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Coordinated Mining Procedures of Open Pit Mines Based on River Management

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Abstract This paper primarily concerns the effective coordination of the procedures and methods employed in open pit mining operations under the background of river management. The central objective of this study is to identify a viable approach for ensuring rational and efficient development of open pit mineral resources while simultaneously protecting and restoring the ecological environment of the river. This approach should facilitate the realization of a harmonious symbiosis between mining and river management. The intricate mutual influence relationship between river management and open pit mining is first analyzed in depth, which provides a solid foundation for the subsequent coordination strategy development. In light of the aforementioned considerations, a set of coordination procedures for open pit mining based on river management conditions is proposed. These procedures emphasize the integration of river protection into the overall layout of mining at the planning stage. The implementation of scientific mining schemes, accompanied by rigorous control of the scope and depth of mining operations, has proven to be an effective means of reducing the impact of mining activities on river environments. This approach has also facilitated the achievement of a balance and coordination between mining and river management.

Key words River management, Open pit mine, Mining procedure, Coordinated mining

1 Introduction

In the context of the current global surge in demand for resources, the significance of open pit mining is becoming increasingly evident. However, while we derive valuable mineral resources from the earth, we must also address the tension between river management and open pit mining. It is crucial to ensure that the river ecosystem is not damaged. Furthermore, the scientific and reasonable development of mineral resources has become a significant issue that requires resolution. In the context of the dual challenges of "river management" and "open pit mining", the study of open pit mining procedures based on river management conditions is not simply a matter of prioritizing the environment over the economy. Rather, it is a matter of identifying and implementing a crucial balance between the two. The No. 1 open pit mine of Inner Mongolia Power Investment Energy Co., Ltd. was selected as a case study for analysis. The location of the river management project within the mining realm was evaluated, and a comprehensive and detailed research and optimization of the mining operation procedure of the No. 1 open pit mine and its subsequent succession plan was conducted. This practical investigation offers invaluable insights that can be leveraged to enhance the environmental stewardship and economic viability of the No. 1 open pit mine. Moreover, it serves as a valuable reference for other comparable open pit mines seeking a viable balance between river ecological protection and efficient and orderly mining operations.

2 Overview of the No. 1 open pit mine

The current mining plan for the No. 1 open pit mine is illustrated in Fig. 1. The No. 1 open pit mine comprises two open pit coal mines, namely the south and north open pit mines, with an authorized production capacity of 20 and 10 Mt/yr, respectively, resulting in a total authorized production capacity of 30 Mt/yr. The principal coal seams of the south open pit coal mine are 8 coal, 10 coal, 14 coal, and 21 coal. The quarry in the area south of No. 8 Road has a strike length of 1.9 km, with the lowest elevation of the current mining area at 678 level and a mining depth of 252 m. The coal mining process employs a semi-continuous mining process, which involves the use of a shovel, truck, semi-fixed crushing plant, and belt conveyor. The stripping process employs a shovel-truck or a combination of shovel-truck, semi-fixed crushing plant, belt conveyor, and dumping plough. The principal coal seams of the north open pit coal mine are 14 coal, 19 coal, 21 coal, and 24 coal. The stripping process employs an intermittent approach, utilizing a shovel-truck. The coal mining process is semi-continuous, involving the use of a shovel-truck, semi-mobile crushing plant, and belt conveyor.

3 Overview of river management

3.1 Implementation location of river management project

The river management project in the north open pit coal mine section of the Heremute River commenced in May 2023 and was brought to a successful conclusion by the end of the same year.

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The precise location of the implementation is depicted in Fig. 2.

3.2 Mining space on both sides of the river management location The location of the river management project serves as the boundary for the No. 1 open pit mine, which is divided into two mining areas. A safety distance is reserved on both sides of the river from the riverbank boundary. Fig. 3 illustrates the spatial layout of the No. 1 open pit mine, which is influenced by the location of the river management project.

4 Optimization of mining procedures

4.1 Marginal condition analysis (i) The river management project of the Heremute River in the north open pit coal mine section is implemented at the permanent river realignment position, which separates the No. 1 open pit mine into two independent mining pits in the north and south.

(ii) The south section will conduct supplementary mobilization of stripped materials to form a permanent river realignment location for the Heremute River channel at the inner dump within the south section. This will enable the recovery of the amount of overburdened coal in the river channel.

(iii) Although the implementation location of the river management project in the north open pit coal mine section of the Heremute River has extended the service life of the mining pits located north of the river boundary, it has also resulted in the postponement of the advancement of the coal mining work line to the south. Based on the smooth succession and stable development of the No. 1 open pit mine, the location of river management will continue to be adjusted to the south, to a position near the boundary between the south and north open pit coal mines. Once the inner dump in the north section has formed a permanent river realignment location for the Heremute River, the river channel will be altered once more to the permanent river realignment location of the inner dump.

4.2 Mining procedure plan The four proposed mining schemes for the aforementioned marginal conditions, in conjunction with the river management plan, are depicted in Fig. 4.

Scheme 1 (Fig. 5): According to the existing production scale in the south and north sections, the implementation location of the river management project in the north open pit coal mine section of the Heremute River is considered as a permanent river realignment location. In light of the fact that the condition of river realignment is no longer available, it is not necessary to form an inner dump space in the north side of the river in order to meet the permanent location of river realignment. The maximum extent of mining operations and the mining plan for the two distinct sections in the south and north are constrained by the boundary of the river management location.

In consideration of the current mining status, the north section is advancing in a southerly direction until it reaches the position of river management in order to circumvent the secondary stripping volume that would otherwise be generated by the inner dumping covering height. The west-side slope work line of the south section has been extended in order to prepare for the continuation of the capacity of the northern pit closure. The south section is advancing in the early stages with the west-side and north-side slope dual work lines. Once the north-side slope reaches the south side of the river, the length of the west-side slope work line is approximately 3.5 km. The west-side slope then continues in a northwesterly direction until the end of mining.

Scheme 2 (Fig. 6): Given the permanent river realignment location in the north open pit coal mine section of the Heremute River and the lack of available information regarding the condition of river realignment, it is unnecessary to form an inner dump space on the north side of the river in order to meet the permanent location of river realignment. The maximum extent of mining operations and the mining plan for the two distinct sections in the south and north are constrained by the boundary of the river management location.

In order to adapt to the revised river policy, enhance the flexibility of the mining program, and extend the remaining service life of the north section, the production scale of the north section has been adjusted to 8 Mt/yr. In consideration of the current status of mining operations, the northern section is advancing in a southerly direction until it reaches the position of river management, while the south section continues to advance in a northwest direction before turning northeast.

Scheme 3 (Fig. 7): Once the open pit mine has permanent river realignment conditions, the overburden, amounting to 100 Mt of resources, will be recovered from the implementation location of the river management project in the north section of the Heremute River. The long-term spatial layout analysis of the south and north open pit coal mines reveals that the Heremute River channel within the south section at the inner dump is an optimal location for the formation of permanent river realignment. This realignment would facilitate the transportation of deficient materials from the north section to the south section by utilizing the north-side slope.

Scheme 4 (Fig. 8): The location of the river management project in the north open pit coal mine section of the Heremute River has extended the service life of the mining pits located to the north of the river boundary. However, the project has also resulted in the continued impact on the advancement of coal mining workings to the south. Based on the smooth succession of mining and the stable development of the north open pit coal mine, the location of the river channel will continue to be adjusted to the south. This will result in the river being shifted for the second time in the location near the boundary between the south and north open pit coal mines. As the quarry working slope progresses in a southerly direction, the inner dump follows the dump by bench, thereby enabling the creation of a permanent river realignment location for a given period of production.

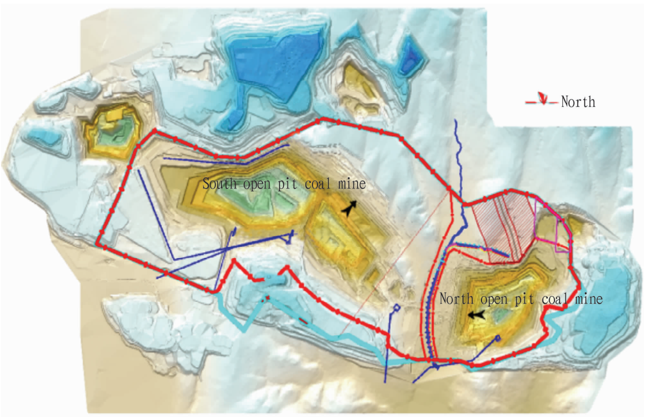

Fig. 1 Current mining plan of No. 1 open pit mine

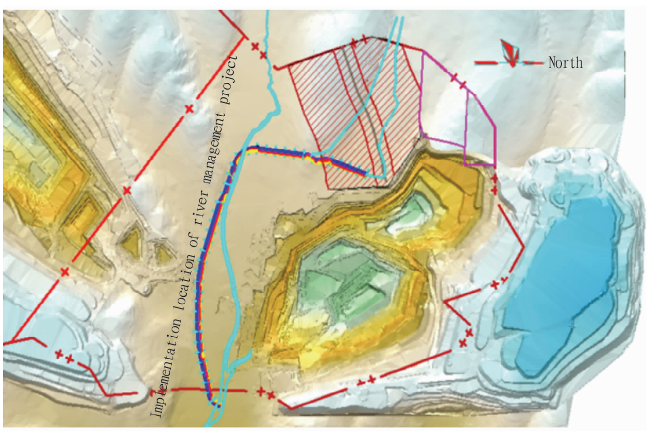

Fig. 2 Implementation location of river management project

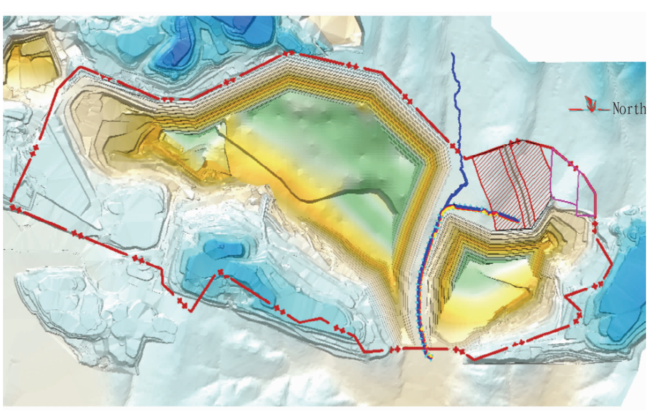

Fig. 3 Schematic diagram of the spatial layout of the No. 1 open pit mine under the influence of the location of river management

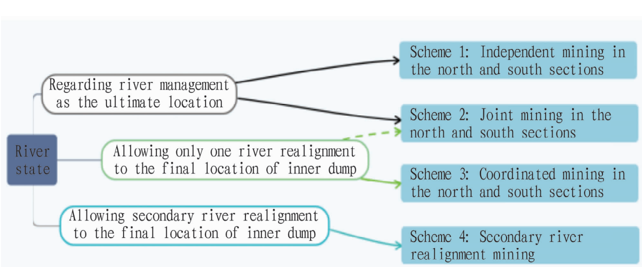

Fig. 4 Mining schemes for river management

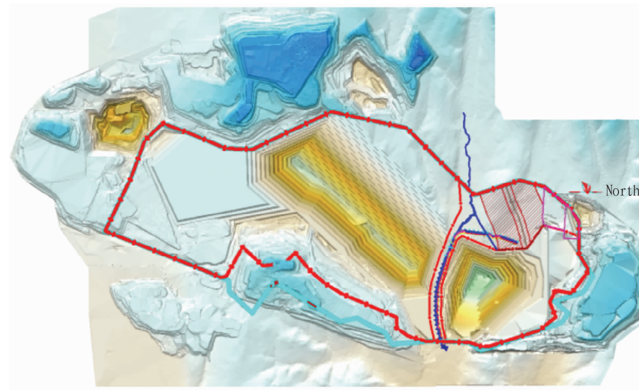

Fig. 5 Mining procedure plan of scheme 1

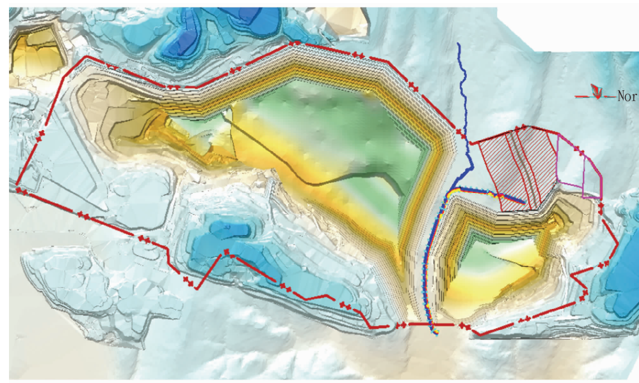

Fig. 6 Mining procedure plan of scheme 2

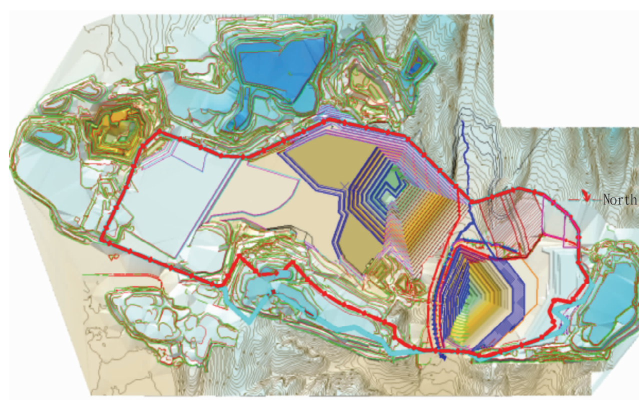

Fig. 7 Mining procedure plan of scheme 3

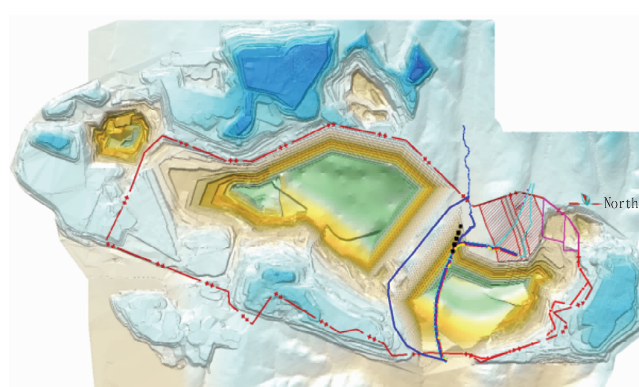

Fig. 8 Mining procedure plan of scheme 4

4.3 Comparison of mining procedure schemes A comparison of the production scale across the entire life cycle of each scheme is presented in Fig. 9, while a comparison of the stripping ratio of each scheme during the production period is shown in Fig. 10. The primary technical parameters of each scheme are presented in Table 1 for comparison.

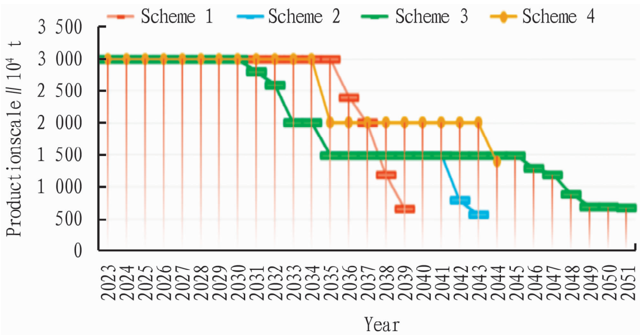

Fig. 9 Comparison of the production scale across the entire life cycle of each scheme

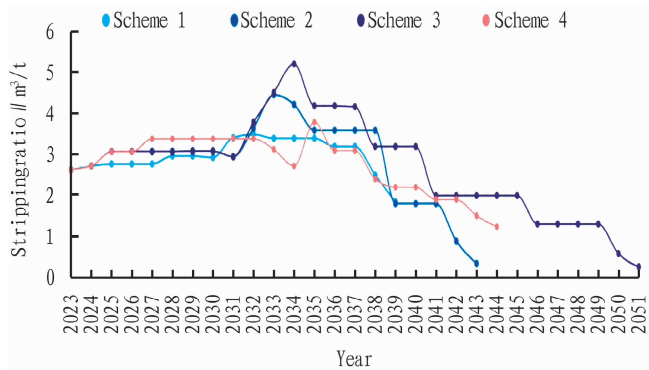

Fig. 10 Comparison of the stripping ratio of each scheme during the production period

Table 1 Comparison of primary technical parameters of each scheme

Major parameter	Scheme 1	Scheme 2	Scheme 3	Scheme 4
	Independent mining in the north and south sections	Joint mining in the north and south sections	Coordinated mining in the north and south sections	Secondary river realignment mining
Raw recoverable coal volume // $\times 10^4$ t	45 275	45 275	54 403	55 386
Total stripping volume // $\times 10^4$ m^3	137 232	137 232	163 328	158 903
Average stripping ratio // m^3/t	3.03	3.03	3.00	2.87
Year of pit closure	2039	2043	2051	2044
Remaining number of river realignment // times	0	0	1	2
Primary river realignment time // yr	–	–	–	2027
Permanent river realignment time // yr	–	–	2034	2033
River realignment/stripping volume // $\times 10^4$ m^3	–	0	11 834	0
Backfill compression coal volume for river realignment // $\times 10^4$ t	–	0	983	0
Production-period weighted transport distance // km	3.92	3.38	3.37	3.05
Total production-period transport work // $\times 10^4$ m^3 · km	538 059	478 918	550 579	484 155
Transport work of tons of coal stripping // m^3 · km/t	11.89	10.58	10.12	8.74
30 Mt/yr stable production period // yr	13	8	8	12
20 Mt/yr stable production period // yr	–	–	–	9
15 Mt/yr stable production period // yr	–	7	11	–
Complexity of mining area succession // yr	Ordinary	Ordinary	Complex	Ordinary
Complexity of river realignment // yr	–	–	Ordinary	Complex

5 Conclusions

The study delineated four mining procedure schemes for different marginal conditions. A comprehensive techno-economic assessment was conducted for each scheme, taking into account the policy requirements for river realignment and long-term planning. The evaluation indicators encompass a number of significant parameters, including production scale, production stripping ratio, recoverable reserves, service life, spatial arrangement of internal dumping, production-period weighted transport distance, and freight charges. Following a comprehensive calculation and comparison process, the following conclusions are reached.

(i) In the event that future conditions permit, it would be prudent to implement a secondary river realignment mining program. This approach ensures a smooth mining succession, effectively reducing the variation in production stripping ratios and avoiding the unnecessary reshipment of stripping volumes.

(ii) Should circumstances arise in the future that permit the establishment of a permanent river realignment location, this would serve to guarantee the uninterrupted advancement of the open pit. Consequently, the transportation distances and freight charges for open pit mines will increase, which will consequently impact the economics.

(iii) In the event that the conditions do not permit the river to be realigned, or if it is only possible to realign the treated river to the inner dump within the north section at one time, it is recommended that a coordinated mining program should be implemented between the south and north sections. This option permits the opti-

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mal utilization of resources and the balanced advancement of the north and south sections in their current state.

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