APPENDIX S11

GROUNDWATER MONITORING AND RESPONSE PLAN

ANGAS PROCESSING FACILITY

MISCELLANEOUS PURPOSES LICENSE APPLICATION 2019/0826

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Groundwater Monitoring Table

The following table has been developed by Terramin, Australian Groundwater Technologies and URS/AECOM for the AZM Mine Closure Plan (MCP), and reflects the groundwater requirements outlined in the Outcome Criteria Tables for Angas Zinc Mine. Is it supported by the TSF Post Construction Monitoring Plan for the TSF Capping System developed by URS/AECOM (Appendix BY of MCP) and the groundwater modelling for AZM developed by Australian Groundwater Technologies (appendix BX of MCP).

Locations of all wells outlined in this plan in Figure 1.

Angas Zinc Mine - Mine Closure Groundwater Monitoring Plan (November 2015)												
Domain	Purpose	Monitoring Bore ID	Aquifer Monitored	Water Level			Water Quality					Assessed by independent expert prior to reducing / ceasing monitoring
				Frequency	Duration	Reporting format	Frequency	Duration	Parameters	Exceedance Values		
Regional	**Mine Void**	**RG 2**	T	Quarterly, biannually	Quarterly until completion of rehabilitation earthworks, thereafter biannually until independent expert confirms can cease	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly until completion of rehabilitation earthworks, thereafter annually until independent expert confirms can cease	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	NA	✓	
Regional	**Mine Void**	**RG1, RG3, RG 4, RG 8**	C	Quarterly, biannually	Quarterly until completion of rehabilitation earthworks, thereafter biannually until independent expert confirms can cease	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly until completion of rehabilitation earthworks, thereafter annually until independent expert confirms can reduce/cease	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	NA	✓	

Central		**Mine void (entrance point)**	Void	Biannually	Biannually from cessation of underground mining until independent expert confirms can reduce/cease.	1. metres below ground level and 2. metres AHD	Annually	Annually until independent expert confirms can reduce/cease.	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	NA	✓
		PF140	Void (source)	Quarterly, biannually	Quarterly during first 12 months of recovery after cessation of underground mining, then biannually thereafter until independent expert confirms can reduce/cease.	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly during first 12 months of recovery after cessation of underground mining, then annually thereafter until independent expert confirms can reduce/cease.	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	Table 1	✓
		DH2	C	Weekly ; monthly; biannually	From Cessation of underground mining weekly when water is detected, then monthly after 150 days; then after 3 years, biannually thereafter until independent expert confirms can reduce/cease.	1. metres below ground level and 2. metres AHD	Weekly to annually	Quarterly during first 12 months of recovery after cessation of underground mining, then annually thereafter until independent expert confirms can reduce/cease.	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	Table 1	✓

		DH3	C	Quarterly, biannually	Quarterly during first 12 months of recovery after cessation of underground mining, then biannually thereafter until independent expert confirms can reduce/cease.	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly during first 12 months of recovery after cessation of underground mining, then annually thereafter until independent expert confirms can reduce/cease.	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	Table 1	✓
Buffer		**Obs Bore South**	C	Quarterly, biannually	Quarterly during first 12 months of recovery after cessation of underground mining, then biannually thereafter until independent expert confirms can reduce/cease.	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly during first 12 months of recovery after cessation of underground mining, then annually thereafter until independent expert confirms can reduce/cease.	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	Table 1	✓

	TSF	**TSF A**	C	Quarterly, biannually	Quarterly during rehabilitation/earth works phase, then biannually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly during rehabilitation/earthw orks phase, then annually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	Table 3	✓
		TSF B, TSF C, TSF D	T	Quarterly, annually	Quarterly during rehabilitation/earth works phase, then biannually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly during rehabilitation/earthw orks phase, then annually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	Table 3	✓

		LG1	T	Quarterly, annually	Quarterly during rehabilitation/earth works phase, then biannually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly during rehabilitation/earthw orks phase, then annually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	NA	✓
		LG2	C	Quarterly, annually	Quarterly during rehabilitation/earth works phase, then biannually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	1. metres below ground level and 2. metres AHD	Quarterly, annually	Quarterly during rehabilitation/earthw orks phase, then annually thereafter until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	NA	✓

		MB 1 - MB 6	TSF clay liner	Monthly, Biannually	Monthly during rehabilitation/earth works phase, then biannually there after until independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	1. metres below ground level and 2. metres AHD	Monthly, Biannually (if water detected)	During rehabilitation/earthw orks phase	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	NA	✓
		New piezometer within TSF, completed above HDPE liner and up gradient of the main embankment	TSF tailings	Biannually	Biannually until sign-off by an independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	1. metres below ground level and 2. metres AHD	Annually	Annually until sign-off by an independent expert verifies TSF has been rehabilitated as per the approved TSF closure design (CC TSF01)	pH, EC, TDS, SO_4^{2-}, Cd, Pb, Zn	NA	✓

Groundwater Monitoring Response Plan

The Response Plan has been developed by Terramin and Australian Groundwater Technologies. The construction for all wells referred to is included in Table 4.

Mine Void

What will be measured and when

Groundwater will be sampled quarterly during first 12 months of recovery after cessation of underground mining, then biannually thereafter until independent expert confirms can reduce/cease., as per AS/NZS 5667.1:1998, at four bores (PF140, DH2, DH3 and Obs Bore South) located on ML 6229 (Appendix R) for; pH, EC, TDS, Zn, Pb, Cd, and SO4.

Pastefill 140 monitoring bore

During underground mining during operations the drillhole was used to supply paste fill for underground stopes to the 140 relative level. The bore is slightly inclined at 5 degrees and is open into the 140 relative level mining drive. The total depth beneath surface is 142m. AZM Orebody contains relatively consistent ratios of the differing metalloids and hence the pastefill140, as it is located within a mine void, is reflective of mine void parameters for the entirety of the mine void.

DH02

Drilled in 2007 and equipped as a mine dewatering well. DH02 has a total depth of 116mwith a SWL of 49 m in 2007 and a salinity (TDS) of 11,500mg/L (approximately 20,900 uS/cm).

DH03

Drilled in 2007 and equipped as a mine dewatering well. DH03 has a total depth of 115m with a SWL of 70 m in 2007 and a salinity (TDS) of 13,000mg/L (approximately 23,600uS/cm).

Observation bore south

Drilled in 2012 and tested for suitability as a re-injection bore, but not used for this purpose during operations. It has been utilised as a monitoring bore since 2015. This bore has a total depth of 100m, a standing water level of 7.27m and salinity (TDS) of 9060mg/L (approximately 16,400 uS/cm) in May 2015.

pH, EC, TDS, Zn, Pb, Cd, and SO_4^{2-} were chosen as trigger analytes as AMD is characterised by low pH water and is typically laden with high concentrations of SO_4^{2-}, Fe and other dissolved metals (Zn, Cd, Co, Pb, Ni and Mn). Therefore the impact of AMD can be seen in water quality indicators such as low pH or anions such as SO_4^{2-}, which can be elevated above background levels. Contaminant source concentrations of Zn, Pb, Cd, and SO_4^{2-} have been assessed by URS/AECOM and AGT and is considered the most useful water quality indicator for the transport of any potential AMD plume.

Data Analysis and Responses

All data collected will be reviewed against "Possible Mine Closure Failure Scenarios – 3.1 Generation of AMD from the Underground Mine" (AGT, 2016, p. 6 – MCP Appendix BX).

Any sample which returns a pH of higher or lower than the operational phase regional groundwater compliance limit for acidity (Table 1) will trigger a resample within three weeks of the initial sampling event to confirm and a review of EC, TDS, Zn, Cd and SO_4^{2-} against the groundwater modelling scenario ("Possible Mine Closure Failure Scenarios – 3.1 Generation of AMD from the Underground Mine" (AGT, 2016, p. 6 – MCP Appendix BX)) to investigate and an appropriate response will be developed if required.

Table 1: Operational Compliance Criteria

Operational Compliance Criteria
6.59

PF140

The decay in the rate of generation of SO_4^{2-} from the underground mine were based on a column leach test, the results of the column leach test show a decay from 8,890 mg/L stabilising towards < 1,000 mg/L over the long term ("Possible Mine Closure Failure Scenarios – 3.1 Generation of AMD from the Underground Mine" (AGT, 2016, p. 6 – Appendix BX)). This decay has been matched with groundwater samples collected from the underground via PF140, collected over the preceding two years of groundwater recovery.

Any SO_4^{2-} concentration at the source (PF140) that is 50% in excess of the predicted concentration (i.e. 1,350mg/L once stabilised –see "Possible Mine Closure Failure Scenarios – 3.1 Generation of AMD from the Underground Mine" (AGT, 2016, p. 6 – MCP Appendix BX)) will trigger the following response:

1. Resample to confirm within three weeks of initial sampling event
2. Increased monitoring frequency for all bores to monthly to confirm trend for three months

If trend is not confirmed, monitoring to return to frequency outlined in this table above.

Should the trend be confirmed, an investigation by an independent expert as to the cause and appropriate response will be developed. This may include but is not limited to recalibration of the model to revise the predicted impact and/or appropriate mitigation strategies and additional on-ground works (such as drilling, sampling, or anything else as recommended by the independent expert at the time of the confirmed trend based on the data obtained and the revised predicted impact).

DH2 DH3

A net increase of SO_4^{2-} by 100 mg/L is predicted to emanate from the mine over the long term, however modelling shows that bores DH2 DH3 are not predicted to be influenced by AMD within 100 years ("Possible Mine Closure Failure Scenarios – 3.1 Generation of AMD from the Underground Mine" (AGT, 2016, p. 6 – MCP Appendix BX)). A concentration of SO_4^{2-} which is 50% greater than modelled (Table 2) baseline, might suggest an impact greater than predicted. If an impact is detected greater than predicted, the following steps will be taken:

1. Resample to confirm within three weeks of initial sampling event
2. Increased monitoring frequency to monthly to confirm trend for three months
3. Analysis to be undertaken in conjunction with data obtained from the source (PF140)

If trend is not confirmed, monitoring to return to frequency outlined in this table above.

Should the trend be confirmed, an investigation by an independent expert as to the cause and appropriate response will be developed. This may include but is not limited to recalibration of the model to revise the predicted impact and/or appropriate mitigation strategies and additional on-ground works (such as drilling, sampling, or anything else as recommended by the independent expert at the time of the confirmed trend based on the data obtained and the revised predicted impact).

Obs Bore South

Modelling shows that Obs Bore Sth (located in e flow path down gradient) is not predicted to be impacted by AMD for >100 years. An upward deviation from the baseline might suggest AMD has reached the well sooner than predicted.

If an impact is detected greater than predicted ("Possible Mine Closure Failure Scenarios – 3.1 Generation of AMD from the Underground Mine" (AGT, 2016, p. 6 – MCP Appendix BX)), the following steps will be taken:

1. Increased monitoring frequency to monthly to confirm trend for three months
2. Analysis of data obtained from the source (PF140)

If trend is not confirmed, monitoring to return to frequency outlined in this table above.

Should the trend be confirmed, an investigation by an independent expert as to the cause and appropriate response will be developed. This may include but is not limited to recalibration of the model to revise the predicted impact and/or appropriate mitigation strategies and additional on-ground works (such as drilling, sampling, or anything else as recommended by the independent expert at the time of the confirmed trend based on the data obtained and the revised predicted impact).

Table 2 Mine Void Wells Exceedance Values

Mine Void Groundwater Exceedance Table							
Monitoring Point	**Location**	**Baseline**	**Observed SO_4^{2-}**	**Predicted SO4 Impact**	**Primary leading indicator criteria**	**Secondary leading indicator criteria**	**Justification (SO_4^{2-})**
PF140	Mine void	Mine inflos 750 to 3,640 mg/L	1,519 decay to 914 mg/L	Decay from 8,890 to 900 mg/L	SO4 measured at PF140 currently plot along the predicted decay curve. A gradual upward deviation from the predicted decay curve may indicate a emerging long-term impact	1350	1350 mg/L represents a 50% increase from the long term predicted concentration of 900 mg/L
DH2	FRA east of mine	No baseline data. Assume mine inflows = 750 to 3,640 mg/L	1,670 - 3,070 mg/L (Preceding 4 samples have stabilised at ~3,070 mg/L)	Net impact of 100 mg/L over the long term near the mine	SO4 has recently stabilised at DH02. A future upward trend based on the preceding 3 sample events may indicate an unforseen impact that has reached this bore sooner than predicted	3740	The variable SO4 concentrations of mine inflows (750 - 3,650 mg/L) is characteristic of the variability observed in the surrounding aquifer, including concentrations measured in up gradient bore DH02 post mine closure (1,670 to 3,070 mg/L). Therefore a trigger level in this bore has been based on the additional impact of 100 mg/L in excess of the upper limit of observed mine inflows (3,740 mg/L)
DH3	FRA west of mine		1,030 - 1,120 mg/L	Net impact of 100 mg/L over the long term near the mine	An upward trend over preceding 3 sample events	1220	The groundwater model predicted an additional impact of 100 mg/L in excess of baseline levels at this location over the long term. Based on available data this equates to 1,220 mg/L.
Obs South (RI5)	FRA south of mine	1190	1,080 - 1,190 mg/L	No impact predicted over the next 100 years	An upward trend over preceding 3 sample events	1290	The groundwater model predicted an additional impact of 100 mg/L in excess of baseline levels at this location over the long term. Based on available data this equates to 1,290 mg/L

Table 3 TSF Bores Exceedance Values (PEPR)

TSF BORES EXCEEDANCE VALUES				
Site	**Units**	**Average**	**Standard Deviation**	**EXCEEDANCE VALUE (Av. + 2SD)**
pH	**pH**	7.06	0.43	7.93
EC-L	**µS/cm**	17252.5	5697.4	28647.2
Cd-T	**mg/L**	0.0011	0.0019	0.0049
Pb-T	**mg/L**	0.0788	0.1133	0.3053
Zn	**mg/L**	0.4109	1.2484	2.9077
Fe-T	**mg/L**	40.1974	67.5296	175.2565

Table 4 Well Construction Table

Drillhole TZN Name	DEWNR Unit Number	Easting MGA54	Northing MGA54	Depth	Drill date	Elevation mAHD	Case from	Case to	Casing diameter	Case material	Piezometer from	Piezometer to	Piezometer diameter
PF140	NA	310480	6097072	140	Dec/2008	82.05	0	140	150	HDPE	140	145	Open mine void 5m diam
DH3	6627-11781	310405	6097065	115	May/2007	78.2	0	9	200	WST	9	115	50
DH2	6627-11782	310590	6097169	116	Apr/2007	76.7	0	67	157	WST	67	116	50
Obs Bore South	6627-14429	310411	6096221	100	Nov/2011	58.5	0	44	200	PVC12	44	100	150
RG1	6627-11539	309958	6097970	21	Jun/2006	78.805	0	14.4	96	PVC	14.4	20.4	96
RG2	6627-11534	309966	6096166	14.6	Jun/2006	58.343	0	8.6	96	PVC	8.6	14.6	96
RG3	6627-11496	309962.95	6096173.8	48	Jun/2006	58.37	0	19.6	100	PVC	19.6	45	50
RG4	6627-11545	310965.5	6095074.5	50	Jun/2006	73.61	0	19	100	PVC	19	50	50
RG5	6627-11538	311520	6096816	30	Jul/2007	92.118	0	21	50	PVC	21	30	50
RG7	6627-11535	311354	6097649	10	May/2006	74.301	0	7	50	PVC	7	10	50
RG8	6627-11536	311351.1	6097647.6	45	Jun/2006	74.28	0	27	100	PVC	27	45	50
LG01	6627-14181	310525	6097328	4.3	Apr/2006	69.61	0	1	50	PVC	1	2.5	50
LG02	6627-14161	310525	6097331	27	Apr/2006	69.59	0	22.5	100	PVC	16.5	22.5	100
TSFA	NA	310555	6096346	48.6	Jun/2008	56.5	0	43	100	PVC	43	48.6	96
TSFB	NA	310555	6096351	12.1	Jun/2008	56.5	0	10	50	PVC	10	12.1	50

TSFC	NA	310472	6096518	<18	Jun/2008	65	0	15	50	PVC	15	18	50
TSFD	NA	310858	6096444	<15	Jun/2008	58.5	0	10	50	PVC	10	15	50

Figure 1 Map of Well Locations