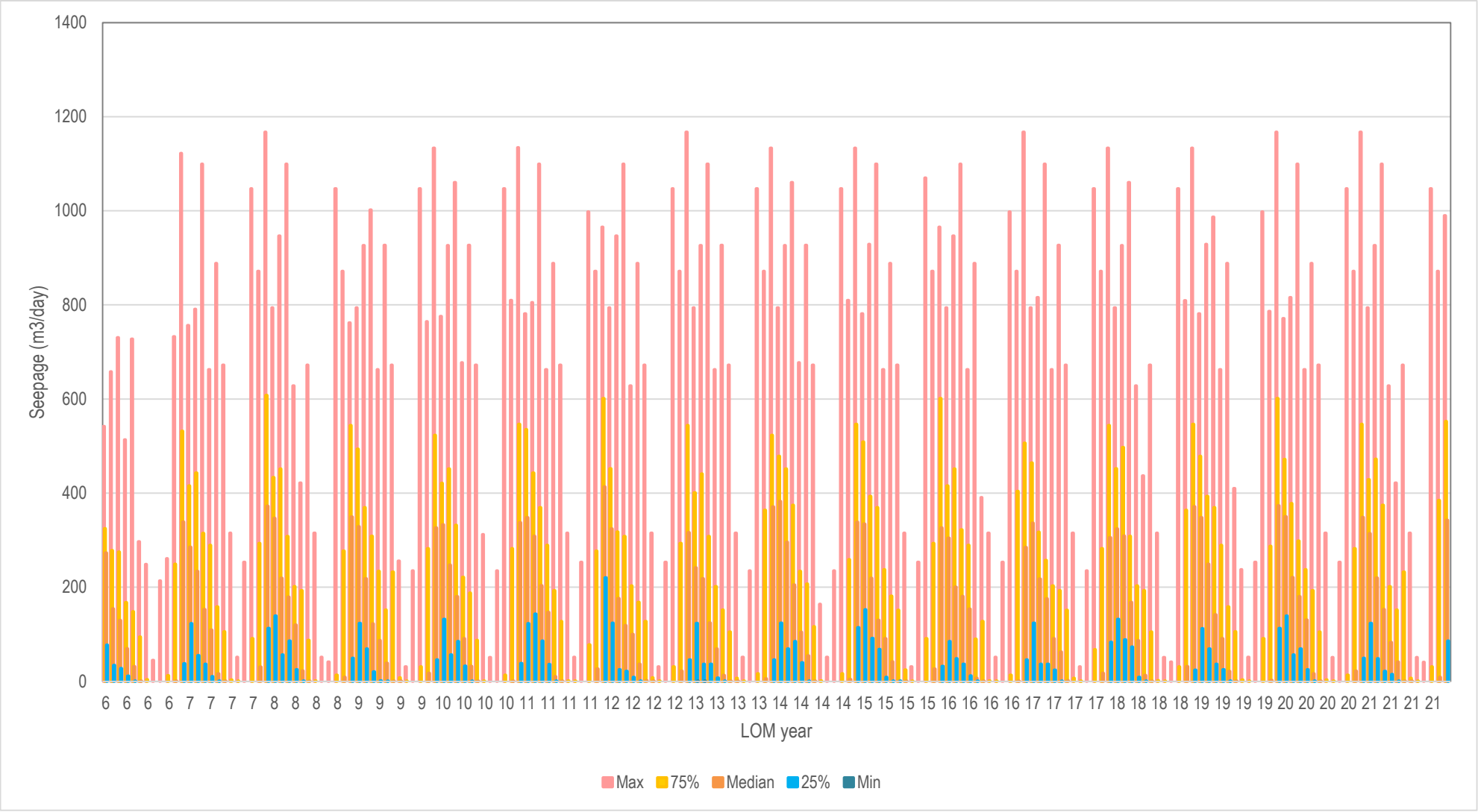
^ Seepage from the embankment only, no tailings seepage

* pH calculated from molar concentration of hydrogen ions

** As described in the EDC

***Standard as Cr(VI) but no exceedance of total so Cr(VI) is also compliant

**** Modelled data is as dissolved concentrations, standard as totals



Source :
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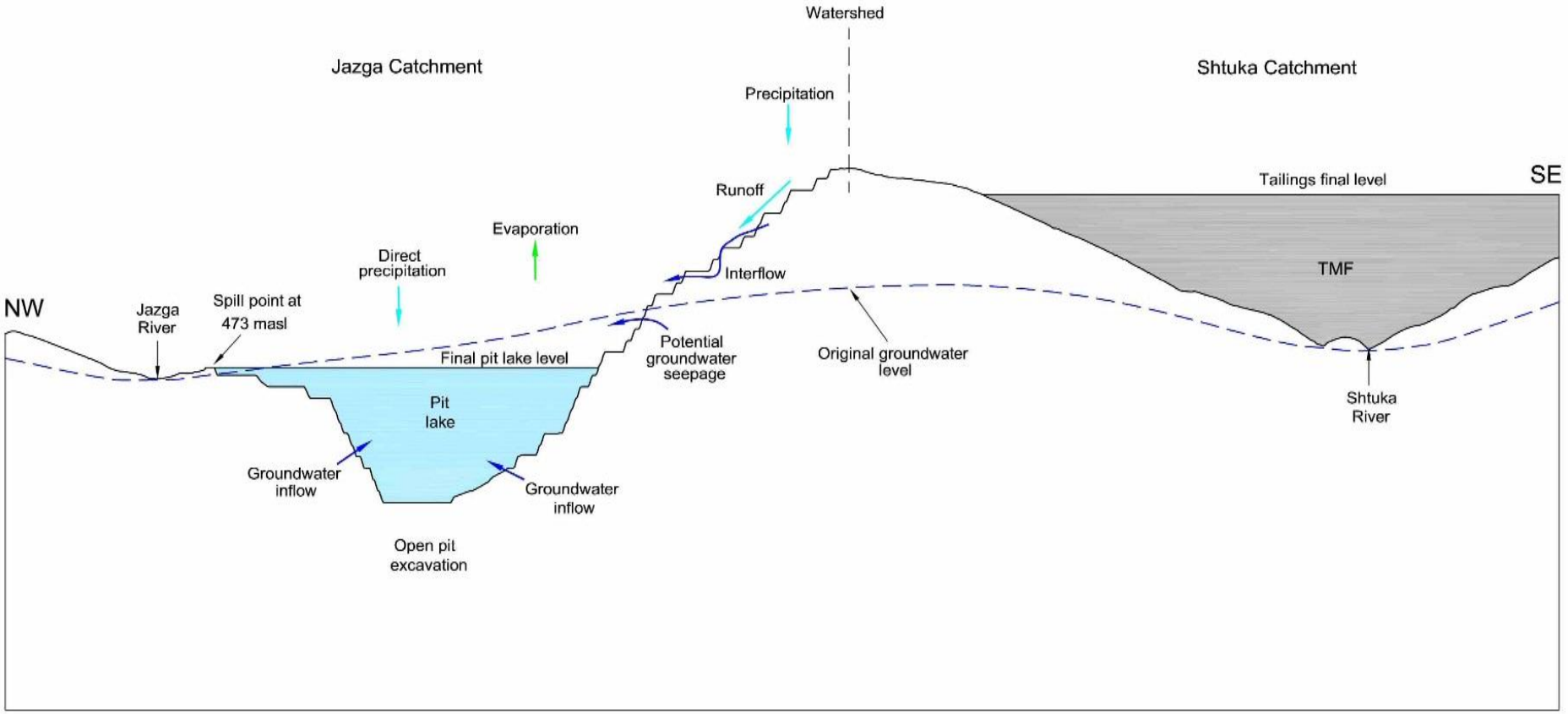
Schlumberger Water Services

Modelled stockpile seepage percentiles through LOM

PROJECT:	Ilovica Copper Gold Project	FIGURE:	A6.1
CLIENT:	Euromax Resources (Macedonia) Ltd.	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016



Schlumberger Water Services

Conceptual diagram of pit

PROJECT:	Ilovica Gold-Copper Project		FIGURE: A6.2
CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT : 55459_R1v2
DRAWN: JD		CHECKED: PB	DATE: January 2016

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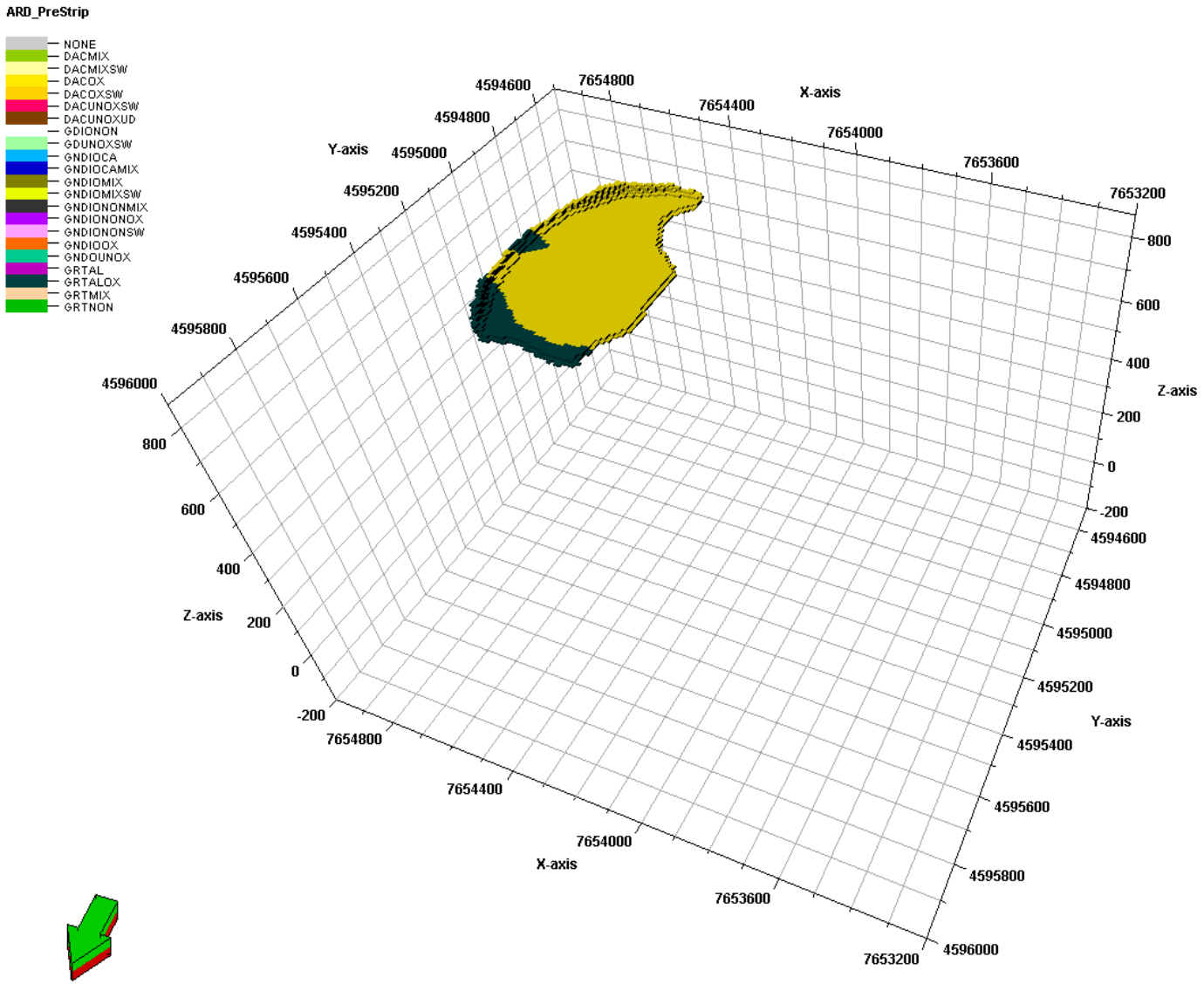

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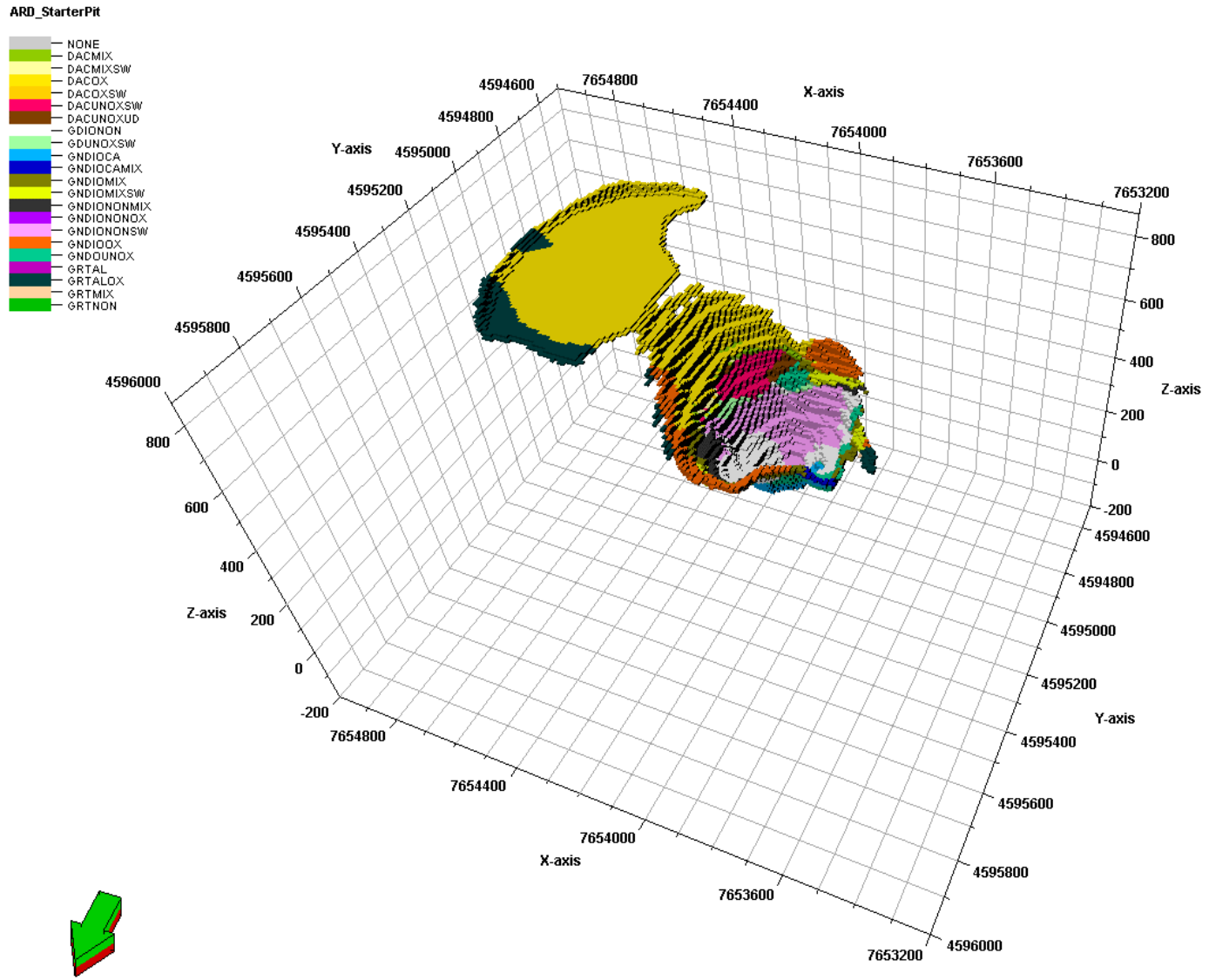
Schlumberger Water Services

Pre-strip pit shell depicting ARD material codes

PROJECT:	Ilovica Copper Gold Project		FIGURE: A6.3
CLIENT:	Euromax Resources (Macedonia) Ltd.		PROJECT: 55459_R1v2
DRAWN: JD	CHECKED: TMW		DATE: January 2016



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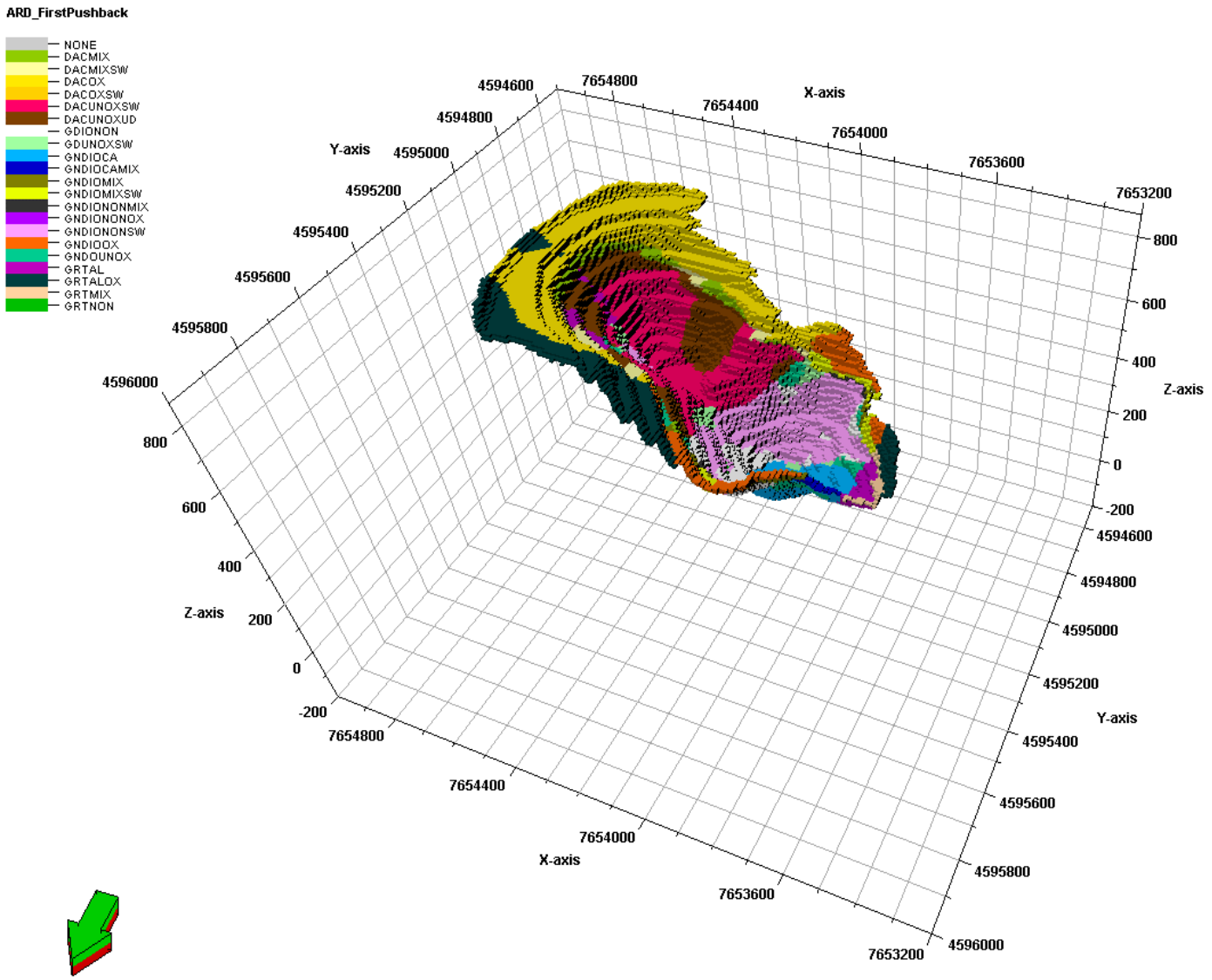
Schlumberger Water Services

Starter pit shell depicting ARD material codes

PROJECT:	Ilovica Copper Gold Project	FIGURE:	A6.4
CLIENT:	Euromax Resources (Macedonia) Ltd.	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016



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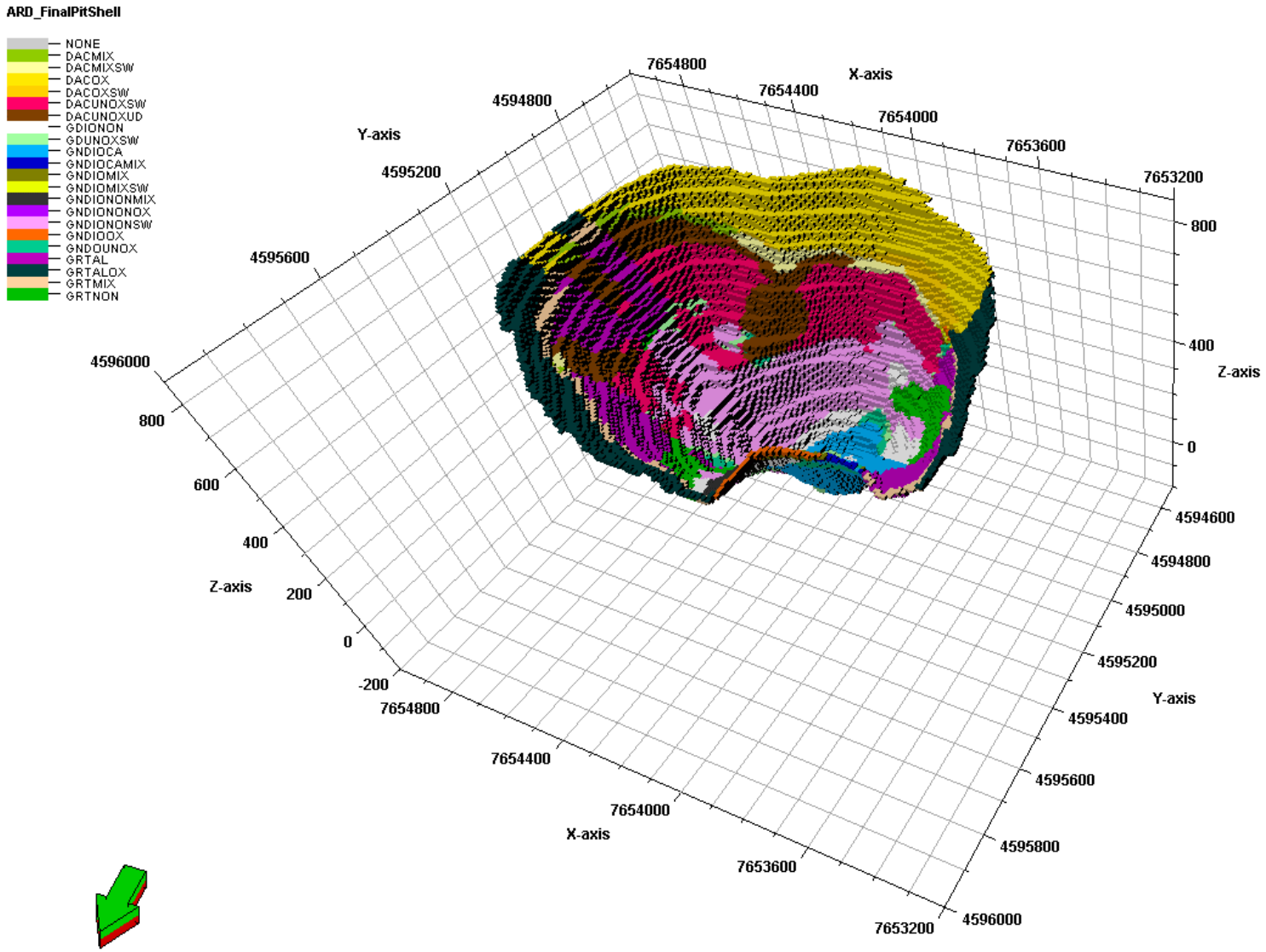
Schlumberger Water Services

First pushback pit shell depicting ARD material codes

PROJECT:	Ilovica Copper Gold Project			FIGURE:	A6.5
CLIENT:	Euromax Resources (Macedonia) Ltd.			PROJECT:	55459_R1v2
DRAWN:	JD	CHECKED:	TMW	DATE:	January 2016



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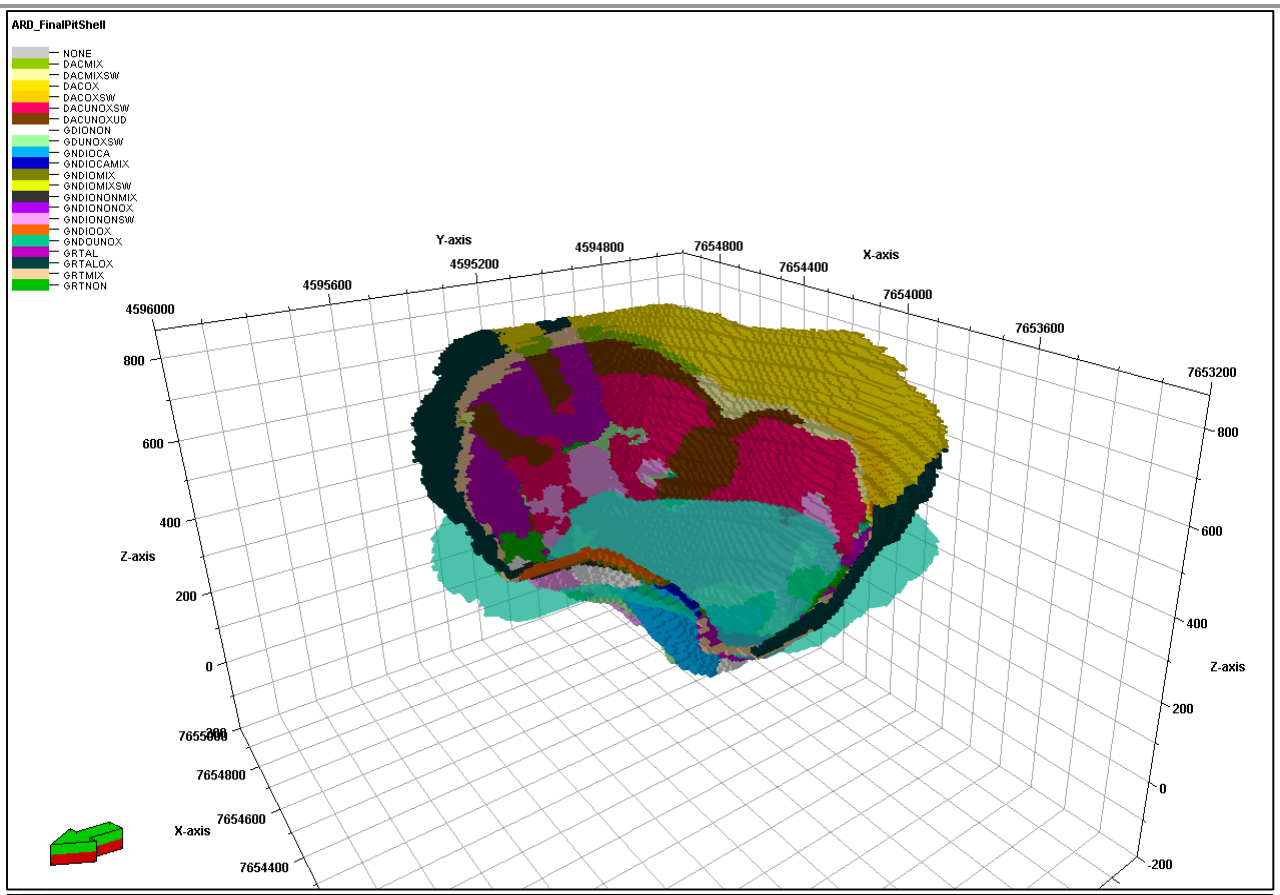
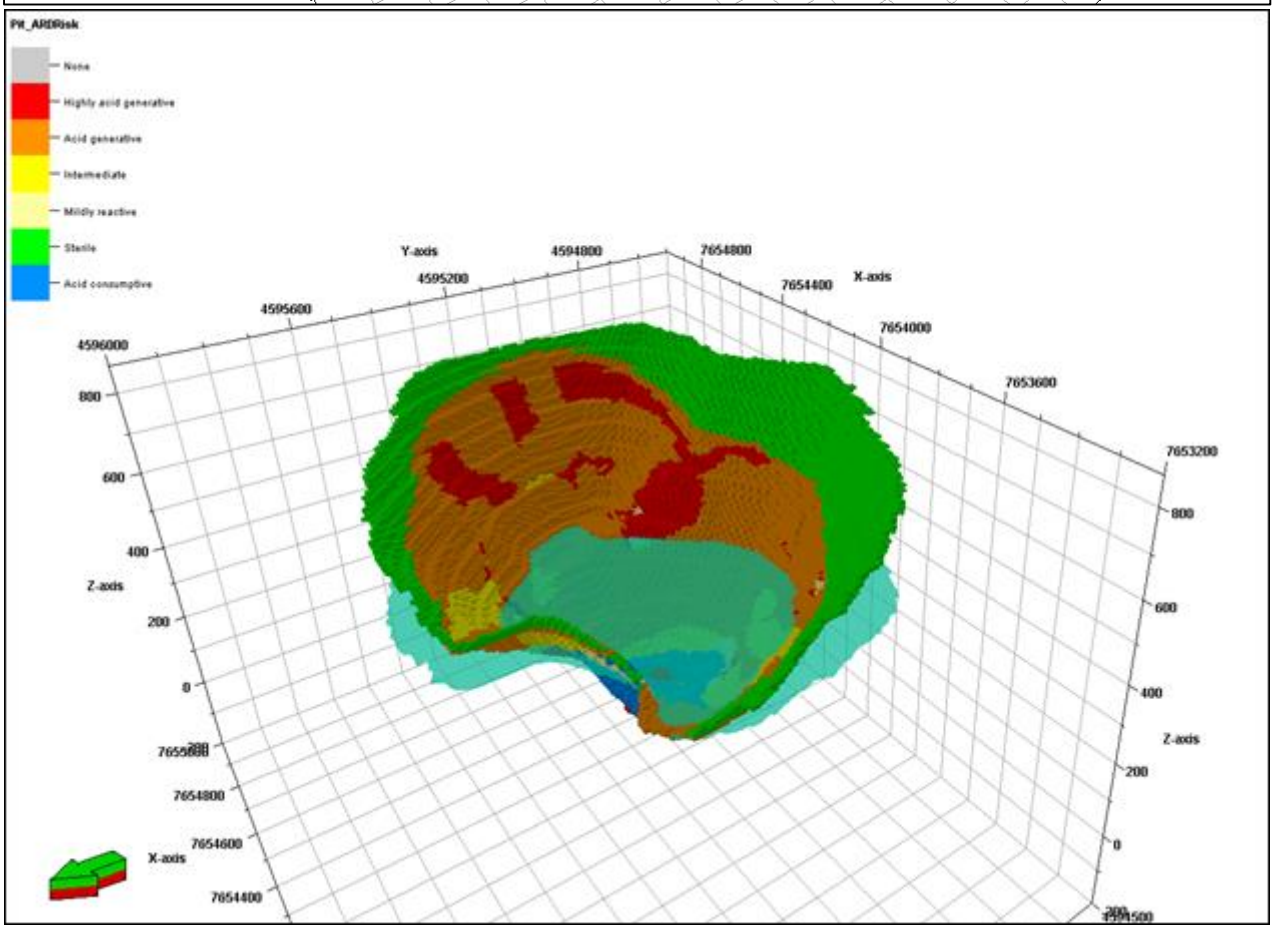
Schlumberger Water Services

Final pit shell depicting ARD material codes

PROJECT:	Ilovica Copper Gold Project	FIGURE:	A6.6
CLIENT:	Euromax Resources (Macedonia) Ltd.	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016





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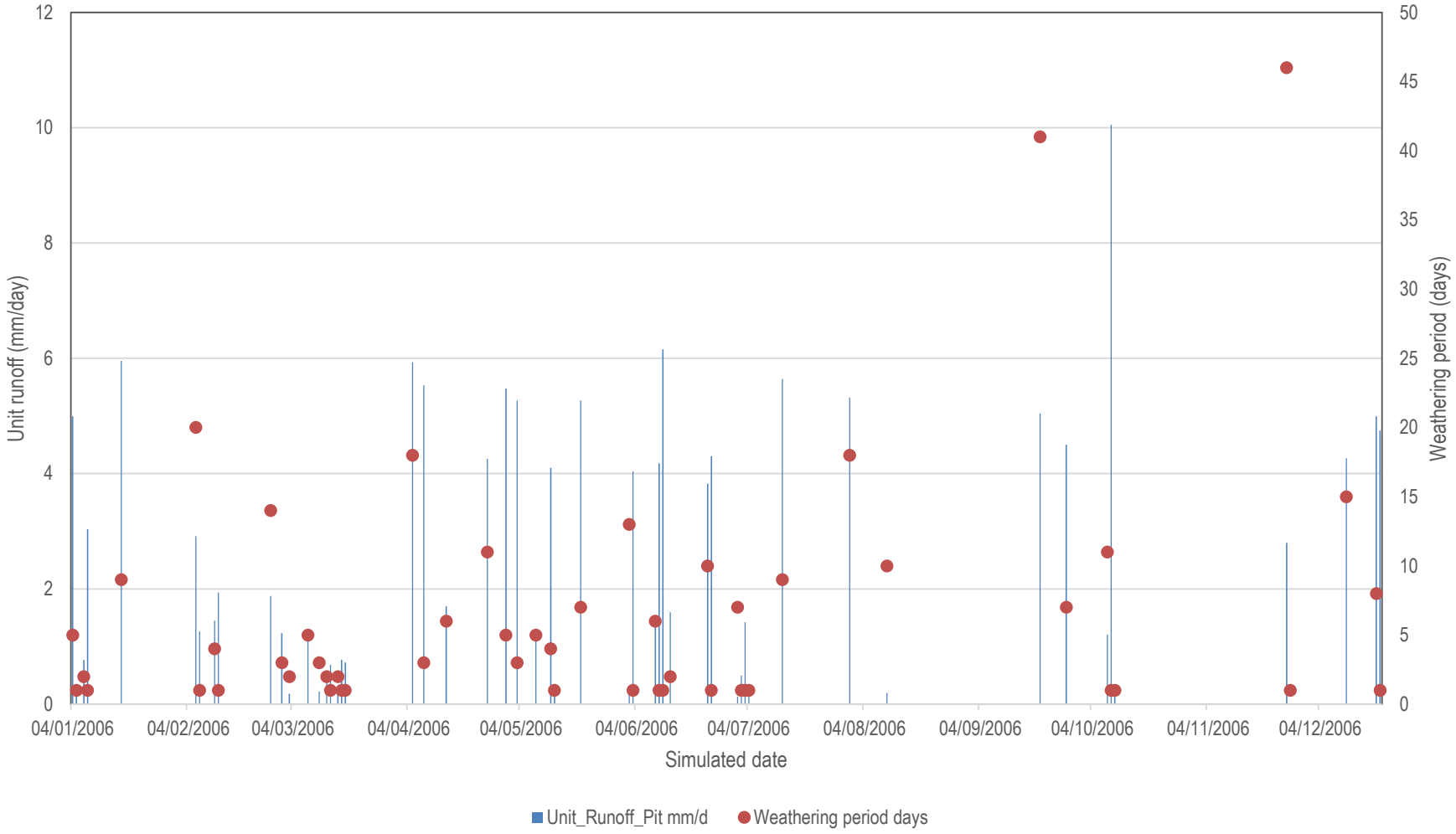
Schlumberger Water Services

Closure pit shell depicting ARD material breakdown and ARD risk, including predicted final pit lake elevation

PROJECT:	Ilovica Copper Gold Project	FIGURE #:	A6.7
CLIENT:	Ilovica Copper Gold Project	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016

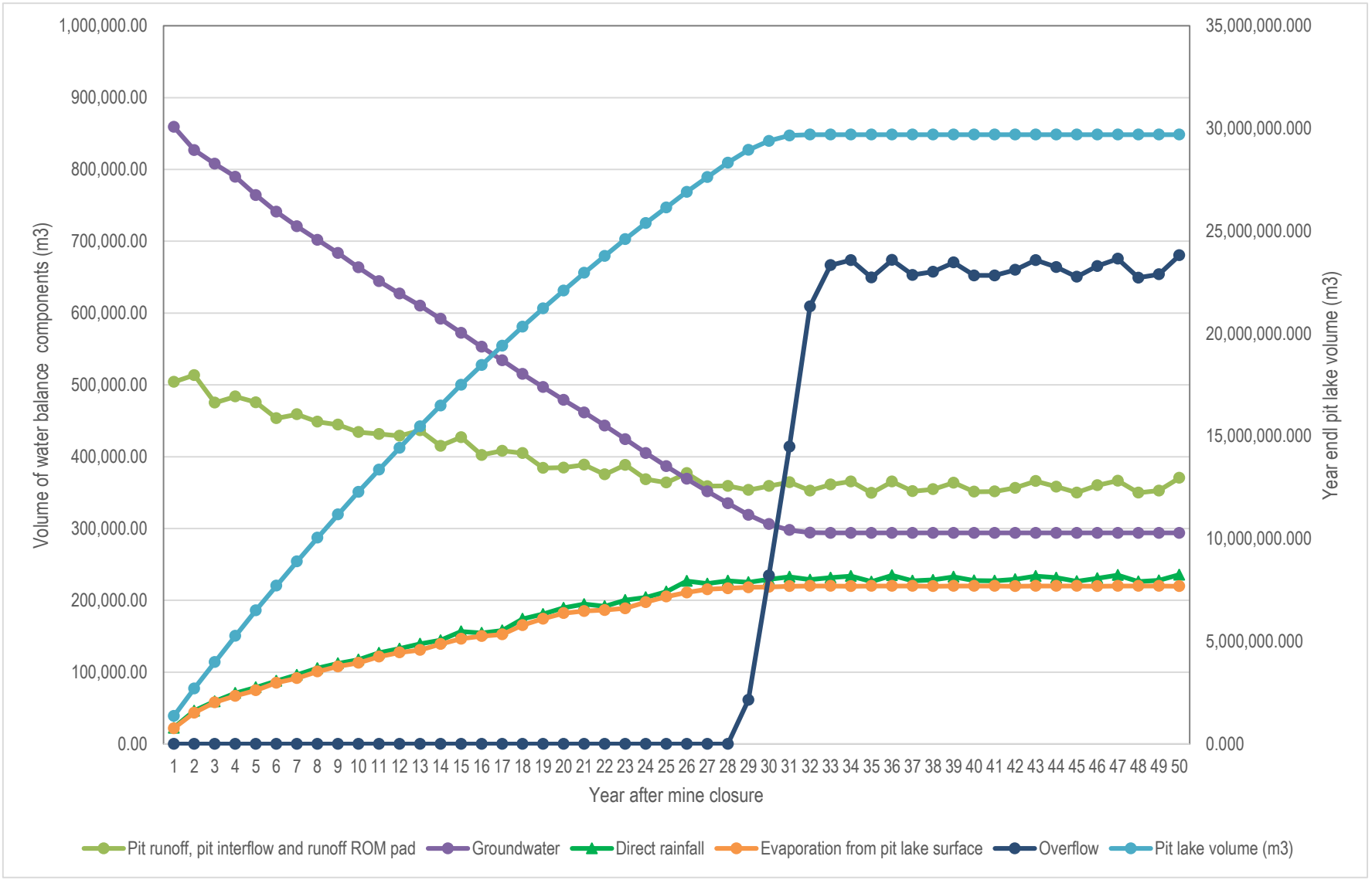


Source:
P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\400_WIP\412_Geochemistry\Model Report Sections

Schlumberger Water Services

Modelled unit (1 m^2 area) runoff events within the open pit

PROJECT:	Ilovica Copper Gold Project	FIGURE:	A6.8
CLIENT:	Euromax Resources (Macedonia) Ltd.	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016

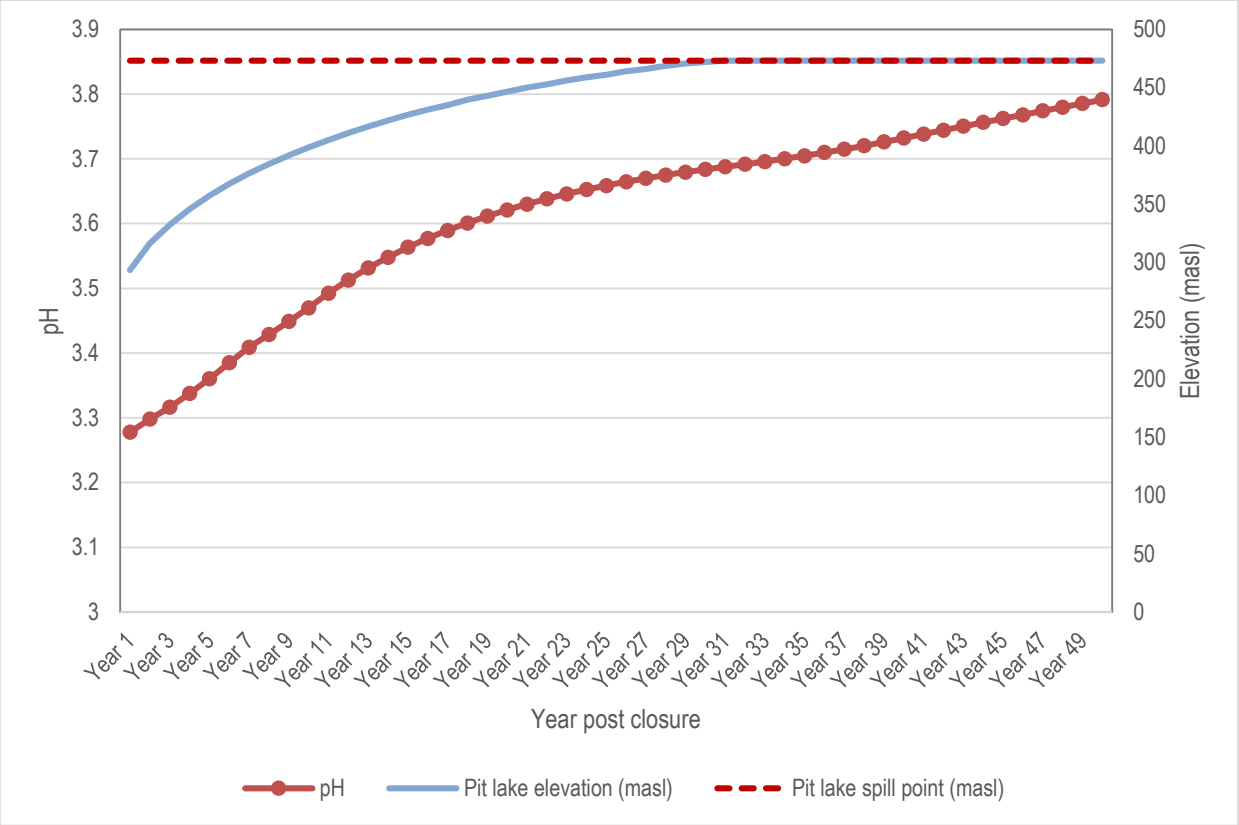


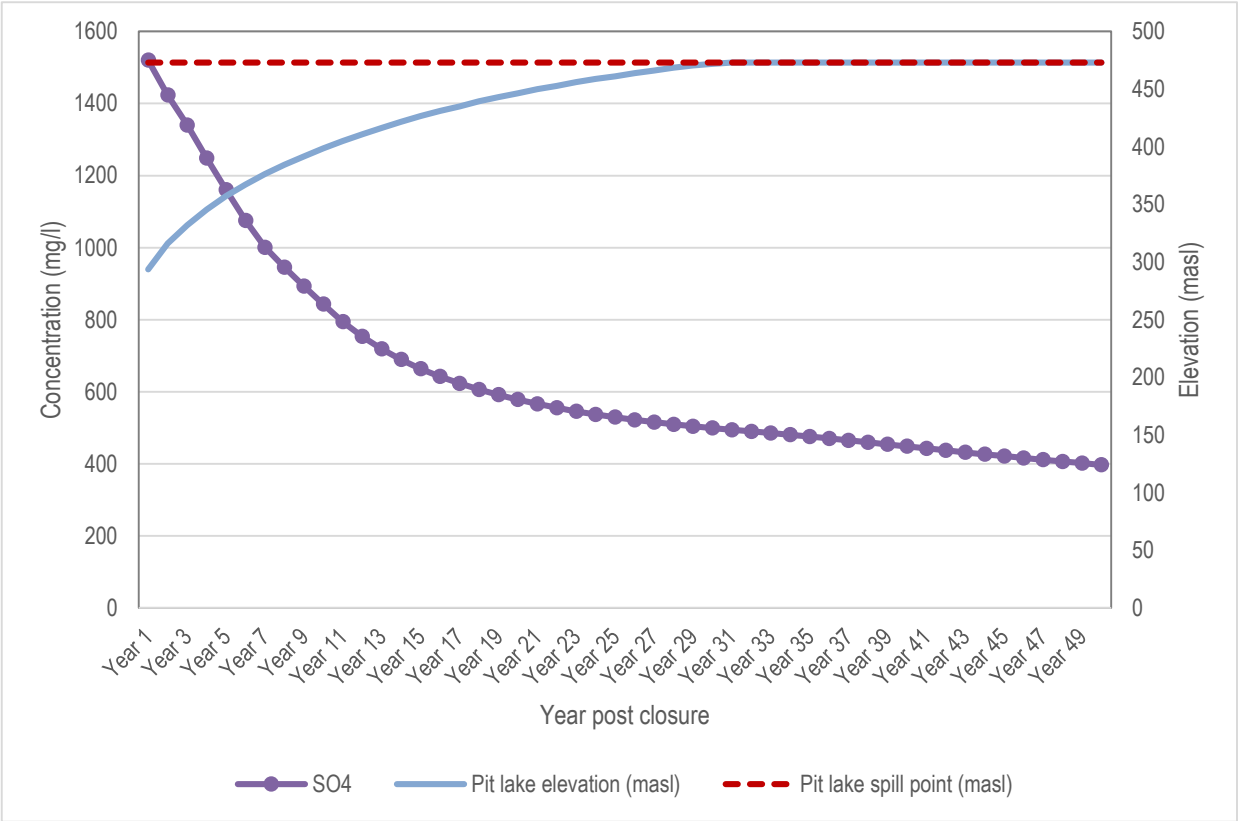
Source:
P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\400_WIP\412_Geochemistry\5. Pit Lake

Schlumberger Water Services

Modelled pit lake formation in closure

PROJECT:	Ilovica Copper Gold Project	FIGURE:	A6.9
CLIENT:	Euromax Resources (Macedonia) Ltd.	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016



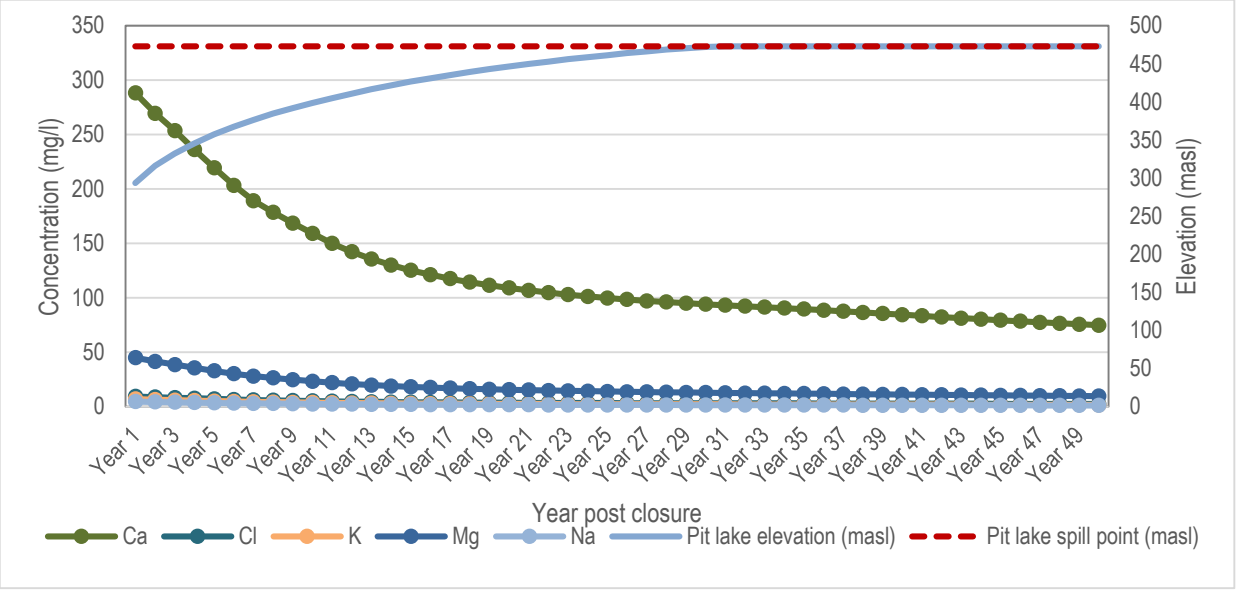


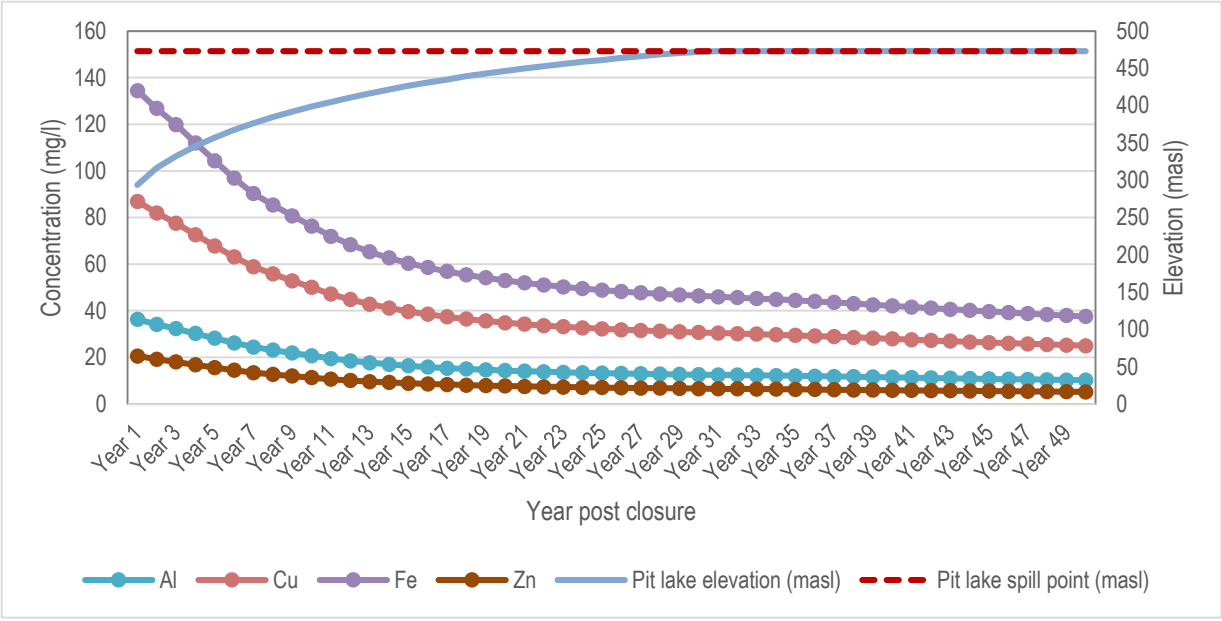
Source: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\400_WIP\412_Geochemistry\5. Pit Lake

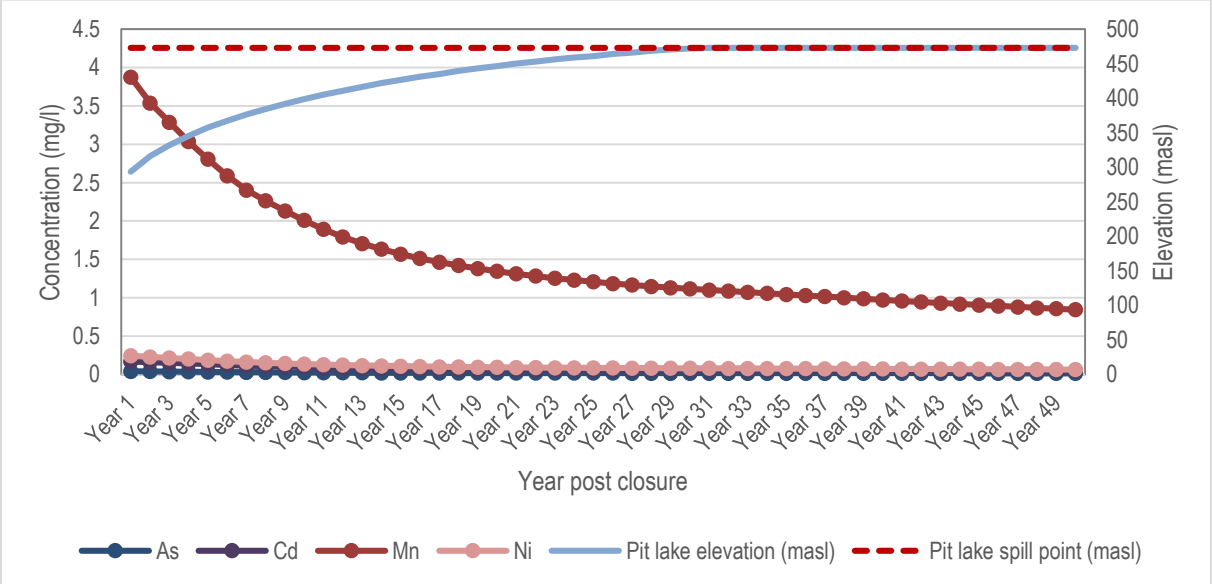
Schlumberger Water Services

Modelled pit lake water quality results: pH and SO4

PROJECT:	Ilovica Copper Gold Project	FIGURE:	A6.10
CLIENT:	Euromax Resources (Macedonia) Ltd.	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016





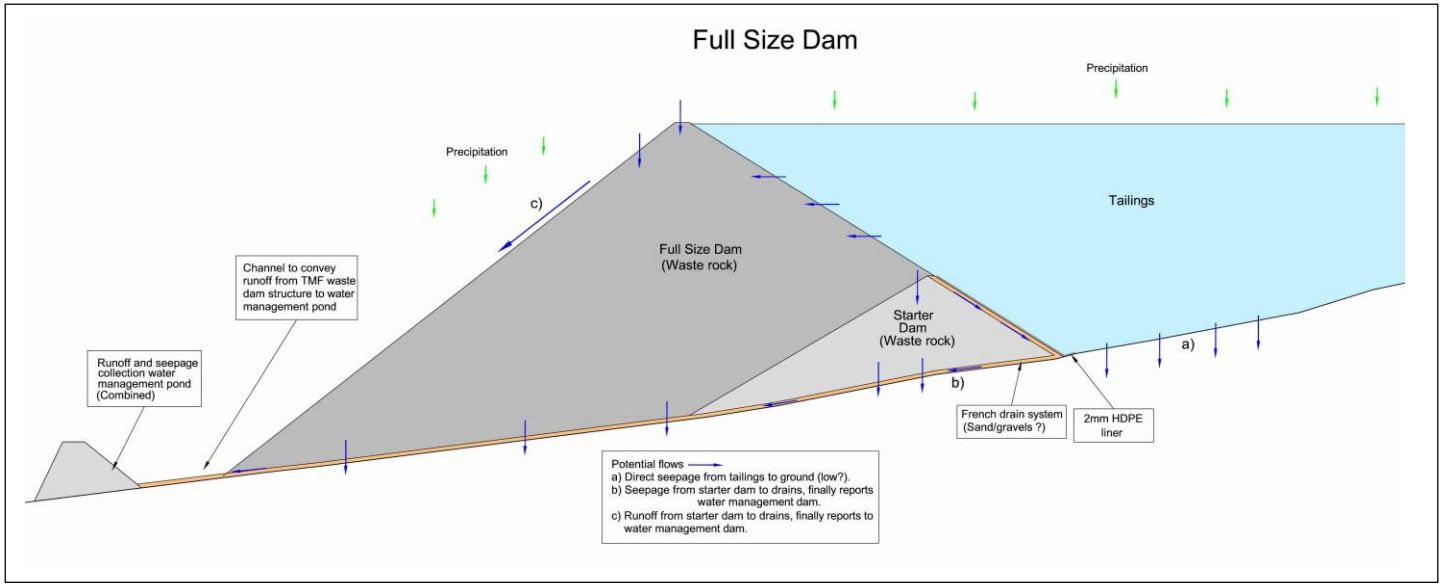


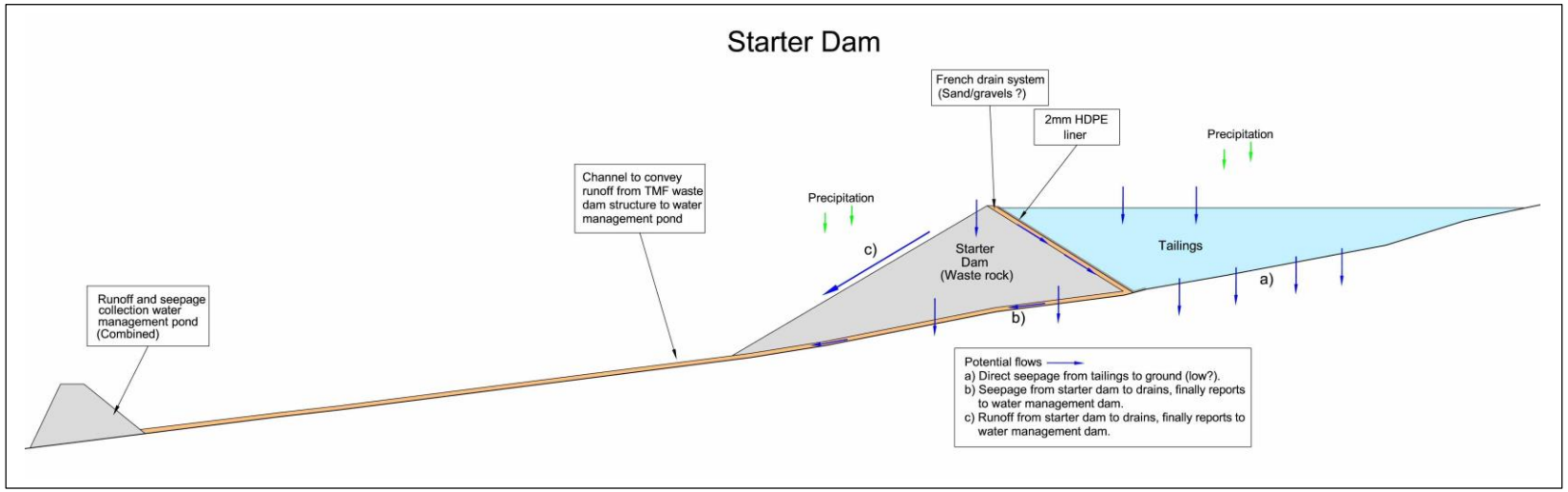
Source: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\400_WIP\412_Geochemistry\5. Pit Lake

Schlumberger Water Services

Modelled pit lake water quality results: major ions and metals

PROJECT:	Ilovica Copper Gold Project	FIGURE:	A6.11
CLIENT:	Euromax Resources (Macedonia) Ltd.	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: TMW	DATE:	January 2016



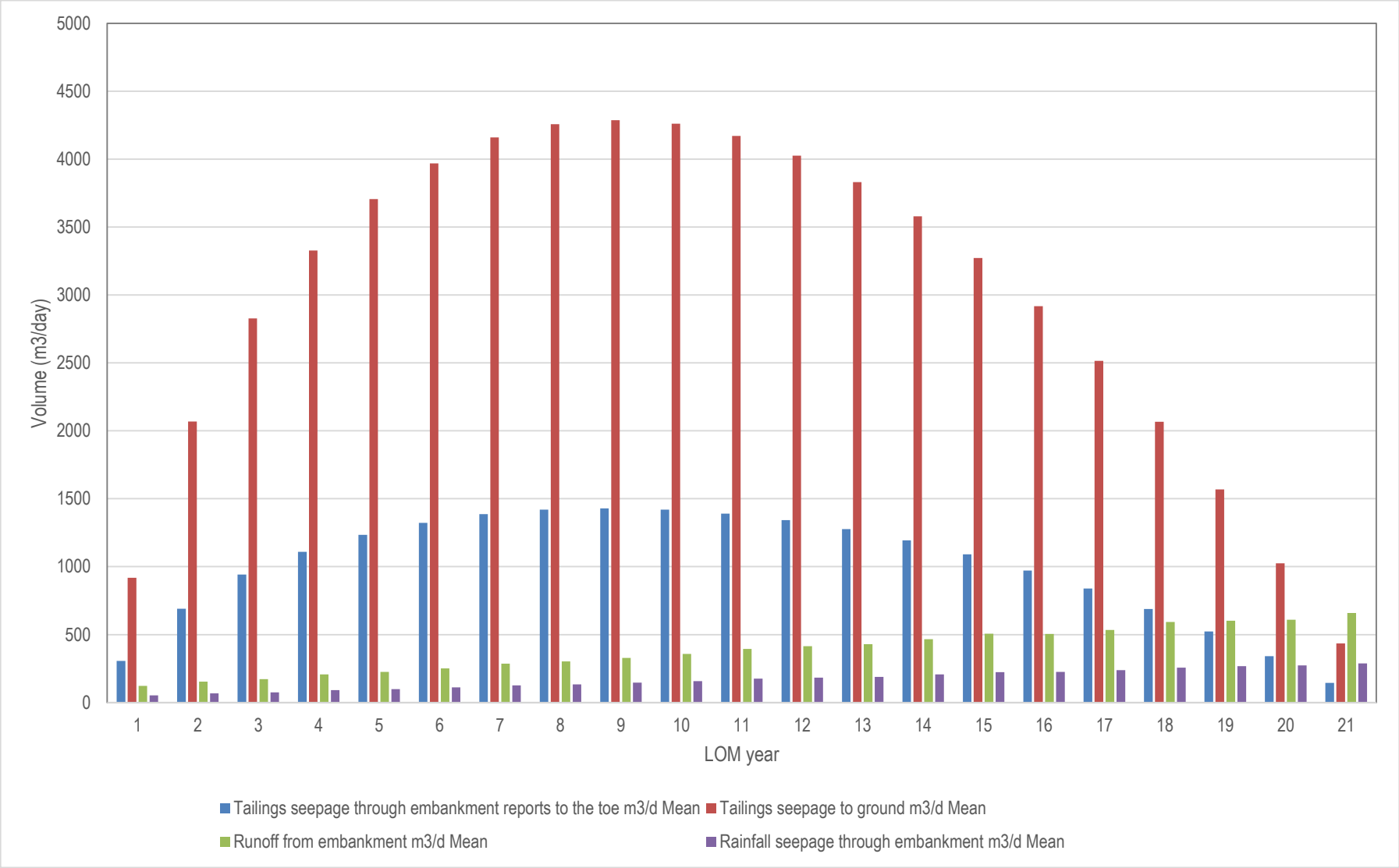


Schlumberger Water Services

Conceptual diagram of TMF

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A6.12
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: JD	CHECKED: PB	DATE:	January 2016

P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\510_Figures\55459R1_ESIA_Annex5\Section_6



Source:
P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\400_WIP\412_Geochemistry\2. TMF

Schlumberger Water Services

The predicted TMF water balance through LOM

PROJECT:	Ilovica Copper Gold Project		FIGURE: A6.13
CLIENT:	Euromax Resources (Macedonia) Ltd.		PROJECT: 55459_R1v2
DRAWN: JD	CHECKED: TMW		DATE: January 2016

7 DOWNSTREAM WATER QUALITY ASSESSMENT

7.1 Introduction

The conceptual and numerical modelling approaches for assessing the effect of the project on baseline surface and groundwater quality in the project area are outlined below. The modelling uses the water quality predictions from the source terms (described in Section 6) and links these with the results of water balance (Section 3), hydrological (Section 4) and hydrogeological (Section 5) modelling, to predict the flow pathways to and effects of source term discharges on downgradient surface and groundwater receptor locations. The layout of the mine facility source terms and the key hydrological components in the project area are presented on Figure A7.1.

7.2 Project source terms

7.2.1 Construction

The construction phase of the project corresponds to LOM year -1. The potential sources of contact water that could affect natural surface and groundwater during this period are listed below and fully described in Section 6:

- The generation of poor quality water from the pre-strip pit shell for the open pit which could discharge into surface water environments.
- The generation of poor quality water from the waste material used in TMF starter embankment construction, which could discharge to surface water.

7.2.2 Operation

The operational phase of the project runs from LOM year 1 to LOM year 23. The potential sources of poor quality water that could affect surface and groundwater bodies during this period are listed below and fully described in Section 6:

- Production of poor quality seepage from below the oxide stockpile, discharging directly to ground or to the water management dam at the toe of the facility, between LOM years 2 and 21
- Production of poor quality seepage water from below the tailings footprint (both tailings pore water and TMF embankment seepage), discharging directly to ground or to the water management dam at the toe of the facility, between LOM years 1 and 23.
- Lowering of flows within the Jazga catchment, due to changes in surface water management in the project area, which could increase the impact of domestic sewage discharges from Ilovica and Shtuka villages, downstream of the communities.

7.2.3 Closure

The closure phase of the project runs from LOM year 24 onwards. The potential sources of poor quality water that could affect surface and groundwater bodies during this period are listed below and fully described in Section 6:

- Production of poor quality seepage water from below the tailings footprint (both tailings pore water and TMF embankment seepage), discharging directly to ground or to the water management dam at the toe of the facility, from LOM year 24 onwards.
- Rebounding of groundwater levels within the pit to form a pit lake which discharges to the Jazga River, the pit lake is expected to reach its final elevation and discharge at approximately 28 years post closure (LOM year 51).

7.3 Receptors

7.3.1 Surface waters

The key surface waters that will be affected by the source terms described in Section 7.2 are the Jazga, Treska and Shtuka Rivers, plus the Ilovica Reservoir. The receptors are grouped into two main categories, based on the use or key function of the water body and receptor:

- Potable surface water supplies,
- Aquatic habitat in rivers.

The pathways that link the source term chemistries to the downstream receptors are flow regimes within the surface water and groundwater. Source terms could discharge to surface or groundwater, as described in Section 7.2. The receptors are listed in Table 7-1.

Table 7-1 Surface water receptors and indicator locations

Category of Receptor and potential impact-related issue	Receptor and indictor location
Potable water supplies **- change to water quality as a result of proposed mining activities upstream.**	▪ Jazga River at intake (JZGS01). ▪ Shtuka River at intake (STGS01).
	▪ Ilovica Reservoir (ILWT01)
Aquatic habitat in rivers **- change in water quality as a result of proposed mining activities upstream.**	▪ Jazga River downstream of the oxide stockpile and open pit (JZGS01). ▪ Treska River downstream of the oxide stockpile (TKGS01) ▪ Jazga River directly downstream of Ilovica Reservoir. ▪ Jazga River at Radovo Bridge (JZGS03) ▪ Ilovica Reservoir (ILWT01) ▪ Shtuka River (STGS01) downstream of tailings facility diversion outfall. ▪ Shtuka River at Sekirnik Road (STGS02) ▪ Turija River at TJGS01 downstream of confluence of Jazga River. ▪ Strumica River at SMGS02 downstream of confluence of Shtuka River. ▪ Strumica River at Novo Selo gauging station

7.3.2 Groundwater

The main groundwater bodies that may be affected by the source terms described in Section 7.2 are those of the Jazga and Shtuka catchments, as well as groundwater on the lower Strumica Plain. Three main indicator user groups have been identified within the groundwater bodies:

- Community water supply wells in Ilovica and Shtuka,
- Springs used for domestic water supply in Ilovica and Shtuka,
- Shallow aquifer used for irrigation in the Strumica plain.

The pathways that link the source term chemistries to the downstream receptors are flow regimes within the surface water and groundwater. Source terms could discharge to surface or groundwater, as described in Section 7.2. The receptors are listed in Table 7-2.

Table 7-2 Groundwater receptors and indicator locations

Receptor and potential impact-related issue	Receptor and indicator locations
Community water supply wells **- change in water quality as a result of proposed mining activities up gradient from Ilovica and Shtuka.**	▪ Potable groundwater supply for Ilovica Well IB39. ▪ Potable Groundwater supply for Shtuka Well SB47. ▪ Potable Groundwater supply for Ilovica Well IB30
Springs used for domestic water supply in Ilovica and Shtuka **- change in water quality as a result of proposed mining activities up gradient from Ilovica and Shtuka.**	▪ Spring ISP41 in Ilovica ▪ Spring SSP49 in Shtuka.
Shallow aquifer used for irrigation in the Strumica plain **- change in water quality as a result of proposed water abstraction from project boreholes in the Strumica plain and from proposed mining activities up gradient of Ilovica and Shtuka.**	▪ Borehole BH347 between Ilovica and Turnovo. ▪ Piezometer IC15111 between Ilovica and Turnovo.

7.4 Baseline conditions

The baseline regime used within the effects analysis is described in Annex 3 and further detail can be found in Annex 3. The maximum baseline recorded for each receptor indicator location is presented in Table 7-3 and these will be used as the baseline to compare against in effects analysis. The effect of poor quality water on baseline conditions generally will cause an increase in concentrations to occur, in most parameters, for instance metals. The project standards are fully described in the EDC (Golder, 2015). However, for pH and alkalinity the discharges from source terms described in Section 6 could cause a decrease which is detrimental. The pH of a water has lower limits to define 'good quality' to assess whether something is too acidic. Alkalinity is not formally regulated within the project EDC but it is an indicator as to the buffering capacity of the water, and whether a water will be able to buffer further changes in pH.

Table 7-3 Maximum baseline water quality concentrations at impact assessment receptors

Parameter	Unit	Surface water								Groundwater						
		Ilovica reservoir	Jazga River at intake	Jazga River at Radovo	Shtuka River at the intake	Shtuka River at Sekirnik	Turija River at Turnovo	Strumica River, downstream of Shtuka confluence	Strumica River at Novo Selo	Shallow irrigation well in Strumica plain	Piezometer on Strumica plain	Ilovica village spring	Shtuka village spring	Ilovica village well	Ilovica village well	Shtuka village well
		ILWT01	JZGS01	JZGS03	STGS01	STGS02	TJGS01	SMGS02	SMGS03	BH347	IC15111	ISP41	SSP49	IB30	IB39	SB47
Ag-D	mg/l	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035
Ag-T	mg/l	0.00035	0.00035	0.00035	0.00035	0.0009	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.0013	0.00035
Al-D	mg/l	0.1	0.05	0.2	0.05	0.05	0.05	0.05	0.7	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Field alkalinity*	mg/l	27.00	24	37	35	31	40	86	101	50	299	71	41	74	75	43
Al-T	mg/l	1.4	0.8	0.5	0.2	0.5	0.2	0.7	0.4	0.05	0.05	0.05	0.2	0.05	0.1	0.1
As-D	mg/l	0.006	0.0007	0.0019	0.0007	0.0007	0.0007	0.0025	0.009	0.0005	0.003	0.003	0.001	0.0036	0.003	0.001
As-T	mg/l	0.0054	0.0007	0.0023	0.0007	0.0007	0.0007	0.003	0.0074	0.0005	0.0017	0.0029	0.0007	0.005	0.0032	0.0014
Ba-D	mg/l	0.018	0.01	0.017	0.007	0.027	0.04	0.055	0.046	0.028	0.011	0.057	0.0208	0.058	0.049	0.021
Ba-T	mg/l	0.04	0.013	0.021	0.009	0.028	0.043	0.057	0.051	0.03	0.01	0.0566	0.02	0.057	0.047	0.021
Bi-D	mg/l	0.005	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Bi-T	mg/l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Ca-D	mg/l	16.2	22.6	30.5	30.5	31.4	35.6	57.7	57.1	39.9	21.5	62	27.9	66.9	49.3	30.4
Ca-T	mg/l	16.9	23.1	31.8	30	31.9	35.8	58.8	56.8	43.2	20.3	60.9	28.9	65.1	46.9	29.9
Cd-D	mg/l	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0006	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Cd-T	mg/l	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Cl-ion	mg/l	4.82	3.3	8.26	4.64	7.43	157	20.1	23.4	10.6	45	35.6	5.25	25.1	31.5	1.5
CN-free	mg/l	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.011	0.014	0.004	0.004	0.004	0.008	0.004	0.004
CN-T	mg/l	0.0045	0.0045	0.012	0.0045	0.0045	0.0045	0.0045	0.014	0.014	0.014	0.0045	0.0045	0.0045	0.0045	0.0045
CN-WAD	mg/l	0.005	0.0075	0.005	0.0075	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
COD	mg/l	43	27	38	19	21	32	20	37	5.5	5.5	35	17	23	16	5.5
Co-D	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Field conductivity	µS/cm	212	254.9	349.3	323.4	300.3	866	536	599	396.1	1156	812	395.1	588	569	370.7
Co-T	mg/l	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr-D	mg/l	0.001	0.008	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr-T	mg/l	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Parameter	Unit	Surface water								Groundwater						
		Ilovica reservoir	Jazga River at intake	Jazga River at Radovo	Shtuka River at the intake	Shtuka River at Sekirnik	Turija River at Turnovo	Strumica River, downstream of Shtuka confluence	Strumica River at Novo Selo	Shallow irrigation well in Strumica plain	Piezometer on Strumica plain	Ilovica village spring	Shtuka village spring	Ilovica village well	Ilovica village well	Shtuka village well
		ILWT01	JZGS01	JZGS03	STGS01	STGS02	TJGS01	SMGS02	SMGS03	BH347	IC15111	ISP41	SSP49	IB30	IB39	SB47
CrVI-D	mg/l	0.0025	0.0025	0.0025	0.0025	0.0025	0.005	0.0025	0.008	0.0015	0.0015	0.0025	0.01	0.0025	0.0025	0.0025
CrVI-T	mg/l	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0015	0.0025	0.0025	0.0025	0.0025	0.0025
Cu-D	mg/l	0.0045	0.009	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Cu-T	mg/l	0.012	0.0045	0.009	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.014	0.0045	0.0045
Fe-D	mg/l	3.5	0.115	0.3	0.115	0.115	0.66	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115
Fe-T	mg/l	5.55	1.28	1.25	0.3	0.5	0.89	1.32	0.82	0.115	0.115	0.115	0.115	0.115	0.115	0.115
F-ion	mg/l	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.5	0.2	0.6	0.3	0.2	0.3	0.2	0.2
Hg-D	mg/l	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Hg-T	mg/l	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
K-D	mg/l	5.44	3.36	4.76	2.86	2.3	5.64	5.18	5.65	5.95	3.81	33.9	5.5	14.4	30.7	3.96
K-T	mg/l	2.91	2.93	5.32	2.2	2.32	5.64	5.31	5.37	6.22	3.33	36.9	5.52	14.2	29.8	4.45
Mg-D	mg/l	3.2	4.45	6.89	7.21	7.29	9.99	14.2	11.9	8.5	3.8	15.4	6.36	13.6	11.2	6.1
Mg-T	mg/l	3.7	4.54	6.83	7.08	7.7	9.89	13.2	12.1	9.3	3.7	15.2	6.6	13.8	10.9	6.1
Mn-D	mg/l	0.852	0.022	0.292	0.011	0.018	0.256	0.117	2.45	0.0035	0.707	0.012	0.0035	0.014	0.009	0.0035
Mn-T	mg/l	0.919	0.071	0.319	0.031	0.027	0.261	0.134	2.5	0.0035	0.688	0.011	0.0035	0.015	0.009	0.0035
Mo-D	mg/l	0.0015	0.0015	0.0015	0.0015	0.0015	0.003	0.139	0.005	0.0015	0.018	0.004	0.003	0.008	0.006	0.0015
Mo-T	mg/l	0.0015	0.019	0.0015	0.019	0.0015	0.0015	0.0015	0.0015	0.0015	0.017	0.0015	0.0015	0.005	0.004	0.0015
Na-D	mg/l	6.38	8.81	12.9	11.6	9.79	102	21.8	22.6	14.4	201	32.8	11.4	20.2	28.5	8.53
Na-T	mg/l	6.63	9	13.1	11.7	9.49	103	22	23.1	15.7	196	32	11.7	20.2	27	8.87
NH4-C	mg/l	0.175	0.175	0.175	0.175	0.175	0.97	0.175	1.37	0.175	0.175	0.175	0.175	0.175	0.42	0.175
Ni-D	mg/l	0.0015	0.006	0.0015	0.0015	0.0015	0.015	0.0015	0.0015	0.0015	0.0015	0.006	0.0015	0.005	0.0015	0.0015
Ni-T	mg/l	0.0015	0.0015	0.0015	0.0015	0.0015	0.007	0.004	0.0015	0.0015	0.0015	0.007	0.0015	0.005	0.0015	0.0015
N-NH3	mg/l	0.135	0.135	0.135	0.135	0.135	0.75	0.135	1.06	0.135	0.135	0.135	0.135	0.135	0.33	0.135
N-NO2	mg/l	0.0125	0.0125	0.034	0.0125	0.067	0.147	0.078	0.156	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125
NO3-NO3	mg/l	0.95	0.95	4	4.9	30.3	11.5	8.3	7.8	65.7	0.95	96.1	5.9	125	95.2	5.8
Oils and greases	mg/l	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Parameter	Unit	Surface water								Groundwater						
		Ilovica reservoir	Jazga River at intake	Jazga River at Radovo	Shtuka River at the intake	Shtuka River at Sekirnik	Turija River at Turnovo	Strumica River, downstream of Shtuka confluence	Strumica River at Novo Selo	Shallow irrigation well in Strumica plain	Piezometer on Strumica plain	Ilovica village spring	Shtuka village spring	Ilovica village well	Ilovica village well	Shtuka village well
		ILWT01	JZGS01	JZGS03	STGS01	STGS02	TJGS01	SMGS02	SMGS03	BH347	IC15111	ISP41	SSP49	IB30	IB39	SB47
Field dissolved oxygen	mg/L	7.75	11.3	10.69	10.9	9.87	9.79	11.04	9.47	5.05	1.69	5.39	7.65	8.79	5.1	3.99
Field ORP	mV	136.3	236.6	259.3	230.2	238.2	204.9	262.3	195.3	130.8	-95.5	281.5	247.7	245.2	277.1	212.3
OrthPO4-P	mg/l	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.6	0.6	2.2	1.5	0.6
Pb-D	mg/l	0.003	0.009	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Pb-T	mg/l	0.012	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Phenols	mg/l	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.05	0.05	0.075	0.075	0.075	0.075	0.075
Field pH*	pH Units	6.73	6.46	6.52	6.32	6.28	6.31	6.77	7.17	6.68	7.09	6.02	6.09	6.14	6.17	6.05
P-T	mg/l	0.34	0.06	0.21	0.06	0.14	1.33	0.21	0.54	0.27	0.37	1.62	0.16	1.72	1.66	0.45
Sb-D	mg/l	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0006	0.0006	0.0008	0.0008	0.0008	0.0008	0.0006
Sb-T	mg/l	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0006	0.0006	0.0008	0.0008	0.006	0.0008	0.0006
Se-D	mg/l	0.0004	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0004	0.0004	0.0008	0.0008	0.0008	0.0008	0.0004
Se-T	mg/l	0.0004	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0004	0.0004	0.0008	0.0008	0.004	0.0008	0.0004
Si-T	mg/l	11.8	11.1	9.74	13.5	11.1	13.7	9.15	9.56	11	9.4	12.6	12.8	16.4	11.6	11.4
SO4-D	mg/l	21.7	30.7	21.4	29.3	29.7	33.4	40.2	35.9	33.4	215	51.6	34.9	41.8	49.7	47.5
Sr-D	mg/l	0.064	0.085	0.134	0.094	0.141	0.189	0.348	0.319	0.185	0.16	0.305	0.097	0.336	0.221	0.126
Sr-T	mg/l	0.071	0.088	0.15	0.091	0.149	0.197	0.352	0.33	0.184	0.168	0.3	0.098	0.333	0.226	0.124
Measured TDS	mg/l	147	125	176	160	184	459	289	310	240	720	437	167	414	411	185
Temp-F	C	18.1	21.7	28.2	23.7	20.4	21.9	24.2	23.9	18.2	17.9	19.8	21.4	17.1	16.7	18.8
TSS	mg/l	156	43	43	15	52	14	55	32	1	1	5	2	6	6	2
Field turbidity	NTU	0	56.6	0	35.7	0	0	0	0	0.59	2.12	1.27	1.91	3.9	2.89	2.23
U-D	mg/l	0.000155	0.000669	0.0007	0.00301	0.0007	0.000983	0.00298	0.00229	0.000155	0.012	0.00115	0.00196	0.00153	0.000182	0.00048
U-T	mg/l	0.00124	0.00104	0.00081	0.00299	0.00093	0.00101	0.00288	0.0024	0.000155	0.012	0.00118	0.00191	0.00155	0.000195	0.00048
V-D	mg/l	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.005	0.002	0.005	0.002	0.002
V-T	mg/l	0.004	0.002	0.002	0.002	0.002	0.002	0.004	0.002	0.002	0.002	0.006	0.002	0.006	0.004	0.002
Zn-D	mg/l	0.009	0.03	0.009	0.084	0.009	0.009	0.009	0.009	0.009	0.009	0.08	0.019	0.238	0.177	0.07

Parameter	Unit	Surface water								Groundwater						
		Ilovica reservoir	Jazga River at intake	Jazga River at Radovo	Shtuka River at the intake	Shtuka River at Sekirnik	Turija River at Turnovo	Strumica River, downstream of Shtuka confluence	Strumica River at Novo Selo	Shallow irrigation well in Strumica plain	Piezometer on Strumica plain	Ilovica village spring	Shtuka village spring	Ilovica village well	Ilovica village well	Shtuka village well
		ILWT01	JZGS01	JZGS03	STGS01	STGS02	TJGS01	SMGS02	SMGS03	BH347	IC15111	ISP41	SSP49	IB30	IB39	SB47
Zn-T	mg/l	0.04	0.05	0.009	0.04	0.03	0.009	0.02	0.009	0.009	0.009	0.06	0.03	0.291	0.223	0.112

*miminum pH and alkalinity are presented rather than maximum as these are the most negative effect on water quality

7.5 Effects analysis methodology

7.5.1 Conceptual model

Groundwater

The conceptual understanding of the groundwater flow system is described in more detail in Section 5.4. The background geology is granite and the Ilovica deposit is a porphyry system. Groundwater storage and flow within both the porphyry deposit and granite is controlled almost exclusively by the degree of fracturing that occurs in each rock type. Hydraulic gradients in the Jazga and Shtuka valleys are typically towards the valley bottom, where groundwater discharges as baseflow into the main river channels and larger tributary streams. These river systems drain groundwater from the mountain catchments to the Strumica Plain. It is believed that a significant volume of streamflow is transmitted within the highly fractured, high conductivity zone that occurs along the main axis of each river valley. The groundwater contaminant transport model (Section 5.9) uses the conceptualization of the flow model but adds in a chemical source term from seepage recharge of the TMF (as tailings pore water), TMF embankment and oxide stockpile to predict magnitude of concentration increases and plume formation in the groundwater system. It should be noted that it is not possible within the current model to represent fracture flow, since there is little known about the degree of fracturing within the valleys. As such plume migration is controlled in the model by the bulk hydraulic conductivity properties assigned to the model, and migration of contaminants through individual fault structures is not represented.

The oxide stockpile is situated on top of the Jazga River and over the high conductivity zone that occurs along the valley bottom. The groundwater level is relatively high beneath the oxide stockpile footprint and it is expected that there is continued interaction between groundwater and surface water underneath and downstream of the stockpile. Seepage that enters the groundwater system underneath the stockpile may enter the Jazga River downstream of the stockpile footprint and culvert. The oxide stockpile is operational between LOM year 3 and 21, so this period is modelled as a source term input.

The TMF footprint is large and situated in the Shtuka valley overlying the main Shtuka River channel and several larger tributaries. As for the Jazga model the groundwater level is relatively high around the high conductivity zones of the main river channel and tributaries. No unsaturated flow modelling between the base of the TMF facility and the piezometric surface has been included, so a direct connection is assumed. The seepage from the tailings begins in LOM year 1 and continues after mine life and into the closure period. The seepage from the TMF embankment begins in LOM year -1 and continues after mine life and into the closure period. The closure model runs for a duration of 100 years. It is assumed in closure that the seepage from the TMF remains at the same level as the final year of operations for 10 years, before being reduced by a factor of 10 to simulate drain-down of stored water within the facility (after the TMF is covered and revegetated to reduce infiltration). The chemical inputs for the closure period will remain the same as in the final year of operation. As described for the Jazga River there is significant interaction between groundwater and surface water underneath and downstream of the TMF. Seepage that enters the groundwater system underneath the stockpile may enter the Shtuka River downstream of the TMF footprint.

Surface water

In construction potential sources of poor quality water to the surface water environment in the Jazga and Shtuka catchments are mainly from uncontrolled runoff from the pre-strip open pit footprint and the waste material used in the initial TMF embankment. If uncontrolled this runoff may reach the surface water bodies (the main Jazga and Shtuka Rivers). The proportion of potential discharge versus the flow volume predicted under differing meteorological and hydrological conditions will directly control the water quality at surface water receptor indicator locations.

During operations it is assumed that there is no discharge to surface water from any mine facility, as water will be managed and re-used to reduce water supply needs. Flow is predicted to reduce during operations, as there will be loss of catchment area to mine facilities and the recharge that would report to surface water bodies will now be managed and collected by the mine. The reduction in flow is likely to cause a change in water quality downstream of the Ilovica and Shtuka villages. The effect has only been assessed in a qualitative approach. In the project baseline studies (Annex 3) groundwater and surface waters beneath and downgradient of the Ilovica and Shtuka villages were found to show evidence of anthropogenic pollution, in the form of elevated nitrogen and phosphorous concentrations most likely derived from uncontrolled sewage discharges and agricultural activities. The actual load of any anthropogenic pollution from the villages is difficult to assess. The reduction in flow will occur along the Jazga and Shtuka Rivers may cause an increase in concentration of these anthropogenic pollution indicators at receptor indicator locations downstream of the villages. The pollution load from the villages is likely to remain the same, however the diluting volume of upstream surface water (derived from upstream Jazga and Shtuka catchments where the mine project is located) is likely to decrease, thus the concentration of solutes downstream of the villages may increase.

Immediately after operations cease there will be no direct discharges to surface water in the Jazga catchment. The groundwater level within the pit is expected to rebound and a pit lake will begin to form (Section 6.3). The elevation of the lake within the closed open pit will continue to rise until 28 years after mine closure. At this point, the lake will start to spill from the lowest point on the circumference of the pit outline, and flow into the Jazga River. The flow rate of the pit lake overflow is predicted to be approximately 20 l/s. The chemistry of the pit lake spill is predicted to be acidic and contain metals. If the pit lake overflow is a large enough component of the flow at the Jazga River this could cause the surface water to become more acidic and have a higher concentration of metals.

As described in the conceptual model of groundwater the baseline data, hydrological and hydrogeological predictive modelling suggest interaction between groundwater and surface water in the reaches downstream of the mine facilities in the Jazga and Shtuka catchments. Seepage of poor quality entering the groundwater beneath the TMF or oxide stockpile could migrate downgradient in the groundwater and discharge into the main channels of the Shtuka and Jazga Rivers, in the same manner as baseflow enters the rivers. The volume of water and concentration of the water entering the river from groundwater has been assessed using the contaminant transport model and the chemical load added to the surface water quality predictions.

7.5.2 Analytical modelling approach

Model set-up

Groundwater

The potential effects of the project on groundwater quality were assessed using an MT3D contaminant transport model, further details described within Section 5.9. Background concentrations were assumed to be zero for the purposes of contaminant transport modelling, as insufficient data on whole-catchment chemical loading does not exist to calibrate background concentrations satisfactorily. The MT3D model gave a conservative indication of the magnitude of increase in concentrations as opposed to providing absolute concentrations. Advection was used as the key control for plume migration as the system is dominated by fracture flow, as there is little data to define other parameters such as diffusion and dispersion. No attenuation or retardation of chemical load is expected or modelled.

Concentrations were assigned to the recharge rates applied to the groundwater flow model to represent seepage from the tailings, TMF embankment and oxide stockpile. The concentrations used for the tailings pore water seepage directly to ground are presented in Table 6-21. The same chemistry was used in operations and closure. The concentrations used through LOM for the TMF embankment are presented in Table 6-23. The final year chemistry presented is used for the closure chemistry within the contaminant transport model. The oxide stockpile

chemical input is based on the average chemistry predicted from the 50th percentile predicted seepage flows through LOM presented in Table 6-4. The seepage is applied between LOM years 2 and 21. Sulphate was modelled as the main chemical parameter, as it is in higher concentrations, and a key parameter of concern from the source terms. Results for other parameters were estimated using relative proportions based on the initial source term concentrations. Indicative results were presented at receptor locations by comparing concentration increases predicted by the contaminant transport model with the maximum baseline concentration recorded at the indicator receptor location.

Surface waters

The effect on water quality of source term discharges at surface water receptor locations was modeled by estimating the potential source term discharges (Section 6) and the proportion of flow that these discharges will represent at surface water receptor indicator points. The baseline chemistries (described in Section 7.4) and the source term chemistries (described fully in Section 6) were mixed according the flow proportions in different conditions, using the geochemical modelling code PHREEQC. The solutions were thermodynamically equilibrated and were allowed to charge balance using chloride ions. Minerals that were over-saturated within the solution were allowed to precipitate if it was kinetically feasible, mostly this was ferrihydrite (iron hydroxide). Any precipitated iron hydroxides were allowed to act as a solid surface for sorption and exchange of ions.

The construction effects analysis on surface water receptors was the change from predicted construction runoff water discharge to the predicted flow regime within the Jazga and Shtuka Rivers, as no significant seepage is expected during the construction period. The modelled construction period percentile flow conditions, as described in Section 4, and the proportion of potential runoff from the pre-strip open pit shell at the downstream receptor indicator JZGS01 is shown in Table 7-4. At a Q95 flow scenario no construction pit runoff is expected to reach the Jazga River, thus water quality models for this scenario have not been completed.

Table 7-4 Modelled flow predictions for construction runoff proportions at JZGS01 gauging station

Flow scenario	Baseline JZGS01 (m^3/s)	Yr -1 Construction JZGS01 (m^3/s)	Proportion of construction pit runoff	Proportion of other flow at JZGS01 in construction
Max	4.0988	4.047	0.142	0.858
Q95	0.005	0.005	0.000	1.000
Q90	0.008	0.008	0.000	1.000
Q75	0.019	0.019	0.000	1.000
Q50	0.058	0.057	0.000	1.000
Q25	0.154	0.152	0.000	1.000
Q10	0.302	0.295	0.000	1.000
Q5	0.413	0.404	0.000	1.000

The proportion of potential runoff from the initial TMF embankment and the modelled Shtuka River flow regime at downstream receptor indicator STGS01 is presented in Table 7-5. The runoff chemistry for the TMF embankment in construction (corresponding to LOM year -1) is presented in Table 6-22 and was used to predict downstream surface water quality.

During operations there will be no direct surface water discharges in the Jazga catchment. There is expected to be seepage to groundwater from the oxide stockpile. The connection between the groundwater and surface water in the reach between the oxide stockpile and JZGS01 means that groundwater is likely to enter the surface water system. The chemistry and volume of water entering the Jazga River from the groundwater in the contaminant transport model will be exported and used to calculate any effect on surface water at JZGS01 in operations.

Table 7-5 Modelled flow predictions for construction runoff proportions at STGS01 gauging station

Flow scenario	BaselineSTGS01 (m^3/s)	Modelled Yr -1 STGS01 (m^3/s)	Proportion of construction runoff from TMF embankment	Proportion of STGS01 flow
Mean	0.055	0.058	0.002	0.998
Q95	0.002	0.002	0.055	0.945
Q90	0.004	0.004	0.037	0.963
Q75	0.008	0.008	0.016	0.984
Q50	0.022	0.023	0.006	0.994
Q25	0.054	0.057	0.002	0.998
Q10	0.126	0.133	0.001	0.999
Q5	0.196	0.208	0.001	0.999

Immediately following closure there will be no direct discharges to the Jazga River from mine facilities. Also seepage from the oxide stockpile will cease as the material will be removed and processed by the end of operational phase. The formation of a pit lake will take approximately 28 years. After this point, the pit lake will discharge directly to the Jazga River. The flow proportions of the overflow and modelled JZGS01 flow regime at this time are presented in Table 7-6 The proportions were used to create a mixing model to predict water quality at JZGS01 in closure.

Table 7-6 Modelled flows for JZGS01 and the pit lake overflow in closure

	Yr 67 Closure JZGS01 (m^3/s)	Yr 67 Modelled pit lake overflow (m3/s)	Proportion of flow as baseline at JZGS01	Proportion of flow as pit lake overflow at JZGS01
Min	0.0037	0.000	1.00	0.00
25th %ile	0.0254	0.000	1.00	0.00
Median	0.0713	0.006	0.92	0.08
75th %ile	0.1744	0.024	0.73	0.27
95th %ile	0.4530	0.081	0.27	0.73
Max	3.9867	0.715	0.01	0.99

In operational and closure phases of the Ilovica project there will be no direct discharges to the Shtuka River. There is expected to be seepage to groundwater from the TMF. The connection between the groundwater and surface water in the reach between the TMF and STGS01 means that groundwater will enter the surface water system. The chemistry and volume of water entering the Shtuka River from the groundwater in the contaminant transport model will be exported and used to calculate any effect on surface water at STGS01 in operations and closure.

Downstream of the STGS01 receptor location the modelled surface water flows are generally the same or less than the flows predicted at STGS01. This is seen at the second Shtuka River gauging station below the villages, STGS02 (Table 7-7). The model suggests that there is loss of water from the river to the groundwater system between STGS01 and STGS02, although it is difficult to predict. The chemistry predictions for STGS02 are therefore based on the conservative assumption that the mass is conserved within the surface water system but that there is potential loss of volume. This was modelled using a similar approach to the groundwater target receptors, indicative results were presented at STGS02 by comparing concentration increases assuming the concentration load stays the same as predicted for STGS01 plus the maximum baseline concentration recorded at STGS02.

Table 7-7 Modelled flows at STGS01 and STGS02 throughout mine life and closure

Receptor location	STGS01				STGS02			
Flow scenario	BaselineSTGS01 (m^3/s)	Yr -1 STGS01 (m^3/s)	Yr 21 STGS01 (m^3/s)	Yr 27 STGS01 (m^3/s)	Baseline STGS02 (m^3/s)	Yr -1 STGS02 (m^3/s)	Yr 21 STGS02 (m^3/s)	Yr 27 STGS02 (m^3/s)
Count	19860	19860	19860	19860	19860	19860	19860	19860
Mean	0.055	0.058	0.051	0.100	0.050	0.052	0.045	0.014
Q95	0.002	0.002	0.002	0.003	0.014	0.014	0.014	0.014
Q90	0.004	0.004	0.004	0.005	0.014	0.014	0.014	0.014
Q75	0.008	0.008	0.008	0.012	0.014	0.014	0.014	0.014
Q50	0.022	0.023	0.022	0.039	0.014	0.014	0.014	0.014
Q25	0.054	0.057	0.052	0.124	0.029	0.032	0.027	0.014
Q10	0.126	0.133	0.119	0.258	0.104	0.109	0.097	0.014
Q5	0.196	0.208	0.182	0.370	0.178	0.191	0.165	0.014

The effect on the reservoir is presented here as an effect to the inflow of the reservoir, it is assumed that water quality at the inflow is similar to that of the inflow to the water treatment plant (as found in the baseline studies). The actual effect on total reservoir water quality is assessed qualitatively, as the water balance, water supply options and future water use could all impact on the actual volume of water within the reservoir. The total reservoir holds approximately 356,000 m3. Ilovica reservoir is modelled using the volume inflows to the reservoir, presented in Table 7-8.

Table 7-8 Modelled inflows to the Ilovica reservoir through LOM

	Baseline Reservoir Inflow (m^3/s)	Yr -1 Construction Reservoir Inflow (m^3/s)	Yr 21 Operations Reservoir Inflow (m^3/s)	Yr 27 Closure Reservoir Inflow (m^3/s)	Yr 67 Closure Reservoir Inflow (m^3/s)	Yr 67 Total inflow (m3/day)	Yr 67 Total inflow (m3/year)
Max	4.813	4.760	4.579	4.652	4.698	405893	148150998
Q95	0.006	0.006	0.001	0.001	0.011	937	342166
Q90	0.009	0.009	0.001	0.001	0.014	1209	441304
Q75	0.022	0.022	0.013	0.013	0.029	2468	900699
Q50	0.067	0.066	0.056	0.057	0.080	6921	2525990
Q25	0.178	0.175	0.162	0.165	0.197	17032	6216748
Q10	0.352	0.345	0.329	0.334	0.383	33099	12081106
Q5	0.482	0.473	0.452	0.460	0.521	45051	16443718

In construction, as is seen for the upstream point JZGS01, there are likely to be zero flows at the Q95 of the modelled flow scenarios, so no water quality modelling has been completed for this scenario. During operations there will be no direct discharges to surface water from mine facilities upgradient of the Ilovica reservoir. There is expected to be seepage to groundwater from the oxide stockpile. The connection between the groundwater and surface water in the reach between the oxide stockpile and Ilovica reservoir means that groundwater is likely to enter the surface water system. The concentration and volume of water entering the Jazga River from the groundwater in the contaminant transport model will be exported and used to calculate any effect on surface water at the Ilovica reservoir in operations. As discussed for the Jazga River upstream of the reservoir the only discharge to the surface water environment in closure will be the pit lake overflow, which will occur 28 years after mine closure. The proportions used to model reservoir inflow chemistry are presented in Table 7-9, based on the modelled flow scenarios. In closure reservoir inflows, around 10% of every 356,000 m^3 entering the reservoir is apportioned to the pit lake spill.

Table 7-9 Modelled flow proportions for the pit lake spill and reservoir inflow (post-pit lake formation in closure)

Flow scenario	Pit lake chem	Reservoir inflow
Min	0.0000	1.0000
25th %ile	0.0000	1.0000
Median	0.0729	0.9271
75th %ile	0.2472	0.7528
95th %ile	0.7044	0.2956
Max	0.9893	0.0107

During construction potential surface water discharges will be short-term and low in volume, so the effect will not be seen downstream of the Ilovica Reservoir. During operations the reservoir will be used as a storage component for mine water supply. The groundwater model will be used to assess the volume and chemistry of groundwater discharges to surface waters in the Jazga catchment in operations, as the only mine project discharge in the Jazga catchment in operations will be seepage to groundwater from the oxide stockpile. It is very likely that there will be no change seen downgradient of the Ilovica reservoir during operations, as water will also be being removed regularly from the reservoir.

The closure water quality for JZGS03, TJGS01 and SMGS02 has been modelled using the flow proportions predicted in Section 4. The reservoir seepage and modelled closure flows for JZGS03 are presented in Table 7-10. The predicted water quality at JZGS03 will be a proportional mix of baseline JZGS03 water chemistry and reservoir inflow chemistry. With distance downstream from the open pit the effect of the pit overflow on the Jazga (which then flows into the Turija and Strumica rivers) decreases and changes in chemistry from other inflows, such as upstream of the Strumica confluence, will have more control on the overall water quality. All inflow chemistries from outside the project area are assumed to be the same as baseline conditions. The predicted flows at downstream receptor points are presented in

Table 7-11. The chemistry at TJGS01 is modelled as a proportional mix of the predicted chemistry at JZGS03 and baseline chemistry of TJGS02. The chemistry at SMGS02 is modelled as a proportional mix of the predicted closure chemistry for the TJGS02 and STGS02 inflows and the baseline SMGS02 chemistry. The water quality downstream at Novo Selo has only been assessed qualitatively. The proportion of flow emanating from the Jazga and Shtuka catchments as a proportion of the total flow at Novo Selo is very low (Section 4) and as such there will be no impact.

Table 7-10 Modelled closure reservoir seepage and flows at JZGS03

	Reservoir seepage in closure (m3/s)	Modelled closure flows JZGS03 (m3/s)
Min	0.0038	0.0013
25th %ile	0.0050	0.0046
Median	0.0050	0.0374
75th %ile	0.0050	0.1596
95th %ile	0.0050	0.4683
Max	0.0050	6.9759

Table 7-11 Modelled median flows for downstream receptor indicator locations in closure scenario

	Median modelled closure flows (m3/s)

JZGS03	0.037
TJGS02	0.422
STGS02	0.014
SMGS02	1.155

Results by receptor indicator location

Predicted changes for Jazga River at intake (JZGS01)

The intake on the Jazga River at JZGS01 is used to collect water for local drinking water and irrigation water. The river is also of importance for ecological habitat. The water quality predictions for the receptor location at JZGS01 during operations were calculated using volume and concentrations entering the surface water body from the groundwater in the MT3D model (Section 5) along the Jazga reach between the oxide stockpile and the JZGS01 monitoring point. The results of these inflows for the modelled parameter sulphate are presented in Table 7-12. These results assume that there is no direct rapid fracture connection beneath the oxide stockpile as the MT3D model uses a bulk hydraulic conductivity. The degree of fracturing in the granite within the Jazga valley is still unknown. These flows and concentrations were used to predict the indicative concentrations from other parameters within the oxide stockpile seepage. A second more conservative estimate of water quality was predicted using an assumption that the concentration and volume of seepage beneath the oxide stockpile could be connected by rapid fracture flow to the surface water downstream. The results of the water quality modelling for the non-conservative and conservative scenarios for JZGS01 is presented in Table 7.13. The predicted water quality is above the maximum baseline parameters for some trace metals.

Table 7-12 Modelled MT3D flows and concentrations entering the Jazga River between the oxide stockpile and JZGS01 in operations

LOM year	Modelled flows from groundwater to surface water (m3/s)				Modelled sulphate concentration (mg/l)			
	JZGS01 to J Upstream 1	J Upstream 1 to J Upstream 2	J Upstream 2 to J Upstream 3	Total seepage to streams (litres)	JZGS01 to Jazga 1 reach	Jazga upstream 1 to Jazga upstream 2 reach	Jazga upstream 2 to Jazga upstream 3 reach	Cumulative concentration in the stream through the reach
5	0.006	0.001	0.014	21.7	0.003	0.009	0.01	0.009
6	0.006	0.002	0.014	21.8	0.014	0.037	0.04	0.035
7	0.006	0.002	0.014	21.7	0.037	0.091	0.10	0.081
8	0.006	0.002	0.014	21.9	0.073	0.173	0.17	0.146
9	0.006	0.002	0.014	21.7	0.116	0.261	0.24	0.204
10	0.006	0.002	0.014	21.6	0.165	0.364	0.30	0.269
11	0.006	0.002	0.014	21.3	0.219	0.475	0.37	0.331
12	0.006	0.001	0.014	21.1	0.280	0.598	0.43	0.401
13	0.006	0.001	0.013	20.7	0.347	0.724	0.50	0.468
14	0.006	0.001	0.013	20.3	0.418	0.849	0.55	0.532
15	0.006	0.001	0.013	20.0	0.497	0.977	0.62	0.602
16	0.006	0.001	0.012	19.6	0.586	1.107	0.68	0.673
17	0.006	0.001	0.012	19.0	0.681	1.226	0.72	0.735
18	0.006	0.001	0.012	18.6	0.782	1.339	0.76	0.797
19	0.006	0.001	0.011	18.1	0.890	1.446	0.80	0.856
20	0.006	0.001	0.011	17.6	1.004	1.549	0.83	0.917
21	0.006	0.001	0.010	16.7	1.120	1.638	0.85	0.969
22	0.006	0.000	0.010	16.5	1.236	1.720	0.87	1.026

Table 7-13 Predicted operational water quality results at JZGS01

Parameter	EQS	DWS	Maximum measured baseline	Modelled JZGS01 in operations (assuming no fracture connection from high concentrations)	Modelled JZGS01 in operations (assuming potential fracture connection from high concentrations)
pH**	5.94 - 8.97	6.5 - 9.5	7.95	6.31	6.31
Ag			0.00035	0.0004	0.0004
Al		0.2	0.05	0.05	0.05
Alkalinity**			67.0	25.0	25.0
As	0.0097	0.01	0.0007	0.0008	0.0008
Ba		0.7	0.01	0.01	0.01
Ca			22.6	23.1	23.1
Cd	Variable*	0.003	0.0003	0.0003	0.0003
Cl			3.3	4.0	4.0
Co			0.001	0.001	0.001
Cr			0.008	0.008	0.008
Cu	0.1	2	0.009	0.009	0.009
F			0.2	0.2	0.2
Fe	4.22	0.2	0.115	0.118	0.118
Hg			0.00005	0.00005	0.00005
K			3.36	3.53	3.53
Mg			4.45	4.56	4.56
Mn	0.72	0.05	0.022	0.022	0.022
Mo	0.024		0.002	0.002	0.002
NH3-N	8.79	0.39	0.135	0.135	0.135
NO3-N			0.950	1.021	1.021
NO2-N			0.013	0.069	0.069
Na			8.81	9.66	9.66
Ni	0.02	0.02	0.006	0.006	0.006
P***	2.21		0.60	6.31	6.31
Pb	0.0072	0.01	0.009	0.009	0.009
SO4		250	30.7	31.9	31.9
Sb		0.005	0.0008	0.0008	0.0008
Se	0.00168	0.01	0.0008	0.0010	0.0010
Sr			0.085	0.087	0.087
U			0.0007	0.0007	0.0007
V			0.002	0.002	0.002
Zn	0.074		0.03	0.03	0.03
Hardness			75	76	76
***Hardness variable**					
** **Minimum values given for baseline rather than maximum**					

The predicted water quality at JZGS01, post pit lake spill (LOM year 67) is presented in Table 7-14. At the median flow proportions the pH is still neutral however by the 75th percentile flow conditions the pH has dropped to less than 6. Copper and iron are significant contaminants of concern, over DWS and EQS guidelines. At the higher pH of the median flow results most of the iron is precipitated as iron hydroxides, this also scavenges some other trace metals such as copper and arsenic, but may cause smothering of aquatic habitat.

Table 7-14 Predicted water quality results at JZGS01 in closure scenario

Parameter	Units	DWS		EQS		Max measured baseline	Median flow statistic			75th %ile flow statistic			95th %ile flow statistic			Max flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
pH**	pH	6.5	9.5	5.94	8.97	6.46	8.17	7.65	7.25	7.20	5.84	5.39	5.28	4.42	3.99	3.82	3.75	3.69
Ag	mg/l					0.00035	0.00039	0.00039	0.00040	0.00047	0.00049	0.00052	0.00066	0.00074	0.00081	0.00077	0.00087	0.00097
Al	mg/l		0.2			0.05	0.9	1.0	1.1	2.8	3.2	3.5	7.5	8.4	9.3	10.1	11.3	12.6
Alkalinity**	mg/l CaCO3					24	13.8	33.6	54.8	5.3	13.4	23.4	0.0	0.0	6.4	0	0	0
As	mg/l		0.01		0.0097	0.0007	0.00001	0.00003	0.00007	0.00006	0.00178	0.00437	0.01087	0.01196	0.01307	0.01562	0.01697	0.01823
Ba	mg/l		0.7			0.01	0.005	0.008	0.011	0.008	0.011	0.014	0.015	0.017	0.020	0.019	0.021	0.024
Ca	mg/l					22.6	10.7	20.7	31.1	24.2	34.2	44.5	56.6	66.6	76.7	74.8	84.8	94.8
Cd	mg/l		0.003		Variable*	0.0003	0.004	0.005	0.005	0.014	0.016	0.017	0.037	0.041	0.045	0.050	0.056	0.061
Cl	mg/l		250			3.3	1.6	2.2	3.3	1.8	2.4	3.3	2.3	2.7	3.2	2.5	2.8	3.2
Co	mg/l					0.001	0.009	0.010	0.011	0.027	0.031	0.034	0.071	0.080	0.089	0.095	0.108	0.120
Cr	mg/l		0.05		0.35	0.008	0.0009	0.0024	0.0049	0.0005	0.0010	0.0014	0.0036	0.0047	0.0060	0.0048	0.0055	0.0062
Cu	mg/l		2		0.1	0.009	1.6	1.8	2.0	5.5	6.8	8.2	18.1	20.5	22.7	24.7	27.7	30.7
F	mg/l		1.5			0.2	0.10	0.13	0.19	0.10	0.13	0.18	0.09	0.11	0.14	0.09	0.10	0.12
Fe	mg/l		0.2		4.22	0.115	0.000	0.000	0.000	0.199	3.675	7.432	24.769	28.603	32.568	37.203	41.826	46.386
Hg	mg/l		0.001		0.00007	0.00005	0.00005	0.00005	0.00005	0.00004	0.00004	0.00004	0.00003	0.00003	0.00003	0.00002	0.00002	0.00003
K	mg/l					3.36	1.74	2.49	3.26	1.72	2.37	3.03	1.67	2.07	2.48	1.65	1.90	2.17
Mg	mg/l					4.45	3.0	4.0	5.2	4.4	5.5	6.8	7.7	9.2	10.7	9.6	11.2	13.0
Mn	mg/l		0.05		0.72	0.022	0.08	0.10	0.11	0.24	0.28	0.33	0.62	0.73	0.84	0.84	0.98	1.12
Mo	mg/l				0.024	0.0015	0.002	0.002	0.003	0.004	0.004	0.005	0.008	0.009	0.011	0.011	0.012	0.014
NH3-N	mg/l		0.39		8.79	0.135	0.3	0.3	0.3	0.5	0.6	0.6	0.8	0.9	1.0	1.0	1.1	1.3
NO3-N	mg/l		11.29		5.05	0.215	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO2-N	mg/l		0.91			0.013	0.11	0.13	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	mg/l		200			8.81	5.14	6.53	8.20	4.31	5.45	6.81	2.32	2.84	3.45	1.20	1.38	1.56
Ni	mg/l		0.02		0.02	0.006	0.007	0.009	0.012	0.019	0.023	0.027	0.048	0.055	0.062	0.065	0.073	0.082
P	mg/l				1.68	0.6	1.4	1.5	1.5	0.5	0.7	0.9	1.4	1.6	1.8	2.0	2.1	2.3
Pb	mg/l		0.01		0.0072	0.009	0.002	0.003	0.004	0.001	0.003	0.004	0.007	0.009	0.011	0.009	0.010	0.011
SO4	mg/l					30.7	40.9	55.2	70.1	115.1	137.6	160.5	293.3	335.5	377.8	393.6	446.9	500.0
Sb	mg/l		0.005			0.0008	0.0006	0.0007	0.0008	0.0006	0.0007	0.0008	0.0007	0.0008	0.0009	0.0007	0.0008	0.0009
Se	mg/l		0.01		0.00168	0.0008	0.001	0.001	0.001	0.003	0.003	0.003	0.007	0.008	0.009	0.009	0.010	0.011
Sr	mg/l					0.085	0.046	0.063	0.082	0.043	0.058	0.074	0.036	0.045	0.055	0.033	0.038	0.044
U	mg/l		0.03			0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001
V	mg/l					0.002	0.000	0.000	0.001	0.003	0.003	0.003	0.004	0.005	0.005	0.005	0.006	0.006

Parameter	Units	DWS		EQS		Max measured baseline	Median flow statistic			75th %ile flow statistic			95th %ile flow statistic			Max flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Zn	mg/l				0.074	0.03	0.44	0.50	0.57	1.41	1.63	1.84	3.81	4.35	4.90	5.15	5.88	6.61
Hardness (calc)	mg/l					74.7	39.1	68.0	98.9	78.5	108.0	139.2	173.1	204.1	235.9	226.3	258.2	290.2
* Hardness variable																		
**Minimum values given for baseline rather than maximum																		

Predicted changes for Ilovica Reservoir (ILWT01)

The predicted water quality during operational phase for the inflow to the Ilovica reservoir is presented in Table 7-15. The predicted water quality pH is circum-neutral but as the oxide stockpile leachate does not contain sulphide material this was to be expected. The modelled water quality are above DWS for iron, but so are the maximum baseline concentrations recorded at this site, so this could be a function of the input data used within the model. The closure water quality predictions for the Ilovica Reservoir (ILWT01) are presented in Table 7-15. The median flow statistics predict water quality of neutral character but the 75th percentile flow scenario predicts that water will become more acidic. Cadmium is greater than DWS in all scenarios and sulphate, iron, copper, arsenic and zinc were also elevated above standards.

Table 7-15 Predicted water quality for the Ilovica reservoir (ILWT01) during operations

Parameter	EQS	DWS	Maximum measured baseline	Modelled ILWT01 (assuming no fracture connection from high concentrations)	Modelled ILWT01 (assuming potential fracture connection from high concentrations)
pH**	5.94 - 8.97	6.5 - 9.5	6.73	6.48	5.73
Ag			0.00035	0.0004	0.0007
Al		0.2	0.1	0.10	0.12
Alkalinity**			27	28	39
As	0.0097	0.01	0.006	0.006	0.007
Ba		0.7	0.018	0.021	0.050
Ca			16.2	16.7	21.6
Cd	Variable*	0.003	0.0003	0.0003	0.0004
Cl			4.82	5.50	12.86
Co			0.001	0.001	0.004
Cr			0.001	0.001	0.001
Cu	0.1	2	0.0045	0.0049	0.0095
F			0.2	0.21	0.32
Fe	4.22	0.2	3.5	3.50	3.54
Hg			0.00005	0.00005	0.00005
K			5.44	5.61	7.45
Mg			3.2	3.31	4.54
Mn	0.72	0.05	0.852	0.852	0.857
Mo	0.024		0.0015	0.0016	0.0022
NH3-N	8.79	0.388889	0.135	0.135	0.136
NO3-N			0.215	0.286	1.052
NO2-N			0.013	0.069	0.682
Na			6.38	7.23	16.43
Ni	0.02	0.02	0.0015	0.0016	0.0032
P***	2.21		6.73	6.48	5.73
Pb	0.0072	0.01	0.003	0.003	0.004
SO4		250	21.7	22.9	36.3
Sb		0.005	0.0006	0.0006	0.0009
Se	0.00168	0.01	0.0004	0.0006	0.0032
Sr			0.064	0.066	0.087
U			0.0002	0.0002	0.0002
V			0.002	0.002	0.003
Zn	0.074		0.009	0.014	0.064
Hardness			54	55	73

*** Hardness variable; **Minimum values given for baseline rather than maximum**

Table 7-16 Modelled water quality results for Ilovica Reservoir in closure post pit lake spill

Parameter	Units	DWS		EQS		Max measured baseline	Median flow statistic			75th %ile flow statistic			95th %ile flow statistic			Max flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
pH**	pH	6.5	9.5	5.94	8.97	7.11	8.19	7.73	7.37	7.48	5.94	5.47	5.37	4.50	4.04	3.82	3.75	3.69
Ag	mg/l					0.0004	0.0004	0.0004	0.0004	0.0005	0.0005	0.0005	0.0007	0.0007	0.0008	0.0008	0.0009	0.0010
Al	mg/l		0.2			0.08	0.79	0.88	0.97	2.56	2.87	3.17	7.19	8.08	8.95	10.08	11.33	12.55
Alkalinity**	mg/l CaCO3					43.5	15.0	34.9	56.2	5.9	14.8	27.8	0.0	1.1	8.1	0.0	0.0	0.0
As	mg/l		0.01		0.0097	0.00325	0.00001	0.00003	0.00006	0.00003	0.00142	0.00389	0.01037	0.01143	0.01248	0.01560	0.01695	0.01820
Ba	mg/l		0.7			0.015	0.005	0.008	0.011	0.007	0.010	0.013	0.014	0.017	0.020	0.019	0.021	0.024
Ca	mg/l					13.8	10.0	19.9	30.4	22.3	32.3	42.6	54.6	64.6	74.7	74.7	84.7	94.7
Cd	mg/l		0.003		Variable*	0.0003	0.0039	0.0044	0.0048	0.0127	0.0141	0.0155	0.0356	0.0396	0.0436	0.0499	0.0556	0.0611
Cl	mg/l		250			3.2	1.6	2.2	3.3	1.8	2.3	3.3	2.2	2.7	3.2	2.5	2.8	3.2
Co	mg/l					0.001	0.008	0.009	0.010	0.024	0.028	0.031	0.068	0.077	0.086	0.095	0.108	0.120
Cr	mg/l		0.05		0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Cu	mg/l		2		0.1	0.005	1.4	1.6	1.7	4.8	6.0	7.3	17.4	19.6	21.8	24.7	27.7	30.6
F	mg/l		1.5			0.15	0.10	0.13	0.19	0.10	0.13	0.18	0.09	0.11	0.14	0.09	0.10	0.12
Fe	mg/l		0.2		4.22	1.81	0.0	0.0	0.0	0.0	2.5	6.0	23.5	27.2	31.0	37.2	41.8	46.3
Hg	mg/l		0.001		0.00007	0.00005	0.00005	0.00005	0.00005	0.00004	0.00004	0.00004	0.00003	0.00003	0.00003	0.00002	0.00002	0.00003
K	mg/l					3.86	1.74	2.50	3.27	1.72	2.38	3.06	1.68	2.09	2.51	1.65	1.91	2.17
Mg	mg/l					2.75	2.93	3.90	5.08	4.19	5.29	6.57	7.49	8.95	10.50	9.55	11.23	12.95
Mn	mg/l		0.05		0.72	0.50	0.07	0.09	0.10	0.22	0.26	0.30	0.60	0.70	0.80	0.84	0.98	1.12
Mo	mg/l				0.024	0.002	0.002	0.002	0.002	0.004	0.004	0.005	0.008	0.009	0.010	0.011	0.012	0.014
NH3-N	mg/l		0.388889		8.79	0.14	0.24	0.27	0.29	0.52	0.55	0.59	0.82	0.91	1.00	1.00	1.13	1.26
NO3-N	mg/l		11.29032		5.05	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO2-N	mg/l		0.913043			0.01	0.14	0.15	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	mg/l		200			5.88	5.18	6.59	8.28	4.43	5.60	7.00	2.45	3.01	3.66	1.21	1.39	1.57
Ni	mg/l		0.02		0.02	0.002	0.006	0.008	0.012	0.017	0.021	0.025	0.046	0.053	0.060	0.065	0.073	0.082
P	mg/l				2.21	0.60	1.46	1.50	1.54	0.56	0.75	0.91	1.33	1.50	1.71	1.96	2.13	2.32
Pb	mg/l		0.01		0.0072	0.003	0.002	0.003	0.005	0.001	0.003	0.004	0.007	0.009	0.010	0.009	0.010	0.011
SO4	mg/l		250			19	37	51	65	105	126	148	282	323	364	393	446	499
Sb	mg/l		0.005			0.0006	0.0006	0.0007	0.0008	0.0006	0.0007	0.0008	0.0007	0.0008	0.0009	0.0007	0.0008	0.0009
Se	mg/l		0.01		0.00168	0.0004	0.0010	0.0012	0.0014	0.0023	0.0027	0.0031	0.0065	0.0074	0.0082	0.0090	0.0102	0.0113
Sr	mg/l					0.0555	0.0459	0.0631	0.0820	0.0434	0.0584	0.0748	0.0368	0.0460	0.0559	0.0326	0.0383	0.0442
U	mg/l		0.03			0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001
V	mg/l					0.002	0.000	0.000	0.000	0.002	0.003	0.003	0.004	0.005	0.005	0.005	0.006	0.006
Zn	mg/l				0.074	0.01	0.39	0.44	0.51	1.29	1.47	1.66	3.66	4.18	4.71	5.14	5.87	6.60

Parameter	Units	DWS		EQS		Max measured baseline	Median flow statistic			75th %ile flow statistic			95th %ile flow statistic			Max flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Hardness (calc)	mg/l					45.8	36.9	65.8	96.7	72.9	102.4	133.5	167.2	198.2	229.9	226.0	257.9	289.9
*** Hardness variable**																		
****Minimum values given for baseline rather than maximum**																		

Predicted changes to the Treska River

The Treska River has been assessed in a qualitative manner for the operational period. The oxide stockpile sits within the Treska catchment. No runoff is expected from the stockpile (see Section 6) however groundwater seepage is expected. The seepage has been modelled within section 6 and the contaminant transport module. The MT3D results are presented in Section 5. No surface water impact has been recorded for the Treska River using the MT3D results.

Predicted changes to the Jazga River at Radovo (JZGS03)

In construction and operation phases of mine life there are no direct discharges to surface water in the Jazga River. The volume and timescale of seepages from the oxide stockpile will not migrate lower than the Ilovica Reservoir. The only change in these periods will be a reduction in river flows. The pollution loading from the villages (sewage discharges and agricultural discharges) is assumed to remain the same as for baseline conditions. The lower flow rate acts as a lower diluting volume downsteam of the villages. An increase in pollutant concentration in the Jazga River downstream of Ilovica and Shtuka could occur, due to the lower dilution volume but the same pollutant load as baseline. The concentration of parameters like nitrogen and phosphorous may increase. The change is not modelled as the pollutant load from the villages cannot be assessed.

In closure, a lake will form in the empty pit void after a period of around 28 years. The lake will be of poor quality and will discharge into the Jazga River. Over a longer period of time it is likely that the effect of the pit lake discharge will travel downstream if no mitigation measures are in place. The water quality of the Jazga River at JZGS03 has been modelled (using predicted median flows and a proportional mixing method) and the results are presented in Table 7-17. The results show a slight increase above baseline conditions for some parameters, including copper and zinc, which are also slightly over project EQS guideline values although the magnitude of the concentrations is similar and the overall change to concentrations is relatively low.

Table 7-17 Predicted water quality changes for JZGS03 in closure conditions (post pit lake overflow)

Parameter	Units	DWS		EQS		Max. measured baseline	Median flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max
pH**	**pH**	6.5	9.5	5.94	8.97	6.94	8.00	6.91	6.50
Ag	**mg/l**					0.00035	0.00035	0.00036	0.00036
Al	**mg/l**		0.2			0.05	0.15	0.21	0.30
Alkalinity**	**mg/l CaCO3**					40	26.7	48.9	72.5
As	**mg/l**		0.01		0.0097	0.0007	0.00028	0.00093	0.00164
Ba	**mg/l**		0.7			0.039	0.007	0.012	0.016
Ca	**mg/l**					36.7	6.4	16.5	25.9
Cd	**mg/l**		0.003		Variable*	0.0003	0.0008	0.0008	0.0009
Cl	**mg/l**		250			18.9	1.5	4.6	7.6
Co	**mg/l**					0.001	0.002	0.002	0.002
Cr	**mg/l**		0.05		0.35	0.001	0.0006	0.0010	0.0014
Cu	**mg/l**		2		0.1	0.0045	0.16	0.19	0.22
F	**mg/l**		1.5			0.3	0.10	0.15	0.20
Fe	**mg/l**		0.2		4.22	0.26	0.0001	0.0008	0.0021
Hg	**mg/l**		0.001		0.00007	0.00005	0.00005	0.00005	0.00005
K	**mg/l**					4.95	3.26	3.91	4.57
Mg	**mg/l**					10.9	2.8	4.7	6.7
Mn	**mg/l**		0.05		0.72	0.196	0.04	0.14	0.27
Mo	**mg/l**				0.024	0.0015	0.0016	0.0016	0.0016
NH3-N	**mg/l**		0.39		8.79	0.42	0.0000	0.0000	0.0000
NO3-N	**mg/l**		11.3		5.05	4.81	0.36	1.78	3.03
NO2-N	**mg/l**		0.91			0.146	0.63	0.65	0.68

Parameter	Units	DWS		EQS		Max. measured baseline	Median flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max
Na	mg/l		200			19.4	7.15	9.50	12.30
Ni	mg/l		0.02		0.02	0.0015	0.0021	0.0024	0.0028
P	mg/l				1.68	0.6	2.1	2.2	2.2
Pb	mg/l		0.01		0.0072	0.003	0.0022	0.0025	0.0027
SO4	mg/l		250			34.6	15.3	21.6	27.1
Sb	mg/l		0.005			0.0008	0.0006	0.0007	0.0008
Se	mg/l		0.01		0.00168	0.0008	0.0005	0.0007	0.0009
Sr	mg/l					0.178	0.050	0.089	0.127
U	mg/l		0.03			0.00064	0.00001	0.00002	0.00003
V	mg/l					0.002	0.001	0.002	0.002
Zn	mg/l				0.074	0.02	0.06	0.07	0.07
Hardness (calc)	mg/l					136	37	66	97
* Hardness variable									
**Minimum values given for baseline rather than maximum									

Predicted changes to the Shtuka River at intake (STGS01)

The results for the construction phase water quality modelling at the Shtuka River intake (STGS01) are presented in Table 7-18. The key discharge upstream of the site is runoff from the TMF embankment made from waste rock. The effective change to the baseline conditions is very minor, as the runoff is short term and low in volume. The material exposed within the construction phase for TMF embankment construction is also mainly oxide or leach cap material, which has been naturally weathered and sulphides and metals leached from the material in situ.

Table 7-18 Predicted water quality in the construction phase at STGS01

Parameter	Units	DWS		EQS		Max measured baseline	Median flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max
pH**	pH	6.5	9.5	5.94	8.97	6.32	8.34	8.12	7.92
Ag	mg/l					0.00035	0.00035	0.00036	0.00036
Al	mg/l		0.2			0.05	0.06	0.09	0.14
Alkalinity**	mg/l CaCO3					35.00	26.8	48.3	68.8
As	mg/l		0.01		0.0097	0.0007	0.00045	0.00049	0.00054
Ba	mg/l		0.7			0.007	0.004	0.006	0.010
Ca	mg/l					30.50	9.5	17.8	26.7
Cd	mg/l		0.003		Variable*	0.0003	0.0003	0.0003	0.0003
Cl	mg/l		250			4.64	1.6	3.2	5.0
Co	mg/l					0.0010	0.001	0.001	0.001
Cr	mg/l		0.05		0.35	0.0010	0.0007	0.0009	0.0010
Cu	mg/l		2		0.1	0.005	0.001	0.002	0.003
F	mg/l		1.5			0.20	0.10	0.15	0.20
Fe	mg/l		0.2		4.22	0.12	0.0001	0.0001	0.0001
Hg	mg/l		0.001		0.00007	0.00	0.00005	0.00005	0.00005
K	mg/l					2.86	1.42	2.12	2.86
Mg	mg/l					7.21	3.1	4.9	7.1
Mn	mg/l		0.05		0.72	0.01	0.004	0.008	0.011
Mo	mg/l				0.024	0.00	0.002	0.002	0.002
NH3-N	mg/l		0.39		8.79	0.14	0.00	0.00	0.00
NO3-N	mg/l		11.3		5.05	4.90	0.52	1.95	4.45
NO2-N	mg/l		0.91			0.04	0.57	0.59	0.63
Na	mg/l		200			11.60	6.07	8.59	11.52
Ni	mg/l		0.02		0.02	0.002	0.001	0.001	0.002

Parameter	Units	DWS		EQS		Max measured baseline	Median flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max
P	mg/l				2.21	0.60	1.9	2.1	2.3
Pb	mg/l		0.01		0.0072	0.003	0.000	0.001	0.001
SO4	mg/l		250			29.30	16.9	22.5	29.2
Sb	mg/l		0.005			0.0008	0.0006	0.0007	0.0008
Se	mg/l		0.01		0.00168	0.0008	0.0004	0.0006	0.0008
Sr	mg/l					0.0940	0.046	0.069	0.093
U	mg/l		0.03			0.0030	0.00004	0.00008	0.00014
V	mg/l					0.0020	0.001	0.002	0.002
Zn	mg/l				0.074	0.08	0.01	0.04	0.09
Hardness (calc)	mg/l					106	36.7	64.7	96.0
* Hardness variable									
**Minimum values given for baseline rather than maximum									

Operational water quality was predicted for the Shtuka River intake (STGS01) by assessing the volume and chemistry of groundwater entering the surface water body between the TMF and the receptor indicator location. There will be no direct discharges to surface water in the Shtuka River during operations as the TMF runoff will be captured and reused. There will be a seepage discharge to groundwater and the connection between surface water and groundwater indicates that some of the effected groundwater may change the surface water quality downstream. The flow rate and sulphate concentration moving from the groundwater to surface water is presented in Table 7-19. The highest concentration of sulphate entering the stream is found in year 21, which is also one of the highest flow rates into the stream. The volume and concentration for year 21 of operations was used to predict the worst case scenario for the water quality at the Shtuka River intake (STGS01) during operations. The predicted water quality results for STGS01 in operations are presented in Table 7-20. The pH of the water is lowered due to the slightly acidic seepage from the TMF. The concentration of some metals such as iron, copper and zinc is also elevated above baseline and some DWS and EQS standards. Sulphate concentrations are predicted to be double baseline conditions.

Table 7-19 Volume and concentration of groundwater seepage to Shtuka surface water between TMF and STGS01 during operations

LOM year	GW seepage to streams (m3/s)				SO4 concentrations in groundwater at nodes (mg/l)			
	STGS01 to S Upstream 1	S Upstream 1 to S Upstream 2	S Upstream 2 to S Upstream 3	Total (m3/s)	STGS01	STGS01_upstream1	STGS01_upstream2	STGS01_upstream3
BASE LINE	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
-1	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
1	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
2	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
3	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
4	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
5	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
6	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
7	0.022	0.006	0.009	0.037	0.000	0.000	0.000	0.000
8	0.022	0.006	0.014	0.042	0.000	0.000	0.000	0.000
9	0.022	0.006	0.015	0.043	0.000	0.000	0.000	0.000
10	0.022	0.006	0.015	0.043	0.000	0.000	0.000	0.018
11	0.022	0.006	0.015	0.043	0.000	0.000	0.000	0.297
12	0.022	0.006	0.015	0.043	0.000	0.000	0.000	1.767
13	0.022	0.006	0.014	0.043	0.000	0.000	0.000	6.159
14	0.022	0.006	0.014	0.042	0.000	0.000	0.000	14.936
15	0.022	0.006	0.014	0.042	0.000	0.000	0.000	27.711

LOM year	GW seepage to streams (m3/s)				SO4 concentrations in groundwater at nodes (mg/l)			
	STGS01 to S Upstream 1	S Upstream 1 to S Upstream 2	S Upstream 2 to S Upstream 3	Total (m3/s)	STGS01	STGS01_upstream1	STGS01_upstream2	STGS01_upstream3
16	0.022	0.006	0.014	0.042	0.000	0.000	0.000	42.192
17	0.022	0.006	0.014	0.042	0.000	0.000	0.003	56.063
18	0.022	0.006	0.013	0.041	0.000	0.000	0.019	68.043
19	0.022	0.007	0.051	0.080	0.000	0.000	0.102	89.712
20	0.022	0.007	0.048	0.077	0.000	0.000	0.411	101.619
21	0.022	0.006	0.044	0.072	0.000	0.000	1.318	106.748

Table 7-20 Predicted operational water quality at STGS01 for LOM year 21

		DWS		EQS			
Parameter	Units	Lower	Upper	Lower	Upper	Baseline	Predicted operational water quality at STGS01
pH**	pH	6.5	9.5	5.94	8.97	6.32	5.21
Ag	mg/l					0.00035	0.00039
Al	mg/l		0.2			0.05	0.28
Alkalinity**	mg/l CaCO3					35	43
As	mg/l		0.01		0.0097	0.0007	0.0015
Ba	mg/l		0.7			0.007	0.013
Ca	mg/l					30.5	38.8
Cd	mg/l		0.003		Variable*	0.0003	0.0017
Cl	mg/l		250			4.64	5.26
Co	mg/l					0.001	0.002
Cr	mg/l		0.05		0.35	0.001	0.001
Cu	mg/l		2		0.1	0.0045	0.28
F	mg/l		1.5			0.2	0.2
Fe	mg/l		0.2		4.22	0.115	0.888
Hg	mg/l		0.001		0.00007	0.00005	0.00005
K	mg/l					2.86	5.41
Mg	mg/l					7.21	8.45
Mn	mg/l		0.05		0.72	0.011	0.018
Mo	mg/l				0.024	0.0015	0.0068
NH3-N	mg/l		0.4		8.79	0.14	0.16
NO3-N	mg/l		11.3		5.05	1.11	1.11
NO2-N	mg/l		0.9			0.01	0.02
Na	mg/l		200			11.6	16.8
Ni	mg/l		0.02		0.02	0.0015	0.0024
P	mg/l				2.21	0.06	0.11
Pb	mg/l		0.01		0.007	0.003	0.003
SO4	mg/l		250			29.3	61.9
Sb	mg/l		0.005			0.0008	0.0010
Se	mg/l		0.01		0.002	0.0008	0.0012
Sr	mg/l					0.094	0.115
U	mg/l		0.03			0.003	0.003
V	mg/l					0.002	0.002
Zn	mg/l				0.074	0.084	0.168
CN-WAD***	mg/l		0.05		0.015	0.0075	0.0098

		DWS		EQS			
Parameter	Units	Lower	Upper	Lower	Upper	Baseline	Predicted operational water quality at STGS01
* Hardness variable							
**Minimum values given for baseline rather than maximum							
*** Standard for Total CN not WAD CN							

The water quality for closure conditions was assessed in the same manner as for operations. It is assumed no direct discharges of poor quality water will enter the River Shtuka as the TMF and embankment design includes a cover in closure. Seepage will continue to discharge to groundwater in closure. The rate is assumed to stay the same for 10 years and then decrease. The chemistry of the seepage is assumed to be the same as predicted in LOM year 21. The peak concentrations predicted in closure were in LOM year 23 and 24 and the predicted water quality of this peak at STGS01 is presented in Table 7-21. The water quality in closure is predicted to have a lower pH than baseline as continued seepage from the TMF embankment will be acidic in nature. The iron, copper, zinc and cadmium concentrations are elevated over baseline conditions and some DWS and EQS guideline values. Sulphate is more than double the baseline concentration.

Table 7-21 Predicted water quality results for STGS01 in closure

		DWS		EQS			
Parameter	Units	Lower	Upper	Lower	Upper	Max. Measured Baseline	Predicted closure water quality at STGS01
pH**	pH	6.5	9.5	5.94	8.97	6.32	4.81
Ag	mg/l					0.00035	0.0004
Al	mg/l		0.2			0.05	0.51
Alkalinity**	mg/l CaCO3					35	48.83
As	mg/l		0.01		0.0097	0.0007	0.002
Ba	mg/l		0.7			0.007	0.02
Ca	mg/l					30.5	45.77
Cd	mg/l		0.003		Variable*	0.0003	0.0031
Cl	mg/l		250			4.64	5.80
Co	mg/l					0.001	0.004
Cr	mg/l		0.05		0.35	0.001	0.001
Cu	mg/l		2		0.1	0.0045	0.58
F	mg/l		1.5			0.2	0.21
Fe	mg/l		0.2		4.22	0.115	1.67
Hg	mg/l		0.001		0.00007	0.00005	0.00005
K	mg/l					2.86	7.49
Mg	mg/l					7.21	9.48
Mn	mg/l		0.05		0.72	0.011	0.03
Mo	mg/l				0.024	0.0015	0.01
NH3-N	mg/l		0.4		8.79	0.14	0.19
NO3-N	mg/l		11.3		5.05	1.11	1.11
NO2-N	mg/l		0.9			0.01	0.02
Na	mg/l		200			11.6	21.08
Ni	mg/l		0.02		0.02	0.0015	0.0034
P	mg/l				2.21	0.06	0.15
Pb	mg/l		0.01		0.007	0.003	0.003
SO4	mg/l		250			29.3	89.9
Sb	mg/l		0.005			0.0008	0.0012
Se	mg/l		0.01		0.002	0.0008	0.0015
Sr	mg/l					0.094	0.13

		DWS		EQS			
Parameter	**Units**	**Lower**	**Upper**	**Lower**	**Upper**	**Max. Measured Baseline**	**Predicted closure water quality at STGS01**
U	mg/l		0.03			0.003	0.003
V	mg/l					0.002	0.003
Zn	mg/l				0.074	0.084	0.26
CN-WAD* **	mg/l		0.05		0.015	0.0075	0.012
*** Hardness variable**							
****Minimum values given for baseline rather than maximum**							
***** Standard for Total CN not WAD CN**							

Predicted changes to the Shtuka River at Sekirnik Road Bridge (STGS02)

The results of the worst case operational water quality models for the receptor indicator location STGS02 are presented in Table 7-22, corresponding to LOM year 21. The model used an approach where mass was conserved between STGS01 and STGS02 but water volume was potentially lost. The water quality shows a depressed pH and elevated metals such as copper, iron and zinc as well as elevated sulphate above baseline conditions. The closure water quality model predicts the peak concentration flowing into the surface water (as described for STGS01) and the STGS02 results are presented in Table 7-23. Again, the water quality model predicts low pH and elevated metals including copper, iron, zinc and cadmium. Sulphate is also elevated above baseline conditions. Some EQS and DWS are exceeded for the STGS02 location.

Table 7-22 Predicted operational water quality at STGS02 in LOM year 21

		DWS		EQS			
Parameter	**Units**	**Lower**	**Upper**	**Lower**	**Upper**	**Baseline**	**Predicted operational water quality at STGS02**
pH**	pH	6.5	9.5	5.94	8.97	6.28	5.21
Ag	mg/l					0.00035	0.0004
Al	mg/l		0.2			0.05	0.28
Alkalinity**	mg/l CaCO3					31	38.65
As	mg/l		0.01		0.0097	0.0007	0.0015
Ba	mg/l		0.7			0.027	0.03
Ca	mg/l					31.4	39.69
Cd	mg/l		0.003		Variable*	0.0003	0.0017
Cl	mg/l		250			7.43	8.05
Co	mg/l					0.001	0.002
Cr	mg/l		0.05		0.35	0.001	0.001
Cu	mg/l		2		0.1	0.0045	0.2797
F	mg/l		1.5			0.2	0.2
Fe	mg/l		0.2		4.22	0.115	0.888
Hg	mg/l		0.001		0.00007	0.00005	0.00005
K	mg/l					2.3	4.9
Mg	mg/l					7.29	8.53
Mn	mg/l		0.05		0.72	0.0180	0.0252
Mo	mg/l				0.024	0.0015	0.0068
NH3-N	mg/l		0.4		8.79	0.135	0.163
NO3-N	mg/l		11.3		5.05	6.84	6.84
NO2-N	mg/l		0.9			0.067	0.071
Na	mg/l		200			9.79	15.02
Ni	mg/l		0.02		0.02	0.0015	0.0024

		DWS		EQS			
Parameter	Units	Lower	Upper	Lower	Upper	Baseline	Predicted operational water quality at STGS02
P	mg/l				2.21	0.14	0.19
Pb	mg/l		0.01		0.007	0.003	0.003
SO4	mg/l		250			29.7	62.31
Sb	mg/l		0.005			0.0008	0.0010
Se	mg/l		0.01		0.002	0.0008	0.0012
Sr	mg/l					0.141	0.16
U	mg/l		0.03			0.0007	0.0008
V	mg/l					0.002	0.002
Zn	mg/l				0.074	0.009	0.093
CN-WAD***	mg/l		0.05		0.015	0.005	0.007
* Hardness variable							
**Minimum values given for baseline rather than maximum							
*** Standard for Total CN not WAD CN							

Table 7-23 Predicted water quality results in closure for STGS02

		DWS		EQS			
Parameter	Units	Lower	Upper	Lower	Upper	Max. Measured Baseline	Predicted closure water quality at STGS02
pH**	pH	6.5	9.5	5.94	8.97	6.28	4.81
Ag	mg/l					0.00035	0.0004
Al	mg/l		0.2			0.05	0.51
Alkalinity**	mg/l CaCO3					31	44.83
As	mg/l		0.01		0.0097	0.0007	0.002
Ba	mg/l		0.7			0.027	0.04
Ca	mg/l					31.4	46.67
Cd	mg/l		0.003		Variable*	0.0003	0.0031
Cl	mg/l		250			7.43	8.59
Co	mg/l					0.001	0.004
Cr	mg/l		0.05		0.35	0.001	0.001
Cu	mg/l		2		0.1	0.0045	0.58
F	mg/l		1.5			0.2	0.21
Fe	mg/l		0.2		4.22	0.115	1.67
Hg	mg/l		0.001		0.00007	0.00005	0.00005
K	mg/l					2.3	6.93
Mg	mg/l					7.29	9.56
Mn	mg/l		0.05		0.72	0.0180	0.03
Mo	mg/l				0.024	0.0015	0.01
NH3-N	mg/l		0.4		8.79	0.135	0.19
NO3-N	mg/l		11.3		5.05	6.84477	6.85
NO2-N	mg/l		0.9			0.067	0.07
Na	mg/l		200			9.79	19.27
Ni	mg/l		0.02		0.02	0.0015	0.0034
P	mg/l				2.21	0.14	0.23
Pb	mg/l		0.01		0.007	0.003	0.003
SO4	mg/l		250			29.7	90.3
Sb	mg/l		0.005			0.0008	0.0012
Se	mg/l		0.01		0.002	0.0008	0.0015
Sr	mg/l					0.141	0.18

		DWS		EQS			
Parameter	**Units**	**Lower**	**Upper**	**Lower**	**Upper**	**Max. Measured Baseline**	**Predicted closure water quality at STGS02**
U	mg/l		0.03			0.0007	0.001
V	mg/l					0.002	0.003
Zn	mg/l				0.074	0.009	0.18
CN-WAD* **	mg/l		0.05		0.015	0.005	0.009
*** Hardness variable**							
****Minimum values given for baseline rather than maximum**							
***** Standard for Total CN not WAD CN**							

Predicted changes to water quality for the Suchica stream (SUGS01)

The Suchica stream (SUGS01) is considered a receptor in the ESIA due to stakeholder concerns and as groundwater modelling has identified that mounding of groundwater levels is plausible at the upstream margins and along the Shtuka valley sides adjacent to the proposed TMF and upstream of the TMF embankment.

This effect may cause groundwater to spill at the margins of the TMF and require drainage management. Another potential effect from groundwater level mounding is possible cross flow from the Shtuka catchment into the Suchica catchment though in reality the risk of this scenario arising is considered very low. Should this very unlikely possibility arise then it only becomes problematic to the receiving Suchica stream should these cross flows from the Shtuka catchment also be contaminated by the TMF seepages.

Predicted changes to water quality for the Turija River (TJGS01)

In construction and operation phases of mine life there are no direct discharges to surface water in the Jazga River and subsequently flows into the Turija River will not be directly affected. The volume and timescale of seepages from the oxide stockpile will not migrate lower than the Ilovica Reservoir. The only change in these periods will be a reduction in river flows. The pollution loading from the villages (sewage discharges and agricultural discharges) is assumed to remain the same as for baseline conditions. The lower flow rate acts as a lower diluting volume downsteam of the villages. An increase in pollutant concentration in the Jazga River downstream of Ilovica and Shtuka could occur, due to the lower dilution volume but the same pollutant load as baseline, could also affect the Turija River where the Jazga River joins. The concentration of parameters like nitrogen and phosphorous may increase. The change is not modelled as the pollutant load from the villages cannot be assessed.

In closure a pit lake will form and discharge to the Jazga River after 28 years. The pit lake spill migration has been modelled into the Turija River. The water quality predicted in closure is presented in Table 7-24. The predicted water quality is very similar to baseline conditions as the pit lake spill has been diluted by the surface water flow within the Turija River.

Table 7-24 Predicted water quality changes for TJGS01 in closure conditions following a pit lake spill

Parameter	Units	DWS		EQS		Max. measured baseline	Median flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max
pH**	pH	6.5	9.5	5.94	8.97	6.31	7.35	6.67	6.31
Ag	mg/l					0.00035	0.00035	0.00035	0.00035
Al	mg/l		0.2			0.05	0.06	0.07	0.08
Alkalinity**	mg/l CaCO3					40	31.1	58.3	84.7
As	mg/l		0.01		0.0097	0.0007	0.00048	0.00062	0.00075
Ba	mg/l		0.7			0.04	0.021	0.029	0.038
Ca	mg/l					35.6	7.8	19.1	33.4
Cd	mg/l		0.003		Variable*	0.0003	0.00034	0.00035	0.00036
Cl	mg/l		250			157	6	60	142
Co	mg/l					0.001	0.001	0.001	0.001
Cr	mg/l		0.05		0.35	0.002	0.0001	0.0005	0.0007
Cu	mg/l		2		0.1	0.0045	0.003	0.01	0.02
F	mg/l		1.5			0.3	0.10	0.21	0.29
Fe	mg/l		0.2		4.22	0.66	0.00032	0.00142	0.00315
Hg	mg/l		0.001		0.0001	0.00005	0.00005	0.00005	0.00005
K	mg/l					5.64	2.2	3.8	5.5
Mg	mg/l					9.99	4.7	7.5	9.7
Mn	mg/l		0.05		0.72	0.256	0.034321	0.1	0.3
Mo	mg/l				0.024	0.003	0.0015	0.0020	0.0029
NH3-N	mg/l		0.39		8.79	0.75	0.000	0.005	0.046
NO3-N	mg/l		11.29		5.05	2.60	0.002	0.290	0.617
NO2-N	mg/l		0.91			0.147	0.38	1.54	2.90
Na	mg/l		200			102	7.5	42.9	93.1
Ni	mg/l		0.02		0.02	0.015	0.001	0.006	0.014
P	mg/l				1.68	0.6	2.23	2.28	2.31
Pb	mg/l		0.01		0.0072	0.003	0.000	0.002	0.003
SO4	mg/l		250			33.4	15.7	24.3	32.8
Sb	mg/l		0.005			0.0008	0.0006	0.0007	0.0008
Se	mg/l		0.01		0.00168	0.0008	0.0004	0.0006	0.0008
Sr	mg/l					0.189	0.072	0.131	0.183
U	mg/l		0.03			0.000983	0.00001	0.00003	0.00004
V	mg/l					0.002	0.002	0.002	0.002
Zn	mg/l				0.074	0.009	0.013	0.014	0.015
Hardness (calc)	mg/l					130	39	78	123
* Hardness variable									
**Minimum values given for baseline rather than maximum									

Predicted changes to water quality for the Strumica River at SMGS02

In construction and operation phases of mine life there are no direct discharges to surface water in the Jazga River and subsequently flows into the Strumica River will not be directly affected. The volume and timescale of seepages from the oxide stockpile will not migrate lower than the Ilovica Reservoir. The only change in these periods will be a reduction in river flows. The pollution loading from the villages (sewage discharges and agricultural discharges) is assumed to remain the same as for baseline conditions. The lower flow rate acts as a lower diluting volume

downstream of the villages. An increase in pollutant concentration in the Jazga River downstream of Ilovica and Shtuka could occur, due to the lower dilution volume but the same pollutant load as baseline, could also affect the Strumica River where the Turija River joins. The concentration of parameters like nitrogen and phosphorous may increase. The change is not modelled as the pollutant load from the villages cannot be assessed.

In closure a pit lake will form and discharge to the Jazga River after 28 years. The pit lake spill migration has been modelled into the Strumica River. The water quality predicted in closure is presented in Table 7-25. The predicted water quality is very similar to baseline conditions as the pit lake spill has been diluted by the surface water flow within the Strumica River.

Table 7-25 Predicted water quality in the Strumica River (SMGS02) in closure (post pit lake overflow)

Parameter	Units	DWS		EQS		Max. measured baseline	Median flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max
pH**	pH	6.5	9.5	5.94	8.97	6.77	7.49	6.99	6.68
Ag	mg/l					0.00035	0.00035	0.00035	0.00035
Al	mg/l		0.2			0.05	0.06	0.06	0.06
Alkalinity**	mg/l CaCO3					86	67.1	100.6	128.6
As	mg/l		0.01		0.0097	0.0025	0.00050	0.00138	0.00238
Ba	mg/l		0.7			0.055	0.033	0.043	0.053
Ca	mg/l					57.7	20.9	30.5	38.6
Cd	mg/l		0.003		Variable*	0.0006	0.0003	0.0004	0.0006
Cl	mg/l		250			20.1	7.6	14.0	19.5
Co	mg/l					0.001	0.001	0.001	0.001
Cr	mg/l		0.05		0.35	0.001	0.0006	0.0006	0.0006
Cu	mg/l		2		0.1	0.0045	0.008	0.010	0.013
F	mg/l		1.5			0.3	0.10	0.20	0.30
Fe	mg/l		0.2		4.22	0.115	0.0002	0.0007	0.0014
Hg	mg/l		0.001		0.00007	0.00005	0.00005	0.00005	0.00005
K	mg/l					5.18	2.50	3.84	5.15
Mg	mg/l					14.2	7.4	10.8	13.8
Mn	mg/l		0.05		0.72	0.117	0.04	0.09	0.12
Mo	mg/l				0.024	0.139	0.0016	0.0513	0.1322
NH3-N	mg/l		0.39		8.79	0.135	0.0000	0.0000	0.0000
NO3-N	mg/l		11.29032		5.05129	8.3	0.76	1.20	1.58
NO2-N	mg/l		0.913043			0.078	0.56	0.59	0.62
Na	mg/l		200			21.8	9.82	16.09	21.36
Ni	mg/l		0.02		0.02	0.0015	0.0015	0.0015	0.0016
P	mg/l				2.21	0.6	2.0	2.0	2.0
Pb	mg/l		0.01		0.0072	0.003	0.0016	0.0020	0.0023
SO4	mg/l		250			40.2	23.1	31.7	39.9
Sb	mg/l		0.005			0.0008	0.0006	0.0007	0.0008
Se	mg/l		0.01		0.00168	0.0008	0.0004	0.0006	0.0008
Sr	mg/l					0.348	0.175	0.266	0.337
U	mg/l		0.03			0.00298	0.00006	0.00009	0.00013
V	mg/l					0.002	0.002	0.002	0.002
Zn	mg/l				0.074	0.009	0.01	0.01	0.01
Hardness (calc)	mg/l					202.47	82.8	120.6	153.4

Parameter	Units	DWS		EQS		Max. measured baseline	Median flow statistic		
		Lower	Upper	Lower	Upper		Min	Mean	Max
* Hardness variable									
**Minimum values given for baseline rather than maximum									

Predicted changes to water quality for the Strumica River at Novo Selo gauge (SMGS03)

The changes in the Strumica River at the upstream gauging point (SMGS02) predict very little variation from baseline conditions after modelling for changes due to the Ilovica mining project. The gauging station at Novo Selo is another few kilometres downstream and has at least one main surface water (the Vodochnica River) entering the Strumica River in this reach and thus the proportion of Jazga or Shtuka River flow is <1% of the total flow. The effect from mining surface water discharges by this receptor location will be minimal and the receptor location has only been assessed qualitatively. The surface water at this location will not see any effect from the mining project.

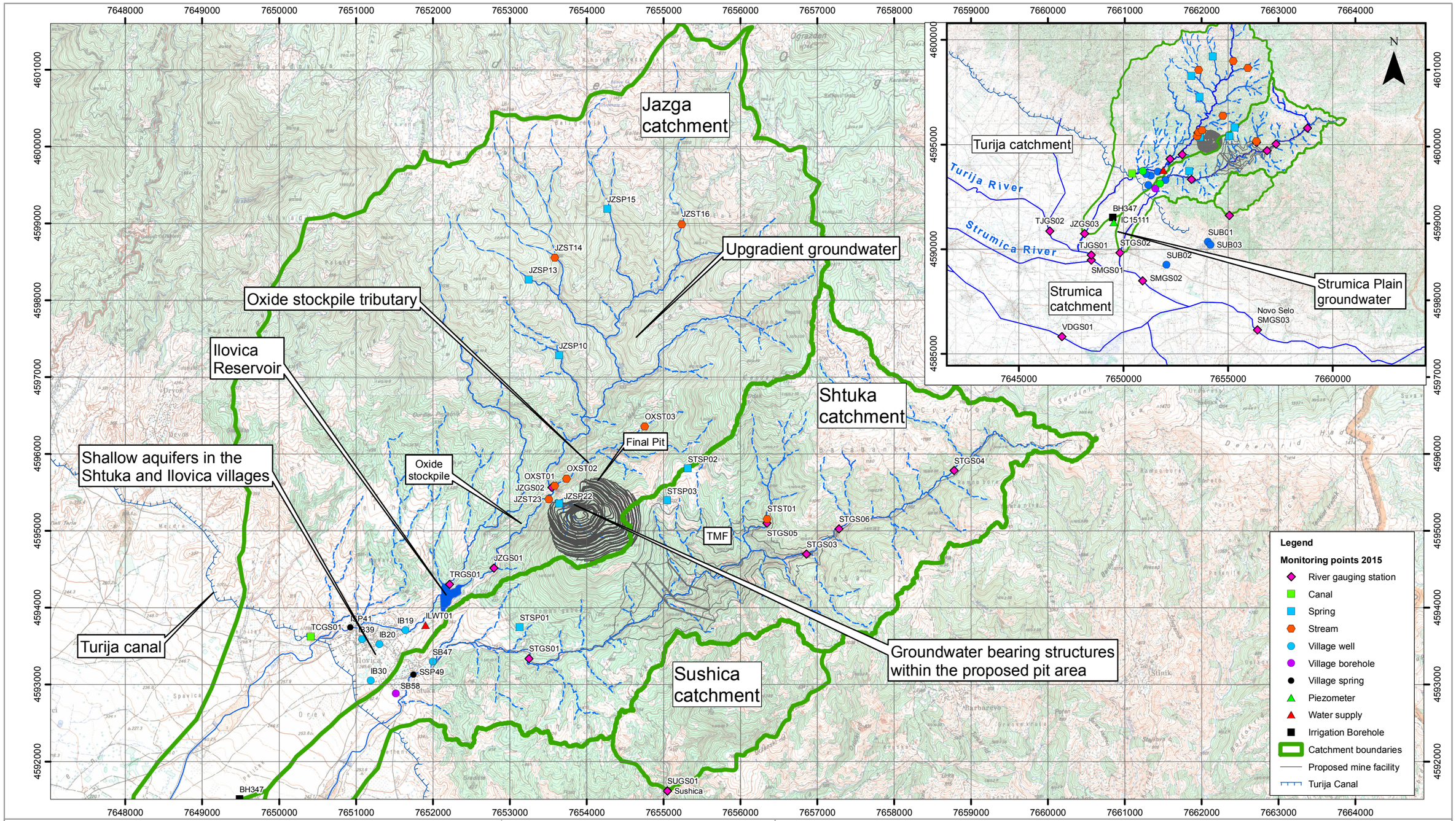
Predicted changes to groundwater quality at community water supplies in Ilovica and Shtuka and at irrigation wells between Ilovica and Turnovo

The groundwater quality was modelled using a contaminant transport model, the results of which are initially discussed in Section 5.9. The plume from seepage from the oxide stockpile and from the TMF tends to discharge from the groundwater into the surface water environment, as discussed above. The predicted contaminant plume is presented in Figures 5.12 and 5.13 at several time points using a minimum concentration cut-off of 1 mg/l sulphate. Only a low impact is seen in the groundwater downgradient of mine facilities during construction and operation periods. In closure (50 years post-closure) the contaminant plume does not reach the villages. The peak of the plume is seen in LOM year 37. The seepage from the TMF is diluted by recharge and groundwater flow from upgradient and the plume starts to decrease in concentration after the LOM year 50. This is seen in the Figure 5.13 as the high concentrations in the centre of the TMF start to decrease by LOM year 50. Overall no impact on groundwater is predicted from the mining project at the receptor locations in the villages and downstream on the Strumica plain.

7.5.3 Linked considerations

The results described in this section will be used in further ESIA chapters which include:

- Social considerations, results will be used to assess the impact on variations in water quality has on the local population in terms of water supply and environmental aesthetics.
- Ecological considerations, results will be used to assess the impact from water quality variations in surface water for aquatic habitat suitability.



Schlumberger Water Services

Mine layout and hydro(geo)logical features and receptors'

PROJECT:	Euromax Resources (Macedonia) UK Ltd.		FIGURE #: A7.1
CLIENT:	Ilovica Gold-Copper Project		PROJECT #: 55459/R1v2
DRAWN: DH	CHECKED: PB		DATE: January 2016

Document Path: P:\55459_Euromax_MKD_Ilovitza_Project_EIS_ESIA\500_Processed\510_Figures\55459R1_ESIA_Annex5\Section_7\Figure_A7-1.mxd

8 FLOOD RISK MODELLING AND ASSESSMENTS

The approach used for assessing changes to flood risk related to the proposed mine scheme draws upon modelling methods very similar to those undertaken for the Annex 3. For predictive analysis the parameterization of model inputs is varied, relative to the baseline condition, to reflect the changes in hydrological response anticipated as a result of the mine scheme. Essentially, the modelling approach entails:

- Prediction of design flood flows using the hydrological modelling package HEC-HMS.
- Translation of the estimated peak design flood flow to predicted design flood levels using the hydraulic modelling package HEC-RAS.

Predictions are undertaken at various stages of mine development (construction, operations, closure & post closure). The 100 year design flood was selected as the basis for undertaking all assessments. For long term, post closure, conditions an additional predictive run was undertaken to reflect the possible combined effect of Climate Change which is predicted to increase future rainfall depths under extreme storm conditions.

8.1 Key receptors to be assessed

The key receptors to be assessed for flood risk are set out in Section 7.5 of the main ESIA report and include:

1. The Jazga River through Ilovica village.
2. The Shtuka River through Shtuka village.
3. The Shtuka River at Sekirnik road bridge.

8.2 Synopsis of baseline regime

8.2.1 River Jazga through Ilovica

The design flood for the Jazga River through Ilovica was determined by modelling the design flood inflow to Ilovica Reservoir and routing this through the reservoir to determine the peak outflow from the reservoir. Since Ilovica village is a very short distance downstream of the reservoir and with no other significant tributary inflows between the reservoir and the village, the peak outflow of 19.8 m^3/s was adopted as the design flood through Ilovica for the hydraulic modelling.

HEC-RAS was used in steady state mode to model levels through Ilovica for the 100 year flood flow. The model conservatively assumed Manning's roughness values (n) of 0.12 and 0.2 for the main channel and flood plain respectively[2]. Modelled results at the three single span road bridges in Ilovica indicate design flood levels are below bridge soffit of the respective road decks which span the river. Moreover, modelled levels for the 100 year flood are generally well within river channel confines along much of its reach within Ilovica though a few spots, in none sensitive locations, do occur where near bank full conditions are predicted. This indicates that the baseline risk of fluvial flooding is very low in Ilovica. The only circumstances under which actual fluvial flooding to Ilovica can be conceived include:

- Fluvial flood events with very extreme return periods.
- A major dam burst at Ilovica Reservoir.
- A significant fluvial flood flow coinciding with a major channel impediment such as blockage of bridges by vegetation debris.

[2] In accordance with tabulated values given in Chow (Chow, Ven Te, Open Channel Hydraulics, McGraw-Hill, 1959)

8.2.2 River Shtuka through Shtuka

The design flood for the Shtuka River through Shtuka was modelled as the design flood flow to gauge SGS01. Since Shtuka village is only a short distance downstream of this gauge and with no other significant tributary inflows between the gauge and the village, the peak outflow of 5.35 m^3/s was adopted as the design flood through Shtuka for the hydraulic modelling. It is highlighted that the design flood flow for the Shtuka is ~¼ of that for the Jazga through Ilovica.

HEC-RAS was used in steady state mode to model levels through Shtuka for the 100 year flood flow. The model conservatively assumed Manning's roughness values (n) of 0.15 and 0.2 for the majority of the main channel and flood plain respectively. In the vicinity of the village square the (n) value for the main channel was increased to 0.2 to reflect a series of 'coarse' drop structures constructed using very large boulders. The downstream boundary to the flood model was taken as the top of the existing ford crossing of the river downstream of the village. Modelled results at the single span road bridge in Shtuka (adjacent to the village square) indicate a design flood level marginally below bridge soffit of the respective road deck which spans the river. Moreover, modelled levels for the 100 year flood are generally within river channel confines along much of its reach within Shtuka. There are some exceptions to this including the ford crossing of the river just upstream of the village square. Here, some spillage onto the street, leading to the village square, is predicted and it is thought this may give minor flood water conveyance downstream and return to the river in the vicinity of the small single span bridge adjacent to the village square. This, and anecdotal evidence, indicates that the baseline risk of minor and inconsequential scale fluvial flooding here is quite high with return periods down to a few years. The only circumstances under which actual and significant scale fluvial flooding to Shtuka can be conceived include:

- Fluvial flood events with high return periods (>100 year).
- A significant fluvial flood flow coinciding with a major channel impediment such as blockage of bridges by vegetation debris.

8.2.3 River Shtuka at the Turnovo-Sekirnik road

The design flood for the Shtuka River at Sekirnik road bridge was modelled as the flow to gauge SGS02 and the peak design flood flow equates to 5.6 m^3/s. It is highlighted that the design flood flow for the lower Shtuka is ~¼ of that for the Jazga through Ilovica and the very subdued flood flow response from the mid and lower reaches of the Shtuka are noted.

HEC-RAS was used in steady state mode to model levels in the vicinity of the Sekirnik road crossing for the 100 year flood flow. The model conservatively assumed Manning's roughness values (n) of 0.035, 0.15 and 0.2 for the central main channel (generally clear), channel embankments (very overgrown) and flood plain respectively. The Sekirnik road crossing comprises a double culvert including rectangular box and circular types and for these, constructed in rough concrete, a Manning's roughness value (n) of 0.02 was assumed.

Modelled results at the road crossing indicate a design flood level marginally below bridge soffit for the larger rectangular box culvert which extends to form the underside of the overlying road deck. At present, the only circumstances under which actual and significant fluvial flooding at the Sekirnik road crossing is likely to arise include:

- Fluvial flood events with high return periods (>100 year).
- A significant fluvial flood flow coinciding with a major impediment of the bridge culvert such as blockage by vegetation debris. Given the relatively small aperture of the culverts and the highly vegetated state of the lower Shtuka River channel this scenario is quite plausible.

8.3 Synopsis of key project source terms

The main mine project proposals which may significantly influence flood flow response at the receptors referred to are summarised in Table 8-1.

Table 8-1 Key aspects of mine proposals which may significantly affect flood flows at receptors

River	Receptor	Aspects of project expected to significantly affect flood response by phase		
		Construction	Operations	Closure
Jazga	**Ilovica village**	Stripping preparations for mine pit, stockpile, ROM pad & plant areas. **Modest increase to response**	Mine water management from mine facilities giving zero discharge to river up to 100 year storm events. **Modest decrease to response**	Modest increase to catchment (mainly the mine pit extension into the Shtuka catchment) and positive contribution once the pit lake has filled. **Modest increase to response**
Shtuka	**Shtuka village** **Sekirnik road bridge**	Stripping preparations for TMF embankment & starter area for tails deposition. **Modest increase to response**	TMF water management giving zero discharge to river up to PMP from the TMF tails area and inflowing tributary catchments. TMF embankment water management to give zero discharge to river up to 100 year storm events. **Modest decrease to response**	The restored TMF (including the TMF embankment) footprint will return storm runoff to the river at rates very much higher than under baseline conditions. **Significant increase to response**

8.4 Conceptualisation and model developments

8.4.1 Flood flow modelling

The HEC-HMS model was used to predict baseline and project scenario flood flows at various stages of mine life. Modelling assessments were undertaken to derive estimations for the 100 year flood (Q_{100}) in response to the equivalent 100 year design storm rainfall for a 24 hour duration.

For post closure an additional model run was undertaken with a 10% uplift to the 100 year design rainfall to account for the potential effect of Climate Change on extreme storm rainfall depths and resulting flood flow responses.

Outline details of HEC-HMS model setups are shown as follows:

1. For the Jazga River through Ilovica including;
    a. Spatial representation of model setups (Figure A8.1).
    b. Tabular summaries of model parameterization (Table 8-2).
2. For the Shtuka River through Shtuka and at Sekirnik road bridge including;
    a. Spatial representation of model setups (Figure A8.2).
    b. Tabular summaries of model parameterization (Table 8-3).

8.4.2 Flood level modelling

Where river reaches required hydraulic modelling one-dimensional hydraulic models were developed using HEC-RAS (River Analysis System). Steady state water surface profiles were predicted using peak 100-year flood flow

estimates along prescribed river reaches. Such models require channel surveys along the target reaches outlined in Table 8-1.

Table 8-2 Model parameterization for HEC-HMS flood modelling on the Jazga to Ilovica Reservoir at various stages in the mine project

Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow		
	Baseline	Construction impacted scenario (Yr -1)					SCS 'composite' Curve Number					SCS Unit Hydrograph		Recession		
	Natural	Natural	Modified	Net Removed			I_a (mm)	Baseline CN	Modified CN	Baseline Imperv (%)	Modified Imperv (%)	Type	Baseline Lag (mins)	Q_I (m^3/s)	K_R	R_TP
Upper JZGS02	17.90	17.84	0.06	0.00	None	None	n/d	58	75	0	0	Std	120	0.02	0.9	0.15
Oxide trib & Jazga to Ilovica Res below JZGS02 including Pit Area	3.52	2.10	0.99	0.43	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15
Pit Lake addition from Shtuka post closure & pit lake filling	0.00	0.00	0.00	0.00	None	None	n/d	n/a	76	n/a	33	Std	121	0	0.9	0.15
Treska and westerly tribs inflowing to Ilovica Res	4.45	4.37	0.06	0.02	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15
Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow		
	Baseline	**Operations impacted scenario (Yr 21)**					SCS 'composite' Curve Number					SCS Unit Hydrograph		Recession		
	Natural	Natural	Modified	Net Removed			I_a (mm)	Baseline CN	Modified CN	Baseline Imperv (%)	Modified Imperv (%)	Type	Baseline Lag (mins)	Q_I (m^3/s)	K_R	R_TP
Upper JZGS02	17.90	17.84	0.06	0.00	None	None	n/d	58	75	0	0	Std	120	0.02	0.9	0.15
Oxide trib & Jazga to Ilovica Res below JZGS02 including Pit Area	3.52	2.10	0.56	0.86	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15
Pit Lake addition post closure & pit lake filling	0.00	0.00	0.00	0.00	None	None	n/d	n/a	76	n/a	33	Std	121	0	0.9	0.15
Treska and westerly tribs inflowing to Ilovica Res	4.45	4.37	0.06	0.02	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15
Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow		
	Baseline	**Post Closure impacted scenario (Yr 27)**					SCS 'composite' Curve Number					SCS Unit Hydrograph		Recession		
	Natural	Natural	Modified	Net Removed			I_a (mm)	Baseline CN	Modified CN	Baseline Imperv (%)	Modified Imperv (%)	Type	Baseline Lag (mins)	Q_I (m^3/s)	K_R	R_TP
Upper JZGS02	17.90	17.84	0.06	0.00	None	None	n/d	58	75	0	0	Std	120	0.02	0.9	0.15
Oxide trib & Jazga to Ilovica Res below JZGS02 including Pit Area	3.52	2.10	0.56	0.86	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15
Pit Lake addition post closure & pit lake filling	0.00	0.00	0.00	0.00	None	None	n/d	n/a	76	n/a	33	Std	121	0	0.9	0.15
Treska and westerly tribs inflowing to Ilovica Res	4.45	4.37	0.06	0.02	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15
Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow		
	Baseline	**Post Closure impacted scenario (Yr 100)**					SCS 'composite' Curve Number					SCS Unit Hydrograph		Recession		
	Natural	Natural	Modified	Net Removed			I_a (mm)	Baseline CN	Modified CN	Baseline Imperv (%)	Modified Imperv (%)	Type	Baseline Lag (mins)	Q_I (m^3/s)	K_R	R_TP
Upper JZGS02	17.90	17.84	0.06	0.00	None	None	n/d	58	75	0	0	Std	120	0.02	0.9	0.15
Oxide trib & Jazga to Ilovica Res below JZGS02 excluding Pit Area within natural Jazga catchment	3.52	2.61	0.00	0.91	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15
Pit Lake addition post closure & pit lake filling	0.00	0.00	0.95	-0.95	None	None	n/d	n/a	76	n/a	33	Std	121	0	0.9	0.15
Treska and westerly tribs inflowing to Ilovica Res	4.45	4.37	0.06	0.02	None	None	n/d	58	75	0	0	Std	120	0	0.9	0.15

Table 8-3 Model parameterization for HEC-HMS flood modelling on the Shtuka to Shtuka village and to Sekirnik road bridge

Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow				
	Baseline	Construction impacted scenario (Yr -1)					SCS Curve Number					SCS Unit Hydrograph		Recession				
	Natural	Residual Natural	Modified	Net Removed			Baseline I_a (mm)	Modified Ia (mm)	Baseline Curve No.	Modified Curve No.	Imperv (%)	Type	Lag (mins)	Baseline Q_I (m^3/s)	Modified Q_I (m^3/s)	Nat K_R	Mod K_R	R_TP
STGS04	2.99	2.99	0.00	0.00	None	None	5.0		50		0	Std	360	0.05		0.78		0.3
STGS03	3.23	3.23	0.00	0.00	None	None	5.0		42		0	Std	300	0.02		0.65		0.25
part STGS03 (Div S)	1.03	1.03	0.00	0.00	None	None	5.0		42		0	Std	300	0.008		0.65		0.25
part STGS03 (Div N)	0.19	0.19	0.00	0.00	None	None	5.0		42		0	Std	300	0.002		0.65		0.25
comp Suchica to Div	0.00	0.03	0.00	-0.03	None	None	15.0		10		0	Std	90	0.005		0.9		0.1
Nat (N of TMF)	3.00	2.88	0.09	0.03	None	None	10.0	5.0	25	45	0	Std	240	0.02	0.00	0.9		0.1
Nat (S of TMF)	1.06	1.06	0.00	0.00	None	None	15.0		10		0	Std	90	0.025		0.9		0.1
TMF (Tails)	1.96	1.72	0.24	0.00	None	None	15.0	10.0	10	30	0	Std	120	0.01	0.00	0.9		0.1
TMF (Embankment)	0.60	0.00	0.60	0.00	None	None	15.0	10.0	10	30	0	Std	60	0.01	0.01	0.9		0.1
Residual Nat (STGS01)	2.64	2.64	0.00	0.00	None	None	15.0		10		0	Std	90	0.05		0.9		0.1
Part to Shtuka Vill (STGS02)	2.40	2.26	0.14	0.00	None	None	15.0		10		0	Std	90	0.04		0.9		0.1
Residual Nat (STGS02)	3.40	3.40	0.00	0.00	None	None	15.0		10		0	Std	90	0.06		0.9		0.1

Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow				
	Baseline	Operations impacted scenario (Yr 21)					SCS Curve Number					SCS Unit Hydrograph		Recession				
	Natural	Residual Natural	Modified	Net Removed			Baseline I_a (mm)	Modified Ia (mm)	Baseline Curve No.	Modified Curve No.	Imperv (%)	Type	Lag (mins)	Baseline Q_I (m^3/s)	Modified Q_I (m^3/s)	Nat K_R	Mod K_R	R_TP
STGS04	2.99	2.99	0.00	0.00	None	None	5.0		50		0	Std	360	0.05		0.78		0.3
STGS03	3.23	3.23	0.00	0.00	None	None	5.0		42		0	Std	300	0.02		0.65		0.25
part STGS03 (Div S)	1.03	1.03	0.00	0.00	None	None	5.0		42		0	Std	300	0.008		0.65		0.25
part STGS03 (Div N)	0.19	0.19	0.00	*0.19*	None	None	5.0		42		0	Std	300	0.002		0.65		0.25
comp Suchica to Div	0.00	0.03	0.00	-0.03	None	None	15.0		10		0	Std	90	0.005		0.9		0.1
Nat (N of TMF)	3.00	3.00	0.00	*3.00*	None	None	10.0		25		0	Std	240	0.02		0.9		0.1
Nat (S of TMF)	1.06	1.06	0.00	0.00	None	None	15.0		10		0	Std	90	0.025		0.9		0.1
TMF (Tails)	1.96	0.00	1.96	*1.96*	None	None	15.0	5.0	10	70	0	Std	120	0.01	0.00	0.9	0.5	0.1
TMF (Embankment)	0.60	0.00	0.60	*0.60*	None	None	15.0	3.0	10	96	0	Std	60	0.01	0.01	0.9	0.3	0.1
Residual Nat (STGS01)	2.64	2.21	0.00	0.43	None	None	15.0		10		0	Std	90	0.05		0.9		0.1
Part to Shtuka Vill (STGS02)	2.40	2.19	0.00	0.21	None	None	15.0		10		0	Std	90	0.04		0.9		0.1
Residual Nat (STGS02)	3.40	3.40	0.00	0.00	None	None	15.0		10		0	Std	90	0.06		0.9		0.1

Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow				
	Baseline	Post Closure impacted scenario (≥Yr 27)					SCS Curve Number					SCS Unit Hydrograph		Recession				
	Natural	Residual Natural	Modified	Net Removed			Baseline I_a (mm)	Modified Ia (mm)	Baseline Curve No.	Modified Curve No.	Imperv (%)	Type	Lag (mins)	Baseline Q_I (m^3/s)	Modified Q_I (m^3/s)	Nat K_R	Mod K_R	R_TP
STGS04	2.99	2.99	0.00	0.00	None	None	5.0		50		0	Std	360	0.05		0.78		0.3
STGS03	3.23	3.23	0.00	0.00	None	None	5.0		42		0	Std	300	0.02		0.65		0.25
part STGS03 (Div S)	1.03	1.03	0.00	0.00	None	None	5.0		42		0	Std	300	0.008		0.65		0.25
part STGS03 (Div N)	0.19	0.19	0.00	0.00	None	None	5.0		42		0	Std	300	0.002		0.65		0.25
comp Suchica to Div	0.00	0.03	0.00	-0.03	None	None	15.0		10		0	Std	90	0.005		0.9		0.1

Catchment	Catchment Areas (km²)				Canopy	Surface	Loss					Transform		Baseflow				
	Baseline	Construction impacted scenario (Yr -1)					SCS Curve Number					SCS Unit Hydrograph		Recession				
	Natural	Residual Natural	Modified	Net Removed			Baseline I_a (mm)	Modified Ia (mm)	Baseline Curve No.	Modified Curve No.	Imperv (%)	Type	Lag (mins)	Baseline Q_I (m^3/s)	Modified Q_I (m^3/s)	Nat K_R	Mod K_R	R_TP
Nat (N of TMF)	3.00	3.00	0.00	0.00	None	None	10.0		25		0	Std	240	0.02		0.9		0.1
Nat (S of TMF)	1.06	1.06	0.00	0.00	None	None	15.0		10		0	Std	90	0.025		0.9		0.1
TMF (Tails)	1.96	0.00	1.96	0.00	None	None	15.0	5.0	10	70	0	Std	120	0.01	0.00	0.9	0.5	0.1
TMF (Embankment)	0.60	0.00	0.60	0.00	None	None	15.0	3.0	10	96	0	Std	60	0.01	0.01	0.9	0.3	0.1
Residual Nat (STGS01)	2.64	2.21	0.00	0.43	None	None	15.0		10		0	Std	90	0.05		0.9		0.1
Part to Shtuka Vill (STGS02)	2.40	2.19	0.00	0.21	None	None	15.0		10		0	Std	90	0.04		0.9		0.1
Residual Nat (STGS02)	3.40	3.40	0.00	0.00	None	None	15.0		10		0	Std	90	0.06		0.9		0.1

This catchment reports to the TMF water management system (or the TMF storm water dam).

HEC-RAS is used to perform backwater analyses for a prescribed design flood flow in accordance with river corridor shape and attributes including:

1. Within bank river channel geometry and condition.
2. River channel structures (shape, geometry and condition).
3. Flood plain (geometry and condition).

The conveyance capacity of any channel or structure is essentially governed by its size, shape, configuration and condition. It is normal practice to characterise condition via the use of a roughness value taking into account both the type and state of the material on (or through) which flow occurs. The normal attributes considered typically include material type (natural (such as silt) or artificial (such as brick)), condition (rough or smooth) and impediments (vegetation, rocks or debris) from which a composite Mannings roughness value (n) is ascribed[3]. The n values assigned for each river reach subject to hydraulic modelling are summarised in Table 8-4.

Table 8-4 Mannings n values applied to HEC-RAS modelling

River reach	Mannings n roughness coefficient			
	In channel		Flood plain	Bridge culverts
	Bed	Banks		
Jazga through Ilovica village	0.12	0.12	0.2	Bridges are single span decks
Shtuka through the majority of Shtuka village	0.15	0.15	0.2	Bridges are single span decks
Shtuka village (in the vicinity of the village square)	0.2	0.2	0.2	Note this short reach includes a series of coarse in channel drop structures comprising large boulders
Shtuka at Sekirnik road bridge	0.035	0.15	0.2	0.02 (concrete lined circular & rectangular culverts)

In order to initiate a model run in HEC-RAS it was necessary to ascribe:

1. An initial longitudinal surface water gradient. This was defined in accordance with the observed channel gradient towards the lower end of each modelled reach.
2. An assumed hydraulic flow regime condition. The sub-critical flow condition has been assumed for all modelled reaches and for the most part this condition holds true in this study. Where super-critical flow conditions are predicted within the modelling routines HEC-RAS will accordingly default to super-critical mode and such conditions may arise where abrupt discontinuities in longitudinal channel bed gradient exist and/or where river channels become very restricted (as may occur due to an artificial structure).

8.4.3 Results for Jazga River through Ilovica village

8.4.3.1 Flood flows

The HEC-HMS models described above for the sub-catchments in the Jazga to Ilovica Reservoir were used to predict design flood flows at Ilovica Reservoir for baseline and different life of mine conditions. Modelling was undertaken to predict the 100-year flood flow and this was done utilising the 24 hour - 100-year rainfall for the Jazga catchment as follows:

[3] Open channel hydraulics; Ven Te Chow; 1959

1. The 24 hour – 100-year rainfall for the project site is 109 mm[4].
2. An areal reduction factor of 0.97 was used to transform a point rainfall estimate to a catchment wide estimate for the Jazga to the reservoir.
3. A symmetrical storm profile was used to distribute the 24 hour rainfall[5]

An additional run was undertaken for the long term post closure condition with rainfall increased by 10% to allow for the potential future effect of Climate Change.

The resultant design inflow hydrographs to the reservoir were routed through the reservoir in order to predict the resultant flow hydrographs out of the reservoir. This used the April 2015 stage-volume relationship for the reservoir and the dam spillway stage-discharge formula provided by SPWMC for the reservoir, $Q = 1.86\ B\ H^{3/2}$, where;

- Q is discharge (m^3/s)
- B is spillway length (30 m)
- H is head over spillway (a 'Kruger' type) with a crest level of 353.74 masl

The resultant peak design outflows are summarised in Table 8-5.

Table 8-5 Peak 100 year design flood outflows from Ilovica Reservoir

Flood Model	Design rainfall	Peak modelled values		
		Qin (m^3/s)	Qout (m^3/s)	Level (masl)
Scenario / Derivation		HEC-HMS	Reservoir routing	
Baseline	100 Yr	20.7	19.8	354.24
Construction (Yr -1)	100 Yr	21.6	20.8	354.26
Operations (Yr 21)	100 Yr	19.9	19.1	354.23
Post Closure (Yr 27)	100 Yr	19.9	19.1	354.23
Post Closure (Yr 100)	100 Yr	23.0	22.1	354.28
Post Closure (Yr 100) + CC*	100 Yr + CC*	30.3	29.2	354.39

CC* = Climate Change effects

The peak design outflows from the reservoir were used to model equivalent 100-year design flood levels through Ilovica. The significant uplift in design flood flow, by ~⅓, given Climate Change effects should be noted.

8.4.3.2 Flood levels

The previously defined 100-year design flood flows out of Ilovica Reservoir are taken as the equivalent Jazga River flows through Ilovica for the hydraulic modelling.

The downstream boundary adopted for all flood models was taken as the top of the existing ford crossing on the river downstream of the village. The modelled design flood levels for the baseline condition through Ilovica are shown in Figure A8.3. The variation to modelled design flood levels through Ilovica relative to the baseline condition for the Life of Mine scenarios previously described (Table 8-5) are shown in Figure A8.4. This figure also depicts the location of cross section 39 used to indicate effects on design flood levels in the main ESIA report (L100). The key results are summarised in Table 8-6.

[4] Euromax; Ilovica Gold-Copper project; Environmental and Social Engineering considerations; July 2015; Table 3.1.11.
[5] Haan CT, Barfield BJ and Hayes JC. 1981. Design hydrology and sedimentology for small catchments. Academic Press.

Table 8-6 Design flood flow and level regimes for the Jazga River through Ilovica

Regime/Parameter		Baseline	Predicted Scenario and Life of Mine stage				
Flood flow (level)	Unit		A (Yr. -1)	D (Yr. 21)	E (Yr.27)	F (Yr100)	F (Yr100+CC)
			Construction	Operation	Post Closure		
Flow Q_{100}	m^3/s	*19.8*	*20.8*	*19.1*	*19.1*	*22.1*	*29.2*
Scenario v Baseline (% change)		*n/a*	5.1	-3.5	-3.5	11.6	47.5
Level L_{100}	masl	*293.48*	*293.51*	*293.45*	*293.45*	*293.55*	*293.78*
Scenario - Baseline (m. increase)		*n/a*	0.03	-0.03	-0.03	0.07	0.30
Comment		*Mine impact changes to flood flow and level in Ilovica are modest but in tandem with projected Climate Change uplift to storm rainfall the changes are quite large (~48%) well into the future (post mine closure) but not sufficient to put Ilovica at significant risk of flooding.*					

8.4.4 Results for Shtuka River through Shtuka village and at Sekirnik road bridge

8.4.3.1 Shtuka river flood flows

The HEC-HMS models described above for the sub-catchments in the Shtuka River to both Shtuka village and Sekirnik road bridge were used to derive design flood flows for the baseline and various life of mine stages. On the Shtuka River no reservoir routing, equivalent to that undertaken through Ilovica Reservoir on the Jazga River, were necessary. The 100 year design rainfall used on the Shtuka is the same as that used on the Jazga and a 10% Climate Change uplift was similarly applied to represent projected long term post closure conditions following the mine scheme. The resultant peak design flood flows at the two key locations are summarised in Table 8-7.

Table 8-7 Peak 100 year design flood flows on the Shtuka River through Shtuka and at Sekirnik road bridge

Flood Model	Design rainfall	Peak design flood flows Q100 (m^3/s)	
		Shtuka village	Sekirnik road bridge
Scenario / Derivation		HEC-HMS	
Baseline	100 Yr	5.3	5.6
Construction (Yr -1)	100 Yr	5.4	5.6
Operations (Yr 21)	100 Yr	4.4	4.7
Post Closure (Yr 27)	100 Yr	9.3	9.6
Post Cosure (Yr 100) + CC	100 Yr + CC	10.7	11.1

CC = Climate Change effects

The peak design flood flows were used to model equivalent 100-year design flood levels through Shtuka and at Sekirnik road bridge respectively. The significant uplift in design flood flow at post closure should be noted when peak flows approximately double. This reflects the dramatic effect of the restored TMF area in heightening storm runoff response when compared to the baseline condition. Climate Change effects further elevate peak design flows but not as dramatically, in relative terms, as is the case on the Jazga River through Ilovica. This contrast relates to the very different characteristics, and associated responses to intense storm events, in respective catchments post closure with the restored TMF area radically altering how the Shtuka catchment behaves.

8.4.3.2 Flood levels through Shtuka village

The previously defined 100-year design flood flows (Table 8-7) are taken for the Shtuka River through Shtuka village for the hydraulic modelling.

The downstream boundary adopted for all flood models was taken as the top of the existing ford crossing on the river downstream of the village. The modelled design flood levels for the baseline condition through Shtuka village are shown in Figure A8.5. The variation to modelled design flood levels through Shtuka village relative to the baseline condition for the Life of Mine scenarios previously described (Table 8-7) are shown in Figure A8.6. This figure also depicts the location of cross section 39 used to indicate effects on design flood levels in the main ESIA report (L100). The key results are summarised in Table 8-8.

Table 8-8 Design flood flow and level regimes for the Shtuka River through Shtuka

Regime/Parameter		Baseline	Predicted Scenario and Life of Mine stage				
Flood flow (level)	Unit		A (Yr. -1)	D (Yr. 21)	E (Yr.27)	F (Yr100)	F (Yr100+CC)
			Construction	Operation	Post Closure		
Design flow Q_{100}	m^3/s	5.3	5.3	4.4	9.3	9.3	10.7
Scenario v Baseline (% change)		n/a	0.6	-16.5	74.8	74.8	100.8
Design level L_{100}	masl	295.98	295.98	295.87	296.59	296.59	296.64
Scenario - Baseline (m. increase)		n/a	0	-0.11	0.61	0.61	0.66
Comment		***L_{100} - At Section 22 - upstream of the road bridge by village square The bridge starts surcharging (running full) at 295.9m asl & overtops at 296.2m asl Post closure changes to flood flow and level in Shtuka are considered significant and are further exacerbated by predicted Climate Change effects in the long-term.***					

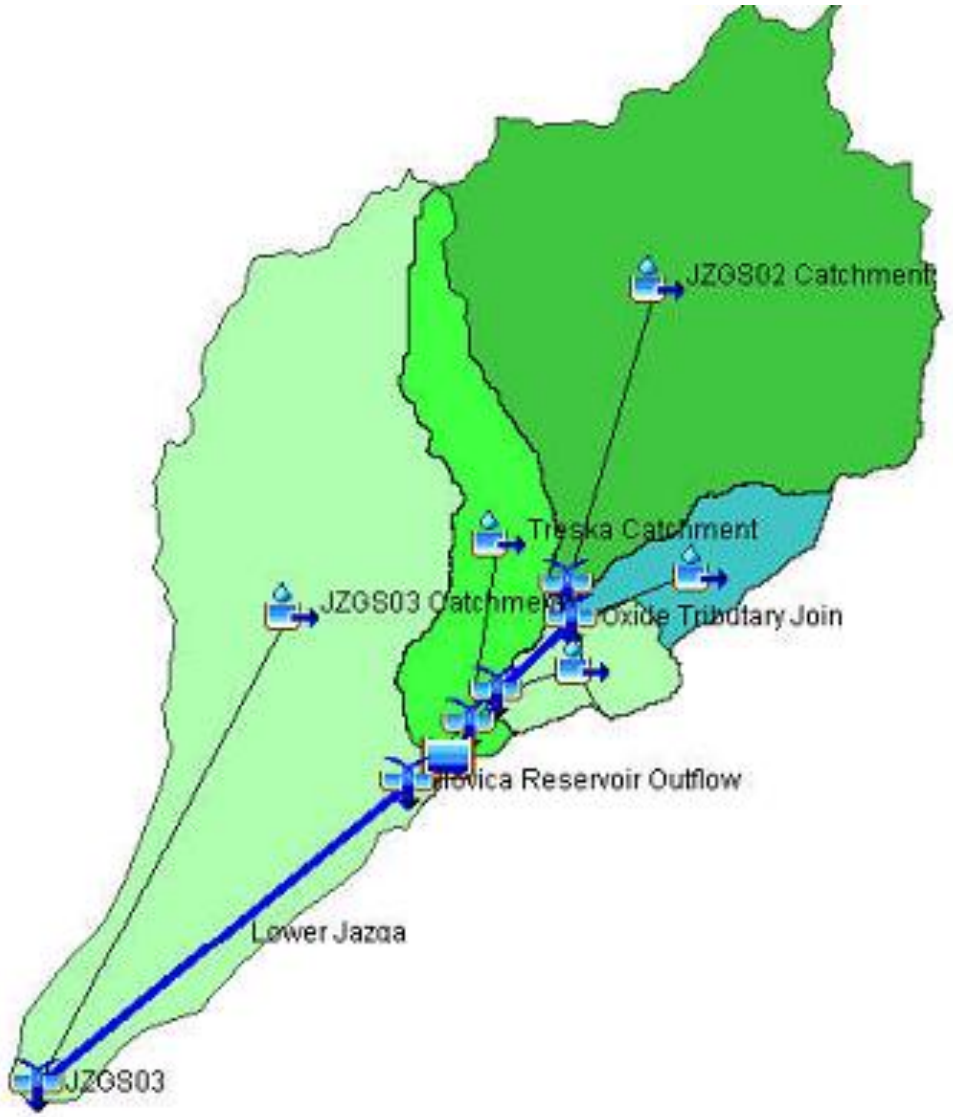
8.4.3.3 Flood levels at Sekirnik road bridge

The previously defined 100-year design flood flows (Table 8-7) are taken for the Shtuka River at Sekirnik road bridge for the hydraulic modelling.

The Sekirnik road crossing itself comprises a double culvert including rectangular box and circular types both constructed in rough concrete. The modelled design flood levels for the baseline condition through and in the vicinity of the road bridge are shown in Figure A8.7. The variation to modelled design flood levels in the vicinity of the bridge and relative to the baseline condition for the LOM scenarios previously described (Table 8-7) are shown in Figure A8.8. This figure also depicts the location of cross section 9 used to indicate effects on design flood levels in the main ESIA report (L100). The key results are summarised in Table 8-9.

Table 8-9 Design flood flow and level regimes for the Shtuka River at Sekirnik road bridge

Regime/Parameter		Baseline	Predicted Scenario and Life of Mine stage				
Flood flow (level)	Unit		A (Yr. -1)	D (Yr. 21)	E (Yr.27)	F (Yr100)	F (Yr100+CC)
			Construction	Operation	Post Closure		
Design flow Q_{100}	m^3/s	***5.6***	***5.6***	***4.7***	***9.6***	***9.6***	***9.6***
Scenario v Baseline (% change)		***n/a***	***-0.4***	***-16.6***	***71.6***	***71.6***	***71.6***
Design level L_{100}	masl	***215.86***	***215.85***	***215.57***	***216.14***	***216.14***	***216.14***
Scenario v Baseline (m. increase)		***n/a***	***-0.01***	***-0.29***	***0.28***	***0.28***	***0.28***
Comment		***L_{100} - At Section 9 - upstream of the culverted road bridge The bridge starts surcharging (running full) at 215.6m asl & overtops at 216.0m asl Post closure changes to flood flow and level at Sekirnik bridge are considered significant and are further exacerbated by predicted Climate Change effects in the long-term.***					



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Water Services

Spatial representation of HEC-HMS model set up for the Jazga River catchment

PROJECT:	Ilovica Gold-Copper Project			FIGURE:	A8.1
CLIENT:	Euromax Resources (Macedonia) UK Ltd			PROJECT:	55459_R1v2
DRAWN:	APu	CHECKED:	PB	DATE:	January 2016

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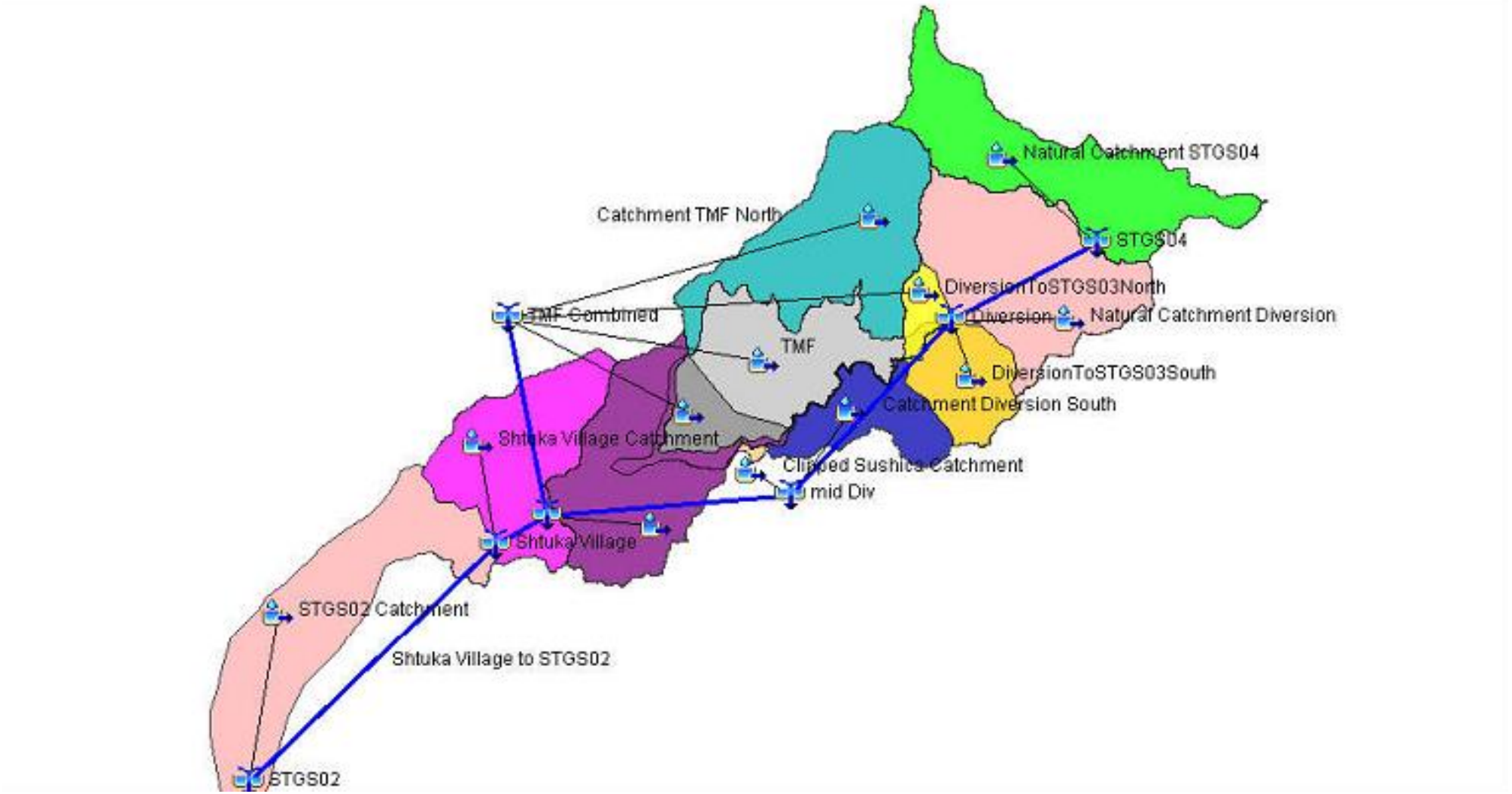

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Water Services

Spatial representation of HEC-HMS model set up for the Shtuka River catchment

PROJECT:	Ilovica Gold-Copper Project			FIGURE:	A8.2
CLIENT:	Euromax Resources (Macedonia) UK Ltd			PROJECT:	55459_R1v2
DRAWN:	APu	CHECKED:	PB	DATE:	January 2016

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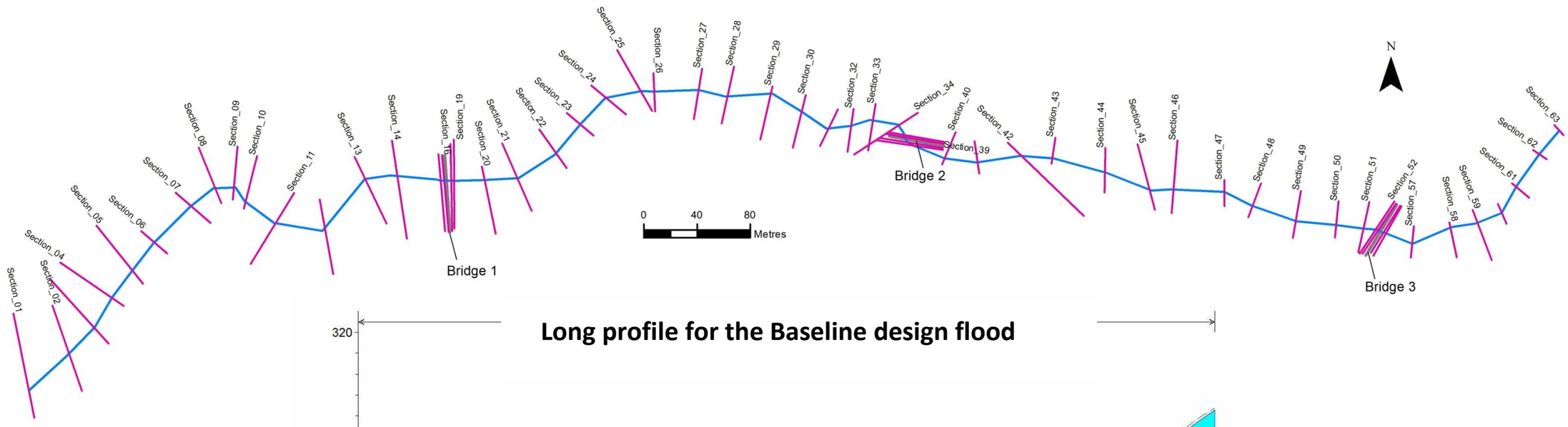
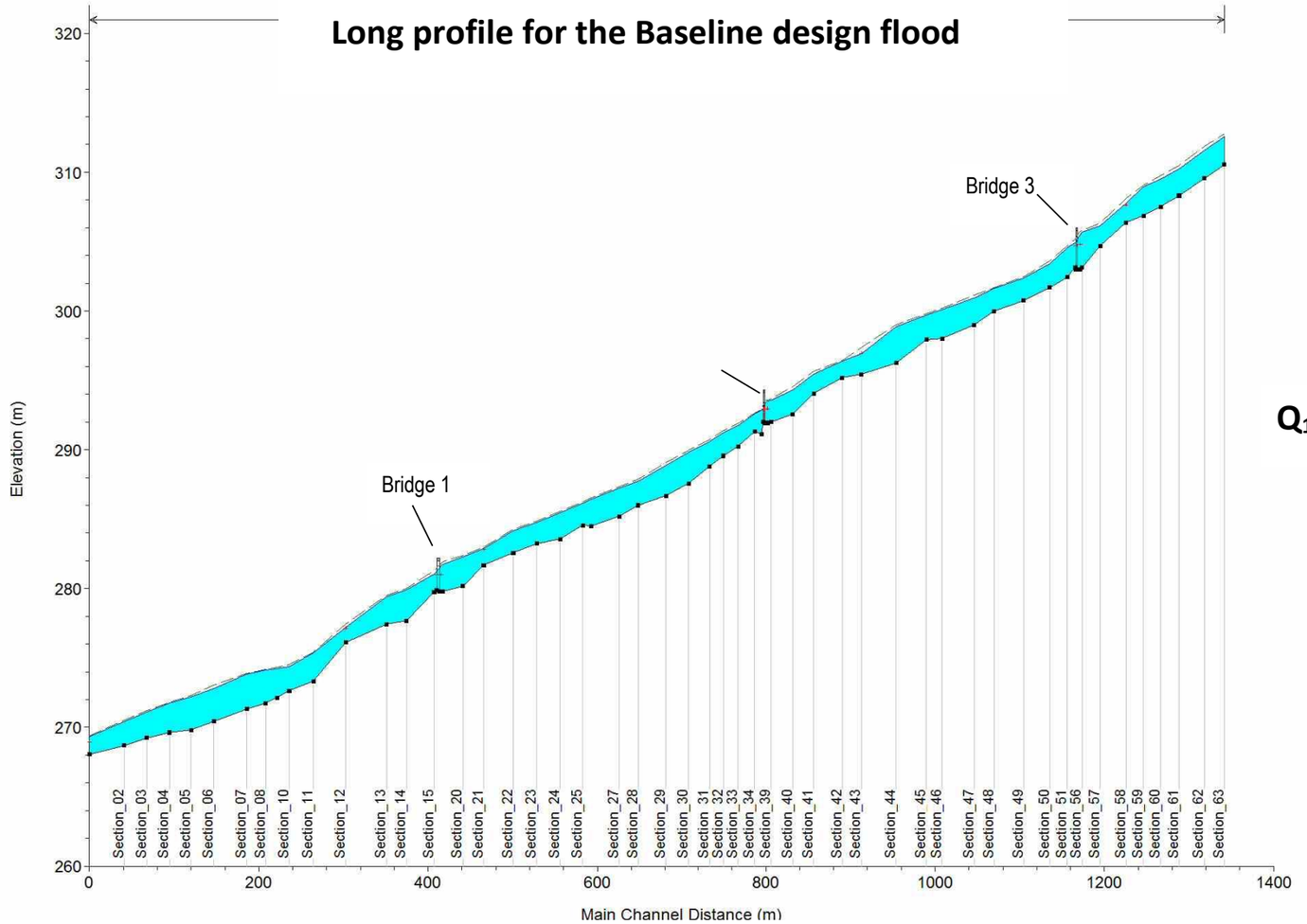


Long profile for the Baseline design flood



Q_{100} = 19.8 m^3/s

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HEC-RAS model extent and surface water profile for the baseline 100 year flood on the Jazga River through Ilovica

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A8.3
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: DH	CHECKED: APu	DATE:	January 2016

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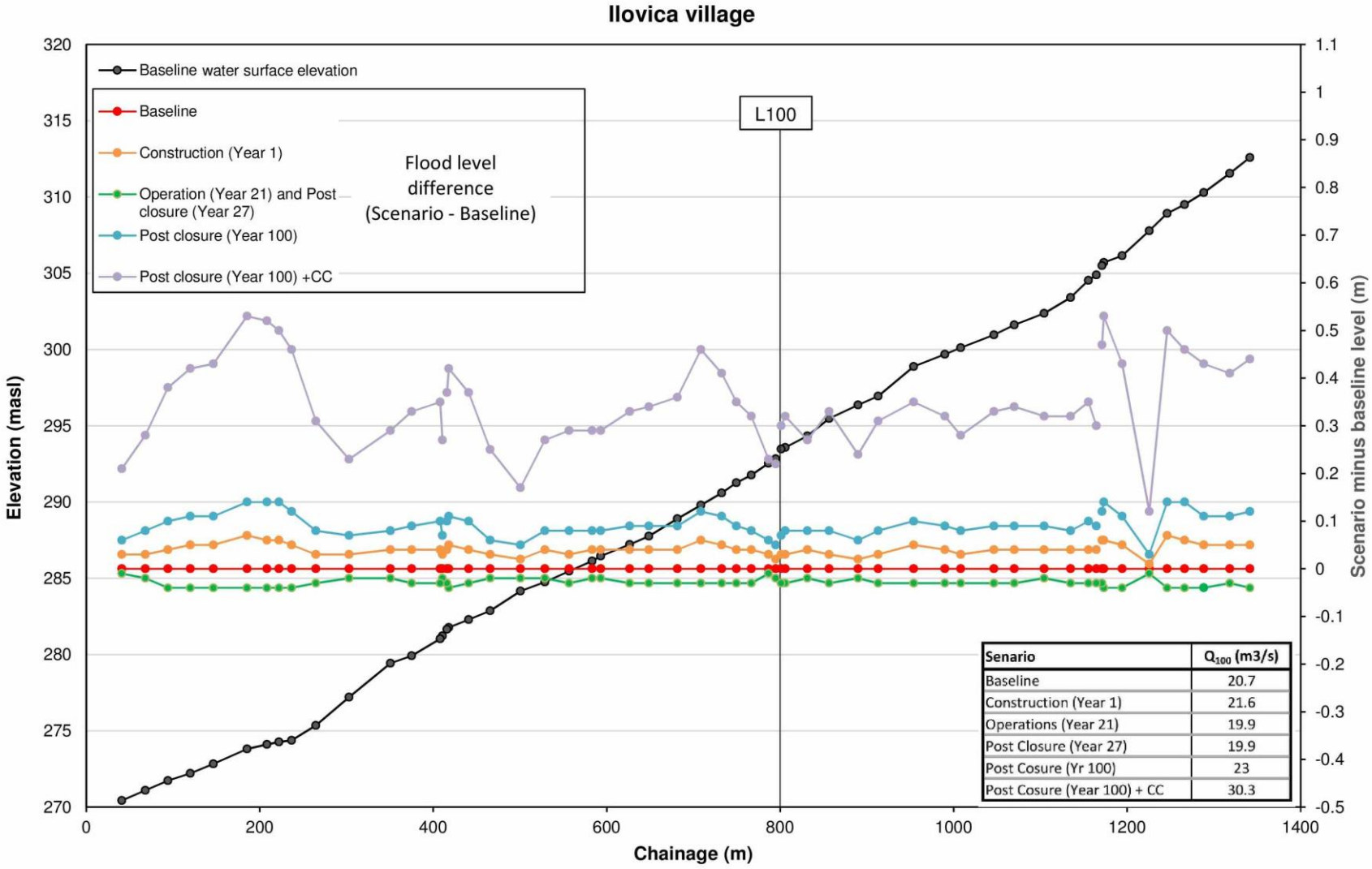

Senario	Q_{100} (m3/s)
Baseline	20.7
Construction (Year 1)	21.6
Operations (Year 21)	19.9
Post Closure (Year 27)	19.9
Post Cosure (Yr 100)	23
Post Cosure (Year 100) + CC	30.3

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Changes to predicted flood levels through Ilovica village

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A8.4
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN:	APu	CHECKED: PB	DATE: January 2016

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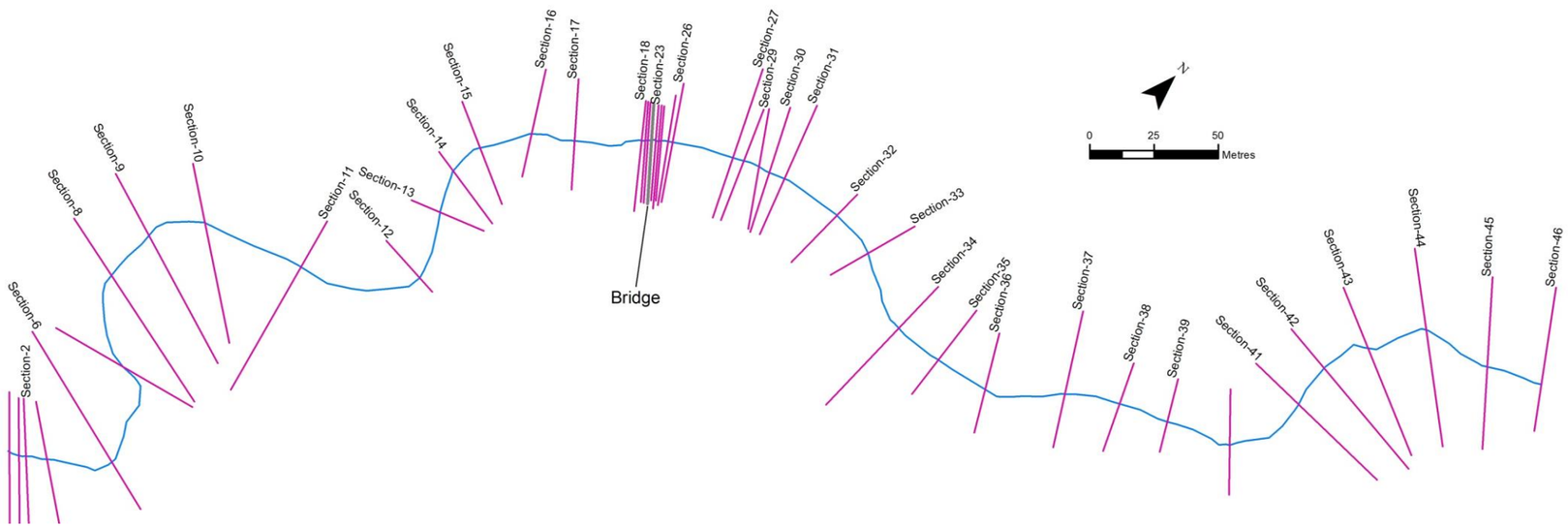

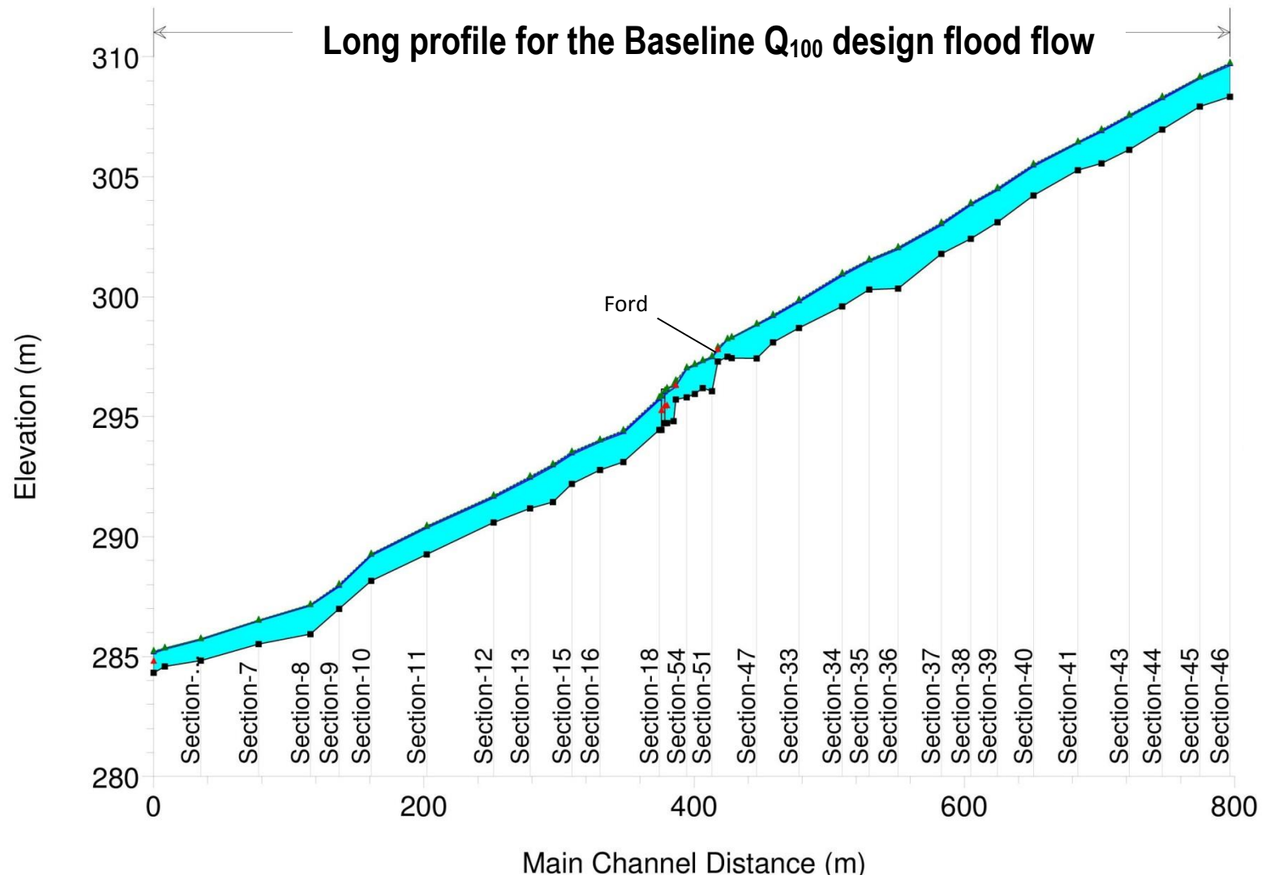

Q_{100} = 5.35 m^3/s

Schlumberger Water Services

HEC-RAS model extend and surface water profile for the 100 year baseline flood on the River Shtuka through Shtuka village

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A8.5
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: DH	CHECKED: APu	DATE:	January 2016

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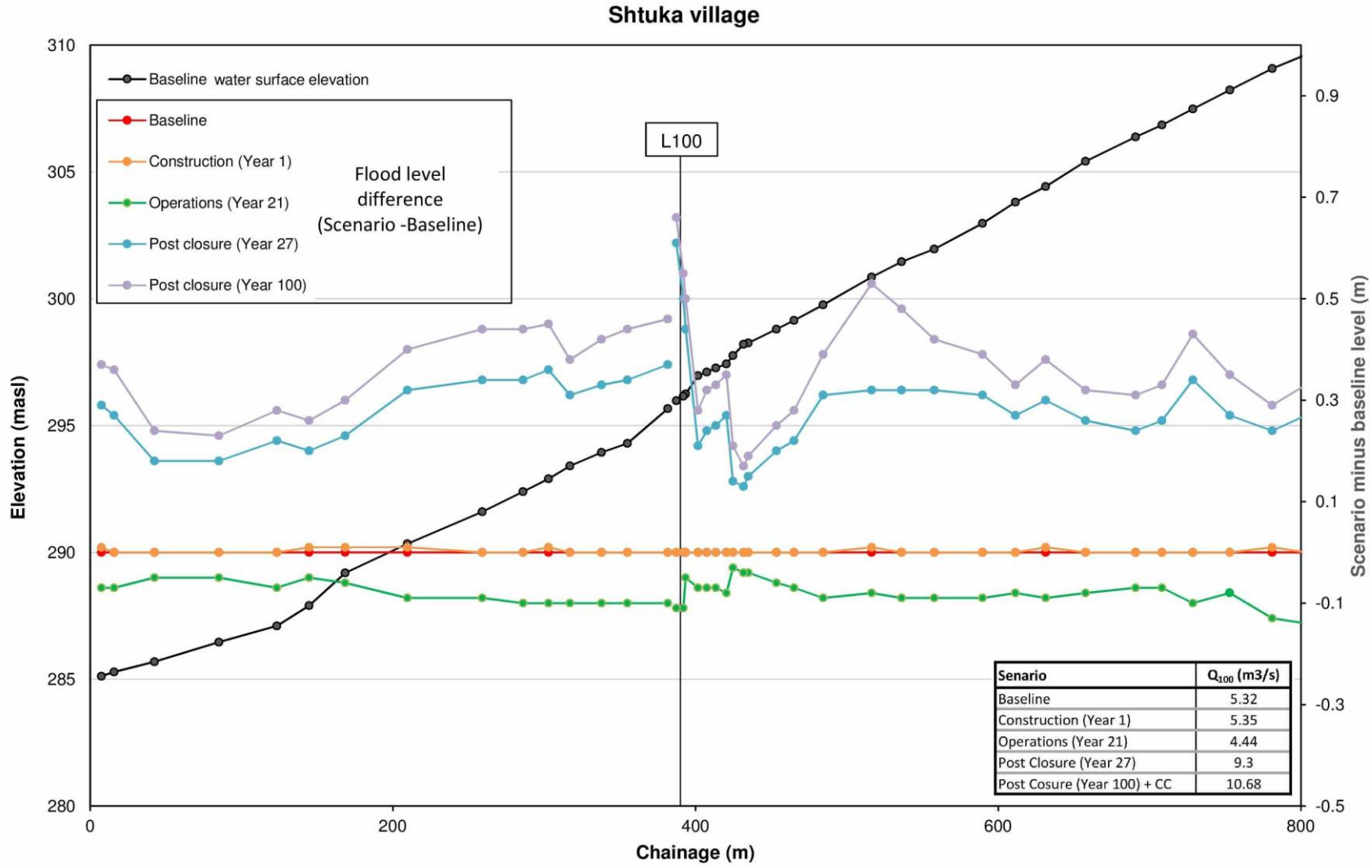

Schlumberger Water Services

Changes to predicted flood levels through Shtuka village

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A8.6
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: APu	CHECKED: PB	DATE:	January 2016

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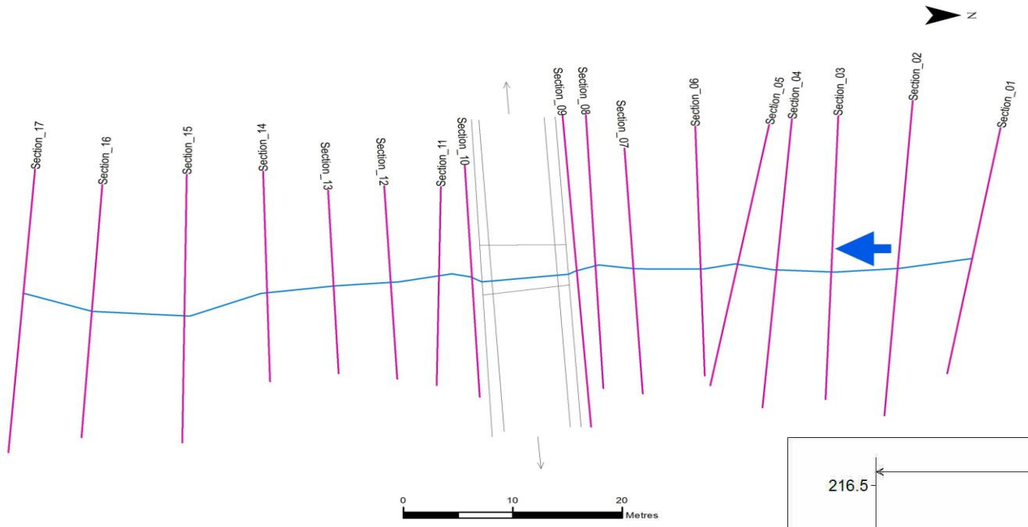
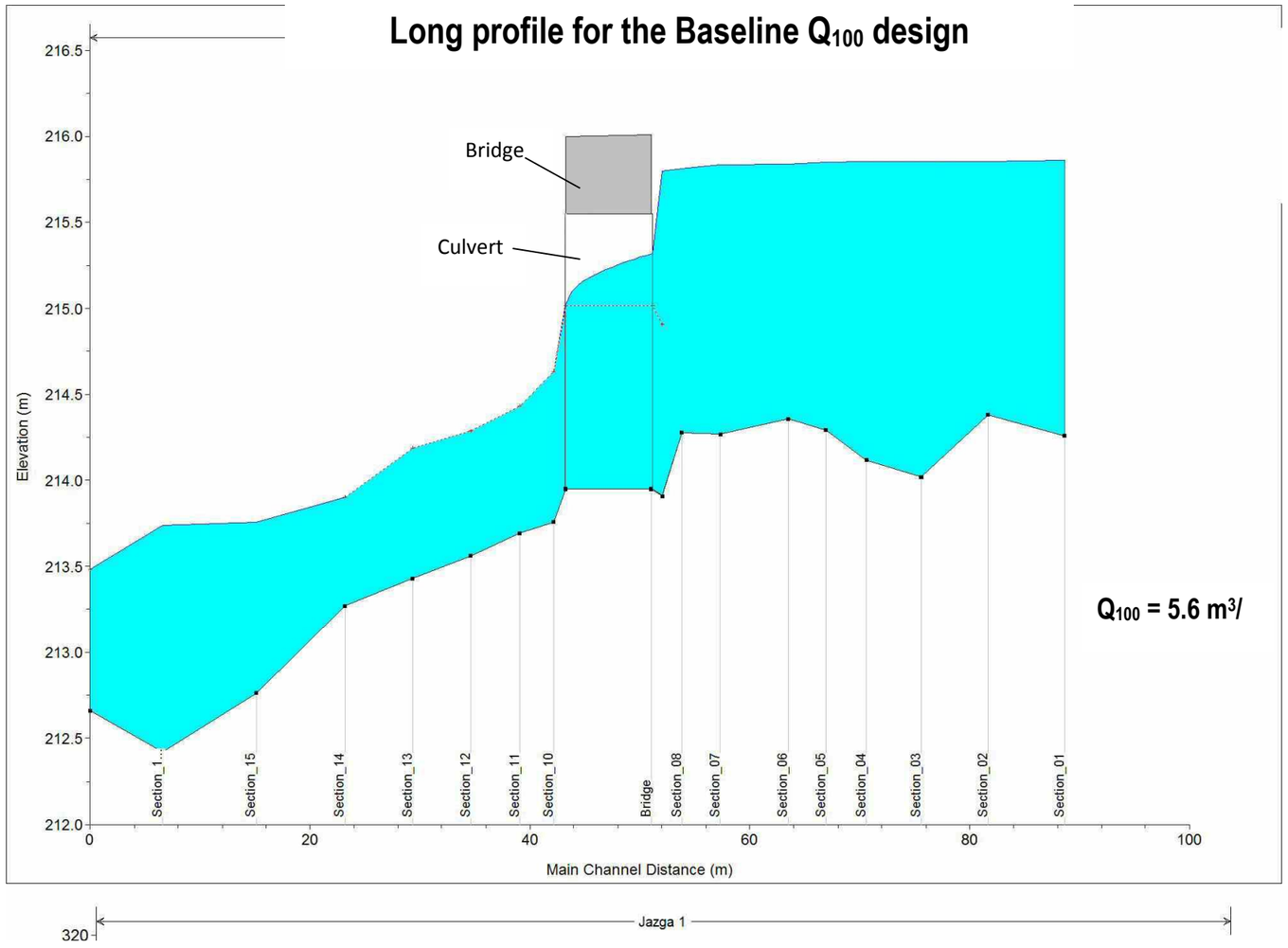


Long profile for the Baseline Q_{100} design



Q_{100} = 5.6 m³/

Schlumberger Water Services	HEC-RAS model extend and surface water profile for the baseline Q_{100} at Shtuka River crossing Sekirnik Road				
	PROJECT:	Ilovica Gold-Copper Project		FIGURE:	A8.7
	CLIENT:	Euromax Resources (Macedonia) UK Ltd		PROJECT:	55459_R1v2
	DRAWN:	DH	CHECKED: APu	DATE:	January 2016

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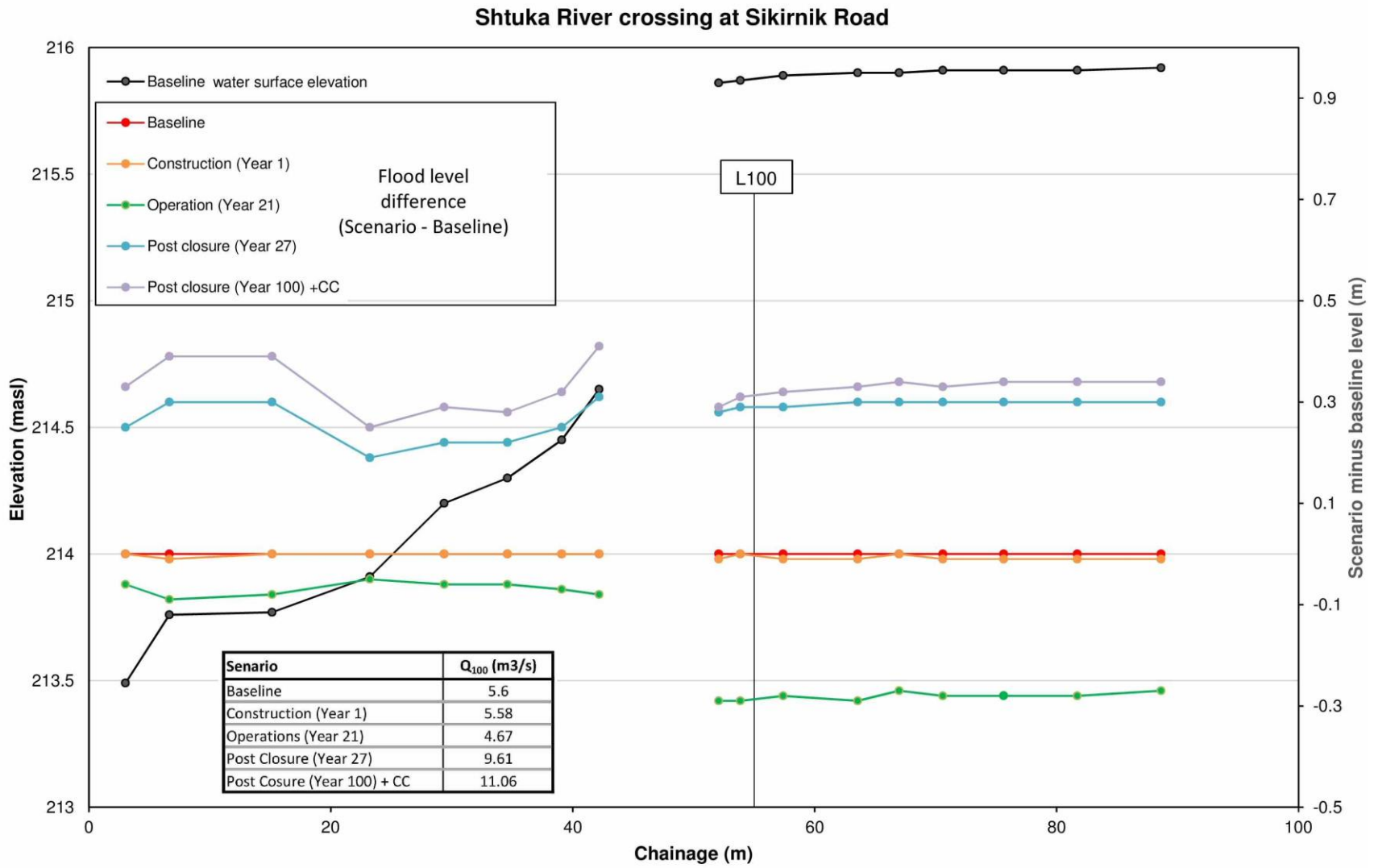

Schlumberger Water Services

Shtuka River crossing at Sekirnik Road

PROJECT:	Ilovica Gold-Copper Project	FIGURE:	A8.8
CLIENT:	Euromax Resources (Macedonia) UK Ltd	PROJECT:	55459_R1v2
DRAWN: APu	CHECKED: PB	DATE:	January 2016

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9 IMPACT CLASSIFICATION MATRICES

9.1 Water quantity

Impact classification matrices are given in tabular form for water quantity related issues as described in Section 5 using the methodology in Section 1 of the main EISA report respectively. These include:

1. Impact classifications given the proposed scheme as defined in the main EISA and in supporting information (Table 9-1).
2. For resulting consequences in Table 9-1 considered significant (classified as negatively moderate or major) consideration has been given to mitigation measures and residual impact classifications are given in light of proposed mitigation measures (Table 9-2).

9.2 Water quality

Impact classification matrices are given in tabular form for water quality related issues as described in Section 6 using the methodology in Section 1 of the main EISA report respectively. These include:

1. Impact classifications given the proposed scheme as defined in the main EISA and in supporting information (Table 9-3).
2. For resulting consequences in Table 9-3 considered significant (classified as negatively moderate or major) consideration has been given to mitigation measures and residual impact classifications are given in light of proposed mitigation measures (Table 9-4).

Table 9-1 Impact classification matrix (Water Quantity)

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Construction (Yr-1)	Jazga River at Ilovica water supply intake	High	Reduction in Q95 flow due to mine construction	Negligible (+)	Local	Short-term	Frequent	Negligible	Negligible (+)
Operations (Yr 21)	Jazga River at Ilovica water supply intake	High	Reduction in Q95 flow due to mine operations	High	Local	Medium-term	Frequent	High	Major
Closure (Yr 27)	Jazga River at Ilovica water supply intake	High	Reduction in Q95 flow due to mine closure	High	Local	Medium-term	Frequent	High	Major
Post pit lake (Yr >57)	Jazga River at Ilovica water supply intake	High	Increase in Q95 flow due to pit lake spilling	Low (+)	Local	Permanent	Frequent	Moderate	Moderate (+)
Construction (Yr-1)	Jazga River at Ilovica water supply intake	High	Reduction in Q50 flow due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Jazga River at Ilovica water supply intake	High	Reduction in Q50 flow due to mine operations	Low	Local	Medium-term	Frequent	Low	Minor
Closure (Yr 27)	Jazga River at Ilovica water supply intake	High	Reduction in Q50 flow due to mine closure	Low	Local	Medium-term	Frequent	Low	Minor
Post pit lake (Yr >57)	Jazga River at Ilovica water supply intake	High	Increase in Q50 flow due to pit lake spilling	Low (+)	Local	Permanent	Frequent	Moderate	Moderate (+)
Construction (Yr -1)	Jazga River at Ilovica water supply intake	High	Increase in number of days Ilovica village is supplied by Ilovica WTW due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Jazga River at Ilovica water supply intake	High	Increase in number of days Ilovica village is supplied by Ilovica WTW due to mine operations	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Closure (Yr 27)	Jazga River at Ilovica water supply intake	High	Increase in number of days Ilovica village is supplied by Ilovica WTW due to mine closure	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Post pit lake (Yr >57)	Jazga River at Ilovica water supply intake	High	Increase in number of days Ilovica village is supplied by Ilovica WTW due to pit lake spilling	Negligible	Local	Permanent	Frequent	Negligible	Negligible
Construction (Yr-1)	Jazga River at gauging station JZGS01	High	Reduction in wetted perimeter due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Jazga River at gauging station JZGS01	High	Reduction in wetted perimeter due to mine operations	High	Local	Medium-term	Frequent	High	Major
Closure (Yr 27)	Jazga River at gauging station JZGS01	High	Reduction in wetted perimeter due to mine closure	High	Local	Medium-term	Frequent	High	Major
Post pit lake (Yr >57)	Jazga River at gauging station JZGS01	High	Increase in wetted perimeter due to pit lake spilling	Negligible (+)	Local	Permanent	Frequent	Negligible	Negligible (+)
Construction (Yr-1)	Ilovica reservoir	High	Reduction in Q95 inflow due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Ilovica reservoir	High	Reduction in Q95 inflow due to mine operations	High	Local	Medium-term	Frequent	High	Major
Closure (Yr 27)	Ilovica reservoir	High	Reduction in Q95 inflow due to mine closure	High	Local	Medium-term	Frequent	High	Major
Post pit lake (Yr >57)	Ilovica reservoir	High	Increase in Q95 inflow due to pit lake spilling	Low (+)	Local	Permanent	Frequent	Moderate (+)	Moderate (+)
Construction (Yr-1)	Ilovica reservoir	High	Reduction in Q50 inflow due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Operations (Yr 21)	Ilovica reservoir	High	Reduction in Q50 inflow due to mine operations	Low	Local	Medium-term	Frequent	Low	Minor
Closure (Yr 27)	Ilovica reservoir	High	Reduction in Q50 flow due to mine closure	Low	Local	Medium-term	Frequent	Low	Minor
Post pit lake (Yr >57)	Ilovica reservoir	High	Increase in Q50 inflow due to pit lake spilling	Low (+)	Local	Permanent	Frequent	Low	Minor (+)
Construction (Yr-1)	Ilovica reservoir	High	Increase in average return period of supply failure due to mine construction	Low (+)	Local	Short-term	Frequent	Negligible (+)	Negligible (+)
Operations (Yr 21)	Ilovica reservoir	High	Increase in average return period of supply failure due to mine operations	Low (+)	Local	Medium-term	Frequent	Low	Minor (+)
Closure (Yr 27)	Ilovica reservoir	High	Reduction in average return period of supply failure due to mine closure	High	Local	Medium-term	Frequent	High	Major
Post pit lake (Yr >57)	Ilovica reservoir	High	Increase in average return period of supply failure due to pit lake spilling	Low (+)	Local	Permanent	Frequent	Moderate (+)	Moderate (+)
Construction (Yr-1)	Ilovica reservoir	High	Reduction to mean level in reservoir	Moderate	Local	Short-term	Frequent	Low	Minor
Operations (Yr 21)	Ilovica reservoir	High	Reduction to mean level in reservoir	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Closure (Yr 27)	Ilovica reservoir	High	Reduction to mean level in reservoir	Low	Local	Medium-term	Frequent	Low	Minor
Post pit lake (Yr >57)	Ilovica reservoir	High	Increase to mean level in reservoir	Negligible (+)	Local	Permanent	Frequent	Negligible (+)	Negligible (+)
Construction (Yr-1)	Jazga River downstream of Ilovica reservoir	Medium	Reduction in Q95 flow due to mine construction	Moderate	Local	Short-term	Frequent	Low	Minor
Operations (Yr 21)	Jazga River downstream of Ilovica reservoir	Medium	Reduction in Q95 or Q50 flow due to mine operations	High	Local	Medium-term	Frequent	High	Moderate
Closure (Yr 27)	Jazga River downstream of Ilovica reservoir	Medium	Reduction in Q95 flow due to mine closure	Low	Local	Medium-term	Frequent	Low	Minor
Post pit lake (Yr >57)	Jazga River downstream of Ilovica reservoir	Medium	Increase in Q95 flow due to pit lake spilling	Moderate (+)	Local	Permanent	Frequent	Moderate	Moderate (+)
Construction (Yr-1)	Jazga River downstream of Ilovica reservoir	Medium	Reduction in Q50 flow due to mine construction	High	Local	Short-term	Frequent	Moderate	Moderate
Operations (Yr 21)	Jazga River downstream of Ilovica reservoir	Medium	Reduction in Q50 flow due to mine operations	High	Local	Medium-term	Frequent	High	Major
Closure (Yr 27)	Jazga River downstream of Ilovica reservoir	Medium	Reduction in Q50 flow due to mine closure	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Post pit lake (Yr >57)	Jazga River downstream of Ilovica reservoir	Medium	Increase in Q50 flow due to pit lake spilling	Moderate (+)	Local	Permanent	Frequent	Moderate	Moderate (+)
Construction (Yr-1)	Flood risk through Ilovica	Medium	Increase in flood flow and flood level due to mine construction	Negligible	Local	Short-term	Infrequent	Negligible	Negligible
Operations (Yr 21)	Flood risk through Ilovica	Medium	Decrease in flood flow and flood level due to mine operation	Negligible (+)	Local	Medium-term	Infrequent	Negligible (+)	Negligible (+)
Closure (Yr 27)	Flood risk through Ilovica	Medium	Decrease in flood flow and flood level due to mine closure	Negligible (+)	Local	Medium-term	Infrequent	Negligible (+)	Negligible (+)
Post closure (Yr 100)	Flood risk through Ilovica	Medium	Increase in flood flow and flood level due to pit lake spilling	Negligible	Local	Permanent	Infrequent	Negligible	Negligible

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Post pit lake(Yr 100)	Flood risk through Ilovica	Medium	Increase in flood flow and flood level due to pit lake spilling and climate change	Low	Local	Permanent	Infrequent	Moderate	Minor
Construction (Yr-1)	Jazga River at Radovo	Low	Reduction in Q95 flow due to mine construction	Moderate	Local	Short-term	Frequent	Low	Minor
Operations (Yr 21)	Jazga River at Radovo	Low	Reduction in Q95 flow due to mine operations	High	Local	Medium-term	Frequent	High	Major
Closure (Yr 27)	Jazga River at Radovo	Low	Reduction in Q95 flow due to mine closure	Low	Local	Medium-term	Frequent	Low	Minor
Post pit lake (Yr >57)	Jazga River at Radovo	Low	Increase in Q95 flow due to pit lake spilling	Low (+)	Local	Permanent	Frequent	Moderate	Minor (+)
Construction (Yr-1)	Jazga River at Radovo	Low	Reduction in Q50 flow due to mine construction	High	Local	Short-term	Frequent	Moderate	Moderate
Operations (Yr 21)	Jazga River at Radovo	Low	Reduction in Q50 flow due to mine operations	High	Local	Medium-term	Frequent	High	Major
Closure (Yr 27)	Jazga River at Radovo	Low	Reduction in Q50 flow due to mine closure	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Post pit lake (Yr >57)	Jazga River at Radovo	Low	Increase in Q50 flow due to pit lake spilling	Moderate (+)	Local	Permanent	Frequent	High	Major (+)
Construction (Yr-1)	Shtuka River at Shtuka water supply intakes	High	Increase in Q95 flow due to mine construction	Negligible (+)	Local	Short-term	Frequent	Negligible	Negligible (+)
Operations (Yr 2, 7 and 21)	Shtuka River at Shtuka water supply intakes	High	Reduction in Q95 flow due to mine operations	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Shtuka River at Shtuka water supply intakes	High	Increase in Q95 flow due to mine closure	Low (+)	Local	Permanent	Frequent	Moderate	Moderate (+)
Construction (Yr-1)	Shtuka River at Shtuka water supply intakes	High	Increase in Q50 flow due to mine construction	Negligible (+)	Local	Short-term	Frequent	Negligible	Negligible (+)
Operations (Yr 2, 7 and 21)	Shtuka River at Shtuka water supply intakes	High	Reduction in Q50 flow due to mine operations	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Shtuka River at Shtuka water supply intakes	High	Increase in Q50 flow due to mine closure	High (+)	Local	Permanent	Frequent	High	Major (+)
Construction (Yr-1)	Shtuka River at Shtuka water supply intakes	High	Decrease in number of days Shtuka village is supplied by Ilovica WTW due to mine construction	Low (+)	Local	Short-term	Frequent	Negligible	Negligible (+)
Operations (Yr 2, 7 and 21)	Shtuka River at Shtuka water supply intakes	High	Increase in number of days Shtuka village is supplied by Ilovica WTW due to mine operations	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Shtuka River at Shtuka water supply intakes	High	Decrease in number of days Shtuka village is supplied by Ilovica WTW due to mine post clsoure	Low (+)	Local	Permanent	Frequent	Moderate	Moderate (+)
Construction (Yr-1)	Shtuka River at Shtuka water supply intakes	High	Increase in wetted perimeter due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 2, 7 and 21)	Shtuka River at Shtuka water supply intakes	High	Decrease in wetted perimeter due to mine operations	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Shtuka River at Shtuka water supply intakes	High	Increase in wetted perimeter due to mine closure	Negligible (+)	Local	Permanent	Frequent	Negligible	Negligible (+)
Construction (Yr-1)	Flood risk through Shtuka	High	Increase in flood flow and level due to mine construction	Negligible	Local	Short-term	Infrequent	Negligible	Negligible
Operations (Yr 21)	Flood risk through Shtuka	High	Increase in flood flow and level due to mine operations	Low (+)	Local	Medium-term	Infrequent	Negligible	Negligible (+)

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Closure (Yr 27)	Flood risk through Shtuka	High	Increase in flood flow and level due to mine closure	High	Local	Permanent	Infrequent	High	Major
Post closure (Yr >57)	Flood risk through Shtuka under climate change	High	Increase in flood flow and level due to mine closure and climate change	High	Local	Permanent	Infrequent	High	Major
Construction (Yr-1)	Flood risk on Shtuka River at Sekirnik road bridge	High	Decrease in flood flow and level due to mine construction	Negligible (+)	Local	Short-term	Infrequent	Negligible	Negligible (+)
Operations (Yr 21)	Flood risk on Shtuka River at Sekirnik road bridge	High	Decrease in flood flow and level due to mine operations	Low (+)	Local	Medium-term	Infrequent	Negligible	Negligible (+)
Closure (Yr 27)	Flood risk on Shtuka River at Sekirnik road bridge	High	Increase in flood flow and level due to mine closure	High	Local	Permanent	Infrequent	High	Major
Post closure (Yr >57)	Flood risk on Shtuka River at Sekirnik road bridge	High	Increase in flood level and level due to mine closure and climate change	High	Local	Permanent	Infrequent	High	Major
Construction (Yr-1)	Shtuka River at Sekirnik road bridge	High	Decrease in Q95 and Q50 due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 2)	Shtuka River at Sekirnik road bridge	High	Decrease in Q95 and Q50 due to mine operations	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 7)	Shtuka River at Sekirnik road bridge	High	Decrease in Q95 and Q50 due to mine operations	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Shtuka River at Sekirnik road bridge	High	Decrease in Q95 and Q50 due to mine operations	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Shtuka River at Sekirnik road bridge	High	Decrease in Q95 and Q50 due to mine closure	Negligible	Local	Permanent	Frequent	Negligible	Negligible
Construction (Yr-1)	Suchica River at Suchica village intake	High	Increase in Q95 or Q50 due to mine construction	Negligible (+)	Local	Short-term	Frequent	Negligible (+)	Negligible (+)
Operations (Yr 21)	Suchica River at Suchica village intake	High	Increase in Q95 or Q50 due to mine operations	Negligible (+)	Local	Medium-term	Frequent	Negligible (+)	Negligible (+)
Closure (Yr 27)	Suchica River at Suchica village intake	High	Increase in Q95 or Q50 due to mine closure	Negligible (+)	Local	Medium-term	Frequent	Negligible (+)	Negligible (+)
Post closure	Suchica River at Suchica village intake	High	Increase in Q95 or Q50 due to mine closure	Negligible (+)	Local	Permanent	Frequent	Negligible (+)	Negligible (+)
Construction (Yr-1)	Turija River at Turnovo	Low	Decrease in contribution of Q50 in Jazga River to Q50 in Turija River at TJGS01 due to mine construction	Low	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Turija River at Turnovo	Low	Decrease in contribution of Q50 in Jazga River to Q50 in Turija River at TJGS01 due to mine construction	Low	Local	Medium-term	Frequent	Low	Negligible
Closure (Yr 27)	Turija River at Turnovo	Low	Decrease in contribution of Q50 in Jazga River to Q50 in Turija River at TJGS01 due to mine construction	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post pit lake (Yr >57)	Turija River at Turnovo	Low	Increase in contribution of Q50 in Jazga River to Q50 in Turija River at TJGS01 due to mine construction	Negligible (+)	Local	Permanent	Frequent	Negligible	Negligible (+)
Construction (Yr-1)	Strumica River at Sekirnik	Medium	Decrease in contribution of Q50 in Jazga River to Q50 in Strumica River at SMGS02 due to mine construction	Negligible	Regional	Short-term	Frequent	Negligible	Negligible

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Operations (Yr 21)	Strumica River at Sekirnik	Medium	Decrease in contribution of Q50 in Jazga River to Q50 in Strumica River at SMGS02 due to mine construction	Negligible	Regional	Medium-term	Frequent	Negligible	Negligible
Closure (Yr 27)	Strumica River at Sekirnik	Medium	Decrease in contribution of Q50 in Jazga River to Q50 in Strumica River at SMGS02 due to mine construction	Negligible	Regional	Medium-term	Frequent	Negligible	Negligible
Post pit lake (Yr >57)	Strumica River at Sekirnik	Medium	Increase in contribution of Q50 in Jazga River to Q50 in Strumica River at SMGS02 due to mine construction	Negligible (+)	Regional	Permanent	Frequent	Negligible	Negligible (+)
Construction (Yr-1)	Strumica River at Sekirnik	Medium	Decrease in contribution of Q50 in Shtuka River to Q50 in Strumica River at SMGS02 due to mine construction	Negligible	Regional	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Strumica River at Sekirnik	Medium	Decrease in contribution of Q50 in Shtuka River to Q50 in Strumica River at SMGS02 due to mine construction	Negligible	Regional	Medium-term	Frequent	Negligible	Negligible
Closure (Yr 27)	Strumica River at Sekirnik	Medium	Decrease in contribution of Q50 in Shtuka River to Q50 in Strumica River at SMGS02 due to mine construction	Negligible	Regional	Medium-term	Frequent	Negligible	Negligible
Construction (Yr-1)	Strumica River at Novo Selo gauge	Medium	Decrease in contribution of flow in Jazga River to flow in Strumica River at Novo Selo due to mine construction	Negligible	Regional	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Strumica River at Novo Selo gauge	Medium	Decrease in contribution of flow in Jazga River to flow in Strumica River at Novo Selo due to mine operation	Negligible	Regional	Medium-term	Frequent	Negligible	Negligible
Closure (Yr 27)	Strumica River at Novo Selo gauge	Medium	Decrease in contribution of flow in Jazga River to flow in Strumica River at Novo Selo due to mine closure	Negligible	Regional	Medium-term	Frequent	Negligible	Negligible
Post pit lake (Yr >57)	Strumica River at Novo Selo gauge	Medium	Increase in contribution of flow in Jazga River to flow in Strumica River at Novo Selo due to pit lake spilling	Negligible (+)	Regional	Permanent	Frequent	Negligible	Negligible (+)
Construction (Yr-1)	Groundwater levels at north Ilovica wells IB19, IB39 and Spring ISP41 (environmental and water supply security)	High	Decrease in groundwater level due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 2)	Groundwater levels at north Ilovica wells IB19, IB39 and Spring ISP41 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Operations (Yr 7)	Groundwater levels at north Ilovica wells IB19, IB39 and Spring ISP41 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Groundwater levels at north Ilovica wells IB19, IB39 and Spring ISP41 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Groundwater levels at north Ilovica wells IB19, IB39 and Spring ISP41 (environmental and water supply security)	High	Decrease in groundwater level due to mine post-closure	Negligible	Local	Permanent	Frequent	Negligible	Negligible
Construction (Yr-1)	Groundwater levels at south Ilovica well IB30 (environmental and water supply security)	High	Decrease in groundwater level due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 2)	Groundwater levels at south Ilovica well IB30 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 7)	Groundwater levels at south Ilovica well IB30 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Groundwater levels at south Ilovica well IB30 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Groundwater levels at south Ilovica well IB30 (environmental and water supply security)	High	Decrease in groundwater level due to mine post-closure	Negligible	Local	Permanent	Frequent	Negligible	Negligible
Construction (Yr-1)	Groundwater levels at Shtuka wells SB47, SB57 and Spring SSP49 (environmental and water supply security)	High	Decrease in groundwater level due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 2)	Groundwater levels at Shtuka wells SB47, SB57 and Spring SSP49 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 7)	Groundwater levels at Shtuka wells SB47, SB57 and Spring SSP49 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Groundwater levels at Shtuka wells SB47, SB57 and Spring SSP49 (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Post closure (Yr 27)	Groundwater levels at Shtuka wells SB47, SB57 and Spring SSP49 (environmental and water supply security)	High	Decrease in groundwater level due to mine post-closure	Negligible	Local	Permanent	Frequent	Negligible	Negligible
Construction (Yr-1)	Groundwater levels at irrigation borehole BH347 and Euromax Monitoring Borehole IC-15-113 between Ilovica and Turnovo (environmental and water supply security)	High	Decrease in groundwater level due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 2)	Groundwater levels at irrigation borehole BH347 and Euromax Monitoring Borehole IC-15-113 between Ilovica and Turnovo (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 7)	Groundwater levels at irrigation borehole BH347 and Euromax Monitoring Borehole IC-15-113 between Ilovica and Turnovo (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Groundwater levels at irrigation borehole BH347 and Euromax Monitoring Borehole IC-15-113 between Ilovica and Turnovo (environmental and water supply security)	High	Decrease in groundwater level due to mine operation	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Groundwater levels at irrigation borehole BH347 and Euromax Monitoring Borehole IC-15-113 between Ilovica and Turnovo (environmental and water supply security)	High	Decrease in groundwater level due to mine post-closure	Negligible	Local	Permanent	Frequent	Negligible	Negligible
		Options: Low Medium High Very High		**Options:** Negligible Low Moderate High	**Options:** Local Regional Beyond regional	**Options:** Short-term Medium-term Long-term Permanent	**Options:** Infrequent Frequent	**Options:** Negligible Low Moderate High	**Options:** Negligible Minor Moderate Major

Table 9-2 Residual impact classification matrix (Water Quantity)

Phase of the project	Receptor	Receptor sensitivity (if relevant)	Source of impact	Consequence classification before mitigation	Mitigation	Magnitude	Geographic Extent	Duration	Frequency	Residual impact classification	Residual impact consequence (only for ecological & social components)
Operations (Yr 21)	Jazga River at Ilovica water supply intake	High	Reduction in Q95 flow due to mine operations	Major	Replace Ilovica water distribution systems and permanently supply Ilovica from Ilovica WTW	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Closure (Yr 27)	Jazga River at Ilovica water supply intake	High	Reduction in Q95 flow due to mine closure	Major	Replace Ilovica water distribution systems and permanently supply Ilovica from Ilovica WTW	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Jazga River at Ilovica water supply intake	High	Increase in number of days Ilovica village is supplied by Ilovica WTW due to mine operations	Moderate	Replace Ilovica water distribution systems and permanently supply Ilovica from Ilovica WTW	Negligible	Local	short-term	Infrequent	Negligible	Negligible
Closure (Yr 27)	Jazga River at Ilovica water supply intake	High	Increase in number of days Ilovica village is supplied by Ilovica WTW due to mine closure	Moderate	Replace Ilovica water distribution systems and permanently supply Ilovica from Ilovica WTW	Negligible	Local	short-term	Infrequent	Negligible	Negligible
Operations (Yr 21)	Jazga River at gauging station JZGS01	High	Reduction in wetted perimeter due to mine operations	Major	None	High	Local	Medium-term	Frequent	High	Major
Closure (Yr 27)	Jazga River at gauging station JZGS01	High	Reduction in wetted perimeter due to mine closure	Major	None	High	Local	Medium-term	Frequent	High	Major
Operations (Yr 21)	Ilovica reservoir	High	Reduction to mean reservoir water level due to modified abstraction management affecting ecology	Moderate	Modify reservoir operating rules and associated water resource operations.	Low	Local	Medium-term	Frequent	Low	Minor
Closure (Yr 27)	Ilovica reservoir	High	Reduction in average return period of supply failure	Major	Supply Ilovica WTW from Turija reservoir	Negligible	Local	Permanent	Infrequent	Negligible	Negligible
Operations (Yr 21)	Jazga River downstream of Ilovica reservoir	Medium	Reduction in Q95 inflow due to mine operations	Moderate	None	High	Local	Medium-term	Frequent	High	Moderate
Closure (Yr 27)	Flood risk through Shtuka	High	Increase in flood flow and level	Major	Design TMF storm water dam to provide flood attenuation upstream of Shtuka village	Moderate (to be modelled)	Local	Short-term	Infrequent	Low	Minor (to be modelled)
Post closure (Yr 100)	Flood risk through Shtuka	High	Increase in flood flow and level under climate change	Major	Design TMF storm water dam to provide flood attenuation upstream of Shtuka village	Moderate (to be modelled)	Local	Short-term	Infrequent	Low	Minor (to be modelled)
Closure (Yr 27)	Flood risk on Shtuka River at Sekirnik road bridge	High	Increase in flood flow and level	Major	Design TMF storm water dam to provide flood attenuation upstream of Shtuka village	Moderate (to be modelled)	Local	Short-term	Infrequent	Low	Minor (to be modelled)

Phase of the project	Receptor	Receptor sensitivity (if relevant)	Source of impact	Consequence classification before mitigation	Mitigation	Magnitude	Geographic Extent	Duration	Frequency	Residual impact classification	Residual impact consequence (only for ecological & social components)
Post closure (Yr 100)	Flood risk on Shtuka River at Sekirnik road bridge	High	Increase in flood level and level under climate change	Major	Design TMF storm water dam to provide flood attenuation upstream of Shtuka village	Moderate (to be modelled)	Local	Short-term	Infrequent	Low	Minor (to be modelled)

Table 9-3 Impact classification matrix (Water Quality)

Phase of the project	Receptor (assessment location)	Receptor sensitivity (if relevant)	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence (only for ecological & social components)
Operations (Yr 21)	Jazga River at Ilovica water supply intake	High	Reduction in water quality due to mine operations assuming bedrock under oxide stockpile and seepage pond is fractured and groundwater interacts with surface water	High	Local	Medium-term	Frequent	High	Major
Post pit lake (Yr 57)	Jazga River at Ilovica water supply intake	High	Reduction in water quality due to pit lake spilling	High	Local	Permanent	Frequent	High	Major
Operations (Yr 21)	Ilovica reservoir	High	Reduction in water quality due to mine operations assuming bedrock under oxide stockpile is fractured and groundwater interacts with surface water	High	Local	Medium-term	Frequent	High	Major
Post pit lake (Yr 57)	Ilovica reservoir	High	Reduction in water quality due to pit lake spilling	High	Local	Permanent	Frequent	High	Major
Operations (Yr 21)	Treska River[6]	High	Reduction in water quality due to oxide stockpile seepage	Low	Local	Medium-term	Frequent	Low	Minor
Construction (Yr -1)	Jazga River at Radovo	Moderate	Reduction in water quality due to mine construction	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations (Yr 21)	Jazga River at Radovo	Moderate	Reduction in water quality due to mine operations	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Post pit lake (Yr 57)	Jazga River at Radovo	Moderate	Reduction in water quality in post closure	Moderate	Local	Permanent	Frequent	High	Major
Construction (Yr -1)	Shtuka River at Shtuka water supply intakes	High	Reduction in water quality due to mine construction	Moderate	Local	Short-term	Frequent	Moderate	Moderate
Operations (Yr 21)	Shtuka River at Shtuka water supply intakes	High	Reduction in water quality due to mine operations	High	Local	Medium-term	Frequent	High	Major
Post pit lake (Yr 57)	Shtuka River at Shtuka water supply intakes	High	Reduction in water quality due to seepage from TMF in closure	High	Local	Permanent	Frequent	High	Major
Operations (Yr 21)	Shtuka River at Sekirnik road bridge	Moderate	Reduction in water quality due to mine operations	High	Local	Medium-term	Frequent	High	Major
Post closure (Yr 57)	Shtuka River at Sekirnik road bridge	Moderate	Reduction in water quality in post closure	High	Local	Permanent	Frequent	High	Major
Construction (Yr-1)	Sushica River at Sushica village intake	High	Change in water quality due to mine construction	Low	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Sushica River at Sushica village intake	High	Change in water quality due to mine operations	Low	Local	Medium-term	Frequent	Low	Low
Closure (Yr 24)	Sushica River at Sushica village intake	High	Change in water quality due to mine closure	Low	Local	Medium-term	Frequent	Low	Low
Post closure (Yr 57)	Sushica River at Sushica village intake	High	Change in water quality due to mine closure	Low	Local	Long-term	Frequent	Low	Low
Construction (Yr -1)	Turija River at Turnovo	Moderate	Reduction in water quality due to mine construction	Low	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Turija River at Turnovo	Moderate	Reduction in water quality due to mine operations	Low	Local	Medium-term	Frequent	Low	Minor
Post closure (Yr 27)	Turija River at Turnovo	Moderate	Reduction in water quality in post closure	Low	Local	Permanent	Frequent	Moderate	Minor
Construction (Yr -1)	Strumica River at Sekirnik	Moderate	Reduction in water quality due to mine construction	Low	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Strumica River at Sekirnik	Moderate	Reduction in water quality due to mine operations	Low	Local	Medium-term	Frequent	Low	Minor

[6] Within the local study area there is a small tributary to the Jazga River, known locally as the Treska River, which flows directly into Ilovica Reservoir. This small river system should not be confused with the much larger Treska River located within the Vardar catchment.

Post closure (Yr 27)	Strumica River at Sekirnik	Moderate	Reduction in water quality in post closure	Low	Local	Permanent	Frequent	Moderate	Minor
All	Strumica River at Novo Selo	Negligible	Reduction in water quality in construction, operations and closure	Low	Local	Permanent	Frequent	Negligible	Negligible
Construction (Yr -1)	Village water supply wells in Ilovica and Shtuka and irrigation wells between Ilovica and Turnovo	High	Reduction in water quality due to mine construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Village water supply wells in Ilovica and Shtuka and irrigation wells between Ilovica and Turnovo	High	Reduction in water quality due to mine operations	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Post closure (Yr 27)	Village water supply wells in Ilovica and Shtuka and irrigation wells between Ilovica and Turnovo	High	Reduction in water quality in post closure	Negligible	Local	Long-term	Frequent	Negligible	Negligible
Post pit lake (Yr 57)	Village water supply wells in Ilovica and Shtuka and irrigation wells between Ilovica and Turnovo	High	Reduction in water quality due to pit lake spilling	Negligible	Local	Permanent	Frequent	Negligible	Negligible
		Options: Low Moderate High Very High		**Options:** Negligible Low Moderate High	**Options:** Local Regional Beyond regional	**Options:** Short-term Medium-term Long-term Permanent	**Options:** Infrequent Frequent	**Options:** Negligible Low Moderate High	**Options:** Negligible Minor Moderate Major

Table 9-4 Residual impact classification matrix (Water Quality)

Phase of the project	Receptor	Receptor sensitivity (if relevant)	Source of impact	Consequence classification before mitigation	Mitigation	Magnitude	Geographic Extent	Duration	Frequency	Residual impact classification	Residual impact consequence (only for ecological & social components)
Operations (Yr 21)	Jazga River at Ilovica water supply intake	High	Reduction in water quality due to mine operations assuming bedrock under oxide stockpile is fractured and groundwater interacts with surface water	Major	Due to water quality impacts and economic considerations the oxide stockpile is no longer proposed as part of the project.	Negligible (ecology) Negligible (water supply security)	Local	Medium-term	Frequent	Negligible (ecology) Negligible (water supply security)	Negligible (ecology) Negligible (water supply security)
Post pit lake (Yr 57)	Jazga River at Ilovica water supply intake	High	Reduction in water quality due to pit lake spilling	Major	Pit lake overflow will be collected and piped to a treatment plant where the pH will be neutralised and metal concentrations will be reduced.	Negligible (ecology) Negligible (water supply security)	Local	Permanent	Frequent	Negligible (ecology) Negligible (water supply security)	Negligible (ecology) Negligible (water supply security)
Operations (Yr 21)	Ilovica reservoir	High	Reduction in water quality due to mine operations assuming bedrock under oxide stockpile is fractured and groundwater interacts with surface water	Major	Due to water quality impacts and economic considerations the oxide stockpile is no longer proposed as part of the project.	Negligible (ecology) Negligible (water supply security)	Local	Medium-term	Frequent	Negligible (ecology) Negligible (water supply security)	Negligible (ecology) Negligible (water supply security)
Post pit lake (Yr 57)	Ilovica reservoir	High	Reduction in water quality due to pit lake spilling	Major	Pit lake overflow will be collected and piped to a treatment plant where the pH will be neutralised and metal concentrations will be reduced.	Negligible (ecology) Negligible (water supply security)	Local	Permanent	Frequent	Negligible (ecology) Negligible (water supply security)	Negligible (ecology) Negligible (water supply security)
Construction (Yr -1)	Jazga River at Radovo	Medium	Reduction in water quality due to mine construction causing decrease in flow combined with baseline pollutant load from Ilovica village	Moderate	Management of Ilovica reservoir during construction and operations to mimic baseline water level behaviour. The exact water levels will be determined during detailed design.	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations (Yr 21)	Jazga River at Radovo	Medium	Reduction in water quality due to mine operations causing decrease in flow combined with baseline pollutant load from Ilovica village	Moderate		Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Post pit lake (Yr 57)	Jazga River at Radovo	Medium	Reduction in water quality due to pit lake spilling combined with baseline pollutant load from Ilovica village	Major	Pit lake overflow will be collected and piped to a treatment plant where the pH will be neutralised and metal concentrations will be reduced.	Negligible	Local	Permanent	Frequent	Low	Negligible
Construction (Yr -1)	Shtuka River at Shtuka water supply intakes	High	Reduction in water quality due to mine construction	Moderate	A Storm Water Dam to control poor quality water and sediment will be constructed downstream of the TMF embankment prior to stripping of the TMF area and placement of any waste rock for the TMF embankment. Appropriate management (capture and re-use) of runoff and seepage in Storm Water Dam	Low (Ecology)	Local	Short-term	Frequent	Low (Ecology)	Negligible (Ecology)
					The water supply distribution network in Shtuka will be replaced by the Municipality of Bosilovo in response to the poor quality of water already in supply to Shtuka residents (the existing supply network is likely to be contaminated with sediment and bacteria). EOX will support the municipality in the replacement of the water supply distribution network in Shtuka and Shtuka residents will be permanently connected to the treated water supply system. Euromax will also investigate options for the 5% of households identified in the baseline where the irrigation system does not reach, with the possibility of extending the existing irrigation supply pipe network owned and operated by SPWMC to supply those in Shtuka who 'have need' for irrigation water from Ilovica reservoir. Shtuka water supply intakes will be abandoned.	Negligible (water supply security)	Local	Medium-term	Frequent	Negligible (water supply security)	Negligible (water supply security)

Operations (Yr 21)	Shtuka River at Shtuka water supply intakes	High	Reduction in water quality due to mine operations	Major	Re-evaluation of contaminant containment will be undertaken. This will include: - At detailed design stage, assess the feasibility (both volumes and timings) for encapsulating ARD producing material. - At detailed design stage ensure the seepage pond downstream of the TMF is designed to collect all groundwater seepage from the TMF. - At detailed design stage, evaluate the consolidation of tailings and re-assess potential seepage rates and pathways. In addition, (i) complete a comprehensive water balance analysis of the TMF to better define seepage volumes from the TMF throughout the TMF life and (ii) model the reduction in seepage post closure. - At detailed design stage, re-evaluate the seepage results from the geochemistry once all tailings laboratory analyses are complete and more comprehensive seepage volumes are evaluated in the updated water balance. - If water quality results during operations are monitored at the predicted quality in the EIA, Euromax Resources will ensure that poor quality water is captured and actively treated to ensure acceptable water quality prior to discharge.	Low (Ecology)	Local	Medium-term	Frequent	Low (Ecology)	Low (Ecology)
					The water supply distribution network in Shtuka will be replaced by the Municipality of Bosilovo in response to the poor quality of water already in supply to Shtuka residents (the existing supply network is likely to be contaminated with sediment and bacteria). EOX will support the municipality in the replacement of the water supply distribution network in Shtuka and Shtuka residents will be permanently connected to the treated water supply system. Euromax will also investigate options for the 5% of households identified in the baseline where the irrigation system does not reach, with the possibility of extending the existing irrigation supply pipe network owned and operated by SPWMC to supply those in Shtuka who 'have need' for irrigation water from Ilovica reservoir. Shtuka water supply intakes will be abandoned.	Negligible (water supply security)	Local	Medium-term	Frequent	Negligible (water supply security)	Negligible (water supply security)
Closure (Yr 24)	Shtuka River at Shtuka water supply intakes	High	Reduction in water quality due to mine closure	Major	Re-evaluation of contaminant containment will be undertaken. This will include: - At detailed design stage, assess the feasibility (both volumes and timings) for encapsulating ARD producing material. - At detailed design stage ensure the seepage pond downstream of the TMF is designed to collect all groundwater seepage from the TMF. - At detailed design stage, evaluate the consolidation of tailings and re-assess potential seepage rates and pathways. In addition, (i) complete a comprehensive water balance analysis of the TMF to better define seepage volumes from the TMF throughout the TMF life and (ii) model the reduction in seepage post closure. - At detailed design stage, re-evaluate the seepage results from the geochemistry once all tailings laboratory analyses are complete and more comprehensive seepage volumes are evaluated in the updated water balance. - If water quality results at closure are monitored at the predicted quality in the ESIA, Euromax Resources will explore passive treatment, but if not viable seepage from the TMF will be actively treated in perpetuity.	Low (Ecology)	Local	Permeant	Frequent	Low (Ecology)	Low (Ecology)
					The water supply distribution network in Shtuka will be replaced by the Municipality of Bosilovo in response to the poor quality of water already in supply to Shtuka residents (the existing supply network is likely to be contaminated with sediment and bacteria). EOX will support the municipality in the replacement of the water supply distribution network in Shtuka and Shtuka residents will be permanently connected to the treated water supply system. Euromax will also investigate options for the 5% of households identified in the baseline where the irrigation system does not reach, with the possibility of extending the existing irrigation supply pipe network owned and operated by SPWMC to supply those in Shtuka who 'have need' for irrigation water from Ilovica reservoir. Shtuka water supply intakes will be abandoned.	Negligible (water supply security)	Local	Permanent	Frequent	Negligible (water supply security)	Negligible (water supply security)
Operations (Yr 21)	Shtuka River at Sekirnik road bridge	Medium	Reduction in water quality due to mine operations	Major	Re-evaluation of contaminant containment will be undertaken. This will include: - At detailed design stage, assess the feasibility (both volumes and timings) for encapsulating ARD producing material. - At detailed design stage ensure the seepage pond downstream of the TMF is designed to collect all groundwater seepage from the TMF. - At detailed design stage, evaluate the consolidation of tailings and re-assess potential seepage rates and pathways. In addition, (i) complete a comprehensive water balance analysis of the TMF to better define seepage volumes from the TMF throughout the TMF life and (ii) model the reduction in seepage post closure. - At detailed design stage, re-evaluate the seepage results from the geochemistry once all tailings laboratory analyses are complete and more comprehensive seepage volumes are evaluated in the updated water balance. - If water quality results during operations are monitored at the predicted quality in the EIA, Euromax Resources will ensure that poor quality water is captured and actively treated to ensure acceptable water quality prior to discharge.	Low (Ecology)	Local	Medium-term	Frequent	Low (Ecology)	Low (Ecology)

Closure (Yr 24)	Shtuka River at Sekirnik road bridge	Medium	Reduction in water quality in post closure	Major	Re-evaluation of contaminant containment will be undertaken. This will include: - At detailed design stage, assess the feasibility (both volumes and timings) for encapsulating ARD producing material. - At detailed design stage ensure the seepage pond downstream of the TMF is designed to collect all groundwater seepage from the TMF. - At detailed design stage, evaluate the consolidation of tailings and re-assess potential seepage rates and pathways. In addition, (i) complete a comprehensive water balance analysis of the TMF to better define seepage volumes from the TMF throughout the TMF life and (ii) model the reduction in seepage post closure. - At detailed design stage, re-evaluate the seepage results from the geochemistry once all tailings laboratory analyses are complete and more comprehensive seepage volumes are evaluated in the updated water balance. If water quality results at closure are monitored at the predicted quality in the ESIA, Euromax Resources will explore passive treatment, but if not viable seepage from the TMF will be actively treated in perpetuity.	Low (Ecology)	Local	Long-term	Frequent	Low (Ecology)	Low (Ecology)

10 REPORT LIMITATIONS

This report has been prepared for the specific purpose identified herein at the request of and for the use of the Client. Observations, conclusions, and recommendations contained herein are opinions based upon the scope of services, information obtained through observations and measurements taken by Schlumberger Water Services at certain points and certain times, and interpretation and extrapolation of secondary information from published and unpublished material. The report may infer the configuration of strata, ground, and groundwater conditions both between data points and below the maximum depth of investigation. The report also may deduce temporal trends and averages for climatic, hydrological, and water quality parameters. Such interpretations and extrapolations are only indicative and no liability is accepted for variations between the opinions expressed herein and conditions that may be identified at a later date through direct measurement and observation.

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Should any information contained in this report be used by any unauthorized third parties, it is done so at their own risk.

APPENDIX A: WASTE SCHEDULE OVER LIFE OF MINE BY ARD CODE

Year	Period	none	DACMIX	DACMIXSW	DACOX	DACOXSW	DACUNOXSW	DACUNOXUD	GNDIONON	GDUNOXSW	GNDIOCA	GNDIOCAMIX	GNDIOMIX	GNDIOMIXSW	GNDIONONMIX	GNDIONONOX	GNDIONONSW	GNDIOOXLOWER	GNDIOOXUPPER	GNDIOUNOX	GRTAL	GRTALOX	GRTMIX	GRTNON	Total
		No classification	Dacite mixed	Dacite mixed stockwork	Daciteoxidised	Dacite oxidised stockwork	Dacite unoxidised stockwork	Dacite unoxidised undisturbed	Granodiorite nontronite	Granodiorite unoxidised stockwork	Granodiorite carbonate unoxidised	Granodiorite carbonate mixed zone	Granodiorite mixed zone	Granodiorite mixed, stockwork	Granodiorite nontronite, mixed	Granodiorite nontronite oxidised	Granodiorite nontronite stockwork	Granodiorite oxidised below 10 m depth of oxide layer	Granodiorite oxidised, above 10m depth of oxide layer	Granodiorite unoxidised	Granite altered unoxidised	Granite altered oxidised	Granite mixed	Granite nontronite	
-1	1	439068	0	0	2815559	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18191	0	0	3272818
	2	202894	0	0	2791543	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	278381	0	0	3272818
	3	132116	0	0	2840201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300502	0	0	3272819
	4	193048	0	0	2995626	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	84144	0	0	3272819
1	5	717446	14565	9665	1114331	1737	0	6161	2160	428	0	102	122326	11412	17427	4189	0	274660	448152	5019	411	0	2001	0	2752191
	6	301070	0	0	0	0	0	0	44658	0	0	1161	443325	149365	82564	0	0	996765	728059	5225	0	0	0	0	2752191
	7	701072	73613	17289	1204041	3772	0	21410	5023	0	0	15542	154575	59334	7462	0	0	248523	180061	2835	209	46137	11294	0	2752193
	8	453713	121950	35175	1565541	26407	2922	26526	885	800	147	583	80225	35091	22991	0	0	153420	178688	4443	5291	143	22155	0	2737097
2	9	378929	127676	17805	1482208	24155	8606	13320	34572	0	3917	3176	56566	5059	15257	0	0	135671	223092	9709	4405	12155	17182	0	2573460
	10	252780	67386	27448	9100	45373	2851	33524	163940	953	75918	0	305413	287051	274607	0	0	449863	336117	85079	0	88413	67644	0	2573460
	11	368677	89576	19564	1241155	5014	13321	10383	27591	644	16573	5292	67956	82880	49805	0	1914	276601	187235	22483	3616	71240	11940	0	2573460
	12	456931	0	0	0	0	0	0	617706	0	236570	155410	104009	57878	58210	0	0	42366	182904	187054	20557	302884	150982	0	2573460
3	13	263654	130618	19591	1440689	5123	27250	26113	11220	1665	516	5752	41438	55672	21430	0	11184	224002	72596	18858	0	194111	1980	0	2573460
	14	59854	202594	149300	1739369	33337	83	218615	411	0	3552	440	0	0	0	0	0	770	0	5123	23027	113230	23756	0	2573460
	15	17168	365088	407570	500005	20253	120851	859520	0	0	0	0	0	0	0	0	0	29968	0	2487	70679	179628	243	0	2573460
	16	14393	358084	336608	414427	4378	144206	627424	0	0	0	0	38009	0	0	0	0	179845	2218	78953	127924	236370	10620	0	2573460
4	17	33488	238356	419335	272368	22643	441158	670536	0	2880	0	0	108738	1576	0	0	0	39400	18147	162361	98348	1970	42156	0	2573460
	18	12255	294695	69981	162278	570	395143	714047	0	35105	0	0	134136	0	0	0	0	154751	19697	437494	96083	47225	0	0	2573460
	19	3643	143102	194470	45182	35023	183171	1132831	0	68949	0	0	130973	0	0	0	0	190795	15001	368538	45754	16031	0	0	2573460
	20	14557	80945	72799	8491	33158	550754	1549807	0	20129	0	0	2360	0	0	0	0	173646	18290	43646	4876	0	0	0	2573460
5	21	12222	33066	19262	0	0	155395	1572410	0	0	0	0	282994	42126	0	0	0	341563	35140	79281	0	0	0	0	2573460
	22	35791	0	0	0	0	35033	1175241	7354	0	0	0	201859	80978	0	0	0	600678	135296	281346	0	19884	0	0	2573460
	23	0	0	0	0	0	285826	353465	154063	40564	0	0	19201	298426	49669	0	113845	682639	283521	112820	0	179422	0	0	2573460
	24	63322	0	0	0	0	6770	2234	0	0	0	0	22382	611756	222411	0	215261	136340	159712	145201	0	988071	0	0	2573460
6	25	406801	0	0	0	0	0	65530	121655	313672	0	0	203568	18525	38228	0	109933	440528	482178	372842	0	0	0	0	2573460
	26	221784	0	0	0	0	0	0	214067	0	0	0	295084	52253	166110	0	0	183870	142630	126209	0	1171452	0	0	2573460
	27	130136	0	0	0	0	4187	121687	588758	0	95363	175953	21879	90725	0	0	0	92887	0	12864	0	1171673	67349	0	2573460
	28	274765	0	0	0	0	0	0	767485	0	190794	1922	0	0	0	0	0	0	0	136152	129870	542913	529644	0	2573545
7	29	424806	289211	119043	1668583	75291	304605	694841	104402	8235	275933	50470	81627	136357	37060	0	20616	372245	139985	270868	285929	1286375	138007	0	6784488
8	30	406520	273191	200483	2099723	84165	271972	687738	45292	7634	694359	19817	42430	133872	32383	0	15069	289961	134440	384174	705283	1383037	270755	0	8182297
9	31	442738	321554	281960	2416784	157162	507547	906178	86094	15389	614970	7540	30887	92047	16255	0	13556	307170	74076	392363	1071844	2266848	385147	5619	10413727
10	32	197195	68589	221284	1092599	141603	304498	468390	25108	49187	751649	5948	15686	50842	27807	0	34598	215207	73495	215540	943190	1810556	338838	7331	7059139
11	33	535204	330501	471743	2586210	283086	625191	1225470	15994	45608	538094	8601	26435	68949	53249	0	60888	556486	48373	220426	1605782	2659071	520186	4029	12489577
12	34	574249	73072	536155	3266663	420992	172414	526038	14044	84075	386123	0	28089	51551	14981	0	19214	476107	9228	261570	1872765	3540071	704870	1395	13033665
13	35	81895	0	0	0	0	570890	141702	474371	268578	101927	0	4849	0	3382	0	561978	0	0	56013	409959	561927	205099	86249	3528820
14	36	372579	221275	337206	2403647	223530	559272	849168	80742	291089	308573	6881	15790	13647	16983	0	209304	118566	20676	50680	1460225	1880798	477578	27529	9945738
15	37	399790	169522	414528	3664214	450014	592974	639929	185638	162759	169599	2493	9828	25091	36656	0	315926	98993	23481	25904	872634	1522691	359622	44142	10186430
16	38	269232	125757	289619	2909376	245255	450165	635028	275211	174990	113314	150	4159	17703	15792	0	760272	49111	7216	21739	1665456	1751865	479746	125219	10386375
17	39	421272	18977	312238	3220179	441371	523864	470590	514808	167920	206373	16169	12443	16271	84343	0	1191285	53548	167032	65628	1579049	1969309	651038	587310	12691015
18	40	220551	143733	437555	4477779	364564	887857	923389	386241	270145	295033	132	4816	19627	1993	0	1202444	12534	126	50960	924865	1232400	319338	303830	12479911
19	41	107949	0	6606	0	0	643302	182677	452993	118791	0	0	0	32579	0	0	4223409	2547	0	83429	136266	997911	110799	96952	7196210
20	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	10615557	4376697	5444280	52447871	3147974	8792076	17551921	5422487	2150190	5079295	483534	3114056	2598643	1367052	4189	9080696	8602027	4546863	4805318	14164295	28927027	5917969	1289606	199931624

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Annex 5C: Supporting Information to the Sediment Impact Assessment

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Table 1: Impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence
Construction	Jazga River - downstream of the open pit, upstream of the reservoir (JZGS01)	n/a	Stripping of prestrip area in pit	Low	Local	Medium-term	Frequent	Low	n/a
	Jazga River - downstream of Ilovica Reservoir and Ilovica village (JZGS03)	n/a	Stripping of prestrip area in pit	Negligible	Local	Medium-term	Frequent	Negligible	n/a
	Shtuka River - downstream of TMF and diversion (STGS01)	n/a	TMF stripping and construction	Moderate	Local	Medium-term	Frequent	Moderate	n/a
	Shtuka River - downstream of TMF and diversion (STGS02)	n/a	TMF stripping and construction	Moderate	Local	Medium-term	Frequent	Moderate	n/a
	Strumica River – downstream of mine area	n/a	TMF stripping and construction	Low	Beyond regional	Medium-term	Frequent	Low	n/a
Operations	Shtuka, Jazga and Strumica	n/a	Mine site	Negligible	Beyond regional	Medium-term	Frequent	Negligible	n/a
Closure	Shtuka, Jazga and Strumica	n/a	Mine site	Negligible	Beyond regional	Medium-term	Frequent	Negligible	n/a

Table 2: Residual impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact classification before mitigation	Mitigation	Magnitude	Geographic Extent	Duration	Frequency	Residual impact classification	Residual impact consequence
Construction	Jazga River - downstream of the open pit, upstream of the reservoir (JZGS01)	n/a	Stripping of prestrip area in pit	Low	Temporary pond/sump constructed in open pit prior to stripping	Negligible	Local	Medium term	Frequent	Negligible	n/a
	Shtuka River - downstream of TMF and diversion (STGS01)	n/a	TMF stripping and construction	Moderate	TMF sediment pond constructed prior to TMF stripping and construction	Negligible	Local	Medium term	Frequent	Negligible	n/a
	Shtuka River - downstream of TMF and diversion (STGS02)	n/a	TMF stripping and construction	Moderate	TMF sediment pond constructed prior to TMF stripping and construction	Negligible	Local	Medium term	Frequent	Negligible	n/a
	Strumica River – downstream of mine area	n/a	TMF stripping and construction	Low	TMF sediment pond constructed prior to TMF stripping and construction	Negligible	Beyond regional	Medium term	Frequent	Negligible	n/a

Annex 5D: Supporting Information to the Noise and Vibration Impact Assessment

April 2016
Report No. 13514150363.701/A.0

Blast Vibration Formulae

Ground-borne Vibration

The United States Bureau of Mines (USBM) established that ground vibration propagation from quarry blasts can be expressed by the following general equation:

$$V = k \cdot \left(\frac{R}{W^{\frac{1}{2}}} \right)^{b}$$

Equation 1

Where:
V = peak particle velocity, in millimetres per second;
R = distance from blast to monitoring point, in metres;
W = explosive charge weight per delay, in kilograms; and

AS 2187 specifies that, in the absence of site-specific constants, the following values for k and b may be used to estimate vibrations levels (50% probability of exceedance) in average conditions:

$$V = 1140 \cdot \left(\frac{R}{W^{\frac{1}{2}}} \right)^{-1.6}$$

Equation 2

As no site-specific measurement data were available, the AS 2187.2 constant has been used to calculate vibration levels.

Air Overpressure

To disturbance, a limit expressed as the 95th percentile of linear peak measurement of 115 dB_L has been adopted. The ICI Handbook of Blasting Tables (ICI, 1995) provides the following formula for estimation of airblast overpressure for unconfined surface charges:

$$P\ [dBL](5\%) = 165.3 - \log_{10}\left(\frac{D}{W^{\frac{1}{3}}} \right)$$

Equation 3

Where:

P = 95th percentile peak pressure (dBL);

D = distance from blast (m); and

W = charge mass per delay (kg)

Table 1: Impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence
Noise Impacts - Construction Phase; Mine and Access Road									
Construction	Ilovica village, daytime period	High	Access road construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, evening period	High	Access road construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, night-time period	High	Access road construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, daytime period	High	Mine & access road option 1	Moderate	Local	Short-term	Frequent	Low	Minor
Construction	Ilovica village, evening period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, night-time period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, daytime period	High	Mine & access road option 2	Moderate	Local	Short-term	Frequent	Low	Minor
Construction	Ilovica village, evening period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, night-time period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, daytime period	High	Access road construction	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Shtuka village, evening period	High	Access road construction	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Shtuka village, night-time period	High	Access road construction	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, daytime period	High	Mine & access road option 1	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Shtuka village, evening period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, night-time period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, daytime period	High	Mine & access road option 2	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Shtuka village, evening period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, night-time period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Access road construction, option 1	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Turnovo village, evening period	High	Access road construction, option 1	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Turnovo village, night-time period	High	Access road construction, option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Access road construction, option 2	Moderate	Local	Short-term	Frequent	Low	Minor
Construction	Turnovo village, evening period	High	Access road construction, option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, night-time period	High	Access road construction, option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, evening period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, night-time period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, evening period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, night-time period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Access road construction, option 1	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, evening period	High	Access road construction, option 1	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, night-time period	High	Access road construction, option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Access road construction, option 2	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, evening period	High	Access road construction, option 2	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, night-time period	High	Access road construction, option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, evening period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, night-time period	High	Mine & access road option 1	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Mine & access road option 2	Low	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, evening period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, night-time period	High	Mine & access road option 2	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Noise Impacts - Operations Phase; Mine and Access Road									
Operations	Ilovica village, daytime period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, evening period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, night-time period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, daytime period	High	Mine & access road option 2	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, evening period	High	Mine & access road option 2	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, night-time period	High	Mine & access road option 2	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Shtuka village, daytime period	High	Mine & access road option 1	High	Local	Medium-term	Frequent	High	Major
Operations	Shtuka village, evening period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Magnitude	Geographic Extent	Duration	Frequency	Impact classification	Consequence
Operations	Shtuka village, night-time period	High	Mine & access road option 1	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Shtuka village, daytime period	High	Mine & access road option 2	High	Local	Medium-term	Frequent	High	Major
Operations	Shtuka village, evening period	High	Mine & access road option 2	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Shtuka village, night-time period	High	Mine & access road option 2	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Turnovo village, daytime period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, evening period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, night-time period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, daytime period	High	Mine & access road option 2	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, evening period	High	Mine & access road option 2	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, night-time period	High	Mine & access road option 2	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, daytime period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, evening period	High	Mine & access road option 1	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, night-time period	High	Mine & access road option 1	High	Local	Medium-term	Frequent	High	Major
Operations	Sekirnik village, daytime period	High	Mine & access road option 2	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Sekirnik village, evening period	High	Mine & access road option 2	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Sekirnik village, night-time period	High	Mine & access road option 2	High	Local	Medium-term	Frequent	High	Major
Noise Impact - Operational Phase; Transport Route									
Operations	Novo Selo village, daytime period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Selo village, evening period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Selo village, night-time period	High	Transport Route Worst-Case	High	Local	Medium-term	Frequent	High	Major
Operations	Novo Selo village, daytime period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Selo village, evening period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Selo village, night-time period	High	Transport Route Best-Case	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Samuilovo village, daytime period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Samuilovo village, evening period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Samuilovo village, night-time period	High	Transport Route Worst-Case	High	Local	Medium-term	Frequent	High	Major
Operations	Samuilovo village, daytime period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Samuilovo village, evening period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Samuilovo village, night-time period	High	Transport Route Best-Case	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Novo Konjarevo village, daytime period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Konjarevo village, evening period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Konjarevo village, night-time period	High	Transport Route Worst-Case	High	Local	Medium-term	Frequent	High	Major
Operations	Novo Konjarevo village, daytime period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Konjarevo village, evening period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Konjarevo village, night-time period	High	Transport Route Best-Case	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Sekirnik village, daytime period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, evening period	High	Transport Route Worst-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, night-time period	High	Transport Route Worst-Case	High	Local	Medium-term	Frequent	High	Major
Operations	Sekirnik village, daytime period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, evening period	High	Transport Route Best-Case	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, night-time period	High	Transport Route Best-Case	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Vibration Impacts - All Phases									
All phases; high blast	Ilovica	High	Blasting	Moderate	Local	Short-term	Infrequent	Low	Minor
All phases; high blast	Shtuka	High	Blasting	Moderate	Local	Short-term	Infrequent	Low	Minor
All phases; high blast	Turnovo	High	Blasting	Low	Local	Short-term	Infrequent	Negligible	Negligible
All phases; high blast	Sekirnik	High	Blasting	Low	Local	Short-term	Infrequent	Negligible	Negligible
All phases; medium blast	Ilovica	High	Blasting	Moderate	Local	Medium-term	Infrequent	Low	Minor
All phases; medium blast	Shtuka	High	Blasting	Moderate	Local	Medium-term	Infrequent	Low	Minor
All phases; medium blast	Turnovo	High	Blasting	Low	Local	Medium-term	Infrequent	Negligible	Negligible
All phases; medium blast	Sekirnik	High	Blasting	Low	Local	Medium-term	Infrequent	Negligible	Negligible

Table 2: Residual impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact classification before mitigation	Mitigation	Magnitude	Geographic Extent	Duration	Frequency	Residual impact classification	Residual impact consequence
Noise Impacts - Construction Phase; Mine and Access Road											
Construction	Ilovica village, daytime period	High	Access road construction	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, evening period	High	Access road construction	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, night-time period	High	Access road construction	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, daytime period	High	Mine & access road option 1	Low	None	Moderate	Local	Short-term	Frequent	Low	Minor
Construction	Ilovica village, evening period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, night-time period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, daytime period	High	Mine & access road option 2	Low	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, evening period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Ilovica village, night-time period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, daytime period	High	Access road construction	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Shtuka village, evening period	High	Access road construction	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Shtuka village, night-time period	High	Access road construction	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, daytime period	High	Mine & access road option 1	Moderate	Acoustic Barrier	Moderate	Local	Short-term	Frequent	Low	Minor
Construction	Shtuka village, evening period	High	Mine & access road option 1	Negligible	Acoustic Barrier	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, night-time period	High	Mine & access road option 1	Negligible	Acoustic Barrier	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, daytime period	High	Mine & access road option 2	Moderate	Acoustic Barrier	Moderate	Local	Short-term	Frequent	Low	Minor
Construction	Shtuka village, evening period	High	Mine & access road option 2	Negligible	Acoustic Barrier	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Shtuka village, night-time period	High	Mine & access road option 2	Negligible	Acoustic Barrier	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Access road construction, option 1	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Turnovo village, evening period	High	Access road construction, option 1	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Turnovo village, night-time period	High	Access road construction, option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Access road construction, option 2	Low	None	Moderate	Local	Short-term	Frequent	Low	Minor
Construction	Turnovo village, evening period	High	Access road construction, option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Low	Negligible
Construction	Turnovo village, night-time period	High	Access road construction, option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, evening period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, night-time period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, daytime period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, evening period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Turnovo village, night-time period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Access road construction, option 1	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, evening period	High	Access road construction, option 1	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, night-time period	High	Access road construction, option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Access road construction, option 2	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, evening period	High	Access road construction, option 2	Moderate	None	High	Local	Short-term	Frequent	Moderate	Moderate
Construction	Sekirnik village, night-time period	High	Access road construction, option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, evening period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, night-time period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, daytime period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, evening period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Construction	Sekirnik village, night-time period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Short-term	Frequent	Negligible	Negligible
Noise Impacts - Operations Phase; Mine and Access Road											
Operations	Ilovica village, daytime period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, evening period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, night-time period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, daytime period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, evening period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Ilovica village, night-time period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact classification before mitigation	Mitigation	Magnitude	Geographic Extent	Duration	Frequency	Residual impact classification	Residual impact consequence
Operations	Shtuka village, daytime period	High	Mine & access road option 1	High	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Shtuka village, evening period	High	Mine & access road option 1	Negligible	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Shtuka village, night-time period	High	Mine & access road option 1	Moderate	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Shtuka village, daytime period	High	Mine & access road option 2	High	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Shtuka village, evening period	High	Mine & access road option 2	Negligible	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Shtuka village, night-time period	High	Mine & access road option 2	Moderate	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, daytime period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, evening period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, night-time period	High	Mine & access road option 1	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, daytime period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, evening period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Turnovo village, night-time period	High	Mine & access road option 2	Negligible	None	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, daytime period	High	Mine & access road option 1	Negligible	All HGVs in Daytime and Evening	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, evening period	High	Mine & access road option 1	Negligible	All HGVs in Daytime and Evening	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, night-time period	High	Mine & access road option 1	Major	All HGVs in Daytime and Evening	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, daytime period	High	Mine & access road option 2	Low	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, evening period	High	Mine & access road option 2	Moderate	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, night-time period	High	Mine & access road option 2	Major	All HGVs in Daytime and Evening and Acoustic Barrier	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Noise Impact - Operational Phase; Transport Route											
Operations	Novo Selo village, daytime period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Novo Selo village, evening period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Novo Selo village, night-time period	High	Transport Route Worst-Case	High	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Selo village, daytime period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Novo Selo village, evening period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Novo Selo village, night-time period	High	Transport Route Best-Case	Low	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Samuilovo village, daytime period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Samuilovo village, evening period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact classification before mitigation	Mitigation	Magnitude	Geographic Extent	Duration	Frequency	Residual impact classification	Residual impact consequence
Operations	Samuilovo village, night-time period	High	Transport Route Worst-Case	High	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Samuilovo village, daytime period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Samuilovo village, evening period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Low	Local	Medium-term	Frequent	Low	Minor
Operations	Samuilovo village, night-time period	High	Transport Route Best-Case	Low	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Konjarevo village, daytime period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Novo Konjarevo village, evening period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Novo Konjarevo village, night-time period	High	Transport Route Worst-Case	High	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Novo Konjarevo village, daytime period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Minor*
Operations	Novo Konjarevo village, evening period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Minor*
Operations	Novo Konjarevo village, night-time period	High	Transport Route Best-Case	Moderate	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, daytime period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Sekirnik village, evening period	High	Transport Route Worst-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Moderate
Operations	Sekirnik village, night-time period	High	Transport Route Worst-Case	High	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Operations	Sekirnik village, daytime period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Minor*
Operations	Sekirnik village, evening period	High	Transport Route Best-Case	Negligible	Run concentrate HGVs during daytime	Moderate	Local	Medium-term	Frequent	Moderate	Minor*
Operations	Sekirnik village, night-time period	High	Transport Route Best-Case	Moderate	Run concentrate HGVs during daytime	Negligible	Local	Medium-term	Frequent	Negligible	Negligible
Vibration Impacts - All Phases											
All phases; high blast	Ilovica	High	Blasting	Moderate	None	Moderate	Local	Short-term	Infrequent	Low	Minor
All phases; high blast	Shtuka	High	Blasting	Moderate	None	Moderate	Local	Short-term	Infrequent	Low	Minor
All phases; high blast	Turnovo	High	Blasting	Low	None	Low	Local	Short-term	Infrequent	Negligible	Negligible
All phases; high blast	Sekirnik	High	Blasting	Low	None	Low	Local	Short-term	Infrequent	Negligible	Negligible
All phases; medium blast	Ilovica	High	Blasting	Moderate	None	Moderate	Local	Medium-term	Infrequent	Low	Minor
All phases; medium blast	Shtuka	High	Blasting	Moderate	None	Moderate	Local	Medium-term	Infrequent	Low	Minor
All phases; medium blast	Turnovo	High	Blasting	Low	None	Low	Local	Medium-term	Infrequent	Negligible	Negligible
All phases; medium blast	Sekirnik	High	Blasting	Low	None	Low	Local	Medium-term	Infrequent	Negligible	Negligible

* Note: The baseline exceeds the noise limit at these receptors. The predicted increase over baseline during the daytime and evening periods, for best-case HGV movements on the M6 transport route will be 0.5 dB or less. Such an increase will be imperceptible, and these moderate impacts have therefore been adjusted to Minor.

Annex 5E: Supporting Information to the Air Quality Impact Assessment

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1.0 AIR DISPERSION MODELLING

1.1 Introduction

This report provides information on the air dispersion modelling (ADM) of atmospheric emissions from the mining and processing components of the Ilovica Gold-Copper project, conducted to support the air quality impact assessment.

The report is organised as follows:

- Section 1.2 describes the background to the assessment (modelling approach and scenario, baseline air quality, and the air quality standards (AQS) to be applied);
- Section 1.3 provides a general summary of the emission sources and rates;
- Section 1.4 describes the atmospheric pathways for pollutant transport;
- Section 1.5 describes the receptors used in the modelling;
- Section 1.6 presents the assessment of emissions at receptors;
- Section 1.7 details identified study limitations; and
- Section 1.6 provides study summary and conclusions.

This modelling assessment draws on information in the air quality baseline report (Annex 3 to the EIA) to establish existing baseline conditions.

1.2 Background

1.2.1 Modelling Approach and Scenario

This modelling study assesses air quality effects on human health and habitats due to expected air emissions from the future operations of the proposed Ilovica Gold-Copper Project (the Project). Ground level air pollutant concentrations and deposition rates are predicted based on detailed ADM using AERMOD (ADM software, version 7.9.1.45). Modelled emissions from the Project include gases (nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) as well as particulates (fine particulates (PM_{10}, $PM_{2.5}$)) and total suspended particles (TSP).

Ore and waste rock production rates are scheduled to peak in year 12 of operations with an annual ore production rate of 10 million tonnes per annum (Mt/yr) and an annual waste rock/low-grade ore production rate of 13 Mt/yr. The model scenario consider is based on year 12 emissions, based on a conservative approach, as it assesses the year of maximum production rates and associated operations. Project emissions in all other years would be expected to have lesser effects due to lesser production rates.

Project mining activities with potential air emissions were identified, quantified, and combined into a single area source in the model. The area source covers the extent of the mine concession area and includes the open pit mine, the processing plant, the tailings facility, all haul roads, the coarse ore stockpile and the oxide ore stockpile.

The ADM predicts the potential effect of emissions on air quality across the model domain (represented by a grid of points) and at sensitive human receptors. Sensitive human receptor locations considered in this assessment include the nearest villages to the mine, namely Ilovica, Shtuka, Turnovo, Sekirnik and Sushica.

The ADM predicts the process contribution (PC) to ambient air quality as a ground level concentration attributable to the modelled project source. For the assessment of human health for each pollutant considered, the ambient air PC concentration is added to the existing background concentration, to calculate the predicted environmental concentration (PEC). The PEC is then compared to the adopted Environmental Design Criteria (EDC) for the Project, which indicate the degree of environmental effect that can be considered acceptable for a particular pollutant at a human receptor.

For the assessment of habitats, the maximum ambient air PC concentrations for NOx and SO_2 predicted to occur anywhere in the modelled domain is added to the existing background concentration at the mining concession, to calculate the PEC. The latter is then compared to the adopted EDC for the Project, which indicate the degree of environmental effect that can be considered acceptable for NOx and SO_2 at habitats.

For the assessment of amenity loss (the adverse effect of a development on the quality of life at individuals in the vicinity) through dust deposition, the model is used to predict the maximum deposition to ground (based on TSP emissions) at the closest sensitive human receptors. The deposited dust rate is added to the existing background deposited dust levels and then compared to the adopted EDC for the Project, which indicate the degree of loss of amenity effect that can be considered acceptable for a particular emission at a relevant receptor.

The findings of this modelling study have been used in the air quality impact assessment (Section 5.6). Outputs have also been provided as input data to the geomorphology, soils and land use capability assessment (Section 5.1), biodiversity and ecology assessment (Section 5.7) and cultural heritage assessment (Section 5.8). In addition to a quantitative modelling approach to assess potential effects during operations, effects of mine construction and mine closure have been assessed qualitatively for the purpose of this EIA.

1.2.2 Project Adopted EDC

The EDC adopted for the Project are based on Air Quality Standards (AQS) and guidelines as detailed in the EDC (Annex 1). The EDC relevant to the ADM assessment are summarised in Tables 1, 2 and 3. Where the EDC has a number of exceedances that are allowed, results are calculated at the appropriate assessment percentile (%ile). For example, the 24 hour average (daily average) PM_{10} EDC states that the standard should be exceeded no more than 35 times (i.e. 35 days) per year, which equates to the 90.4 %ile (i.e. the number of 24 hours in a year is 365, (365-35)/365×100 = 90.41).

The EDC for the assessment of human health and habitats are taken from Macedonian and EU limit values. The EDC for loss of amenity caused by dust deposition are taken from TA Luft. EDC for the assessment of human health apply where human exposure to pollutants over the applicable averaging period may occur. The EDC for loss of amenity applies where soiling by dust deposition may impact on people. For both, human health and loss of amenity, such locations include villages in the vicinity of the mining concession such as Ilovica and Shtuka (see Section 1.5 of this Appendix). The EDC for habitats apply anywhere in the local biophysical study area.

Table 1: Summary of EDC adopted for human health

Emission	Time weighted average	Concentration ($\mu g/m^3$)	Assessment percentile (%ile)
NO_2	1 hour	200	99.79
	annual	40	100
SO_2	1 hour	350	99.73
	24 hours	125	99.18
PM_{10}	24 hours	50	90.41
	annual	40	100
$PM_{2.5}$	annual	20	100
CO	8 hours	10,000	100

Abbreviations: %ile = percentile; CO = carbon monoxide; $\mu g/m^3$ = micrograms per cubic metre; NO_2 = nitrogen dioxide; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

Table 2: Summary of EDC adopted for habitats

Emission	Time weighted average	Concentration (µg/m^3)	Assessment percentile (%ile)
SO_2	annual	20	100
NO_x	annual	30	100

Abbreviations: %ile = percentile; µg/m^3 = micrograms per cubic metre; EDC = environmental design criteria; NO_x = oxides of nitrogen; SO_2 = sulphur dioxide.

Table 3: Summary of EDC adopted for dust deposition

Emission	Time weighted average	Deposition (mg/m^2/day)	Assessment percentile (%ile)
TSP	annual mean	350	100

Abbreviations: mg/m^2/day = milligrams per square metre per day; TSP = total suspended particles.

1.2.3 Estimated Background Air Quality

Background ambient air concentrations and dust deposition were derived based on the findings of the air quality baseline study (Annex 3). Baseline monitoring has been undertaken at eight monitoring locations detailed in Table 4.

Table 4: Monitoring locations details

Name	Coordinates (UTM) Zone 34T		Elevation (masl)	Description of location
	Easting (m)	Northing (m)		
MKD1	654815	4595458	794	On-site meteorological station
MKD2	653654	4593950	556	On-site to south of the ore body, east of area of additional facilities to support mining operations.
MKD3	651907	4593759	326	Water treatment plant north-east of Ilovica village
MKD4	652069	4593073	349	East of Shtuka, close to route of proposed access road
MKD5	650998	4593018	277	South of Ilovica, close to the Turija canal
MKD6	649098	4590216	212	North-east of Turnovo centre
MKD7	650004	4589828	211	West of Sekirnik, close to the A4 road
MKD8	653555	4590536	250	North-west of Sushica

Abbreviations: m = metre; masl = metres above sea level.

Background ambient air concentrations for NO_2, SO_2 and NOx were derived based on diffusion tube monitoring results. The 11-monthly average concentrations for NOx, NO_2 and SO_2 at the various monitoring locations are presented in Table 5.

Table 5: 11-month average concentrations based on diffusion tube monitoring (µg/m^3)

Pollutant	MKD1	MKD2	MKD3	MKD4	MKD5	MKD6	MKD7	MKD8
NOx	7.34	7.08	8.80	9.31	11.53	12.12	16.50	9.73
NO2	1.49	2.11	3.17	3.61	7.05	6.78	9.96	4.95
SO2	1.91	2.03	1.34	1.62	1.50	1.31	1.32	1.62

Abbreviations: µg / m^3 = micrograms per cubic metre; NO_2 = nitrogen dioxide; NO_x = oxides of nitrogen; SO_2 = sulphur dioxide.

The 11-month average concentrations were used to estimate the annual average concentration for each pollutant, which can be directly compared to the applicable long-term annual average AQS.

The short-term air quality concentrations were calculated utilising the United Kingdom Environment Agency, H1 Annex F guidance document methodology (2011b). In the absence of any international methodology or guidance relating to this, the following assumptions were applied:

- The long-term annual average concentration is taken as the mean of the monthly monitored data;
- The annual average concentration x 2 = hourly average concentration;
- The hourly average concentration x 0.59 = 24 hour average concentration;
- The hourly average concentration x 0.7 = 8 hour average concentration;
- The hourly average concentration x 1.34 = 15 minute average concentration; and
- The hourly average concentration x 1.65 = 10 minute average concentration.

The data detailed in Table 6 presents the measured annual and estimated short-term average monitored concentrations for NO_x, NO_2 and SO_2 for each of the monitoring stations, which represent estimated background air quality concentrations.

Table 6: Estimated air quality background concentrations for NO_2, SO_2 and NO_x (µg/m^3)

Pollutant	Averaging Period	MKD1	MKD2	MKD3	MKD4	MKD5	MKD6	MKD7	MKD8
NO_2	1 hour	2.99	4.22	4.22	7.23	14.10	13.56	19.93	9.90
	annual	1.49	2.11	2.11	3.61	7.05	6.78	9.96	4.95
SO_2	1 hour	3.83	4.05	4.05	3.25	3.00	2.62	2.65	3.24
	24 hour	2.26	2.39	2.39	1.92	1.77	1.55	1.56	1.91
NO_x	annual	7.34	7.08	8.80	9.31	11.53	12.12	16.50	9.73

Abbreviations: µg / m^3 = micrograms per cubic metre; NO_2 = nitrogen dioxide; NO_x = oxides of nitrogen; SO_2 = sulphur dioxide.

For particulate matter (PM_{10} and $PM_{2.5}$), estimated background concentrations were based on the results of the OSIRIS dust monitoring from December 2013 to July 2014 and November 2014 to April 2015 at MKD3. OSIRIS dust monitoring at all other monitoring locations occurred over limited time periods only. For this reason the monitoring results are not deemed sufficiently representative to be used to derive background concentrations.

The average concentrations over the monitoring period were used to estimate an annual average concentration which can be directly compared to the applicable long-term annual average AQS for PM_{10} and $PM_{2.5}$. The short-term air quality concentrations were calculated following the methodology outlined above. The data detailed in Table 7 presents the annual average and estimated short-term average monitored concentrations for PM_{10} and $PM_{2.5}$ used as estimated background air quality at all receptor locations.

Table 7: Estimated air quality background concentrations for PM_{10} and $PM_{2.5}$ (µg/m^3)

Pollutant	Concentration (µg/m^3)
PM_{10} 24 hour	13.9948
PM_{10} annual	11.86
$PM_{2.5}$ annual	4.75

Abbreviations: µg/m^3 = micrograms per cubic metre; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns.

Carbon monoxide was not monitored as part of the baseline study. The estimated air quality background concentration was based on background air quality monitoring results reported in *Air quality assessment report. Air quality assessment of sulphur dioxide, nitrogen dioxide, nitrogen oxides, carbon monoxide,*

*particulate matter, ozone, lead, arsenic, nickel and cadmium concentrations in Republic of Macedonia (*Ministry of Environment and Physical Planning, 2012). Based on the reported maximum daily 8-hour mean within a calendar year of CO for the period 2005-2010 in the Eastern zone of Macedonia (including the east, north east, south east and Vardar statistical region), a conservative assumption of 2,000 µg/m^3 background concentrations was adopted for all receptor locations.

Deposited dust was sampled monthly using Frisbee type dust collection plates. Measured average background dust deposition rates at each monitoring location are shown in Table 8.

Table 8: Estimated background dust deposition (mg/m^2/day)

	MKD1	MKD2	MKD3	MKD4	MKD5	MKD6	MKD7	MKD8
TSP	28.51	25.49	28.79	26.59	28.35	87.84	64.66	54.99

Abbreviations: mg/m^2/day = milligrams per square metre per day; TSP = total suspended particles.

1.3 Project Emissions

Atmospheric emissions from project activities during mine operations can be categorised into two groups: mechanical processes and combustion processes. Mechanical processes emit most of the particulate emissions, including TSP, PM_{10} and $PM_{2.5}$. Mechanical processes include the extraction and handling of ore and waste rock, travel of traffic on unpaved roads, and wind erosion from stockpiles. Combustion processes emit most of the gaseous emissions, including NO_2, SO_2, and CO. Combustion processes include fuel combustion in vehicles and fuel combustion in mobile mining equipment as well as fuel combustion in the carbon regeneration kiln.

1.3.1 Emissions Identification

A review was undertaken of project activities to identify the potential for atmospheric emissions associated with each activity for year 12 of mine operations. Table 9 identifies each activity considered to have the potential for major air emissions and the associated pollutants emitted. These emissions were assessed quantitatively by ADM. Activities for year 12 of mine operations that were considered to have minor emissions and, therefore, minor effects were screened out and not included in the detailed modelling assessment. The potential effects of minor emissions have been considered in the qualitative assessment (Appendix 2).

Table 9: Potential emission sources and associated emissions included in the ADM analysis

Phase	Source area	Activity/Process	Emission
Operation	Ilovica mine area	Drilling	TSP, PM_{10}, $PM_{2.5}$
		Blasting	TSP, PM_{10}, $PM_{2.5}$, CO, NOx, SO_2
		Traffic on unpaved haul roads	TSP, PM_{10}, $PM_{2.5}$
		Material transfer (loading/unloading, conveyor belt transfers)	TSP, PM_{10}, $PM_{2.5}$
		Wind erosion	TSP, PM_{10}, $PM_{2.5}$
		Bulldozing	TSP, PM_{10}, $PM_{2.5}$
		Grading	TSP, PM_{10}, $PM_{2.5}$
		Ore processing	TSP, PM_{10}, $PM_{2.5}$
		Carbon regeneration	TSP, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO

Phase	Source area	Activity/Process	Emission
		Combustion emissions from on-site vehicles and mobile equipment.	TSP, PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO

Abbreviations: CO = carbon monoxide; NO_2 = nitrogen dioxide; NO_x = oxides of nitrogen; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide; TSP = total suspended particles.

1.3.2 Emission Quantification

Emissions from the mining operations were estimated using a combination of published data for mining activities and site specific information. Details of the methods used and input data to the calculations are provided in the following sections.

1.3.2.1 Activities and Sources Quantified by Emission Factors

1.3.2.1.1 TSP, PM_{10} and $PM_{2.5}$

Emission factor calculations to determine TSP, PM_{10} and $PM_{2.5}$ release for blasting, road traffic on unpaved roads, material transfer, wind erosion, bulldozing, and grading are based on the USEPA guidance document, Compilation of Air Pollution Emission Factors (AP-42) (USEPA 1992, 1995, 1998, 2006a, 2006b). These emission factors have the advantage of being calculated rather than default factors because they take into account variable inputs for which site-specific data can be used. If site-specific data for the variable inputs are not available, typical values can be obtained from the reference documents. The site-specific data used for the variables are summarised in Table 10.

Table 10: Site-specific data for variables used for emission factor calculations

Variable	Modelled source area
Silt content (%)	10
Ore moisture content (%)	3
Annual mean wind speed (m/s)	1.77
Number of days with rainfall ≥ 0.20 mm (n)	111
Percentage of time with wind speed > 5.4 m/s (%)	3.63
Horizontal blast area (m^2)	1,540
Speed limit within mining concession (km/hr)	50
Assumed typical speed of vehicles within mining concession (km/hr)	25

Abbreviations: % = percent; km/hr = kilometre per hour; m/s = metres per second; m^2 = square metre; n = number.

For the ore processing sources (primary crushing) AP-42 default emission factors for low-moisture ore were used (USEPA 1995). AP-42 defines low-moisture ore as an ore with a moisture content, as measured at the primary crusher inlet or at the mine, of less than 4% by weight. Because AP-42 does not have a relevant emission factor for drilling, the emission factor for this activity was taken from the National Pollutant Inventory (NPI) guidance document (Commonwealth of Australia 2012). Table 11 summarises the emission factors used for various activities and processes before mitigation.

Table 11: Summary of PM2.5, PM10, and TSP emission factors (before mitigation)

Activity	$PM_{2.5}$ emission	PM_{10} emission	TSP emission	Unit	Reference
Drilling	0.05	0.31	0.59	kg/hole	NPi (default)
Blasting	0.4	6.9	13.3	kg/blast	AP-42 (calculated)
Traffic on unpaved roads	0.097	0.97	3.3	kg/VKT	AP-42 (calculated)
Material transfer	0.000036	0.000239	0.000506	kg/t	AP-42 (calculated)

Activity	$PM_{2.5}$ emission	PM_{10} emission	TSP emission	Unit	Reference
Wind erosion	0.248497	1.656647	3.313294	kg/ha/day	AP-42 (calculated)
Bulldozing	1.04	2.29	9.88	kg/hr	AP-42 (calculated)
Grading	0.329	2.10	10.63	kg/VKT	AP-42 (calculated)
Ore processing - primary crushing	0.0030	0.020	0.200	kg/t	AP-42 (default)

Abbreviations: kg/blast = kilograms per blast; kg/hole = kilograms per hole; kg/hr = kilograms per hour; kg/day/hectare = kilograms per day per hectare; kg/t = kilograms per tonne; kg/VKT = kilogram per vehicle kilometre travelled; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10}= particulate matter less than or equal to 10 microns; TSP = total suspended particles.

Sources: USEPA (1992, 1995, 1998, 2006a, 2006b); Commonwealth of Australia (2012)

Emissions from some dust generating activities can be mitigated during mining operations (WRAP 2006, Commonwealth of Australia 2012). Table 12 details mitigation measures and efficiencies used in this assessment. The uncontrolled emission factor is assumed to be reduced by the mitigation efficiency factor.

Table 12: Particulate matter mitigation measures and efficiencies

Activity/Process	Mitigation measure	Mitigation efficiency (%)
Drilling	Water spray	50
Traffic on unpaved roads	Typical vehicle speed 25 km/hr. Water spray/dust suppressant	85
Material transfer – loading or unloading haul truck	-	0
Material transfer – loading or unloading of stock piles	Water spray	50
Material transfer – primary processing	Primary crusher scrubber	75
Material transfer – secondary processing	Reclaim dust extraction scrubber	75
Grading	Water spray	50
Ore processing – crushing	Primary crusher scrubber	75
Ore processing – grinding	Wet process	100
Wind erosion – conveyors	All conveyors fully covered	100

Abbreviations: % = percent; km/hr = kilometres per hour.

Sources: Commonwealth of Australia (2012), WRAP (2006)

1.3.2.1.2 CO, NO_x and SO_2

Emission factor calculations to determine CO, NOx and SO_2 release for blasting are based on the USEPA guidance document, Compilation of Air Pollution Emission Factors (AP-42), Chapter 13.3 Explosives Detonation (USEPA 1980). It is assumed that in year 12 of operations 2788t of ANFO (ammonium nitrate/fuel oil) will be used as explosive to facilitate blasting. Table 13 details the emission factors used to calculate CO, NO_x and SO_2 emissions from blasting.

Table 13: Emission factors for blasting fumes from ANFO

CO emissions (kg/t)	NO_x emissions (kg/t)	SO_2 emissions (kg/t)
34	8	1

Abbreviations: ANFO = ammonium nitrate/fuel oil explosive; CO = carbon monoxide; kg/t = kilogram per tonne; NO_x = oxides of nitrogen; SO_2 = sulphur dioxide.

Note: Emissions presented here do not include any mitigation.

1.3.2.2 Carbon Regeneration Kiln

Emission estimates for the carbon regeneration kiln were provided by Amec Foster Wheeler as detailed in Table 14.

Table 14: Carbon regeneration kiln emission estimates

	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$[1]	TSP[2]
Emission (tonnes/year)	22.0	19.2	9.3	0.62	0.62	0.65

Abbreviations: CO = carbon monoxide; NO_x = oxides of nitrogen; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide; TSP = total suspended particles.

Source: Amec Foster Wheeler (2015)

Notes: 1. As a conservative assumption PM2.5 was assumed to equal PM10 emissions.

2. Proportioning of particulates between TSP and PM10 for combustion emissions was based on the description of particle size categories for internal combustion engines using gasoline or diesel fuel provided within the AP-42 guidance (USEPA 1990).

3. Emission estimates presented here do not include any mitigation other than what was included in the project design. Emission estimates were provided by project engineers (Amec Foster Wheeler).

1.3.2.3 Mobile Equipment

Emission estimates for the emissions from mobile equipment were provided by Amec Foster Wheeler as detailed in Table 15.

Table 15: Mobile equipment emission estimates

	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$[1]	TSP[2]
Emission (tonnes/year)	14.12	1.29	0.003	0.05	0.05	0.05

Abbreviations: CO = carbon monoxide; NO_x = oxides of nitrogen; PM_{10} = particulate matter less than or equal to 10 microns; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; SO_2 = sulphur dioxide; TSP = total suspended particles.

Source: Amec Foster Wheeler (2015)

Notes: 1. As a conservative assumption PM2.5 was assumed to equal PM10 emissions.

2. Proportioning of particulates between TSP and PM10 for combustion emissions was based on the description of particle size categories for internal combustion engines using gasoline or diesel fuel provided within the AP-42 guidance (USEPA 1990).

3. Emission estimates presented here do not include any mitigation other than what was included in the project design. Emission estimates were provided by project engineers (Amec Foster Wheeler).

1.3.2.4 Mining Vehicles

Emission estimates for the emissions from mobile equipment were provided by Amec Foster Wheeler as detailed in Table 16. In this assessment, a fuel sulphur content of 10 ppm was assumed in accordance with EURO 5 standard for the sulphur content of diesel.

Table 16: Mining vehicles emission estimates

	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$[1]	TSP[2]
Emission (tonnes/year)	428.98	667.65	0.27	25.73	25.73	26.81

Abbreviations: CO = carbon monoxide; NO_x = oxides of nitrogen; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO2 = sulphur dioxide; TSP = total suspended particles.

Source: Amec Foster Wheeler (2015)

Notes: 1. As a conservative assumption PM2.5 was assumed to equal PM10 emissions.

2. Proportioning of particulates between TSP and PM10 for combustion emissions was based on the description of particle size categories for internal combustion engines using gasoline or diesel fuel provided within the AP-42 guidance (USEPA 1990).

3. Emission estimates presented here do not include any mitigation other than what was included in the project design. Emission estimates were provided by project engineers (Amec Foster Wheeler).

1.3.3 Emission Quantification Summary

Table 17 summarises the calculated expected annual emissions for each pollutant for the assessed operation scenario based on above emission source quantifications.

Table 17: Annual emissions estimated for Year 12 of the mine operations (tonnes/year)

PM2.5	PM_{10}	TSP	NO_X	CO	SO_2
107	558	2,214	710	560	14

Abbreviations: CO = carbon monoxide; NO_2 = nitrogen dioxide; NO_x = oxides of nitrogen; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide; TSP = total suspended particles.

1.3.4 Emission Source Parameters and Rates

All described emissions have been combined and modelled to be released from an area source represented by a polygon. Figure 1 shows a schematic of the emission source. Table 18 details the emission source parameters used for the ADM and Table 19 details the pollutant emission rates.

Figure 1: Outline of modelled Ilovica area source

Table 18: Model parameters for Ilovica area source

Parameter	Ilovica area source
Source type	Area source represented by a polygon
Release height (m)	25
Initial vertical dimension (m)	23.3
Total source area (m^2)	15494790

Abbreviations: m = metre; m^2 = square metre.

Table 19: Emission source rates used in the modelling

Emission	Ilovica area source ($g/s/m^2$)
TSP	4.53E-06
PM_{10}	1.14E-06
$PM_{2.5}$	2.20E-07
NO_x	1.45E-06
CO	1.15E-06
SO_2	2.85E-08

Abbreviations: CO = carbon monoxide; $g/s/m^2$ = grams per second per square metre; NO_x = oxide of nitrogen; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide; TSP = total suspended particles.

1.4 Atmospheric Pathway

1.4.1 Atmospheric Dispersion Model

AERMOD (ADM software, version 7.9.1.45) was used for the ADM. This model predicts ground-level concentrations in ambient air as well as particulate deposition, and can account for complex terrain as well as multiple emission sources.

1.4.2 Meteorology

The pathway by which emissions to air may impact upon sensitive receptor locations is through atmospheric dispersal. Emissions to air from the sources will be transported by the wind to potential downwind receptors. The distance and dilution of emissions dispersed, and potentially deposited, will be dependent on the prevailing meteorological conditions.

Meteorological data was collected at the Ilovica EOX meteorological station for the period of June 2013 to June 2015. Data collection and quality assurance was undertaken by Euromax Resources DOO Skopje and an analysis of the data is provided in Annex 3. The data provided the necessary parameters used in ADM to calculate pollutant dispersal, however there were periods of low data capture. To get around this, and to minimise meteorological data processing an alternative dataset was obtained and utilised in the ADM.

The closest meteorological station with appropriate data cover was identified to be Sandanski meteorological station in Bulgaria (41.55N, 23.27E), approximately 35 km to the east of the mining concession. The station records 3-hourly data which has been interpolated to hourly data for modelling purposes. The assessment is based on one year of meteorological data (1 June 2013 to 31 May 2014) and the included parameters are detailed in Table 20.

Table 20: Hourly sequential readings used in the meteorological dataset

Parameter	Units
Wind speed	m/s
Wind direction	Degrees measured clockwise from north
Cloud cover	oktas
Surface temperature	C˚
Relative humidity	%
Rainfall	mm

Abbreviations: % = percent; C° = degree Celsius; mm = millimetre; m/s = metre per second.

Data from the Ilovica EOX meteorological station indicates a different wind regime from Sandanski. Figure 2 compares the windrose from both stations. While both stations display a bimodal wind distribution, the prevailing wind direction appears to be shifted by approximately 180°. This shift may reflect a localised and site-specific channelling effect at the on-site meteorological station. The meteorological data from Sandanski represents a more conservative assessment scenario as the prevailing wind direction is from the north/northwest blowing towards the majority of sensitive human receptors located in the valley to the south and east of the mining concession (Section 1.5.1.2). Using the meteorological data from the Ilovica EOX station, the prevailing south-easterly wind would disperse pollutants away from the majority of village locations and into the uninhabited mountainous area to the north of the mining concession.

The wind roses associated with the meteorological data are shown in Figure 2.

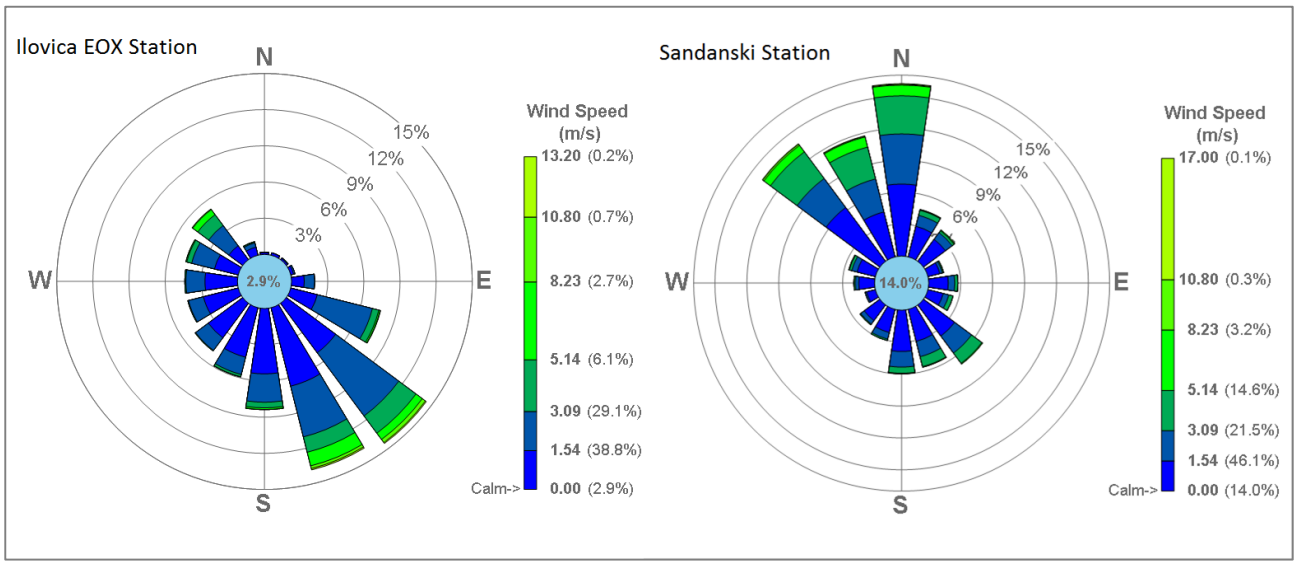

Figure 2: Windroses for Ilovica EOX and Sandanski meteorological stations (1 June 2013 to 31 May 2014)

1.4.3 Terrain and Land Use

A terrain data set of the area surrounding the concession area was obtained from ASTER GDEM copyright of Japan Space Systems 2015. The data set was used to represent the terrain surrounding the site for modelling purposes. The terrain data set covers 623 km^2 at 50 m resolution, with southwest corner located at coordinates 638945, 4580092 (UTM 34N). The terrain used in the ADM is shown in Figure 3.

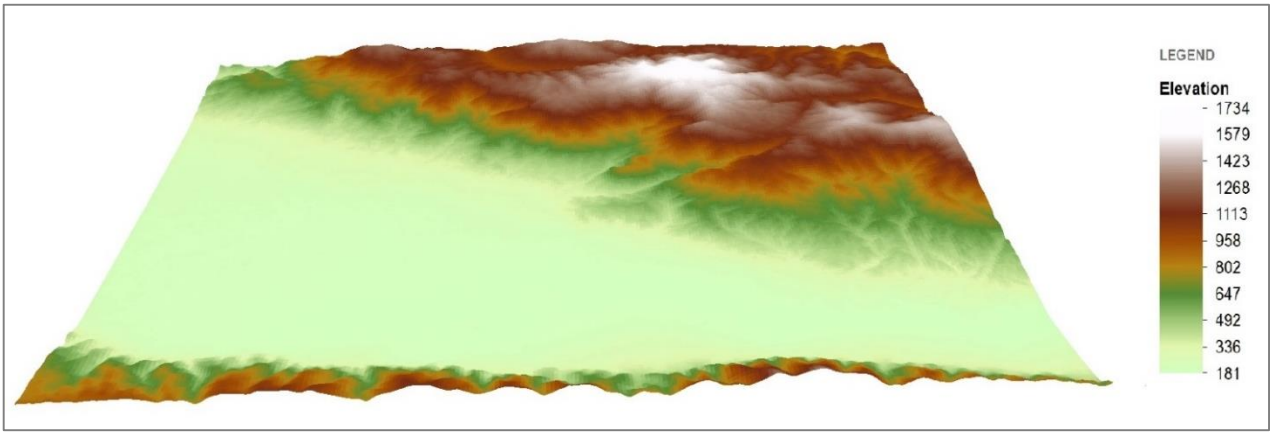

Figure 3: Terrain used in the ADM

Land use settings identifying the dominant land use categories are described in Tables 21 and 22. The meteorological data set was processed into a suitable format for dispersion modelling using the surface roughness (Table 21) and albedo/bowen ratios (Table 22) shown. The surface roughness values were based on land use within a 1 km radius of the site as described by the AERMET model methodology. The albedo/bowen ratios consider a 10 km^2 area centring on the site following the AERMET methodology for classifying albedo/bowen ratios.

Table 21: Surface roughness values used to process the meteorological data

Start (degrees)	End (degrees)	Category
0	180	Coniferous forest
180	360	Cultivated land

Table 22: Albedo/Bowen ratio values used to process the meteorological data

Category	Coverage percent
Cultivated land	50
Coniferous forest	50

1.5 Receptors

1.5.1 Modelled Domain

The modelled domain covers an area approximately 25 km in both east-west and north-south direction, extending at least 5.5 km form the Site in all directions. The domain covers an area of approximately 623 km^2 and incorporates the grid area, the local biophysical study area and all sensitive human receptors considered. The dimensions are shown in Table 23.

Table 23: Extent of modelled domain

	Easting (m)	Northing (m)
Southwest corner	638945	4580092
Northeast corner	663895	4605042

Abbreviations: m = metre.

1.5.1.1 Receptor Grid

A receptor grid extending 613 km2 at a resolution of 250 m has been used in the model (SW corner 638945, 4580092, UTM 34N). Figure 4 outlines the Ilovica source area within the Cartesian receptor grid.

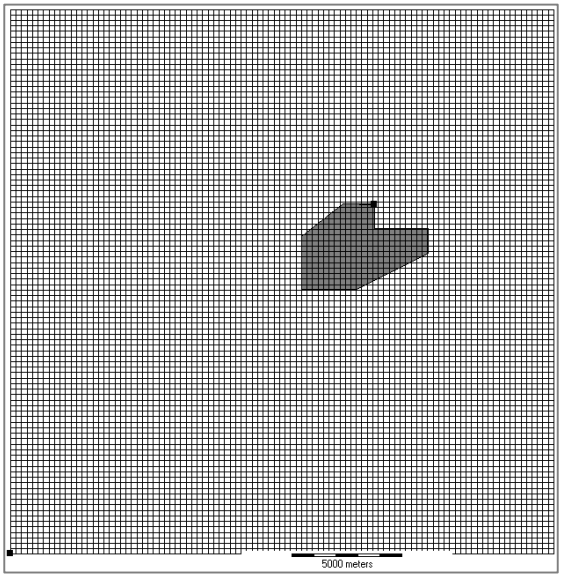

Figure 4: Receptor Grid around the Ilovica Area Source

1.5.1.2 Sensitive Human Receptors

Sensitive human receptors considered in the assessment include the five villages of Ilovica, Shtuka, Turnovo, Sekirnik and Sushica as shown in Table 24.

Table 24: Sensitive human receptors

Receptor	Easting (m)	Northing (m)
Ilovica	650862	4592738
Sekirnik	649899	4589137
Turnovo	648274	4589089
Sushica	653353	4589265
Shtuka	651143	4592317

Abbreviations: m = metre.

Figure 5 shows the location of each sensitive receptor in relation to the air quality baseline monitoring locations and the mining concession.

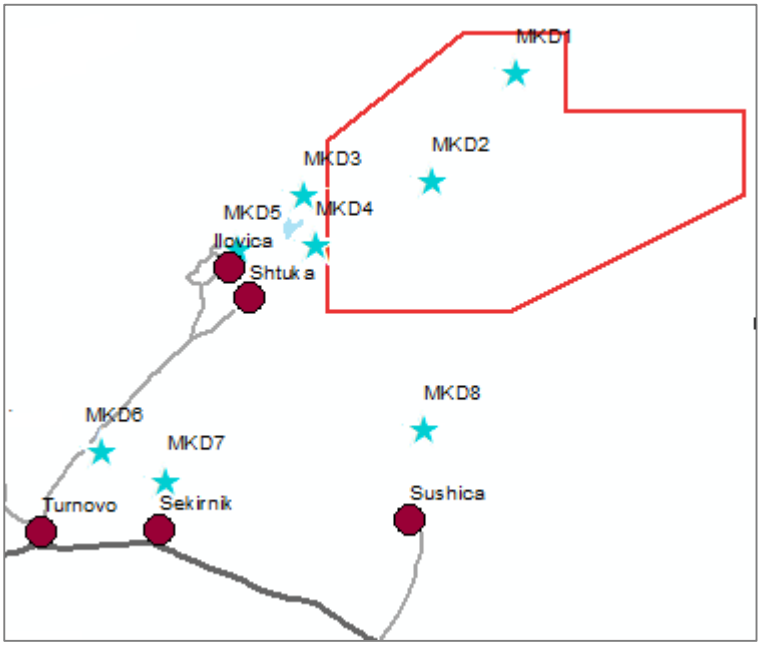

Figure 5: Sensitive human receptors

Based on proximity to the air quality baseline monitoring stations, estimated background concentration and dust deposition for the following receptors have been applied (Table 25).

Table 25: Sensitive human receptors and relevant baseline monitoring stations

Receptor	Baseline monitoring station
Ilovica	MKD5
Sekirnik	MKD4
Turnovo	MKD6
Sushica	MKD7
Shtuka	MKD8

1.5.1.3 Habitats

The habitat assessment has been conducted for the entire modelled domain. Estimated annual background concentrations for NO_x and SO_2 from MKD2 situated within the mining concession (Figure 4) was used in the assessment. Estimated background concentrations at MKD2 are thought to represent typical concentrations for the habitats surrounding the mining concession.

1.6 Emission Assessment

1.6.1 Human Health

The results of the ADM to evaluate potential effects on human health at sensitive human receptors are shown in Tables 26 to 30. Contour plots for emission PCs are included in the Drawings section of the EIA. As can be seen in Tables 26 to 30, the ADM indicates that no exceedances of long-term or short-term EDC for the protection of human health are to be expected at any sensitive human receptor location.

Table 26: ADM results for human health at Ilovica

Emission	Time weighted average	PC (µg/m^3)	Estimated background concentration (µg/m^3)	PEC (µg/m^3)	EDC (µg/m^3)	PEC % EDC	PC % EDC
NO_2	1 hour	65.36	14.10	79.46	200	39.73	32.68
	annual	2.80	7.05	9.85	40.00	24.63	4.61
SO_2	1 hour	2.39	3.00	5.39	350	1.54	0.68
	24 hours	0.39	1.77	2.16	125	1.73	0.31
PM_{10}	24 hours	6.93	13.99	20.93	50	41.86	13.87
	annual	2.20	11.86	14.06	40.00	35.16	5.51
$PM_{2.5}$	annual	0.42	4.75	5.17	20.00	25.87	2.12
CO	8 hours	49.70	2000.00	2049.70	10,000	20.50	0.50

Abbreviations: % = percent; µg/m^3 = microgram per cubic metre; CO = carbon monoxide; EDC = environmental design criteria; NO_2 = nitrogen dioxide; PC = process contribution; PEC = predicted environmental concentration; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

Table 27: ADM results for human health at Sekirnik

Emission	Time weighted average	PC (µg/m^3)	Estimated background concentration (µg/m^3)	PEC (µg/m^3)	EDC (µg/m^3)	PEC % EDC	PC % EDC
NO_2	1 hour	46.75	7.23	53.97	200	26.99	23.37
	annual	1.70	3.61	5.32	40.00	13.29	4.25
SO_2	1 hour	1.18	3.25	4.43	350	1.26	0.34
	24 hours	0.30	1.92	2.22	125	1.77	0.24
PM_{10}	24 hours	3.89	13.99	17.89	50	35.78	7.79
	annual	1.34	11.86	13.20	40.00	32.99	3.34
$PM_{2.5}$	annual	0.26	4.75	5.01	20.00	25.04	1.29
CO	8 hours	47.35	2000.00	2047.35	10,000	20.47	0.47

Abbreviations: % = percent; µg/m^3 = microgram per cubic metre; CO = carbon monoxide; EDC = environmental design criteria; NO_2 = nitrogen dioxide; PC = process contribution; PEC = predicted environmental concentration; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

Table 28: ADM results for human health at Turnovo

Emission	Time weighted average	PC (µg/m^3)	Estimated background concentration (µg/m^3)	PEC (µg/m^3)	EDC (µg/m^3)	PEC % EDC	PC % EDC
NO_2	1 hour	38.61	13.56	52.17	200	26.08	19.30
	annual	1.29	6.78	8.07	40.00	20.17	3.22
SO_2	1 hour	1.06	2.62	3.69	350	1.05	0.30
	24 hours	0.27	1.55	1.82	125	1.45	0.21
PM_{10}	24 hours	3.01	13.99	17.00	50	34.00	6.01
	annual	1.01	11.86	12.87	40.00	32.18	2.53
$PM_{2.5}$	annual	0.23	4.75	4.98	20.00	24.90	1.15
CO	8 hours	40.98	2000.00	2040.98	10,000	20.41	0.41

Abbreviations: % = percent; µg/m^3 = microgram per cubic metre; CO = carbon monoxide; EDC = environmental design criteria; NO_2 = nitrogen dioxide; PC = process contribution; PEC = predicted environmental concentration; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

Table 29: ADM results for human health at Sushica

Emission	Time weighted average	PC (µg/m^3)	Estimated background concentration (µg/m^3)	PEC (µg/m^3)	EDC (µg/m^3)	PEC % EDC	PC % EDC
NO_2	1 hour	66.70	19.93	86.63	200	43.32	33.35
	annual	6.92	9.96	16.89	40.00	42.22	17.31
SO_2	1 hour	2.54	2.65	5.19	350	1.48	0.73
	24 hours	0.56	1.56	2.12	125	1.70	0.45
PM_{10}	24 hours	11.81	13.99	25.80	50	51.60	23.61
	annual	5.44	11.86	17.30	40.00	43.24	13.59
$PM_{2.5}$	annual	1.05	4.75	5.80	20.00	28.98	5.23
CO	8 hours	54.45	2000.00	2054.45	10,000	20.54	0.54

Abbreviations: % = percent; µg/m^3 = microgram per cubic metre; CO = carbon monoxide; EDC = environmental design criteria; NO_2 = nitrogen dioxide; PC = process contribution; PEC = predicted environmental concentration; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

Table 30: ADM results for human health at Shtuka

Emission	Time weighted average	PC (µg/m^3)	Estimated background concentration (µg/m^3)	PEC (µg/m^3)	EDC (µg/m^3)	PEC % EDC	PC % EDC
NO_2	1 hour	67.05	9.90	76.95	200	38.47	33.53
	annual	3.13	4.95	8.08	40.00	20.19	7.82
SO_2	1 hour	2.52	3.24	5.76	350	1.65	0.72
	24 hours	0.43	1.91	2.34	125	1.87	0.34
PM_{10}	24 hours	7.56	13.99	21.55	50	43.10	15.11
	annual	2.46	11.86	14.32	40.00	35.79	6.14
$PM_{2.5}$	annual	0.47	4.75	5.22	20.00	26.12	2.37
CO	8 hours	51.81	2000.00	2051.81	10,000	20.52	0.52

Abbreviations: % = percent; µg/m^3 = microgram per cubic metre; CO = carbon monoxide; EDC = environmental design criteria; NO_2 = nitrogen dioxide; PC = process contribution; PEC = predicted environmental concentration; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

1.6.2 Habitats

The results of the ADM to evaluate potential effects on habitats within the modelled domain are shown in Table 31. The assessment uses the maximum PC in the modelled domain and the estimated background concentrations at MKD2 to derive a conservative estimate of the PEC. As can be seen in Table 31, the ADM indicates that no exceedances of the EDC for the protection of habitats are to be expected anywhere in the modelled domain.

Table 31: ADM results for habitats (modelled domain)

Emission	Time weighted average	Maximum PC (modelled domain) (µg/m^3)	Estimated background concentration (µg/m^3)	PEC (µg/m^3)	EDC (µg/m^3)	PEC % EDC	PC % EDC
NO_x	annual	22.32	7.08	29.40	30.00	98.01	74.41
SO_2	annual	0.44	2.03	2.46	20.00	12.32	2.19

Abbreviations: % = percent; µg/m^3 = microgram per cubic metre; EDC = environmental design criteria; NO_x = oxides of nitrogen; PC = process contribution; PEC = predicted environmental concentration; SO_2 = sulphur dioxide;

1.6.3 Dust Deposition

The results of the ADM to evaluate potential effects on loss of amenity due to dust deposition at sensitive human receptors are shown in Table 32. As can be seen in Table 32, the ADM indicates that no exceedances of the EDC to prevent loss of amenity due to dust deposition are to be expected at any sensitive human receptor location.

Table 32: ADM results for loss of amenity due to dust deposition at sensitive human receptors

Receptor	PC ($mg/m^2/day$)	Estimated Background Concentration ($mg/m^2/day$)	PEC ($mg/m^2/day$)	EDC ($mg/m^2/day$)	PEC % EDC	PC % EDC
Sekirnik	9.75	26.59	36.34	350	10.38	2.79
Ilovica	27.30	28.35	55.65	350	15.90	7.80
Turnovo	6.41	87.84	94.25	350	26.93	1.83
Sushica	27.35	64.66	92.01	350	26.29	7.82
Shtuka	36.13	54.99	91.12	350	26.03	10.32

Abbreviations: % = percent; EDC = environmental design criteria; $mg/m^2/day$ = milligram per square metre per day; PC = process contribution; PEC = predicted environmental concentration.

1.7 Limitations

The assessment is currently based on 1 year of meteorological data only. Using five years of meteorological data in the assessment would provide an indication of the effect that variability in the meteorological data may have on the modelling results.

1.8 Conclusions

The results from ADM for the Project emissions dispersion suggest that:

- PECs of gaseous emissions (NO_2, SO_2 and CO) as well as fine particulates (PM_{10} and $PM_{2.5}$) at sensitive human receptors are less than the Project-adopted EDC for the protection of human health;
- PECs of annual NO_x and SO_2 are less than the Project-adopted EDC for the protection of habitats in the entire modelled domain; and

PECs of deposited dust at sensitive human receptors are less than the Project-adopted EDC for the prevention of loss of amenity due to dust deposition.

1.9 References

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2.0 QUALITATIVE ASSESSMENT

2.1 Assessment Scope

Quantitative air quality assessments are presented in the ADM assessment (Section 1 of this annex). The ADM assessment addresses major emission sources in Year 12 of mine operations when projected ore and waste rock production rates are scheduled to peak, resulting in maximum emissions and effects on air quality from the mining activities. Project emissions for all other years would be expected to have lesser air quality effects.

This report qualitatively assesses the effect of emission sources which are considered minor sources and activities. Short-term activities during construction and closure, as well as sources scoped out of the quantitative ADM assessment, are assessed qualitatively using a source-pathway-receptor approach.

2.2 Spatial Scope

This qualitative assessment considers four sources of emissions associated with the Project that have the potential to generate emissions to air. The source areas are:

- The Ilovica mine area incorporated within the mining concession;
- The sewage treatment plant to the south-west of the mining concession;
- The access road from the highway to the mine Site entrance; and
- The highway from the access road to the Bulgarian border.

The spatial extent of potential emissions from Project activities is based on the distance from the potential emission source to the sensitive receptor, to a maximum 1000 metres (m) from a potential source. A distance of 1 km is considered to represent a suitable settling distance for fine particulates or dust released from point or fugitive sources (LAQM.TG(09), 2009). A distance of 1 km is also considered a suitable for determining the effects of gaseous pollutants, or odours, which will typically be fugitive emissions or point sources with a low momentum, thus any emission plume will ground close to the point of emission. The extent of the assessment is shown in Figure 6.

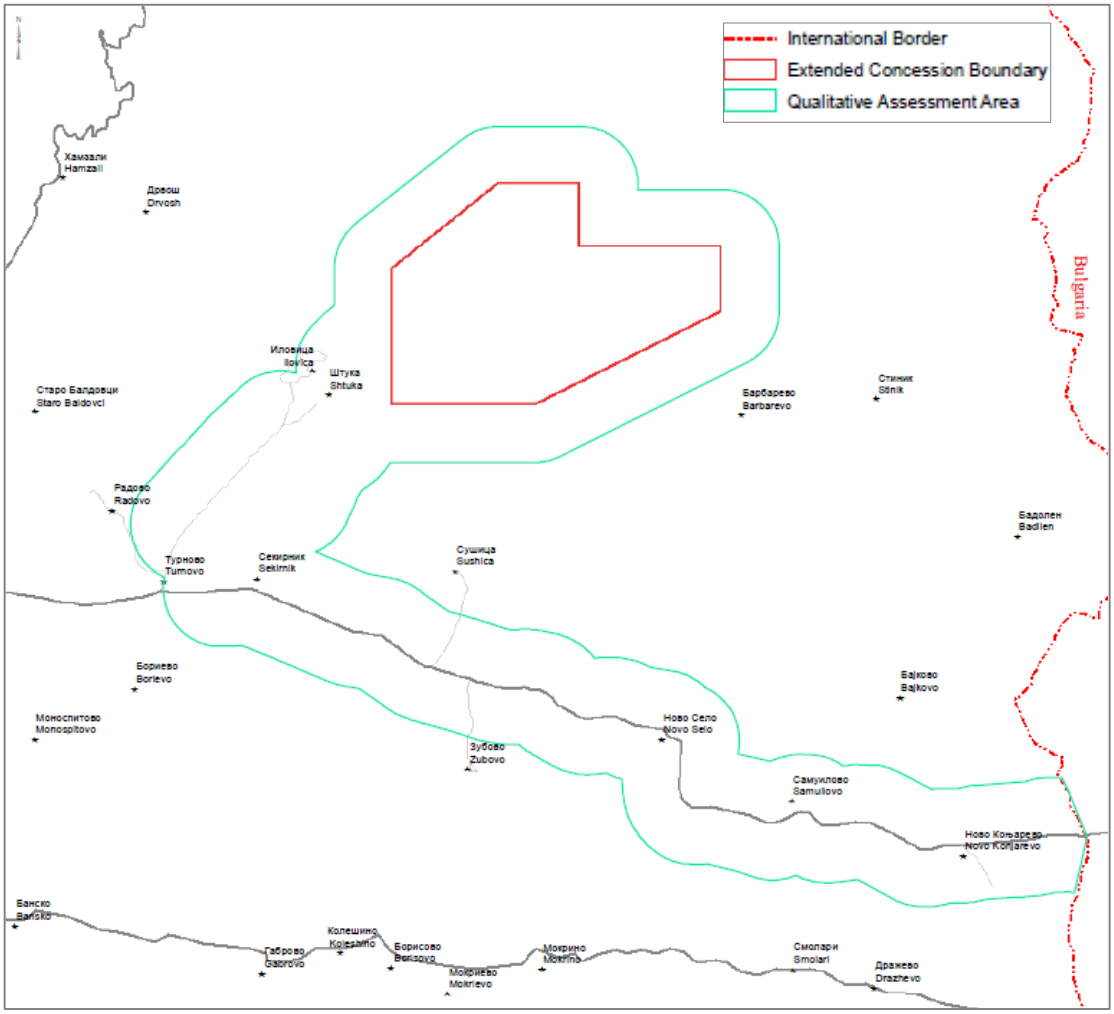

Figure 6: Site layout for qualitative air quality assessment

2.3 Assessment Timeframe

Potential effects on air quality are likely to occur during the construction, operations, and closure phases. Potential effects occurring during construction and closure phases are considered to be short-term. Potential effects occurring during the operations phase are considered to be medium-term. Minimal air quality effects are anticipated in the post-closure phases. Air quality effects for all phases are considered to be reversible.

2.4 Adopted Assessment Criteria

The EDC adopted for the Project are based on air quality standards (AQS) and guidelines as detailed in the EDC (Annex 1). The EDC relevant to this qualitative assessment are summarised in Tables 33 and 34. The EDC for the assessment of human health are taken from Macedonian and EU limit values. The EDC for loss of amenity caused by dust deposition are taken from TA Luft.

Table 33: Summary of EDC adopted for human health

Emission	Time weighted average	Concentration (µg/m^3)	Assessment percentile (%ile)
NO_2	1 hour	200	99.79
	annual	40	100
SO_2	1 hour	350	99.73
	24 hours	125	99.18
PM_{10}	24 hours	50	90.41
	annual	40	100
$PM_{2.5}$	annual	20	100
CO	8 hours	10,000	100

Abbreviations: %ile = percentile; µg/m^3 = micrograms per cubic metre; CO = carbon monoxide; NO_2 = nitrogen dioxide; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

Table 34: Summary of EDC adopted for dust deposition

Emission	Time weighted average	Deposition (mg/m^2/day)	Assessment percentile (%ile)
TSP	annual mean	350	100

Abbreviations: %ile = percentile; mg / m^2 / day = milligrams per square metre per day; TSP = total suspended particles.

In addition to the EDC for fugitive and combustion emissions, the qualitative assessment requires assessment criteria for odour. There is no prescribed international assessment method for odour. Therefore, the method for assessing the effects of odour emissions from the Project is broadly based on the United Kingdom (UK) Environment Agency Guidance, H1 Environmental Risk Assessment for Permits and Horizontal Technical Guidance Note H4 Odour Management (Environment Agency 2002, 2011).

2.5 Assessment Approach

A source-pathway-receptor assessment approach has been used to identify possible effects. This assessment method involves the following stages:

- Source characterisation: to identify the potential emission sources associated with the Project;
- Pathway: to show the manner in which potential emissions from the Project are transported to the receptor;
- Receptor evaluation: to review the receptors which could be affected by the potential emissions from the Project; and

- Impact assessment: to evaluate the risk of adverse effects from Project emissions and define any impact on the identified receptors.

2.6 Existing Air Quality

Background ambient air concentrations and dust deposition were derived based on the findings of the air quality baseline study (Annex 3). Table 35 summarises the long-term background concentrations for gaseous and particulate emissions as well as deposited dust used in this qualitative assessment. The figures are based on the maximum background concentrations found at monitoring locations outside the mining concession.

Table 35: Pollutant background concentrations

Pollutant	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	CO ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	Deposited dust ($mg/m^2/day$)
Annual background concentration	9.96	1.62	8000	11.86	4.75	87.84

Abbreviations: $\mu g/m^3$ = micrograms per cubic metre; CO = carbon monoxide; $mg/m^2/day$ = milligrams per square metre per day; NO_2 = nitrogen dioxide; $PM_{2.5}$ = particulate matter less than or equal to 2.5 microns; PM_{10} = particulate matter less than or equal to 10 microns; SO_2 = sulphur dioxide.

2.7 Source-Pathway-Receptor Assessment

2.7.1 Emission Sources

The qualitative assessment focuses on emission sources during the construction and closure phases. Minor emission sources during the operations scoped out of the quantitative ADM assessment have also been included within this assessment.

2.7.1.1 Fugitive Dust and Odour Emissions

Table 36 presents the activities deemed to release dust or odour emissions (after mitigation) during construction, operations, and closure that were assessed qualitatively. Some project activities, such as waste management, will occur over the entire lifetime of the Project. Their potential effect has only been assessed for the operations phase in which the maximum effect of the Project's activities are expected.

Table 36: Potential fugitive dust and odour generating activities during construction, operations, and closure

Phase	Source area	Activity / Process	Emission
Construction	Ilovica mine area	Earthworks	Fugitive dust
		Drilling	Fugitive dust
		Blasting	Fugitive dust
		Traffic on unpaved haul roads	Fugitive dust
		Building and infrastructure construction.	Fugitive dust
Operation	Ilovica mine area	Solid waste landfill	Odour, fugitive dust
	Sewage treatment plant	Sewage treatment plant	Odour
Closure	Ilovica mine area	Ground disturbance	Fugitive dust
		Traffic on unpaved haul roads	Fugitive dust
		Reclamation activities (e.g. dismantling infrastructure, re-landscaping, profiling).	Fugitive dust

2.7.1.2 Combustion Emissions

Emergency Diesel Generators

Generator use will primarily be during construction of the incoming electrical transmission line(s) and substation. During mine operations power will be provided via a branch connection to the existing high voltage transmission line running along the Strumica Valley ("the Sushica alignment"), with the project's substation located at the plant site. A medium and lower voltage distribution network will supply power from the substation to other site facilities. During operations, diesel generator will be employed as emergency back-up only. Any fuel used to power emergency diesel generators will supply to EURO 5 standards with a maximum sulphur content of 10 ppm. Given the anticipated short-term usage of diesel generators during the Project the potential impact of associated combustion emissions on any receptors within 1,000 m of the mine area is deemed **insignificant**.

Traffic on Access Road and Highway

The impact of road traffic emissions associated with the construction and operation phases of the proposed development are assessed in accordance with United Kingdom Design Manual for Roads and Bridges (DMRB) guidance on assessing air quality impacts (DMRB 2007). The assessment method allows for a screening assessment of road traffic emissions based on the percentage change in vehicle movements on any road to be considered.

The DMRB assessment method provides screening and scoping criteria to assess the likely impact of changes to traffic flows on local air quality. The scoping phase of the assessment identifies the following potential changes which are likely to have a significant impact on air quality:

- Road alignment changes by 5 m or more;
- Daily traffic flows changes of 1,000 (annual average daily traffic [AADT] flow) or more;
- Heavy duty vehicle (HDV) flow changes of 200 AADT or more;
- Daily average speed changes of 10 km/hr or more; and
- Peak hour speed changes of 20 km/hr or more.

Where a significant impact on air quality is identified DMRB requires that dispersion modelling tools are used to predict the impact of emissions on the nearest receptors. DMRB provides a spreadsheet model for predicting pollutant concentrations at receptor locations based on an inbuilt emissions dispersion algorithm and database of emission factors for road traffic.

For the purposes of assessing the potential effects of traffic from the Project, estimations of traffic flows were made for both the construction and operation phases of the Project. The direction development traffic will take when leaving the site cannot be determined at this stage, however as a worst case it is assumed that all traffic will take the same route and as such the combined traffic flow is assessed against the above assessment criteria. The assumed number of truck movements are:

- During construction, 17 truck (HDV) per day as a maximum on the main road network, equating to 34 movements per day; and
- During operation, 18 truck (HDV) movements per day as a maximum on the main road network, equating to 36 movements per day.

In addition, there will be vehicle movements attributable to the transport of staff during both the construction and operation phases. The majority of workers will be transported by bus (assumed to be less than 40 per day i.e. 20 movements in the morning and 20 movements in the evening at peak during construction). Car travel numbers are anticipated to be low and less than 100 per day. The estimated peak increases in traffic movements are below the daily movements identified in DMRB screening assessment criteria, for both construction and operations phases, therefore are below the threshold at which potential for significant adverse effects on air quality could occur.

Based on the results of the DMRB assessment, the potential impact of combustion emissions from traffic on any receptors within 1000 m of the access road or highway have been deemed **insignificant**.

2.8 Receptors

Table 37 identifies sensitive receptors for which a potentially significant fugitive dust or odour source and a pathway have been identified within 1000 m of the source area. To determine the approximate distance the residential property closest to the emission source area was used.

Table 37: Receptors included in qualitative assessment

Emission source areas	Receptors within 1,000 m of source area	Approximate distance to source area (m)
Ilovica mine area	Ilovica	970
	Shtuka	700
Sewage treatment plant	Ilovica	750
	Shtuka	780

Abbreviations: m = metre.

2.9 Impact Assessment

2.9.1 Pathway

Fugitive dust, odours, and combustion emissions from the Ilovica Mine Area are identified to have the potential to be emitted directly to air and therefore have the potential to be transported to nearby sensitive receptors by air dispersion. The dispersion of air pollutants will largely be influenced by weather conditions and in particular wind speed and direction at the time that any fugitive / suspended emissions become airborne.

Two sources of data for the local meteorological conditions have been considered:

- **Ilovica EOX meteorological station**

  Meteorological data was collected at the Ilovica EOX meteorological station for the period of June 2013 to June 2015. Data collection and quality assurance was undertaken by Euromax Resources DOO Skopje and an analysis of the data is provided in Annex 3. The data provided the necessary parameters used for quantitative assessments using air dispersion modelling (ADM) (Appendix 1) to calculate pollutant dispersal, however there were periods of low data capture. To get around this, and to minimise meteorological data processing an alternative dataset was obtained and utilised in the ADM.

- **Sandanski meteorological station**

  The closest meteorological station with appropriate data cover was identified to be Sandanski meteorological station in Bulgaria (41.55N, 23.27E), approximately 35 km to the east of the mining concession.

Figure 7 shows the windrose for both locations from June 2013 to May 2014. While both stations display a bimodal wind distribution, the prevailing wind direction appears to be shifted by approximately 180°. This shift may reflect a localised and site-specific channelling effect at the on-site meteorological station and might not be reflective of the wider area surrounding the mining concession. The meteorological data from Sandanski represents a more conservative assessment scenario as the prevailing wind direction is from the north-west blowing towards the majority of receptors located to the south and east.

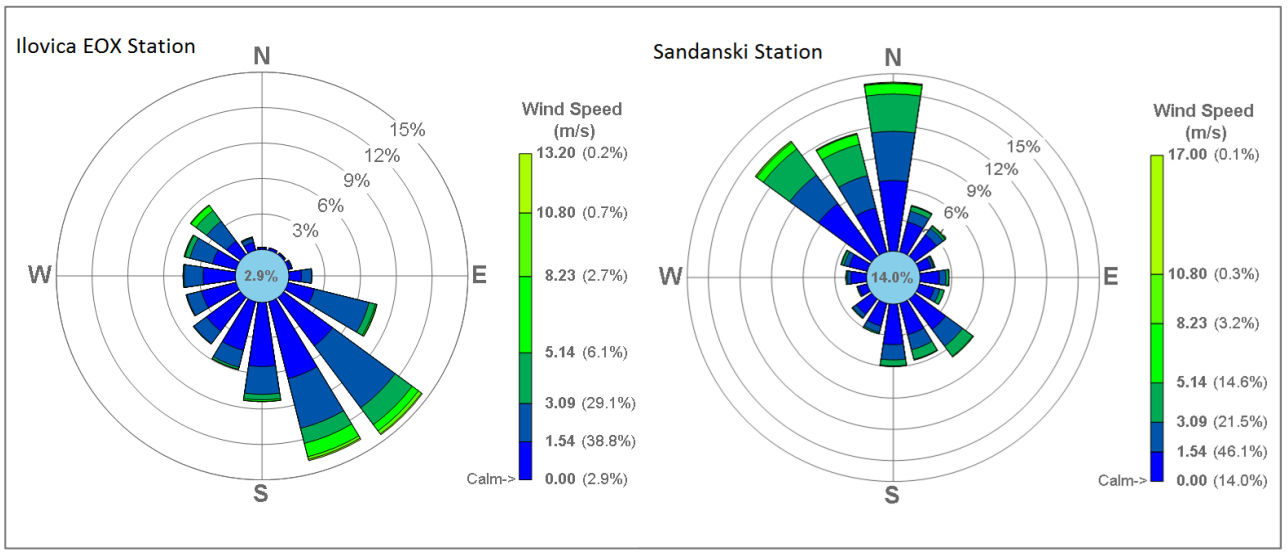

Figure 7: Windroses for Ilovica EOX and Sandanski meteorological stations 1 June 2013 - 31 May 2014

2.9.2 Magnitude of Potential Effects

The magnitude of potential effects on identified receptors was determined adapting guidelines provided by the Institute for Air Quality Management (IAQM) for the assessment of odour and dust from demolition and construction (IAQM 2014a, 2014b).

Source Emission Potential

The source emission potential for dust was established taking into account the total building volume, potentially affected site areas and volumes of earthworks. The source emission potential for dust was established taking into account the potential magnitude of the odour release, how inherently odorous the compound are and the unpleasantness of the odour. The resulting source odour potential by activity are summarised in Table 38.

Table 38: Source emission potential

Source	Emission	Source emission potential
Earthworks	Dust	Large
Stockpiles	Dust	Large
Drilling	Dust	Large
Blasting	Dust	Large
Traffic on unpaved haul roads	Dust	Large
Building and infrastructure construction	Dust	Large
Ground disturbance	Dust	Large
Reclamation activities	Dust	Large
Landfill	Odour	Large
Sewage treatment plant	Odour	Large

Pathway Effectiveness

The pathway effectiveness was established taking into account the distance between source and receptor as well as the amount of time wind is likely to blow from the source in the direction of the receptors. Table 39 details the assessment criteria used.

Table 39: Pathway effectiveness criteria

	Highly effective pathway	Moderately effective pathway	Ineffective pathway
Criterion 1	Close proximity of receptor to source (0-5m)	Receptor local to source (6-350 m)	Receptor distant from source (350-1,000m)
Criterion 2	High frequency (%) of winds from source to receptors (>30%)	n/a	Low frequency of winds from source to receptor (≤30%)

Abbreviations: % = percent, > = greater than, ≤ = less than or equal to, m = metre, n/a = not applicable.

The distance between source and receptor is detailed in Table 39 above. The closest proximity from each receptor to any source has been used for the assessment of the pathway effectiveness.

The frequency of winds from source to receptors was assessed using data from both the Ilovica EOX meteorological station as well as Sandanski meteorological station. The identified receptor locations (Ilovica and Shtuka) were assumed to be downwind whenever the wind direction was between 0° (North) and 90° (East) (see Figure 7). Using the Ilovica EOX meteorological station data, the wind direction was between 0° (North) and 90° (East) 2% of the time (June 2013 to May 2014). Using Sandanski meteorological station data, wind direction was between 0° (North) and 90° (East) 27% of the time (June 2013 to May 2014). The meteorological data from Sandanski is more conservative and has been used for the assessment of the pathway effectiveness.

Based on above considerations the pathway effectiveness for each receptors was assessed as detailed in Table 40.

Table 40: Pathway effectiveness assessment

Receptor	Distance to closest source (m)	Frequency of winds from source to receptor (%)	Pathway effectiveness
Ilovica	700	27	Ineffective pathway
Shtuka	750	27	Ineffective pathway

Abbreviations: m = metre, % = percent

Magnitude of Effects

The magnitude of potential effects has been established based on the source emission potential and the pathway effectiveness following the criteria set out in Table 41. The magnitude of effects for both receptors and all fugitive or dust releasing activities is assessed as **low**.

Table 41: Magnitude of effects assessment

	Small source potential	Medium source potential	Large source potential
Highly effective pathway	Low	Moderate	High
Moderately effective pathway	Negligible	Low	Moderate
Ineffective pathway	Negligible	Negligible	Low

2.9.3 Impact Classification

The qualitative impact classification has been undertaken based on the criteria set out in Section 1 of the EIA. The results for assessing the impact of potential fugitive dust or odour generating activities (Table 36) at identified receptors (Table 37) are summarised in Table 42. The impact has been assessed as being **low**.

Table 42: Qualitative assessment impact classification

Magnitude	Geographic extent	Duration	Frequency	Impact classification
Low	Local	Medium-term	Frequent	**Low**

Table 43 summarises the impact classification for each receptor, project phase and source as deducted by the qualitative assessment.

Table 43: Qualitative impact assessment summary

Receptor	Project phase	Key source of impact	Impact target	Impact classification
Ilovica	Construction	Ilovica mine area	Dust	Low
		Access road	Combustion emissions (traffic)	Negligible
	Operations	Ilovica mine area	Dust and odour	Low
			Combustion emissions (emergency generators)	Negligible
		Sewage treatment plant	Odour	Low
		Access road	Combustion emissions (traffic)	Negligible
	Closure	Ilovica mine area	Dust	Low
Shtuka	Construction	Ilovica mine area	Dust	Low
		Access road	Combustion emissions (traffic)	Negligible
	Operations	Ilovica mine area	Dust and odour	Low
			Combustion emissions (emergency generators)	Negligible
		Sewage treatment plant	Odour	Low
		Access road	Combustion emissions (traffic)	Negligible
	Closure	Ilovica mine area	Dust	Low
Sekirnik	Construction	Access road	Combustion emissions (traffic)	Negligible
	Operations	Access road	Combustion emissions (traffic)	Negligible
Turnovo	Construction	Access road	Combustion emissions (traffic)	Negligible
	Operations	Access road	Combustion emissions (traffic)	Negligible
Novo Selo	Construction	Highway	Combustion emissions (traffic)	Negligible
	Operations	Highway	Combustion emissions (traffic)	Negligible
Samuilovo	Construction	Highway	Combustion emissions (traffic)	Negligible
	Operations	Highway	Combustion emissions (traffic)	Negligible
Novo Konjarevo	Construction	Highway	Combustion emissions (traffic)	Negligible
	Operations	Highway	Combustion emissions (traffic)	Negligible

2.10 Conclusion

The qualitative assessment has identified the following potential Project impacts:

- During the construction, operations and closure phase **low impacts** are expected from fugitive dust emissions from the Ilovica mine area;
- During the operational phase **low impacts** are expected from fugitive odour emissions from the Ilovica mine area and the adjacent sewage treatment plant;

- During the operational phase **insignificant impacts** are expected from combustion emissions associated with the use of emergency generators within the Ilovica mine area; and
- During the construction and operational phase **insignificant impacts** are expected from combustion emissions of traffic on the access road and highway.

Table 44: Impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Emission parameter		Magnitude	Geographic extent	Duration	Frequency	Impact classification	Impact consequence
Operations	Ilovica – human health	n/a	NO_2	1 hour	Moderate	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			SO_2	1 hour	Low	Regional	Medium-term	Frequent	Low	n/a
				24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
			PM_{10}	24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			$PM_{2.5}$	annual	Low	Regional	Medium-term	Frequent	Low	n/a
			CO	8 hours	Low	Regional	Medium-term	Frequent	Low	n/a
	Ilovica – loss of amenity	n/a	Dust deposition	annual	Low	Regional	Medium-term	Frequent	Low	n/a
	Shtuka – human health	n/a	NO_2	1 hour	Moderate	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			SO_2	1 hour	Low	Regional	Medium-term	Frequent	Low	n/a
				24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
			PM_{10}	24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			$PM_{2.5}$	annual	Low	Regional	Medium-term	Frequent	Low	n/a
			CO	8 hours	Low	Regional	Medium-term	Frequent	Low	n/a
	Shtuka – loss of amenity	n/a	Dust deposition	annual	Low	Regional	Medium-term	Frequent	Low	n/a
	Sekirnik – human health	n/a	NO_2	1 hour	Low	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			SO_2	1 hour	Low	Regional	Medium-term	Frequent	Low	n/a
				24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
			PM_{10}	24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			$PM_{2.5}$	annual	Low	Regional	Medium-term	Frequent	Low	n/a
			CO	8 hours	Low	Regional	Medium-term	Frequent	Low	n/a
	Sekirnik – loss of amenity	n/a	Dust deposition	annual	Low	Regional	Medium-term	Frequent	Low	n/a
	Turnovo – human health	n/a	NO_2	1 hour	Low	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			SO_2	1 hour	Low	Regional	Medium-term	Frequent	Low	n/a
				24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
			PM_{10}	24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			$PM_{2.5}$	annual	Low	Regional	Medium-term	Frequent	Low	n/a
			CO	8 hours	Low	Regional	Medium-term	Frequent	Low	n/a
	Turnovo – loss of amenity	n/a	Dust deposition	annual	Low	Regional	Medium-term	Frequent	Low	n/a
	Sushica – human health	n/a	NO_2	1 hour	Moderate	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			SO_2	1 hour	Low	Regional	Medium-term	Frequent	Low	n/a
				24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
			PM_{10}	24 hours	Low	Regional	Medium-term	Frequent	Low	n/a
				annual	Low	Regional	Medium-term	Frequent	Low	n/a
			$PM_{2.5}$	annual	Low	Regional	Medium-term	Frequent	Low	n/a
			CO	8 hours	Low	Regional	Medium-term	Frequent	Low	n/a

Phase of the project	Receptor	Receptor sensitivity	Emission parameter		Magnitude	Geographic extent	Duration	Frequency	Impact classification	Impact consequence
	Sushica – loss of amenity	n/a	Dust deposition	annual	Low	Regional	Medium-term	Frequent	Low	n/a
	Habitats	n/a	NO_x	annual	Moderate	Regional	Medium-term	Frequent	Low	n/a
			SO_2	annual	Low	Regional	Medium-term	Frequent	Low	n/a

Annex 5F: Supporting Information to the Biodiversity and Ecology Impact Assessment

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Table 1: Impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Magnitude	Geographic extent	Duration	Frequency	Impact classification (RSA-level effect)	Impact consequence
Construction, operations, closure	Terrestrial habitats - pasture	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Low	Local	Long-term	Frequent	Low	Minor
Construction, operations, closure	Terrestrial habitats – settlements and fields	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Negligible	Local	Long-term	Frequent	Negligible	Negligible
Construction operations	Terrestrial habitats – forest communities (excluding the TMF)	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Moderate	Local	Long-term	Frequent	Moderate	Moderate
Construction, operations, closure	Terrestrial habitats – forest communities (TMF)	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Moderate	Local	Permanent	Frequent	High	Major
Construction, operations, closure	Habitats supporting endangered species – Ograzden Prime Butterfly Area	Very high	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Moderate	Local	Long-term	Frequent	Moderate	Major
Construction, operations, closure	Flora SoCC	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Moderate	Local	Long term	Frequent	Moderate	Moderate
Construction, operations, closure	Terrestrial fauna SoCC (non-butterfly)	High	Site clearance and project footprint, noise from traffic, blasting, and crusher; increased air emissions and dust deposition	Moderate	Local	Long-term	Frequent	Moderate	Moderate
Construction, operations, closure	Aquatic habitat and species – Jazga River	High	Reduction in flows between the pit and the Ilovica Reservoir, resulting in reduced wetted perimeter within this stretch of the Jazga River.	Low	Local	Long-term	Frequent	Low	Minor
Construction, operations	Aquatic habitat and species – Ilovica Reservoir	High	Fluctuation in water levels due to project abstraction and reduction in inflows from the Jazga River.	Moderate	Local	Long-term	Frequent	Moderate	Moderate
Construction, operations, closure	Aquatic habitat and species – downstream portion of Jazga River	Medium	Reduction in flows due to reduced overflow from Ilovica Reservoir.	Low	Local	Long-term	Frequent	Low	Minor
Construction, operations, closure, post-closure	Aquatic habitat and species – Shtuka River	High	Permanent diversion of the Shtuka River into the diversion channel.	Moderate	Local	Permanent	n/a	High	Major

Table 2: Residual impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact consequence before mitigation	Mitigation	Magnitude (revised)	Geographic extent	Duration	Frequency	Residual impact classification (RSA-level effect)	Residual impact consequence
Construction, operations, closure	Terrestrial habitats - pasture	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Minor	Re-vegetate TMF to pasture at closure. Avoid disturbance to high quality pasture at higher elevations. Fences to be installed to prevent traffic access. As feasible, salvage flora SoCC during site clearance, for use in progressive ecological restoration. Undertake revegetation trials throughout operations. Maintain existing grazing regime on grasslands within the concession area, or replication of grazing regime through artificial means. Implement invasive flora monitoring and mitigation. Mandatory environmental training for all workers and contractors.	Low (potentially negligible or low positive post-closure)	Local	Long-term	Frequent	Low (potentially negligible post closure)	Minor (potentially positive post closure)
Construction, operations, closure	Terrestrial habitats – settlements and fields	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Negligible	As feasible, salvage flora SoCC during site clearance, for use in progressive ecological restoration.	Negligible	Local	Long-term	Frequent	Negligible	Negligible
Construction and operations	Terrestrial habitats – forest communities (Outside of the TMF)	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Moderate	As feasible, salvage flora SoCC during site clearance, for use in progressive ecological restoration. Revegetate project footprint (except TMF) to forest and scrub mosaic which reflects baseline conditions. Undertake revegetation trials throughout operations.	Low	Local	Long-term	Frequent	Low	Minor
Construction, operations, closure	Terrestrial habitats – forest communities (Inside of the TMF)	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Major	As feasible, salvage flora SoCC during site clearance, for use in progressive ecological restoration. Revegetate TMF to grassland. Undertake revegetation trials throughout operations	Moderate	Local	Permanent	Permanent	Moderate	Moderate
Construction, operations, closure	Habitats supporting endangered species – Ograzden Prime Butterfly Area	Very high	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Major	Avoid disturbance to high quality pasture at higher elevations. Fences to be installed to prevent traffic access. Revegetate TMF to pasture and scrub mosaic at closure, designed for suitability for Large Blue butterfly and other invertebrates. Maintain the existing grazing regime (or replicate through artificial means) for the higher elevation grasslands.	Low (potentially low positive post-closure)	Local	Long-term	Frequent	Low (potentially low positive post-closure)	Moderate (potentially moderate positive post-closure)
Construction, operations, closure, post closure	Flora SoCC	High	Site clearance and project footprint; change in soil quality and quantity; increased air emissions and dust deposition.	Moderate	Revegetate project footprint (except TMF) to forest and scrub mosaic. Revegetate TMF to pasture at closure. Avoid disturbance to high quality pasture at higher elevations. Fences to be installed to prevent traffic access. As feasible, salvage flora SoCC during site clearance, for use in progressive ecological restoration. Undertake revegetation trials throughout operations and develop plant nursery.	Low	Local	Long-term	Frequent	Low	Minor

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact consequence before mitigation	Mitigation	Magnitude (revised)	Geographic extent	Duration	Frequency	Residual impact classification (RSA-level effect)	Residual impact consequence
					Implement invasive flora monitoring and mitigation. Mandatory environmental training for all workers and contractors.						
Construction, operations, closure, post closure	Terrestrial fauna SoCC (non-butterfly)	High	Site clearance and project footprint, noise from traffic, blasting, and crusher; increased air emissions and dust deposition Creation of pitfall traps from construction earthworks	Moderate	Pre-clearing rapid surveys plus selective SoCC salvage and relocation. Where possible, clearing will be in a direction that would push mobile species away from the Project. Undertake progressive ecological restoration to minimise impacts to wildlife. Remove oxide ore stockpile from design, reducing loss of forested and riparian habitat. Develop and apply species action plans for SoCC. Placement of artificial bat roosting habitats (bat boxes). Implement invasive fauna mitigations. Mandatory environmental training for all workers and contractors. Seasonal constraints applied to earthworks (where practicable) and hibernacula active searches during spring, summer and autumn. Removal of bird nesting habitat outside of the nesting season. Bird scaring techniques used to prevent ground nesting species from using the construction footprint. Environmental technician to check excavations such as the diversion channel for trapped mammals and herpetofauna. Prior to construction activities an assessment of amphibian and reptiles migration corridors shall be carried out and culvers will be constructed where practicable along with fences to divert animals toward the culverts.	Low	Local	Long-term	Frequent	Low	Minor
Construction, operations	Aquatic habitat and species – Ilovica Reservoir	High	Reduction in water levels due to Project water use and reduced inflows from the Jazga.	Moderate	Alter the augmentation regime to mimic baseline water level fluctuation in the reservoir.	Low	Local	Medium-term	Frequent	Low	Minor
Construction, operations, closure	Aquatic habitat and species – downstream portion of Jazga River	Medium	Reduction in flows due to reduced overflow from Ilovica Reservoir.	Minor	Alter the augmentation regime to provide sufficient inflow to the Ilovica Reservoir so that overspills mimic natural flow pattern.	Negligible	Local	Long-term	Frequent	Negligible	Negligible
Construction, operations, closure, post-closure	Aquatic habitat and species – Shtuka River	High	Permanent diversion of the Shtuka River into the diversion channel.	Major	Undertake fish and decapod rescue prior to diversion of the Shtuka. Naturalise the diversion channel at closure, if possible*.	Moderate	Local	Permanent	n/a	High	Major

* Due to uncertainty of success, this mitigation does not affect the residual impact consequence.

Annex 5G: Supporting Information to the Cultural Heritage Impact Assessment

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Table 1: Impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Magnitude	Geographic extent	Duration	Frequency	Impact classification	Consequence
'Living' cultural heritage									
Construction	SP-01	medium	Ground disturbance - construction of plant site	high	local	permanent	-	high	moderate
Construction	NF-01	medium	Ground disturbance - construction of TMF	high	local	permanent	-	high	moderate
Construction and operations	CE-01	high	Visual	low	local	medium-term	frequent	low	minor
Construction and operations	CE-02	high	Noise – construction	moderate	local	short-term	frequent	low	minor
			Visual	low	local	medium-term	frequent	low	minor
Construction and operations	RE-01	high	Visual	low	local	medium-term	frequent	low	minor
Construction and operations	RE-02	high	Visual	low	local	medium-term	frequent	low	minor
Construction and operations	CE-03	high	Noise – construction	moderate	local	short-term	frequent	low	minor
			Visual	low	local	medium-term	frequent	low	minor
Construction and operations	CE-04	high	Noise - construction of access road	low	local	short-term	frequent	negligible	negligible
			Visual	low	local	medium-term	frequent	low	minor
Construction and operations	CH-02	high	Noise – construction	moderate	local	short-term	frequent	low	minor
			Visual	low	local	medium-term	frequent	low	minor
Construction and operations	CH-03	medium	Noise – construction	moderate	local	short-term	frequent	low	minor
			Ground-borne vibrations - blasting	negligible *(limited potential for moderate)*	local	medium-term	frequent	negligible *(limited potential for moderate)*	negligible *(limited potential for minor)*
			Air quality	moderate	local	medium-term	frequent	moderate	minor
			Visual	moderate	local	medium-term	frequent	moderate	minor
			Air quality	moderate	local	medium-term	frequent	moderate	minor
			Visual	moderate	local	medium-term	frequent	moderate	minor
Construction and operations	RE-04	medium	Noise – construction	moderate	local	short-term	frequent	low	minor
			Ground-borne vibrations - blasting	negligible *(limited potential for moderate)*	local	medium-term	frequent	negligible *(limited potential for moderate)*	negligible *(limited potential for minor)*
			Air quality	moderate	local	medium-term	frequent	moderate	minor
			Visual	moderate	local	medium-term	frequent	moderate	minor
Construction and operations	CH-06	medium	Noise – operations (transport)	negligible	local	short-term	frequent	negligible	negligible
Construction and operations	CM-01	high	Noise, air quality and visual (all indirect)	negligible	local	short/medium-term	infrequent	negligible	negligible
Construction and operations	CH-10	medium	Noise – operations (transport)	negligible	local	short-term	frequent	negligible	negligible
Intangible cultural heritage									
Construction and operations	Religious beliefs and practices	very high	Noise - construction	moderate	local	short-term	frequent	low	moderate
			Noise – operations (blasting)	negligible *(limited potential for moderate)*	local	medium-term	frequent	negligible *(limited potential for moderate)*	Minor *(limited potential for major)*
Construction and operations	Traditional music and dance	high	Noise, air quality and visual (all indirect)	negligible	local	medium-term	frequent	negligible	negligible
Construction and operations	Traditional agricultural lifestyle	high	Noise, air quality and visual (all indirect)	negligible	local	medium-term	frequent	negligible	negligible

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Magnitude	Geographic extent	Duration	Frequency	Impact classification	Consequence
Archaeology									
Construction and operations	AR-06	high	Ground disturbance – construction and ore extraction in open pit area (creation of mine pit)	high	local	permanent	-	high	major
Construction	AR-07	high	Ground disturbance - construction of plant site	high	local	permanent	-	high	major
Construction	AR-08	high	Ground disturbance - construction of plant site	high	local	permanent	-	high	major
Construction and operations	AR-10	high	Ground disturbance - construction of TMF	high	local	permanent	-	high	major
Construction and operations	AR-11	medium	Ground disturbance - construction of TMF	high	local	permanent	-	high	moderate
Operations	AR-03	medium	Ground-borne vibrations - blasting	negligible	local	medium-term	frequent	negligible	negligible
Operations	AR-04	high	Ground-borne vibrations - blasting	negligible *(limited potential for moderate)*	local	medium-term	frequent	negligible *(limited potential for moderate)*	negligible *(limited potential for minor)*
Construction	AR-01	high	Potential ground disturbance - construction of access road	Negligible *(limited potential for high)*	local	permanent	-	negligible *(limited potential for high)*	negligible *(limited potential for major)*
Construction	AR-05	medium	Potential ground disturbance - construction of access road	negligible *(limited potential for high)*	local	permanent	-	negligible *(limited potential for high)*	negligible *(limited potential for moderate)*
Construction	AR-29	high	Potential ground disturbance - construction of access road	negligible *(limited potential for high)*	local	permanent	-	negligible *(limited potential for high)*	negligible *(limited potential for major)*

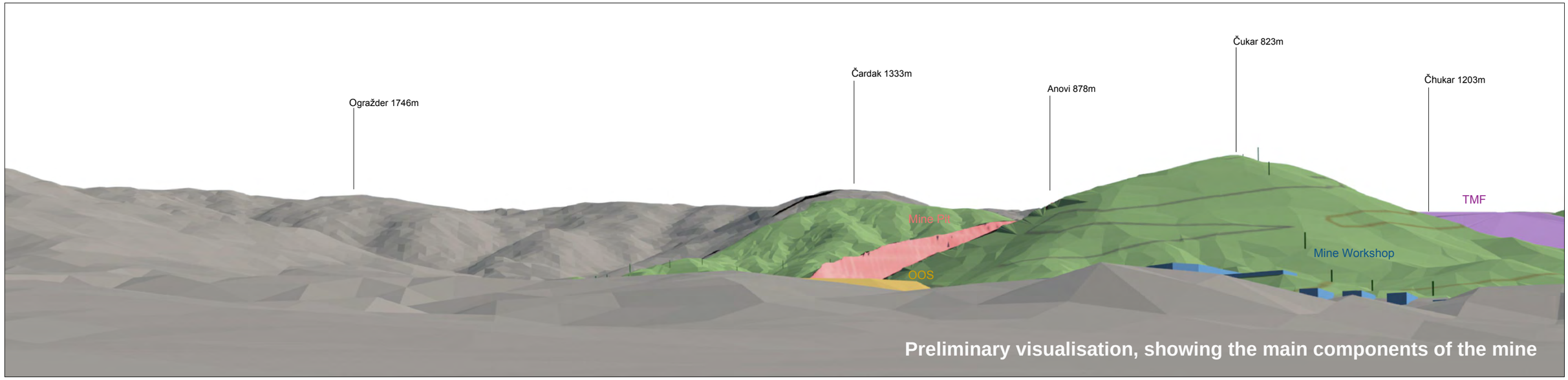
Table 2: Residual impact classification matrix

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact classification before mitigation	Mitigation	Magnitude	Geographic extent	Duration	Frequency	Residual impact classification	Residual impact consequence
'Living' cultural heritage											
Construction	SP-01	medium	Ground disturbance - construction of plant site	high	Relocation of receptor	low	local	permanent	-	moderate	minor
Construction	NF-01	medium	Ground disturbance - construction of TMF	high	Photographic recording and enhanced access	low	local	permanent	-	moderate	minor
Construction and operations	CE-01	high	Visual	low	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	CE-02	high	Noise – construction	low	Noise mitigation	moderate	local	short-term	frequent	low	minor
			Visual	low	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	RE-01a/b	high	Visual	low	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	RE-02	high	Visual	low	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	CE-03	high	Noise – construction	low	Noise mitigation	moderate	local	short-term	frequent	low	minor
			Visual	low	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	CE-04	high	Noise - construction of access road	negligible	Noise mitigation	low	local	short-term	frequent	negligible	negligible
			Visual	low	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	CH-02	high	Noise – construction	low	Noise mitigation	moderate	local	short-term	frequent	low	minor
			Visual	low	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	CH-03	medium	Noise – construction	low	Sympathetic construction schedule	negligible	local	short-term	frequent	negligible	negligible
			Ground-borne vibrations - blasting	negligible *(limited potential for moderate)*	Visual inspection and vibration monitoring *(precautionary measure)*	negligible	local	medium-term	frequent	negligible	negligible
			Air quality	moderate	Sympathetic transport and blasting regime	low	local	medium-term	frequent	low	minor
			Visual	moderate	Visual mitigation	low	local	medium-term	frequent	low	minor
Construction and operations	RE-04	medium	Noise – construction	low	None	moderate	local	short-term	frequent	low	minor
			Ground-borne vibrations - blasting	negligible *(limited potential for moderate)*	Visual inspection and vibration monitoring *(precautionary measure)*	negligible	local	medium-term	frequent	negligible	negligible
			Air quality	moderate	None	moderate	local	medium-term	frequent	moderate	moderate
			Visual	moderate	Visual mitigation and surrounding vegetation to be retained.	low	local	medium-term	frequent	low	minor
Construction and operations	CH-06	medium	Noise – operations (transport)	negligible	Sympathetic transport regime *(precautionary measure)*	negligible	local	medium-term	frequent	negligible	negligible
Construction and operations	CM-01	high	Noise, air quality and visual (all indirect)	negligible	None	negligible	local	short/medium-term	infrequent	negligible	negligible
Construction and operations	CH-10	medium	Noise – operations (transport)	negligible	Sympathetic transport regime *(precautionary measure)*	negligible	local	medium-term	frequent	negligible	negligible

Phase of the project	Receptor	Receptor sensitivity	Source of impact	Impact classification before mitigation	Mitigation	Magnitude	Geographic extent	Duration	Frequency	Residual impact classification	Residual impact consequence
Intangible Cultural Heritage											
Construction and operations	Religious beliefs and practices	very high	Noise – construction	low	Noise mitigation	moderate	local	short-term	frequent	low	moderate
					Sympathetic construction schedule (particularly for CH-03)	negligible	local	short-term	frequent	negligible	minor
			Noise – operations (blasting)	negligible *(limited potential for moderate)*	Sympathetic transport and blasting regime *(precautionary measure)*	negligible	local	medium-term	frequent	negligible	minor
Construction and operations	Traditional music and dance	high	Noise, air quality and visual (all indirect)	negligible	Sympathetic transport regime *(precautionary measure)*	negligible	local	medium-term	frequent	negligible	negligible
Construction and operations	Traditional agricultural lifestyle	high	Noise, air quality and visual (all indirect)	negligible	None	negligible	local	medium-term	frequent	negligible	negligible
Archaeology											
Construction and operations	AR-06	high	Ground disturbance – construction and ore extraction in open pit area (creation of mine pit)	high	Archaeological evaluation and excavation	low	local	permanent	-	moderate	moderate
Construction	AR-07	high	Ground disturbance - construction of plant site	high	Archaeological evaluation and excavation	low	local	permanent	-	moderate	moderate
Construction	AR-08	high	Ground disturbance - construction of plant site	high	Archaeological evaluation and excavation	low	local	permanent	-	moderate	moderate
Construction and operations	AR-10	high	Ground disturbance - construction of TMF	high	Archaeological evaluation and excavation	low	local	permanent	-	moderate	moderate
Construction and operations	AR-11	medium	Ground disturbance - construction of TMF	high	Archaeological evaluation and excavation	low	local	permanent	-	moderate	minor
Operations	AR-03	medium	Ground-borne vibrations - blasting	negligible	None	negligible	local	long-term	frequent	negligible	negligible
Operations	AR-04	high	Ground-borne vibrations - blasting	negligible *(limited potential for moderate)*	Visual inspection and vibration monitoring *(precautionary measure)*	negligible	local	long-term	frequent	negligible	negligible
Construction	AR-01	high	Ground disturbance - construction of access road	negligible *(limited potential for high)*	Archaeological watching brief *(precautionary measure)*	negligible	local	permanent	-	negligible	negligible
Construction	AR-05	medium	Ground disturbance - construction of access road	negligible *(limited potential for high)*	Archaeological watching brief *(precautionary measure)*	negligible	local	permanent	-	negligible	negligible
Construction	AR-29	high	Ground disturbance - construction of access road	negligible *(limited potential for high)*	Archaeological watching brief *(precautionary measure)*	negligible	local	permanent	-	negligible	negligible

Annex 5H: Supporting Information to the Landscape and Visual Assessment

April 2016
Report No. 13514150363.701/A.0



Latitude	N41°28'24.93"
Longitude	E22°48'11.53"
Elevation	296 M
Direction of Photograph	75°
Distance to Mine	3.18 km
Focal Length	27 mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

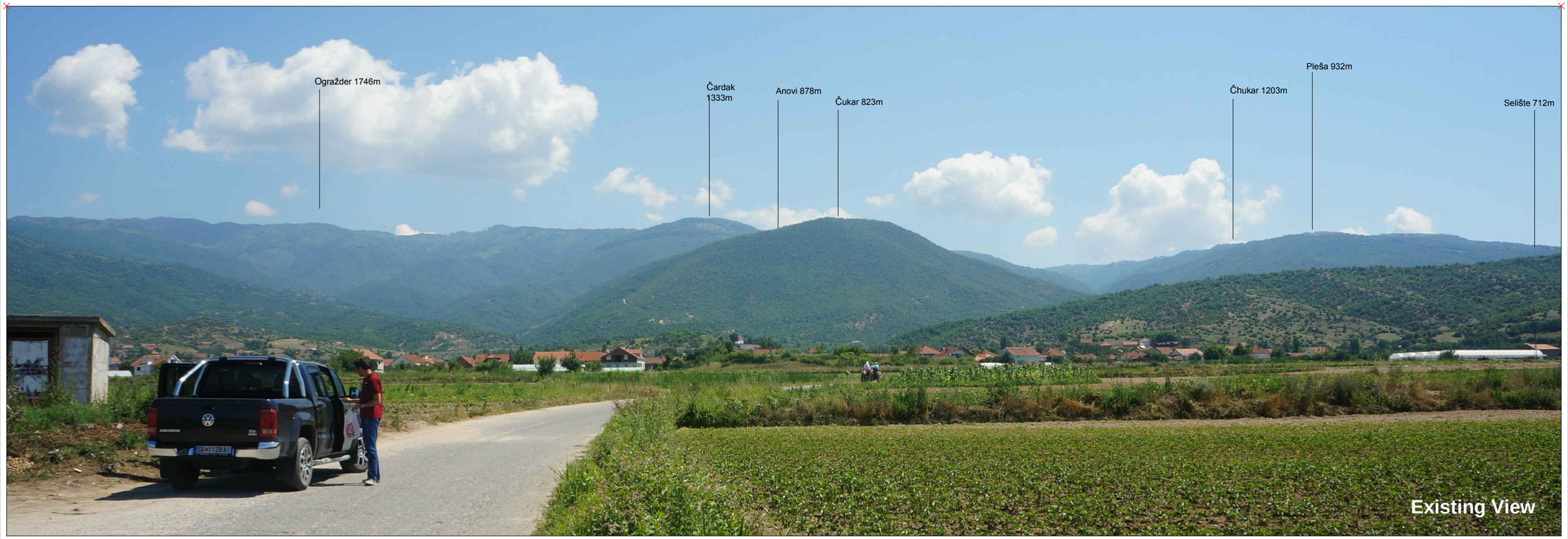
Viewpoint 1 : Ilovica

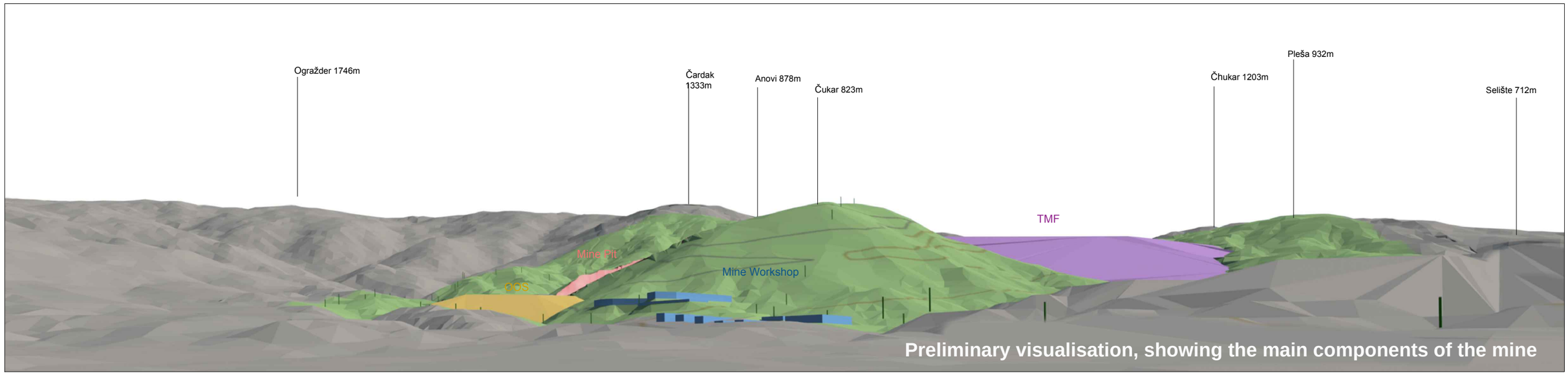
Northwest of the village adjacent to the Jazga River

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 264
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP1
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 1

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates





Latitude	N41°27'47.72"
Longitude	E22°47'59.22"
Elevation	265 m
Direction of Photograph	59°
Distance to Mine	3.88 km
Focal Length	27 mm
Date of Photograph	24 June 2015

- Concession Area
- Mine Pit
- Taillings Management Facility (TMF)
- Oxide Ore Stockpile (OOS)
- Access Road/ Haul Roads
- Plant/Workshop
- Powerline

Location

Viewpoint 2 : South of Ilovcia

Junction South of Ilovica and Shtuka Roads

Client: EUROMAX RESOURCES DOO SKOPJE

Project: Ilovica Environmental and Social Impact Assessment

Title: Landscape and Visual Assessment Viewpoint 2

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

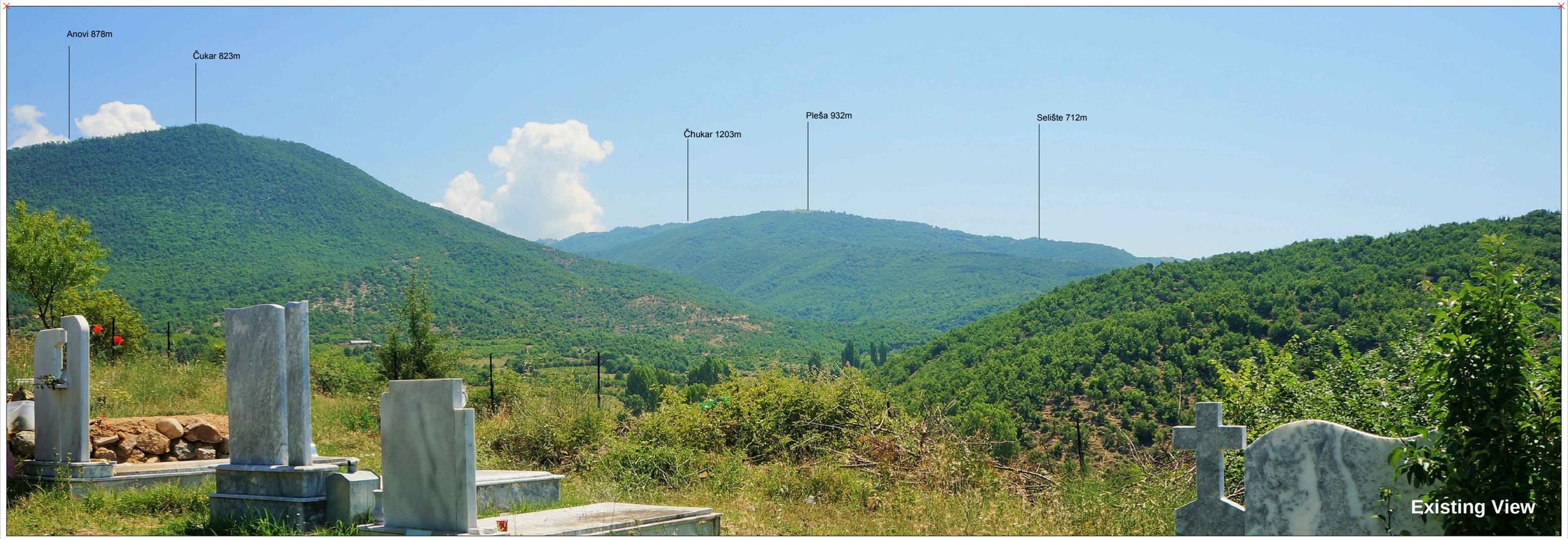
File No.	Project No.
265	13514150363

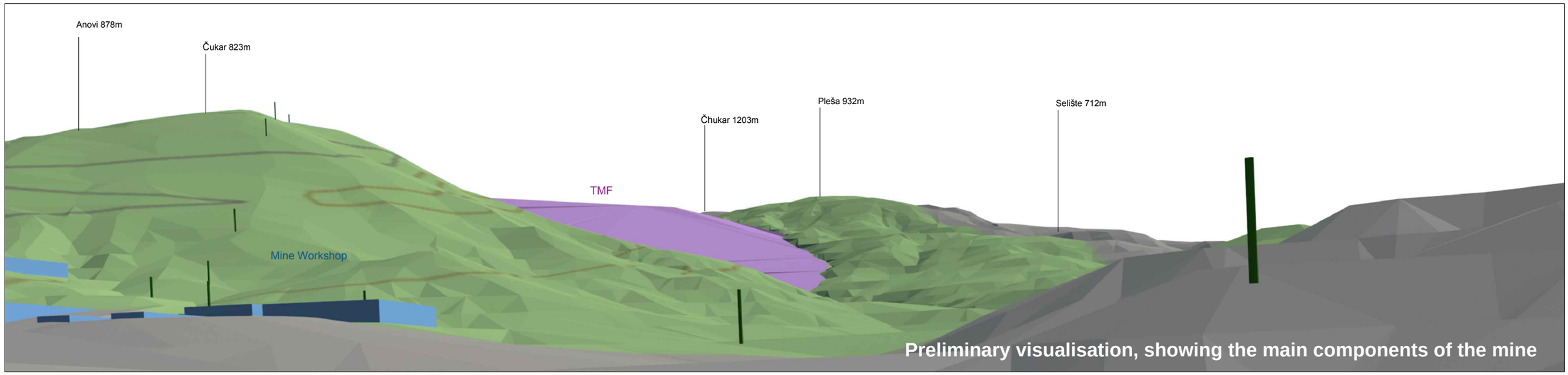
Size	Scale	Status
A3	NTS	FINAL

Drawing No.: VP2

Rev: B.0

Golder Associates





Latitude	N41°28'14.41"
Longitude	E22°48'47.49"
Elevation	334 m
Direction of Photograph	63°
Distance to Mine	2.5 km
Focal Length	27 mm
Date of Photograph	24 June 2015

- Concession Area
- Mine Pit
- Taillings Management Facility (TMF)
- Oxide Ore Stockpile (OOS)
- Access Road/ Haul Roads
- Plant/Workshop
- Powerline

Location

Viewpoint 3 : Shtuka

Shtuka Church

Client: EUROMAX RESOURCES DOO SKOPJE

Project: Ilovica Environmental and Social Impact Assessment

Title: Landscape and Visual Assessment Viewpoint 3

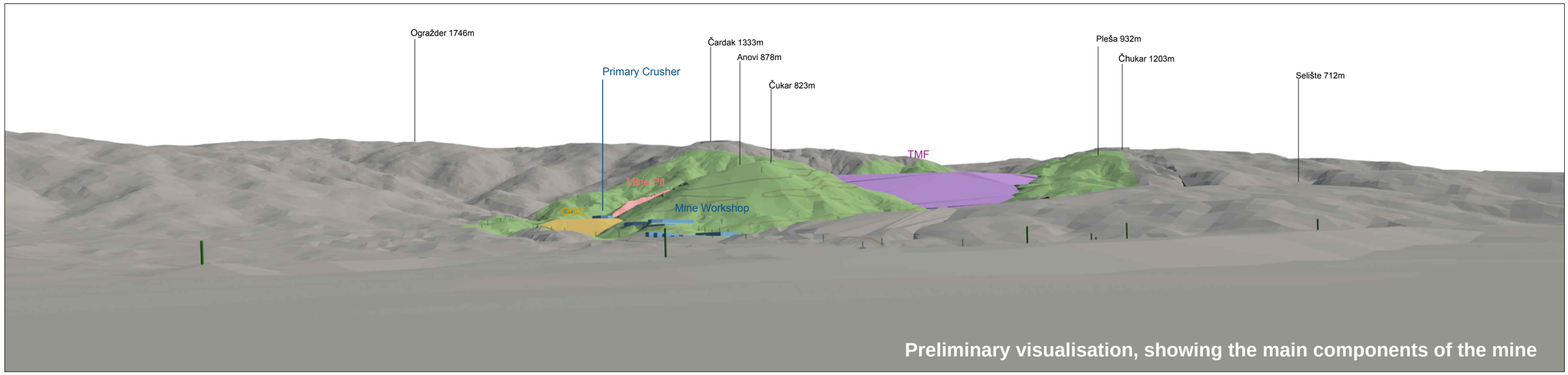
Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

File No. 266 | Project No. 13514150363

Size A3 | Scale NTS | Status FINAL

Drawing No. VP3 | Rev B.0

Golder Associates



Latitude	N41°26'46.93"
Longitude	E22°46'40.32"
Elevation	218 m
Direction of Photograph	53°
Distance to Mine	6.44 km
Focal Length	27 mm
Date of Photograph	24 June 2015

- Concession Area
- Mine Pit
- Taillings Management Facility (TMF)
- Oxide Ore Stockpile (OOS)
- Access Road/ Haul Roads
- Plant/Workshop
- Powerline

Location

Viewpoint 6 : Turnovo

Ilovica Road north of the village

Client: EUROMAX RESOURCES DOO SKOPJE

Project: Ilovica Environmental and Social Impact Assessment

Title: Landscape and Visual Assessment Viewpoint 6

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov15

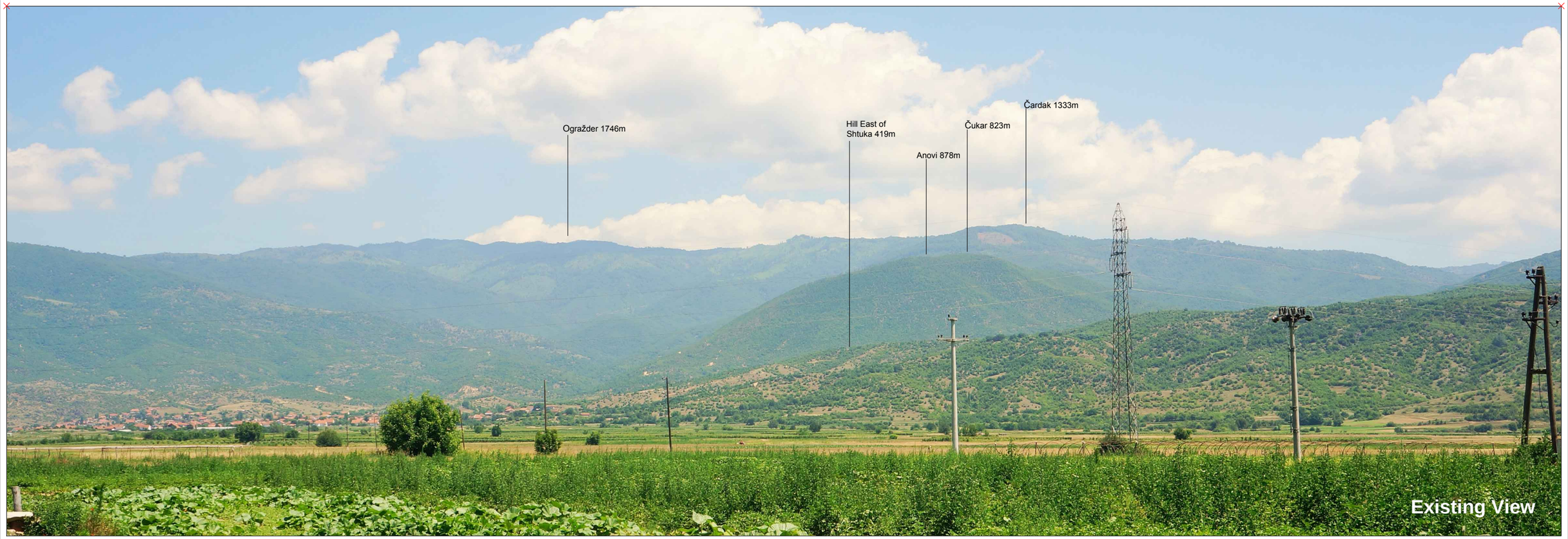
File No.	Project No.
267	13514150363

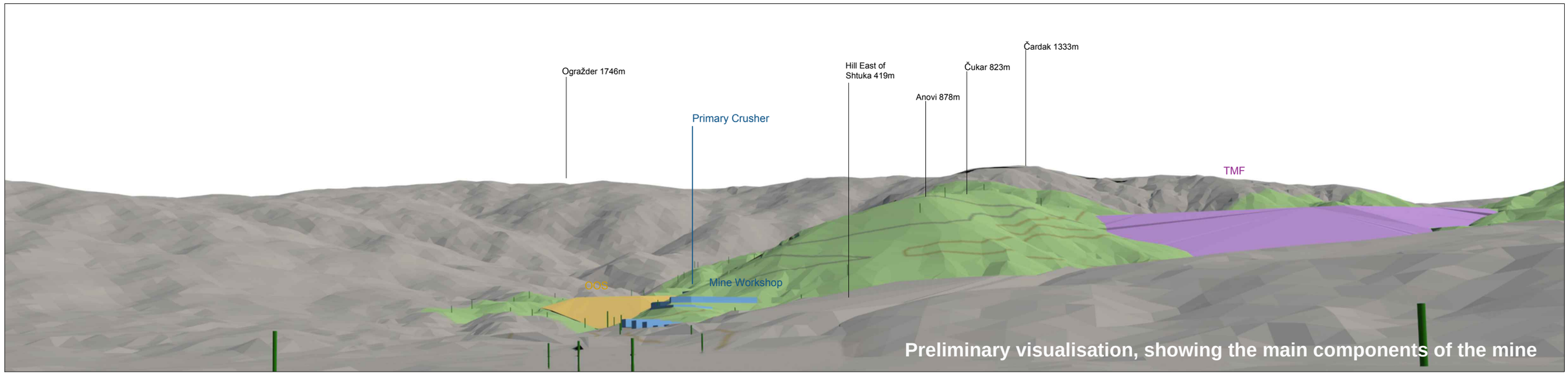
Size	Scale	Status
A3	NTS	FINAL

Drawing No.: VP6

Rev: B.0

Golder Associates





Latitude	N41°26'41.37"
Longitude	E22°47'43.41"
Elevation	225 m
Direction of Photograph	42°
Distance to Mine	5.44 km
Focal Length	40 mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

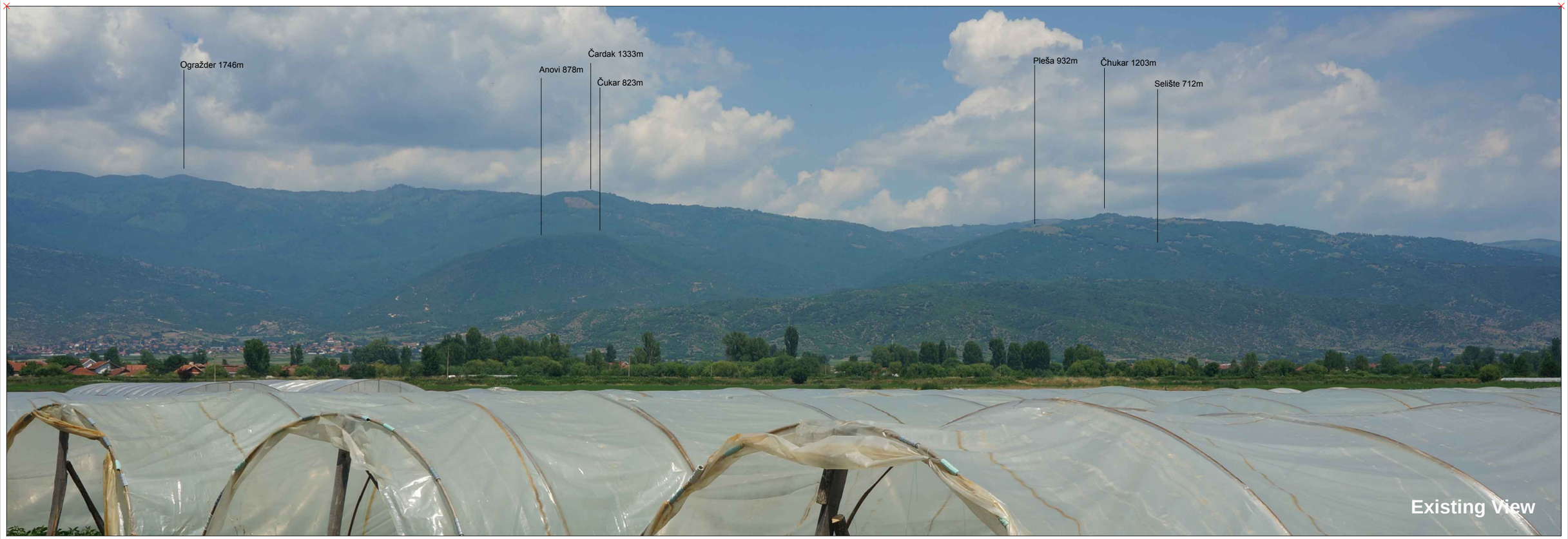
Viewpoint 8 : Sekirnik

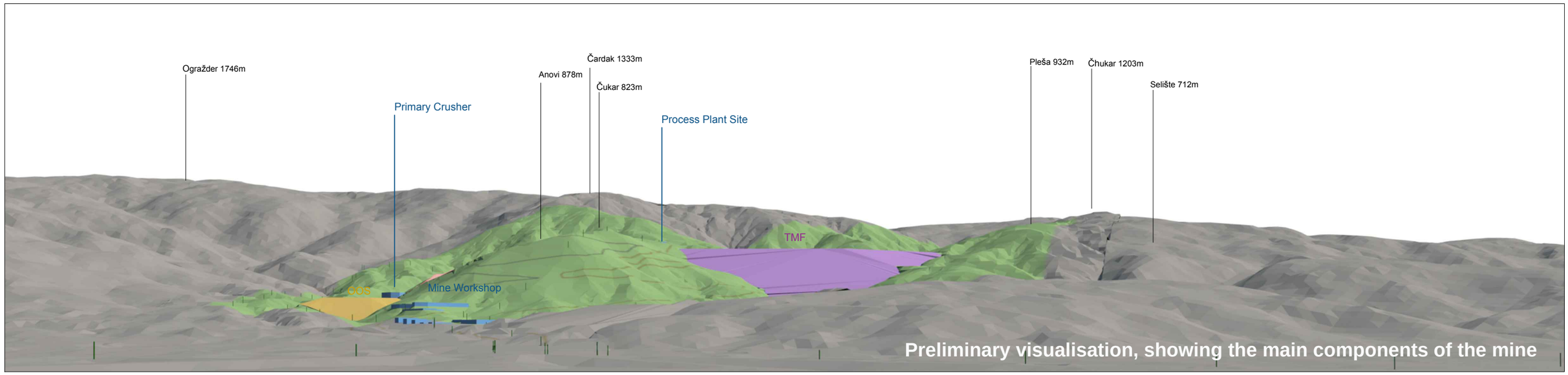
North of the village

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 268
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP8
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 8

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates





Latitude	N41°25'46.50"
Longitude	E22°46'7.22"
Elevation	210 m
Direction of Photograph	45°
Distance to Mine	8.22 km
Focal Length	42 mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

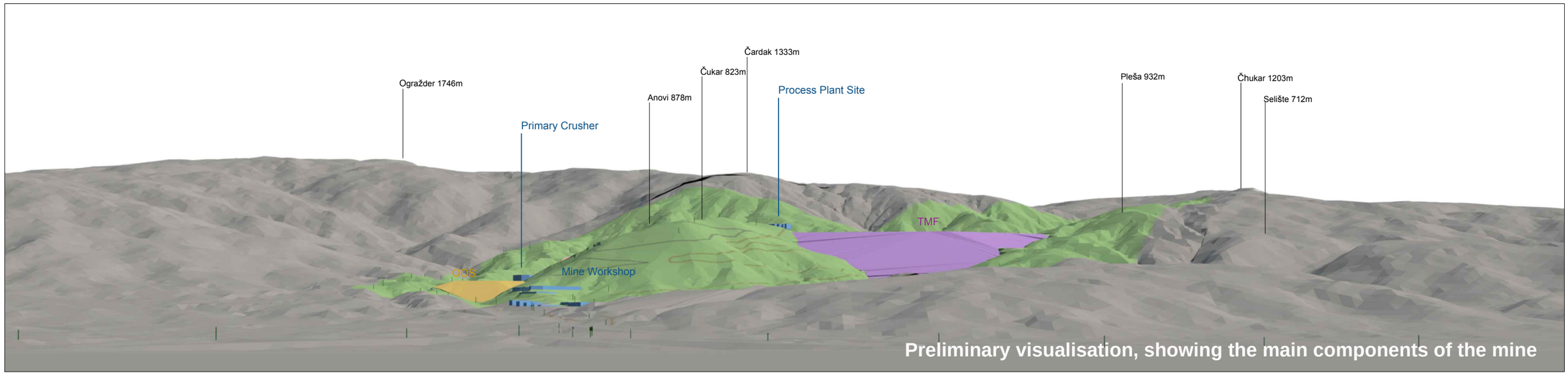
Viewpoint 12 : Borievo

North side of the village

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 269
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP12
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 12

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates



Latitude	N41°25'3.38"
Longitude	E22°45'38.87"
Elevation	207 m
Direction of Photograph	42°
Distance to Mine	9.66 km
Focal Length	46 mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

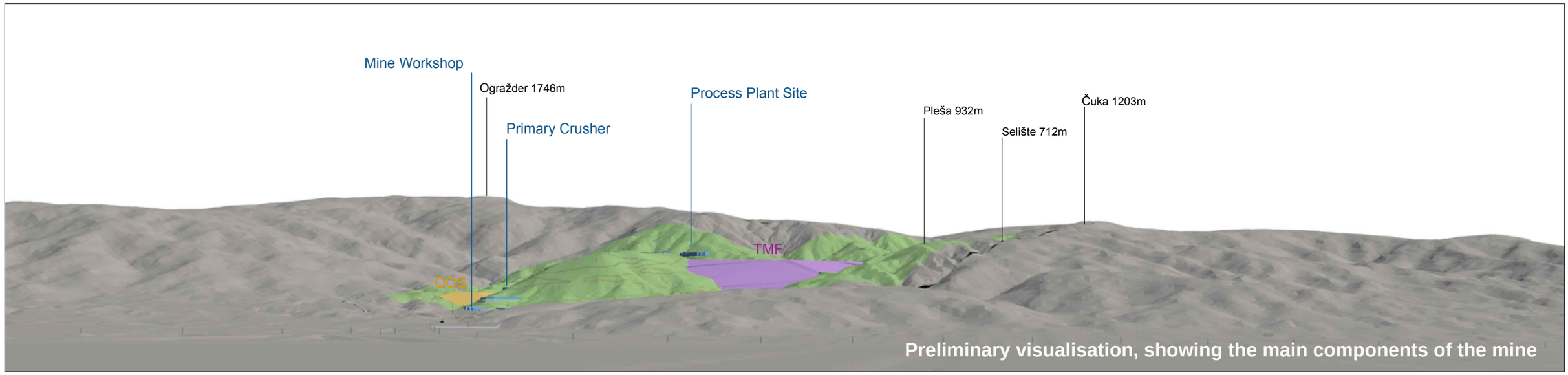
Viewpoint 13 : Monospitovo

Road between Monospitovo and Borievo

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 270
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP13
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 13

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates



Latitude	N41°23'12.52"
Longitude	E22°45'10.23"
Elevation	255 m
Direction of Photograph	34°
Distance to Mine	12.71 km
Focal Length	30 mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

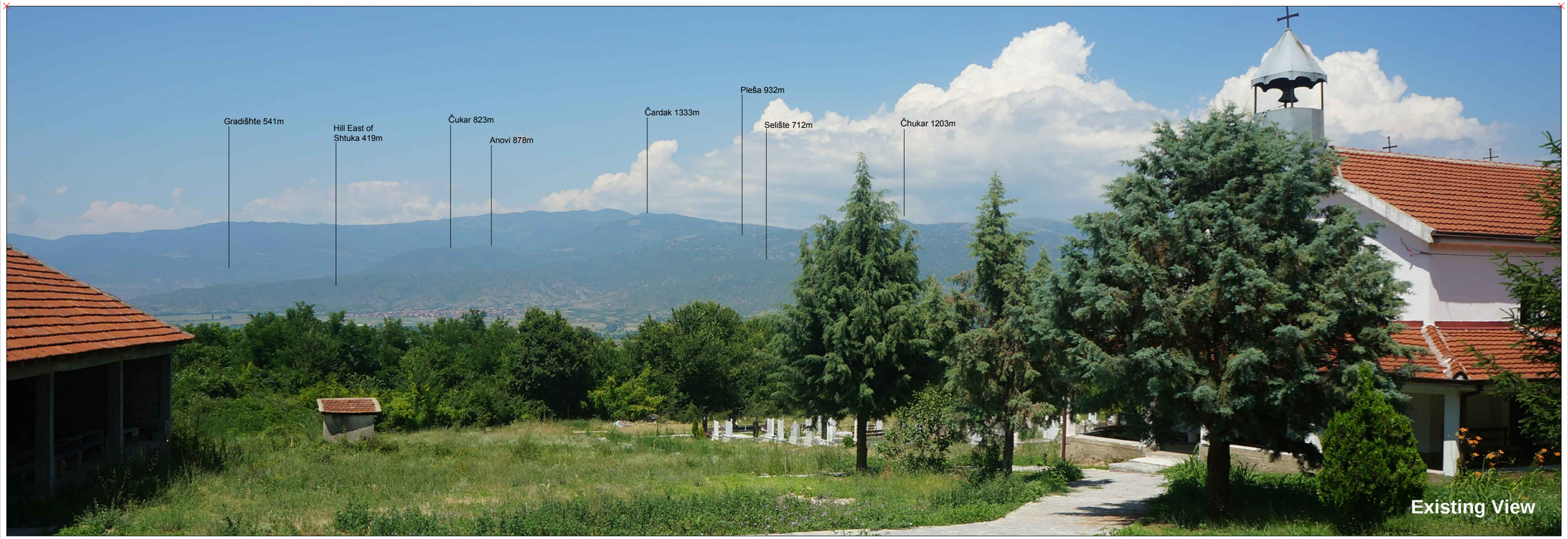
Viewpoint 15 : Bansko

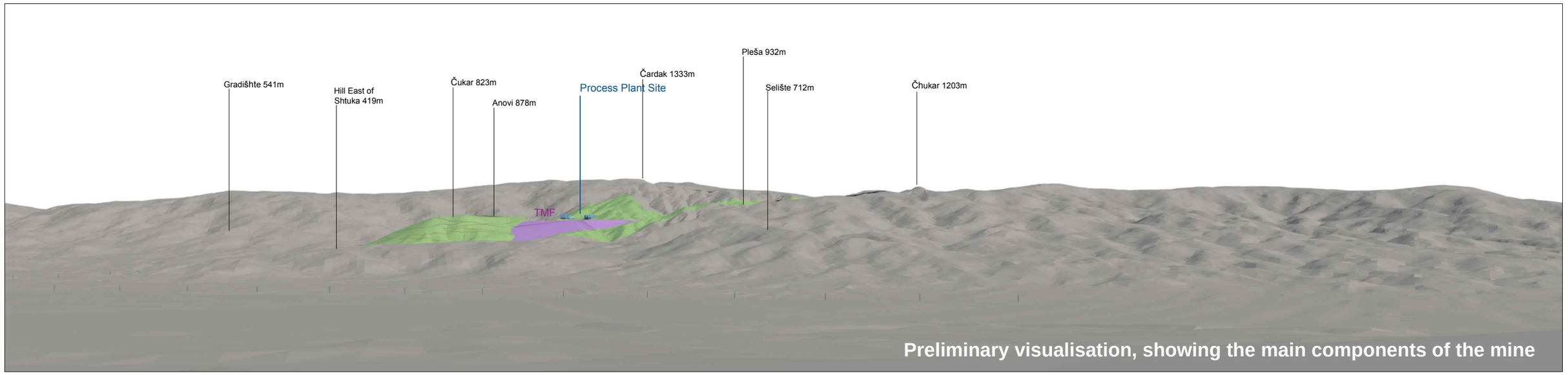
Road junction northeast of the village

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 271
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP15
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 15

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates





Latitude	N41°22'42.00"
Longitude	E22°49'48.15"
Elevation	337 m
Direction of Photograph	3°
Distance to Mine	11.37 km
Focal Length	27 mm
Date of Photograph	24 June 2015

- Concession Area
- Mine Pit
- Taillings Management Facility (TMF)
- Oxide Ore Stockpile (OOS)
- Access Road/ Haul Roads
- Plant/Workshop
- Powerline

Location

Viewpoint 17 : Borisovo

Church between Borisovo and Mokrievo

Client: EUROMAX RESOURCES DOO SKOPJE

Project: Ilovica Environmental and Social Impact Assessment

Title: Landscape and Visual Assessment Viewpoint 17

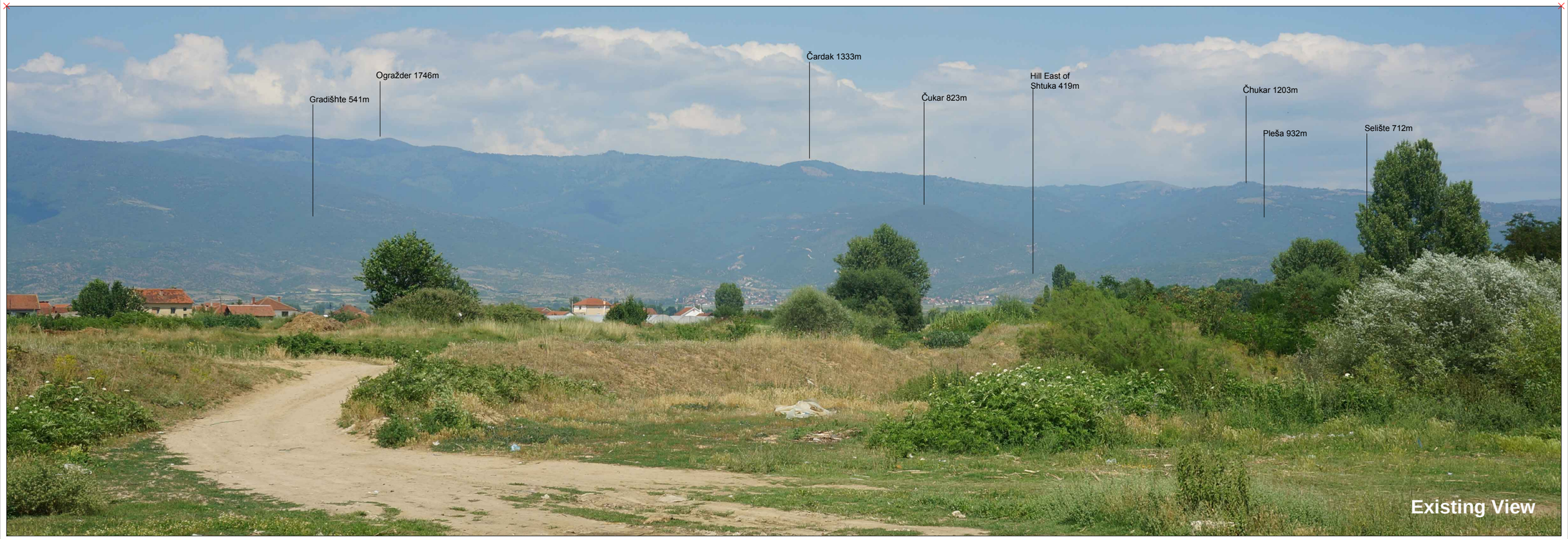
Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

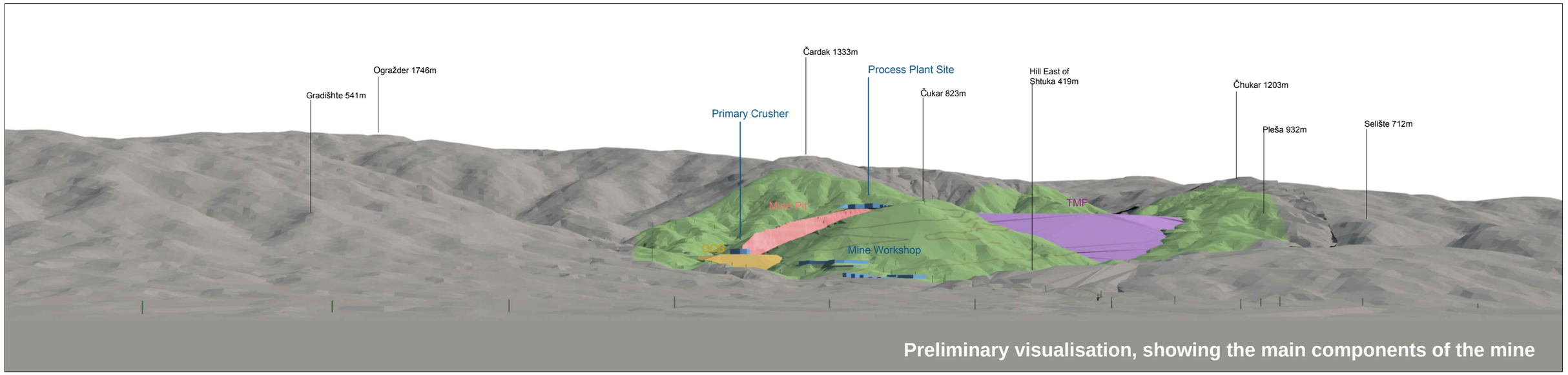
File No. 272 | Project No. 13514150363

Size A3 | Scale NTS | Status FINAL

Drawing No. VP17 | Rev B.0

Golder Associates





Latitude	N41°26'1.86"
Longitude	E22°43'52.11"
Elevation	214 m
Direction of Photograph	59°
Distance to Mine	10.48 km
Focal Length	45 mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

Viewpoint 18 : Ednokukjevo

North side of village, next to River Strumica

Client: EUROMAX RESOURCES DOO SKOPJE

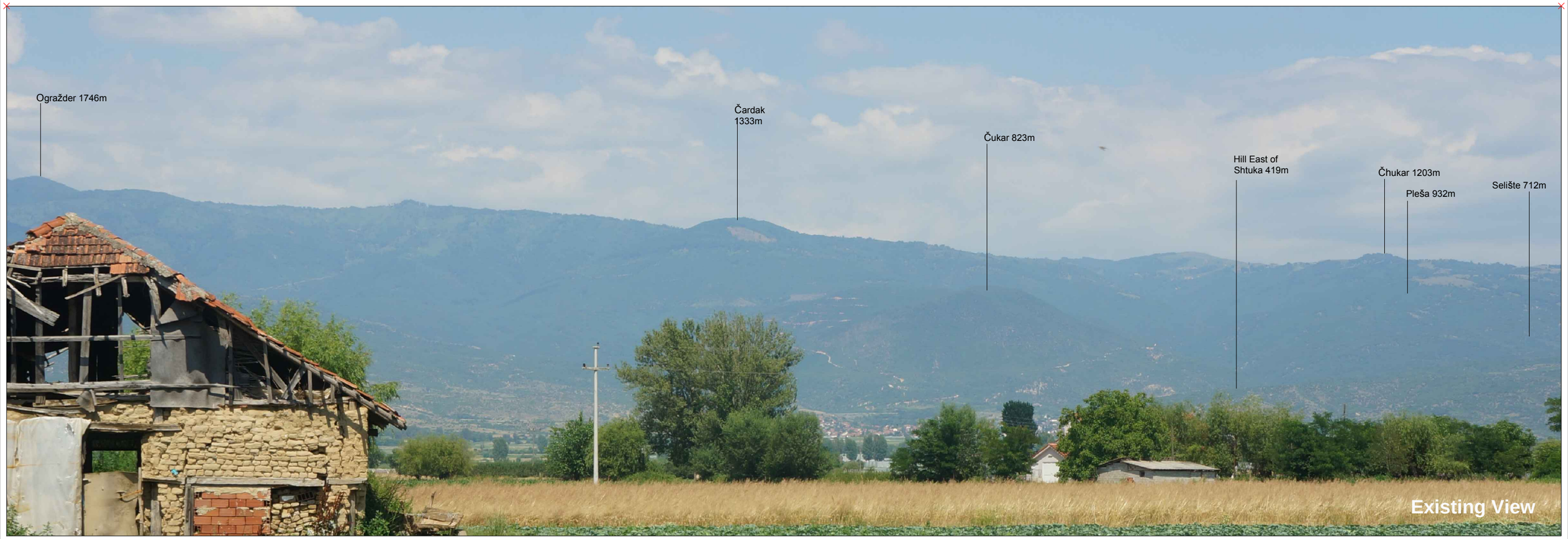
Project: Ilovica Environmental and Social Impact Assessment

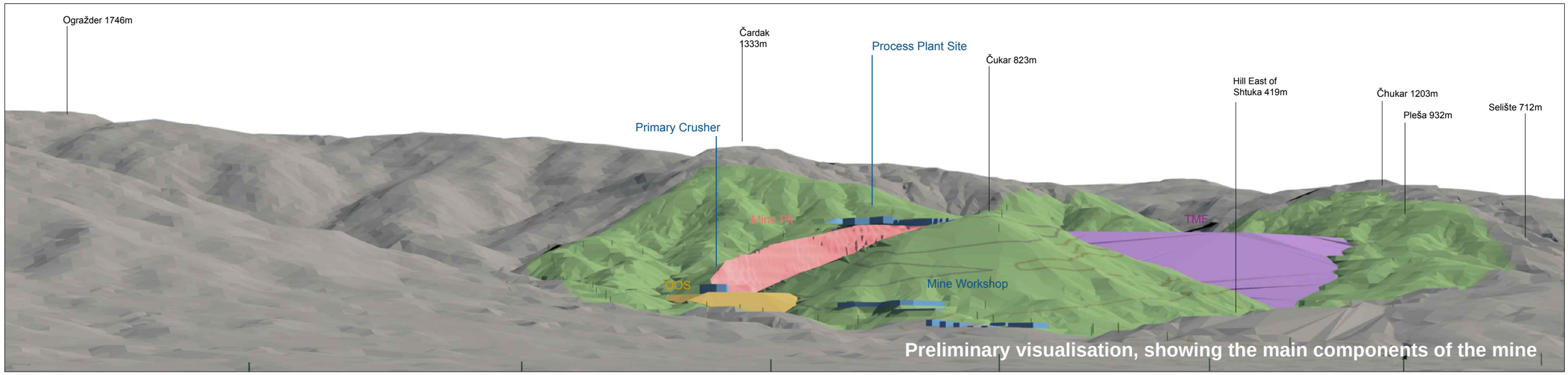
Title: Landscape and Visual Assessment Viewpoint 18

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

File No. 273 | Project No. 13514150363
Size A3 | Scale NTS | Status FINAL
Drawing No. VP18 | Rev B.0

Golder Associates





Latitude	N41°26'34.32"
Longitude	E22°43'34.90"
Elevation	215 m
Direction of Photograph	65°
Distance to Mine	10.38 km
Focal Length	60mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

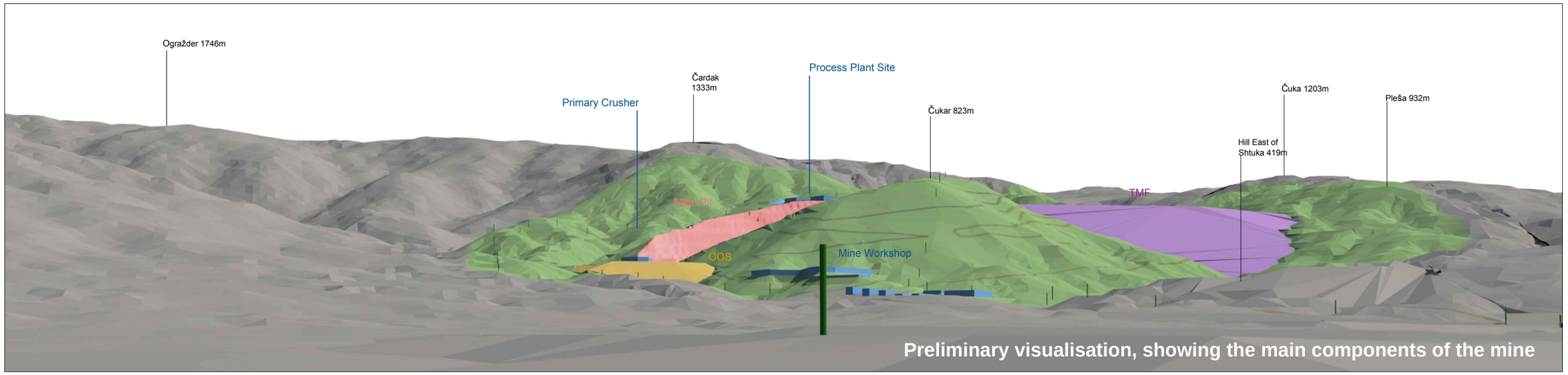
Viewpoint 19 : Bosilovo

Northwest of the village. North of the burial ground

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 274
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP19
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 19

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates



Latitude	N41°27'25.17"
Longitude	E22°46'13.17"
Elevation	227 m
Direction of Photograph	65°
Distance to Mine	6.39 km
Focal Length	43 mm
Date of Photograph	24 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

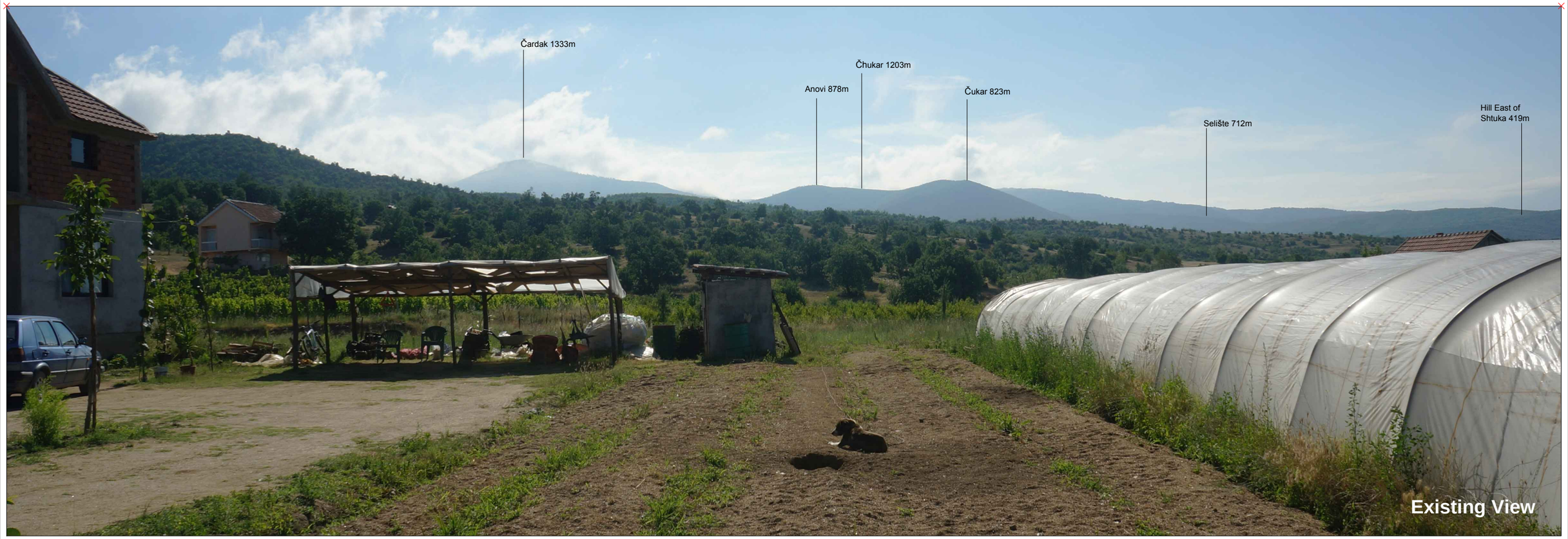
Viewpoint 20 : Radovo

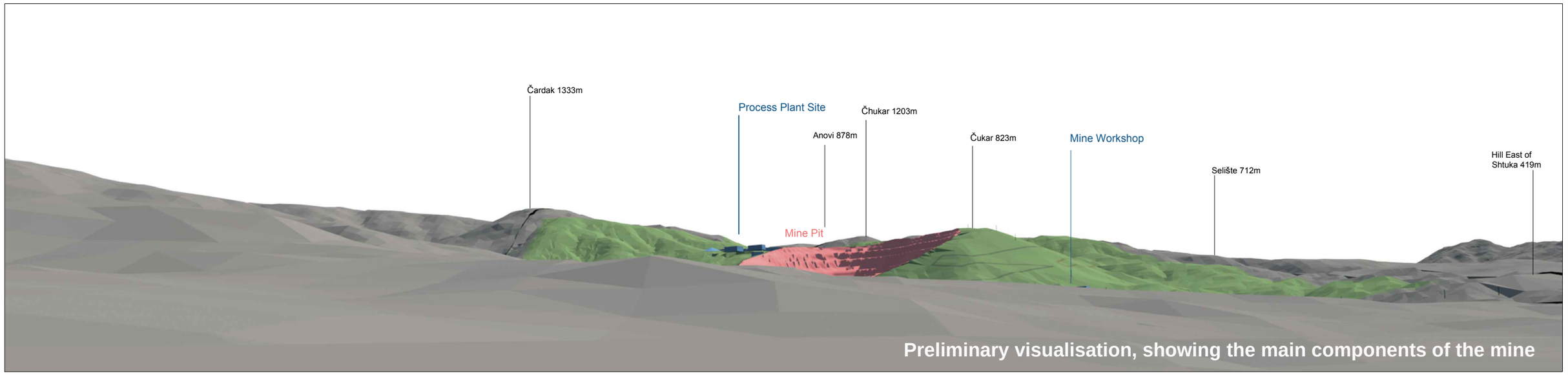
North end of village

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 275
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP20
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 20

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates





Latitude	N41°29'25.27"
Longitude	E22°46'17.71"
Elevation	315 m
Direction of Photograph	100°
Distance to Mine	5.83 km
Focal Length	27 mm
Date of Photograph	25 June 2015

- Concession Area
- Mine Pit
- Taillings Management Facility (TMF)
- Oxide Ore Stockpile (OOS)
- Access Road/ Haul Roads
- Plant/Workshop
- Powerline

Location

Viewpoint 23 : Drvosh

Road south of village

Client: EUROMAX RESOURCES DOO SKOPJE

Project: Ilovica Environmental and Social Impact Assessment

Title: Landscape and Visual Assessment Viewpoint 23

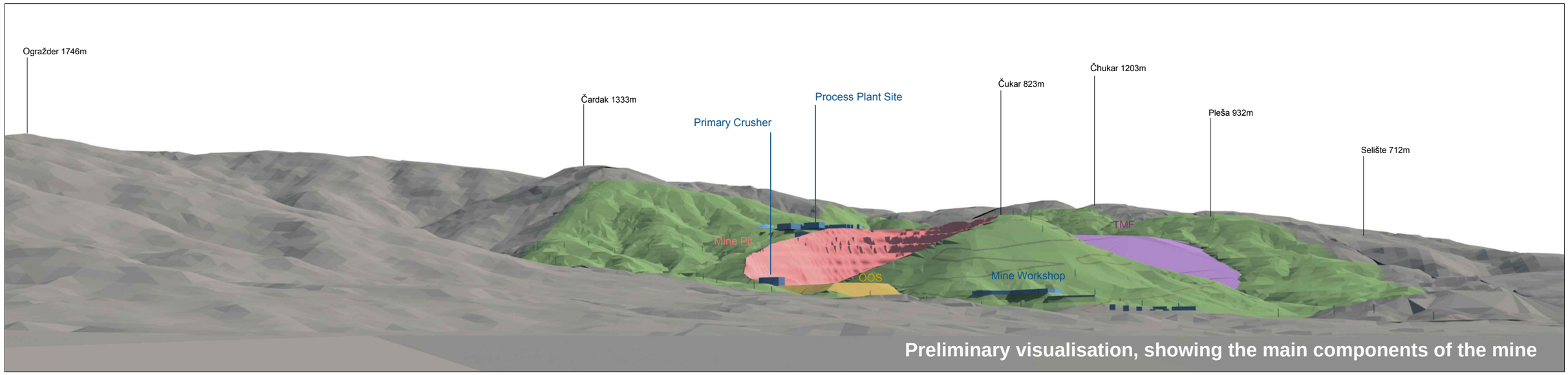
Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

File No.	Project No.
276	13514150363

Size	Scale	Status
A3	NTS	FINAL

Drawing No.: VP23 Rev: B.0

Golder Associates



Latitude	N41°28'33.15"
Longitude	E22°43'55.27"
Elevation	231 m
Direction of Photograph	86°
Distance to Mine	9.05 km
Focal Length	48 mm
Date of Photograph	25 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

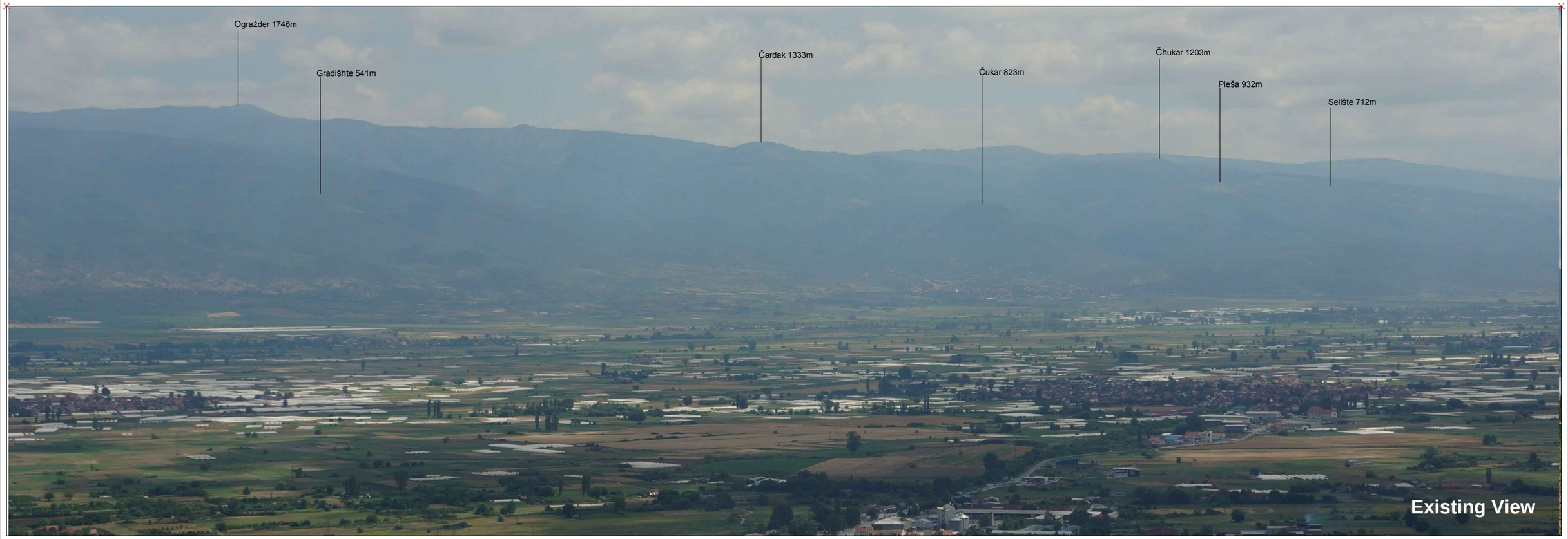
Viewpoint 24 : Petralinci

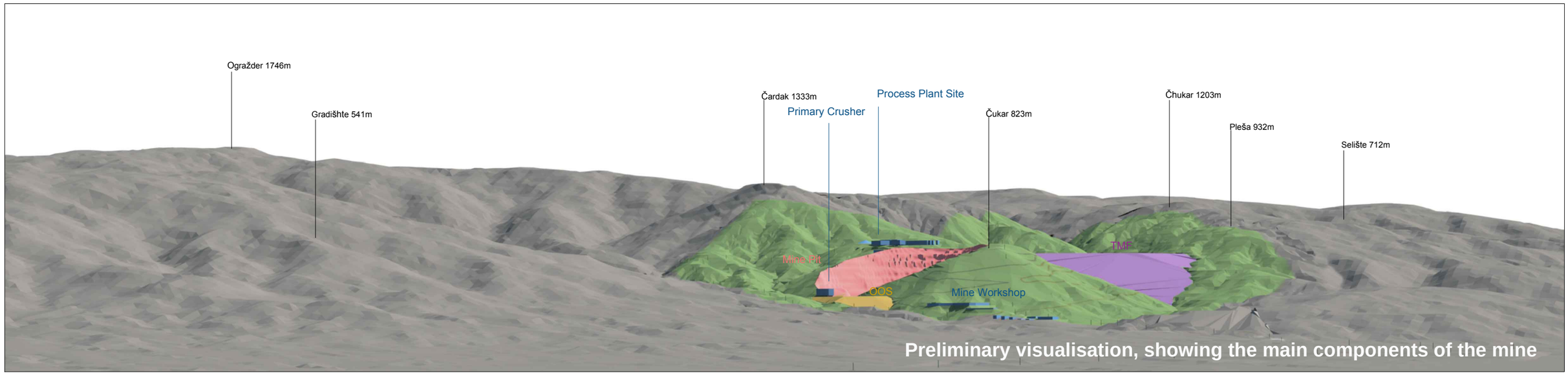
North end of the village

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 277
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP24
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 24

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates





Latitude	N41°25'59.23"
Longitude	E22°37'52.19"
Elevation	412 m
Direction of Photograph	72°
Distance to Mine	18.24 km
Focal Length	69 mm
Date of Photograph	25 June 2015

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

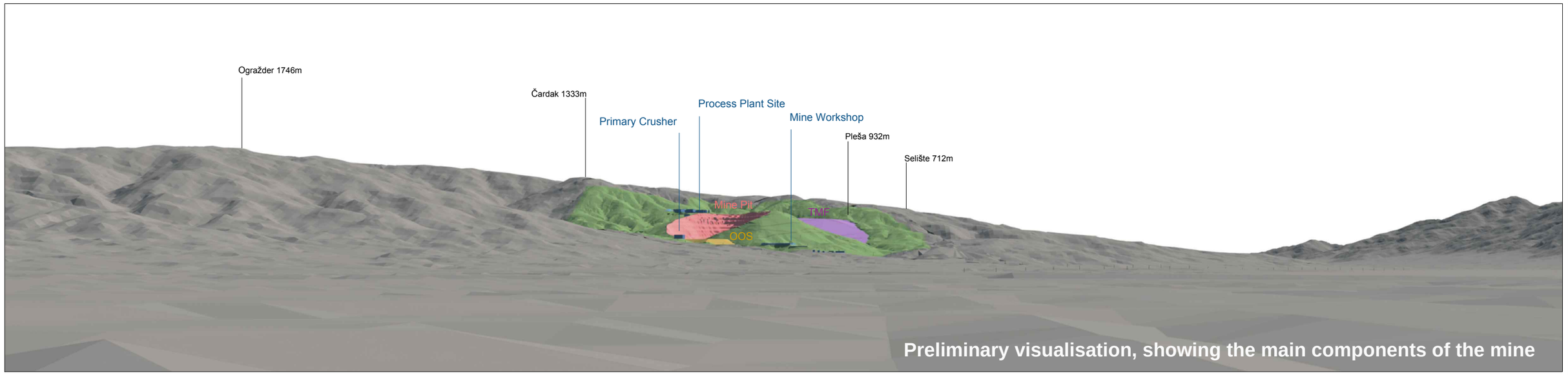
Viewpoint 26 : Carevi Kuli Fortress

Castle and telecomunication mast on the hill south of Strumica

Client: EUROMAX RESOURCES DOO SKOPJE
File No.: 278
Project No.: 13514150363
Project: Ilovica Environmental and Social Impact Assessment
Size: A3
Scale: NTS
Status: FINAL
Drawing No.: VP26
Rev: B.0
Title: Landscape and Visual Assessment Viewpoint 26

Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

Golder Associates



Latitude	N41°28'42.83"
Longitude	E22°38'52.87"
Elevation	233 m
Direction of Photograph	86°
Distance to Mine	15.99 km
Focal Length	34 mm
Date of Photograph	25 June 2015

- Concession Area
- Mine Pit
- Taillings Management Facility (TMF)
- Oxide Ore Stockpile (OOS)
- Access Road/ Haul Roads
- Plant/Workshop
- Powerline

Location

Viewpoint 27 : Vasilevo

Fields east of the village

Client: EUROMAX RESOURCES DOO SKOPJE

Project: Ilovica Environmental and Social Impact Assessment

Title: Landscape and Visual Assessment Viewpoint 27

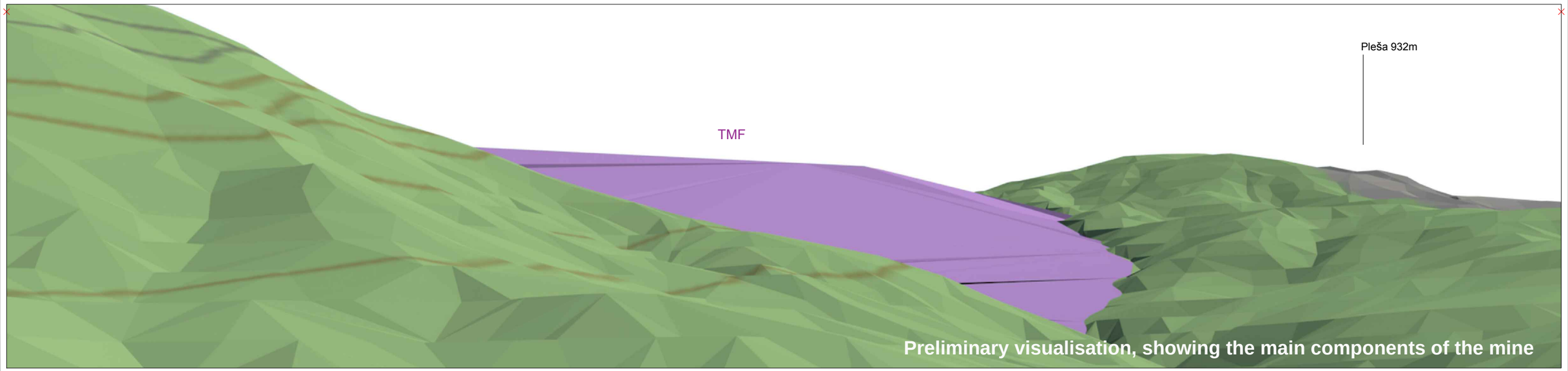
Created by	Requested by	Proj Manager	Reviewer	Date
NR	MS	MS	ANDREW MORSLEY	Nov 15

File No.	Project No.
279	13514150363

Size	Scale	Status
A3	NTS	FINAL

Drawing No.: VP27 Rev: B.0

Golder Associates



Latitude	N 41°28'12.21"
Longitude	E 22°49'30.87"
Elevation	353 M
Direction of Photograph	47°
Distance to Mine	1,660 m
Focal Length	30 mm
Date of Photograph	Not Applicable

- Concession Area
- Mine Pit
- Taillings Management Facility (TMF)
- Oxide Ore Stockpile (OOS)
- Access Road/ Haul Roads
- Plant/Workshop
- Powerline

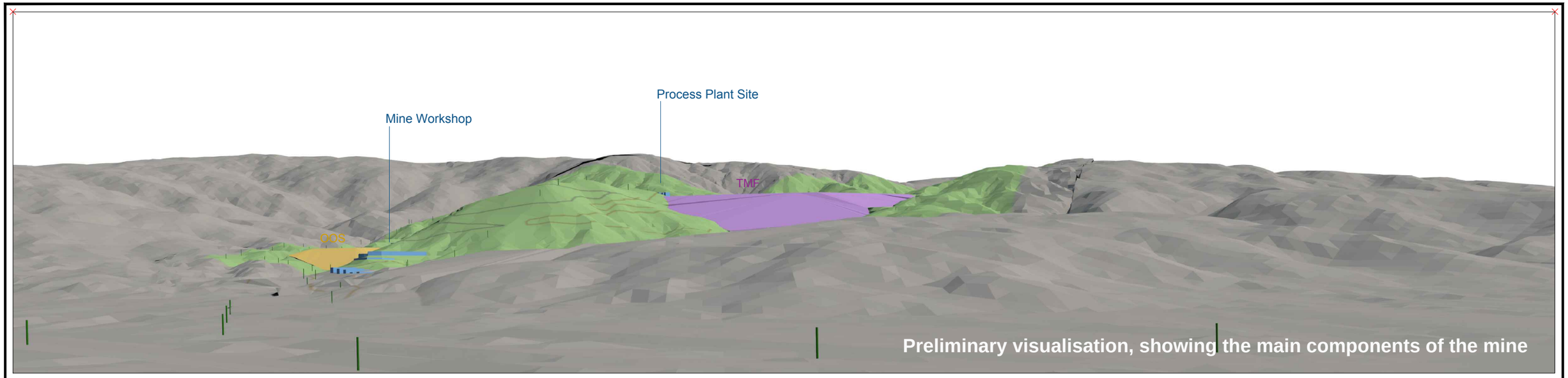
Location

Viewpoint 29 : Monastery of St George

Chapel in the Shtuka Valley

Client	EUROMAX RESOURCES DOO SKOPJE			File No. 280	Project No. 13514150363	
Project	Ilovica Environmental and Social Impact Assessment			Size A3	Scale NTS	Status FINAL
				Drawing No. VP29		Rev B.0
Title	Landscape and Visual Assessment Viewpoint 29					
Created by NR	Requested by MS	Proj Manager MS	Reviewer ANDREW MORSLEY	Date Feb 16		

Golder Associates



Latitude	N41°26'17.33"
Longitude	E22°47'36.99"
Elevation	691 M
Direction of Photograph	51°
Distance to Mine	6.06 km
Focal Length	30 mm
Date of Photograph	Not Applicable

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

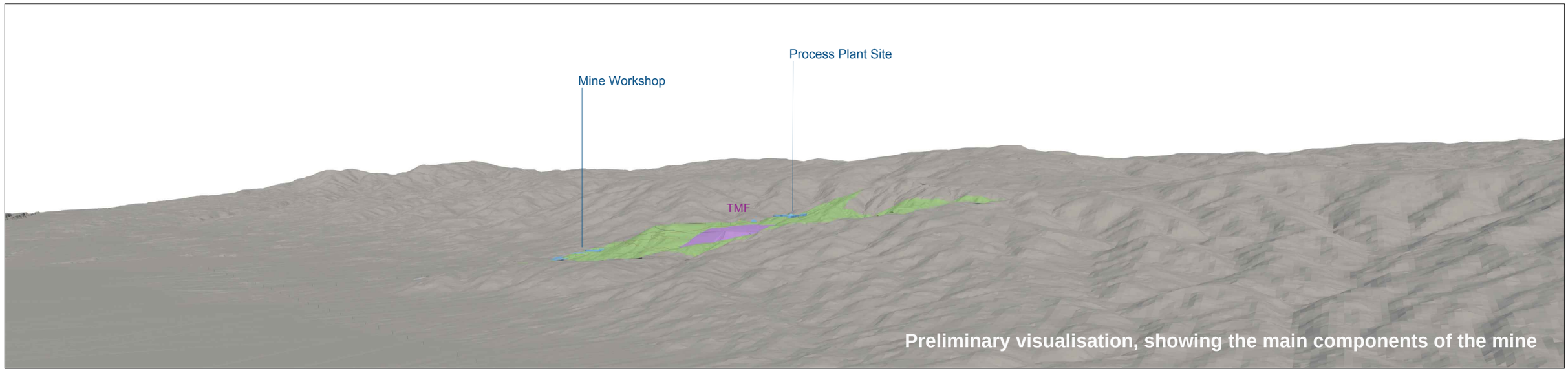
Location

Viewpoint 31 : Sekirnik Park

Cultural site in Sekirnik

Client	EUROMAX RESOURCES DOO SKOPJE				File No. 281	Project No. 13514150363	
Project	Ilovica Environmental and Social Impact Assessment				Size A3	Scale NTS	Status FINAL
					Drawing No. VP31		Rev B.0
Title	Landscape and Visual Assessment Viewpoint 31 - Wireline visualisation						
Created by NR	Requested by MS	Proj Manager MS	Reviewer ANDREW MORSLEY	Date Nov 15			

Golder Associates



Latitude	N41°20'18.72"
Longitude	E22°55'39.75"
Elevation	1880 M
Direction of Photograph	207°
Distance to Mine	17.23 km
Focal Length	30 mm
Date of Photograph	Not Applicable

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

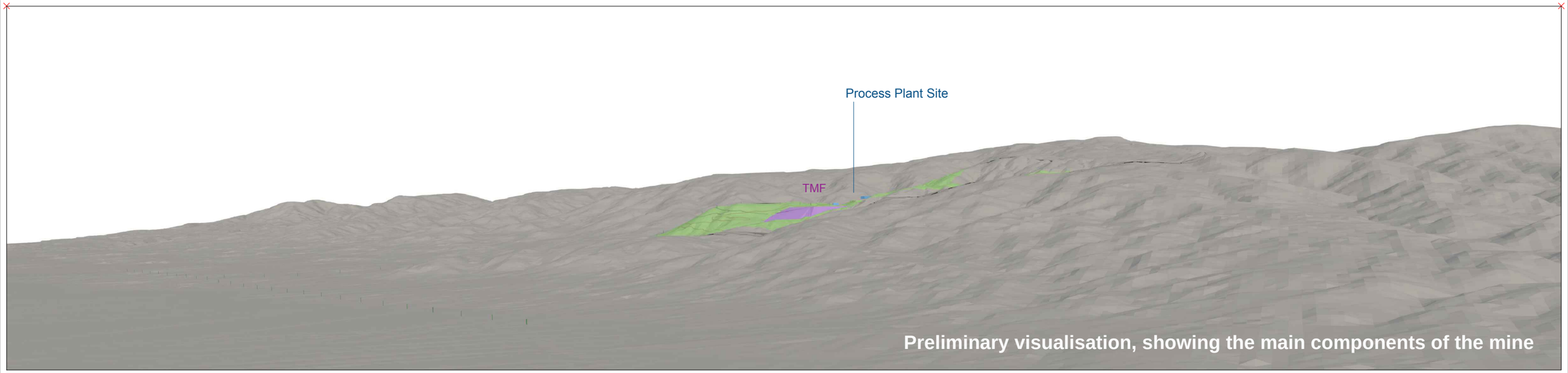
Location

Viewpoint 32 : Tumba Peak

Mountain peak southwest of the site.

Client	EUROMAX RESOURCES DOO SKOPJE				File No. 281	Project No. 13514150363	
Project	Ilovica Environmental and Social Impact Assessment				Size A3	Scale NTS	Status FINAL
					Drawing No. VP32		Rev B.0
Title	Landscape and Visual Assessment Viewpoint 32 - Wireline visualisation						
Created by NR	Requested by MS	Proj Manager MS	Reviewer ANDREW MORSLEY	Date Nov 15			

Golder Associates



Latitude	N41°21'57.21"
Longitude	E22°53'57.58"
Elevation	570 M
Direction of Photograph	338°
Distance to Mine	13.59 km
Focal Length	30 mm
Date of Photograph	Not Applicable

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

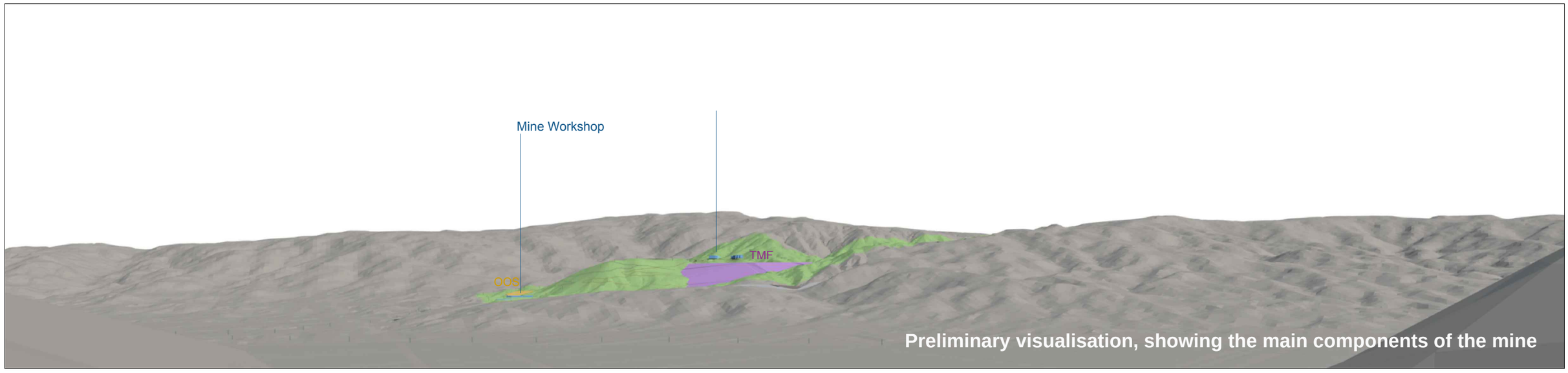
Location

Viewpoint 33 : Smolare Falls

Visitor attraction south of Smolare

Client	EUROMAX RESOURCES DOO SKOPJE				File No. 282	Project No. 13514150363
Project	Ilovica Environmental and Social Impact Assessment				Size A3 / Scale NTS	Status FINAL
					Drawing No. VP33	Rev B.0
Title	Landscape and Visual Assessment Viewpoint 33					
Created by NR	Requested by MS	Proj Manager MS	Reviewer ANDREW MORSLEY	Date Nov 15		

Golder Associates



Latitude	N41°22'7.57"
Longitude	E22°48'24.88"
Elevation	485 M
Direction of Photograph	12°
Distance to Mine	12,72 km
Focal Length	30 mm
Date of Photograph	Not Applicable

Concession Area
Mine Pit
Taillings Management Facility (TMF)
Oxide Ore Stockpile (OOS)
Access Road/ Haul Roads
Plant/Workshop
Powerline

Location

Viewpoint 34 : Koleshino Falls

Visitor attraction south of Koleshino Falls

Client	EUROMAX RESOURCES DOO SKOPJE				File No. 282	Project No. 13514150363
Project	Ilovica Environmental and Social Impact Assessment				Size A3 / Scale NTS	Status FINAL
					Drawing No. VP34	Rev B.0
Title	Landscape and Visual Assessment Viewpoint 34					
Created by NR	Requested by MS	Proj Manager MS	Reviewer ANDREW MORSLEY	Date Nov 15		

Golder Associates

Annex 5I: Supporting Information to the Socio-economic Impact Assessment

April 2016
Report No. 13514150363.701/A.0

Table 1: Impact classification matrix

Topic	Effect	Project phase	Key source of impact	Magnitude	Extent	Duration	Impact classification	Direction
Economy	The Project will contribute to the GDP of the Republic of Macedonia	Construction, operations	Capital and operational expenditures	High	National	Medium-term	High	Positive
	The Project will contribute to the importance of the national mining industry in international trade	Operations	Export of copper concentrate and gold doré	High	National	Medium-term	High	Positive
	The Project will contribute annual revenue to the national government	Construction, operations	Tax and royalty payments	High	National	Medium-term	High	Positive
	The Project will contribute annual revenue to the municipal governments of Bosilovo and Novo Selo	Operations	Royalty payments	High	Local	Medium-term	High	Positive
	The Project will contribute to local business development and economic growth	Construction, operations	Local procurement of goods and services	High	Local	Medium-term	High	Positive
	The Project will result in an induced effect on economic activity as employees spend their incomes locally	Construction, operations	Spending of employment income	Moderate	Local	Medium-term	Moderate	Positive
Employment	The Project will create new direct employment outside the local area in construction and mining	Construction, operations	Direct workforce demand	Low	National	Medium-term	Low	Positive
	The Project will create new direct local employment opportunities in construction and mining	Construction, operations	Direct workforce demand	High	Local	Medium-term	High	Positive
	The Project will indirectly result in employment outside the local area in industries servicing the mining industry	Construction, operations	Purchase of goods and services	Low	National	Medium-term	Low	Positive
	The Project will indirectly result in employment at the local level in industries servicing the mining industry	Construction, operations	Purchase of goods and services	High	Local	Medium-term	High	Positive
	The Project will induce employment as direct and indirect workers spend their incomes outside the local area	Construction, operations	Spending of employment income	Low	National	Medium-term	Low	Positive
	The Project will induce employment as direct and indirect workers spend their incomes locally	Construction, operations	Spending of employment income	Moderate	Local	Medium-term	Moderate	Positive
Incomes	Project employment will generate incomes outside the local area that are high in comparison to average annual incomes	Construction, operations	Payment of employment incomes and contracting	Low	National	Medium-term	Low	Positive
	Project employment will generate incomes in the local area that are high in comparison to average annual incomes	Construction, operations	Payment of employment incomes and contracting	High	Local	Medium-term	High	Positive
	Project-related indirect employment will generate incomes outside the local area in line with industry standards	Construction, operations	Purchase of goods and services	Low	National	Medium-term	Low	Positive
	Project-related indirect local employment will generate incomes in line with industry standards	Construction, operations	Purchase of goods and services	Moderate	Local	Medium-term	Moderate	Positive
	Project-related induced employment outside the local area will generate incomes in line with industry standards	Construction, operations	Spending of employment incomes	Low	National	Medium-term	Low	Positive
	Project-related induced local employment will generate incomes in line with industry standards	Construction, operations	Spending of employment incomes	Moderate	Local	Medium-term	Moderate	Positive
Population	The Project will result in in-migration to Strumica and an incremental increase in population in 2019	Operations	Direct workforce demand	Negligible	Local	Permanent	Negligible	Positive
Community health, safety and security	Project-induced in-migration could increase demand for healthcare services	All phases of the Project	Direct workforce demand	Negligible	Local	Permanent	Negligible	Neutral
	Project on-site medical clinic will provide services to workers, removing some pressure on existing healthcare services	Construction, operations	Requirement to provide medical services	Moderate	National	Medium-term	Moderate	Positive
	Potential accidental injury of workers could increase demand for emergency healthcare services	Construction, operations	Operation of equipment and machinery, injury	Low	Local	Medium-term	Low	Negative

Topic	Effect	Project phase	Key source of impact	Magnitude	Extent	Duration	Impact classification	Direction
Quality of life	Project community investment can support community development initiatives	Construction, operations	Community investment	Moderate	Local	Medium-term	Moderate	Positive
	Project incomes can enhance access to housing, education, consumer goods and services, and savings	Construction, operations	Payment of employment incomes and contracting	High	Local to national	Medium-term	High	Positive
	Project noise will exceed baseline and guideline values in some communities	Construction	Project access road construction activities and traffic	Moderate	Local	Short-term	Moderate	Negative
	Project components will alter the visual character of forest and agricultural plains	All phases of the Project	Project land clearing, infrastructure construction and TMF	Moderate to High	Local	Permanent	Moderate to High	Negative
	Perception of harm may change day-to-day life for those concerned about water and air pollution	Construction, operations	Stigma of environmental effects of mining	High	Local	Long-term	High	Negative
Physical infrastructure	Project traffic may increase physical wear on the M6 highway	Operations	Transport of copper concentrate to Bulgaria	Low	Local to national	Medium-term	Low	Negative
	Project utility corridor and transmission line may improve existing electrical utilities in Ilovica and Shtuka	Post-closure	Demand for electricity	Low	Local	Permanent	Low	Positive
	Project replacement of the water reticulation system in Ilovica and Shtuka will improve water distribution infrastructure	All phases of the Project	Replacement of water reticulation system	Moderate	Local	Permanent	Moderate	Positive
	Project replacement of the water reticulation system in Ilovica and Shtuka may increase the cost of water for users	All phases of the Project	Replacement of water reticulation system	Moderate	Local	Permanent	Moderate	Negative
	Project replacement of the water reticulation system in Ilovica and Shtuka will improve access to treated water	All phases of the Project	Replacement of water reticulation system	Moderate	Local	Permanent	Moderate	Positive
Land use	Project land acquisition will remove arable land suitable for agricultural production	Construction, operations	Project land take	Moderate	Local	Medium-term	Moderate	Negative
	Project land acquisition will remove grazing land	Construction, operations	Project land take	High	Local	Medium-term	High	Negative
	Project land acquisition will temporarily remove productive forestry land	Construction, operations	Project land take	Moderate	Local	Medium-term	Moderate	Negative
	The Project will result in the permanent loss of productive forestry due to the TMF	All phases of the Project	TMF	High	Local	Permanent	High	Negative
	Project land acquisition will remove land used for mushroom and religious plant harvesting	Construction, operations	Project land take	Low	Local	Medium-term	Low	Negative
	Project activities may disturb beekeeping activity on the slope of Ograzden Mountain	Construction, operations	Project traffic and blasting	Low	Local	Medium-term	Low	Negative
	Project activities may disturb recreational fishing in the Ilovica Reservoir	Construction, operations	Stigma of environmental effects of mining	Low	Local	Medium-term	Low	Negative
	Project activities may disturb wildlife hunted in the vicinity of the Project	Construction, operations	Project traffic and blasting	Low	Local	Medium-term	Low	Negative

Table 2: Residual impact classification matrix

Topic	Effect	Phase of the Project	Impact classification before mitigation	Mitigation	Magnitude	Extent	Duration	Residual impact	
								Classification	Direction
Economy	The Project will contribute to the GDP of the Republic of Macedonia	Construction, operations	High	None practical	High	National	Medium-term	High	Positive
	The Project will contribute to the importance of the national mining industry in international trade	Operations	High	None practical	High	National	Medium-term	High	Positive
	The Project will contribute annual revenue to the national government	Construction, operations	High	None practical	High	National	Medium-term	High	Positive
	The Project will contribute annual revenue to the municipal governments of Bosilovo and Novo Selo	Operations	High	None practical	High	Local	Medium-term	High	Positive
	The Project will contribute to local business development and economic growth	Construction, operations	High	Please refer to the mitigation identified in Section 16.9.2.1	High	Local	Medium-term	High	Positive
	The Project will result in an induced effect on economic activity as employees spend their incomes locally	Construction, operations	Moderate	None practical	Moderate	Local	Medium-term	Moderate	Positive
Employment	The Project will create new direct employment outside the local area in construction and mining	Construction, operations	Low	None required	Low	National	Medium-term	Low	Positive
	The Project will create new direct local employment opportunities in construction and mining	Construction, operations	High	Please refer to the mitigation identified in Section 16.9.2.2	High	Local	Medium-term	High	Positive
	The Project will indirectly result in employment outside the local area in industries servicing the mining industry	Construction, operations	Low	None required	Low	National	Medium-term	Low	Positive
	The Project will indirectly result in employment at the local level in industries servicing the mining industry	Construction, operations	High	Please refer to the mitigation identified in Section 16.9.2.2	High	Local	Medium-term	High	Positive
	The Project will induce employment as direct and indirect workers spend their incomes outside the local area	Construction, operations	Low	None practical	Low	National	Medium-term	Low	Positive
	The Project will induce employment as direct and indirect workers spend their incomes locally	Construction, operations	Moderate	None practical	Moderate	Local	Medium-term	Moderate	Positive
Incomes	Project employment will generate incomes outside the local area that are high in comparison to average annual incomes	Construction, operations	Low	None required	Low	National	Medium-term	Low	Positive
	Project employment will generate incomes in the local area that are high in comparison to average annual incomes	Construction, operations	High	Please refer to the mitigation identified in Section 16.9.2.2	High	Local	Medium-term	High	Positive
	Project-related indirect employment will generate incomes outside the local area in line with industry standards	Construction, operations	Low	None practical	Low	National	Medium-term	Low	Positive
	Project-related indirect local employment will generate incomes in line with industry standards	Construction, operations	Moderate	None practical	Moderate	Local	Medium-term	Moderate	Positive
	Project-related induced employment outside the local area will generate incomes in line with industry standards	Construction, operations	Low	None practical	Low	National	Medium-term	Low	Positive
	Project-related induced local employment will generate incomes in line with industry standards	Construction, operations	Moderate	None practical	Moderate	Local	Medium-term	Moderate	Positive
Population	The Project will result in in-migration to Strumica and an incremental increase in population in 2019	Operations	Negligible	None practical	Negligible	Local	Permanent	Negligible	Positive
Community health, safety and security	Project-induced in-migration could increase demand for healthcare services	All phases of the Project	Negligible	None practical	Negligible	Local	Permanent	Negligible	Neutral
	Project on-site medical clinic will provide services to workers, removing some pressure on existing healthcare services	Construction, operations	Moderate	Assist in improving the Ilovica clinic	Moderate	National	Medium-term	Moderate	Positive
	Potential accidental injury of workers could increase demand for emergency healthcare services	Construction, operations	Low	Assist in improving the Ilovica clinic	Low	Local	Medium-term	Negligible	Negative

Topic	Effect	Phase of the Project	Impact classification before mitigation	Mitigation	Magnitude	Extent	Duration	Residual impact	
								Classification	Direction
Quality of life	Project community investment can support community development initiatives	Construction, operations	Moderate	Please refer to the benefit enhancements identified in Section 16.9.2.5	High	Local	Medium-term	High	Positive
	Project incomes can enhance access to housing, education, consumer goods and services, and savings	Construction, operations	High	None required	High	Local to National	Medium-term	High	Positive
	Project noise will exceed baseline and guideline values in some communities	Construction	Moderate	None practical	Moderate	Local	Short-term	Moderate	Negative
	Project components will alter the visual character of forest and agricultural plains	All phases of the Project	Moderate to High	None practical	Moderate to High	Local	Permanent	Moderate to high	Negative
	Perception of harm may change day-to-day life for those concerned about water and air pollution	Construction, operations	High	Public education of environmental effects	Negligible	Local	Long-term	Negligible	Negative
Physical infrastructure	Project traffic may increase physical wear on the M6 highway	Operations	Low	Implement a traffic and transportation infrastructure management plan	Negligible	Local to national	Medium-term	Negligible	Negative
	Project utility corridor and transmission line may improve existing electrical utilities in Ilovica and Shtuka	Post-closure	Low	None required	Low	Local	Permanent	Low	Positive
	Project replacement of the water reticulation system in Ilovica and Shtuka will improve water distribution infrastructure	All phases of the Project	Moderate	None required	Moderate	Local	Permanent	Moderate	Positive
	Project replacement of the water reticulation system in Ilovica and Shtuka may increase the cost of water for users	All phases of the Project	Negligible	Cost will be in-line with that paid in other communities; No mitigation practical	Negligible	Local	Permanent	Negligible	Negative
	Project replacement of the water reticulation system in Ilovica and Shtuka will improve access to treated water	All phases of the Project	Moderate	None required	Moderate	Local	Permanent	Moderate	Positive
Land use	Project land acquisition will remove arable land suitable for agricultural production	Construction, operations	Moderate	Implement Land Acquisition Framework and Livelihood Restoration Plan	Low	Local	Medium-term	Negligible	Negative
	Project land acquisition will remove grazing land	Construction, operations	High	Implement Land Acquisition Framework and Livelihood Restoration Plan	Low	Local	Medium-term	Negligible	Negative
	Project land acquisition will temporarily remove productive forestry land	Construction, operations	Moderate	Compensation paid to the Forestry Management Company and reclamation	Low	Local	Medium-term	Low	Negative
	The Project will result in the permanent loss of productive forestry due to the TMF	All phases of the Project	High	None practical	High	Local	Permanent	High	Negative
	Project land acquisition will remove land used for mushroom and religious plant harvesting	Construction, operations	Low	Identify alternate harvesting locations suitable to mushroom and religious plant harvesters	Negligible	Local	Medium-term	Negligible	Negative
	Project activities may disturb beekeeping activity on the slope of Ograzden Mountain	Construction, operations	Low	Relocation of beehives to location suitable to the beekeepers	Negligible	Local	Medium-term	Negligible	Negative
	Project activities may disturb recreational fishing in the Ilovica Reservoir	Construction, operations	Low	Public education of environmental effects	Negligible	Local	Medium-term	Negligible	Negative
	Project activities may disturb wildlife hunted in the vicinity of the Project	Construction, operations	Low	Cooperation with hunters associations to identify alternate hunting areas	Negligible	Local	Medium-term	Negligible	Negative

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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