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## Heemskirk Tin

### *Review of Heemskirk Access Options*

December 2014



Prepared for: - *Stellar Resources Ltd.*  
By: - *Alan Fudge, 23 December 2014*



## Heemskirk Tin Project – Review of Access Options

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### 1.0 Introduction

Mining One previously conducted a Heemskirk Tin project Pre-Feasibility Study (PFS) directed toward the recovery of the Lower Queen Hill, Severn and Montana tin mineralisation as defined in the Mineral Resource estimate of February 2013 prepared by Resource and Exploration Geology.

In the PFS Mining One assumed decline access for all mining operations with initial mining coming from the Lower Queen Hill orebody followed by production from Severn and Montana – the advance rates utilised appear realistic given the potential ground conditions and the number of operating headings available.

The Mining One schedule prepared for the PFS included a 17 month delay between the start of the major access development and the start of ore production.

In the PFS Mining One indicated that the intent was to mine the three main deposits from the lowest level proceeding upwards permitting strike retreat bench production from below solid ground above filled voids. It is clear, from examination of the PFS mine schedule, that in order to support the target production of 600,000 tpa production was actually scheduled from numerous levels in both the Lower Queen Hill and Severn deposits.

The impact of this scheduled production from different horizons is that mining directly below filled voids was scheduled to be undertaken during the mine life – the issue of mining strike oriented retreat benching below filled voids is a significant one and was not addressed in the PFS.

During a recent review of the PFS Polberro Consulting recommended the consideration of transverse open stoping (TOS) for wider sections of the Severn Orebody. This mining method – as with the original Mining One proposal - requires that mining proceed from the lowest levels upwards except that an orebody split is possible to support early production – in all such instances footwall development is required to support extraction of any level below a previously mined and filled upper section of the orebody or a crown pillar of ore must be left behind.

### 2.0 Scope of Report

The purpose of this report is to examine mine development access options to remove the element of multiple level mining and to determine if earlier access to the base of the Severn orebody at 770m RL is viable. The options to be reviewed are as follows: -

- Mine all access development with traditional drill and blast and decline access – review Mining One PFS schedule and examine alternative strategies such as predetermined Severn orebody division into upper and lower sections are viable.
- Substitute the use of road header for mine development work.
- Utilise shaft access

### 3.0 Data Sources

All references to development access refer to the Mining One development design and development schedule as indicated in the PFS.

The Transverse Open Stopping (TOS) method is as defined in the PFS review conducted by Polberro Consulting. The Ore Resource is as estimated by Resource and Exploration Geology and indicated in Table 1.



Category	Tonnes	% Sn
Indicated	1,410,000	1.26
Inferred	4,870,000	1.10
<b>Total</b>	<b>6,280,000</b>	<b>1.14</b>

Table 1 Heemskirk Ore Resource (REG 2013)

The Mining Inventory as estimated in the PFS by Mining One is utilised as the production base for this review.

Ore Source	Tonnes	% Sn
Development	865,230	0.98
Stoping	3,085,760	1.08
<b>Total</b>	<b>3,951,000</b>	<b>1.06</b>

Table 2 Heemskirk Mining Inventory (Mining One 2013)

Unless otherwise stated the mining method, fill media and filling procedures assumed in this review are as proposed by Mining One in the PFS.

The PFS production schedule was utilised to provide production information for LOM planning and costing. The schedule was derived to support a production rate of 600,000 tonnes of ore per year. The schedule indicated a 17 month pre-production stage while the mine is developed and infrastructure and critical items are installed.

Year	1	2	3	4	5	6	7	8	9
<b>Development</b>									
Queen Hill		96,991	43,444	13,846					
Severn Dev		48,883	120,791	197,977	143,061	1,559	2,600	7,302	322
Severn C+F		25,265	61,873	74,090	74,809	35,278	34,605	73,876	13,665
Montana				11,303	49,272	92,823	9,785	0	0
<b>Total Development Ore</b>	<b>0</b>	<b>171,139</b>	<b>226,109</b>	<b>297,215</b>	<b>267,142</b>	<b>129,660</b>	<b>46,990</b>	<b>81,178</b>	<b>13,987</b>
<b>Production</b>									
Queen Hill		81,510	340,031	224,135	29,117				
Severn LHS		0	16,552	76,707	275,931	379,344	453,816	343,131	83,004
Montana					41,267	96,713	107,822	113,214	30,007
<b>Total Production Ore</b>	<b>0</b>	<b>81,510</b>	<b>356,584</b>	<b>300,842</b>	<b>346,316</b>	<b>476,058</b>	<b>561,638</b>	<b>456,345</b>	<b>113,011</b>
<b>Total Ore Mined</b>	<b>0</b>	<b>252,649</b>	<b>582,692</b>	<b>598,057</b>	<b>613,458</b>	<b>605,717</b>	<b>608,628</b>	<b>537,523</b>	<b>126,997</b>

Table 3 Production Schedule (Mining One PFS 2013)

It should be noted that poor correlation between the EPS schedule and the above summary data was observed.

For the purpose of this report only the pre-production stage is of interest it is assumed that once access to the initial stoping area is provided then the scheduled production rate can be supported.

For lateral development the distances and time taken to reach and develop the three ore bodies is shown in Table 4 based on simple first principals



#### 4.0 Drill and blast access development

Development rates in the Mining One PFS were based upon an initial heading rate of 120m per month for a single drill jumbo working exclusively in a single heading.

Once multiple headings were available the overall rate per jumbo rose from 120m to 240m at the maximum heading rate of 80m per month.

Examination of the development design and the rates used by Mining One in the EPS schedule indicate the overall development time was realistic given the development rates utilised.

Examination of a new and separate evaluation of the Mining Inventory with mid level orebody splitting revealed the same time expectation for initial stope production and also a mining inventory within 2.6% of the PFS estimation.

Minable Resource in Long Hole Stopping Zones										
	Location	From	To	Vol	SG	Tonnes	Sn%	Ramp Dev (m)	Level Dev (m)	Dev time (Mo) at PFS rates
A	Queen Hill Lower -Upper	990	1110	156,148	3.3	517,162	1.18	1760	300	16.5
B	Queen Hill Lower -Lower	870	990	95,245	3.3	310,308	1.25	2720	300	24.5
C	Queen Hill North	1010	1110	60,686	3.3	203,055	1.32	with A	150	14.5
D	Severn Upper Main	870	970	252,935	3.2	802,057	1.001	2720	360	24.9
E	Severn Lower Main	770	870	268,693	3.2	854,712	1.055	3520	400	31.8
F	Severn Upper South	870	970	40,147	3.3	131,883	1.192	with D	120	25.7
G	Severn Lower South	770	870	31,154	3.3	102,185	0.93	with E	150	32.8
H	Montana All	830	1090	119,040	3.7	436,996	1.43	3040	180	26.5
Minable Resources						3,358,359	1.15			
Mining Inventory						3,378,299	1.05	excludes C&F		
Above estimates derived from Polberro Consulting perimeter interpretation (C&F zone not assessed - original estimate was 393,000t)										
Recovery = (0.75*0.9+0.25*1.0)		92.5%								
Dilution = (0.75*0.1+0.25*.05)		8.8%								
This estimate		3.8Mt								
PFS estimate		3.9Mt								
Variance		2.6%								
PFS rate = 120m/Mo for single heading										
PFS rate = 80m/Mo per heading when multiple headings available and 240m/Mo per jumbo										

Table 4: Review of LHS inventory by level

It is evident that no change to the PFS development design will expedite stope production to any earlier than the 17 months proposed in the PFS as this is the shortest possible development time at the given rate to the upper half of Queen Hill Lower (990-1110m RL).

The most potential for shortening the pre-production stage when utilising traditional lateral development methods would be to target a higher single heading development rate than the current proposed 120m/month which is relatively conservative.

Industry performance indicates that a single heading development rate of between 180m and 210m per month is achievable and 220-300m for multiple headings from a single development jumbo.

In the case of Heemskirk development rates may be impacted on by any firing restrictions resulting from the location of the mine within the township of Zeehan.

Estimations of the shortest development for individual sections of each orebody are shown in Table 4 – the impact of achieving increased single heading development rates is shown in Table 5. A reduction in the development time to the first ore production from 16.5 months to 10.7 months at a rate of 200m per month single heading rate appears to be viable.



Accelerated single heading rate					
	Location	150m/mo	200m/Mo	250m/Mo	300m/Mo
<b>A</b>	Queen Hill Lower -Upper	13.6	10.7	8.9	7.7
<b>B</b>	Queen Hill Lower -Lower	20.0	15.5	12.8	10.9
<b>C</b>	Queen Hill North	14.5	11.6	9.9	8.7
<b>D</b>	Severn Upper Main	20.4	15.9	13.1	11.3
<b>E</b>	Severn Lower Main	26.0	20.1	16.6	14.2
<b>F</b>	Severn Upper South	21.1	16.6	13.9	12.1
<b>G</b>	Severn Lower South	26.9	21.0	17.5	15.2
<b>H</b>	Montana All	21.4	16.3	13.3	11.3

Table 5: Reduced development time at increasing single heading advance rate

Increase to single heading development rates is clearly the most realistic means of expediting full production for a traditional drill and blast development approach.



## 5.0 Road Header Development

The use of a road header has been examined as a potential option for development of the mine at an earlier time. Road headers operate by cutting through rock mass and thus typically operate best in soft rock that contains a high level of discontinuities and typically operate in shale, slate, coal measures and chalk. At rock mass strengths exceeding 40-50 MPa the capital cost of the road header and the development cost per metre rise rapidly and the development rate drops off dramatically.

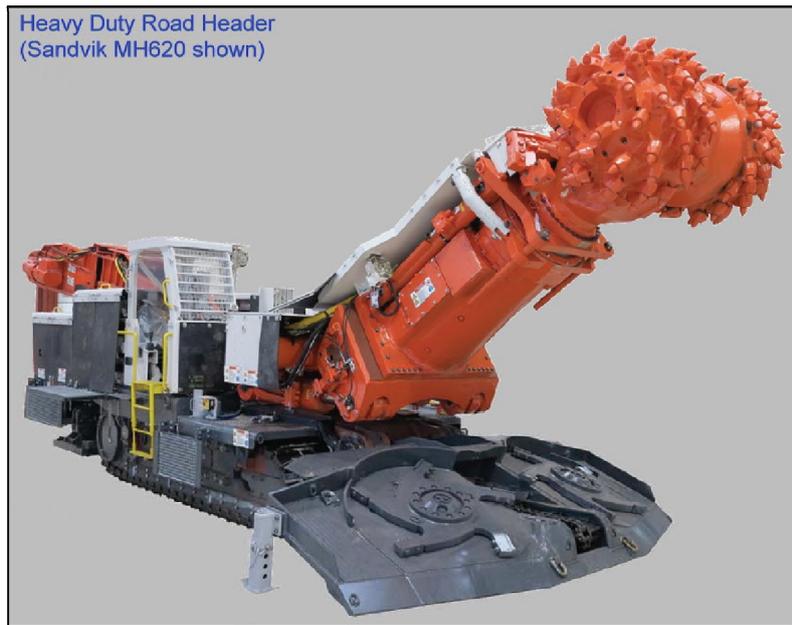


Figure 1: Heavy duty road header

The road header shown would typically cost of the order of AU\$4.5-5.5m prior to the addition of specialised additions such as rock bolting or shotcrete application capacity. The following table shows the available rock strength data for the Heemskirk project.

Summary of Laboratory Testing Results (Average Values)								
Rock Type	Number	UCS (MPa)	Youngs Modulus (GPa)-Tangent	Youngs Modulus (GPa)-Secant	Poisson Ratio-Tangent	Poisson Ratio-Secant	Dry Density (t/m <sup>3</sup> )	Wet Density (t/m <sup>3</sup> )
Queen Hill Volcaniclastic	3	79.4	53.2	54.2	0.145	0.145	2.75	2.76
Queen Hill Black Shale	2	43.3	32.3	32.1	0.076	0.076	2.73	2.74
Queen Hill Quartzite	3	124.6	46.8	47.2	0.077	0.077	2.75	2.76
Queen Hill Quartzite-Shale	2	68.9	66.0	64.4	0.058	0.058	2.78	2.79
Crimson Creek Volcaniclastics	3	67.9	62.5	69.0	0.409	0.409	2.87	2.88
Montana Dolomite	2	103.4	57.9	53.9	0.102	0.102	2.82	2.83

Table 6 Rock Type and Properties



Examination of the Table 6 indicates that the Queen Hill black shale (QHBS) is the only rock type present that would provide a suitable host for a road header as confirmed by the plot of cutting rate versus UCS shown below in Figure 2.

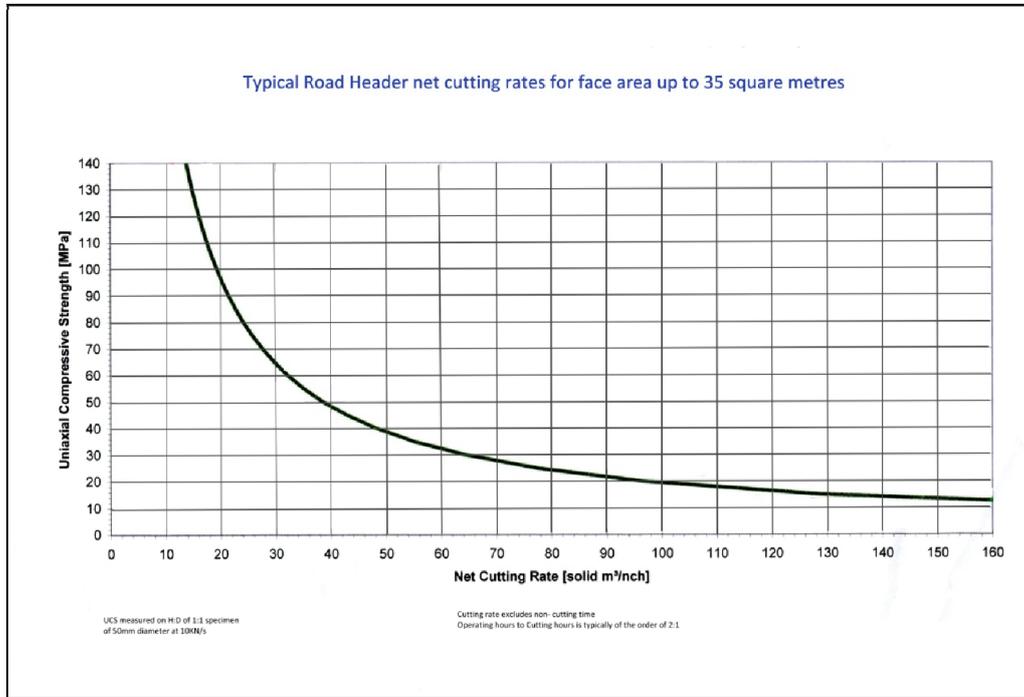


Figure 2 Cutting Rate against UCS for heavy duty Road Header (300KW) (Source: Atlas Copco/Sandvik)

For QHBS the net cutting rate would be 40m<sup>3</sup> per hour equivalent to 20m<sup>3</sup> per operating hour or 0.73m advance per operating hour and assuming that there are 10 operating hours in a shift with the equipment operating at 80% efficiency.

The maximum advance rate in QHS would be 10\*0.8\*0.73 or 5.84m per shift.

Assuming that up to one shift will be utilised to apply ground support (and conduct maintenance) for every 15m advanced i.e. 1 shift in 4 then in the QHBS an overall advance rate of 5.84\*0.75m or 4.4m per shift could be achieved.

This equates to 264m per month in the QHBS which is the only rock type where an increase over traditional drill and blast might be anticipated – this currently represents the first 350-400m of decline access.

#### Road Header - Assessed advance rates for Heemskirk rock types

Rock Type	UCS Mpa	Cutting Rate m <sup>3</sup> /hr	Max Rate m/hr	Per Shift m/shift	Overall m/Month	D&B m/Mo
Queen Hill Volcaniclastic	79.4	24	0.44	3.5	157	200
Queen Hill Black Shale	43.3	40	0.73	5.8	262	200
Queen Hill Quartzite	124.6	16	0.29	2.3	105	200
Queen Hill Quartzite Shale	68.9	28	0.51	4.1	183	200
Crimson Creek Volcaniclastics	67.9	28	0.51	4.1	183	200
Montana Dolomite	103.4	19	0.35	2.8	124	200

Table 7: Advance rates for different rock types (Heemskirk)



Overall there is unlikely to be any benefit derived from the use of a road header for development given that the capital cost of the equipment is up to four times greater for a road header and development costs are likely to be at least double those for a conventional decline. (Operating Cost was \$10,000 per metre for the Costerfield main decline.)

Service costs for road header operations are also high given that dust removal using fixed rather than flexible ducting is likely to be a requirement. With the exception of the QHBS rock type the road header rate estimated is less than that for conventional drill and blast and road headers are generally not considered suitable for rock strength's of 100MPa and greater.

A potential use for a road header might be in a fixed term hire capacity to mine the first 350-400m of the Main Decline near the surface and the Upper Queen Hill decline system if severe restrictions are placed on near surface blasting times.

*Example 1* Tunnel in high strength rock

Tunnels in civil engineering are often driven by necessity in conditions that exceed the recommended rating for road header equipment the following data is for a 2.75m diameter 1037m long tunnel driven in mainly 109MPa UCS limestone using a 224KW road header with 90KW cutter power which achieved 47% utilisation in 2002/2003.

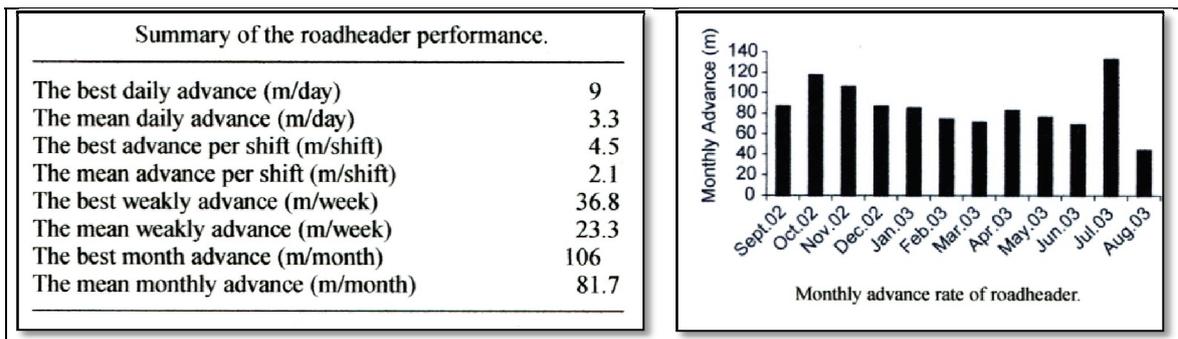


Figure 3: Road Header performance (actual) in >100MPa limestone

Whilst most of the tunnel was driven in limestone other rock types were encountered and the impact recorded as follows in Figure 4.

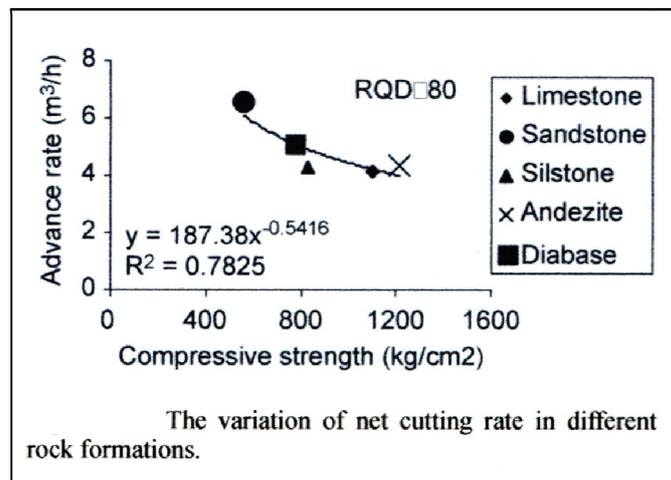


Figure 4 Effect of different rock strength



*Example 2* Tunnel with road header with 300KW cutter power

Current road header equipment for mining in high strength ground conditions such as Sandvik’s MH620 have high cutter power ratings of up to 300KW.

The following data was derived from the Kartal metro tunnel project which commenced in 2005 utilising road headers, drill and blast and impact breakers.

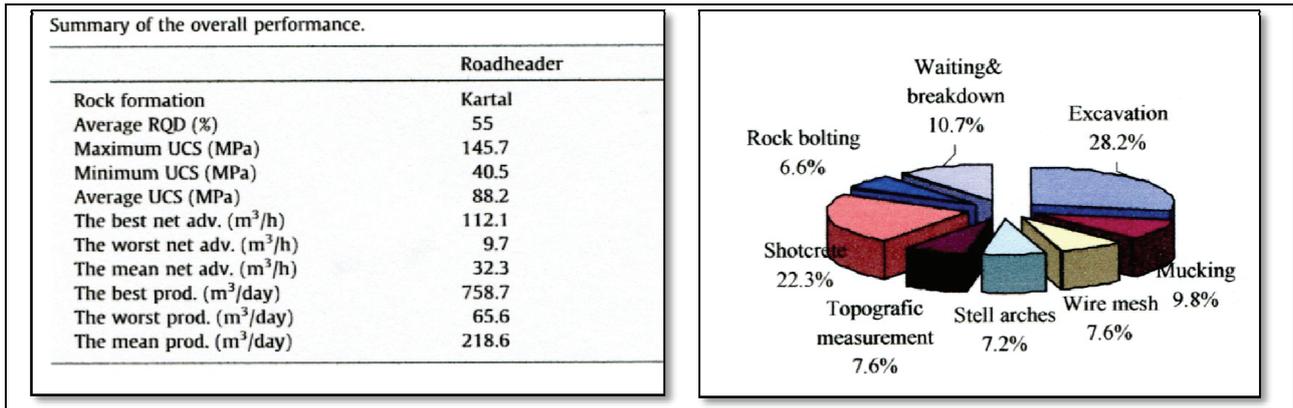


Figure 4: Kartal Tunnel Road Header with 300KW cutter power in hard rock.

At an average UCS 88.2MPa the Kartal mean advance rate for the road header was 32.3m<sup>3</sup>/hour which is within the range of the proposed estimates for Heemskirk shown in Table 7 – Kartal rates are slightly elevated probably due to the bigger drive dimensions in the project (up to double the face area).

It is significant that the road header was only used for large station excavations rather than the main metro tunnel because of high cutter wear, poor availability and associated operating costs – most of the tunnelling for the project was conducted with traditional drill and blast (where viable (urban environment)) and a series of impact hammer rigs (70% lower m<sup>3</sup>/hr but lower operating costs than the road header).

It is evident that the large modern powerful cutting rigs can excavate hard rock effectively but at a premium in terms of cutter wear, operating cost and availability.



## 6.0 Shaft Access

The final option reviewed is shaft access. A shaft access option is reviewed to examine the viability of reducing the access time to the Severn Orebody at 770m RL. This review does not represent a shaft design or proposal but is a broad brush review of the scale, cost and time taken to develop a shaft and any advantages that may eventuate most particularly with respect to early access to the Severn Orebody.

A shaft to access and service the Severn orebody would be of the order of 450m deep – for the purpose of this exercise it is assumed that a conventionally sunk and lined 4-5m diameter circular shaft would fulfil the hoisting and personnel requirements of the project.

In order to access the Severn orebody early a shaft would need to be located in the footwall of the Severn orebody between the Severn and Queen Hill ore bodies – it could suffer mining effects from extraction of the Queen Hill which would be minimised by installing rope rather than fixed guidance for any conveyance system.

In order to utilise a hoisting shaft for continuous production (24 hours) in a semi-urban environment the head frame would need to be internally located beneath Queen Hill. A basic rope guided hoisting system would be the quickest to mine and install and would take approximately 24 months to install and provide access to the lower Severn workings at an (order of magnitude) additional cost of \$5m to sink, \$3m to develop and \$15m to equip.

As this is longer than it would take to access the area by drill and blast and significantly more costly the option is discounted.

Previous shaft projects with similar depth, size and capacity were reviewed for this evaluation as well as the projection for a Heemskirk shaft as shown in Figure 5 following.

Item	Metres	Time
Preliminary Development		
<i>Decline</i>	350	
<i>Ramp</i>	240	
<i>Chambers etc</i>	50	
sub-total	640	<b>3.2</b>
Install sinking winder		<b>1.0</b>
Shaft Sink	412	<b>6.0</b>
Lower Shaft development		
<i>Plat</i>	50	
<i>Access ramps</i>	240	
sub-total	290	<b>1.5</b>
Install guides, commission hoist etc		<b>6.0</b>
Develop stope access		
<i>Develop access ramp</i>	170	
<i>Orebody development</i>	700	
sub-total	870	<b>5.2</b>
Stope preparation		<b>0.5</b>
<b>Total time to develop</b>		<b>23.3</b>
Single Heading	200m/Mo	
Multiple headings	80m/Mo	per heading
Sink & lining rate (4-5m diameter)	70m/Mo	
(Assumes a winder is available at project start -- long lead time can be experienced (up to 12 months))		

Figure 5: Projected Heemskirk shaft development time span



## 7.0 Recommendations

- The single heading rate of 120m per month (m/Mo) utilised in the PFS development schedule was conservative and may be raised to within the range 180-210m (200m) per month at the DFS stage as industry advice indicates this to be a more realistic level. This will bring forward production from Queen Hill from month 17 to month 11 and Severn from month 25 to month 16.
- The multiple heading rate of 240m/Mo per rig with a maximum of 80m/Mo per heading used in the PFS schedule matched the industry advice (range of 220-300m/Mo) and may continue to be utilised for scheduling purposes.
- The use of a road header would raise the cost of mine development and would be unlikely to provide any time benefit given that only one rock type falls within the recommended road header rock strength operating range. Modern high cutting power rigs (300KW) are capable of operating within stronger rocks but at the expense of high operating costs resulting from high cutter wear and poor utilisation.
- The short term hire of a road header to mine the initial 300-400 m of Main Decline development from surface and the upper Queen Hill decline might be considered to limit the surface impact of the initial mine development on the township particularly if restrictions on blasting near the surface are imposed by MRT/EPA.
- A hoisting shaft would not improve access time to the Lower Severn orebody, would duplicate the development that is required to be installed for the proposed mining methods and would significantly elevate project capital costs by of the order of \$23m. A shaft option is not recommended for further review.
- Conventional drill and blast appears to be the quickest and most economic means of providing access to the Heemskirk ore deposits. Effectively maximising development rates within any mine development contract set up appears the most appropriate means of providing early access to ore production.
- The assessment made in this review is based upon the Mining One PFS schedule including the development designs and the staged filling approach which incorporates the mining and filling of the Queen Hill Lower stopes prior to moving the fill plant underground to be used to fill Severn stopes.
- The principal risk affecting all assumptions regarding schedule rates in the PFS and this review is that there may be some potential for restrictions to be placed upon near surface works and blasting times.

*A.D. Fudge*

**A.D.Fudge – Consulting Mining & Geotechnical Engineer ACSM MSc (Geotech) MAusIMM**



## References

1. Heemskirk Tin Pre-Feasibility Study (*MiningOne - Aug 2013*)
2. PFS Study Review and Optimisation (*Polberro Consulting- Apr 2014*)
3. Comparative Studies on the performance of roadheader, impact hammer and drill and blasting method in the excavation of metro station tunnels in Istanbul Ocak and Bilgin (*Elsevier -Nov 2009*)
4. Roadheader excavation performance – geological and geotechnical influences (*ISRM Thruro & Plinninger 2009*)
5. The performance of a roadheader in high strength rock formations in the Kiksu Tunnel (*Bilgin, Tumac, Feridunoglu, Karakas & Akgul 2005*)
6. Renison Shaft Hoisting Study (*Red River Mining – Fudge 1993*)
7. Jabiluka Hoisting Study – (*MAMIC for ERA – 1992*)

## Limitations and consent

The report is provided to the Stellar Resources as a review into alternative means of provision of access to the Heemskirk as proposed in the MiningOne PFS. The report has been prepared using information available to the author at the time of writing. The opinions stated herein are given in good faith and with the belief that the basic assumptions are factual and correct and the interpretations reasonable. The document is not intended for public release in any form.

## Statement of independence

Alan Fudge has no material interest or entitlement in the securities or assets of the Stellar Resources or any associated companies.

## Map conventions/other

Coordinates in this report and in digital data associated with this report are recorded as GDA Zone 55. Levels (RL) in this report are MSL +1000m. References to cross sections look west and long sections look north. Surface topography is based upon lands department map information only.

## Competent Person Statement

1. Not required