

King Fahd University of Petroleum and Minerals

College of Petroleum & Geosciences

Term 252 - MINE 348

Surface Mine Design

Project Report

Student Name	ID number
Nasser Alzuabi	202259820
Ammar Allahyani	202267200
Omar Althubyani	202262580

Instructor: Dr. Zaka Emad

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1 Executive Summary

This report gives a preliminary open pit design for the Copper Canyon porphyry copper deposit. The work follows the MINE 348 project brief and covers the main items needed at pre-feasibility level: pit geometry, bench layout, haul road design, waste dump design, drill and blast design, a five-year production schedule, simple economics, and safety/environmental controls. The design is intentionally kept practical because the data set is still conceptual.

The deposit was treated as an elliptical orebody with a plan dimension of 400 m north-south by 300 m east-west and an economic depth of 80 m. The ore is divided into three vertical zones: a top 20 m low-grade zone at 0.4% Cu, a middle 40 m mill feed zone at 1.2% Cu, and a bottom 20 m marginal zone at 0.8% Cu. Using the given density of 2.8 t/m3, the simplified geological inventory is about 21.11 Mt of ore before mining losses or detailed pit constraints.

A conceptual pit shell was prepared using a 45-degree overall slope limit. The pit crest was estimated by expanding the bottom ellipse by 80 m in the main directions. This gives a top ellipse of about 560 m by 460 m and a total pit volume of about 11.59 million m3. The corresponding first-pass material inventory is about 21.11 Mt ore, 7.90 Mt waste rock, and 1.82 Mt overburden. The ultimate strip ratio is therefore about 0.46:1, which is below the 3:1 limit from the brief.

The haul road was designed for Cat 777F-size trucks using a practical two-way width of about 25 m, including allowance for traffic lanes, a safety berm, and drainage. The maximum grade was limited to 8%, so the ramp needs at least 1,000 m of developed length to reach the pit bottom from the crest. The waste dump is placed approximately 500 m west of the pit, as required, and uses 10 m lifts, 8 m benches, and a 30-degree overall slope.

One important constraint check was identified. The brief asks for a maximum ore production of 2 Mt/y, a minimum total mining rate of 15 Mt/y, and a strip ratio limit of 3:1. These three constraints cannot all be satisfied at the same time. At 2 Mt/y ore, a 15 Mt/y

total mining rate would require 13 Mt/y of waste, equal to a 6.5:1 strip ratio. For this reason, the base-case schedule follows the ore production cap and strip ratio control rather than forcing an unrealistic 15 Mt/y material movement rate.

The simple five-year plan produces 2 Mt/y of ore, with waste movement declining as the pit is opened. The average operating cash flow is positive under the assigned copper price of US$8,500/t Cu and 85% metallurgical recovery. A simplified discounted cash flow gives a positive NPV under the placeholder capital assumptions used in this report. The values should be updated after software volume verification and more accurate cost estimation.

2 Project Basis and Key Input Data

The Copper Canyon project is a conceptual surface mine design for a porphyry copper deposit in a semi-arid setting. The design objective is to prepare a practical open pit layout that can be presented to potential investors at a pre-feasibility level. The project brief requires pit design, haul roads, waste dump design, drilling and blasting, production scheduling, software visualization, and a simple economic check.

Item	Given Value / Adopted Basis	Design Use
Orebody shape	Elliptical in plan view	Used for simplified pit and resource calculations
Orebody dimensions	400 m N-S × 300 m E-W	Defines the bottom economic footprint
Economic depth	80 m below surface	Used for pit depth and volume estimates
Dip	15° east	Recorded for geological description; pit design mainly controlled by economic shell
Overburden	5 m soil/saprolite	Removed before ore and waste mining
Top ore zone	20 m at 0.4% Cu	Low-grade stockpile or early feed depending on economics
Middle ore zone	40 m at 1.2% Cu	Main mill feed
Bottom ore zone	20 m at 0.8% Cu	Marginal but still economic under given price
Ore density	2.8 t/m³	Converts ore volume to tonnes
Waste density	2.6 t/m³	Converts waste volume to tonnes
Overburden density	1.8 t/m³	Converts overburden volume to tonnes
Overall pit slope angle	45° maximum	Used for pit crest expansion and slope control
Bench height	10 m	Eight benches to the 80 m pit bottom
Bench face angle	70°	Used in bench geometry checks
Berm width	5 m every two benches	Catch berm basis for safety and slope control
Water table	30 m below surface	Requires dewatering and drainage planning
Copper price	US$8,500/t Cu	Revenue calculation
Metallurgical recovery	85%	Payable copper estimate
Mining cost	US$2.50/t mined	Mining cost basis
Processing cost	US$12.00/t ore	Ore treatment cost basis
G&A cost	US$1.50/t ore	Operating overhead basis
Strip ratio limit	3:1 waste:ore	Used as a pit and schedule control

Table 1. Key design inputs used for the Copper Canyon preliminary surface mine design.

3 Methodology and Design Assumptions

The design method combines manual engineering calculations with a software-ready layout. The calculations give a transparent check on the pit size, ore tonnes, waste tonnes,

road width, blast pattern, and production schedule. The software model should then be used to confirm the same design visually and to extract more accurate volumes.

1. Build the surface topography using the nine UTM coordinate points supplied in the project brief.
2. Model the orebody as an ellipse with 400 m by 300 m dimensions and 80 m economic depth.
3. Create a conceptual pit shell using the 45 degree maximum overall slope angle.
4. Check the bench design using the 10 m bench height, 70 degree face angle, and berm requirements.
5. Design a main haul road suitable for Cat 777F trucks, with an 8% maximum gradient and at least 25 m curve radius.
6. Place the valley-fill waste dump approximately 500 m west of the pit.
7. Design a first-pass drill and blast pattern for the middle 40 m ore zone.
8. Prepare a five-year production schedule and calculate annual copper output.
9. Prepare a simple economic model using the provided price, recovery, and operating cost assumptions.

The main simplification is that the orebody is treated as a continuous elliptical body with constant horizontal area by depth. In an actual feasibility study, the design would need block model grades, geotechnical sectors, variable recovery, detailed haul profiles, bench-by-bench phase designs, and detailed environmental permits. For this term project, the simplified geometry is acceptable because it allows the major design decisions to be checked clearly.

4 Geological and Resource Description

Copper Canyon is described as a porphyry copper deposit. The resource has simple geometry for this exercise: an elliptical plan shape, moderate dip to the east, and vertical grade zoning. This type of data is enough for a conceptual open pit design, but not enough for detailed pit optimization in the professional sense.

Zone	Thickness (m)	Grade (% Cu)	Volume (m3)	Ore tonnes (Mt)	Design comment
Top low-grade zone	20	0.4	1,884,956	5.28	Stockpile or low-grade plant feed
Middle mill feed zone	40	1.2	3,769,911	10.56	Main economic ore source
Bottom marginal zone	20	0.8	1,884,956	5.28	Marginal ore but positive at given price
Total orebody	80	Variable	7,539,822	21.11	Simplified geological ore inventory

Table 2. Simplified ore inventory based on the elliptical Copper Canyon geometry.

The ore zones are all treated as mineable in the base case. The top 0.4% Cu material has lower margin, but it is still positive using the copper price, recovery, and cost data supplied. In practice, this material could be stockpiled separately and blended with higher-grade ore from the middle zone.

Zone	Grade (% Cu)	Revenue before cost (US$/t ore)	Ore operating cost (US$/t ore)	Margin before waste (US$/t ore)
Top low-grade	0.4	28.90	16.00	12.90
Middle mill feed	1.2	86.70	16.00	70.70
Bottom marginal	0.8	57.80	16.00	41.80

Table 3. Grade zone value check using the assigned copper price and operating costs.

5 Pit Design and Optimization

5.1 Ultimate Pit Limit Basis

The project brief allows the pit boundary to be determined manually or using software. For the manual check, the final pit shell was estimated as a frustum between the orebody ellipse at the bottom and an expanded ellipse at the surface. With an 80 m depth and a 45 degree maximum overall slope angle, the pit expands about 80 m horizontally from the bottom limit to the crest.

Floating cone interpretation
A detailed floating cone needs a block model with block values. Because only simplified grade zones are provided, the manual approach treats all three ore zones as economic and uses the 3:1 strip ratio limit as the main economic boundary check. The pit shell stays below this limit.

Pit item	Calculation / value	Result
Bottom ellipse semi-axes	200 m and 150 m	Bottom area = 94,248 m2
Pit expansion for 45 degree slope	80 m depth / tan 45 degrees	80 m expansion
Top ellipse semi-axes	280 m and 230 m	Top area = 202,319 m2
Approximate pit volume	Frustum equation	11,590,761 m3
Ore volume	Bottom ore area x 80 m	7,539,822 m3
Overburden volume	Top pit area x 5 m	1,011,593 m3
Internal waste volume	Pit volume - ore - overburden	3,039,346 m3
Ultimate strip ratio	(waste + overburden) / ore	0.46:1

Table 4. Manual pit shell and strip ratio check.

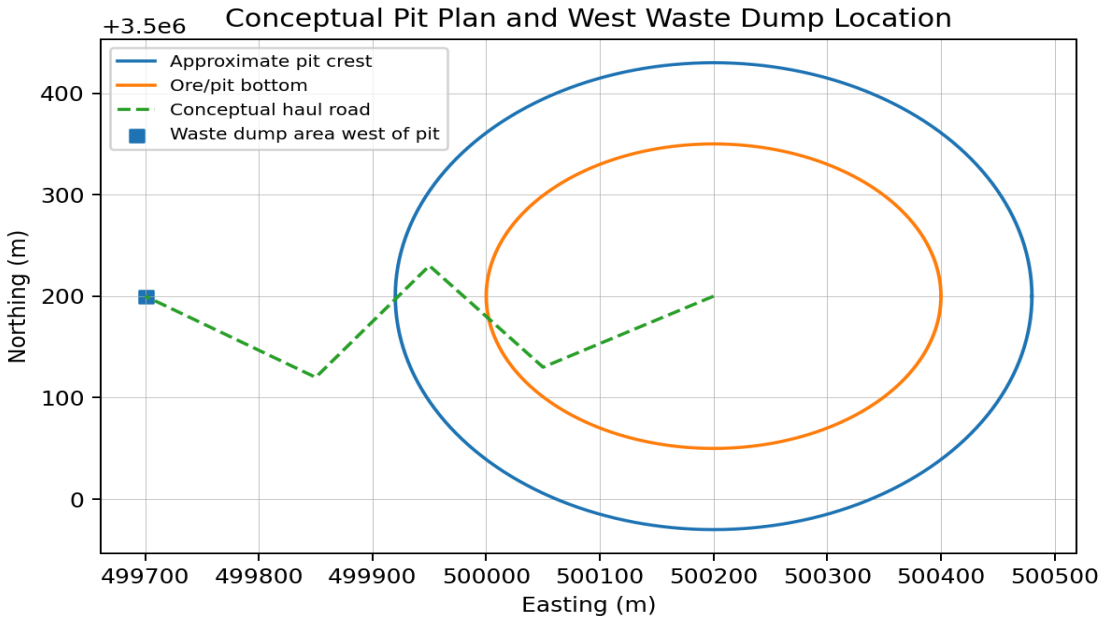


Figure 1. Conceptual plan view of the open pit crest, ore footprint, haul road direction, and west waste dump area.

5.2 Bench Configuration

The pit uses 10 m benches, so the 80 m deep pit contains eight working benches. The bench face angle is 70 degrees. A 5 m berm is placed every two benches as required by the brief. This gives a practical working layout, but the overall pit shell still needs to be flattened to 45 degrees by using ramps, safety berms, and additional wall setback.

Bench parameter	Value	Comment
Pit depth	80 m	Eight 10 m benches
Bench height	10 m	Matches project requirement
Bench face angle	70 degrees	Steep face; requires catch berm control
Horizontal projection of one bench face	10 / tan 70 degrees = 3.64 m	Used for slope geometry check
Berm width	5 m every two benches	Required catch berm system
Overall slope limit	45 degrees	Controls final pit shell, not only face angle
Design action	Use expanded pit crest and ramp setbacks	Keeps the global wall within the allowed angle

Table 5. Bench and slope design parameters.

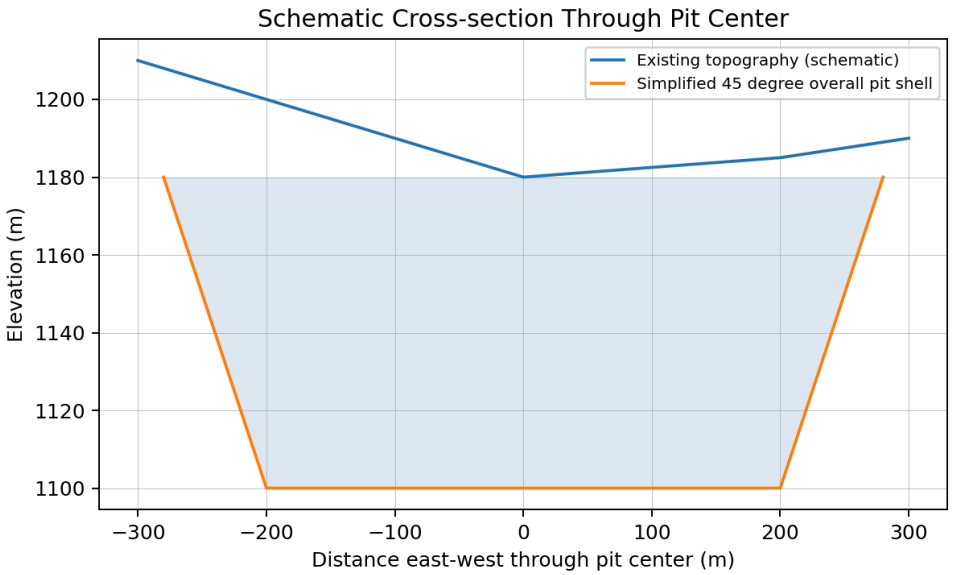


Figure 2. Schematic east-west cross-section through the conceptual pit shell.

5.3 Pit Volume and Tonnage Estimate

Material	Volume (m3)	Density (t/m3)	Tonnes (Mt)	Comment
Ore	7,539,822	2.8	21.11	Includes all vertical grade zones
Waste rock	3,039,346	2.6	7.90	Internal pit waste outside orebody
Overburden	1,011,593	1.8	1.82	5 m soil/saprolite over top pit area
Total material	-	-	30.83	First-pass material inventory

Table 6. First-pass pit material inventory.

The manual volume check indicates a small to moderate conceptual pit with a low overall strip ratio. The low strip ratio is mainly caused by the simplified elliptical orebody and the shallow 80 m economic depth. Software volumes should be used in the final version to confirm the numbers after the pit, ramps, and dump surfaces are generated.

6 Haul Road Design

The main haul road connects the pit bottom to the crusher or plant area and to the waste dump located west of the pit. The road is sized for Cat 777F trucks based on the given truck width of 6.5 m. The design uses two-way traffic on the main ramp because it is safer and more practical for a production pit.

Road design item	Calculation / value	Adopted design
Truck width	Given = 6.5 m	Cat 777F basis
Two-way running width	3.5 x truck width = 22.75 m	Allows truck passing
Safety berm allowance	Minimum berm height = 1.5 m	Included on outside edge
Drainage/shoulder allowance	Approx. 1.0 m	Added for drainage and maintenance
Main road width	22.75 + 1.5 + 1.0 = 25.25 m	Use 25 m to 26 m in design
Maximum gradient	8%	Complies with project requirement
Minimum ramp length	80 m / 0.08	1,000 m from crest to bottom
Minimum curve radius	25 m	Use 30 m where space allows
Road surface	Compacted mine rock with drainage crown	Reduces erosion and truck rolling resistance

Table 7. Main haul road design for Cat 777F trucks.

The 1,000 m minimum ramp length means the ramp cannot be drawn as a short straight line from crest to bottom. It needs to wrap around the pit wall or use switchbacks. In the software model, the ramp should be placed on the wall that gives the safest tie-in to the plant and waste dump, while avoiding sharp turns below the 25 m minimum curve radius.

7 Waste Dump Design

The waste dump is located approximately 500 m west of the pit, following the project requirement. A west-side location is suitable because the topographic data shows higher ground toward the west, which helps keep the dump away from the pit crest and allows a short haulage connection. The dump is treated as a valley-fill or side-hill dump at conceptual level.

Waste dump item	Requirement / design value	Comment
Location	500 m west of pit	Follows project brief
Dump type	Valley-fill / side-hill dump	Suitable for conceptual topography
Lift height	10 m	Matches required value
Berm width	8 m	Provides traffic and catch capacity
Overall slope	30 degrees	Required overall dump angle
Foundation preparation	Clear topsoil, proof-roll, remove soft pockets	Improves stability and drainage
Drainage	Diversion ditch above dump and toe drain	Important in semi-arid storm events
Material placement	End-dump in controlled lifts, then regrade	Reduces local instability
Rehabilitation	Progressive contouring and topsoil cover	Reduces dust and erosion

Table 8. Preliminary waste dump design parameters.

The five-year base schedule moves about 9.72 Mt of waste and overburden, which is consistent with the first-pass pit material inventory. Using an average waste/overburden bulk density around 2.4 t/m3 after mixing and swell, the loose dump volume should be checked during detailed design. A conservative design would allow extra capacity for swell, rehandling, and road construction material.

8 Drilling and Blasting Design

The drill and blast pattern was prepared for the middle 40 m ore zone, as required by the project brief. The bench height is 10 m and the drill diameter is 12.25 in, equal to about 311 mm. ANFO is used in the calculation because the brief gives ANFO density. Since the water table is 30 m below surface, wet holes should be checked in deeper benches and emulsion may be needed in practice.

Blast design item	Calculation / basis	Adopted value
Bench height	Given	10 m
Drill diameter	12.25 in	311 mm
Burden	About 29D	9.0 m
Spacing	About 1.2 x burden	11.0 m
Subdrill	10% of bench height	1.0 m
Hole depth	Bench height + subdrill	11.0 m
Stemming length	Preliminary value	3.0 m
Charge length	11.0 - 3.0	8.0 m
ANFO density	0.82 g/cc	820 kg/m3
Charge per metre	Area x density	62.3 kg/m
Charge per hole	Charge per metre x charge length	498 kg/hole
Rock volume per hole	Burden x spacing x bench height	990 m3/hole
Actual powder factor	Charge / volume	0.50 kg/m3
Required powder factor	Given	0.50 kg/m3

Table 9. Preliminary ore-zone drill and blast pattern.

Blast quantity	Calculation	Result
Number of holes	10 rows x 10 columns	100 holes
Blast volume	100 x 990 m3	99,000 m3
Total explosives	100 x 498 kg	49,833 kg ANFO
Tonnes broken at ore density	Blast volume x 2.8 t/m3	277,200 t
Approximate copper zone	Middle 40 m at 1.2% Cu	Main mill feed ore

Table 10. Total explosives and blasted material for a 100-hole production blast.

9 Production Scheduling

The project brief asks for a five-year production plan with a maximum annual ore production of 2 Mt, a minimum total mining rate of 15 Mt/y, and a strip ratio limit of 3:1. These conditions conflict with each other. If ore is limited to 2 Mt/y, the largest total movement allowed by a 3:1 strip ratio is 8 Mt/y. A 15 Mt/y total movement at 2 Mt/y ore would require a 6.5:1 strip ratio, which is higher than the project limit.

Constraint check	Calculation	Result
Maximum ore production	Given	2.0 Mt/y
Strip ratio limit	Given	3:1
Maximum waste at 2 Mt/y ore	2.0 x 3	6.0 Mt/y
Maximum total mining at 3:1	2.0 + 6.0	8.0 Mt/y
Waste required for 15 Mt/y total	15.0 - 2.0	13.0 Mt/y
Resulting strip ratio if 15 Mt/y is forced	13.0 / 2.0	6.5:1, not acceptable

Table 11. Check showing the conflict between production, total mining rate, and strip ratio constraints.

For this reason, the schedule below is the recommended base case. It follows the 2 Mt/y ore limit and keeps the strip ratio controlled. The 15 Mt/y value can be treated as a maximum fleet-capacity screening target, not as a realistic yearly requirement for this simplified pit.

Year	Ore (Mt)	Waste + OB (Mt)	Total (Mt)	Strip ratio	Average grade (% Cu)	Recovered Cu (t)	Recovered Cu (Mlb)
1	2.00	3.00	5.00	1.50:1	0.55	9,350	20.61
2	2.00	2.50	4.50	1.25:1	0.90	15,300	33.73
3	2.00	2.00	4.00	1.00:1	1.20	20,400	44.97
4	2.00	1.20	3.20	0.60:1	1.20	20,400	44.97
5	2.00	1.02	3.02	0.51:1	1.00	17,000	37.48
Total	**10.00**	**9.72**	**19.72**	**0.97:1**	**0.97**	**82,450**	**181.76**

Table 12. Five-year base-case production schedule and recovered copper output.

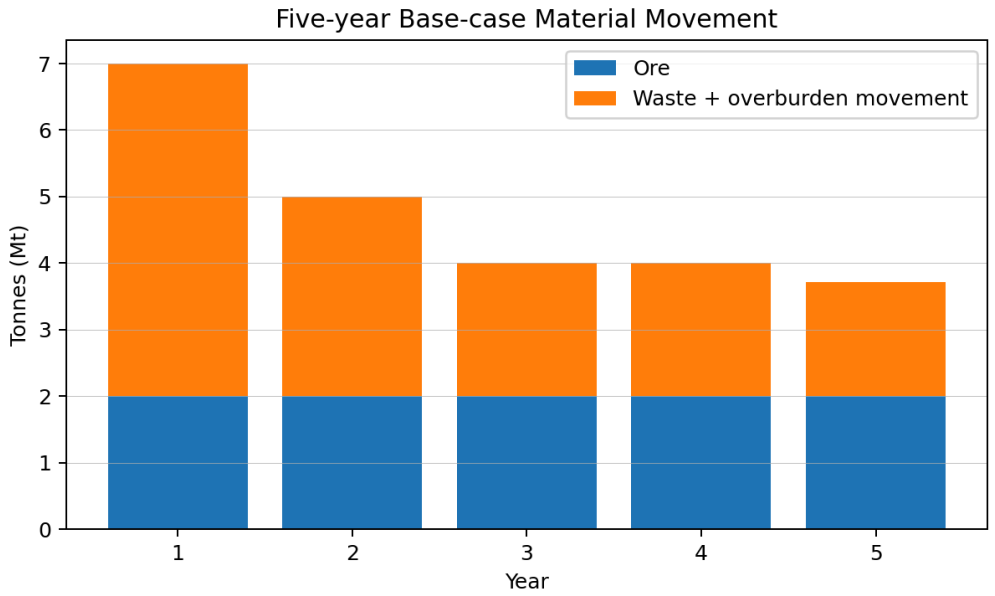


Figure 3. Five-year base-case ore and waste movement schedule.

The schedule mines 10 Mt of ore in the first five years and leaves about 11 Mt for the later years of the conceptual 10-year operation. This is reasonable because the project scenario describes a 10-year mine, while the required schedule covers only the first five years. In a final pit design, the yearly sequence should be tied to pushbacks, ramp access, and stockpile management.

10 Software Modelling and Required Outputs

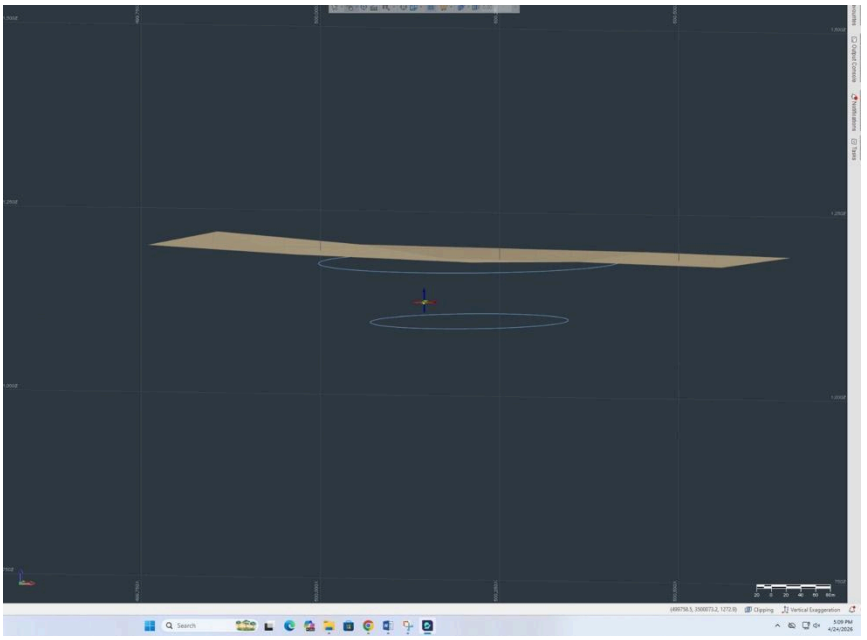


Figure 4. 3D view of orebody surface and elliptical footprint used for pit design.

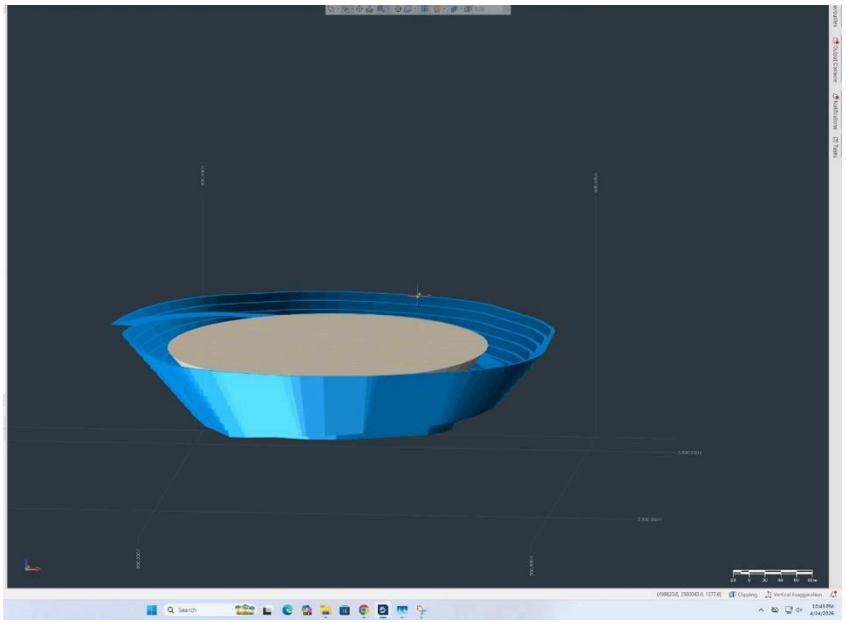


Figure 5. 3D view of the final open pit showing bench geometry and overall slope design.

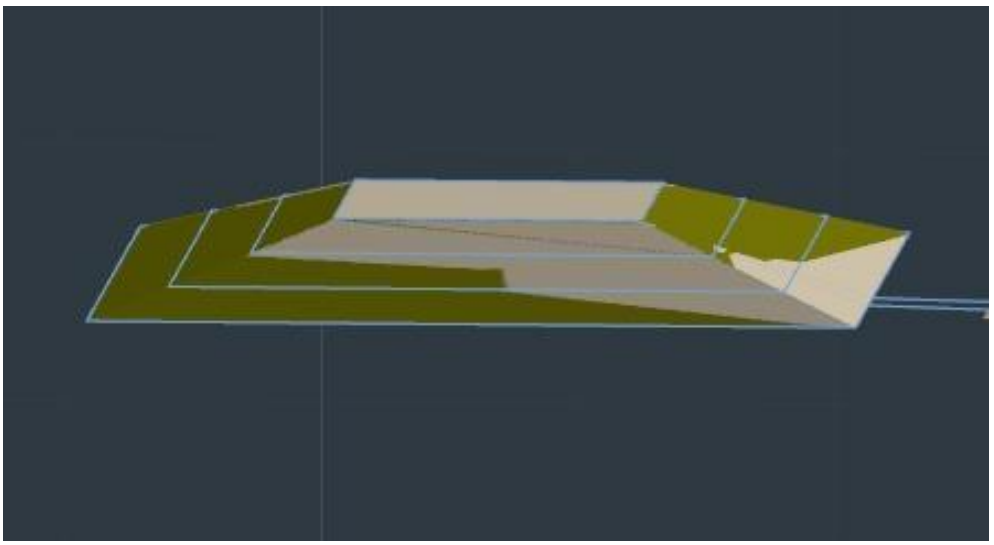


Figure 6. 3D view of the waste dump showing layered lift development and final geometry.

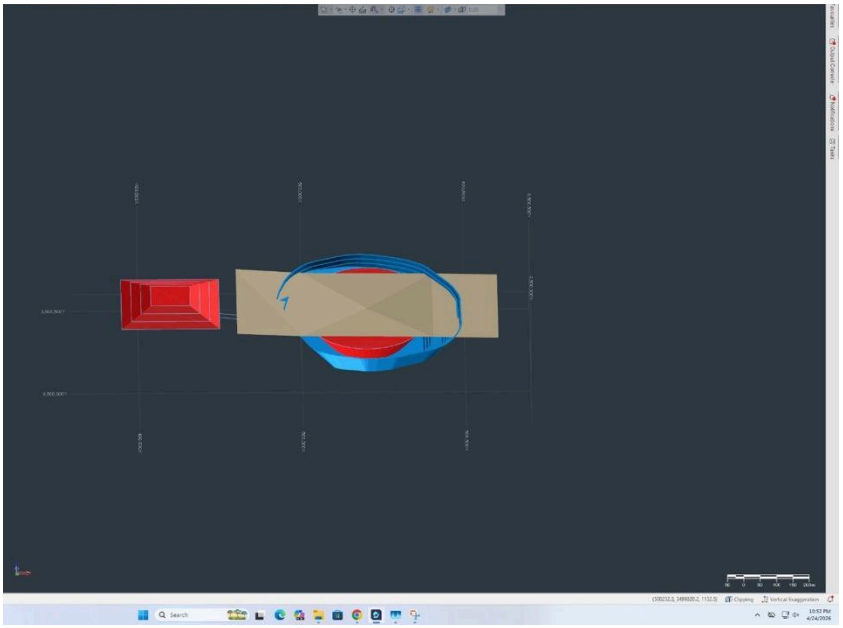


Figure 7. Plan view of the open pit, haul road alignment, and adjacent waste dump layout.

11 Simple Economic Evaluation

A simple economic model was prepared using the copper price, recovery, and operating costs from the brief. The estimate is not a full feasibility valuation. It is only a first-pass check to confirm that the proposed pit has positive operating value under the supplied assumptions.

Year	Revenue (US$M)	Operating cost (US$M)	Operating cash flow (US$M)
1	79.47	39.50	39.98
2	130.05	38.25	91.80
3	173.40	37.00	136.40
4	173.40	35.00	138.40
5	144.50	34.55	109.95

Table 13. Simple annual revenue and operating cash flow estimate.

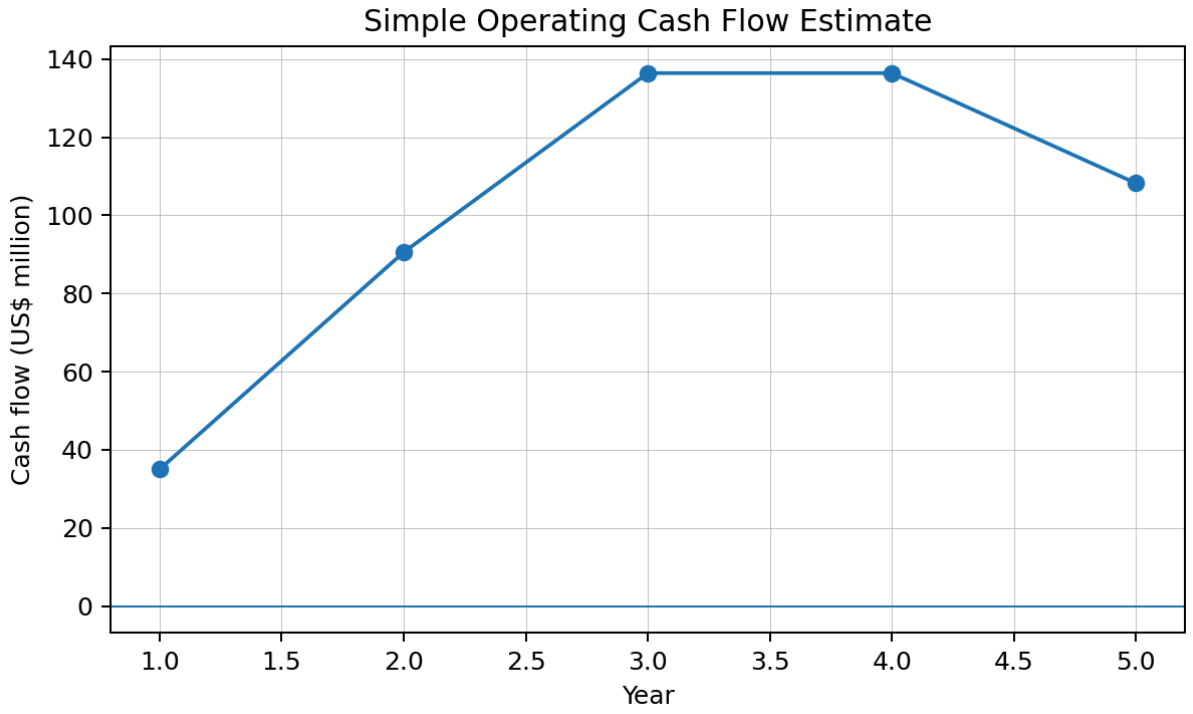


Figure 8. Simple operating cash flow before sustaining capital.

Economic assumption	Value
Copper price	US$8,500/t Cu
Metallurgical recovery	85%
Mining cost	US$2.50/t total material mined
Processing cost	US$12.00/t ore
G&A cost	US$1.50/t ore
Initial capital placeholder	US$60 million
Sustaining capital placeholder	US$5 million/year
Discount rate	8%
Simple NPV result	US$320.6 million

Table 14. Simplified NPV assumptions and result.

The calculated NPV is positive under the placeholder capital assumptions. The result is sensitive to grade, copper price, ramp and waste movement, and capital cost. For final submission, the economic sheet should be linked to the verified software volumes and any updated cost assumptions from the team workbook.

12 Safety and Environmental Considerations

Safety and environmental control should be considered from the start of the design, not added at the end. The main risks for Copper Canyon are slope failure, haul road incidents, blasting hazards, dust, water management, and waste dump stability.

Area	Main risk	Design control
Pit slopes	Bench-scale rockfall and overall instability	Maintain 45 degree overall slope, inspect benches, use catch berms, and monitor cracks
Haul roads	Truck interaction, runaway risk, and poor visibility	Use 25 m two-way width, 8% maximum grade, berms, signage, and speed control
Blasting	Flyrock, vibration, misfires, and fumes	Use exclusion zones, blast guards, proper stemming, and post-blast inspection
Water	Water table at 30 m and storm runoff	Use perimeter drains, sumps, pumps, and diversion channels
Waste dump	Foundation failure or erosion	Clear topsoil, compact base, install toe drain, and place lifts in controlled stages
Dust	Dust from roads, blasting, and dumping	Water spraying, speed limits, and progressive rehabilitation
Environment	Disturbance in semi-arid setting	Limit footprint, stockpile topsoil, rehabilitate inactive areas, and control sediment

Table 15. Main safety and environmental controls for the Copper Canyon design.

The water table begins 30 m below surface, so the lower five benches may require active dewatering. The pit should include sumps on working levels, drainage ditches along the ramp, and a pumping plan. Water management also improves road safety because wet ramps increase rolling resistance and braking risk.

13 Conclusions and Recommendations

1. The Copper Canyon deposit can be designed as a shallow conceptual open pit with an 80 m economic depth and a 45 degree overall slope limit.
2. The simplified ore inventory is approximately 21.11 Mt, with the middle 40 m zone providing the strongest mill feed at 1.2% Cu.

3. The first-pass pit shell contains about 7.90 Mt of waste rock and 1.82 Mt of overburden, giving an ultimate strip ratio of about 0.46:1.
4. The bench design uses 10 m benches, 70 degree face angles, and 5 m berms every two benches, but final wall geometry must still respect the 45 degree overall slope angle.
5. The main haul road should be designed at about 25 m width for two-way Cat 777F traffic, with a maximum gradient of 8% and curve radii of at least 25 m.
6. The waste dump should be placed west of the pit and built in 10 m lifts with 8 m berms and a 30 degree overall slope.
7. The preliminary blast pattern uses a 9 m burden, 11 m spacing, 1 m subdrill, 3 m stemming, and about 498 kg ANFO per hole.
8. The production schedule should not force 15 Mt/y total movement because that would break the 3:1 strip ratio limit when ore is capped at 2 Mt/y.

14 Appendix A. Key Equations Used

Parameter	Equation	Purpose
Ellipse area	A = pi a b	Calculates orebody or pit plan area
Pit frustum volume	V = h/3 (A1 + A2 + sqrt(A1 A2))	Approximates pit volume between top and bottom ellipses
Ore tonnes	T = volume x density	Converts ore volume to mass
Strip ratio	SR = waste tonnes / ore tonnes	Checks waste-to-ore limit
Bench face projection	x = bench height / tan(face angle)	Checks bench geometry
Ramp length	L = vertical drop / gradient	Checks minimum haul road length
Road width	W = 3.5 x truck width + allowances	Sizes two-way haul road
Charge per metre	kg/m = (pi D2 / 4) x explosive density	Calculates explosive loading in a hole
Powder factor	PF = explosive mass / blasted volume	Checks blast energy against requirement
Recovered copper	Cu = ore tonnes x grade x recovery	Calculates annual copper production
Revenue	Revenue = recovered Cu x copper price	Calculates annual gross revenue
Discounted cash flow	DCF = cash flow / (1 + r)^n	Calculates simple NPV

Table 16. Equations used in the preliminary design calculations.

15 Appendix B. Manual Calculation Summary

Calculation	Result
Orebody plan area	94,248 m2
Pit top area	202,319 m2
Total pit volume	11,590,761 m3
Ore volume	7,539,822 m3
Ore tonnes	21.11 Mt
Waste rock tonnes	7.90 Mt
Overburden tonnes	1.82 Mt
Ultimate strip ratio	0.46:1
Minimum ramp length at 8% grade	1,000 m
Main haul road width	25 m to 26 m
Explosive per hole	498 kg
Total explosives for 100-hole blast	49,833 kg
Simple NPV	Simple NPV = US$320.6 million

Table 17. Main numerical outputs from the preliminary calculations.

16 Appendix C. Software Input Data

The following coordinate table can be used to create the first topographic point file for the software model. The point names may be kept simple because the purpose is to build a basic surface for pit and dump layout.

Point	Easting (m)	Northing (m)	Elevation (m)	Comment
1	500000	3500000	1200	South-west/central surface point
2	500400	3500000	1195	South-east surface point
3	500000	3500400	1190	North-west surface point
4	500400	3500400	1185	North-east surface point
5	500200	3500200	1180	Pit center
6	499800	3500000	1210	West boundary
7	499800	3500400	1205	North-west boundary
8	500600	3500000	1190	East boundary
9	500600	3500400	1180	East/north-east boundary

Table 18. Topographic points to be imported into the mine design software.

17 References

Emad, Z. (2026). MINE 348: Surface Mine Design term project, “Copper Canyon” pre-feasibility design brief. King Fahd University of Petroleum & Minerals.

Hartman, H. L., & Mutmansky, J. M. (2002). Introductory mining engineering (2nd ed.). John Wiley & Sons.

Hustrulid, W., Kuchta, M., & Martin, R. (2013). Open pit mine planning and design (3rd ed.). CRC Press.

Darling, P. (Ed.). (2011). SME mining engineering handbook (3rd ed.). Society for Mining, Metallurgy, and Exploration.

Kennedy, B. A. (Ed.). (1990). Surface mining (2nd ed.). Society for Mining, Metallurgy, and Exploration.