Application of mine planning software to resources estimation of the lava lignite deposit in Servia, Greece

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Abstract: The use of mine planning software in the evaluation and estimation of mineral resources and reserves is well established nowadays in the mining industry for the design and scheduling of surface mines and it is a requirement for the reporting of mineral resources according to international reporting codes. This paper describes the application of mine planning software in the estimation and modelling procedures of the operational lignite mine of LARCO GMMSA at the Lava deposit in Servia, Kozani. All stages of exploration data analysis, geological modelling, grade estimation, resources reporting, mine design and optimisation of the mining operations are explained. Data integration, advanced 3D graphics and specialised modelling algorithms all within a user-friendly environment contribute to the successful implementation of mining industry accepted procedures to the effective planning and estimation of the surface lignite mine.

Keywords: mine planning; mineral resources estimation; lignite mining; Greece.

Reference to this paper should be made as follows: Kapageridis, I., Apostolikas, A. and Koundourellis, E. (2019) 'Application of mine planning software to resources estimation of the lava lignite deposit in Servia, Greece', *Int. J. Mining and Mineral Engineering*, Vol. 10, Nos. 2/3/4, pp.158-176.

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This paper is a revised and expanded version of a paper entitled 'Use of Mine planning software in mineral resources and reserves estimation of the lava lignite deposit in Servia – Greece' presented at 14th International Symposium of Continuous Surface Mining, Thessaloniki, Greece, 23–26 September 2018.

1 Introduction

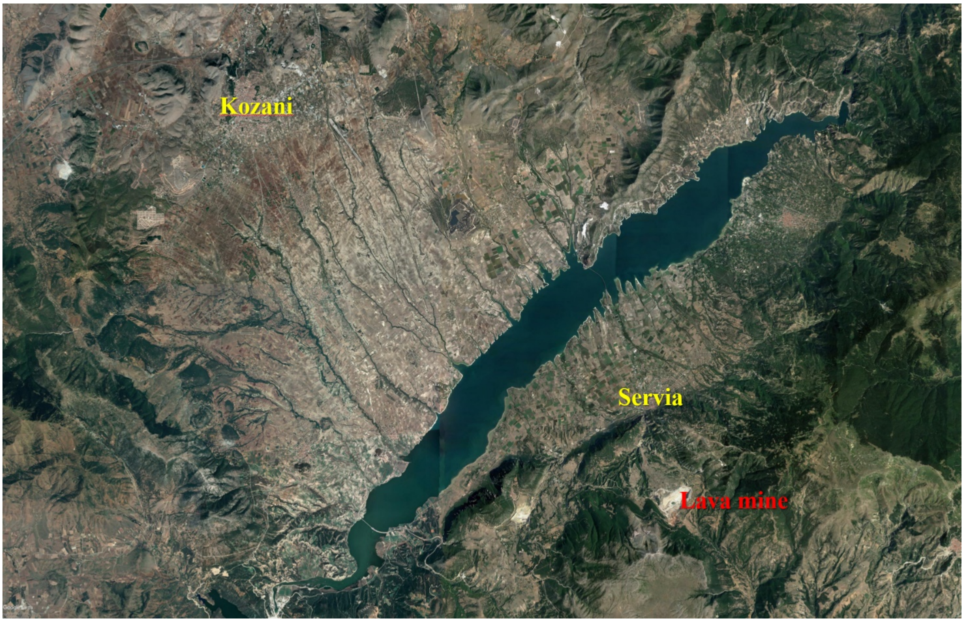
1.1 Background

The lava lignite mine is located 12 km south of the town of Servia and 30 km south-east of the town of Kozani in the Kozani Prefecture in NW Greece (Figure 1). It was originally developed to satisfy the needs for solid fuels of LARCO's smelting plant at Larymna. Its annual production is approximately 250 kt of lignite, depending on the demand from the lava deposit. Geologically the basin that the lignite deposit belongs to is considered part of the wider tectonic dip that starts from FYROM. The dip having a general direction NNW-SSE was created from the Alpic tectonic activity during Neogene and is consisted of several smaller tectonic dikes. Into these dikes the neogenic lignitic and other sediments were deposited and then unconformably the quaternary formations were overlaid. The area geologically belongs to the Pelagonic zone. The formations encountered from the bottom to the top are:

- Mesozoic crystallic and dolomitic limestones (Triassic – Middle Jurassic).
- Unconformably to the Mesozoic formations, lie the Neogene sediments (clay, silt, sandstone, marl), which contain the lignite horizons.
- Quartenery sediments consisting mainly of conglomarates with clayish or calcious connecting material.

Tectonically the area has faults of small displacement. All the lignite layers converge towards the centre of the basin with an inclination of 5°. Concerning the lava deposit, there are two main lignite layers and a minor third that appears at the edges of the basin. The lowest layer has an age of 6.72–6.43 million years and spreads across the central and the most part of the south part of the deposit. Its thickness varies between 1.5 to 25 metres. Its largest part consists of brown coal with alternations with small layers of clay. On top of that layer lays a layer of marl, on top of which the second lignite layer, consisting of compacted coal with a thickness of 2–3 metres and has an age of 6.27–6.01 million years. That second layer overlaps the lowest layer and expands furthermore to the north and the south of the deposit. Finally, the third layer that appears at the edges of the basin has an average thickness of 5 metres and lies above the second lignite layer.

Figure 1 Location of the lava lignite mine near the town of Servia in NW Greece (see online version for colours)



Source: image from Google Earth Pro

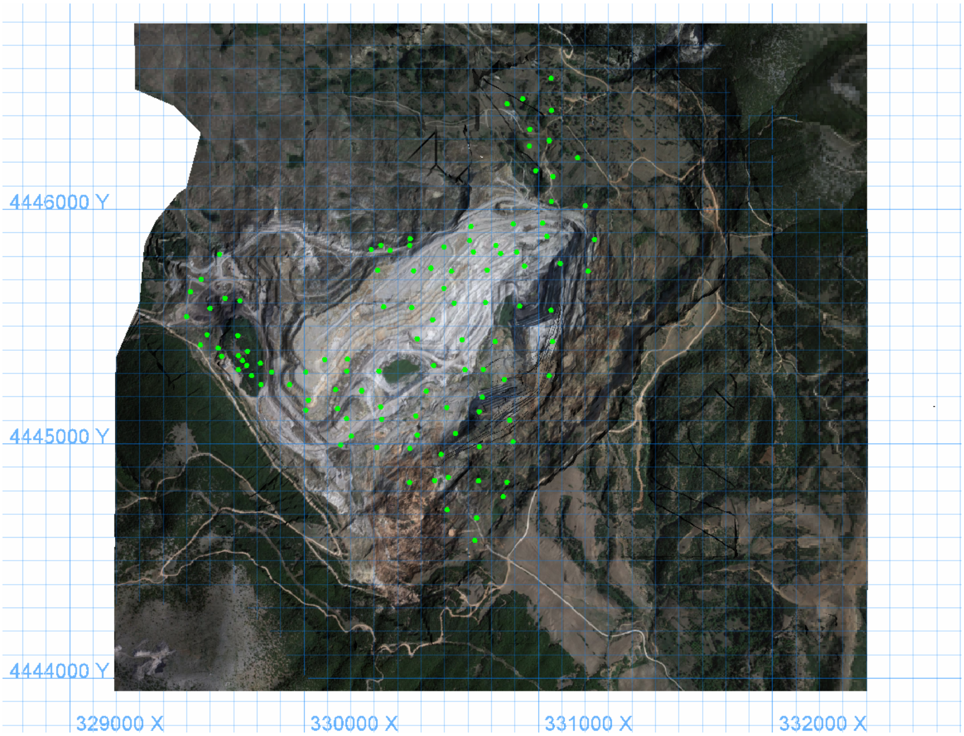
1.2 Available data

The data used in modelling and estimation of lignite resources of the lava deposit included 120 drillholes, drilled and analysed using LARCO's own equipment between 1977 and 2007, and survey data of the original and current topography. All data were imported into appropriate Maptek Vulcan databases and validated. Figure 2 shows the current topography triangulation model with draped imaged from Google Earth Pro and the location of the drillhole collars. It should be noted that the image data is older than the current topography model.

1.3 Software implementation

Since 2007, LARCO GMMSA has been using Maptek Vulcan for mine planning in all of its mining operations including the nickel mines in Kastoria, Agios Ioannis and Evoia. The mineral resources and reserves estimation procedure for the nickel deposits has been presented in the past (Kapageridis et al. 2013). This software package is also used for mine planning of the lignite operation in Servia which is the subject of this paper. Its application to lignite resource estimation, though for uncorrelated seams, has been presented in the past (Kapageridis and Kolovos, 2009). However, the steps involved in modelling the lava lignite deposit and estimating resources have important differences to the procedure applied to the nickel mines and the other lignite mines in the region, as it will be discussed over the following sections.

Figure 2 Current topography model with draped image from Google Earth Pro and drillholes collar location (see online version for colours)



The software package used integrates one of the most complete integrated stratigraphic modelling (ISM) modules providing a variety of modelling methods to develop stratigraphic, structural and grade/quality grid models using an automated modelling process. Combined with advanced visualisation capabilities, a complete set of geological analysis, interpretation and modelling tools, a number of different block model structures and estimation methods, and advanced mine design tools suitable for stratigraphic deposits, it provides a complete environment for the development of accurate and resource models taking advantage of all available information.

1.4 Scope of the study

Coal and lignite resource modelling has been covered in a number of studies (Tercan and Karayiğit, 2001; Heriawan and Koike, 2008a, 2008b; Kapageridis and Kolovos, 2009; Olea et al., 2011; Hatton and Fardell, 2012; Tercan et al., 2011; Deutsch and Wilde, 2013; Tercan et al., 2013). Lignite deposits, such as the one examined in this paper, require the development of a thorough stratigraphic model to allow the reporting of accurate lignite resources and form the basis for solid mine planning and lignite reserves calculation. Such a stratigraphic model requires the painful but irreplaceable step of seam correlation in sections and plans before any compositing of mineable lignite takes place. With a correlated stratigraphic model in place, mineable lignite resources can be evaluated using mining and processing criteria applied to modelled raw lignite seams leading to an overall three-dimensional model of the deposit that allows accurate lignite resources calculation even in the presence of tectonism. The paper aims to present how common geological modelling and mine planning tools are configured and applied to resource modelling and estimation of a lignite deposit in NW Greece, mined using a truck and shovel operation and feeding nearby power plants. Pit optimisation is also used to derive the optimum pit limits based on technical and financial parameters related to the lignite mining operation.

2 Data processing

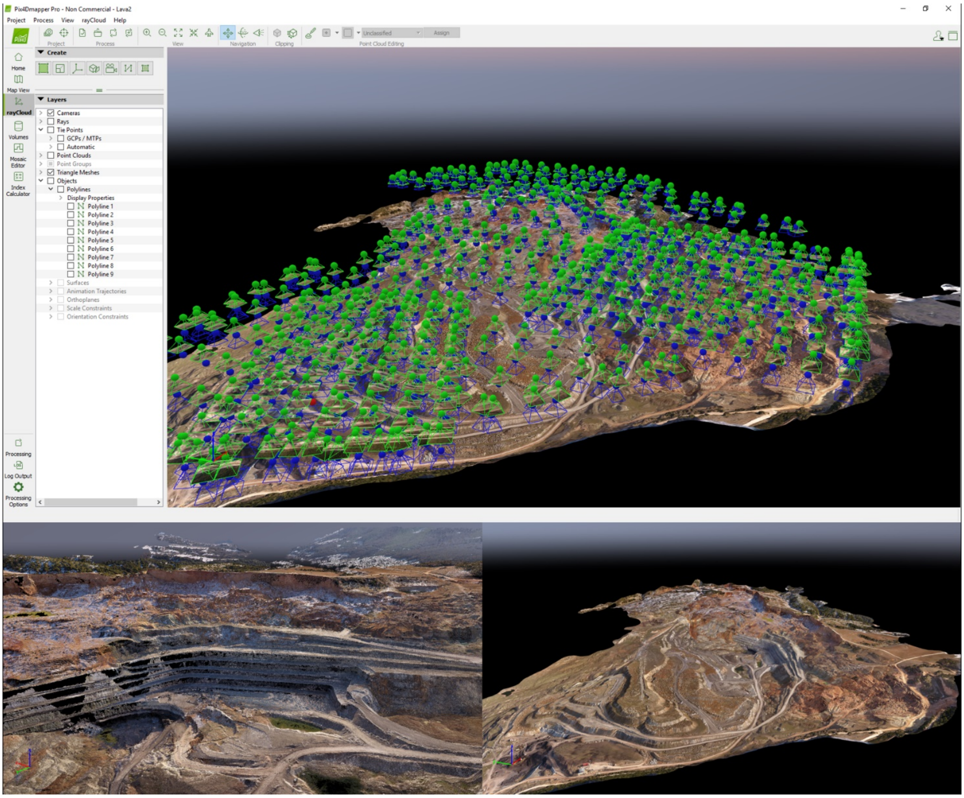
2.1 Current topography

Current topography was surveyed by drone and modelled using Pix4Dmapper Pro (Pix4D SA). Figure 3 shows screenshots from the software and produced output using data acquired from the lava mine. Pix4Dmapper Pro software uses images taken by hand, drone, or plane and creates precise, geo-referenced 3D maps and models used for data analysis. Some of the key outputs of the software include (Pix4D, 2018):

- 3D point cloud: accurate digital reconstruction and the geolocation of each point.
- Digital surface and terrain model: the elevation value of each pixel, with or without above-ground objects.
- Orthomosaic: a geolocated high-resolution map with each pixel of the original images projected onto the digital surface model.
- Volume calculation: accurate volume calculations on a representation of stockpiles, with fully-adjustable base height.
- Contour lines: a simplified representation of the topography with closed contours displaying the elevation.
- 3D textured model: triangular mesh with photorealistic texture.
- Reflectance maps: reflectance based on the pixel value in multi-spectral or thermal imagery.
- Index maps: indices such as NDVI and NDRE or create of custom indices.

The triangulation model produced by Pix4Dmapper Pro was imported in Maptek Vulcan to be used for lignite resources modelling. The imported model was checked against previous topography models based on conventional surveying techniques and also against the resource block model extents. The maximum triangle side length was 10 m (mostly applicable outside the current excavation area) while the minimum was approximately 0.5 m. The model covered an area of 12.5 km^2 and ranged between 598 m and 1,212 m vertically.

Figure 3 Screenshots from topography drone scan in Pix4Dmapper Pro (see online version for colours)



Notes: Top: camera locations and triangulation model, bottom left: point cloud, bottom right: triangulation model.

2.2 Drillhole database development and validation

Typically, data for coal and lignite resource modelling is collected in the form of drillholes in which the positions of horizons of interest are logged. Rarely, however, are the data so perfectly collected so as to provide information about all of the horizons to be modelled in every hole. Most drillhole data sets will contain holes where some of the horizons are not represented. The reasons for this are various; some inherent in the nature of the deposit being drilled, some introduced by the methods of the drilling program and some by poor logging practice or lost data. The reasons for the missing information fall into two main categories:

1. Data that was not collected by the drilling program.
2. Data that was not available for collection because of pre and post-depositional geological processes.

The problems that can be caused by the first of these categories are:

- Short holes which are not deep enough to include all horizons of interest.

- Problems determining the position of missing horizons that have thinned to zero thickness.
- Problems determining the position of the boundary of daughter horizons in their merged parent horizon.
- Lost core, lost data or poor logging.

The problems that can be caused by the second category are:

- Removal of horizons from the top of the sequence by erosion.
- Weathering of horizons blurring upper boundaries.
- Sub-cropping of horizons against other geological features.
- Washout by erosion processes at the time of deposition.

Data used in this study came from 120 drillholes with a 100 m average horizontal spacing that were imported to a drillhole database through CSV files containing collar information (hole ID, collar XYZ) and sample intervals (top and bottom depth, length, lithology, ash, etc.). The database was checked and validated both visually and through a number of tests related to collar coordinates and overlapping intervals. The following data collection issues were found that needed to be addressed:

- Short holes, which were not deep enough to include all horizons of interest or had a collar, lower than the original topography surface.
- Difficulty determining the position of missing horizons that have thinned to zero thickness.
- Lost core, lost data or poor logging.

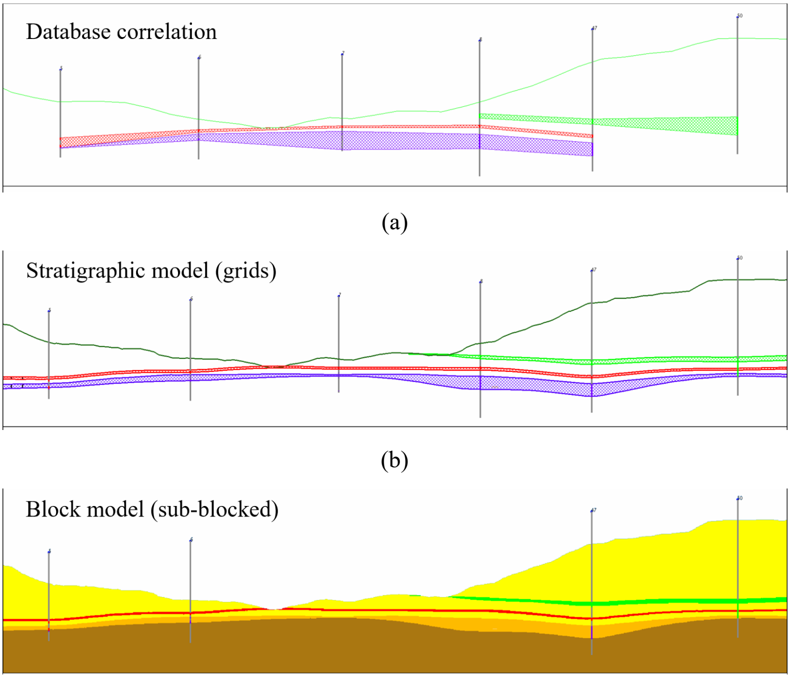
A separate database lithology table was generated by combining consecutive intervals of the same lithology. This table and lithology field were used to create drillhole sections in Vulcan and proceed with the correlation of lignite layers and the fixing of issues mentioned above. The resulting correlation was stored in an extra field in order to have both the original lithology and the interpretation.

Sample intervals were composited to a standard length of 0.5 m as they were originally of varying length, thus not suitable for block model qualities estimation. The choice of composite length was based on the mining method used and the average length of the original samples. The final composites database consisted of 2,851 composited samples.

3 Geological modelling

The lignite seams were examined in cross sections and were manually correlated by selecting the drillhole intervals considered to belong to a particular seam and coding an appropriate seam field in the database. This was a fairly time-consuming process, the results of which were based to some degree on the geologist's interpretation. Figure 4 (top) shows a drillhole section with the seam correlation stored in the database. This type of section helps to visualise the way correlation works before actual modelling of the seams. The software automatically links intervals with the same seam code between successive drillholes in a linear fashion aiding the user during correlation. A colour legend helps distinguish between seams. Linking of correlated seams is not allowed through drillholes that do not contain them.

Figure 4 (a) Example section showing database lignite layers correlation between drillholes (b) Grid models representing stratigraphy (c) Complete block model containing both structural and quality information of the lignite deposit (see online version for colours)



(a)

(b)

(c)

Note: Drillholes missing in the bottom section are hidden behind the block model section.

All lignite seam and waste codes were stored in a special database table and field to be used for structural modelling of the seams. A horizon list (table) was also stored for reference by other functions of the software. This horizon list contains only the part of the stratigraphy that will be modelled. It is important to list the horizons in proper stratigraphic order with the first horizon being the uppermost deposit and the last horizon being the bottom of the modelling area of interest.

Once seam correlation was complete, the drillhole database could be used to develop a complete structural and qualities model of stratigraphy. Seam extents, seam merging and splitting, faulting, and other aspects of geology need to be effectively addressed by the modeller and the software. The end result of this effort would be a stratigraphic model and a corresponding resource model commonly in the form of multiple grid models or an overall stratigraphic block model.

The correlated lignite layers intervals were used to build grid models of the roof and floor of each of the three lignite layers [Figure 4(b)]. The grid models were cropped by the current topography surface and were checked against drillholes in sections. Seam existence limits were also generated to control the horizontal area of the seams of the correlated lignite intervals. Inverse distance weighting was used to produce all structural grid models. Minor layers of low lignite quality (waste) within the three main lignite layers were also modelled separately. Blocks inside these waste layers were to be excluded from estimation, as were the composites that came from these layers to minimise dilution.

4 Lignite resources estimation

4.1 Block model development

The structural grid models of stratigraphy and the current topography triangulation model were used to create a sub-blocked block model. The main block size was set to 10 × 10 × 10 m vertically following the applied bench height and horizontally controlled by the sampling density, while the sub-block size ranged from 1 × 1 × 0.5 m up to the main block size. The sub-block size reflected the selectivity of the applied mining process. The block model origin and extents were set in a way to cover all the area of interest in all three coordinate axes. Several block variables were defined allowing storage of quality estimations, lithology, resource classification and estimate validation parameters. The following table gives a summary of the main block model parameters.

Table 1 Block model parameters – all dimensions and coordinates are in metres

Type	*Sub-blocked – unrotated*	*Number of variables*	*19*
Origin X	330,000	Main block size X	10
Origin Y	4,444,000	Main block size Y	10
Origin Z	650	Main block size Z	10
Extent X	2,200	Minimum sub-block size X	1
Extent Y	3,200	Minimum sub-block size Y	1
Extent Z	550	Minimum sub-block size Z	0.5

Sub-blocking occurred only in cases where a main block intersected one of the surfaces included in the model, i.e., lignite and waste layers roof and floor surface, and the current topography surface. Maptek Vulcan initially breaks main blocks to sub-blocks of the minimum size (1 × 1 × 0.5 m in our case) and then joins together sub-blocks that no longer intersect the surface that caused the sub-blocking (a process referred to as coalescing), thus leading to sub-blocks of sizes multiple of the minimum size (e.g., 2 × 2 × 2.5 m). The aim of this process is to reduce the number of sub-blocks down to the absolutely necessary while still following the controlling surface to the greatest resolution possible.

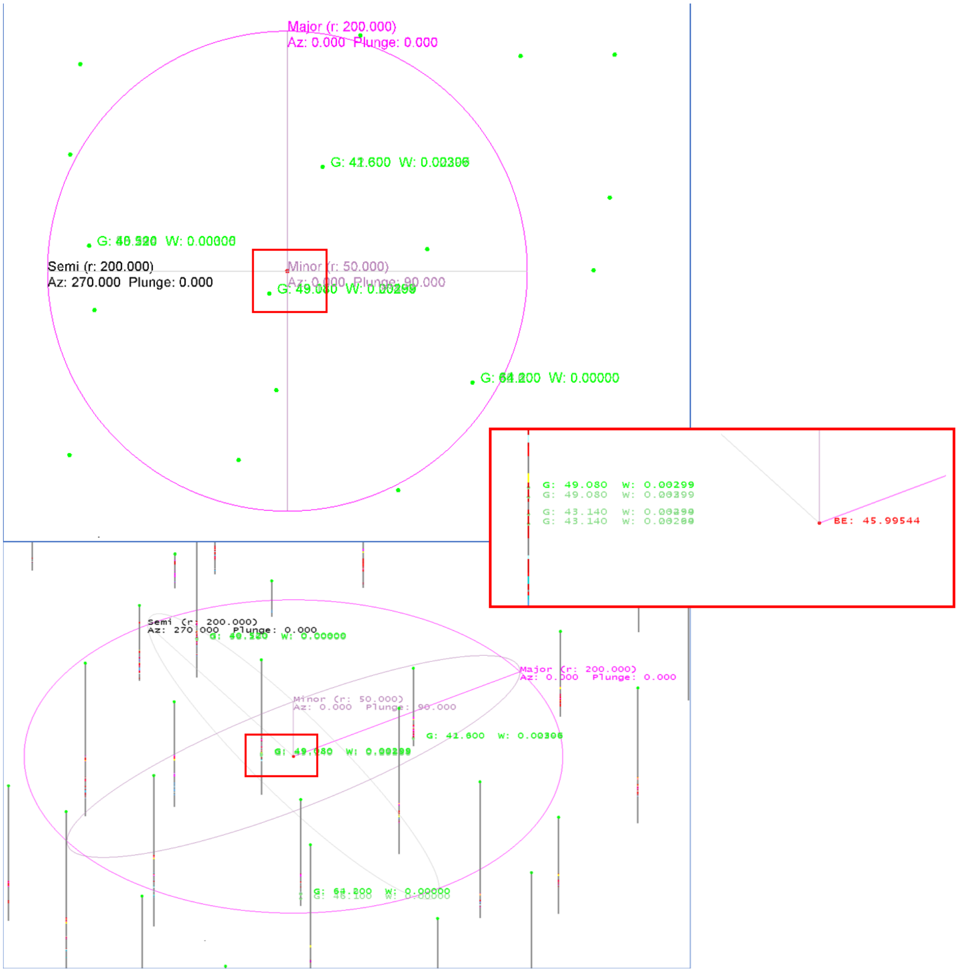
All blocks were flagged according to the controlling surfaces as belonging to a particular zone of the deposit. The flagging values were stored in a lithology variable that could be later used to select blocks for estimation, processing and reporting. The bottom section in Figure 2 shows the blocks coloured according to this variable.

Once the block model was constructed, multiple estimation runs were defined – one for each lignite layer (block model zone). A single estimation run was used to estimate each layer with the resource classification of the produced estimates taking place afterwards through block model scripting. The main estimation parameters used in all lignite layers quality estimation are summarised in Table 2.

Table 2 Main lignite quality estimation parameters

Search ellipsoid		*Other parameters*	
Bearing	0	Minimum samples	4
Plunge	0	Maximum samples	16
Dip	0	Maximum samples per octant	2
Major	200	Discretisation along X	4
Semi-major	200	Discretisation along Y	4
Minor	50	Discretisation along Z	1

Figure 5 Plan and 3D view of search ellipsoid used to estimate ash in the lower lignite layer (see online version for colours)

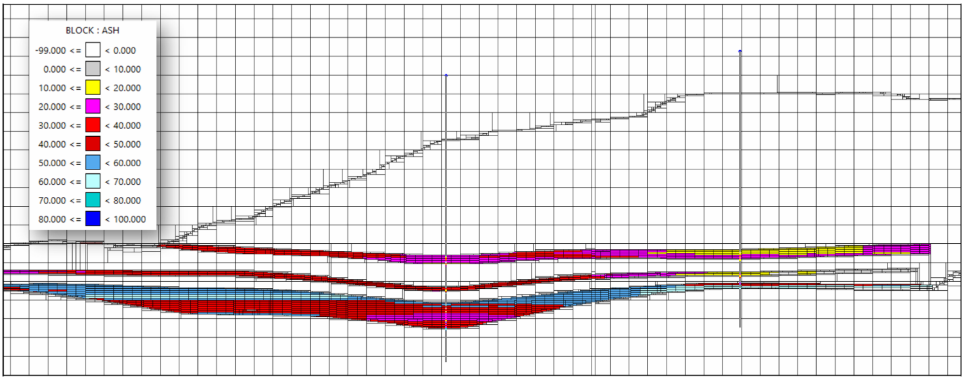


Notes: The red box shows the area of the detail view on the right. The block in question is shown with a red dot while the selected samples are shown in blue.

The inverse distance squared weighting method was used to estimate ash and other quality variables in the block model. Ash and the other lignite quality parameters were considered to vary along all three axes (i.e., even along Z) within each layer, unlike the strictly stratigraphic approach of estimating qualities using grids.

Each block was split into 4 × 4 × 1 points (discretisation) which were estimated separately and then averaged to produce the final block value. This is a just a practical way to better approach the distribution of the estimated parameter within the block volume as inverse distance weighting is a point and not a volume estimator. As already mentioned, estimation was performed separately for each lignite layer, i.e., only blocks being inside the specific layer were estimated using sample composites only from that layer. Octant based search was used to ensure sample selection from surrounding drillholes to the block being estimated as shown in Figure 5. After estimation, it was possible to check how the sample selection strategy worked by using a special ‘explain’ function of the software which allows the user to see graphically which samples were used in the estimation of a particular block and estimation related information about them (applied distance, applied weight, octant number, etc.) as shown in the detail window in Figure 5.

Figure 6 Block model section showing ash estimation inside each of the three lignite layers (see online version for colours)



The estimates were visually validated in cross and plan sections showing drillholes and block estimates together, like the one shown in Figure 6. Estimates presented good agreement with the drillhole interval values. The estimation method was also validated by running cross-validation separately for each lignite horizon. Cross-validation was run on the samples used to estimate the blocks, by hiding a sample and estimating grade at its location using the same method that estimated the blocks. The cross-validation estimates produced a strong positive correlation to the actual sample values, with limited underestimation of high grades and overestimation of low grades (Figure 7).

Generating a grade/tonnage curve for ash required some manipulation of the table produced by the corresponding function. The software expects a grade parameter and the tonnage calculated for each cut-off includes the blocks with an estimated grade value higher than the cut-off. In the case of ash, we need to report the material with an ash value lower than the cut-off, thus it was necessary to effectively reverse the tonnage table and reproduce the graph as shown in Figure 8. The curves show the sensitivity of lignite ash content and tonnage to the ash upper limit applied. It seems that after 60% there is little or no change on lignite ash and tonnage.

Figure 7 Scatter plots of cross validation results using drillhole samples from the three lignite horizons and the estimation method used in the study (see online version for colours)

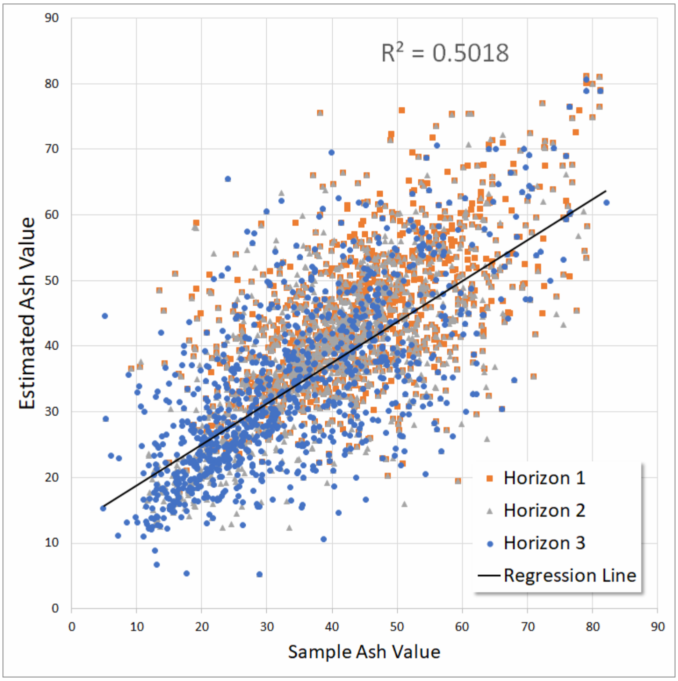


Figure 8 Grade/tonnage curve of lignite resources showing the effect of applying a different ash upper limit (cut-off) (see online version for colours)

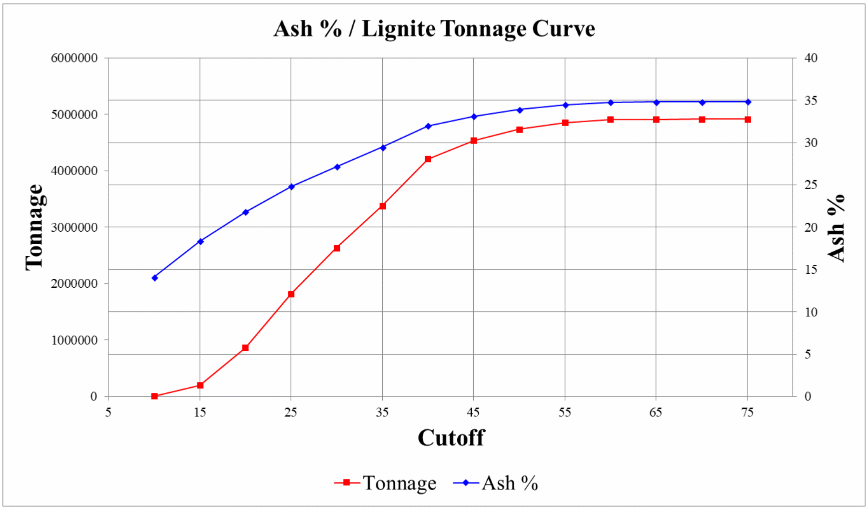
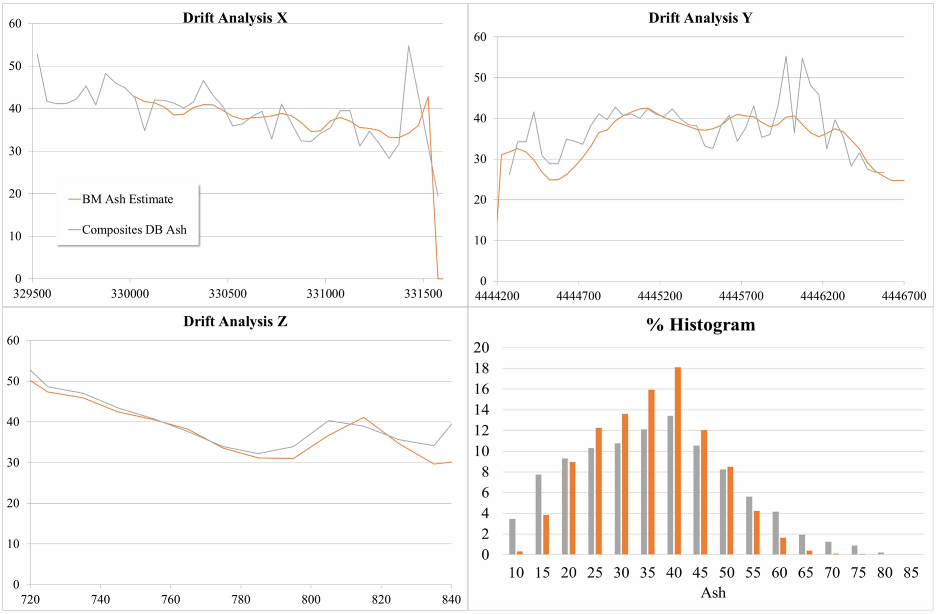


Figure 9 shows the results of drift analysis (swath plots) and comparison between the composited ash values used as input to resource estimation and the produced block estimates of ash. The smoothing effect of block model estimation with inverse distance is clear mainly along the X and Y axes. The histogram also shows that the block estimates distribution is narrower than the composites, which is expected due to the change of support (support effect). Generally, the estimates followed the main trends of the composites.

Figure 9 Drift analysis and histogram of composites database ash values and block model ash estimates (see online version for colours)

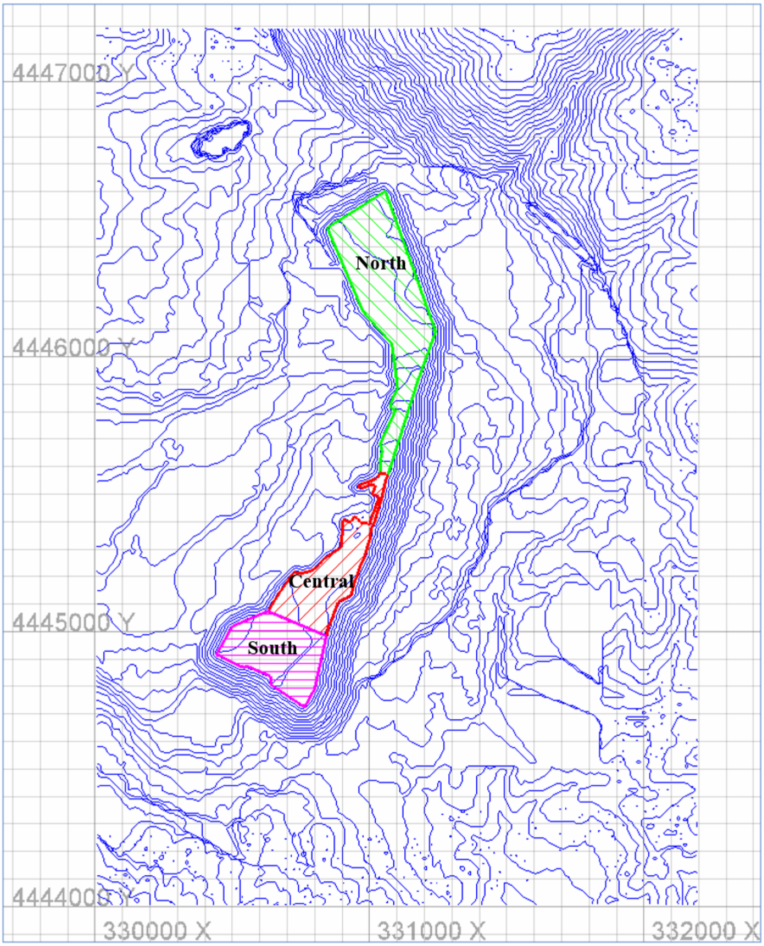


Block estimates were classified into three resource categories using samples, drillholes and octants count as well as the average distance to the samples used to produce each estimate. A simple block model script was used to classify estimated blocks after estimation using the inverse distance method.

4.2 *Pit optimisation*

Surface lignite deposits in Greece have been commonly modelled in the past using a more two-dimensional approach (Karamalikis, 1992; Kavouridis et al., 2000; Roumpos et al. 2011, 2014), based on grid or triangulation models that did not allow the application of open pit optimisation algorithms, normally requiring a three-dimensional block model of the deposit. The financial aspects of coal deposits are also considered constant along the Z axis, in most cases where the deposit consists of a small number of coal horizons with standard qualities, leading to the conception that pit optimisation is an unnecessary effort. The lignite deposits in Greece, however, normally consist of multiple lignite layers with varying quality parameters in all three dimensions, making them ideal targets for computerised open pit optimisation. Lignite resources estimated in this study refer to the material from the three lignite layers discussed earlier, with the following characteristics: moisture content 38–44%, calorific value 1,900–2,200 Kcal/kg, volatile matter 35–47% and sulphur 1–2%.

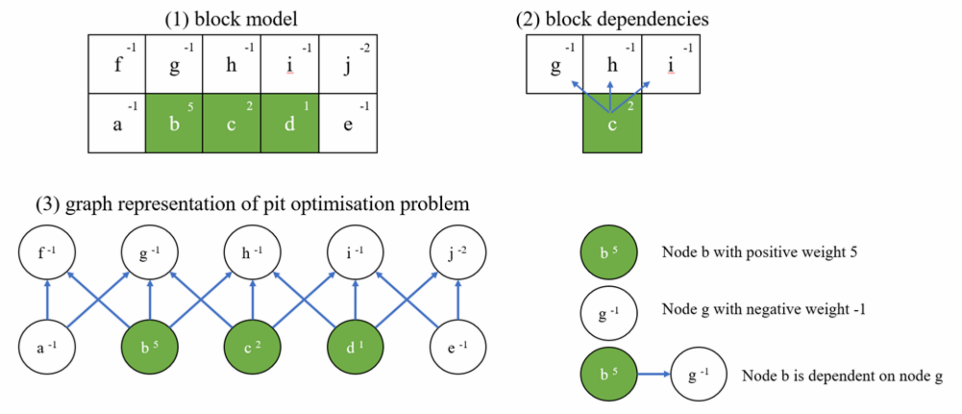
Figure 10 Optimised pit limits of the lava lignite mine used to limit the material reported as resources. The three pit sectors are also identified (see online version for colours)



For the lignite resources calculation in this study, a solid triangulation of the conceptual final pit was used to limit the considered volume to a technically feasible and economically viable pit. The final pit was derived using the Push-Relabel pit optimisation algorithm with financial and pit slope parameters related to the considered lignite mining operation (Figure 10). The Push-Relabel algorithm produces exactly the same results as the well-established Lerchs-Grossman algorithm, but at a fraction of the time (Cherkassky and Goldberg. 1997). The reduced computational time required by this method makes it ideal in cases where the pit to be optimised has large horizontal and vertical extents and the corresponding block model consists of hundreds of thousands or even millions of blocks, such as the one considered in this paper (3.9 million blocks) (Mpinos and Kapageridis, 2018). The Push-Relabel algorithm, used in this study, is one of the first efficient *maximum flow algorithms* used in solving the open pit optimisation problem. The pit optimisation module of Maptek Vulcan mine planning software is based on implementations of both the Lerchs-Grossman and Push-Relabel algorithms.

Maximum flow algorithms such as the Push-Relabel method used in this study, consider a pit with valid slopes as a ‘closed set’ or ‘closure’ (Goldberg, 1987; Goldberg and Tarjan, 1988). This set consists of nodes *V* that have no arcs initially. Based on the required pit slopes, a set of arcs *E* is defined representing the dependencies between blocks. A closed set of blocks is free to be removed and does not depend on the removal of other blocks. Finding an optimal pit is the process of finding a closure with maximum total value (Bai et al., 2017). This problem is called a maximum closure problem. It is easy to observe in Figure 11, that the optimal pit consists of block {*b*, *c*, *f*, *g*, *h*, *i*}, with a total value of 3.

Figure 11 Simple example of block model (1), block dependencies (2) and graph representation (3) for a pit optimisation problem (see online version for colours)



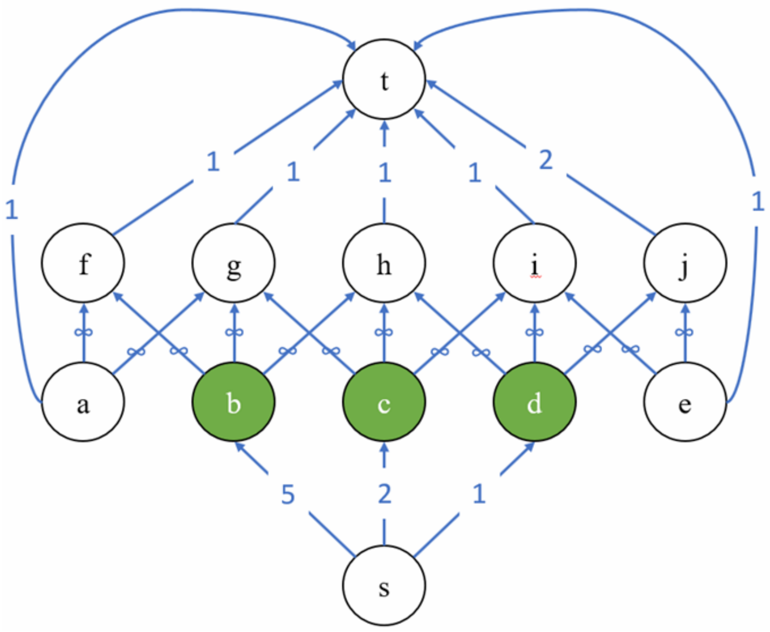
Source: Bai et al. (2017)

Two additional special nodes are required: the flow starts from the source node and finishes at the sink node. Each arc is like a pipe and has a nonnegative capacity function u allowing flow up to a limit passing through it. The flow and capacity along an arc must be positive. The nodes (blocks) represent a joining of pipes, so the amount of flow into a node must equal the total flow out of the node, which is called the conservation constraint. Each node (block) has a weight value equal to the economic value of the block. Defining a complete flow graph requires the following changes to the graph of the block model in Figure 11:

- Add two special (virtual) nodes: source s and sink node *t*.
- For all the existing arcs (blue), assign infinite capacities.
- Add links from source to all positive nodes, with the capacities equal to the weight of the nodes.
- Add links from negative nodes to sink, with the capacities equal to the absolute weight value of the nodes.
- Remove the weights on nodes.

Figure 12 shows the final graph after all changes are made. The relation between the flow and mining concepts is not as straightforward as the relation between a closure and a pit (Bai et al., 2017). One way to describe this is to consider the ore as the water stored in a source that as much as possible needs to be sent to a destination through a pipe network. The source node s connects to all ore blocks, and the destination (sink, t) connects to all waste blocks. In the network, the economic value of a block is not reflected on a node but is measured by the capacity of the pipe (arc) that connects it with the source or the destination. Since the pipes representing block dependency have unlimited capacity, the bottlenecks of the networks are the pipes connected to the source or destination. Three types of pipes can be identified: 'waste-to-destination', 'source-to-ore' and 'block-to-block'.

Figure 12 Flow graph representation of the pit optimisation problem (see online version for colours)



The conservation constraint at a node v indicates that the excess *ef*(*v*), defined as the difference between the incoming and outgoing flows, is equal to zero. A preflow satisfies the capacity constraints and the conservation constraints that requires the excesses to be nonnegative. An arc is residual if the flow on it can be increased without exceeding its capacity and saturated once the capacity is reached. The residual capacity $uf(v, w)$ of an arc between nodes v and w is the amount by which the arc flow can be increased. The distance labelling $d: V \to N$ satisfies the following conditions: $d(t) = 0$ and for every residual arc (v, w), $d(v) \leq d(w) + 1$. A residual arc (v, w) is admissible if $d(v) = d(w) + 1$. A node v is active if v is not the source or the sink node, $d(v) <$ number of nodes and $ef(v) > 0$.

The Push-Relabel method maintains a *preflow f*, initially set to zero an all arcs, and a *distance labelling d*. The $d(v)$ is initially set to the distance from v to t in the graph. In its first stage, the Push-Relabel method repeatedly performs the update operations, push and re-label until there are no active nodes left. The update operations modify the *preflow* f and the labelling d. A push from v to w increases $f(v, w)$ and $ef(w)$ by $\delta = \min \{ef(v), uf(v, w)\}$, and decreases $f(w, v)$ and $ef(v, w)$ by the same amount. A relabelling of v sets the label of v equal to the largest value allowed by the valid labelling constraints. The second stage of the method converts f into a flow.

The economic value of the blocks passed to the pit optimisation process was calculated in advance and stored to a block model variable. This value was the result of all applicable costs (lignite mining cost at €2/t, waste mining cost at €1/m^3, lignite crushing cost at €7/t, lignite hauling cost at €15/t) and expected revenue (€25/t of lignite) based on current contracts. An overall pit slope of 42° was used in the optimisation.

4.3 Lignite resources calculation

Table 3 summarises the lignite resources estimate for the lava mine based on the mining operation at the start of 2018. Two scenarios are presented based on a different upper limit for ash (50% or 60%). Only blocks classified as measured and indicated during the resource estimation stage were included in the pit optimisation and lignite resources calculation. The resources are reported separately for each pit sector as identified in Figure 10. Stripping ratio in the South Sector is considerably higher than in the other two sectors of the pit (15.79 m^3/t in the case of the 50% maximum ash) but still producing a profit as the lignite is sold to plants within a 50–55 km distance from the pit.

Table 3 Lava lignite mine resources at the start of 2018

Ash 50%

Lignite kTonnes	*Ash %*	*Waste $m^3 \times 1,000$*	*SR m^3/t*	*Sector*	*Lignite kTonnes*	*Ash %*	*Waste $m^3 \times 1,000$*	*SR m^3/t*
2,421	34.89	26,624	11.00	North	986	34.35	8,749	8.88
				Central	643	37.01	5,372	8.36
				South	792	33.84	12,503	15.79

Ash 60%

Lignite kTonnes	*Ash %*	*Waste $m^3 \times 1,000$*	*SR m^3/t*	*Sector*	*Lignite kTonnes*	*Ash %*	*Waste $m^3 \times 1,000$*	*SR m^3/t*
3,040	38.85	26,106	8.59	North	1,056	35.59	8,690	8.23
				Central	962	42.67	5,105	5.30
				South	1,022	38.62	12,311	12.05

5 Conclusions

Effective use of available geological and mining data and information requires advanced software solutions with the right tools to build realistic models of lignite geology and produce solid mining scenarios. Development of a sound lignite resource model should be based on maximum usage of available sampling data, while converting the resource model to a reserve should be based on proper application of mining factors. This paper discussed the application of mine planning software to the evaluation of lignite resources of the lava lignite deposit in NW Greece. The implementation of mine planning software produced results that increased confidence as to the available resources, formalised the mine planning procedure, aided the configuration of the mining methods applied, and helped in planning future mining operations by developing different mining scenarios with speed and clarity. Adopting the discussed approach increased confidence in the produced results and reduced the risks associated with the estimates, ensuring all important geological controls are considered. The use of a pit optimisation tool helped to increase confidence in the estimated resources, as commonly practiced by the mining industry.

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