Appendix G

Tailings disposal options

REGIS RESOURCES LTD

MCPHILLAMYS GOLD PROJECT

TAILINGS DISPOSAL OPTIONS

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1. INTRODUCTION

The McPhillamys Development Application (DA) and Environmental Impact Statement (EIS), which was submitted to the Department of Planning, Industry and Environment in July 2019, received submissions from regulators, interest groups and the community.

The EIS included explanations as to why the thickened slurry tailings disposal option was selected. The explanations were technically based and were accompanied by a detailed risk assessment.

Meetings held with the Resources Regulator (RR) and the Environmental Protection Agency (EPA) throughout the submissions phase highlighted a need for additional explanation at a less technical level so that assessors who were less familiar with the varying tailings disposal options could better understand the explanations in the EIS.

This section therefore aims to articulate the reasons, with simple explanations of technical jargon, why thickened slurry tailings disposal was selected for the McPhillamys Gold Project Development Application.

There are a number of tailings disposal options that can be used for the deposition or disposal of tailings streams. Tailings can be defined as a stream which contains material that has had the valuable commodity (gold) removed from it via a processing route.

There are a number of tailings disposal options[1] that can be applied for the deposition or disposal of tailings streams.

They include:

- slurry disposal (subaerial or subaqueous);
- thickened or paste disposal;
- dry stacking;
- co-disposal with coarse wastes (coalmine coarse reject, metalliferous smelter scats/slag and waste rock or spoil).

2. DISPOSAL OPTIONS

2.1. SLURRY DISPOSAL

Slurry is a term used to describe a mixture of ore that has been ground to a relatively fine size, for example, less than 0.5mm, and a solution (eg. water). The resultant mud like mixture is called a slurry and its properties can vary significantly depending on a number of factors including; the nature or type of ore particles, the sizing of the ore particles, the percentage of water in the mixture.

Although the solids concentration of slurry varies considerably due to a range of factors, gold tailings typically have a solids concentration of slurry at 45% solids by weight, (Department of Industry, Science, Energy and Resources (DISER), 2016: 14.). Depending on the nature (viscosity or thickness) of the slurry, this can range from about 40% to 60% solids by weight.

There are two main sub-categories of slurry disposal, namely *subaerial deposition and subaqueous deposition*.

[1] "Tailings Management – Leading Practice Sustainable Development Program for the Mining Industry – September 2016"

Subaerial deposition is when the slurry is discharged or disposed above the surface, allowing the solid particles in the slurry to settle as the stream flows to the lowest point where once all of the solid particles have settled, only water or solution will remain in what is usually termed a decant pond area. An example of this is shown in Figure 1.

This method generally utilises multiple discharge points so that the tailings deposition profile can be managed and the decant pond area can be maintained in a position where a pump is available to recycle the water back to the processing facility.

Figure 1 - Subaerial Tailings Discharge[2]

This deposition method can tend to expose the beached tailings to oxygen if they are allowed to dry, which in the presence of reactive sulphide minerals, can facilitate the production of a lower pH decant water pond. In terms of the McPhillamys Gold Project, the deposition method provides for maximum volatilisation of the solution, which in effect aids in the rapid disintegration of cyanide species.

Subaqueous deposition is when the slurry is discharged below the water level and is kept the below the water level.

This is often utilised in areas where the tailings are benign (non reactive) and the disposal point is very deep so that the tailings will not affect the marine environment, or alternatively, for the opposite case, where the slurry is reactive, possibly containing reactive sulphides that are likely to oxidise, forming potentially acid solutions, which in turn can mobilise soluble metals into the water system, or possibly producing acid water. This deposition method isolates the stream from the surface environment and where required, can restrict the slurry access to oxygen. Two examples are shown in Figure 2.

Figure 2 - Subaqueous Tailings Discharge[3]

[2] Image sourced from tailings.info web site. HTTP://WWW.TAILINGS.INFO/DISPOSAL/DEPOSITION.HTM
[3] Image sourced from tailings.info web site. HTTP://WWW.TAILINGS.INFO/DISPOSAL/DEPOSITION.HTM

The subaqueous deposition method requires a significant volume of water on the tailings storage facility, with the volume of water typically required to remain indefinitely.

An example of subaqueous tailings deposition is the Benambra Mine Site in south-eastern Australia, which was operated as an underground base metal mine from 1992 to 1996. Upon closure the rehabilitation plan for this site was to design the tailings storage facility (TSF) to have a permanent water cover with a minimum of two metres depth.

2.1.1. EMBANKMENT DESIGNS

TSF's using slurry deposition generally have embankment designs that fit into one of the following three categories:

- upstream construction;
- downstream construction;
- centreline construction.

Upstream Construction

The upstream method is a cost efficient method appropriate for areas of low seismic risk, or where there is insufficient waste rock fill or clay core material, as they require the minimum amount of new embankment material. This method may utilise existing tailings from within the facility, or available waste rock, on the basis that those tailings or waste rock possess acceptable physical properties to construct the new walls. The *Responsible Mining Foundation* however considers that dams constructed upstream from the original dyke (embankment) "is the most likely type of dam to fail" (AusIMM, 2016.)

An example of the upstream construction method is shown in Figure 3.

Downstream Construction

The downstream method is generally considered to be a more robust design method, provided that there is adequate clay material available to construct the core of the wall.

The downstream method starts with an impervious clay core toward the inner side of the embankment, as shown in Figure 4, with natural rock, or similar material placed on the outer side (and sometimes on the inner side) of the wall for engineering strength. The final TSF behaves in a similar manner to a water dam. The main downside with the downstream construction method can be the higher cost of suitable natural rock fill for the embankment, as well as the volume of the embankment, which is by its nature, much wider as the embankment is raised in height. An example of the downstream construction method is shown in Figure 4.

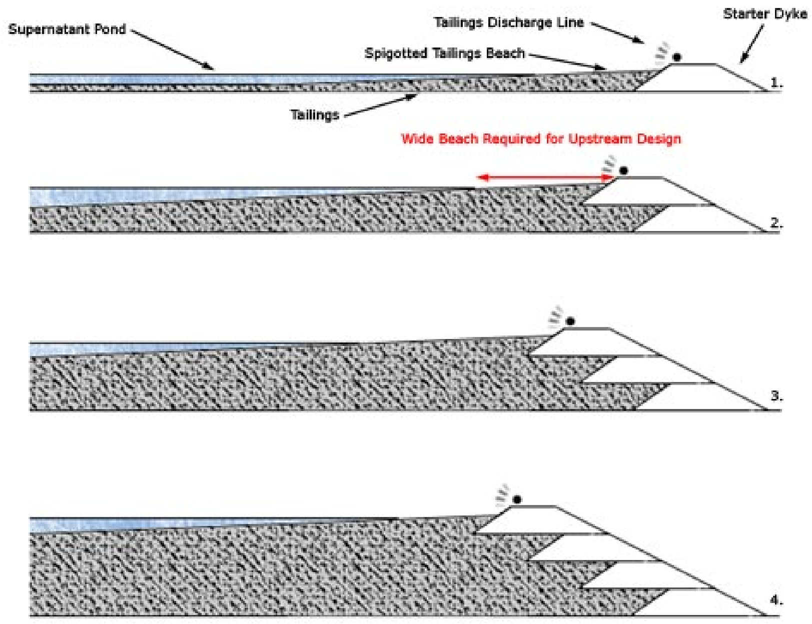

Figure 3 - Upstream TSF Construction[4]

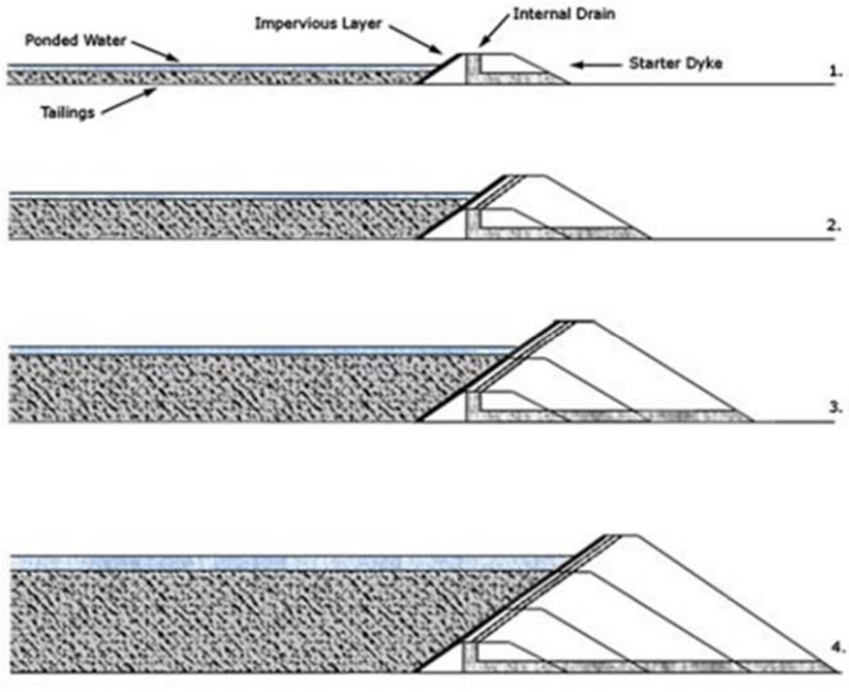

Figure 4 - Downstream TSF Construction[5]

[4] Imaged sourced from tailings.info web site. HTTP://WWW.TAILINGS.INFO/DISPOSAL/DEPOSITION.HTM
[5] Imaged sourced from tailings.info web site. HTTP://WWW.TAILINGS.INFO/DISPOSAL/DEPOSITION.HTM

Centreline Construction

The centreline method is a combination of the upstream and downstream construction methods and is generally considered to be more stable than the upstream method and has the advantage that it does not require as much natural rock fill material or clay core material as the downstream construction method does. The embankment is raised vertically and encroaches marginally back on the previously deposited tailings, as shown in Figure 5.

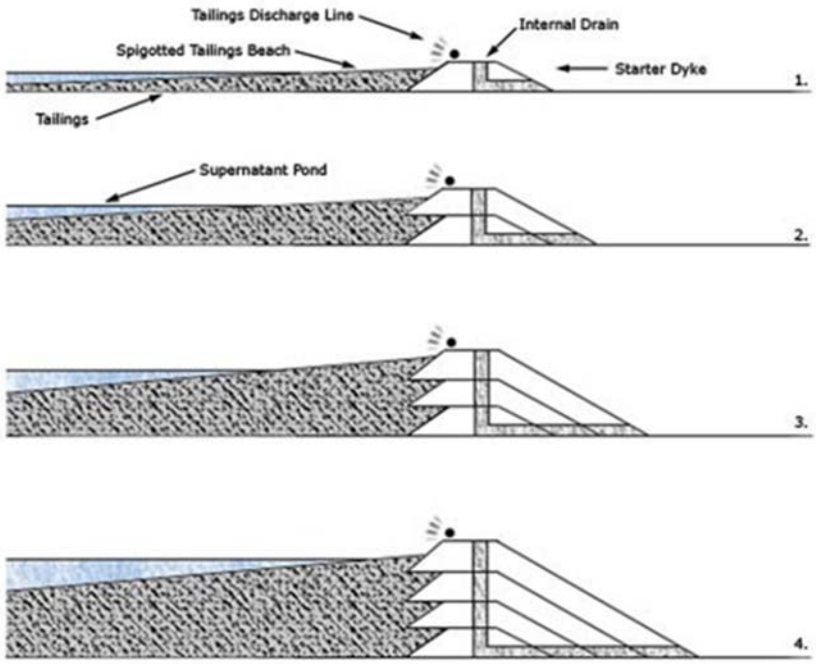

Figure 5 - Centreline TSF Construction

2.2. THICKENED TAILINGS OR PASTE TAILINGS DISPOSAL

Thickened or paste disposal involves a process of removing water (dewatering) from the tailings prior to deposition or disposal.

Thickened tailings disposal normally involves a mechanical device known as a thickener, which is normally the shape of a tank with a large diameter to height ratio, as shown in Figure 6.

Figure 6 - Typical High Rate Thickener[6]

The thickener works as follows. The slurry stream is introduced into the centre of the thickener via a radial flow path into what is known as a feedwell. A benign chemical called flocculant (similar to what is often used in home swimming pools) is added to the flow and the flocculant causes fine particles to coagulate and therefore settle at a faster rate. As the solid particles settle, a rake which extends to the outer edge of the thickener slowly rotates and moves material that has settled to the centre outlet.

At the same time as the solids are settling to the base of the thickener, the water or solution towards the surface is now becoming clear and as more slurry is introduced, this water level rises and a launder at the outer perimeter captures it for return to the process as recycled water.

The solid particles that have settled at the centre and those that have been raked toward the centre then flow out of the central discharge pipe at the base of the thickener with significantly less water than was in the slurry when it entered the thickener. This thickened slurry can then be transferred by conventional slurry pumps to the TSF.

The main advantage of thickeners, in particular, high rate thickeners, which are the most efficient, is that a significant amount of water can be recycled and the slurry properties have not been significantly altered to a point where hazardous high pressure pumps are required for tailings transfer.

This is why the use of high rate thickeners are generally considered the preferred method for tailings disposal. The methodology is safe, environmentally friendly, water efficient and relatively simple to operate for conventional processing operations. A secondary advantage of high rate thickeners is that tailings when deposited have a reduced potential for liquefaction (similar to a slumping or flow failure), or in simple terms, failure, compared to some other options. High rate thickeners can typically increase the solids concentrations to around 60% solids.

Paste tailings are similar to thickened tailings, except that the shape of the thickener tends to have a lower diameter to height ratio, and the removal of water is greater leaving a thicker slurry (typically 72% solids – (DISER, 2016: 14), known as a paste, which is much more difficult to pump and as a result requires high pressure equipment that requires significantly more power, maintenance and safety precautions.

[6] Image sourced from Outotec website: HTTPS://WWW.OUTOTEC.COM/PRODUCTS/THICKENING-AND-CLARIFICATION/HIGH-RATE-THICKENER/

Paste tailings are generally produced when the operation has an underground ore source. The advantage of paste is that the added reduction in water content can, with the addition of cement, make the material (pending its properties) into a weak form of cement that can then be used for backfilling areas of the mine where ore has been removed. This in turn means that more ore can be removed as the voids are supported to some extent structurally. A secondary advantage is that the paste generally only needs to be pumped a shorter distance before it can be transferred to different areas underground using gravity.

Paste tailings generally need the material to have certain properties, known as 'shear thinning'. This is in simple terms where a thick mud actually thins out, or becomes less viscous, without the addition of water, but through the addition of pumping power. The tailings are often thickened using a conventional high rate thickener and then pumped around a pipe loop before being introduced to the paste thickener.

Although the paste disposal option is more efficient in terms of water recovery, these advantages are more often than not (without a secondary use such as underground backfill) offset by the complications in producing the paste tailings, the need for high pressure positive displacement pumps to transport the paste tailings, and, achieving an acceptable final settled tailings density that has long term stability and is not prone to liquefaction. A typical paste thickener is shown in Figure 7.

Figure 7 – Typical Paste Thickener[7]

2.3. DRY STACKING

Dry stacking is a process where the slurry is filtered to a level that allows it to be stacked either by truck or by conveyor into a long term stable landform.

Although dry stacking would appear to provide a great outcome in terms of tailings disposal, the major disadvantage of dry stacking is the actual practicality of achieving the targeted moisture content, at all, or consistently over the life of the mine.

There are two main types of filter available for smaller and larger scale production applications; a vacuum style filter using a disc or belt, and a pressure style filter using a plate or frame arrangement.

[7] Image sourced from: HTTPS://WWW.OUTOTEC.COM/PRODUCTS/THICKENING-AND-CLARIFICATION/PASTE-THICKENER/

Vacuum filters utilise a vacuum pump to remove water or solution from the slurry with the aim of producing a solid material that can form a stable landform and not slump due to excessive residual moisture. For larger throughputs, belt filters are normally more appropriate, although for filters to have any chance of success, the sizing of the ore in the tailings generally needs to be quite coarse and absent of finer (difficult to filter) material if it is to have any chance of success. Disc filters have similar limitations and are generally used in smaller scale processes. Figure 8 shows a typical vacuum disc filter.

Figure 8 - Vacuum Disc Filter[8]

Pressure plate and frame filters utilise compressors to blow air through the slurry to remove water and like vacuum filters, can generally only produce a stable product if the ore sizing is considerably coarse.

It should also be noted that the power and footprint requirements for a filtration system (of either type) for a large scale processing operation generally, without any other limitations, make them non-viable. Figure 9 shows a typical pressure plate and frame filter, of which tens of units of this size might normally be required.

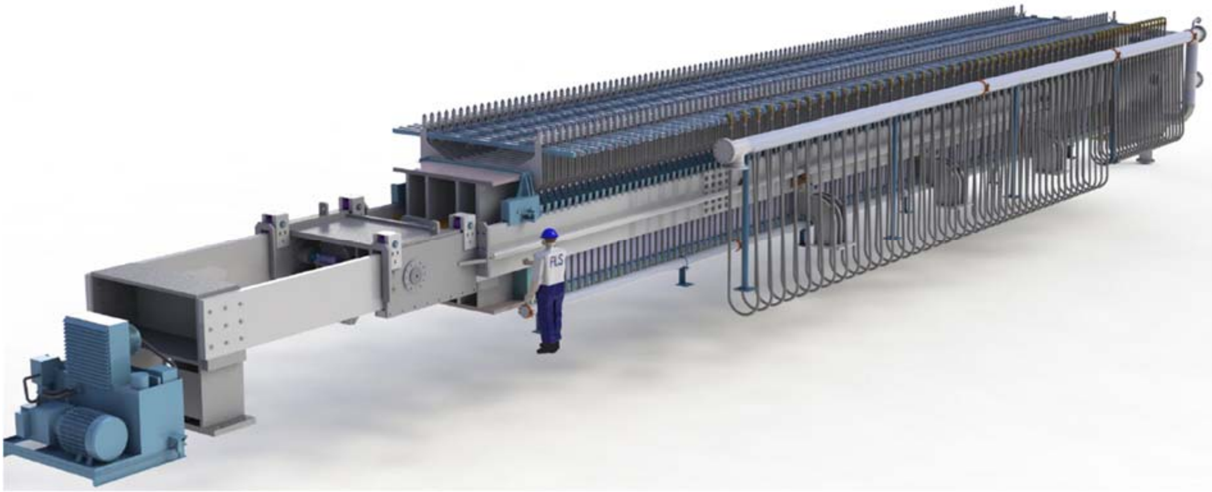

Figure 9 - Pressure Plate and Frame Filter[9]

[8] Image sourced from: HTTPS://WWW.OUTOTEC.COM/PRODUCTS/FILTRATION/LAROX-CC-CERAMIC-FILTER

[9] Image sourced from FLS Product Brochure

Despite the aforementioned challenges, the use of filtered tailings as a disposal option is still used in some parts of the world where there is essentially no surface or ground water available for processing, for example, some parts of Chile, where approximately 60 filters are required to be installed involving significant power demand. In these cases, the excessive power consumption required to operate the filters and produce the dry stacked tailings and the logistical difficulties in stacking the tailings is deemed an appropriate compromise. In that particular climate, the risk of the dry stacked tailings being eroded by a high rainfall event is very low, unlike locations such as McPhillamys where the long term stability of the standalone dry stacked tailings without engineered containment walls would be inappropriate.

2.4. CO-DISPOSAL WITH COARSE WASTE

Co disposal with coarse waste is in simple terms the combination of filtered tailings and crushed waste rock from the mine.

As discussed previously, it can often be impractical to produce filtered tailings that, by themselves can produce a stable landform. However, if the 'still too wet' filtered tailings are combined with a drier co-product, like waste rock, then a more stable land form can often be achieved.

Co disposal is commonly used in large diamond mines in the southern parts of the African continent. These mines have very limited water supplies, and low rainfalls, so filtering the processed product for maximum water recycle is a significant advantage and the risk of rainfall events eroding the landforms is low.

The diamond process, which discards coarsely crushed rock from the heavy media cyclone circuit, provides an ideal opportunity for a coarser dry stream to be recombined with a smaller scale filtered wetter stream.

One of the challenges with co-disposal is the ability to marry or match the filtered wetter stream with the coarser dry stream, which often consists of waste rock and is not always mined at the same rate that the tailings are produced, and vice versa.

A further challenge is that to co-deposit, the waste stream particles need to be of a size that can be conveyed, that is, they need to be crushed (typically to 100mm diameter waste rock size or less.) The higher power and maintenance costs of crushing all of the extra rock can in remote locations, be offset by the saving of water. However, in areas where communities are nearby, then the additional environmental impacts (noise and air quality) from crushing an entire waste stream normally preclude co-disposal as a viable option, even if the commercial viability of such a method was justified. This is the case at McPhillamys where the overall noise and air quality impacts from the crushing of waste rock for the co-disposal would be at the very least doubled and more realistically tripled in magnitude.

3. SUMMARY

Figure 10 shows a qualitative breakdown of the various tailings disposal options over the past decades, whilst Table 1 shows a conceptual analysis of the 'technical criteria' for the various tailings disposal options and their general appropriateness in relation to CIL gold processing operations. The green text indicates a favourable outcome, the black text an average outcome and the red text an unfavourable outcome.

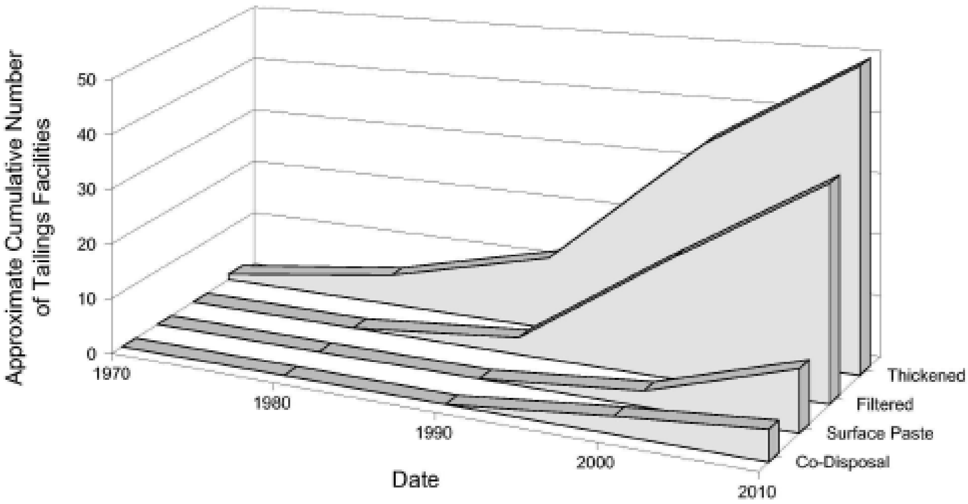

Figure 10 - Trend in Tailings Disposal Methods10

Table 1 - Technical Criteria for Tailings Disposal Options (General)

Variables	Thickened Slurry Disposal	Sub-Aqueous Disposal	Paste Disposal	Dry Stacking / Co-disposal
Tailings Stability	High	Low	Moderate	High
Water Use	Low to Moderate	High	Low	Very Low
Liner/Seepage Complexity	Moderate	High	Moderate	Low
CN Breakdown Rate	High	High	Low	High
AMD Risk (for PAF)	Moderate	Low	Moderate	Moderate
Capital Cost	Moderate	High	High	High
Operating Cost	Low	Moderate	Moderate	High
Energy Use	Low	Low	High	Very High

In addition to the above, natural and engineering factors contribute to the optimal selection of the proposed tailings disposal option at a specific location, in this case, McPhillamys.

For example, is the project located near the sea, is it located on a sandy desert, or a clay rich valley. These criteria are particularly important in the case of McPhillamys where the application of certain tailings disposal options (eg. sub-aqueous) would be fatally flawed.

10 Image sourced from Australian Government – Tailings Management (September 2016)

Table 2 shows a conceptual analysis of the 'natural and engineered criteria' for the various tailings disposal options and their appropriateness in relation to the McPhillamys Gold Project.

The Responsible Mining Foundation has also called on global mining companies to consider following measures to ensure more responsible tailings risk management including to commit to not use riverine, lake or marine disposal of tailings. Under that scenario sub aqueous tailings deposition therefore would be limited to specifically engineered and isolated structures.

Given the above and that there is no suitable water body within the vicinity of McPhillamys, the sub-aqueous tailings disposal option, for which selection is therefore fatally flawed, has been removed from further analysis.

The general consideration of Table 1 above relating to technical criteria for TSF options for McPhillamys has been broken down further in Table 2 taking into account life of mine factors.

Table 2 – Natural and Engineered Criteria for Tailings Disposal Options at McPhillamys

Area	Sub Category	Thickened Slurry Disposal	Paste Disposal	Dry Stacking / Co-disposal
NATURAL/ENVIRONMENTAL				
Geography	Topography	Good	Good	Poor
	Climate	Good	Good	Moderate
	Position in Catchment	Good	Good	Good
	Compatibility with Rivers / Springs	Good	Good	Poor
Geology	Sub-surface Permeability	Good	Good	Good
	Surface & Groundwater Interaction	Good	Good	Good
Geotechnical	Seismicity	Good	Moderate	Good
	Stability of Tailings	Good	Moderate	Moderate
	Foundations	Good	Good	Good
Geochemical	Natural Reactivity	Good	Good	Poor
	Mineralogy	Good	Good	Poor
Disturbance footprint	Land area required	Good	Moderate	Poor
ENGINEERING				

Area	Sub Category	Thickened Slurry Disposal	Paste Disposal	Dry Stacking / Co-disposal
Construction	Length of Wall	Good	Moderate	Good
	Height of Wall	Good	Moderate	Moderate
	Clay Core & Lining	Good	Good	N/A
	Rock Armouring	Good	Good	N/A
	Available Expertise	Good	Good	Moderate
	Available Equipment	Good	Good	Good
Operations	Proven Methodology	Good	Good	Moderate
	Flexibility	Good	Moderate	Poor
	Water Consumption	Moderate	Good	Good
	Power Consumption	Good	Poor	Poor
	Noise	Good	Good	Poor
	Air Quality	Good	Good	Poor
	Safety	Good	Poor	Poor
Post Closure	Long term stability	Good	Moderate	Moderate
	Control of leachates	Good	Good	Poor
	Water diversion	Good	Moderate	Moderate
	Rehabilitation	Good	Good	Good

Tailings Management: Leading Practice Sustainable Development for the Mining Industry (Tailings Management Leading Practice) states that "optimal strategies for tailings management are very much site specific" and "may be stored in a variety of ways, depending on their physical and chemical nature, the site topography, climatic conditions, regulations and environmental constraints, and the socioeconomic context in which the mine operations and processing plant are located (Commonwealth of Australia, 2016: 2.)

Tailings Management Leading Practice further considers that:

> *The selection of the appropriate and optimal tailings disposal method for a particular project is a function of the extent of pre-disposal dewatering applied to the tailings, which in turn is a function of the rheology and transportability of the tailings, the chemical and biological reactivity of the tailings, the return water requirements, the process water quality and its suitability for recycling to the processing plant, and the availability of raw water for processing. The selection is also influenced by the site climatic conditions, the topography, the distance to and elevation of the selected TSF site relative to the plant, and the conditions imposed by the regulator* (Commonwealth of Australia: 2016: 14.)

Regis has, based on the technical, natural and engineered criteria for various tailings disposal options, selected conventional thickened tailings disposal as the most appropriate for the type and volume of tailings produced.

Thickened tailings provide a robust solution to disposal where water conservation is important and the need for a long term stable landform is paramount. In conjunction with an engineered clay (or similar) lining system as proposed for McPhillamys, it allows for accurate seepage rate control so that the tailings can in turn consolidate for long term stability. It provides for low to moderate water consumption and is compatible with conventional cyanide detoxification processes and it provides optimal conditions for further cyanide breakdown after the tailings have been deposited.

Conventional thickened tailings disposal also satisfy the natural geographical, geological, geotechnical and geochemical conditions found at site. The geography of McPhillamys, including the undulating landscape is well suited to a natural valley style TSF location. Further to this, it is ideally located at the headwaters of the catchment and is therefore less affected by inundation from high rainfall upstream events than downstream catchment locations. The underlying geology and design for controlled seepage allows for long term consolidation and stability and the TSF design enables efficient use of the natural (valley style) topography in the area.

In terms of engineering, the limited wall length that results from a valley style facility minimises risk of failure and also enables rehabilitation to be completed early in the project life. Design optimisation has also facilitated long term water diversion with slopes matching natural conditions pre-development.

The location of the TSF in the upper catchment to reduce interception of upstream catchment flows; that can accommodate the volume of tailings produced; and which minimises its impact on high quality soils and agricultural lands (BSAL) and plant communities results in a TSF at a higher elevation than the proposed processing plant.

The external water supply that reduces the need to compete with other users for local water supply increases options for tailings disposal including thickened tailings.

The proximity of residences to the project raises potential impacts from noise and dust generation with associated socio-economic considerations. The location of the processing plant in close proximity to both the ore body and the TSF reduces truck movements for processing and TSF embankment construction with associated noise and air quality benefits. Pumping of thickened tailings to the TSF generates less noise than additional conveyors or trucks required for depositing paste or dry stacked tailings. The close proximity of the WRE and topsoil/subsoil stockpiles also facilitates access to TSF capping materials for closure. The planning and redesign of the TSF improves the diversion of water around the TSF and water shedding of the capped TSF at closure. Downstream embankment raises resulting in a final landform slope gradient of 1:4 which can be rehabilitated in the early years of mine life.

Regis considers that together these characteristics support the preferred option for the management of tailings disposal at McPhillamys, consistent with a life-of-mine risk based approach.

4. REFERENCES

Department of Industry, Science, Energy and Resources (2016) ***Tailings Management: Leading Practice Sustainable Development Program***; Commonwealth of Australia.

Responsible Mining Foundation (2019) ***Tailings Management :Learnings and Good Practice***. AusIMM Bulletin March 2019 (HTTPS://WWW.AUSIMMBULLETIN.COM/