PD-NCB Consultants Limited

In association with

Wright Engineers Ltd & Golder Associates

Report No. 7

Hat Creek Power Project

Combined Pit Operation Study for 5,000-MW Power Plant

to

British Columbia Hydro and Power Authority

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CHAPTER I

INTRODUCTION

1. The original reports on Openpits No 1 and 2 (ie Report No 2 dated March, 1976, and Report No 3 dated June, 1976) considered the economics of supplying a 2,000-MW power station from a single pit. Using the data developed in these reports, it is now possible to consider the economics of using both pits to supply this same power station. This should result in a lower maximum stripping ratio and the advantages could offset the extra development costs. Also, the most economical way of supplying coal to this station, and to a further 3,000-MW plant, from the total coal reserves of both pits can be considered.

TERMS OF REFERENCE

2. It was on this basis that PD-NCB Consultants were asked, as part of the continuation of their services, to produce a further report based on the following Terms of Reference:-

(i) Identify the most economic means of supplying coal to a 2,000-MW plant at Hat Creek for a 35-year life.

(ii) Identify the most economic means of supplying a 2,000-MW plant to be followed by an additional 3,000-MW plant within a four-year period.

(iii) Indicate the possible constraints on the extent to which the Hat Creek deposit can be mined from the point of view of the economics of mining.

GENERAL BACKGROUND

3. The original choice of a 2,000-MW power station at Hat Creek was based on the belief that there were sufficient reserves of coal to supply a station of this size for a reasonable working life and also because a station of this size was required to match the expected future electricity load growth in British Columbia. However, ultimate capacities of 3,000 MW or even 4,000 MW have been proposed from time to time. It now seems that the two pits contain sufficient reserves for a 5,000-MW station, hence the choice of this figure for the present study.

4. The present level of geotechnical knowledge permits evaluation to a maximum pit depth of 600 ft only, so the main assessment must be made within this constraint. However, mention has also been made of the implications of being able to mine to greater depths.

5. Since this report uses many of the data developed in the earlier reports on Openpits No 1 and 2, it must be read in conjunction with these. The full particulars of these reports, which will subsequently be referred to by their numbers, are:-

Report No 2 - Preliminary Report on Hat Creek Openpit No 1, Volumes I and II - March, 1976

Report No 3 - Preliminary Report on Hat Creek Openpit No 2, Volumes I and II - June, 1976.

CHAPTER II

GENERAL METHOD OF EVALUATIONS

1. Reports No 2 and 3 included a build-up of the capital and operating costs and cash flows for Openpits No 1 and 2 respectively. As will be evident from the number of tables involved, this was a lengthy procedure. The present study requires the consideration of several combinations and extensions of the two openpits and the evaluation of these would be a considerable task if each variant had to be calculated from first principles. Fortunately, however, the data already developed are capable of adaptation for this purpose, provided a number of simplifying assumptions are accepted.

COSTING METHOD

2. For each openpit, Stage 1 is a six-year development phase. It has been assumed that the cost of this phase is independent of the maximum output of the pit. This is a simplification as an increased output would require higher capacity conveyors and a higher capacity electricity supply system. However, the cost of these items would be small compared with the cost of constructing the access ramp and the initial excavation, both of which are independent of the output capacity.

3. During the main production stages it has been assumed that the cost of mining the coal available in each stage would be independent of the time taken to complete this stage. In other words, a stage requires a fixed number of machine and man-hours, irrespective of the annual production rate. This means that 15-yd^3 excavators and 100-ton off-highway trucks have been treated simply as "consumable stores", which indeed they are when considered in the context of a billion dollar project such as Hat Creek. Obviously, this interpretation can only apply in simple cash-flow costing. Where costs must be reduced to their present value, then the timing is critical and the figures have been adjusted accordingly.

4. In cases that involve the operation of both pits, use of the already calculated costs may mean that certain minor items such as access roads may be included twice. There may also be a conflict of interest over the precise method of diverting Hat Creek. The cost of these items is, however, only a small component of the total so the errors this simplification introduces can be ignored.

AVAILABLE RESERVES

5. Report No 2 (Openpit No 1) showed that there were marginally insufficient reserves above the 600-ft level to supply a 2,000-MW power station for 35 years. However, it was suggested that a few deeper benches would easily yield the extra coal at a reasonably economic cost or, alternatively, further coal could be found laterally. The same assumption has been made in this report and the extra cost per ton has been extrapolated.

6. A somewhat similar situation would arise in Openpit No 2 if it were required to supply a 3,000-MW power station for 35 years, and a similar solution is proposed. This is discussed in more detail in the relevant section of the report.

7. It is appreciated that the above involve simplifying assumptions, but they are necessary to reduce the mathematics to manageable proportions, and are acceptable because they would only marginally influence the results. It is the comparative rather than the absolute costs which are important at this time.

8. The basic sources of the data used have been taken from the 10% and 15% discount cases developed in Reports No 2 and 3 (the relevant tables being Tables XXV (for Openpit No 1) and LIV (for Openpit No 2) respectively).

CHAPTER III

SUPPLY TO A 2,000-MW POWER STATION

EARLIER WORK

1. The cost of producing coal from either Openpits No 1 or No 2 to supply a 2,000-MW power station has already been discussed in Reports No 2 and No 3. Tables I and II show these costs in a slightly modified form. The changes are that certain figures have been rounded off and an additional stage, termed "8A", has been added to Openpit No 1 to cover the marginal extra capacity required during the last few years of the operation of the power station. The reason for this and its justification were discussed in Chapter VIII of Report No 2 and in Chapter II of this report.

2. These tables show that, at a 10% discount rate, the uniform coal selling prices are $5.70/ton using Openpit No 1 and $9.10/ton using Openpit No 2 (ie a 37% advantage to Openpit No 1). At a 15% discount rate these figures become $6.40 and $11.20 respectively (ie a 43% advantage). This merely restates what is already known, that if only one pit were to be developed then there would be a major economic advantage in making it Openpit No 1. While there could be environmental or other advantages for preferring Openpit No 2, these would have to be very strong to outweigh the extra costs involved.

A TWO-PIT OPERATION

3. While it has been shown that it would be more economic to develop Openpit No 1, it does not follow that it is best to produce the total fuel requirement from this pit. In addition to the figures already considered, Tables I and II show the cash flow for each production stage divided by the output of that stage. Reflection will show that it is immaterial what discount rate is used for this calculation since the discount factor will be the same for both costs and tonnages. This ratio is a crude indication of the marginal production cost for each stage. This is also shown graphically on Plate 1(a) and indicates that while, after an initial high, the production costs for Openpit No 2 are comparatively constant, those for Openpit No 1 increase markedly towards the end of the life of that pit. In fact, in the later stages the cost is higher than for Openpit No 2. This opens up the possibility of limiting the production from Openpit No 1 and obtaining the balance from Openpit No 2. Before considering the economics in detail, it is worth looking at the other possible reasons for a two-pit operation.

4. There are clearly two basic methods of obtaining the coal requirement from two pits. They can either be worked concurrently or consecutively.

Concurrent Operation of Two Pits

5. The potential advantages of concurrent operation, within the context of supplying a 2,000-MW power station, are as follows:-

(i) Two sources allow flexibility in the day-to-day operation and, in particular, increase the scope for blending the fuel.

(ii) In the longer term, the division of the production between the two pits can be adjusted in accordance with the actual mining costs, should these vary from those predicted.

(iii) In the event of a major catastrophe in one pit it should be possible to redeploy the production plant to obtain the total power plant requirements from the second pit, thus avoiding any possible reduction in electrical output whilst remedial work is being carried out.

6. However, the following factors must be offset against these advantages:-

(i) It would be necessary to develop both pits initially and the resultant front-end loading is bound to make the production cost higher than for a consecutive or single-pit operation.

(ii) There is sufficient in-built flexibility in the operation of a pit so the loss of one or two benches, due to a local slide, would not affect output. The only event which could stop production would be the blockage of the main access ramp. This could be due to a slide or possibly a belt breaking and running back and the belt and its load blocking the incline and/or damaging the other conveyors. In either case, there would be approximately one month's reserve capacity in the surface stockpile and this should give sufficient time to carry out any reasonable remedial work, bearing in mind the large reserves of men and machines available for deployment.

(iii) If this risk is still considered unacceptable, it could well be more economic to have one pit with two access ramps.

7. On balance, the disadvantage of the extra costs more than outweighs the advantages of the extra flexibility, and concurrent operation of two pits is not recommended.

Consecutive Operation of Two Pits

8. In consecutive operation, the pits can be worked in either order, but superficial examination shows that it would be more economic to develop Openpit No 1 first. This has the lower capital and operating costs and the longer the development of the higher-cost Openpit No 2 can be deferred, the cheaper it becomes in present value terms.

9. With economics calculated on a discounted cash flow basis, the easy (and therefore cheap) operations should always be started first, and the difficult (and therefore expensive) ones deferred as long as possible. It is therefore necessary to investigate whether it is worthwhile to cut short the exploitation of Openpit No 1, possibly at the end of Stage 8, thereby abandoning the high cost coal of Stage 8A, and instead to develop Openpit No 2 to supply the balance of the demand.

10. The end of Stage 8 is only one of the possible changeover points. The implications of a range of possibilities are shown in Table III and on Plate 1(b). These show that there is never an economic advantage in developing Openpit No 2 but that the cost penalty for taking a comparatively small tonnage (say 100 million) is small. This applies irrespective of whether a 10% or 15% discount rate is used. It is therefore worth considering whether there are any important practical advantages in this course of action.

11. The whole mine concept is based on a 2,000-MW power station requiring 13.1 million tpa of rom coal for a 35-year life. The actual consumption could well be different for a variety of reasons:-

(i) The calorific value of the coal could differ from that assumed.

(ii) The overall thermal efficiency of the station could differ from that assumed.

(iii) Most likely of all, the load factor at which the station is required to operate could be different and, in fact, this is likely to be time-dependent.

12. Similarly, the predicted life of the power station is only an estimate. It may well be economic to keep it operating longer, provided an economic supply of fuel is available. Alternatively, a major commercial breakthrough with fast breeder nuclear power, or, more fancifully, a major development of wave or windpower, could render it uneconomic after 30 years or less.

13. Finally, the mineable reserves in Openpit No 1 are also only an estimate (though it is thought to be a conservative estimate) and are dependent on the exact extent of the coal deposit and the actual depth to which it is possible to work.

14. Thus, the main conclusion that can be reached is that Openpit No 1 should be developed initially with the option of later developing Openpit No 2 should there be any problems in obtaining the total fuel requirements from Openpit No 1 and, equally important, provided the extra cost of this option is marginal.

CHAPTER IV

FUEL REQUIREMENTS FOR A 5,000-MW POWER STATION

1. Before considering the mining implications involved in supplying a 5,000-MW power station, it is necessary to make some assumptions regarding the make-up of the power station and the timetable for its start-up.

ARRANGEMENT OF POWER STATION

2. The original concept was based on a power station with a "sent out" capacity of 2,000 MW. It has been estimated that an additional 10% should be added to this to cover the internal power requirements of the power station and the associated mine. This results in a gross installed capacity of some 2,250 MW.

3. This could be provided in a variety of ways, but the assumption made in the earlier reports was that it would take the form of three 750-MW boiler/generator units. It now appears that BCH favour four 560-MW units. This could make a minor difference to the build-up of coal requirements but the difference over the life of the project would be negligible. For this reason, and to utilise the costs already developed, this report is based on the earlier assumption that the initial development would be in the form of three 750-MW units. Making the same allowances for internal power requirements, a net capacity of 3,000 MW requires a gross installed capacity of 3,400 MW. Unfortunately, this does not correspond to an integral number of 750-MW units. For convenience, therefore, it has been assumed that the additional capacity would be provided in the form of four 850-MW units.

4. If four 560-MW units were installed initially, it would be possible for the additional capacity to be in the form of six 560-MW units. However, it is likely that natural development would result in larger units; possibly four 850-MW units, or a compromise of five 660-MW units.

5. In the earlier reports it was assumed that the 2,000-MW station would be commissioned as follows:-

1st unit (750 MW) July 1983

2nd unit (750 MW) July 1984

3rd unit (750 MW) April 1985

6. For this report it has been assumed that the additional 3,000 MW would be commissioned as follows:-

4th unit (850 MW) mid 1988

5th unit (850 MW) mid 1989

6th unit (850 MW) mid 1990

7th unit (850 MW) mid 1991

7. The latter units have been numbered consecutively, in accordance with normal power station practice and units 1 to 3 have been referred to as the "A"

Station and units 4 to 7 as the "B" Station. This has been done without prejudice to the fact that they may be on adjacent or separate sites.

8. This build-up has been selected as being a realistic scenario for development. The three-year gap between units 3 and 4 lies within the four-year period specified in the terms of reference and, although conceptual design of the second stage would have to start before No 1 unit was commissioned, it would still be possible to modify the design to overcome any shortcomings discovered. The proposed build-up also fits within the expected increase in electrical energy demand in British Columbia.

ANNUAL FUEL REQUIREMENTS

9. Scaling up the fuel requirements of the original 2,000-MW station gives an annual power station fuel requirement, for "A" and "B" Stations combined, of 30 million tpa (based on a calorific value of 6,000 Btu/lb). The corresponding in-situ and rom coal requirements (using the definitions adopted in Reports No 2 and No 3) are 38.5 million tpa and 32.8 million tpa respectively. This gives total requirements, based on a plant operating life of 35 years, as follows:-

	Million Tons	
	In Situ	Rom
"A" Station	540	459
"B" Station	810	688
Total	1,350	1,147

10. The build-up of this requirement is shown graphically on Plate 2.

11. This, then, is the requirement. How does this compare with what is available? The available reserves down to 600 ft depth have been quoted in Reports No 2 and No 3 as being:-

	Million Tons	
	In Situ	Rom
Openpit No 1	450	380
Openpit No 2	781	664
Total	1,231	1,044

At first sight, therefore, there is insufficient coal in the two pits to supply a 5,000-MW power station. However, it has already been assumed that there are enough reserves in Openpit No 1 to supply the 2,000-MW "A" Station and it is reasonable to make a similar assumption regarding Openpit No 2 and the "B" Station, ie that the additional shortfall of 20 million to 30 million tons could be obtained from this pit.

PRODUCTION ALTERNATIVES

12. These figures considerably reduce the number of options open. There is no question as to which pit should be worked, or even how much should be taken from

each pit. As long as 600 ft is accepted as the maximum pit depth, then all the available coal above this level must be taken from both pits. Thus the problem is reduced to deciding what order to work the two pits.

13. The possibility of being able to work deeper than 600 ft is only conjectural at this stage and, in any case, no costs are available. It is, however, worth considering the implications if this were possible. The available reserves down to 1,500 ft depth have been previously quoted as being:-

	Million Tons	
	In Situ	Rom
Openpit No 1	910	775
Openpit No 2	3,996	3,397

14. These figures also put some constraints on the possible options. The reserves in Openpit No 1 are insufficient for the full life of the combined power station. The total in-situ reserves in this pit are only 1,000 million tons, so even mining deeper than 1,500 ft would not alter this situation.

15. On the other hand, the reserves down to 1,500 ft in Openpit No 2 are greatly in excess of the total requirement and, in fact, there are further substantial reserves below this depth, so if it were possible to work deeper than 600 ft it would be possible to develop only Openpit No 2, though it does not follow that this is economically the best solution. The more detailed implications of this will be considered later, after the various combinations of working to 600 ft have been evaluated.

CHAPTER V

ECONOMICS OF MINING TO 600-FT DEPTH

1. As stated in the previous chapter, supplying a 5,000-MW power station for 35 years requires mining all the coal in both pits down to 600 ft depth. Within this constraint, there are three basic methods of working:-

(i) To develop Openpit No 1 to supply the "A" power station and to develop Openpit No 2 in time to supply the "B" power station.

(ii) To develop Openpit No 1 first and use it to supply both power stations and then, as it becomes exhausted, to phase in Openpit No 2.

(iii) To develop Openpit No 2 first to supply both power stations and, as it becomes exhausted, to phase in Openpit No 1.

2. These are by no means the only methods of working but examination of these should show what further methods are worth pursuing. These methods are shown in diagrammatic form on Plate 3 and the costs involved in Table IV. Since costs have not been developed for Openpit No 2 beyond the tonnage required for a 2,000-MW power station, the costs for the extra tonnage required for the 3,000-MW power station have had to be estimated.

3. The change in pit outputs alters the time scale of the previously quoted production phases which now no longer generally coincide with complete financial years. All reference to stages has therefore been omitted and Table IV is presented in terms of seven basic periods of about seven years each. The choice of this interval is somewhat arbitrary but it basically divides the project into a build-up stage, five production stages and a final run-down stage.

4. Summarising this table gives the following:-

Uniform Selling Price, $/ton		Discount Rate 10%	Discount Rate 15%
(i)	Parallel operation - No 1 leading	7.00	7.90
(ii)	No 1 followed by No 2	6.30	6.50
(iii)	No 2 followed by No 1	7.90	9.40

5. This shows that it is always financially preferable to develop and exhaust Openpit No 1 and then follow it with Openpit No 2. This is basically due to the high initial costs of Openpit No 2, since the longer these can be postponed the less they become in present value terms. Examination of these results allows certain other cases to be dismissed without a formal cost evaluation. Parallel operation, but with Openpit No 2 developed first, would obviously be more expensive than the parallel case already considered. Completely simultaneous development, as distinct from delaying the second pit to correspond with the second power station, would also prove more expensive as well as producing enormous logistical problems.

6. There is, however, one other variant worth considering. While the advantage of having two pits in operation does not justify any significant additional production cost, it is still desirable. This leads to the possibility of developing Openpit No 1 first and expanding it to some intermediate level of production (say

23 million tpa rom) and then to phasing in Openpit No 2 to supply the balance of some 10 million tpa. This would delay the start-up of Openpit No 2, even if only very marginally, but, more important, it would minimise the quantity of high-cost production from Openpit No 2 during the early years of the project. The simplest case, which is still to exhaust Openpit No 1 first, though at a slower rate, is shown on Plate 4(a) and the costs involved in Table V. The latter shows the uniform coal selling price to be $6.70/ton or $7.10/ton, depending on the discount rate used.

7. A refinement would be to cut back the production of Openpit No 1 before it was completely exhausted so that it could be operated at, say, 5 million tpa for the rest of the life of the power station. This is shown diagrammatically on Plate 4(b) and the costs involved in Table V. The resultant uniform coal selling prices of $6.60/ton or $7.00/ton are marginally less than the simple case. The reason for this improvement is that it postpones the high-cost final stages of Openpit No 1 until the very end of the project, which is of benefit to the present value cost. Even so, this method would still be more expensive than the simple case of working and exhausting Openpit No 1 first.

8. This then completes the economic analysis. It now remains to consider whether practical or environmental considerations should modify these conclusions.

PRACTICAL IMPLICATIONS

9. The basic options are to work either pit first or to work them in parallel. Each of these has various advantages.

Concurrent Working

10. The basic advantage of working two pits concurrently is the additional flexibility that it allows. This has already been considered in connection with the 2,000-MW case, and the conclusion was reached that it does not justify the extra cost. The flexibility arrangement is slightly reinforced at the higher output required for a 5,000-MW station. There is also the argument that if, in the last resort, it were necessary to cut back electricity production, then a 5,000-MW station would be a more significant percentage of the total BCH system.

11. The principal disadvantages, other than cost, of working two pits, are the additional environmental impact and the fact that it is not possible to return any of the waste to one of the pits.

Consecutive Working

12. The advantages of working the pits consecutively are the reduced environmental impact of a single pit and the facility for tipping the waste from the second pit into the worked-out pit. Also, since slope stability is time dependent, the shorter the working life of each pit the better. These arguments apply whichever pit is worked first.

Openpit No 1 First

13. There is an economic advantage in working Openpit No 1 first. Other advantages are that the quality of the coal appears to be better than that in Openpit No 2 and the slope stability problems appear to be less severe. Openpit No 2 would still have to be developed in due course, but, on a present value basis, it always pays to develop the best and easiest reserves first.

14. When the time comes to develop Openpit No 2, it will be possible to deposit the overburden produced into Openpit No 1 and this would sterilise less of the deep reserves than if the pits were worked in the opposite order.

Openpit No 2 First

15. The principal advantage of working Openpit No 2 first is that if it were later found feasible to work deeper than 600 ft, it might be possible to avoid developing Openpit No 1 altogether. This is considered in more detail in Chapter VI.

16. There is also the advantage that the environmental impact could be less in the earlier years due to the location higher up the valley.

17. It is considered, however, that these advantages are more than outweighed by the cost and other advantages of working Openpit No 1 first.

CHAPTER VI

IMPLICATIONS OF BEING ABLE TO MINE TO A GREATER DEPTH THAN 600 FT

1. It is not possible to develop costs for mining to depths greater than 600 ft at this time. However, it is possible, and indeed profitable, to consider briefly the implications involved.

2. Assuming that Openpit No 1 were developed first, then a point would come at which a decision must be made from one of the following possible courses of action:-

(i) To develop Openpit No 2 and to tip the resultant spoil into Openpit No 1. This would clearly prevent further exploitation of Openpit No 1.

(ii) To develop Openpit No 2 but to tip the spoil outside the pit area (as envisaged in Report No 3), thus to a certain extent keeping the options open.

(iii) To develop Openpit No 1 to a greater depth, realising that this would not eliminate the need to exploit Openpit No 2 but would postpone it. The cost of this extra coal might well be higher than obtaining it from Openpit No 2 but there would be resource conservation advantages.

3. However, a more interesting prospect would be to develop Openpit No 2 only. If this could be worked to a depth of 750 ft to 800 ft then it would not be necessary to use Openpit No 1 at all. While it is not possible to postulate on the feasibility of this greater depth, it appears far more likely than an increase to 1,500 ft. The costs involved would be unlikely to fall below a constant selling price of $8/ton (based on a 10% discount rate). Thus, a cost penalty would be incurred of about 15% compared with working Openpit No 1 first.

4. There are considerable environmental advantages in developing one pit only and these favour Openpit No 2 rather than Openpit No 1, if only because it would be further up the valley and therefore further "out of sight and out of mind".

5. There is, however, one major fallacy in this argument because if it is attractive to mine Openpit No 2 then it would be even more attractive to mine Openpit No 1. Thus, even if Openpit No 2 were used to supply a power station it is unlikely that Openpit No 1 would be left unexploited. It could be used for a further power station extension or possibly for the production of Substitute Natural Gas (SNG) or Syncrude.

CHAPTER VII

ECONOMIC CONSTRAINTS ON MINING AT HAT CREEK

1. It has already been shown that there are sufficient established reserves, not deeper than 600 ft, to supply a 5,000-MW power station for a 35-year life, but that any further increase in capacity would require either a discovery of additional reserves or the ability to mine to greater depths. These are the technical not economic limitations. The economics of building a power station at Hat Creek depend on its ability to deliver electrical power to the Greater Vancouver area at a lower cost than any other competitive source. The latter includes, hydro, nuclear or other thermal within BC, or the import of electricity across Provincial or National boundaries.

2. A complete evaluation is beyond the scope of this report, which has been confined to consideration of the coal production costs of the various options.

3. Table VI shows the production costs for the various stages of the two pits. These are shown both as $/ton and ¢/million Btu. Since the analysis that follows requires that these costs should be independent of the time scale, they have been based on Tables XXIV and LIII of Reports No 2 and 3, ie on conventional rather than DCF accounting. They are not, therefore, compatible with figures quoted earlier. Also, since these tables do not give any "production costs" for the initial development phase (Stage 1), it has been necessary to develop these from data presented elsewhere in the reports. Stages 1 to 3, for each pit, have purposely been amalgamated in this presentation as it would not be practical to develop a pit to extract such a small tonnage. This modification also has the advantage of concealing the high production costs of the two development stages, which would otherwise produce apparent anomalies.

4. Table VI shows that the production costs for the different stages of the two pits vary between $4.60/ton and $11/ton or, when expressed in heat content terms, between ¢42/million Btu and ¢100/million Btu. These costs are not restricted to the requirements of a 2,000-MW or a 5,000-MW power station nor to a working life of 35 years, but they are the basis from which the costs can be calculated for any reasonable total coal requirement. This is done by putting together sufficient stages to meet the requirement. Obviously, the stages in one pit can only be worked in numerical order but there are no practical constraints to how the balance is made between the pits though the objective, of course, is to minimise the costs of production.

5. It will be noticed that the production costs for Stages 8 and 8A of Openpit No 1 are higher than the average costs for Openpit No 2. This re-opens the question whether all the recoverable reserves in Openpit No 1 should be worked before developing Openpit No 2.

6. For the present analysis it has been assumed that if the total requirement can be obtained from Openpit No 1 then this will be done. In other words, whatever the economics may indicate, it would not sensible to develop the second pit unless at least 100 million tons were to be extracted from it. If, however, the total requirements could not be developed from Openpit No 1, then production would be stopped at the end of Stage 7 and Openpit No 2 developed to produce the balance, or as much of the balance as possible. The remaining high-cost reserves in Openpit No 1 would only be exploited if the tonnage required were such that there were no other alternative. This then allows a series of "milestones" to be set dependent on the total tonnage required. These are shown in Table VII, together with the production costs of the last stage. The latter are shown both as $/ton and ¢/million Btu.

7. They are also shown in diagrammatic form on Plate 5 which indicates that, except for a high-cost zone at the point of changeover from a one-pit to a two-pit operation, the production cost generally increases with increased total coal requirement. It is, perhaps, ironic that the fuel requirement for a 2,000-MW station falls on this intermediate peak.

8. While the production cost of the marginal tonnage is important because it allows the possible economic cut-off point to be determined, it is also important to know the average production cost for any given quantity of coal extracted. This is shown graphically on Plate 5. Again, the figures are expressed both in terms of $/ton and ¢/million Btu. These are plotted against total tonnage extracted as there is no economic reason why the end use need be for power generation. However, as this is the most likely use, a second abscissa scale is included, showing the equivalent (net) power station capacity. These curves also show an intermediate peak corresponding to a 2,000-MW power station requirement. This suggests that if it were decided to build only a 2,000-MW power station then thought should be given to finding a use for some 150 million to 250 million tons of extra coal. If this could be done at an opportunity value of $6.50/ton (¢60/million Btu) then it would improve the economics of the overall operation.

9. As already stated, these figures cannot be directly compared with the DCF ones developed in earlier chapters. It is, however, worth looking at them to see if there is any correspondence. Considering the requirements of a 2,000-MW and a 5,000-MW power station, and using the most economic method of mining, the figures become:-

	Production cost, $/ton	
	2,000-MW station	5,000-MW station
Conventional accounting	6.90	8.10
Uniform selling price (10% discount)	5.70	6.30
Uniform selling price (15% discount)	6.40	6.50

10. Usually, mining projects show a higher production cost when calculated on a DCF basis because this method emphasises the costs of the initial capital development and discounts the benefits of the subsequent production stages. The reason these figures show an opposite effect must be because this is more than counteracted by the advantage of working the low-cost coal in the earlier years and leaving the high-cost sections until the end of the project.

11. It is also significant that the cost difference between the 2,000-MW and 5,000-MW cases decreases as the discount rate increases. This reduced sensitivity of cost in relation to tonnage extracted would also apply for other intermediate tonnages. In other words, the system should be sized to meet the production required and not to suit a rather hypothetical minimum extraction cost.

CHAPTER VIII

CONCLUSIONS

1. The most economic method of coal production is to develop Openpit No 1 and to work it to exhaustion. In the case of the 2,000-MW power station, the pit would provide sufficient fuel for the required power station life of 35 years. In the case of the 5,000-MW power station, it would also be necessary to develop Openpit No 2, but this should be deferred as long as possible. The exact timing depends on the practicability and the economics of being able to work Openpit No 1 to a greater depth than 600 ft. Even if it were possible to recover all the reserves from Openpit No 1, these would be insufficient for the full life of the larger power station, so some development of Openpit No 2 would be required.

2. If it were possible to work Openpit No 2 to a depth of between 750 ft and 800 ft then all the requirements for the 5,000-MW power station could be met from this pit, but the costs would be about 15% greater than for developing Openpit No 1 first.

3. A further increase in power station capacity beyond 5,000-MW, or the construction of an SNG or similar plant, would require either the ability to work deeper than 600 ft or a substantial increase in the quantity or quality of the reserves.

4. Whatever the long-term options, the short-term objective should be to develop Openpit No 1 to supply a 2,000-MW power station. However, the pit, the coal handling system and the power station should all be laid out to facilitate later expansion to an output equivalent to 5,000-MW capacity.

TABLE I

ECONOMICS OF SUPPLYING COAL TO A 2000-MW POWER STATION USING OPENPIT NO 1

Item	Unit	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	Stage 8A
		1977-83	1983-85	1985-88	1988-94	1994-2000	2000-06	2006-11	2011-13	2013-20
Cash flow expenses	$ 10^6	134.2	68.6	131.4	313.3	301.8	401.9	425.2	236.5	790.0
Coal production (rom)	10^6 ton	1	12	39	79	78	79	66	26	79
Discounted cash flow at 10%	$ 10^6	89.7	33.3	50.8	77.8	43.9	32.4	20.5	8.0	17.5
Discounted cash flow at 15%	$ 10^6	75.0	23.8	32.7	41.0	18.0	10.1	4.9	1.7	2.9
Discounted coal production at 10%	10^6 ton	0.7	5.76	15.08	20.11	11.23	6.43	3.16	0.88	1.75
Discounted coal production at 15%	10^6 ton	0.56	4.1	9.7	10.72	4.56	2.01	0.77	0.18	0.29
Stage cash flow divided by production	$/ton	-	5.7	3.4	4.0	3.9	5.1	6.4	9.1	10.0

Uniform selling price at 10% discount rate = $ 5.70/ton

at 15% discount rate = $ 6.40/ton

Notes: 1. Figures developed from Table XXV of Report No 2.

2. Stage 8A costs are extrapolated.

3. The addition of Stage 8A modifies the uniform selling price quoted in Report No 2.

TABLE II

ECONOMICS OF SUPPLYING COAL TO A 2000-MW POWER STATION USING OPENPIT NO 2

Item	Unit	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
		1977-83	1983-85	1985-93	1993-2004	2004-16	2016-20
Cash flow expenses	$\$ 10^6$	290.8	117.8	591.2	891.2	922.8	234.1
Coal production (rom)	10^6 ton	1	12	105	144	157	40
Discounted cash flow at 10%	$\$ 10^6$	199.4	58.1	182.2	109.5	39.4	4.6
Discounted cash flow at 15%	$\$ 10^6$	168.3	41.8	107.0	41.2	8.6	0.7
Discounted coal production at 10%	10^6 ton	0.7	5.76	32.62	18.51	6.80	0.80
Discounted coal production at 15%	10^6 ton	0.56	4.1	19.21	7.29	1.62	0.12
Stage cash flow divided by production	\$/ton	-	9.9	5.6	6.2	5.9	5.9

Uniform selling price at 10% discount rate = \$ 9.10/ton

at 15% discount rate = \$ 11.20/ton

Note: Figures developed from Table LIV in Report No 3.

TABLE III

ECONOMICS OF SUPPLYING COAL TO A 2000-MW POWER STATION USING A COMBINATION OF OPENPITS NO 1 & 2

Item	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Total rom coal from Openpit No 1	10^6 ton	Nil	131	209	288	354	380	459
- Corresponds to Stages	-	-	1-4	1-5	1-6	1-7	1-8	1-8A
Total rom coal from Openpit No 2	10^6 ton	459	328	250	171	105	69	Nil
- Corresponds to Stages	-	1-6	1-4 and part 5	1-3 and part 4	1-3 and part 4	1-2 and part 3	1-2 and part 3	-
Proportion from Openpit No 1	%	-	28.5	45.5	62.7	77.1	82.8	100
Total cash flow expenses discounted at 10%	\$ 10^6	593.2	469.7	413.0	386.8	378.9	378.1	373.9
Total cash flow expenses discounted at 15%	\$ 10^6	367.6	262.0	228.4	216.0	212.2	211.7	210.1
Uniform selling price discounted at 10%	\$/ton	9.1	7.2	6.3	5.9	5.8	5.8	5.7
Uniform selling price discounted at 15%	\$/ton	11.2	8.0	6.9	6.6	6.5	6.4	6.4

Note: It is assumed that Openpit No 1 is developed first to produce 13.1 million tpa rom, but that production is stopped at the end of the appropriate stage. Openpit No 2 is developed in sufficient time to take over at this point.

TABLE IV

ECONOMICS OF VARIOUS METHODS OF SUPPLYING COAL TO A 5000-MW POWER STATION

OUTPUT REQUIRED (COMMON TO ALL CASES)

Item	Unit	1977 - 85	1985 - 92	1992 - 99	1999 - 06	2006 - 13	2013 - 20	2020 - 26
Coal production (rom)	10^6 ton	13	141	229	230	229	217	88
Discounted coal production at 10%	10^6 ton	6.46	42.78	38.23	19.61	10.06	4.95	0.98
Discounted coal production at 15%	10^6 ton	4.66	24.85	16.78	6.31	2.36	0.85	0.13

A. TWO PITS IN PARALLEL NO 1 LEADING

Cash flow expenses	\$ 10^6	318.1	869.5	1,156.8	1,243.9	1,472.5	1,737.2	541.3
Discounted cash flow at 10%	\$ 10^6	179.4	271.3	193.4	105.6	63.8	39.7	7.1
Discounted cash flow at 15%	\$ 10^6	139.3	159.7	85.1	33.8	14.9	6.8	1.0

Uniform selling price at 10% discount rate = \$7.00/ton
at 15% discount rate = \$7.90/ton

B. OPENPIT NO 1 FOLLOWED BY OPENPIT NO 2

Cash flow expenses	\$ 10^6	202.8	545.3	1,264.8	2,013.4	1,406.6	1,248.7	658.5
Discounted cash flow at 10%	\$ 10^6	123.0	166.0	200.2	181.2	62.6	28.5	8.7
Discounted cash flow at 15%	\$ 10^6	98.8	96.4	85.6	59.6	14.8	4.9	1.1

Uniform selling price at 10% discount rate = \$6.30/ton
at 15% discount rate = \$6.50/ton

C. OPENPIT NO 2 FOLLOWED BY OPENPIT NO 1

Cash flow expenses	\$ 10^6	408.5	814.0	1,406.6	1,481.9	1,173.4	1,264.8	790.0
Discounted cash flow at 10%	\$ 10^6	257.5	253.5	238.0	126.2	53.5	27.0	10.5
Discounted cash flow at 15%	\$ 10^6	210.1	149.3	105.1	40.6	12.8	4.6	1.4

Uniform selling price at 10% discount rate = \$7.90/ton
at 15% discount rate = \$9.40/ton

TABLE V

ECONOMICS OF SUPPLYING COAL TO A 5000-MW POWER STATION

OUTPUT REQUIRED (COMMON TO ALL CASES)

Item	Unit	1977 - 85	1985 - 92	1992 - 99	1999 - 06	2006 - 13	2013 - 20	2020 - 26
Coal production (rom)	10^6 ton	13.0	141.0	229	230	229	217	88
Discounted coal production at 10%	10^6 ton	6.46	42.78	38.23	19.61	10.06	4.95	0.98
Discounted coal production at 15%	10^6 ton	4.66	24.85	16.78	6.31	2.36	0.85	0.13

A. OPENPIT NO 1 WORKED FIRST AND EXPANDED TO 23 MILLION TPA - BALANCE OF REQUIREMENT FROM OPENPIT NO 2

Cash flow expenses	$ 10^6	202.8	853.3	1,221.7	1,749.9	1,404.4	1,252.0	658.5
Discounted cash flow at 10%	$ 10^6	123.0	251.6	200.0	146.3	62.4	28.6	8.7
Discounted cash flow at 15%	$ 10^6	98.8	143.6	87.0	46.5	14.8	5.0	1.1

Uniform selling price at 10% discount rate = $6.70/ton
at 15% discount rate = $7.10/ton

B. AN ALTERNATIVE STAGGERED DEVELOPMENT OF THE TWO PITS

Cash flow expenses	$ 10^6	202.8	853.3	1,247.6	1,442.5	1,483.8	1,520.0	589.2
Discounted cash flow at 10%	$ 10^6	123.0	251.6	204.7	121.8	63.7	34.7	7.7
Discounted cash flow at 15%	$ 10^6	98.8	143.6	89.2	39.1	14.8	6.1	1.0

Uniform selling price at 10% discount rate = $6.60/ton
at 15% discount rate = $7.00/ton

TABLE VI

COAL PRODUCTION COSTS
(At 1975 Prices)

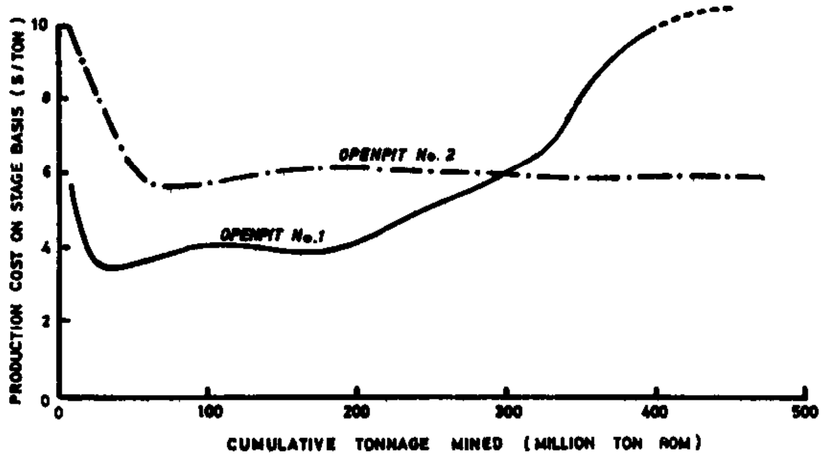
Stage	Output 10^6 rom ton	Production Cost for Stage	
		\$/ton	¢/10^6 Btu
Openpit No 1			
1 - 3	52	6.7	60
4	79	4.6	42
5	78	5.0	45
6	79	5.5	50
7	66	7.5	68
8	26	9.7	88
8A	79	11.0	100
Openpit No 2			
1 - 3	118	9.9	90
4	144	7.8	71
5	157	7.5	68
6	40	8.4	77
6A	229	10.0	91

TABLE VII

MOST ECONOMICAL METHODS OF PRODUCING DIFFERENT TOTAL COAL REQUIREMENTS

Total Tonnage Required (10^6)	Stages Worked		Production Cost of Last Stage			
	From Openpit No 1	From Openpit No 2	Openpit	Stage No	\$/ton	¢/10^6 Btu
289- 354	1 to 7	NIL	No 1	7	7.5	68
355- 380	1 to 8	NIL	No 1	8	9.7	88
381- 459	1 to 8A	NIL	No 1	8A	11.0	100
460- 472	1 to 7	1 to 3	No 2	1 to 3	9.9	90
473- 616	1 to 7	1 to 4	No 2	4	7.8	71
617- 773	1 to 7	1 to 5	No 2	5	7.5	68
774- 813	1 to 7	1 to 6	No 2	6	8.4	77
814- 839	1 to 8	1 to 6	No 1	8	9.7	88
840-1,068	1 to 8	1 to 6A	No 2	6A	10.0	91
1,069-1,147	1 to 8A	1 to 6A	No 1	8A	11.0	100

EFFECTS OF SUPPLYING VARYING PROPORTIONS OF OUTPUT FROM TWO PITS TO A 2000 MW POWER STATION



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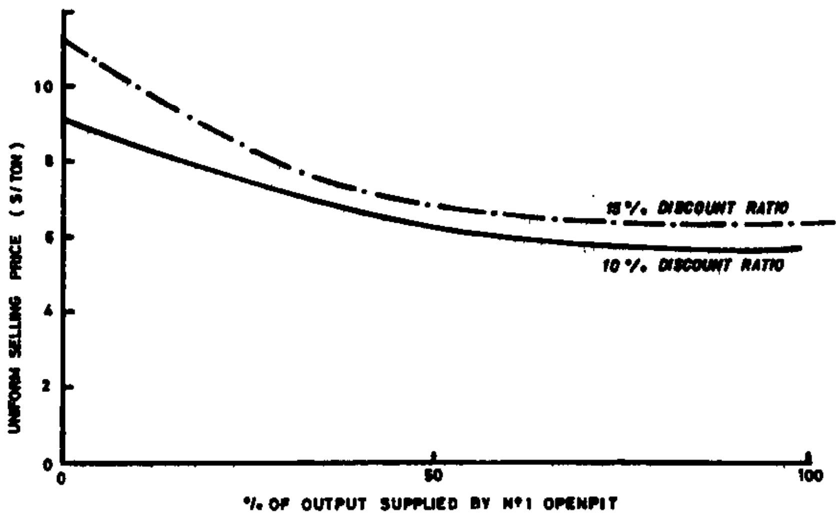

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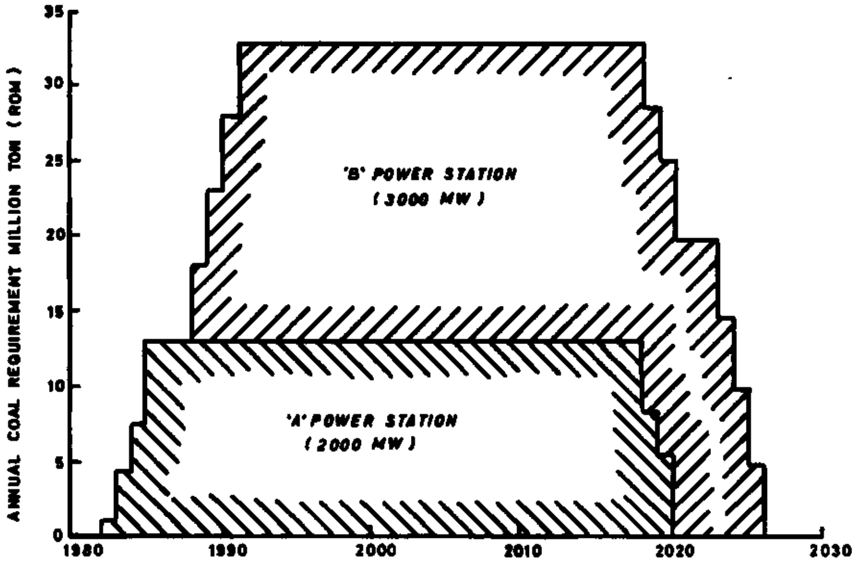
COAL REQUIREMENTS FOR A 5000 MW POWER STATION



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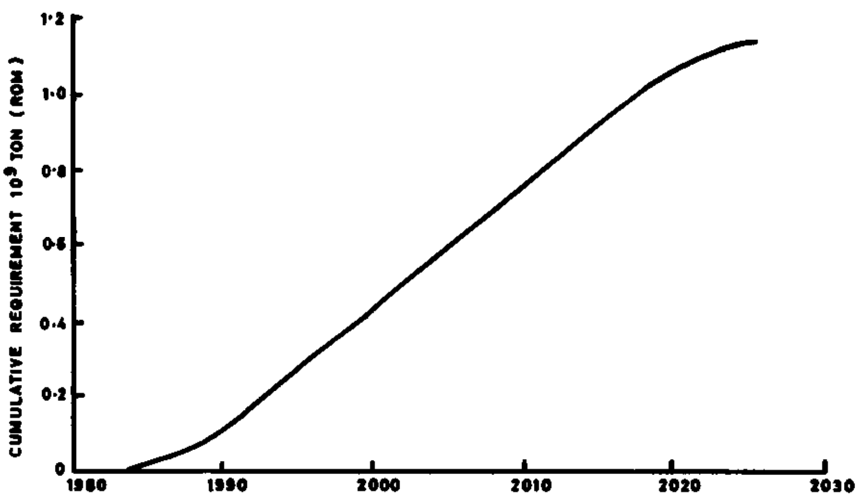

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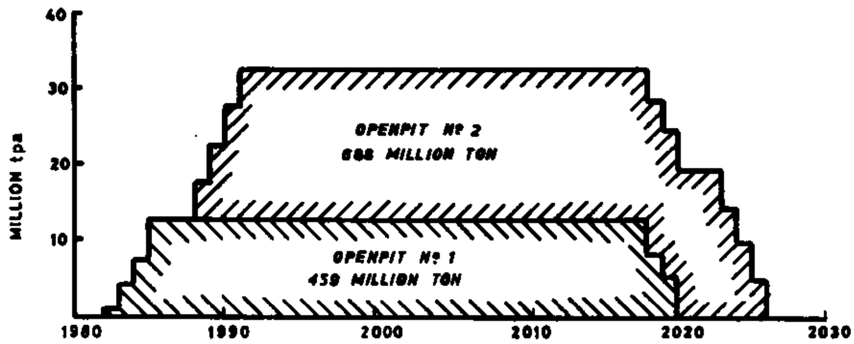
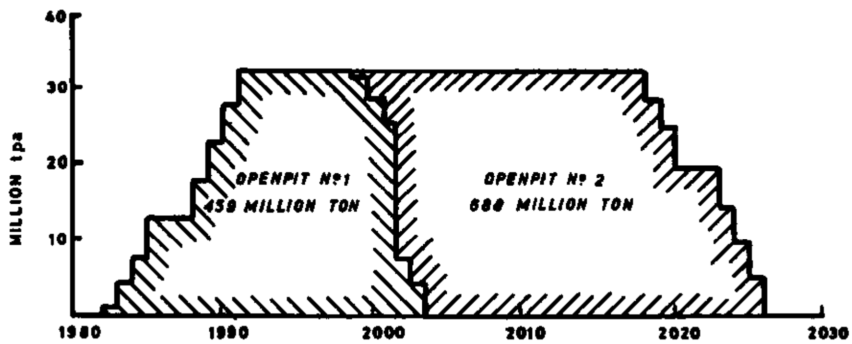
BASIC METHODS OF TWO PIT OPERATION TO SUPPLY A 5000 MW POWER STATION

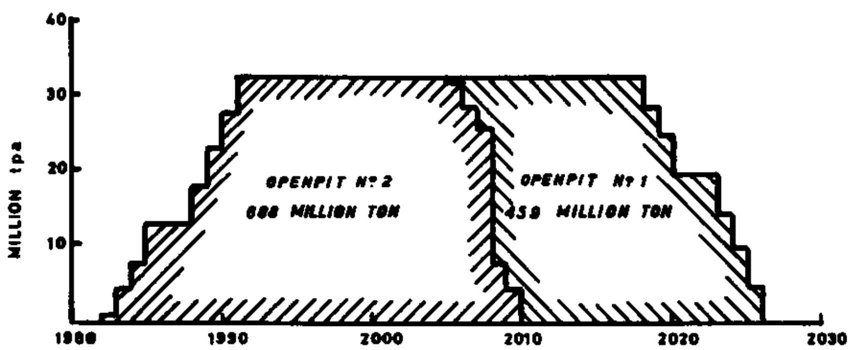
TWO PITS IN PARALLEL - Nº1 LEADING



OPENPIT Nº1 FOLLOWED BY OPENPIT Nº 2



OPENPIT Nº 2 FOLLOWED BY OPENPIT Nº1



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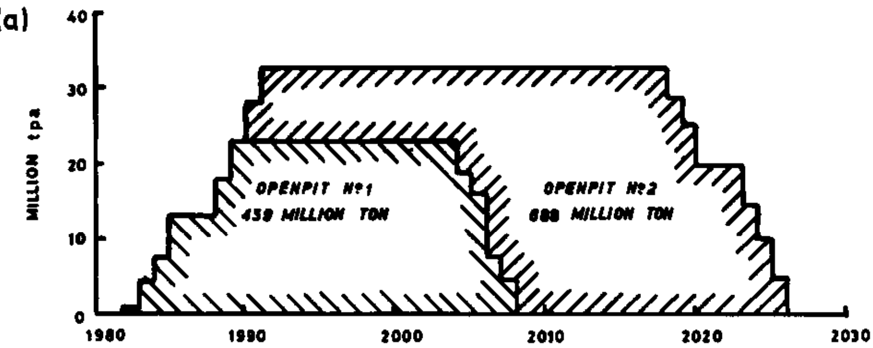
OTHER METHODS OF TWO PIT OPERATION

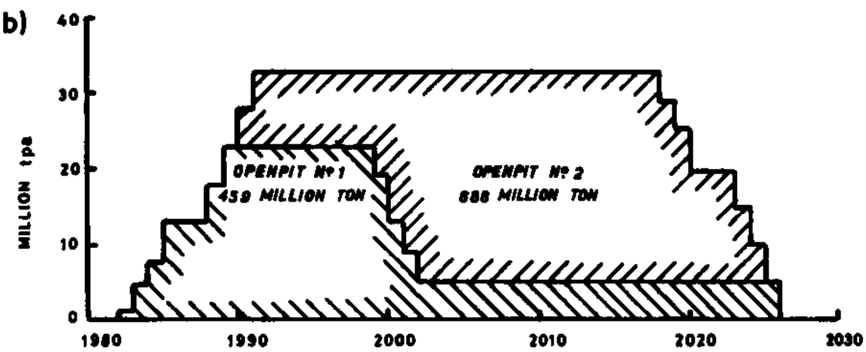
OPEN PIT Nº1 RESTRICTED TO 23 MILLION tpa

(a)



ONE PIT WORKED AT HIGH OUTPUT AND THE OTHER ON "STAND-BY"

(b)



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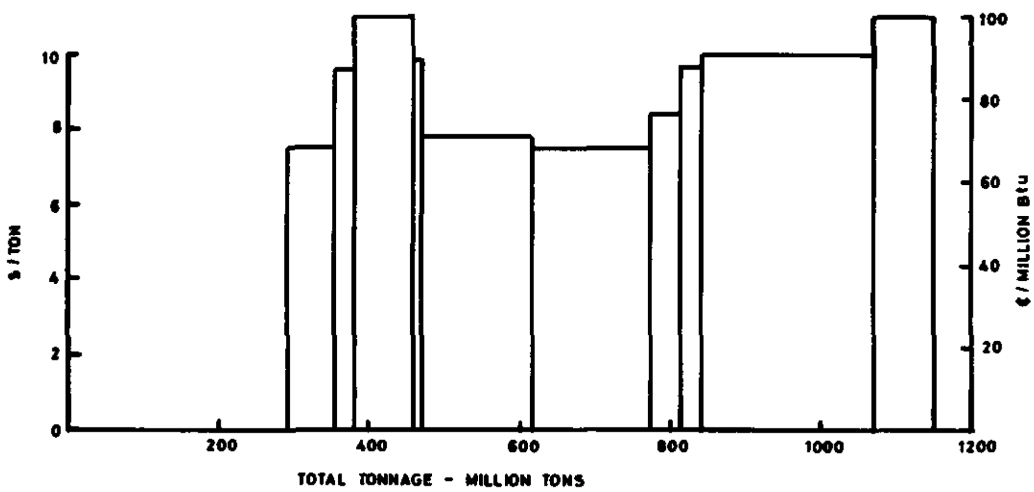
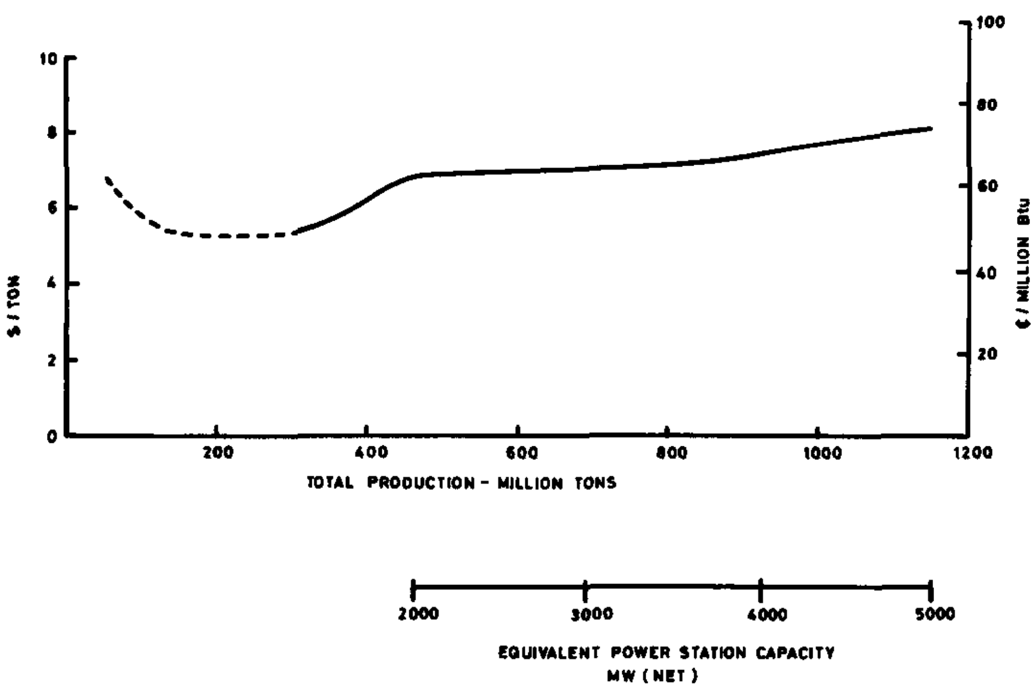
PRODUCTION COSTS FOR VARIOUS TOTAL COAL REQUIREMENTS BASED ON CONVENTIONAL ACCOUNTING

COST OF LAST STAGE



AVERAGE PRODUCTION COST



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