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4 PROJECT ALTERNATIVES

4.1 Introduction

This chapter considers the various feasible alternatives that have been investigated as part of the DFS and ESIA. The IFC Performance Standards no longer require consideration of the 'no project alternative'. However, this is worthy of brief consideration. The no project alternative in this case would leave the Kingamyambo tailings deposit as a major source of dust in the area, and the Musonoi river valley filled with tailings. Although other projects are being developed in the Kolwezi area (re-opening of Kamoto, KOV and the Kolwezi Concentrator), which will lead to some economic revival, a sustained recovery in the Kolwezi area will be enhanced by the KMT project.

The project will effectively result in environmental clean-up in that it will eliminate Kingamyambo and also remove a major proportion of the tailings deposited in the Musonoi river valley. While the quality of the river water entering the concession cannot be controlled, the Kasobantu dam will hold back a water body rather than tailings.

The social benefits of the project are very significant too, bringing direct jobs, indirect employment and very considerable tax revenues to the run-down town.

The project has a commitment to producing a smaller footprint than at present, minimising discharges to the extent possible and reducing the legacy of the project on its completion. These commitments have been incorporated into the engineering design of the project via the process described in Chapter 3.

The sections below present the preferred option for the following project activities:

4.2 Plant and Tailings Storage Facility (TSF) site Selection

4.3 Mining method

4.4 Technical options:

- Process
- Tailings Storage Facility (TSF)
- Water resources.

4.2 Plant and Tailings Storage Facility Site Selection

Within the Musonoi valley area, various alternative sites for both the plant and tailings Storage facility (TSF) have been considered by successive owners of the project. Owing to the extent of land transformation caused by former mining activities around Kolwezi, in the form of old open pits, waste rock dumps and tailings dams, the Musonoi valley to the north of the town is the only potential site for major new infrastructure. The Luilu valley to the west is occupied by the Luilu plant and associated infrastructure and to the east is a low- lying area, which drains into the Nzilo Lake.

The proposed plant and TSF sites were selected by the previous owner, both on their suitability in terms of size, topography and substrate, and for their avoidance of villages, marshy areas, power lines, water courses and other existing infrastructure.

The present owner has adopted these locations, although the plant site orientation and size has changed and the TSF footprint has been expanded.

4.2.1 General principles for plant site selection

The plant site was selected according to the following criteria:

- concession boundary,
- topography,
- area required,
- soils and geology (including possible presence of ore body),
- proximity to settlements, sensitive areas and land used for crops,
- rail, road, water and power access,
- proximity to power and power line routing,
- hydrology and hydro geological conditions,
- ecological status, and
- Proximity to the existing tailings and the new TSF.

Each of these aspects was investigated for the four alternative sites as shown in Table 4.1 below. During drilling of the site originally proposed for the location of the plant (Site A), the shallow water table and high permeability in two of the boreholes led to the decision to investigate three other alternative sites for the plant. These alternative sites have been named Plant Sites B, C and D respectively and their locations are shown in Figure 4.1.

Plant site D is the preferred option given the larger available surface area, geotechnical characteristics of the site, flat topography, and environmental suitability.

The overall objective of the preliminary process plant layout is to ensure that the plant is operationally safe, constructible, environmentally, socially and publicly acceptable, economically viable and sustainable, and considers logical and sequential process flow around the plant.

The following engineering principles and philosophies were used for the layout development:

- The plant footprint needs to be minimized to reduce cost and environmental impact, without compromising safety.
- The copper and cobalt circuits need to be separated with separate spillage sumps.
- The aim was for a logical and sequential process flow around the plant but still keeping operations using the same type of equipment close to each other (feed filtration, primary leaching and thickeners).
- The layout was developed with one central control room and laboratory facility.

Table 4.1: Criteria used in the Plant Site Selection

Proposed Plant Site	**A**	**B**	**C**	D
Boundary constraints	Within KMT Concession boundary.	Within KMT Concession boundary.	Within KMT Concession boundary.	Within KMT Concession boundary.
Topography in terms of Plant footprint/ laydown construction yard	Flat less than 5m elevation change over site (slope 0.005%).	Slope of 0.015 %(15 m change in elevation over 1000m distance).	Slope of 0.02% (15m change in elevation over 750m distance).	Flat, less than 3m elevation change over site (0.005%).
Area in terms of Plant footprint/ laydown construction yard	Surface area approximately 72.96 Ha.	Surface area approximately 68.4 Ha.	Surface area approximately 70.9 Ha.	Surface area approximately 116.38 Ha.
Founding conditions (soils corrosivity/ geotechnics) and geology	Laterite in NE corner and test pits show foundations require compacted soil raft. Unstable limestone formation (Ks 1.3.1) on northern boundary adjacent to dambo. Southern boundary bounded by contact with Klippe Nord orebody, stability of this contact not known, but fissure on southern margin of Klippe Nord has opened resulting in sinkhole formation in Kakifuluwe River.	Founding can be on laterite with bearing pressures not exceeding 150kpa. Confirmation after lab test results received.	Founding can be on laterite with bearing pressures not exceeding 150 kpa. Confirmation after lab test results received.	Geotechnical investigation suggests most suitable option for foundation.
Sterilization of orebody	Southern boundary adjacent to Klippe Nord orebody is mineralised at depth. Heterogenite workings exist along the southern boundary of this site and the implication is that the usable surface area is reduced along this contact.	None – un-mineralised purple grey arkosic siltstone and shale (Ks 1.2.2) underlain by Ks1.1 conglomerate.	None – unmineralised purple grey arkosic siltstone and shale (Ks 1.2.2) underlain by Ks1.1 conglomerate.	None – unmineralised purple grey arkosic siltstone and shale (Ks 1.2.2) underlain by Ks1.1 conglomerate.
Social areas/crop compensation	Proximity to Tshala cemetery ±500m. Cassava lands and vegetable gardens along Dambo require crop compensation.	Proximity to Tshala cemetery 2000 m. Cassava lands require crop compensation.	Proximity to Tshala cemetery 2100 m. Cassava lands and sugar cane fields require crop compensation.	Proximity to Tshala cemetery ± 800m. Cassave lands require crop compensation.
Rail Access	Shortest rail access to existing marshalling yard approximately 3.5 km.	Extension of option 1 railway from site A NE to site B total length approx. 5.1 km.	Extension of option 1 railway from site A to Site D and then NE to site C, will need to go under 3 railway lines total length 7.7 km.	Alternative route could bypass the Kakifuluwe orebody.

Proposed Plant Site	A	B	C	D
Power access	Distance to INGA for power 2.5km.	Shortest distance to INGA 4.1 km.	Distance to INGA 6.7 km.	Longest distance to INGA 4.5 km.
Impacts of DC line	Could potentially require cathodic protection and could impact on electronic equipment.	Could potentially require cathodic protection and could impact on electronic equipment.	Could potentially require cathodic protection and could impact on electronic equipment.	Could potentially require cathodic protection and could impact on electronic equipment.
Water access	Depends on water supply source.	Depends on water supply source.	Depends on water supply source.	Depends on water supply source.
Road access	Existing road access from weather station.	Road access from "pipeline road" bridge required over Kasambo river.	Road access from "pipeline road", bridge required over Kakifuluwe dambo.	Existing road access from weather station and road to Tshala cemetery will have to be extended.
Hydro geological conditions/Water table	Shallow groundwater table (6 m) and saturated permeable aquifer associated with Ks 1.3.1 on northern boundary (>30 m^3/hr sustainable yield). Buffer zone of at least 200m from dambo required, reducing usable surface area.	Minor seepage (<1 m^3//hr) at contact with conglomerate (± 40 m).	Minor seepage (<1 m^3//hr) at contact with conglomerate (± 40 m). Shallow water table towards NE corner.	Minor seepage (<1 m^3//hr) at contact 16m.
Rivers/ Dambo's/ Flood lines	Adjacent to Kakifuluwe Dambo but 2.5 km from Musonoi. Artificial recharge along this side of Dambo due to blocked river suspected.	< 1 km from Musonoi River. Need to remain at least 100m from 1:100 year Musonoi flood line (preferably on western side of existing pipeline road.	<1 km from Musonoi River. Need to remain at least 100m from 1:100 year Musonoi flood line (preferably on western side of existing pipeline road).	Far from Musonoi (2 km) but between the Kakifuluwe Dambo and Kanamwamwa River.
Proximity to TSF	Tailings pipeline will have to cross Kakifuluwe Dambo and two other water courses (Muninga and Kananawamwa).	Furthest from TSF site and pipeline will have to cross Kakifuluwe Dambo and the Kananawamwa	Tailings pipeline will not have to cross Kakifuluwe Dambo but will cross the Kananwamwa water course. Distance 1.5km to TSF site.	Closest to TSF site (1.5 km) and pipeline will not have to cross Kakifuluwe Dambo, but will cross the Kanamwamwa.
Proximity to tailings ore	Nearest to Kingamyambo tailings (6km) and 2-4 km from Musonoi Tailings.	Closest to Musonoi tailings (0.5-4.5 km) and 6.5 km from Kingamyambo Tailings.	7.5 km from Kingamyambo tailings and 1-5.5 km from the Musonoi tailings.	6.5 km from Kingamyambo and Musonoi tailings 2-2.5 km).

4.3 Mining Methods

Three mining methods were investigated, namely hydraulic mining, dredge mining and mechanical mining. These are described in further detail below.

4.3.1 Hydraulic Mining

Hydraulic mining will be undertaken at Kingamyambo as follows:

- Water from boreholes will be provided to the plant and to the tailings reclamation (mining) site. Once established, water is recycled to the tailings reclamation area when the reclaimed tailings are dewatered in the processing plant.
- Water is then fed into a 5000 m^3 HDPE lined earthen pond at the hydraulic reclamation site.
- Water is extracted from the reservoir by a series of pumps, to boost the pressure to around 30 bar (3000 kPa).
- These high pressure pumps deliver into a steel pipe that reticulates the water around and onto the TSF. The high pressure water is delivered to the monitors.
- Four monitors will be operated simultaneously and will be manually controlled, although the production rate could be obtained from just one. However, operating a single monitor would limit any blending potential.
- Mining will be done, top-down, in benches. At the Kingamyambo dam the generated slurry will flow in naturally created launders to the topographically low NE corner of the dam where it will pass through a static screen to remove oversize and debris, and into a collection sump.
- A slurry pump will deliver the slurry from the sump, discharging this over a vibratory screen above a header tank, feeding the main tailings slurry pumps which deliver the slurry overland, via pipeline, to the process plant.

In the Musonoi valley, hydraulic mining will be carried out after dredge mining and when the water level in the Kasobantu dam has been reduced by either pumping or siphoning. A river diversion channel will also be constructed along the eastern bank of the Musonoi valley to collect and channel water from the Musonoi and its tributaries from the mining areas to the Nzilo channel or to the Musonoi river channel. (The Musonoi channel downstream of Kasobantu dam represents the best aquatic habitat in the area, and the Nzilo channel is the favoured route for these waters in order to protect the high biodiversity value of this stretch of the Musonoi river valley). The river diversion must be capable of containing the high flows experienced in the rainy season.

Once the tailings in the Musonoi have drained, the tailings will be removed by hydraulic mining using a similar technique to that outlined above, generally working from the downstream end up the valley in a southerly direction in order to utilise the slope of the valley flow towards a series of sumps and take-off points for the slurry to be transported back to the plant.

4.3.2 Mechanical Mining

Mechanical mining, using front end loaders (FEL) or face shovels has also been considered. As tailings material of this type is held together by soil suction which can cause the mining faces to overhang the machinery, the working benches are limited to the height of the raised bucket of the machines, typically 4 – 5 m. The excavated material would be transported from the working face to a slurrying tank using a conveyor, which will be repositioned as mining progresses.

4.3.3 Dredge Mining

Mining of the Musonoi can be achieved through floating dredge barges which pipe the slurry back to the plant for processing. The water level in the Kasobantu would need to be maintained to give enough depth of water. A series of locations for the suction dredge would be used before the Kasobantu is drained to allow hydraulic mining to take place (see 4.3.1 above).

4.3.4 Preferred Mining Option

The feedstock for the Kolwezi project will be a blend of material from the Kingamyambo TSF and the Musonoi River deposit. The Musonoi tailings will be recovered through dredge mining, switching to hydraulic mining when the Kasobantu dam has been partially drained. It has already been established that the material in the Musonoi deposit is not suitable for dry mining. Fraser Alexander, in its revised report (Jan 2005), recommends that hydraulic mining is the better option. Whilst some initial capital cost savings can be achieved by dry mining, the hydraulic system represents a significantly lower technical risk.

Hydraulic mining was considered to be the preferred option from an environmental perspective for the following reasons:

- Reduced dust emissions during the mining of the Musonoi and Kingamyambo tailings deposits;
- Less safety risks associated with the transport of material between the tailings deposits and plant;
- Although the monitors will be a source of noise, the noise emissions will be restricted to the tailings deposits and once monitoring moves below the current surface this source of noise will be less perceptible to sensitive receptors. The low frequency noise associated with diesel engines involved in the dry mining option transmits over far greater distances and would also move closer to sensitive receptors suggesting that hydraulic mining is a better option in terms of potential noise impacts.
- Although hydraulic mining requires a supply of water, the abundance of ground water in the area eliminates this as a limiting factor.

The specialist studies focused primarily on the impacts associated with hydraulic mining as this option was agreed on relatively early.

4.4 Technical Options

4.4.1 Process flow sheet options

The proposed project involves the extraction of the oxide tailings from Kingamyambo using high-pressure water monitors in a series of paddocks and dredging (initially) in the Musonoi. Metallurgical process flow sheets to extract copper and cobalt using sulfuric acid leaching followed by solvent extraction and electro-winning has been developed.

The DFS investigations focussed largely on identifying the most appropriate method of extracting copper and cobalt from the tailings, and various technical alternatives have been considered. These alternatives have largely involved subtle metallurgical differences in the basic process of acid leach followed by solvent extraction and electro-winning.

The process flow sheet has been defined in detail for the extraction of copper and cobalt from the reclaimed tailings at Kolwezi. Initially, the KMT project will produce LME Grade A copper cathode and cobalt hydroxide. Depending on further technical evaluations, it may be feasible to construct a cobalt refinery at KMT in the future to enable the production of cobalt metal.

The cobalt refining step includes a zinc solvent extraction step in which the pH has to be controlled by the addition of a solids-free alkali. This requirement excludes the use of calcium hydroxide due to its tendency to form insoluble gypsum during the neutralisation reaction. Other alkalis were also investigated but presented safety and handling risks. The most feasible and cost-effective alkali to use would be sodium hydroxide. This, however, would produce a highly soluble sodium sulfate waste stream, in which the sulfate is not amenable to removal by precipitation. The decision to defer construction of a cobalt refinery at KMT means that a sodium rich waste stream will not be produced initially, as cobalt is precipitated using magnesia (magnesium oxide) instead of sodium hydroxide as the neutralising agent to minimise the concentrations of soluble salts in the tailings slurry liquor.

There are significant differences in environmental impacts for the various processes investigated, particularly in that the rejected flow sheet produced an effluent containing almost twice the concentration of soluble salts (19,500 mg/l) than the one proposed (8,300 to 10,600 mg/l).

4.4.2 Process waste streams

The process flow sheet selected produces two waste streams:

- The residue stream neutralised to a pH greater than pH 9.0 pumped to the TSF, made up of a strongly leached solids fraction and liquor containing precipitated heavy metals and only soluble constituents such as Ca, Mg and sulphate.
- An excess solution stream derived from the CCD reflux circuit, neutralised to a pH greater than pH 10.0 and containing no heavy metals and soluble concentrations of Ca, Mg and sulphate.

Residue stream

The residue stream produces two types of discharge to the environment around the TSF:

- **An excess of slurry liquor** during periods of high rainfall, necessitating the discharge of excess volumes peaking at about 1,300 m^3/h, containing dissolved salts of 3,000 to 8,000 mg/l depending on the dilution due to rainfall. This excess water will need to be discharged either to the Kasobantu Dam or to the Luilu River. The preferred option is to pump this water to the Luilu River when it arises during wet weather, for the following reasons:
  - It is preferable to minimize flows into the Kasobantu Dam because of their possible interference with dredge mining or hydraulic mining
  - It is preferable to discharge to the Luilu River where the potential impact of the discharge on water quality is minimized by the very high pit dewatering flows expected from other operations.

Reflux circuit effluent

This effluent is expected to be produced at the rate of about 2500 m^3/d, containing TDS at typical levels of 10,600 mg/l, made up approximately of calcium 580 mg/l, magnesium 1740 mg/l, chloride 60 mg/l and sulfate 8,200 mg/l.

The main alternatives for managing this effluent disposal are:

- Disposal of Reflux Effluent via the TSF

The initial option considered assumes that the 2,500 m^3/d of reflux effluent could be blended into the residue circuit, expected to comprise 14,900 m^3/d of liquor. Mass balance calculations show that the addition of this effluent to the residue slurry liquor will potentially raise its TDS from 8,300 mg/l to about 8,700 mg/l, an increase of about 5%. This 5% increase will raise the spillage and seepage TDS values pro rata with insignificant additional environmental impact for the receiving waters in the Luilu River or the shallow aquifer.

- FQM has confirmed that this is the preferred option. Disposal of the Reflux Effluent to the Luilu River

Prior to the process flow sheet being changed, the only immediately viable option was to discharge the effluent stream to the Luilu River. However, the preferred option of incorporating it into the residue stream to the RSF appears the more responsible approach and the Luilu discharge option has been discarded.

4.4.3 Ground Water Supply

Based on the water requirements for the hydraulic transport of tailings to the plant and the retreatment of tailings at the plant, a number of sites were investigated for the establishment of a well-field. These included a site on the Manga orebody (preferred location), and at plant site A and on the Kingamyambo orebody; each of these options is discussed in further detail below. The well-field investigated is shown on Figure 4.2.

Manga orebody

This area is the most feasible for development of a well-field for the following reasons:

- High yielding borehole BH1 showed that at least 100-200m^3/h per borehole could be abstracted from the CMN formation in this area providing the borehole dimensions are sufficiently large (17” in diameter). The sustainability of this abstraction rate has not been proven as it was not possible to test pump this borehole due to the capacity of the pump on site.
- There are no other users exploiting this aquifer and no villages close to the site.
- On the basis of the current dataset, the water quality (after filtration) complies with the preferred quality specification in all respects with the exception of the high concentrations of ferrous iron and manganese present. The iron and manganese will need to be removed before use. Contamination from other sources is unlikely.
- The source lies within the KMT concession area, well placed for use in hydraulic monitoring at Kingamyambo tailings and the upper reaches of the Musonoi tailings.

The drawdown equations used the following assumed data from the KOV CMN aquifer and indicate the longer term drawdown rate is expected to depend largely on the transmissivity as shown in Table 4-2.

Table 4-2: Summary of drawdown of Manga orebody

Transmissivity	Storativity	Abstraction rate	Radius of influence	Drawdown (m)		
m^2/day		m^3/hour	m	1 year	10 years	30 years
30	0.0001	100	500	44 m	58 m	80
Dolomitic CMN	0.001	200	500	58	87	131
400	0.0001	100	500	4.5	5.6	7
Altered CMN	0.001	200	500	6.8	9	12

Since the blow yield intercepted in BH1 was more than 100 m^3/h in a small diameter hole (8"), it is likely that the CMN is altered (rather than dolomitic) and a transmissivity close to 400 m^2/day is feasible. Depending on the storativity, the expected cone of drawdown at a distance of 500m is expected to be only 6 to 10m after 30 years of pumping at this rate.

If the project water make-up requirements are estimated at about 620 m^3/h including about 260 m^3/h to slurry tailings solids to the TSF, a total of 4 to 6 boreholes would be required to supply this volume, assuming the aquifer parameters used in these calculations to be representative.

Therefore with boreholes spaced 250m apart one could expect double the drawdown after 10 years of pumping (i.e. the expected core of drawdown at a distance of 500m will be 20m), and providing the boreholes are deep enough (at least 100m in depth) this drawdown should be acceptable, as the aquifer is not exploited by other users.

The monthly samples taken over a period of a year from BH1 have contained excessive manganese and very high iron concentration (typically 50 – 70 mg/l).

It should be noted that conclusions itemized above are based on only a single borehole and are therefore tentative. It will be necessary to investigate the Manga ore body more extensively by drilling a number of suitably sized boreholes and test-pumping these to establish the assured yield. At the same time, boreholes that may be used by communities will be monitored to determine whether abstraction from the Manga well-field would impact negatively on other ground water supplies. The occurrence of elevated iron and manganese levels in the ground water will need to be confirmed, and if so, a treatment system to remove these metals will be specified.

It should also be noted that other developers, currently assessing the feasibility of re-opening existing mines in the Kolwezi area, are likely to undertake extensive dewatering of open pits and underground workings for the foreseeable future. It is possible that some of this abstracted water could be used by KMT for process purposes, in lieu of the Manga well-field supply. These opportunities will be investigated when the relevant information from other miners becomes available.

Kingamyambo Orebody

The Kingamyambo orebody should not be considered as an option for water supply for the KMT project for the following reasons:

- It is within the cone of drawdown of the KOV pit and therefore wells would have to be drilled very deep and water depths will fluctuate with the pit lake depth and dewatering of the KOV;

- It has a higher salt load due to seepage from the Kingamyambo Tailings

Plant Site A

Whilst it is feasible that 4 to 8 boreholes spaced 500m apart along the margins of the dambo, at a distance of at least 250m from the margins could meet the project requirements of 6400 m^3/h, this shallow saprolitic aquifer is not deemed suitable for the following reasons:

- The quality of the water pumped from BH6 is corrosive (low pH and very low EC) and as such it would preferably be blended with an alternative water supply.

- In addition, the social impact of even only a 3m drawdown at the margins of the dambo will have a major impact on the vegetable crops and hand dug wells exploited by the local communities of Luilu and Tshala village. The shallow water table would drop and the dambo would in all probability dry up as the groundwater would no longer intercept the topography in this area.

At an abstraction of 30 m^3/h there was drawdown of only a few centimetres and during the 30 hours of pumping the water level actually started to recover indicating a recharge boundary (presumably from the dambo). The assumption is therefore made that with a larger diameter hole, at least double this abstraction volume would be sustainable. The calculations were made assuming 50 and 100 m^3/h abstraction rates.

Using the aquifer parameters determined from the test-pumping of BH6, the following drawdown at a distance of 250m (i.e. distance to the dambo) is predicted using these calculations.

Table 4.2: Summary of drawdown at Plant Site A

Transmissivity	Storativity	Abstraction rate	Radius of influence	Drawdown (m)		
m^2/day		m^3/hour	m	1 year	10 years	30 years
300 Ks 1.3.1	0.0001	50	250	3 m	4 m	5.1
	0.001	100	250	5	6.7	8.8

Figure 4.1 : Four alternative plant sites investigated

Figure 4.2: Location of proposed well field