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COMPUTER AIDED EXCAVATION AND PRODUCTION PLANNING OF AFŞIN-ELBISTAN LIGNITE KISLAKOY OPEN CAST MINE

MINING ENGINEERING DIVISION

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ABSTRACT

MASTER THESIS

COMPUTER AIDED EXCAVATION AND PRODUCTION PLANNING OF AFSIN-ELBISTAN LIGNITE KISLAKOY OPEN CAST MINE

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To make optimum mine plans first the solid and block model of the mine deposit must be obtained at the right way. There are a lot of computer programs for mine planning. One of these programs is the national resource and the new developed computer program Netpro/Mine. In this study, the Netpro/Mine program is introduced in the Kışlaköy area which belongs to the lignite basin of Afşin- Elbistan and is one of the most important lignite reserves of our county.

This study is including the generated the solid and block model with using of drill hole data and the Netpro/Mine and the detailed volume and mass calculations from the block model.

Keywords: Netpro/Mine, Solid Model, Block Model, Kışlaköy Lignite Mine

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1. INTRODUCTION

Energy is one of the most fundamental and locomotive requirements of a country's economic and social development. The energy required for meeting the needs of the people and maintaining the development in a healthy manner is used especially in sectors such as industry, housing and transportation. Energy is regarded as a first-degree requirement in meeting the basic needs of humanity, extending the average life span of the human and increasing the living standards. On the other hand, with the increase in population in the world, the increase in industrialization, the development of technology and the increasing commercial opportunities as a result of globalization increase the need for energy every day. On the other hand, the fact that a large part of this demand increase is obtained from fossil sources in certain regions of the world makes energy an important key point in determining policies and strategies not only at national level but also internationally. Above all, we are confronted with the realities that threaten the world, such as climate change and global warming, as demand for energy increases and is met.

Electricity is produced by the combustion of fossil fuels such as coal, fuel oil or gas. In water plants, the water circulating in the boiler section of the furnace turns into a very hot steam, and this steam activates the turbines connected to the alternators producing electric current. The first major oil crisis had been slowed down the construction of such thermal power plants in industrialized Western countries. However, this type of power plants continues to take charge in meeting the energy demand in many countries.

Although the Afşin-Elbistan Lignite Basin has a low calorific value, it is an important energy source with the greatest potential among lignite deposits in our country. The basin, located north of the Afşin and Elbistan districts of Kahramanmaraş province, has a measured resource of 4.6 billion tonnes. According to the other lignite fields, Afşin-Elbistan Lignite Basin has the mine site characteristic that should be evaluated with priority in terms of economical stripping ratio.

Two thermal power plants, which started production in 1984 and 2004, were established in Afşin-Elbistan region for the purpose of generating electrical energy, and low-calorie lignite coal in the region was introduced to the economy. It is estimated that both power plants contributed more than 16 billion TL (Turkish Liras) to the national economy. For this reason, the efficient assessment of coal with high electricity generation potential in the Afşin-Elbistan basin and its acquisition to the country's economy should be done in a plan

and program.

In the mining sector, various computer programs have been developed in order to evaluate all the available resources, to obtain maximum benefit from the operated mines and to fully determine the mineral reserves. One of these computer programs is the Turkey's first domestic product in this area called Netpro/Mine software. Netpromine has been developed in cooperation between Hacettepe University, Turkish Coal Enterprises (TKİ), and TÜBİTAK and it allows to make all technical designs from exploration to production.

Netpro/Mine has been developed to perform production designs by producing topographic terrain model, obtaining 3D orebody model using drill hole data and geological surveys made, performing resource and reserve calculations, determining which method is the most efficient, economical and environmentally friendly production method for ore deposit using terrain and orebody model.

To make an effective production planning, firstly it is necessary to determine the qualitative and quantitative characteristics of the lignite deposit. Qualitative properties are the properties that are result of geological and geophysical surveys; quantitative properties are defined as the properties that occur depending on the sensitivity of calculations such as quality and quantity. Usually, the first step is to complete research and exploration drillings and field surveys. The second step is the creation of a geological solid model showing the properties of the lignite deposit such as geometry, mineralization and its continuity, lignite quality and quantity by using the information obtained as a result of these surveys. The block model of an ore body is obtained by dividing the ore body into discrete small blocks. A single block in any block model can be defined by the 3-dimensional index notation system (i, j, k). While determining the dimensions of these blocks; factors such as quality changes, geological continuity, machine capacities, rock mechanics properties and data capacity of the computers should be considered.

2. PREVIOUS STUDIES

2.1. Studies Related to Netpro/Mine Software

In the M.Sc. thesis (Arıöz, 2011) named "Evaluation of Çöllolar section of the Afşin-Elbistan lignite field by using Netpro/Mine", 215 drill hole data taken from the area are used. The geostatistical evaluations, 3D orebody modelling studies, block modelling studies, thematic maps studies and detailed reserve calculations are performed by Arıöz with Netpro/Mine. The results of the study have been compared with the results of previous studies and the difference has been found to be acceptable.

2.2. Studies Related to Afşin-Elbistan Lignite Basin

The first studies in Afşin-Elbistan lignite basin were made on the coal investigation and coal reserve. Then, the feasibility, geophysical and geotechnical studies of the lignite coal field were conducted. Major studies carried out on this basin in the pasts are given below in chronological order.

The first studies in the region were conducted by Önen (1936). He examined the lignite deposits in the vicinity of Sivas, Malatya, Kahramanmaraş and Gaziantep and stated that coal formation exists in four different places around Kahramanmaraş province, but they do not have economic value.

Otto-Gold (1969), as a Consultancy-Engineering company, conducted detailed studies about the presence of Afşin-Elbistan lignite within the framework of German technical assistance and then conducted some other feasibility studies. For this purpose, the feasibility studies of Afşin-Elbistan lignite were carried out to find the lignite potential, formation, extent, potential reserve and properties by conducting surveys, drillings, analysis and some other studies between 1966 and 1969.

In the production planning and reserve calculation report of Kışlaköy Open Pit Mine prepared by Rheinbraun Consulting (1976), it was stated that 1.576 x 10^6 m^3 burden and interburden and 577,9 x 10^6 tonnes lignite exist in the area.

As a result of the hydrogeological studies carried out in the Maraş-Elbistan Çöllolar lignite sector, Özbek and Güçlüer (1977) found that the limestones in the foundation formations are aquifer and stated that there can be an effective amount of water that can

come from these levels to the operation area.

Aydoğan (1978) stated that 245 drillings are taken in the feasibility studies of the lignite deposit which is previously discovered in the Elbistan-Çöllolar sector and according to these drill data, it was stated that the coal thickness is decreased from east towards west and towards the northwest.

Gürsoy et al. (1981) found a 466 million-tonnes lignite reserve in the survey of the area between the Çöllolar, Hurman and Sinekli villages. From the samples taken from the lignite seam, the age of lignite was determined as Pliocene, and according to the Ostracods found in the gytia unit, the age of the sediments was determined as Plio - Pliostesen.

Perinçek and Kozlu (1984) studied the stratigraphy of the units in the area between Afşin, Elbistan and Doğanşehir and their relations with each other. According to the drilling data, the researchers found that there are thick coal seams in the area between Kızıldağ and Afşin.

Yörükoğlu (1991) carried out a study on geology-hydrogeology, planning criteria, coal production amount and machinery and equipment of Kışlaköy open pit mine.

The information about the basin of Afşin-Elbistan lignite was collected by Gökmen et al. (1993). According to the collection; they reported that pre-Neogene rocks forms the basis of lignite-bearing units and Neogene-aged sediments evolve in limnic facies.

Kürkçü, Ersoy and Ersun (1993) aimed to re-examine the Afşin-Elbistan Çöllolar (B) sector, which was determined by previous studies, by using geostatistical method. As a result of the studies, it was understood that there is no big difference between the amount of reserves obtained with the Contour-II and Reserve-Coal programs using the Taylor approach and the amount of reserves obtained from the 'GEO-EAS' program using the kriging method. The reason for this is that the coal deposits have a sedimentary structure. In other words, it can be attributed to the fact that it is different from the structuring of metallic mines, which have more application area with geostatistical methods. In this study, it was concluded that geostatistical method can be applied because it allows statistical examinations in order to minimize the error rate.

Öztürk (1994) revealed that there is hard rock problem in the Afşin-Elbistan open cast mine and shown the degree to which it affects the operation. It was revealed the role of hard rocks in the causes of excavator stopping. In addition, hard rock volumes were determined according to the benches by drillings conducted by TKI and Rheinbraun Consulting. Working techniques of excavators were investigated depending on the position of the hard

rock layer in the bench. As a result, methods that can be applied to remove those rocks were introduced. Machine park was selected accordingly, and specifications of the investments was made. In addition, the production of loadable material for rotary excavators by drilling and blasting was investigated. Cost and efficiency were investigated among the methods.

The study on the effect of block size selection on coal reserve estimation by Saydam (1995) was started with the creation of a database by transferring 305 drilling data including coordinate values (x, y, z) and coal thickness information to computer environment. Statistical analysis and variogram analysis of the coal thicknesses were made using this database. Using the data obtained from the variogram analysis, the coal thickness estimates of each block in the ore deposit divided into the theoretical blocks starting from 100 x 100 m up to 1000 x 1000 m were made by the Kriging Method with keeping the kriging radius constant. Then by keeping the block sizes constant, the effect of the kriging radius of 300-150 m, 600-300 m, 600-400 m, 800-400 m and 1200-600 m on thickness estimation were investigated. In the constant kriging radius, it was determined that the block size had little effect on the coal thickness estimation and that the thickness of the coal decreased when the kriging radius increased.

Kılıç (1996) carried out the stability analysis in the Kışlaköy area. It was emphasized that the most important layer for the stability of the slopes in the field is the clay layer just below the lignite, which has the lowest internal friction angle and cohesion, and that this layer is very critical when interacted with water. In addition, it was stated that a few meters of freshwater limestones on the coal layer had a negative effect on the working performance of bucket wheel excavators. Several aquifers (Quaternary, Gytia, Karstic Limestone, Kızıldağ Aquifers) were found to be rich in underground and surface water and negatively affect stability. It was stated in the benches where these aquifers are located that drainage of groundwater should be ensured by means of drainage wells.

A total of 305 drilling data on the Çöllolar area by Dağ (1997) were evaluated by geostatistical methods and a block model of the sector was produced. The final limits of the pit area were determined by a software developed for computer aided production, and production planning was made.

The reasons for the low performance of the Afşin-Elbistan (A) Thermal Power Plant by Ural (1999) were investigated and one of these reasons was determined as the insufficiency of the limiting parameters that determine the quality of lignite used as fuel. The two most important limiting parameters that determine the quality of salable coal are the

strength properties of Afşin-Elbistan lignite and the ratio between the calorific value and the ash content. In order to determine the strength of lignite, a method called corrected impact strength test was developed. The impact strength values of Afşin-Elbistan lignite vary between 9.8% and 56%. Salable lignite should have an average impact strength of 45% and a variance of 4%. Therefore, it was determined that lignite with different properties should be blended.

Ergüder et al. (2000) conducted studies to determine the dip and strike of the faults in this region within the scope of geophysical survey in the eastern final benches of the Kışlaköy Open Cast Mine. They found that the existing faults continued in the direction of the mining operation.

The C and E sectors in the west of the Hurman Streamlet in the Elbistan Lignite Basin were re-evaluated by Koçak (2000) with existing data. It was stated that there was 796 million tons of exploitable lignite reserves in the two sectors and if the drilling was done in the west of the basin, the reserve might increase.

The dynamic stability analysis related to the in pit waste dump areas of the Afşin Elbistan Lignite Kışlaköy Open Cast Mine was performed by Kılıç and Onur (2001) taking into consideration the earthquake importance of the region. With the dynamic stability calculation programs developed, analyzes were made by using Bishop, Carter, Winding methods to analyze three different water conditions and earthquake effects. As a result of these calculations, it was determined that there was not any failure hazard in benches of the dump area even in case of taking all probability and earthquake coefficient into account.

In their studies on the lignite reserve of the region, Koçak et al. (2003) determined that the proven reserve in the basin is 4.3 billion tons and the economically exploitable lignite reserve is 3.8 billion tons.

Ural and Yüksel (2004) identified some factors affecting the stability in their research on stability in Kışlaköy Open Cast Mine. These factors are that the high level of groundwater exists, the gytia unit is weak zone, clay unit under lignite could cause potential sliding failure and the shear strength values of the units in the study area are represented by the residual shear strength values.

In the Ph.D. thesis prepared by Mert (2010), primarily databases were prepared by analyzing geological data and drill hole data of the Afşin-Elbistan lignite basin. Then, numerical thematic maps used in mining activities were formed and combined under GIS. As a result, “the Production Tracking and Planning Information System” software was

developed with the ability to integrate both the graphical and non-graphical data and the logical and topological relationships between these data and thus to perform spatial analyzes. With the help of this software, it was made possible to watch them on the digital maps by placing GPS receiver on excavators. It was provided to monitor quality data such as production amount, calorific value, %humidity, and %ash simultaneously with the production of lignite, and to store stock records as database. In addition, it was revealed that it is possible to prepare land use maps or to determine the reserve-quality distributions in a defined area from the screen, by means of these databases which are important in terms of blending, and other processes and the information system developed.

In a master thesis of comparison of reserve modelling methods in a lignite seam prepared by Turhan (1993), calculation of seam thickness, coal thickness, ash content, moisture content, calorific value, surface elevation and base elevation values in a lignite bed were performed with different estimation methods. As a result of each point estimation technique, performances of these techniques were compared by evaluating statistical errors. In this comparison, it was concluded that kriging, inverse distance weighting, inverse square distance weighting and trend surface analysis methods have reached better performances than polygon, Taylor approximation and triangular methods.

3. MATERIAL AND METHOD

3.1. Material

The Kışlaköy sector of the Lignite basin located between Afşin and Elbistan districts of Kahramanmaraş province has been selected in this study. In the previous years, 280 core drillings have been opened by the General Directorate of Mineral Research and Exploration (MTA). The data obtained from these drillings have been evaluated with Netpro/Mine software which is one of the computer programs used in mining sector.

3.1.1. Field of Study

Afşin-Elbistan lignite basin is located to the north of Afşin and Elbistan districts of Kahramanmaras province. It is the basin with the largest reserve among lignite deposits in Turkey. At the same time, the basin has the most important potential in terms of electricity production in Turkey.

The exploration studies of the basin begun in 1966 in cooperation with the General Directorate of MTA and a German company and in 1967, abundant amount of lignite reserves with low calorie have been determined in the basin. Within the scope of the investment program of 1968, it has been decided to establish a thermal power plant by taking advantage of Afşin-Elbistan lignite. In 1973, the first unit of the power plant, which started to be constructed as four units of 344 MW each, has started production in July 1984.

Afşin-Elbistan A Thermal Powerplant, which is one of the biggest electrical powerplant of the Turkey and the world in those years, and shown as the biggest public investment done by Turkey, has produced 98 billion kWh of electrical energy for 24 years, and by this time, burned over 200 million tons of lignite coal. Afşin-Elbistan B Thermal Power Plant, which started construction in 2000 and started to produce electricity in 2004, has produced a total of 16 billion kWh electric energy to date.

Afşin-Elbistan lignite basin is divided into sectors A, B, C, D, E, F in order to determine the location of the lignite reserve due to the size of the reserve and the basin. There is a total of 4.6 billion tons of lignite in the basin. The lignite basin, which covers an area of approximately 120 km^2, consists of three main sectors, Kışlaköy (A), Çöllolar (B) and Afşin (C) and D, E and F sectors. Lignite reserves in the west of the Hurman Streamlet passing

through the middle of the basin have defined as C and E sectors, lignite reserve to the east are defined as A, B, D and F sectors. (Otto Gold, 1969).

The feasibility report of the basin was prepared in 1969 and it was decided to firstly start the lignite excavations in the Kışlaköy sector because of the fact that both depth of the open cast mine is low in the Kışlaköy sector and the opinion about that thermal power plants should also be founded in other sectors. (Özdemir, 2013).

3.1.1.1. Location and Boundary of the Study Area

Afşin-Elbistan lignite basin constitutes about 46% of lignite reserves in Turkey. For this reason, it has an important place in the energy production of our country. The general location of the basin and the Kışlaköy sector is shown in Figure 3.1.

The study area is located on the 1/25.000 scale Afşin L 38 a4 sheet. The mine site is in the northeast of Afşin district of Kahramanmaraş and 15 km away from the district center.

The lignite basin is divided into A (Kışlaköy), B (Çöllolar), C (Afşin), D (Kuşkayası), E (Çobanbey) and F sectors. Kışlaköy Open Cast Mine (AEL) is in A sector of the basin. Çoğulhan is in the west of the basin and Kışlaköy is in the southeast of the Afşin-Elbistan basin.

The area around the study area is bordered by Binboğa, Nurhak and Engizek mountains. The Ceyhan River, which is 3 km southeast of Elbistan and rises from Pınarbaşı and passes through the middle of Elbistan, is the lifeblood of the city. The important reach of the Ceyhan River in the basin is the Hurman Streamlet. The Hurman Streamlet starts from the west of the Afşin-Elbistan basin and leaves the basin to the south, and mixes with the waters of the Özdere, Karasu, Taşardı and the Atlaskaya Creeks.

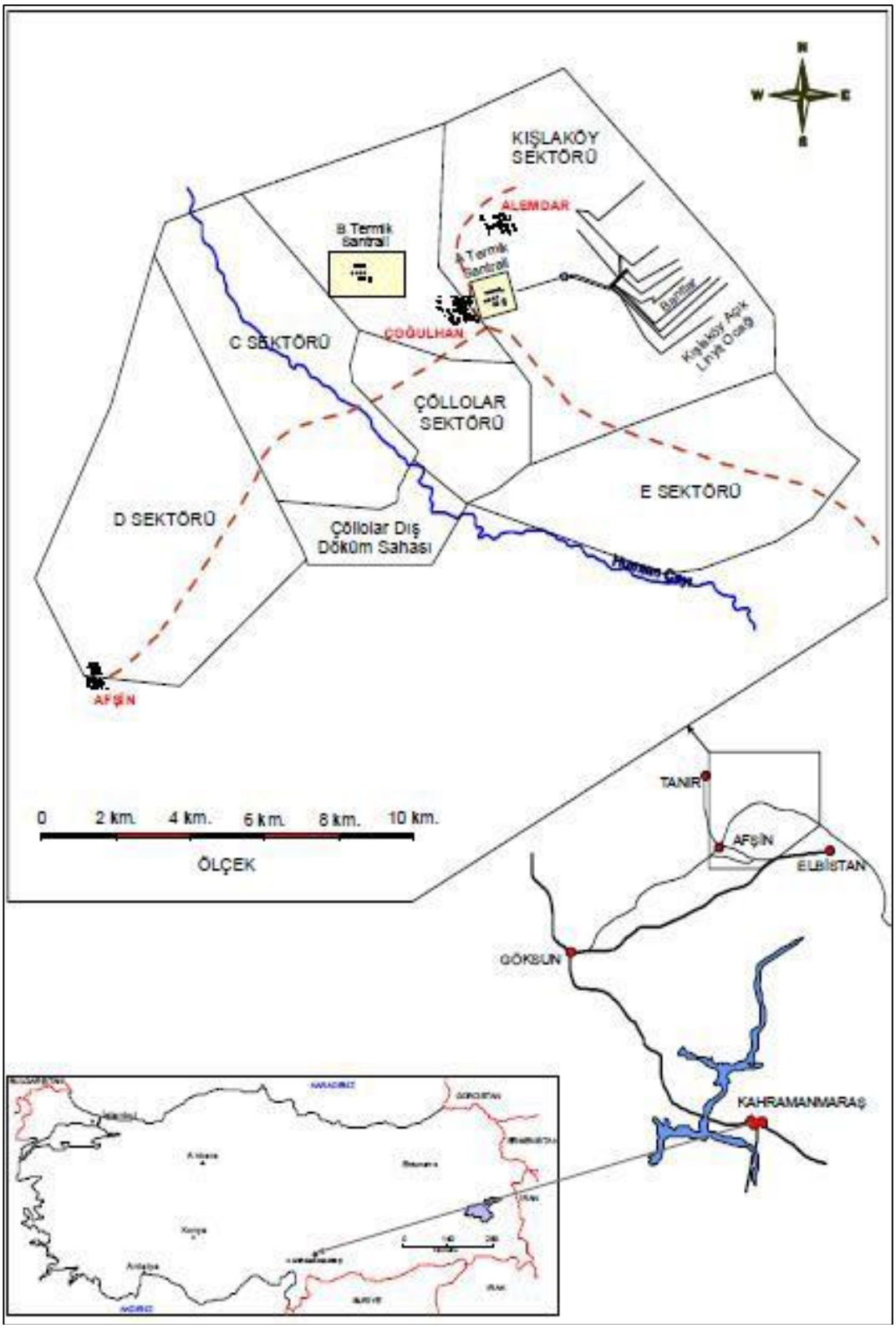


Figure 3.1. Location map of the study area (Mert, 2010).

3.1.1.2. Climate, Vegetation and Morphology

Afşin-Elbistan lignite basin is in the transition zone between the Mediterranean climate and the continental climate. The western part of the basin mostly reflects a transition type of the Mediterranean climate. A cold and humid winter season and a hot and dry summer season are seen. On the other hand, because of the more continental climate in the eastern part, the winter season is cold.

Precipitation occurs during March-April in spring and October-November in autumn. Northeastern winds blow from the north and southwestern from the southwest. Northeastern winds mostly brings snow and southwestern winds brings plenty of rain to the area.

In the semi-arid climate, plants and trees tend to grow slowly. Juniper, Oak, larch and cedar species which are semi-arid climate-resistant tree species exist in the region. There are willow and cypress trees on the sides of the stream. The surrounding mountainous areas are covered with limestones and this region is bare in terms of vegetation. Wheat, beet, beans, potatoes and sunflowers are grown in the lowland. Although stock breeding is underdeveloped, beef cattle and sheep are cultivated.

There are plateaus lined up in various elevation steps between the high parts of the mountains, which limit the Elbistan area to the north and east, and the lowland. These plateaus located between 1500-2000 meters carry the effects of the Mediterranean climate through the Ceyhan Valley. The study area is in Afşin- Elbistan Lowland and has an altitude of 1200 m. Kızıldağ, which is located at the east of Kışlaköy open pit mine and limited the pit area, has a altitude of 1700 m.

3.1.1.3. Exploitation Method

In the facility, the overburden and coal, which are excavated by the bucket wheel excavators (BWE), are sent to the belt transfer point via the belt conveyors. At the belt transfer point, the bands coming from the excavation area can be easily adjusted by means of moving drums to a suitable belt leading to the stockpile. The lignite excavated by BWEs is sent to the stockpile and the overburden is sent to the outer or in pit dump area.

BWEs can excavate approximately 3,000 m^3/hour on-site and have the capacity to excavate up to 30 m and 4 m below in height. According to the situation BWEs can make excavations in steps up to the desired height in the same bench. The bench heights in the

excavation area are tried to be kept at a maximum of 18-20 m in proportion to the bucket wheel radius (bucket wheel diameter = 12.25 m) in terms of excavation efficiency. The belt conveyors have a width of ,800 mm and a speed of 5.2 m/s. As the bench proceed, the belts carrying the overburden from the excavator are shifted either by an angular or parallel belt slider.

3.1.1.4. General Geology of the Basin

Afşin-Elbistan Basin is a closed basin formed during the elevation of the Taurus Mountains at the end of the Alpine Orogenesis and approximately 1150 m above sea level. Permo-Carboniferous old limestones are the base of the area. Kızıldağ, located in the northeast and east of the area, consists of pinkish, whitish crystalline limestones and is of Upper Cretaceous age. There are more Neogene formations in the basin. The lignite formation in the western part of the basin also occurred at this time (Figure 3.2-3).

Figure 3.2. A view of the clay basis (Mert, 2010)

Figure 3.3. A view of the lignite horizon; dipping bed (Mert, 2010)

The Neogene formation outcrops to the south of Kızıldağ in the form of Plio-Pleistocene aged formations and is covered by Quaternary sediments in other places (Figure 3.4-5).

Stream sediments as like pebble, sandy clay and brownish-red loam is located above dolomite and limestone units which composes the basin bed in the Kışlaköy Open Cast Mine. These sediments multiply upward into fine-grained classical materials and continue as a thick clay layer under coal. The clays are turned into marl to the southwest and sometimes completely turn into marns. Apart from the boundary of the coal field, these layers are sandy, and the gravelly materials show transition with slope wash.

The structural geology of the basin is mainly determined by two factors. These are Alpine orogenesis and younger sedimentations during Pliocene. Alpine orogenesis creates normal and reverse-slip faults on the basin floor and sides. The Pliocene graben also follows these weak zones along faults in the northwest-southeast direction. The weak zones in the north of the basin are turning towards the northwest. These faults, which are almost parallel, are concentrated in the northeast of the Kışlaköy open pit mine and form the synthetic fault bench. For this reason, there are occasional auxiliary sections in the area. Strike-slips of the faults affecting the northwest of the open pit mine are around 50 m. In the mining area, coal layers are laid between 3-20 m. The dip of the faults is 60-70 degrees in the southeast direction. In the area that is exposed to tectonism only in the northeast, the dip angle reaches to partially 15 degrees (Öztürk, 1994).

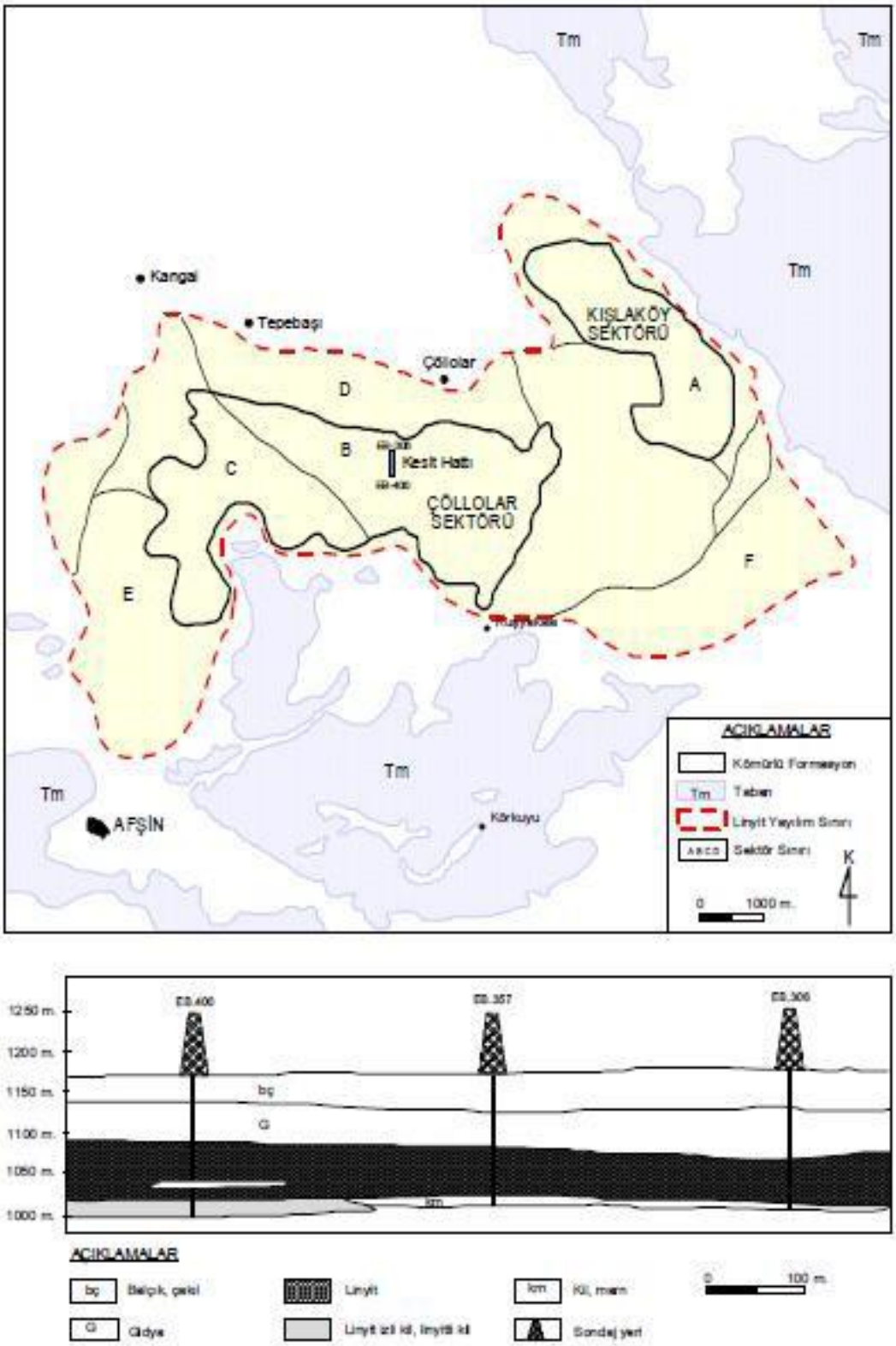


Figure 3.4. Generalized geological map and cross-section of Afşin-Elbistan region and its surrounding (Gökmen et al., 1993; Mert, 2010).

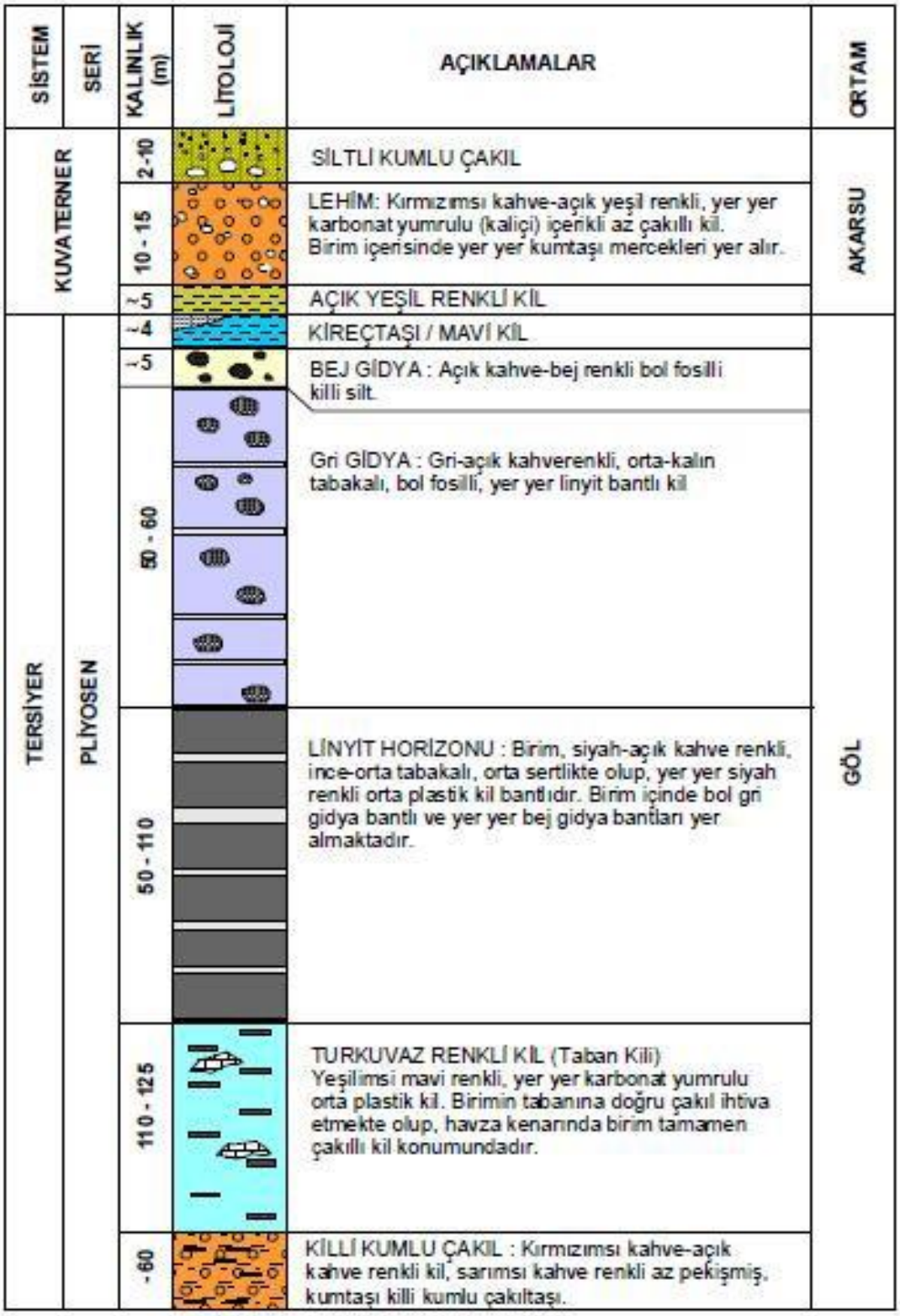


Figure 3.5. Generalized stratigraphic vertical section of the study area (Akbulut et al., 2007: Mert, 2010)

3.1.1.5. Hydrogeological Structure of the Basin

Small streamlets such as Çoğulhan and Demirdere affects the surface hydrogeology of the area. Two large channels, called the eastern channel and the western channel, have been constructed to control the surface water from the western and northern side slopes of Kızıldağ. The eastern channel collects both surface waters and pumped water from the karstic field. In addition to the surrounding water, the western channel collects water pumped from the upper aquifer and gytia wells.

Underground water drainage is as follows. The gytia which is usually above of the coal and sometimes intercalated with charcoal, usually contains 50-70% water. The water in the gytia is characterized by a confined aquifer. It shows an elevation of about 2-3 atm from the upper level. It has less permeability and does not release water. Due to the lack of permeability, the underground water flow in the gytia aquifer is very slow.

Because the water contained in the quaternary pebbles of the upper aquifer is not abundant and because of its permeability, the gytia and the upper aquifer are drained from the same water well. Due to the lack of permeability, drainage of gytia is very difficult. It is very difficult to excavate and pile up gytia formation which is not sufficiently purified from the water. For drainage of Gytia, 200 drainage wells with 125 m spacing and 1,000 mm diameter have been opened in the northwest of the site. Flow rate of the gytia wells are 0.3-0.5 lt/sec. For this reason, low capacity submersible pumps have been installed in the wells. (Öztürk, 1994).

3.1.2. Drilling Data

In Afşin-Elbistan lignite field that is the study area, 280 drillings have been conducted by Mineral Research and Exploration (MTA) in the previous years. The distribution of drilling locations is shown in Figure 3.6. Drilling data consists of drilling id’s and 3-dimensional coordinate values (X, Y, Z) of drilling points.

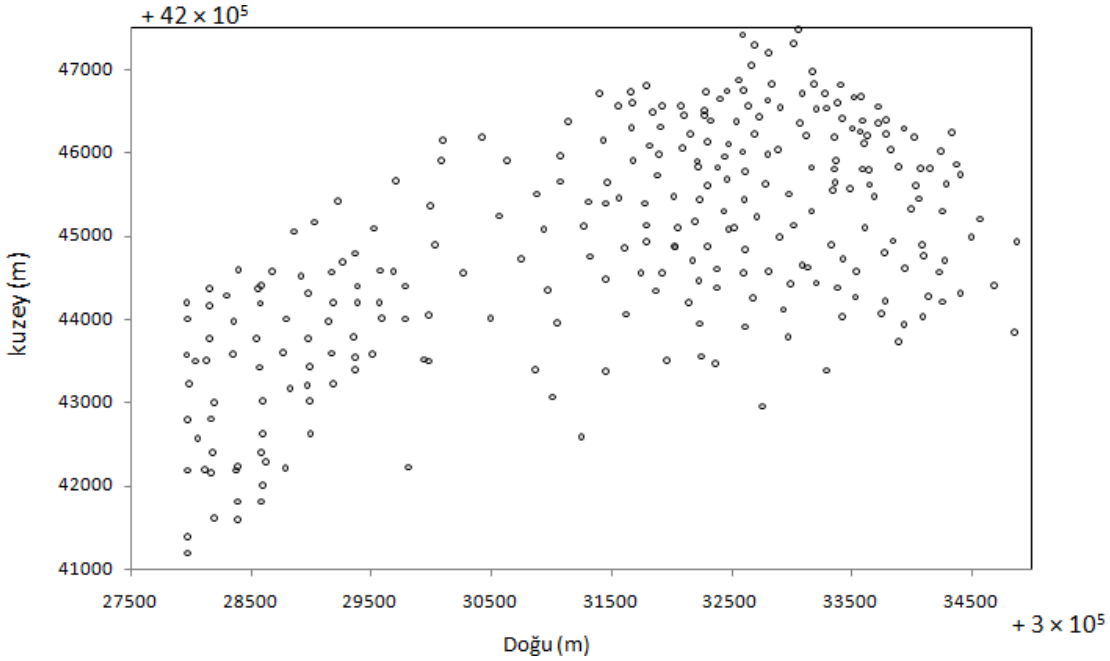


Figure 3.6. Drill hole locations

3.1.3. Netpro/Mine Software

NetCad has launched Turkey's first domestic product in December 2010 called Netpro/Mine that enables all the technical design from the exploration stage to production stage with the collaboration with Hacettepe University Department of Mining Engineering, Turkish Coal Enterprises (TKİ) and TUBITAK. Netpro / Mine software is still being developed by related institutions. Netpro/Mine, which is developed with 100% native information, is available in Turkish and English versions.

Netpro/Mine is a NetCad module that realizes all the stages of orebody modelling and mining applications. The software gathers all the tools such as data entry, creating digital terrain model, 3D viewing and digitization, geological solid modeling, block modeling, geostatistical resource and reserve estimation, mine design and production planning under Netcad's roof.

It is thought that it will be a preferred software by Turkish mining sector in the near future due to the fact that it was developed locally imposing the language advantage (Özdemir, 2013).

3.2. Method

3.2.1. Entering Drill Hole Data

To create a project with Netpro/Mine, 4 database tables should be available with at least the following columns.

- Collar; hole id, depth, X, Y, Z
- Survey; hole id, depth, from, to, dip, azimuth
- Lithology; hole id, depth from, depth to, lithology
- Samples; hole id, depth from, depth to, sample values (grade, calorific value, ash content, moisture, etc.…)

Table columns are matched with each other by selecting the database table prepared in CSV format, transfer type, bracket style, and then table information is transferred to the empty access (*.mdb) file by pressing the "OK" button. After each file column are matched with the corresponding column to be added in the "Column Pairing" section, matching should be confirmed by pressing "Add" button. When all column matching is done with this method, data transfer should be performed by "OK" command. This should be done separately for each table. The tables to be transferred are given below and the transfer windows are given in Figure 3.7-10.

- Collar
- Survey
- Lithology
- Raw Sample

3.2.2. Compositing

The cores taken from the drillings are different in length. Compositing (equivalent sample length) operation is applied to convert cores of different lengths into cores of the same length. Resource or reserve estimations are made on composite data.

The operation can be made by either clicking right mouse on “Composites” layer in the data catalog and selecting “Add Composites” command or clicking right mouse on the project and then selecting “Add Composites” command (Figure 3.11).

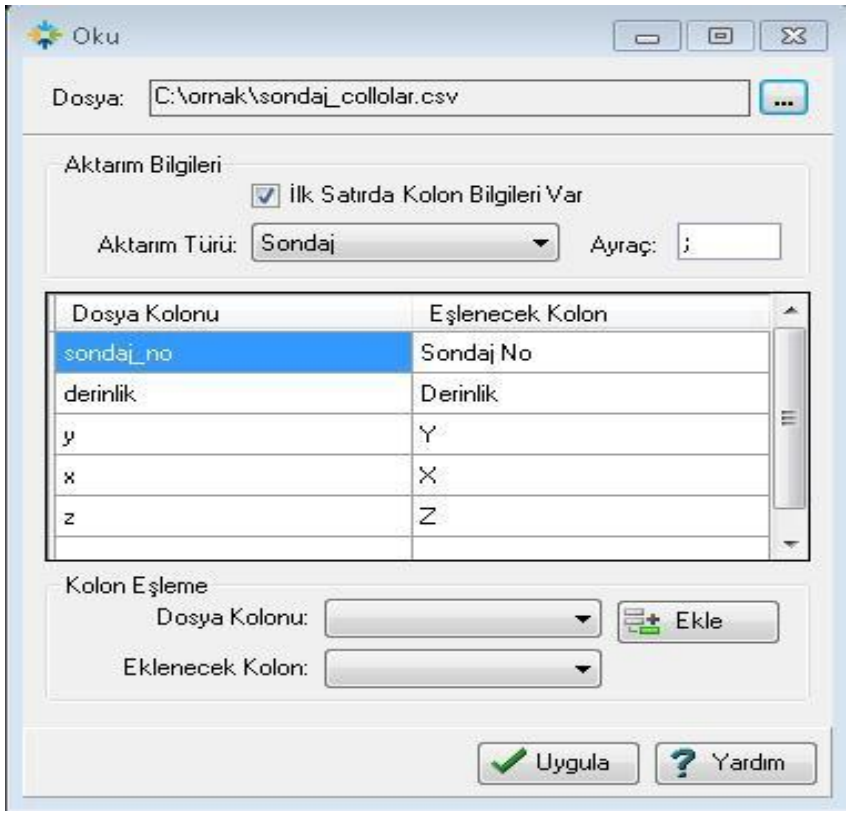


Figure 3.7. Importing collar table

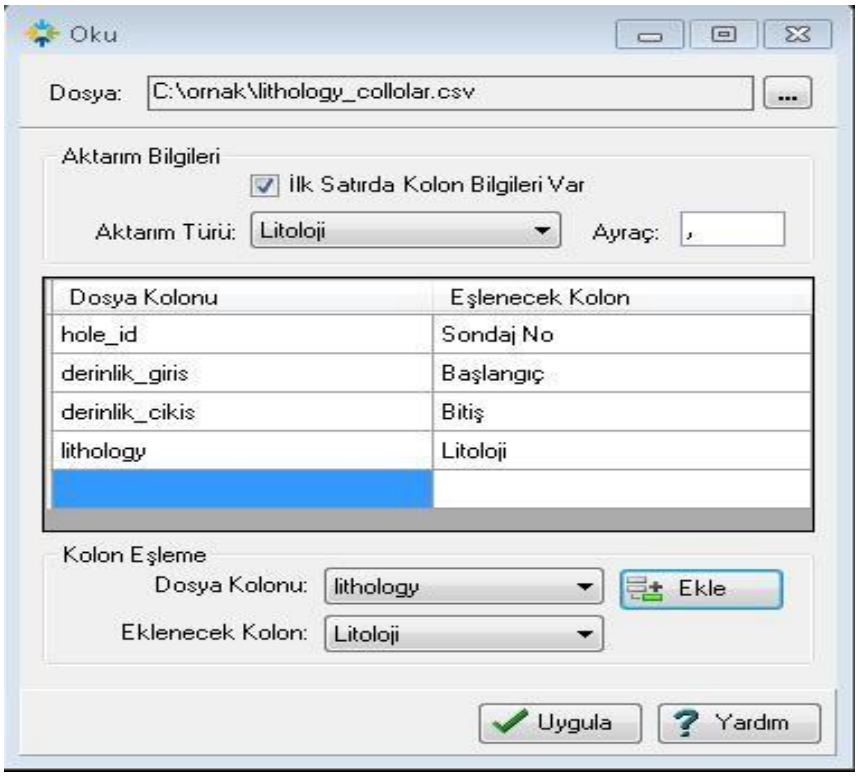


Figure 3.8. Importing lithology table

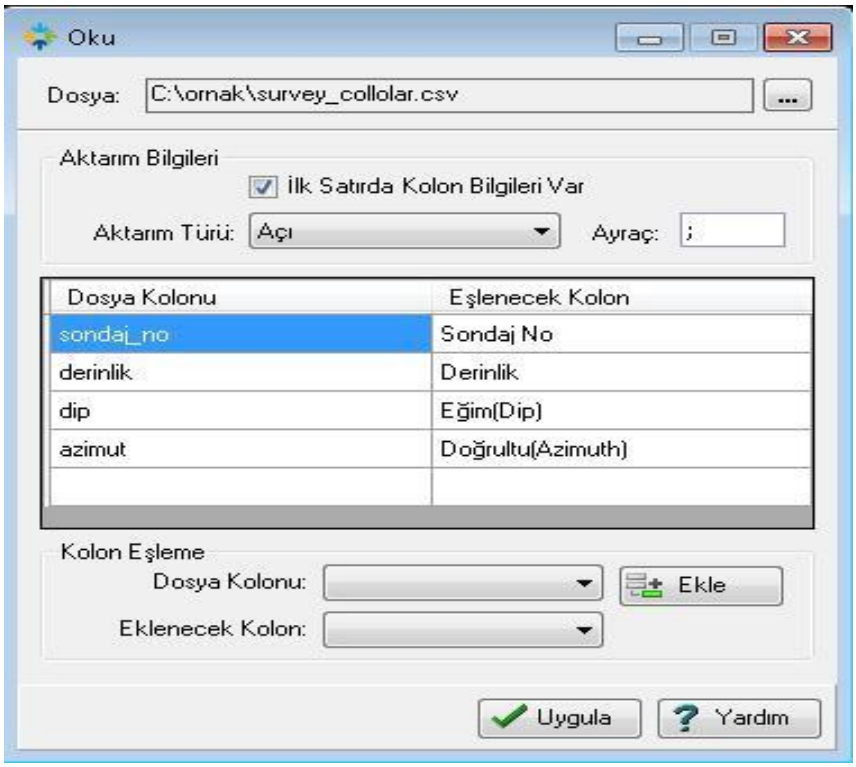


Figure 3.9. Importing survey table

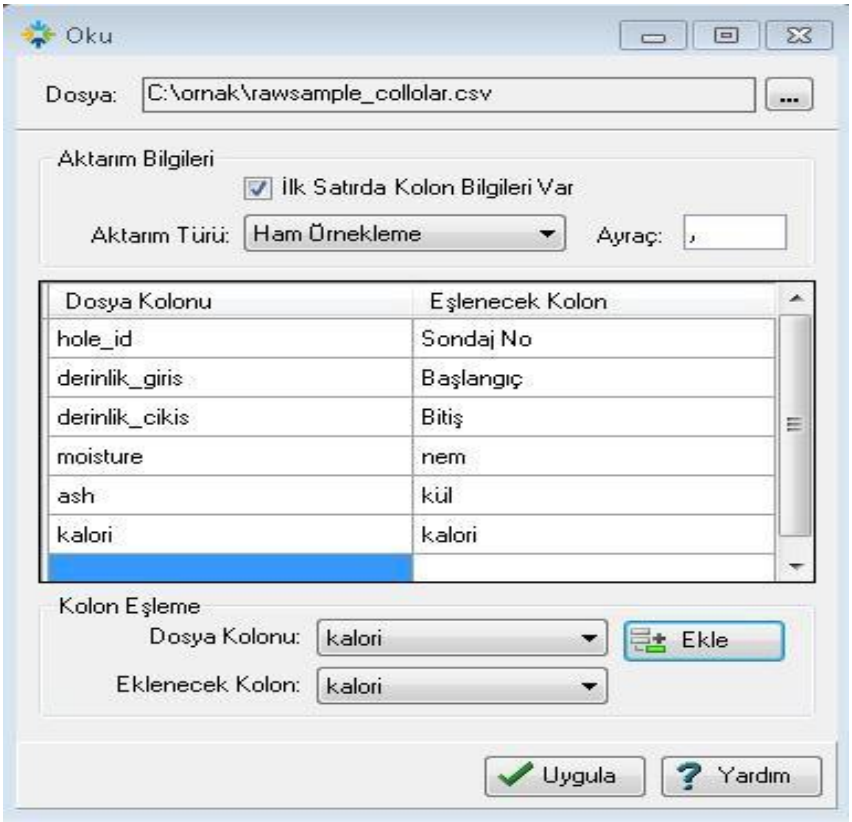


Figure 3.10. Importing raw sample table

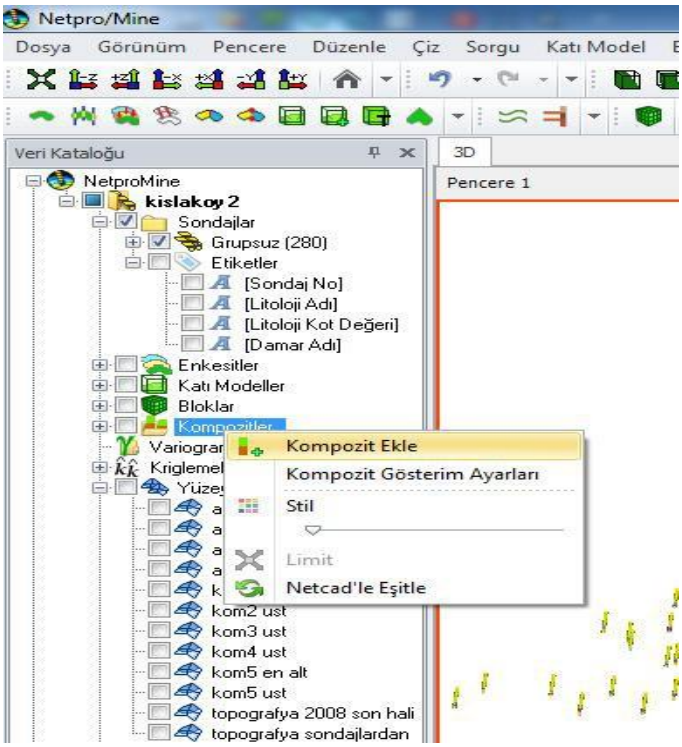


Figure 3.11. Access to add composite menu

Suitable parameters are entered from the "Add Composite" window opened. (Figure 3.12).

Composite Length: It is the unit length of the composites to be formed. As a rough approach, the composite length can be selected slightly longer than the average length of the samples.

Acceptance Percentage: Samples with a shorter length than the composite length can be accepted during compositing. Acceptance percentage is used to determine the smallest acceptable sample length. Suppose that the selected composite length is 3 meters. If the acceptance percentage is 50%, this means that samples up to 1.5 m in length (3 m x 0,5 = 1.5 m) will be considered among the 3 m composite samples.

Compositing Using Lithology: The compositing operation can be done by using lithology information. In this case, one or several lithological units are selected and the parts to be composited are specified. If "With Lithology" option is passive, the compositing operation are performed by taking into consideration all lithological units.

Core Recovery: It is expressed as the percentage of the ratio of the total length of the core parts recovered to length drilled.

Specific Weight: It is defined as weight per unit volume (NETCAD, 2012).

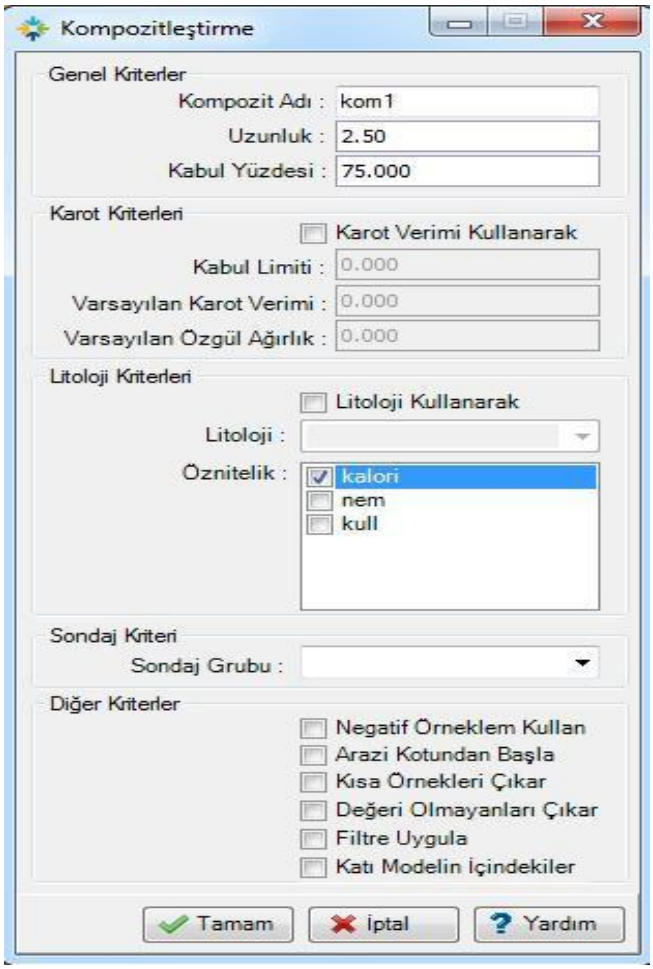


Figure 3.12. Compositing values

According to the parameters given at the end of the composite, "Raw Sample Records" are rearranged and transferred to "Sample Records". (Figure 3.13-14).

Composites created can be viewed by activating “Show Composites” option with the mouse right click button on project in 3D screen (Figure 3.15).

3.2.3. Surface Modelling

Top, middle, bottom and lowermost surfaces of the seams can be formed by estimating points with the methods like nearest neighborhood, inverse distance, kriging, or by making no estimation (Figure 3.16). In addition, as shown in Figure 3.17, the user can select the desired lithology to create the surfaces of that lithology (NETCAD, 2010). A surface thus obtained is shown in Figure 3.18 as an example.

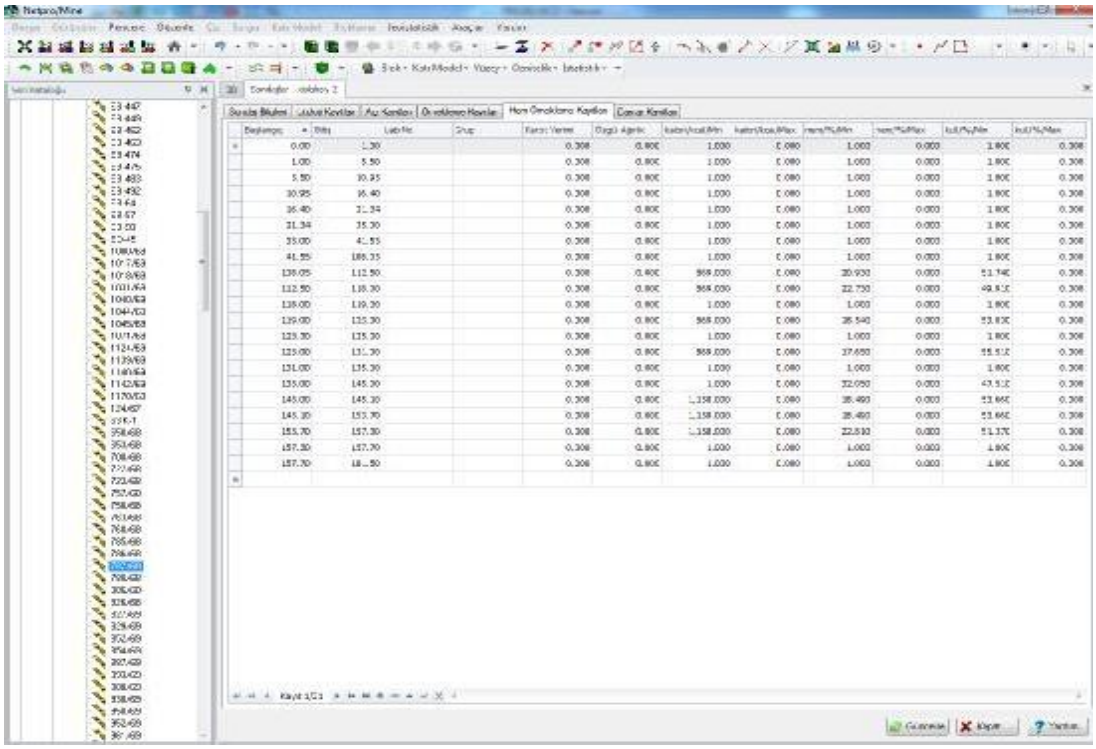


Figure 3.13. Values before compositing

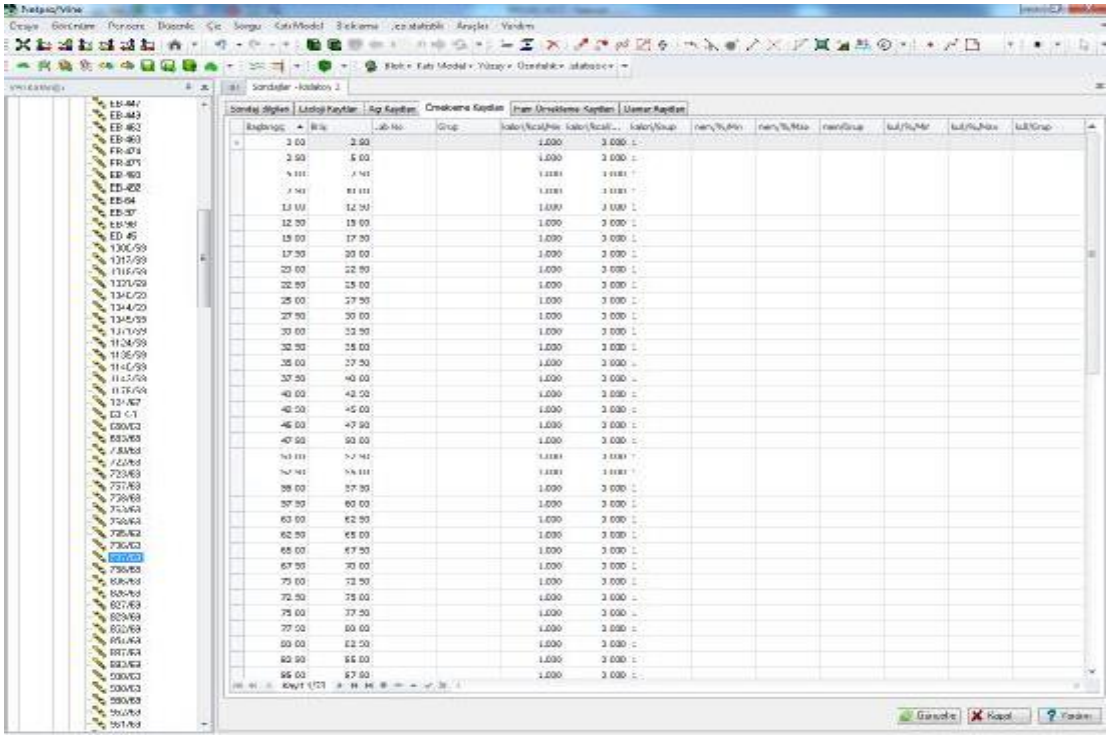


Figure 3.14. Values after compositing

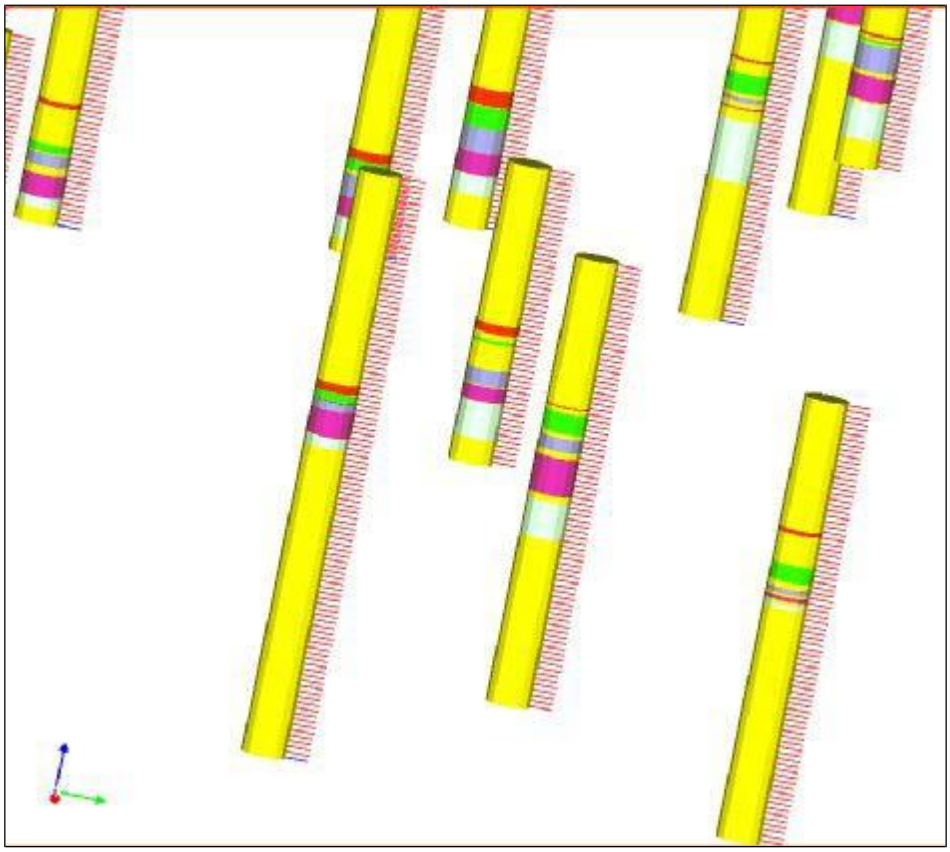


Figure 3.15. Composite view

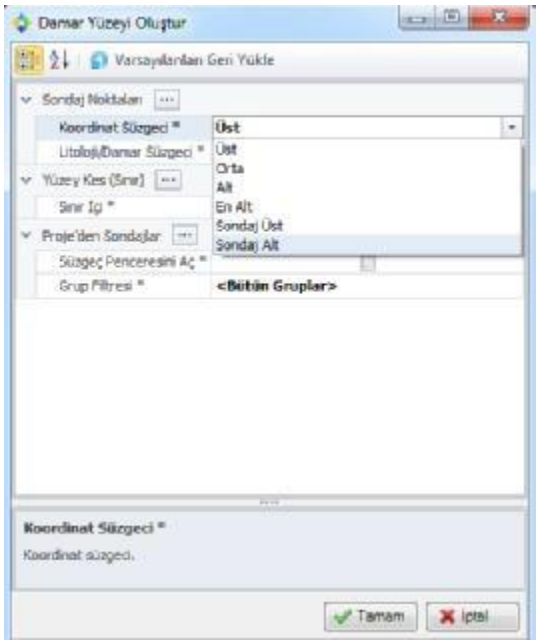


Figure 3.16. Coordinate selection table

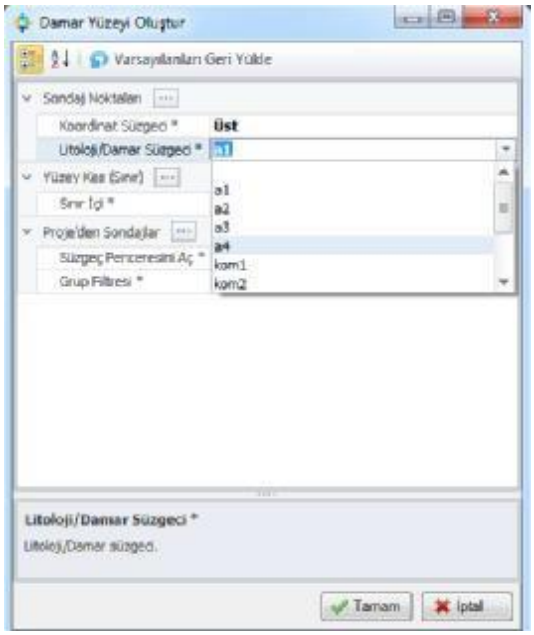


Figure 3.17. Lithology selection table

The program provides the user with information such as surface area of the generated surfaces, number of triangles, average elevation, minimum and maximum coordinate values (Figure 3.19).

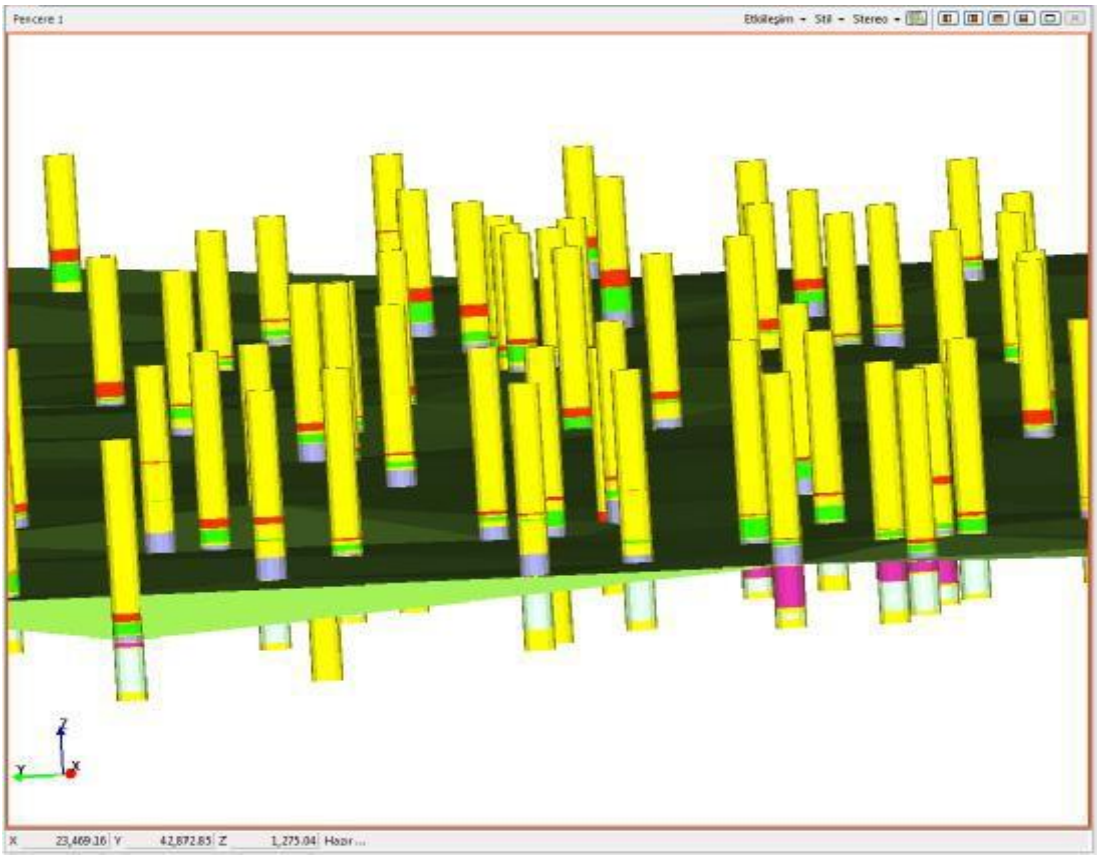


Figure 3.18. Upper surface view

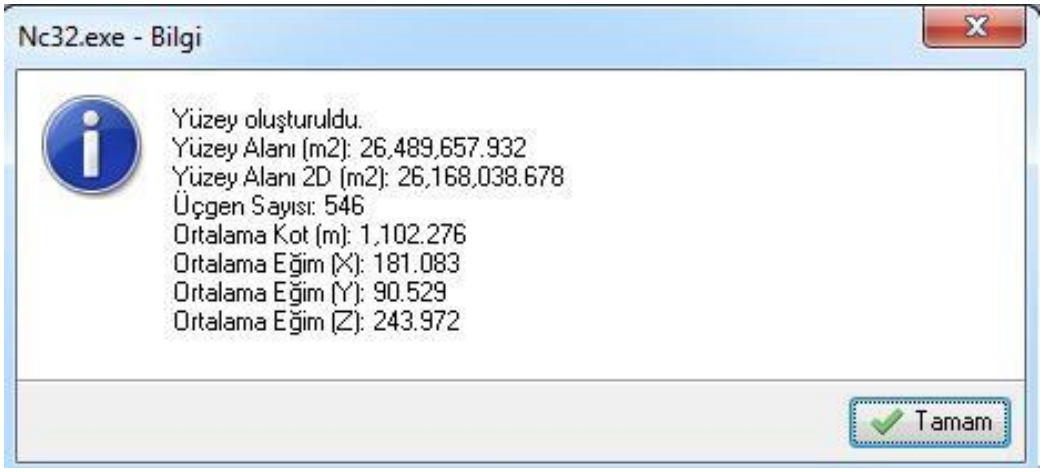


Figure 3.19. Generated surface information

3.2.4. Cross-Section Modelling

Cross-sectioning is performed throughout the sections for the correlation and digitization of the sections taken throughout the field (Figure 3.20).

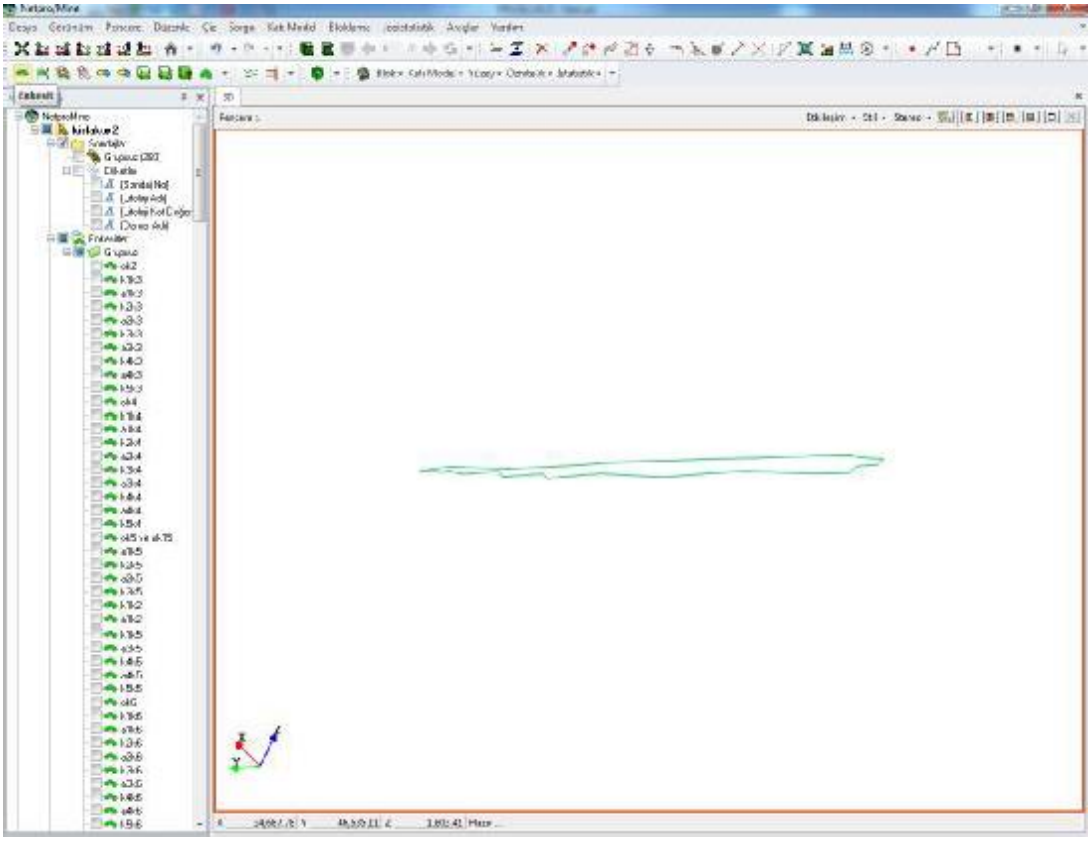


Figure 3.20. Creating cross-sections

The right mouse button must be used to terminate the digitization process. The lines created because of the digitization process are kept under the “Cross-Sections” layer in the data index. By using the “Properties” button that appears with the right mouse click on any cross-section, it can be learnt the number of cross-section and number of points in the layer (Figure 3.21-22).

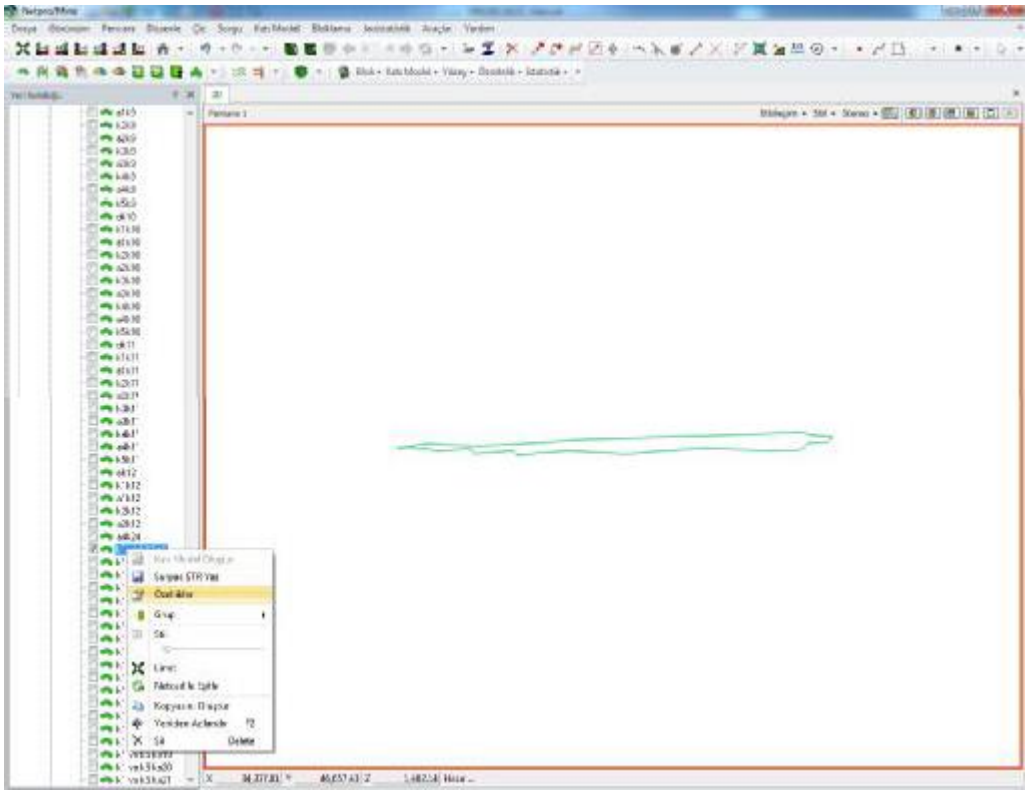


Figure 3.21. Access to the cross-section properties

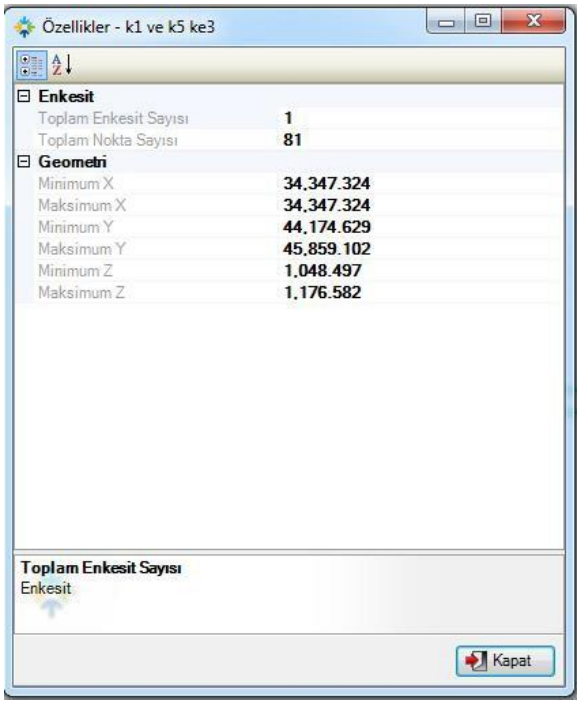


Figure 3.22. Cross-section properties

3.2.5. Solid Modelling

There are many different solid modelling techniques applied in practice. Although the application methods of these techniques are different, they do the same operation. There is no specific standard in computer softwares developed for 3D modelling. Different softwares can use different techniques. In the selection of the modelling technique to be used in the solid modelling process, many parameters such as the type of ore in the ore deposit, the bedding type of the ore deposit and the geology of the study area should be taken into consideration. After these parameters are evaluated, solid modelling can be performed accurately and reliably. Apart from this, the person who will perform the modelling should have knowledge and experience about modelling methods (Özdemir, 2013).

The Netpro/Mine mining software used in the study has three different solid modelling techniques, including solid modelling from cross-section to point, solid modelling from cross-sections and solid modelling between surfaces.

3.2.5.1. Solid Modelling from Cross-Sections

After digitization of all cross sections is completed, the cross sections that will form the model is introduced to the software respectively by using the Model → Solid Model command. The solid model is created according to the cross-sectional sequence introduced by the user (Figure 3.23).

After all the cross sections are introduced, the right mouse button is used to create a model (Figure 3.24-25).

Create Intersections: When creating a solid model, it serves to create virtual inter-sections between two cross sections.

Normalize Cross-sections: It is the same digitization process made in the cross-section menu.

Maximum Point Distance: It is the maximum distance considered between two points.

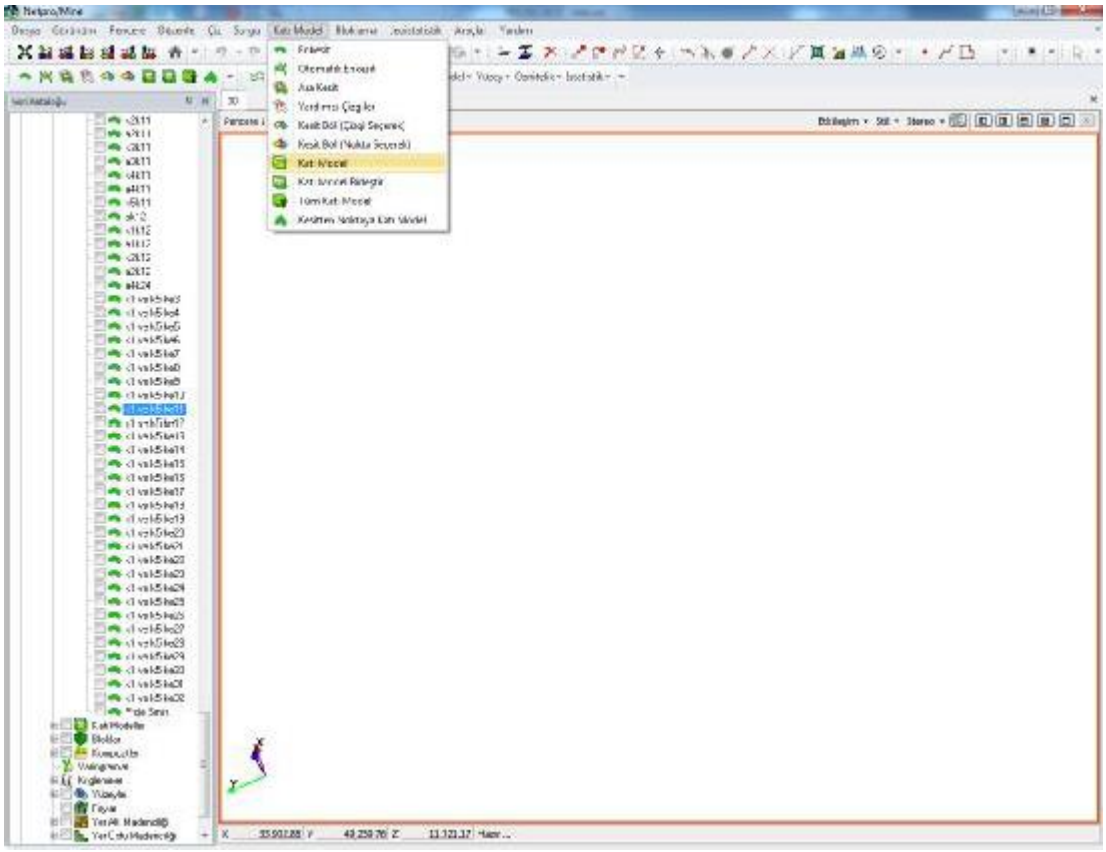


Figure 3.23. Access to the solid modelling options

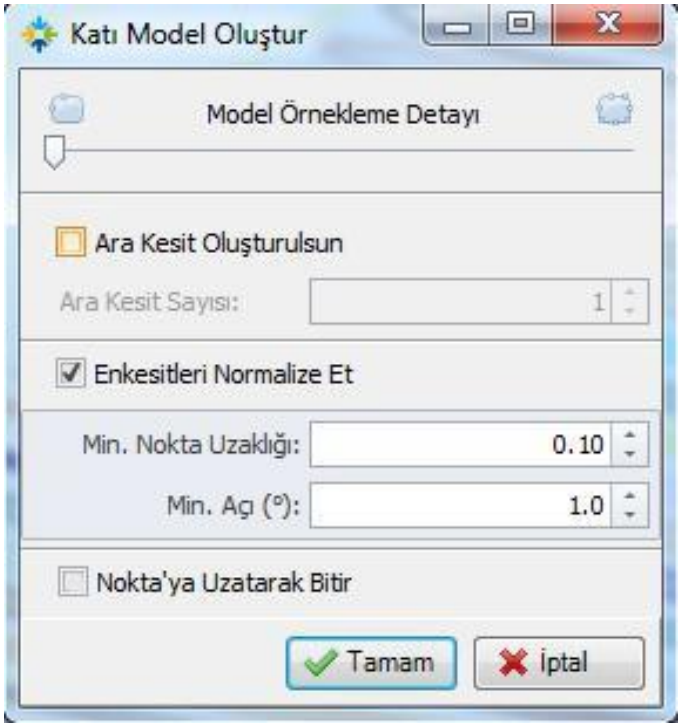


Figure 3.24. The window showing properties of the solid model to be created

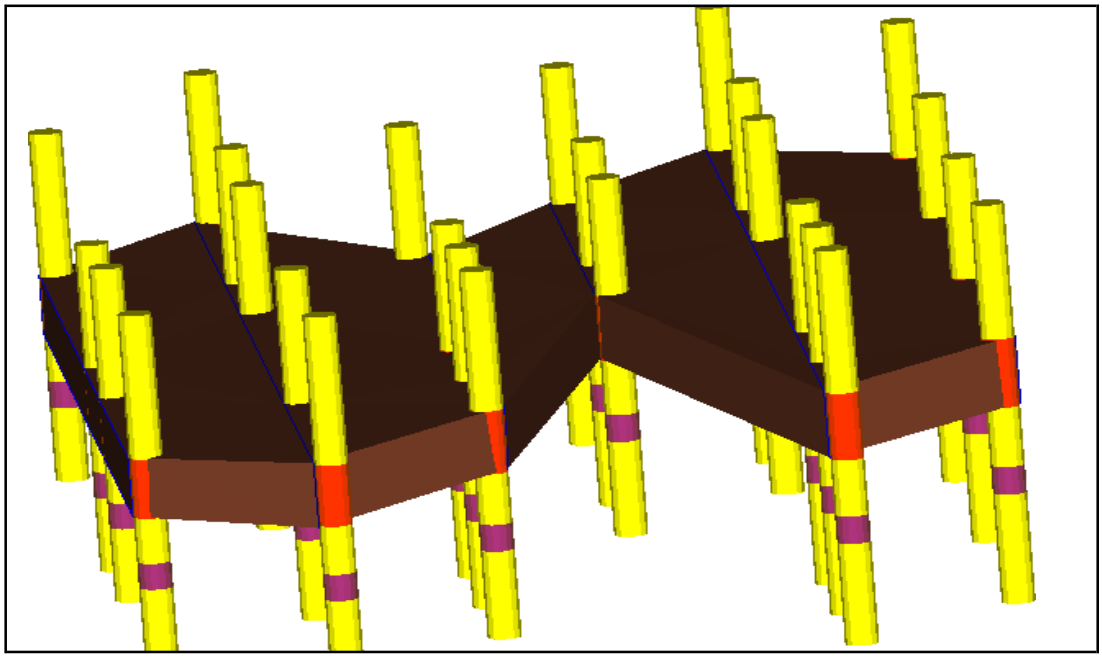


Figure 3.25. Solid model view (Özdemir, 2013)

3.2.5.2. Solid Modelling between Surfaces

To create a solid model between two surfaces, Solid Model → Solid Modelling Between Surfaces option is selected from the menu (Figure 3.26).

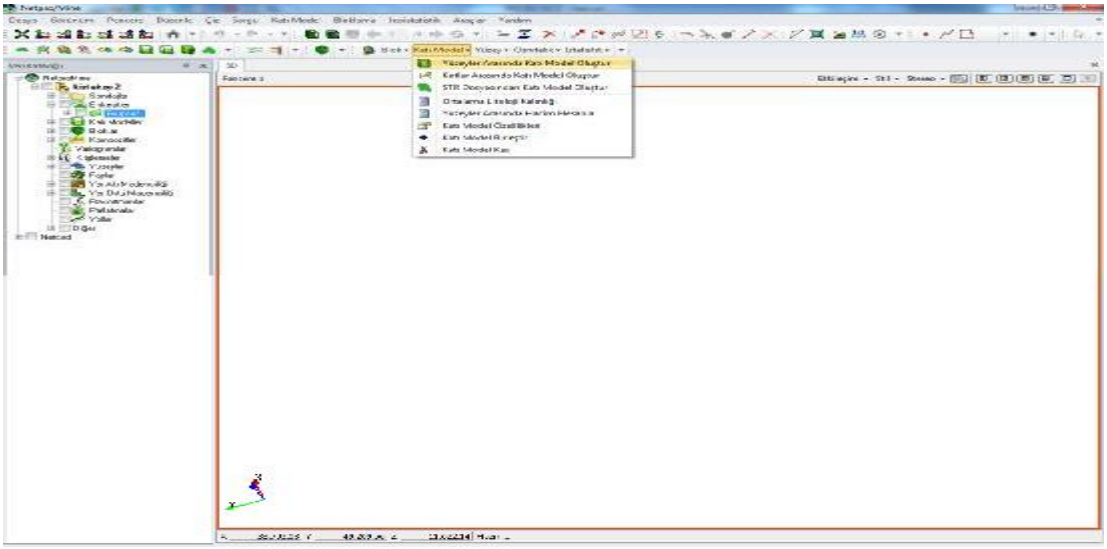


Figure 3.26. Access to the solid modelling between surfaces command

Solid surface modelling method consists of the 3D modelling of two surfaces (top and bottom) which determine the boundaries of the ore deposit and generating the solid model by modelling between these surfaces. The advantage of this method is that the boundaries of the ore deposit are determined by means of the surfaces obtained during 3D modelling.

Figure 3.27 shows the lower and upper surfaces obtained by using drillings, starting and ending point of the ore. In Figure 3.28, the appearance of the solid model obtained by the method of solid modelling between surfaces is given.

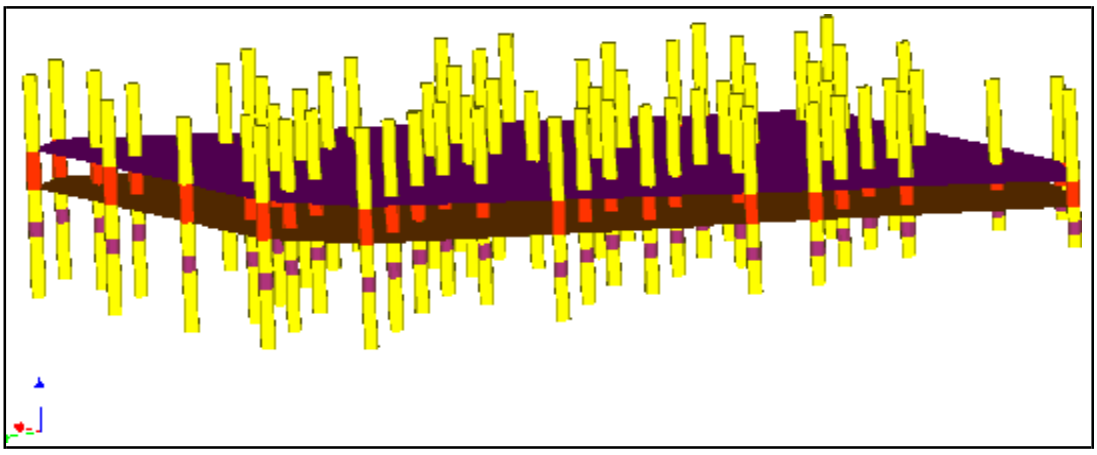


Figure 3.27. The view of the upper and lower surfaces created to produce the solid model (Özdemir, 2013)

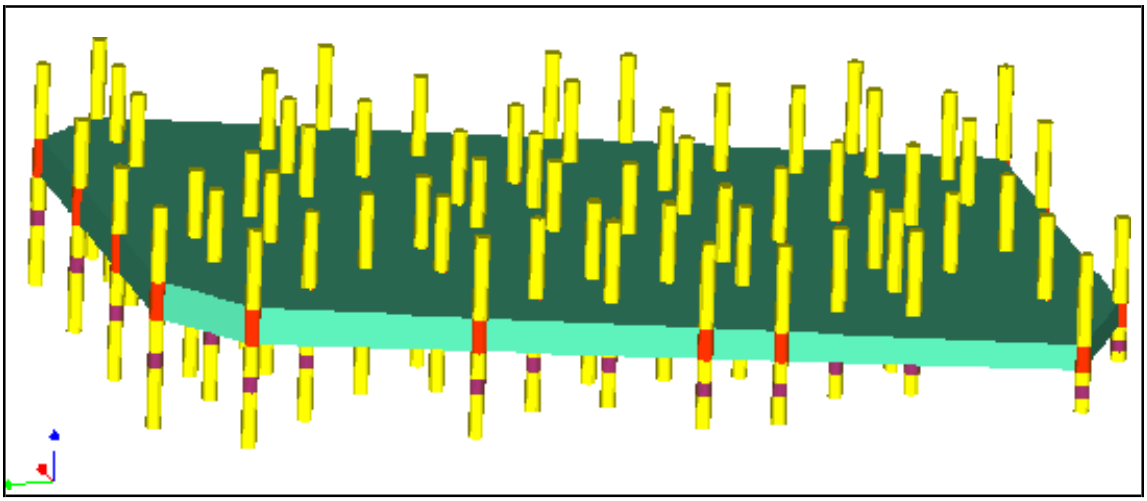


Figure 3.28. The view of the solid model obtained by the method of solid modelling between surfaces (Özdemir, 2013)

3.2.6. Block Modelling

The block model of an ore body is obtained by dividing the ore body into small discrete blocks. A single block in any block model can be defined by 3D index notation system (i, j, k). This definition is generally expressed in 3D. While determining the dimensions of these blocks; factors such as quality changes, geological continuity, machine capacities, rock mechanics properties and data capacity of the computer should be considered (Mert, 2004).

In 3D block model, geological characteristics, metallurgical properties and geomechanical parameters are assigned to each block. The assignment of these parameters is done by one of the interpolation methods such as geometric, inverse distance weighting or Geostatistics (Arıöz, 2011).

3.2.6.1. Block Modelling within the Solid Model

This process can be done by using the “Blocking” command that appears with the right mouse click on the layer of the solid model to be blocked in data catalog (Figure 3.29).

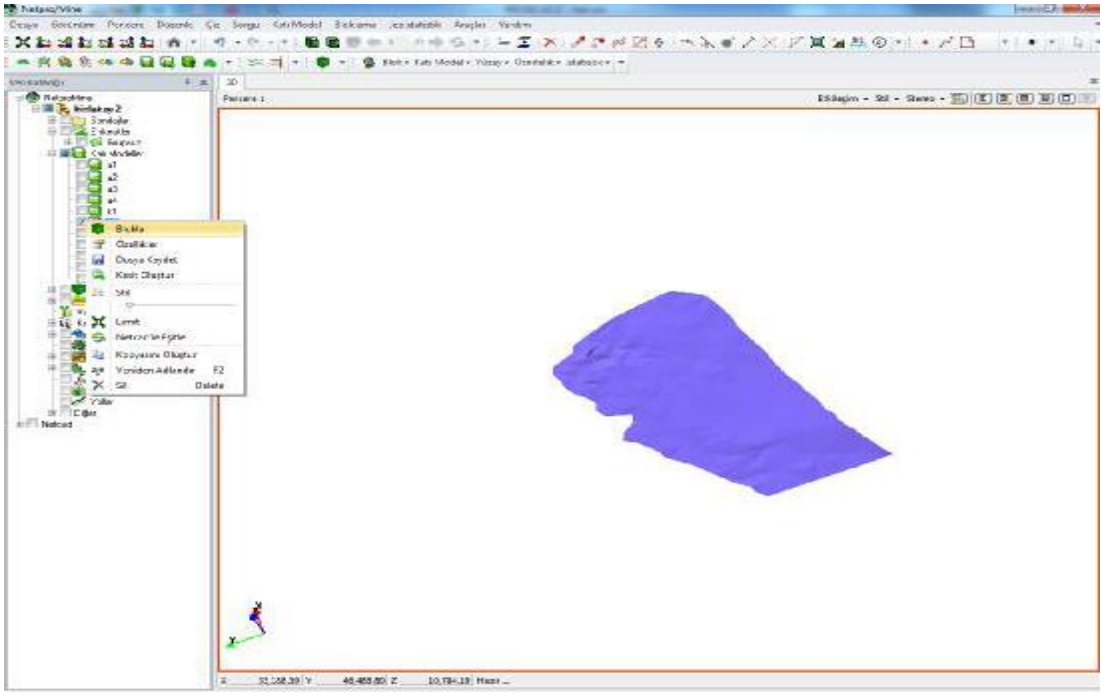


Figure 3.29. Access to blocking command

The process is performed with pressing “Okay” button by entering the parameters like block sizes (X, Y, Z) and if required, block angles and variable-size block parameters to the opened “Blocking” window (Figure 3.30-31).

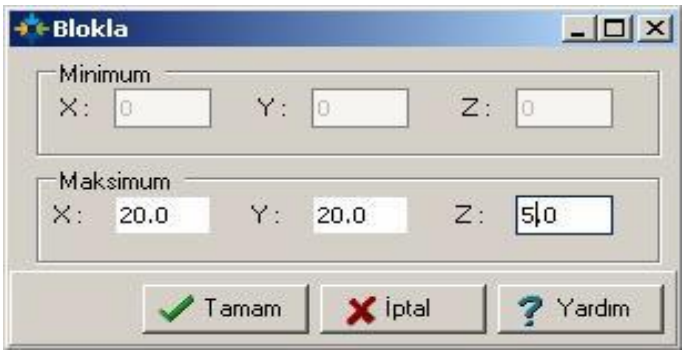


Figure 3.30. Block parameters table

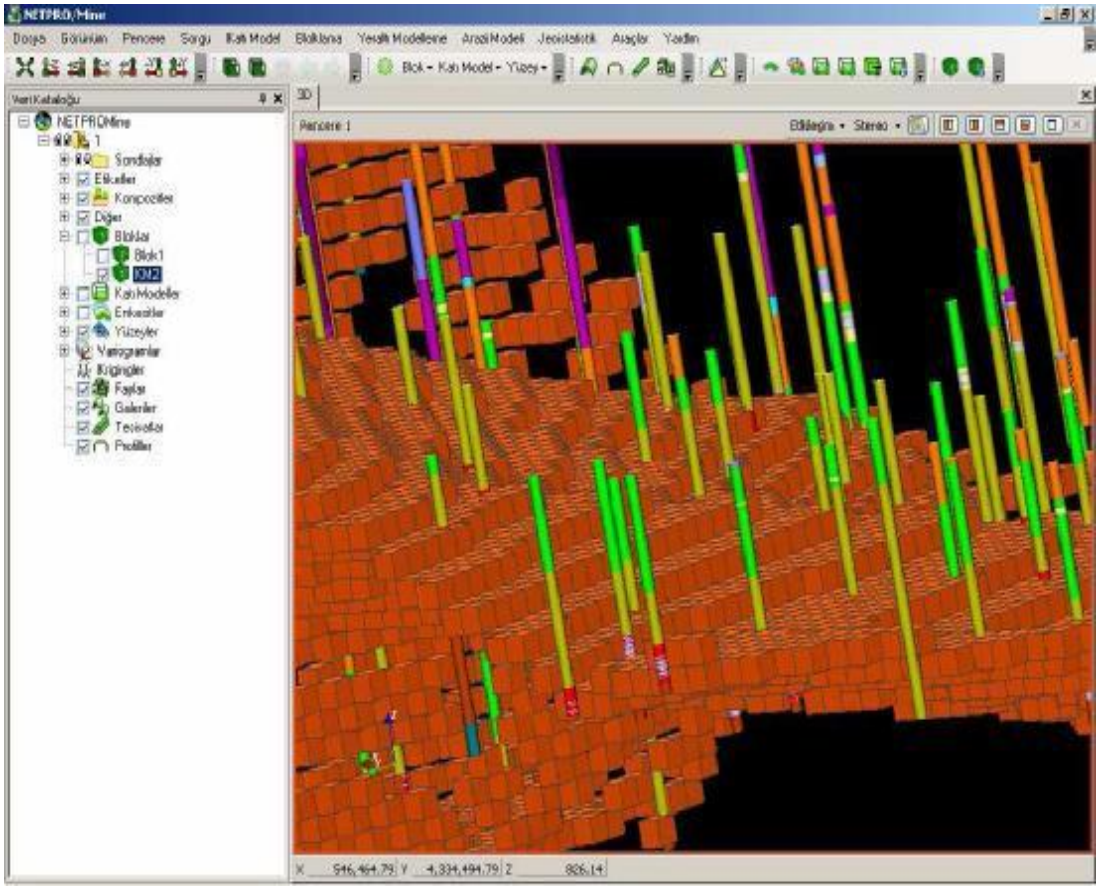


Figure 3.31. View after blocks are generated (Arıöz, 2011)

3.2.6.2. Obtaining Desirable Blocks from Existing Block Model

3.2.6.2. (1). Obtaining the Blocks Under/Above a Surface

To filter the created blocks according to upper/lower surface limit of a particular layer, Blocks → Limit Blocks command should be selected. (Figure 3.32-33).

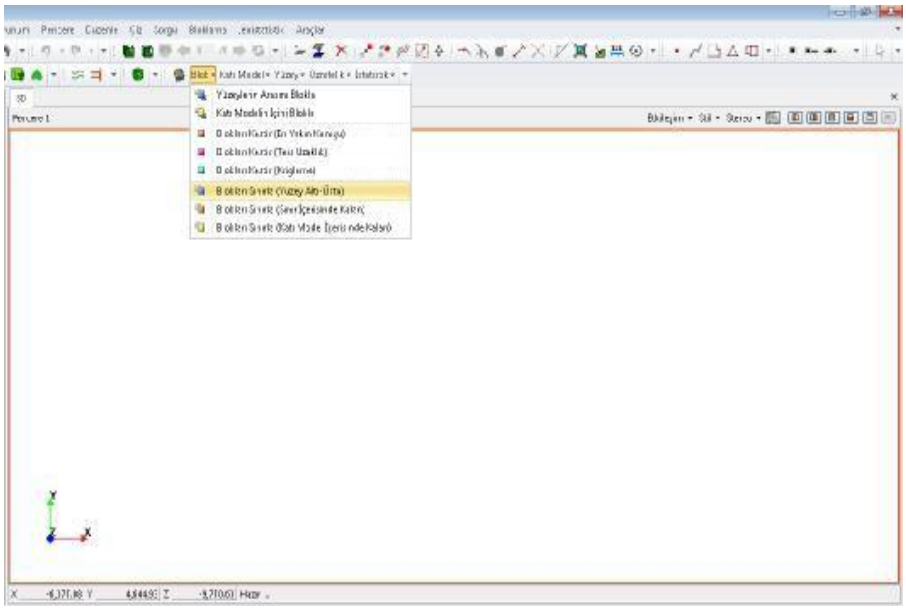


Figure 3.32. Access to portal to obtain blocks under/above a surface

Figure 3.33. Limit the blocks command window

When upper boundary is selected as a limiting surface, the blocks under the surface are accepted as a filtering result and the blocks above the surface are discarded.

Surface information, lower surface boundary or upper surface boundary is entered. The operation is performed when pressing “Okay” button.

3.2.6.2. (2). Obtaining the Blocks Between Two Surfaces

To obtain the blocks between two surfaces, block → limit blocks command is selected. First, the blocks below the first surface are restrained (Figure 3.34), then the blocks on the second surface are restrained by re-filtering through the received blocks (Figure 3.35). Thus, blocks between two surfaces are obtained.

Figure 3.34. Restraining the blocks under the first surface

Figure 3.35. Restraining the blocks under the second surface

3.2.7. Estimation of the Block Values

3.2.7.1. The Nearest Neighbor Method

It is a polygon method. The value that is closest to the point to be estimated is taken as the estimation value. If the mean values of the blocks are to be estimated, block division numbers in the x, y and z directions must be entered. The number of blocks in the x, y and z direction should be equal to 1 in the estimation of the points. In block estimation, division numbers depend on the direction and degree of anisotropy of the variable to be estimated. In an isotropy condition, these numbers can be taken equal to three in each direction.

Geostatistics → Estimation → Nearest Neighbor command is chosen (Figure3.36).

After the parameters are entered and blocks to be estimated are chosen, estimation is performed by pressing “Okay” button and blocks are thematized (Figure 3.37).

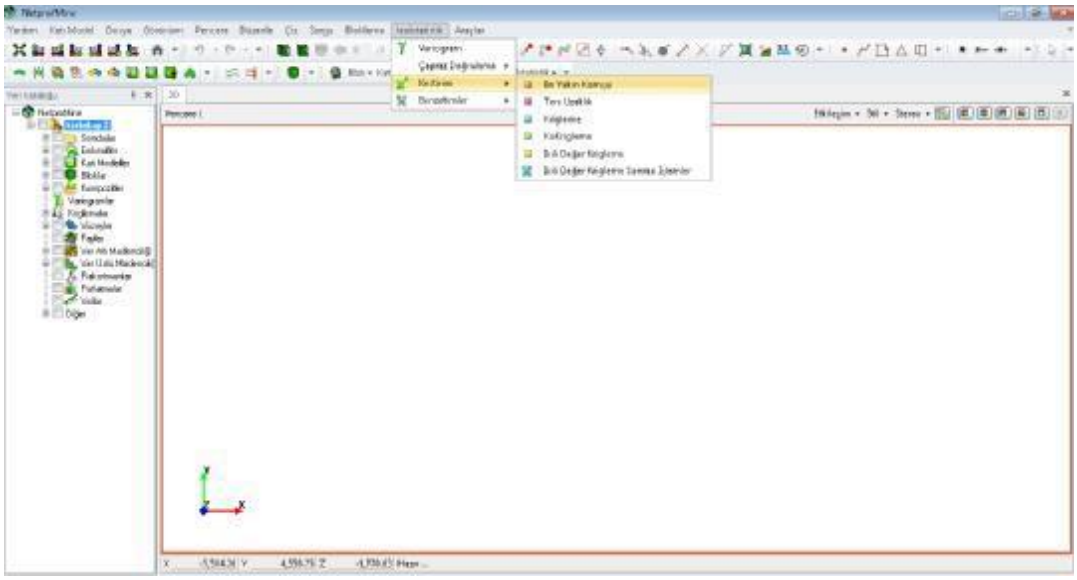


Figure 3.36. Access to the nearest neighbor estimation method

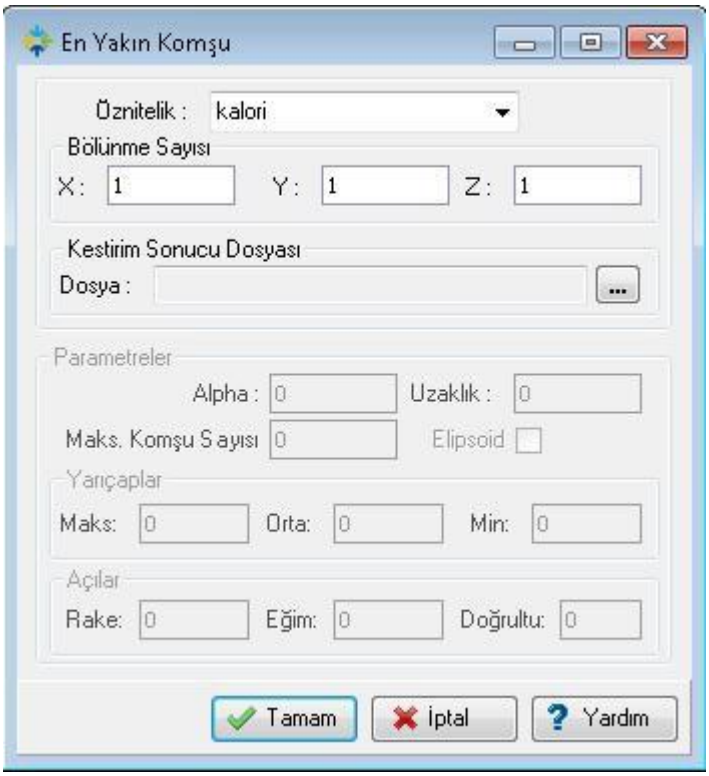


Figure 3.37. Parameter window of the nearest neighbor method

3.2.7.2. Inverse Distance Weighting Method

The value of the point to be estimated is calculated by taking the weighted average of the composite data to be used in the estimation of this point. The weights are calculated in proportion to the inverse of the distance between the point to be estimated and the composite data. The degree of this ratio is determined by the alpha parameter. Alpha can be set between 1 and xx. As the value of this parameter increases, the method approaches the nearest neighbor method. Then it is necessary to enter the parameters related to the estimation geometry. These are alpha, distance, maximum number of samples and search ellipsoid. In practice, alpha can be taken as 1 or 2. The maximum number of samples is the highest number of samples to be used in the estimation of a point or block. The distance refers to the radius of the sphere in which these samples will be selected. If the variable to be estimated is anisotropic, it is necessary to select samples from an ellipsoid instead of selecting them from a sphere that has a distance radius. The ellipsoid geometry (axis lengths and angles) can be determined by variogram analysis. Geostatistics→ Estimation→Inverse distance weighting command is chosen. (Figure 3.38).

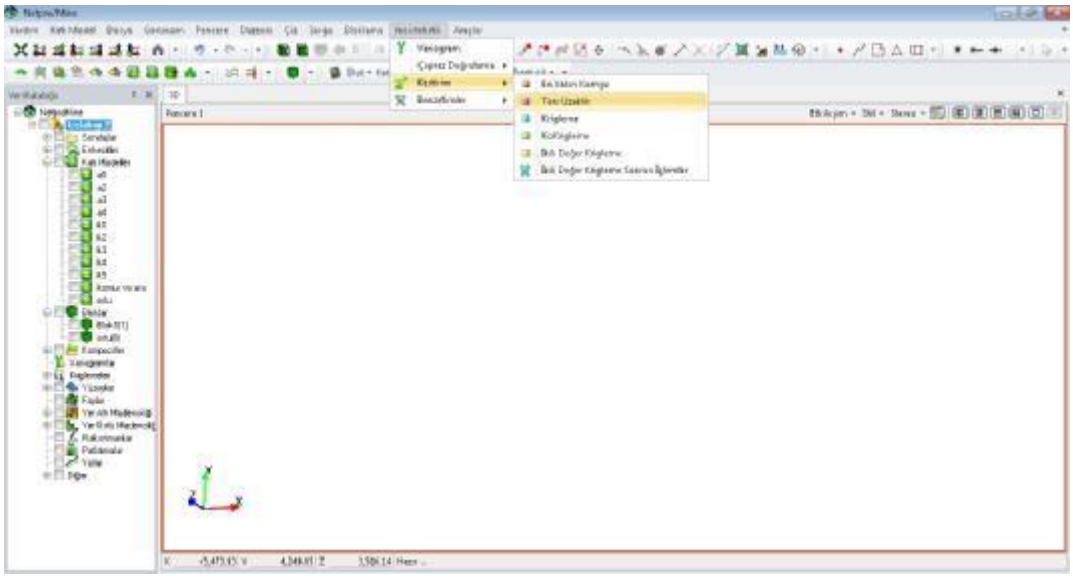


Figure 3.38. Access to the inverse distance weighting estimation method

Required attribute information and other parameters are entered. Estimation is performed by pressing “Okay” button (Figure 3.39 and Figure 3.40).

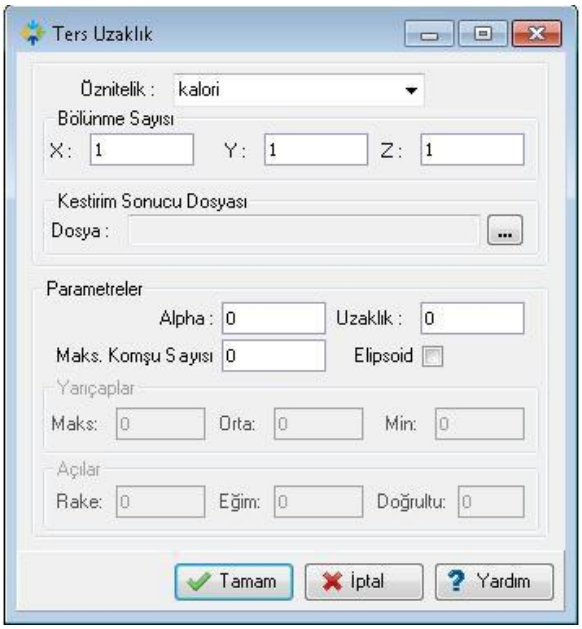


Figure 3.39. Parameter window of the inverse distance weighting method

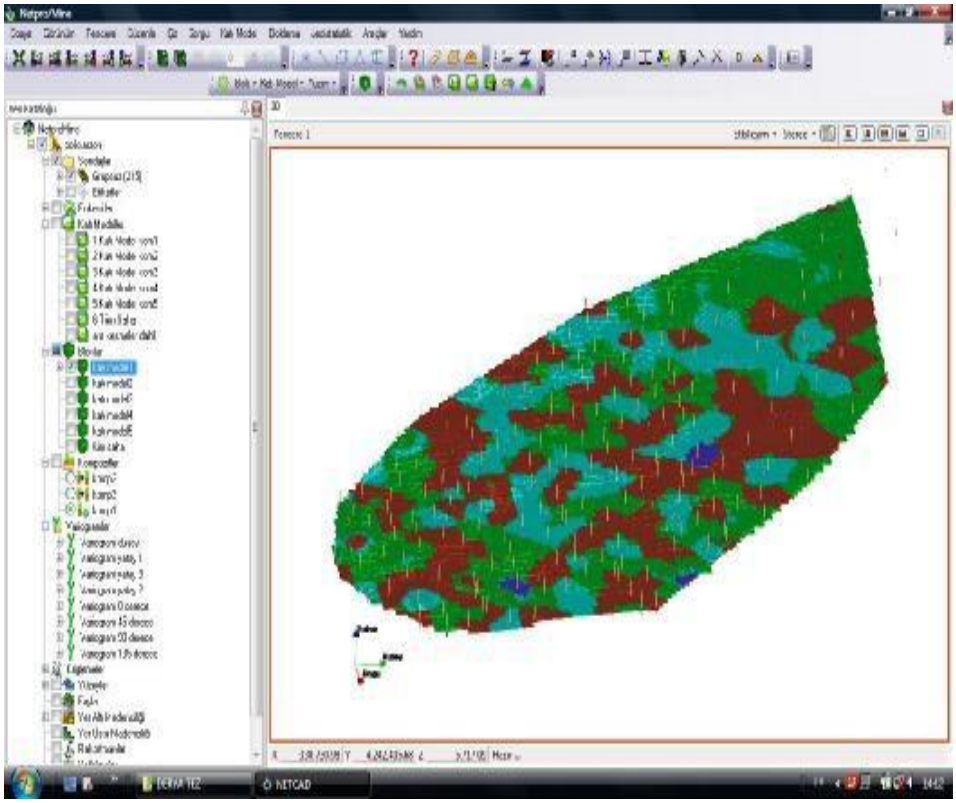


Figure 3.40. View of the blocks after estimation (Arıöz, 2011)

3.2.7.3. Kriging Method

The value of the point to be estimated is calculated by taking the weighted average of the composite data to be used in the estimation of this point. The weights are determined in such a way that the estimation errors are zero and the variance is the smallest. Therefore, it is a method that produces the least error among others. The method requires a prior variogram analysis of the variable to be estimated.

Estimation can be done by simple kriging or ordinary kriging method. Ordinary kriging technique is mostly used for linear estimation, while simple kriging is used for simulation applications. Estimation can be done with a regular grid or an irregular point set. If done with grid, grid dimensions (number) in x, y, z coordinates, cell length (size) and initial coordinates (coordinates of the center point of the block in the bottom right corner) must be entered. Block kriging should be used if the average of the blocks is to be estimated in the regular grid system.

For the search ellipsoid, the information about the ellipsoid geometry to be used to estimate the point or block must be entered. Among these, min represents the lowest number of samples and max represents the highest number of samples to be taken into account in the estimation. The max, mid, min parameters under the distances heading represent the longest-length axis of the ellipsoid, the medium-length axis of the ellipsoid and the shortest-length axis of the ellipsoid respectively. And dip, azimuth and rake under “Angles” heading represent the corresponding angles.

Geostatistics→ Estimation→ Kriging commands are chosen (Figure 3.41).

When all required kriging parameters are entered, estimation is performed by pressing “Okay” button (Figure 3.42).

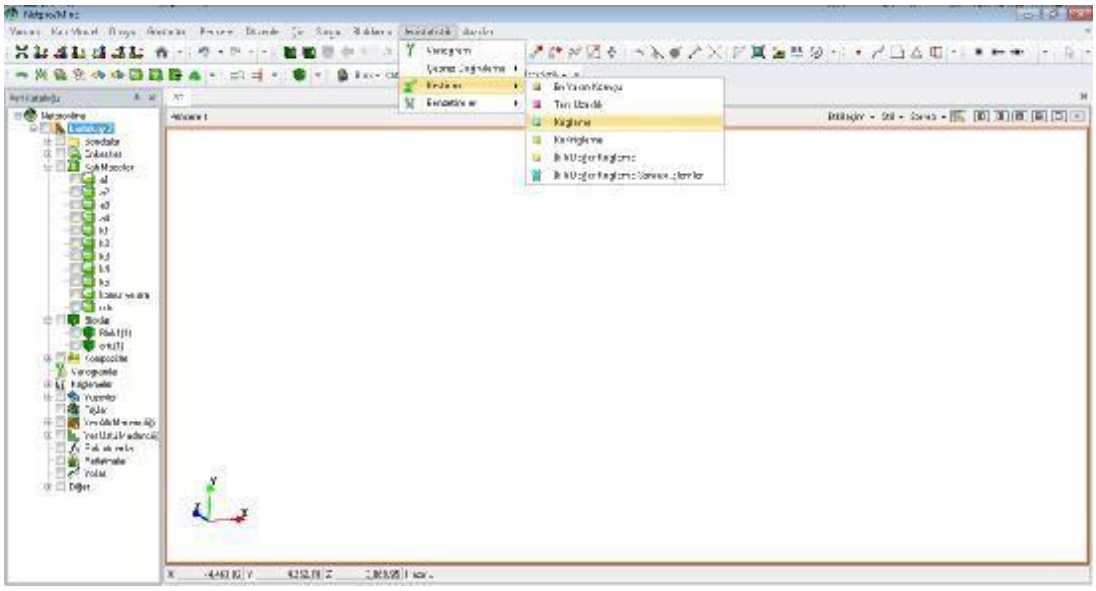


Figure 3.41. Kriging estimation method

Figure 3.42. Kriging parameters

3.2.8. Inquiry on the Block Model Obtained and Reporting

3.2.8.1. Inquiry Attributes

Volume of the created block model is calculated by Blocking → Block Properties command. Number of blocks, average-minimum-maximum block sizes and if estimation is made, average-minimum-maximum attribute values and standard deviation is displayed.

This information window of the block model can be called from "Properties" command that is displayed by pressing right click of the mouse presented related block model layer in the data catalogue (Figure 3.43).

The results will be displayed on the report screen of the block properties (Figure 3.44).

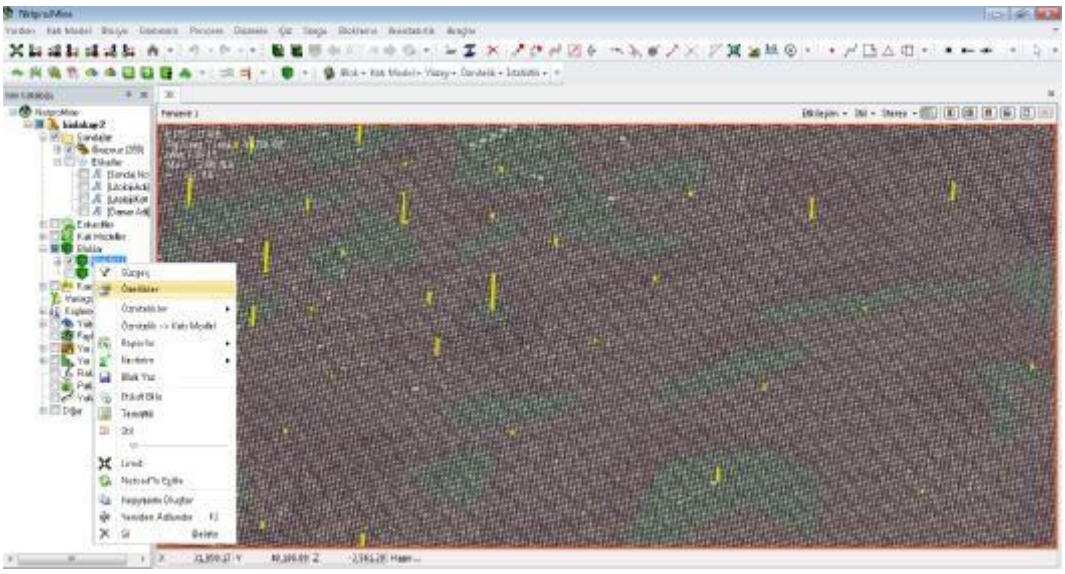


Figure 3.43. Access to block model properties command

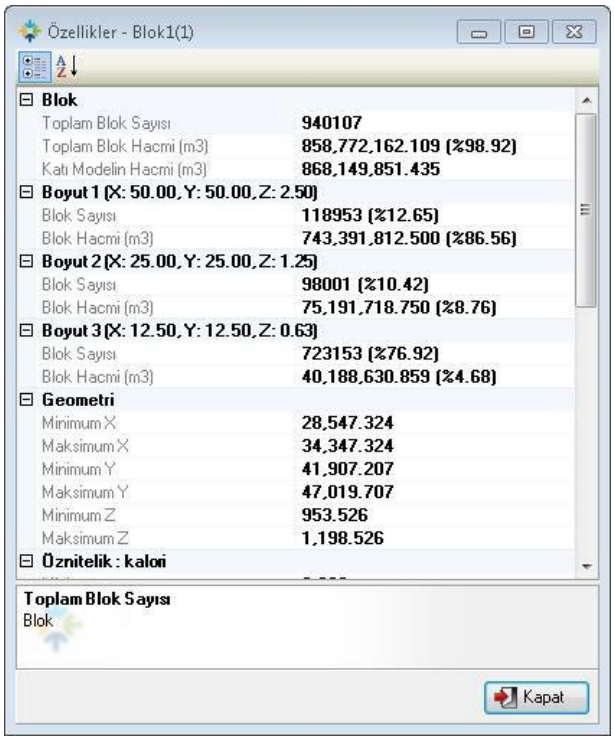


Figure 3.44. Report of the block model properties

3.2.8.2. Filtering the Blocks that have Desired Properties by Thematizing

The existing block model is used to easily determine and calculate parameters such as planning, attribute, volume of a specified area.

This operation of the block model can be called from “Filter” command that is displayed by pressing right click of the mouse presented related block model layer in the data catalogue (Figure 3.45-46).

Filter Style: If all conditions are true, the blocks that provide all the sorted filter types are filtered. If any condition is true, blocks provide any of the sorted filter types are filtered.

Attributes: The center values of block are based on the center point of the block model. The block points are based on any point for the entire block model.

Block width: It is the widths of the block model.

Density: This value is the density values assigned to the block model.

The filter is applied to the block model by “Apply” command.

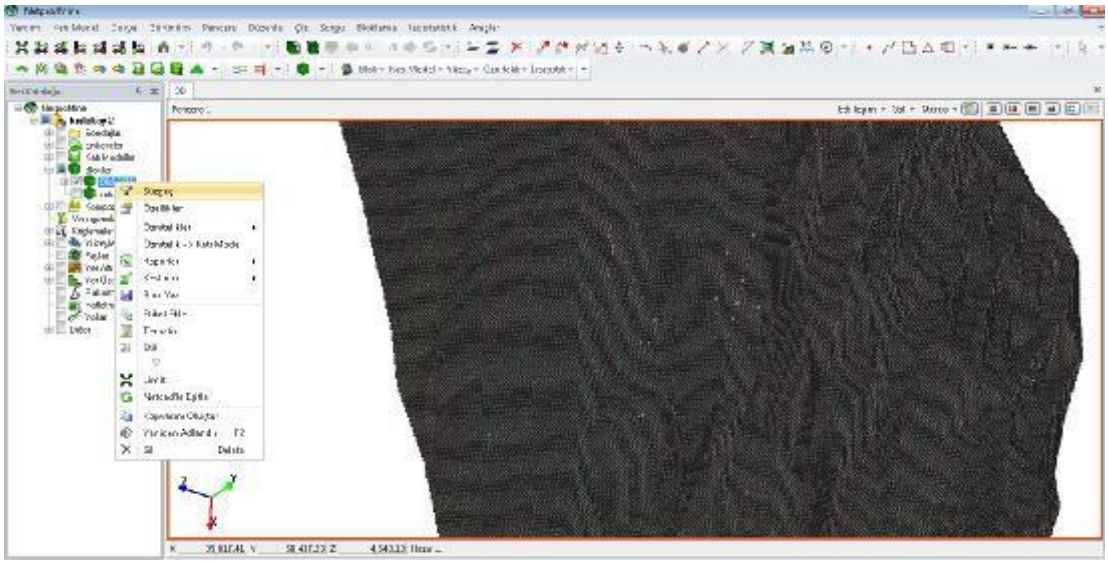


Figure 3.45. Access to the filter command of the block model

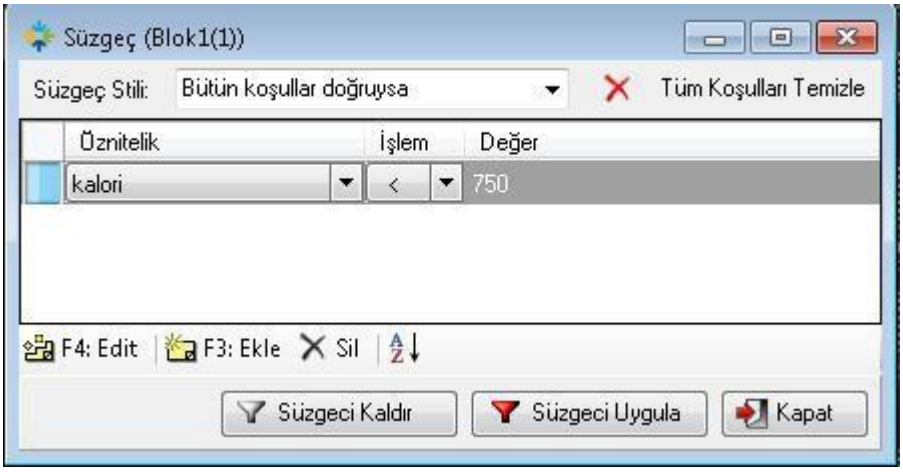


Figure 3.46. Filtering window of the block model

4. RESEARCH FINDINGS

This study that is based on the core drillings of both unexcavated part of the Kışlaköy (A) sector of the Afşin-Elbistan basin and Corridor (D) bed, consists of determination of the blocks in the final pit limit formed by the 1:2.7 (vertical: horizontal) bank angle and the calorific value estimation of these blocks and the inquiry and evaluation calculations on the obtained block model.

Netpro/Mine mining software has been used to determine the behavior of the data by doing descriptive statistical analysis according to the drill hole data. Compositing operation has been applied to the data set, and distribution behavior of the obtained new data set has been determined by examining its descriptive statistics and histograms.

In this section, the results of the operations listed below have been obtained by using Netpro/Mine software.

- Evaluation of the drill hole data,
- Creating the surface,
- Solid modelling,
- Block modelling,
- Calorific value estimation,
- Volume and quality estimation,
- Creating thematic maps.

4.1. Evaluation of the Drill Hole Data and Compositing

The processes given below are applied while creating project data files from the available information of 280 core drills (Figure 4.1).

- Values out of the data between the entrance and exit of the coal seam were removed from the raw sampling file.
- If sum of partings is greater than 0.3 m, these were extracted from raw data.
- Selective excavation thickness was considered as 0.3 m. Therefore, the parting that has a thickness less than 0.3 m were included in the coal and the calorific value for it was assigned as 1.

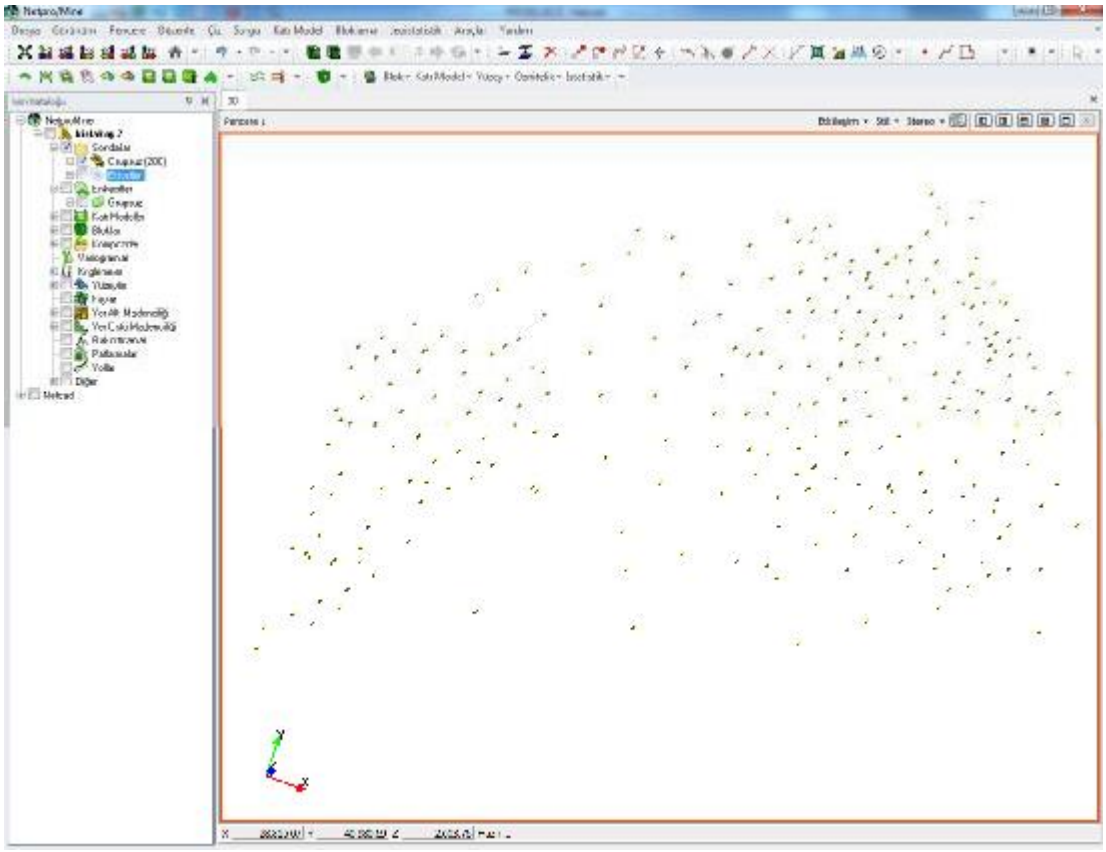


Figure 4.1. Distribution of drill hole locations

The cores taken from the drillings are different in lengths. Composites are used to convert cores of different lengths into cores of the same length. Resource or reserve estimations are performed using composite data. Composite data were obtained by dividing the drill hole log at 2.5 m intervals. The summary statistics of the obtained composite data and normal data are presented in Table 4.1.

To determine the characteristics of the mineralization and the structural differences before the geostatistical analysis, the composite data of the different lengths of the calorific value variable have been compared among each other. Since the data that has skewness value closer to zero value will represent the original data better, composite1 (minimum skewness value, 1.20) data is used in this study (Table 4.1). The histogram plot of the composite data obtained at 2.5 m length in the modeling is given in Figure 4.2.

Table 4.1. Summary statistics of the obtained composite data and raw data

Statistical Parameter (calorie)	Raw Data	Comp1 (2.5 m length)
Number of Samples	9000	19075
Minimum	1.00	1.00
Average	468.23	301,72
Median	62	1
Maximum	2119	2119
Variance	302,364.97	220,689.91
Standard Deviation	549.87	469.78
Skewness	0.60	1.20

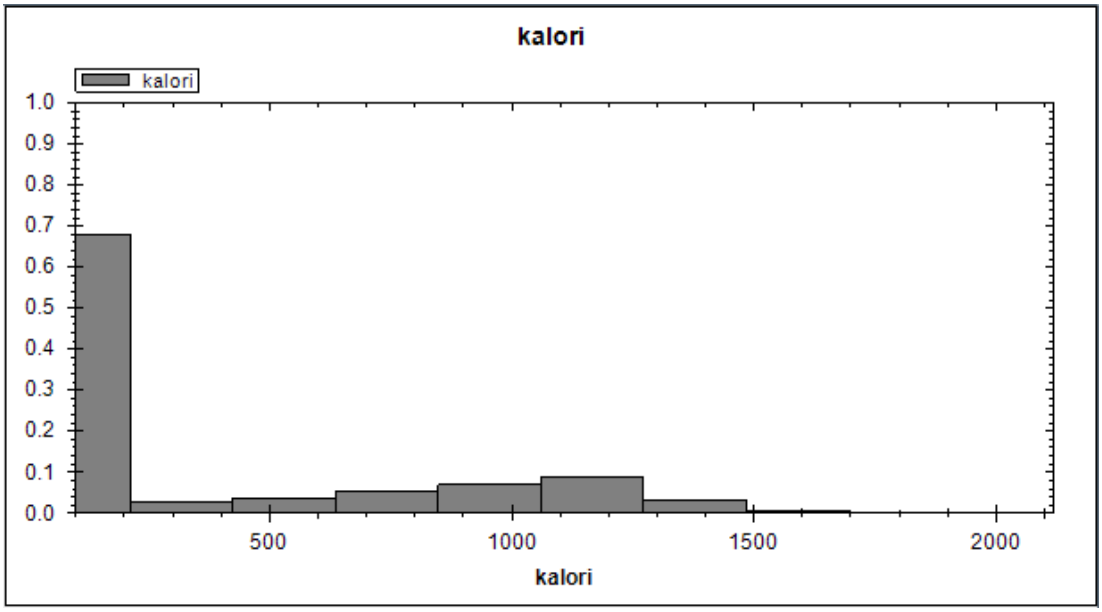


Figure 4.2. Histogram graph of the Composite1

4.2. Surfaces

Surfaces that limit the solid model must be obtained to form cross-sections to be used in obtaining solid models. For overburden, knowing the topography, the top of the lignite horizon and the final surface of the pit and for coal, the final surface of the pit, the top and the bottom surface of the lignite horizon.

Through the existing block model, it is necessary to obtain these surfaces to extract

the desired blocks from above/below of a surface or from between two surfaces and make the volume calculations. For example, knowing the two surface such as the upper and lower surfaces for querying the volume and quality of the blocks in any stage.

4.2.1. Obtaining the Surface of the Overburden

The topographic surface (Figure 4.3) required to form the solid model of the overburden was obtained from the April 2008 dated location plan, from the locations (X, Y) obtained by the top surface (Figure 4.4) drilling logs of the coal horizon and from the roof and floor elevations of the coal (Figure 4.5).

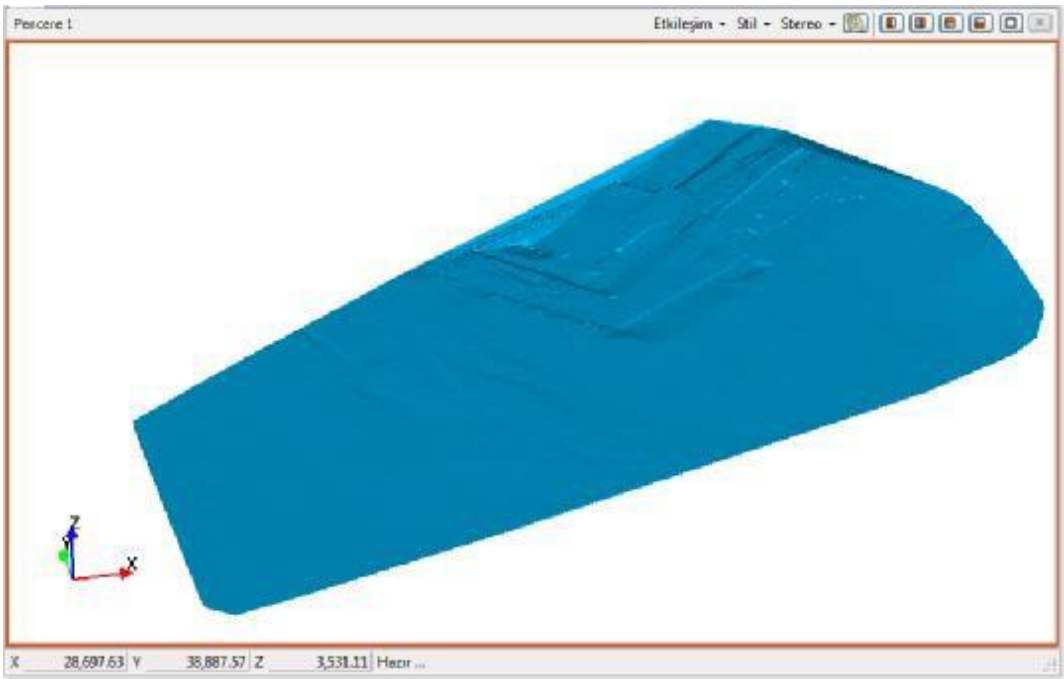


Figure 4.3. Topographic surface of the April 2008 dated mine site

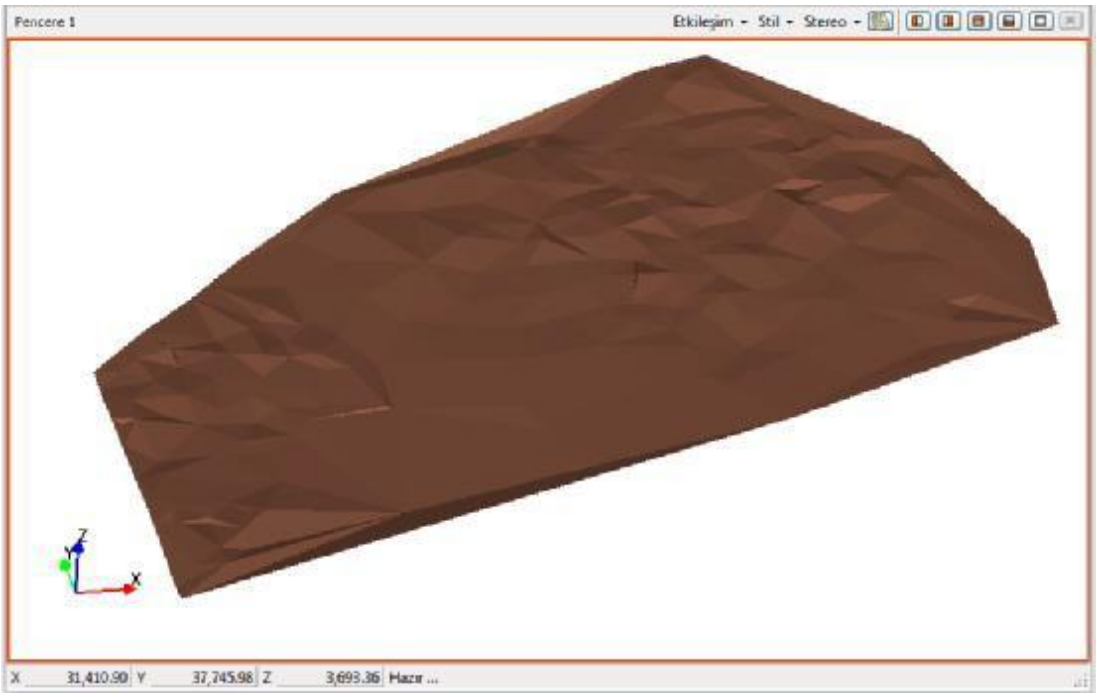


Figure 4.4. Roof surface of coal horizon

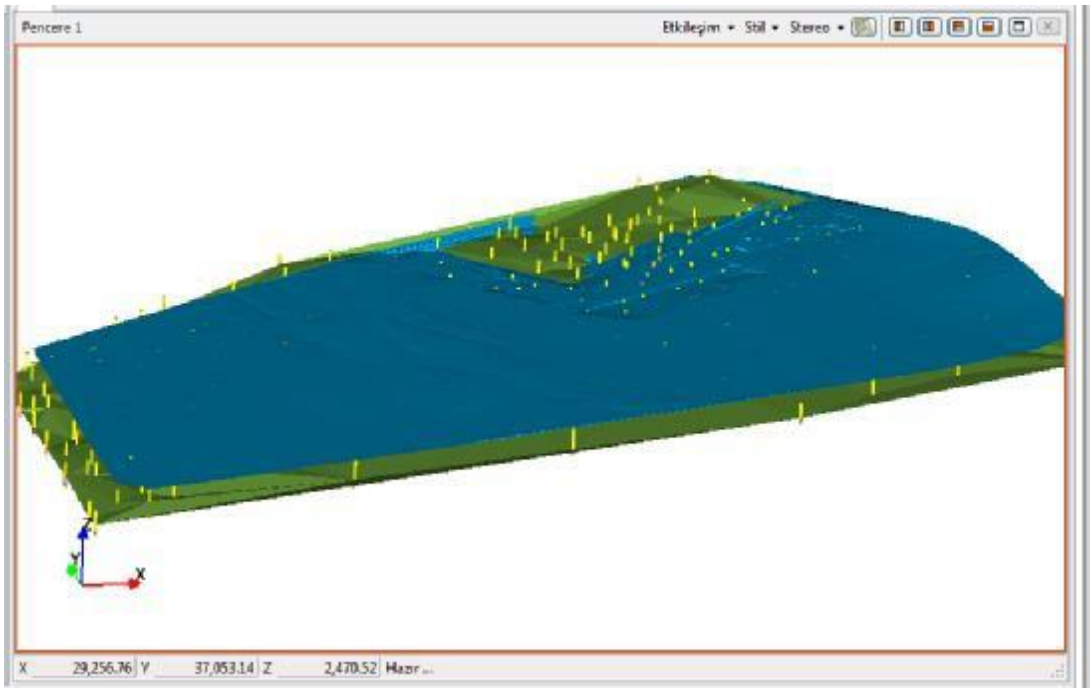


Figure 4.5. Roof-floor surfaces of coal horizon and drills.

4.2.2. Obtaining Surface of the Coal Horizon

The roof (Figure 4.4) and the floor surfaces (Figure 4.6) of coal horizon required to form the solid model was obtained from the coordinates (X, Y) of the drills, and top and bottom elevations of the coal given in the drills.

4.2.3. Obtaining the Final Pit Surface

The final pit surface, which is required to form the solid models of the overburden and lignite horizon within the final pit limits, was obtained with a 1:2.7 ultimate pit slope angle (Figure 4.8).

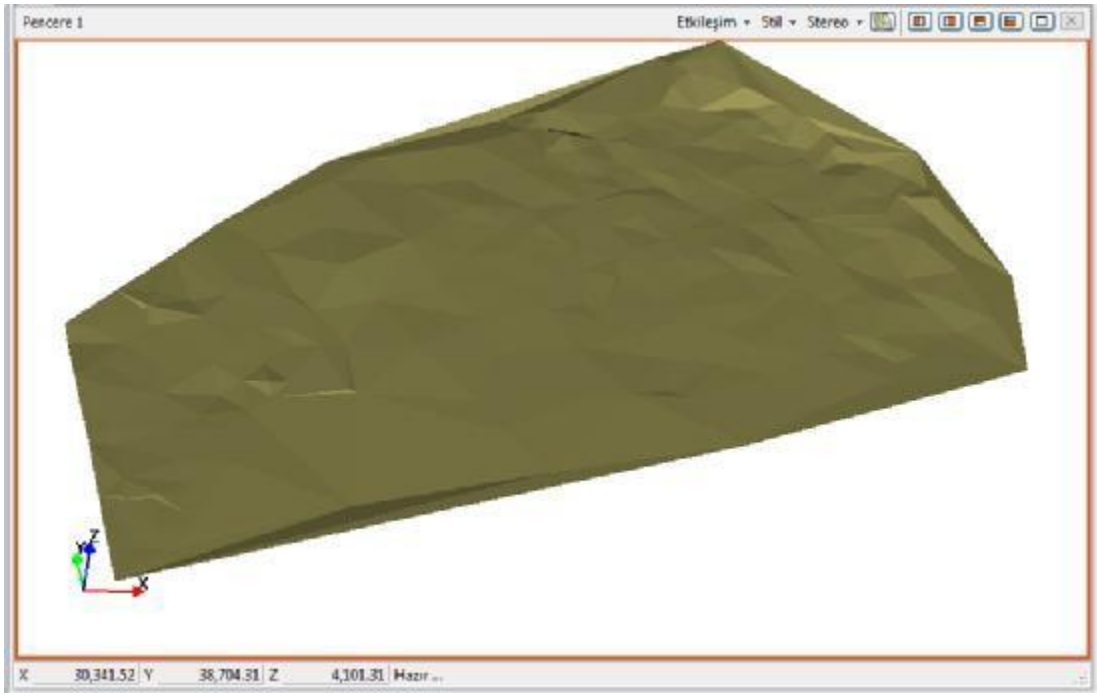


Figure 4.6. Floor surface of coal horizon

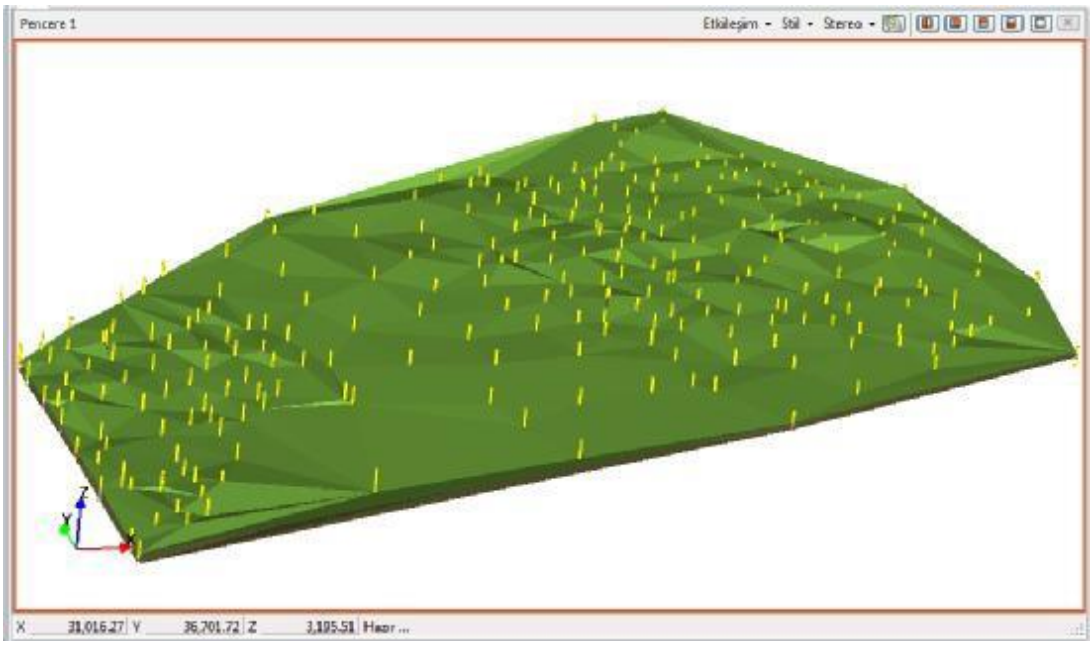


Figure 4.7. Roof-floor surfaces of coal horizon and drills

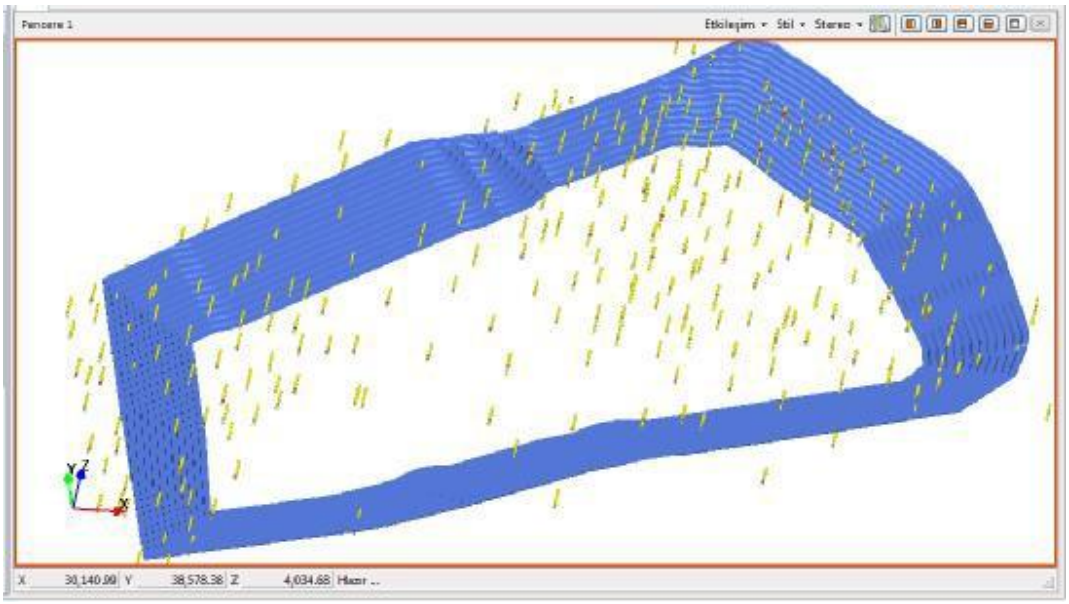


Figure 4.8. Final pit surface

4.2.4. Creating Level Surfaces

The level surfaces required to sort the blocks out according to levelss and to determine the distribution of the excavation volumes according to the levels were obtained from the surface data of the existing 6 levels (Figure 4.9).

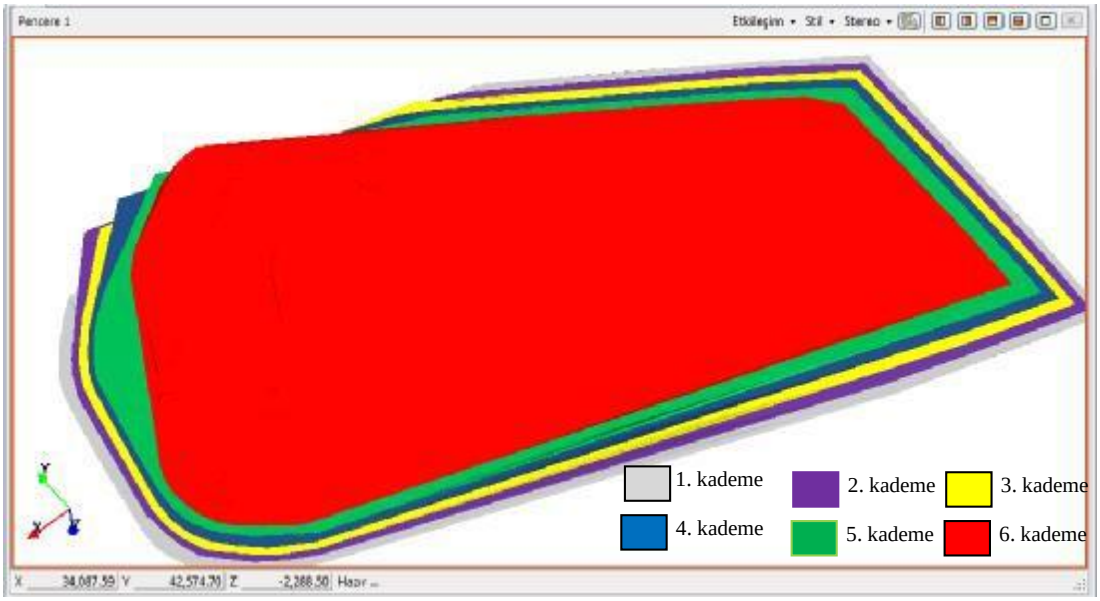


Figure 4.9. View of the level surfaces from reverse

4.3. Creating Cross-sections

In this study, geological model is created by using "create solid model from cross-sections" method. For the accuracy of solid models, the cross sections must be numerous and accurately drawn.

4.3.1. Section Planes

34 parallel cross-sections covering entire pit boundary have been taken at 200 m intervals in north-south direction to form cross-sections of the overburden and lignite within the final pit limits (Figure 4.10).

4.3.2. Cross-sections for Overburden

Each one of the section plane lines determined have been intersected with the overburden layer and the pit limits. The part within the pit limit of the multiple lines (Figure 4.11) obtained on the plane has been obtained by digitizing with special point capture modes. All the cross sections of the lignite horizon obtained in this way are given in Figure 4.12.

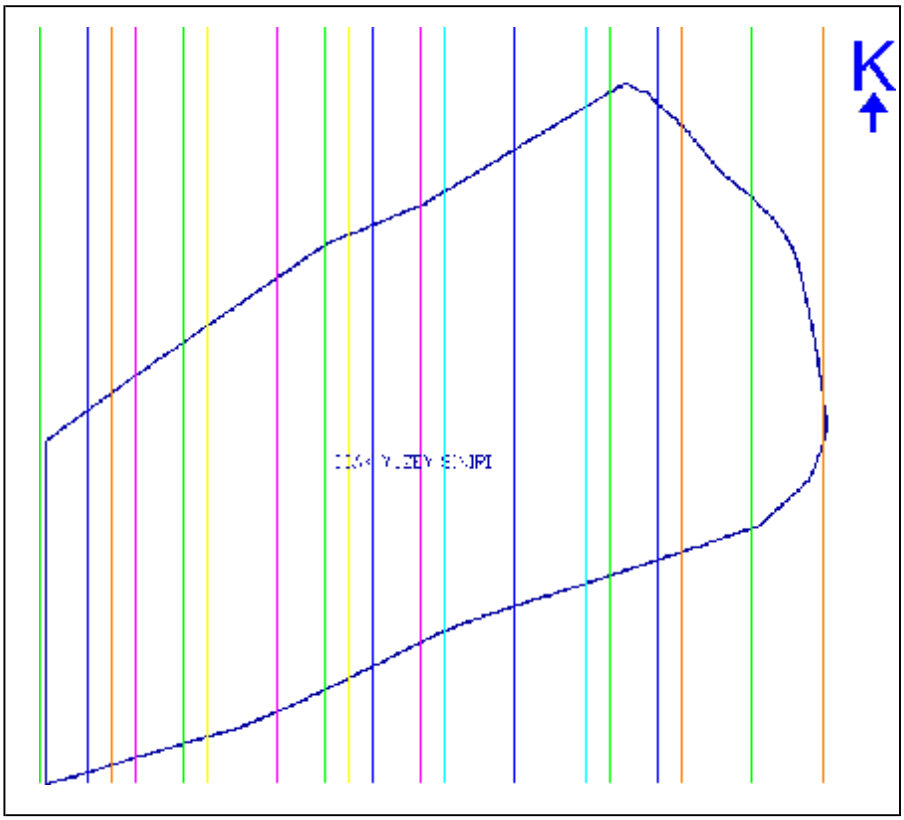


Figure 4.10. Section planes

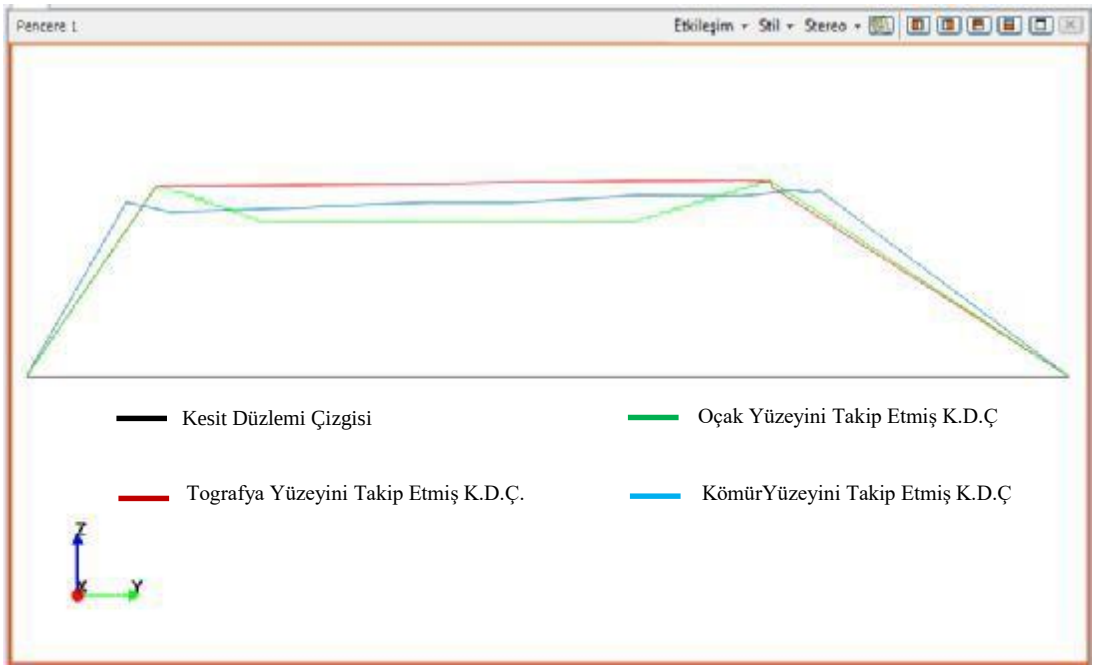


Figure 4.11. Cross-section of the overburden obtained from the a-a’ section plane

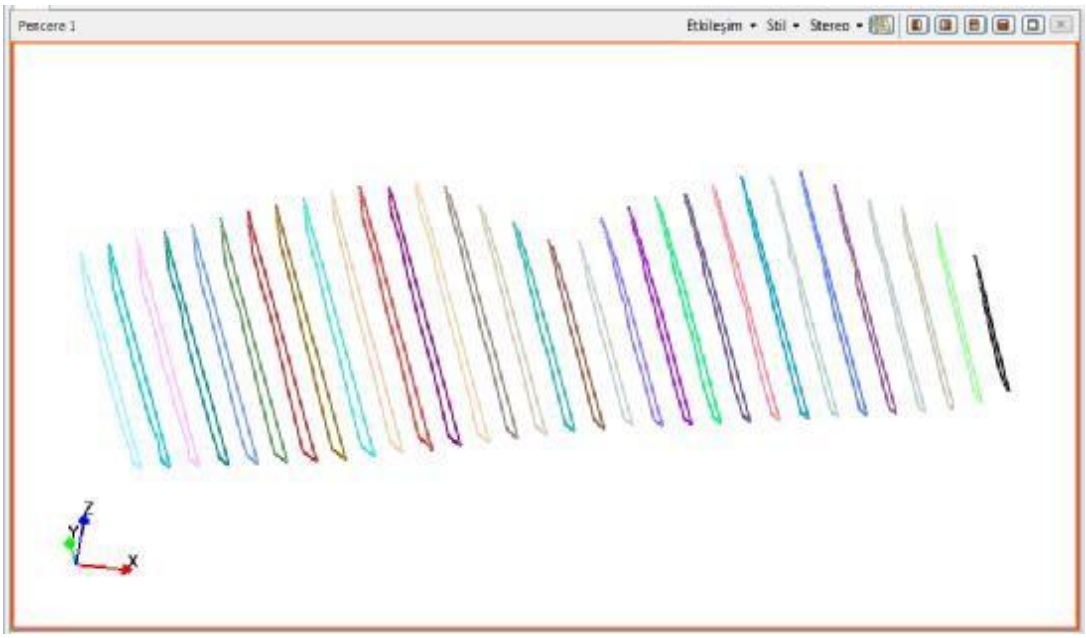


Figure 4.12. All cross-sections obtained for the overburden

4.3.3. Cross-sections for Coal

As in the digitization of overburden cross-sections; each of the cross-section lines have been intersected with the coal horizon and the pit surfaces, and the part within the pit limit of the multiple lines obtained on the plane has been obtained by digitizing with special point capture modes. All the cross sections of the lignite horizon obtained in this way are given in Figure 4.13.

4.4. Creating the Solid Models

4.4.1. Solid Model of the Overburden

A solid model is created for the overburden by selecting all cross-sections obtained for the overburden arbitrarily with "create solid model from cross-sections" command. (Figure 4.14).

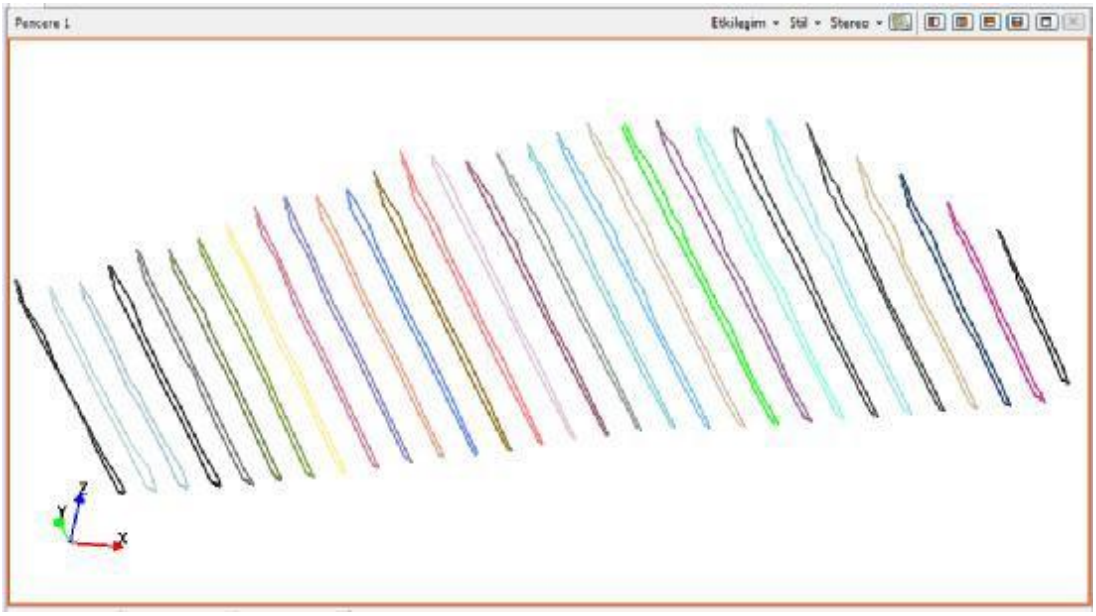


Figure 4.13. All cross-sections obtained for the coal horizon

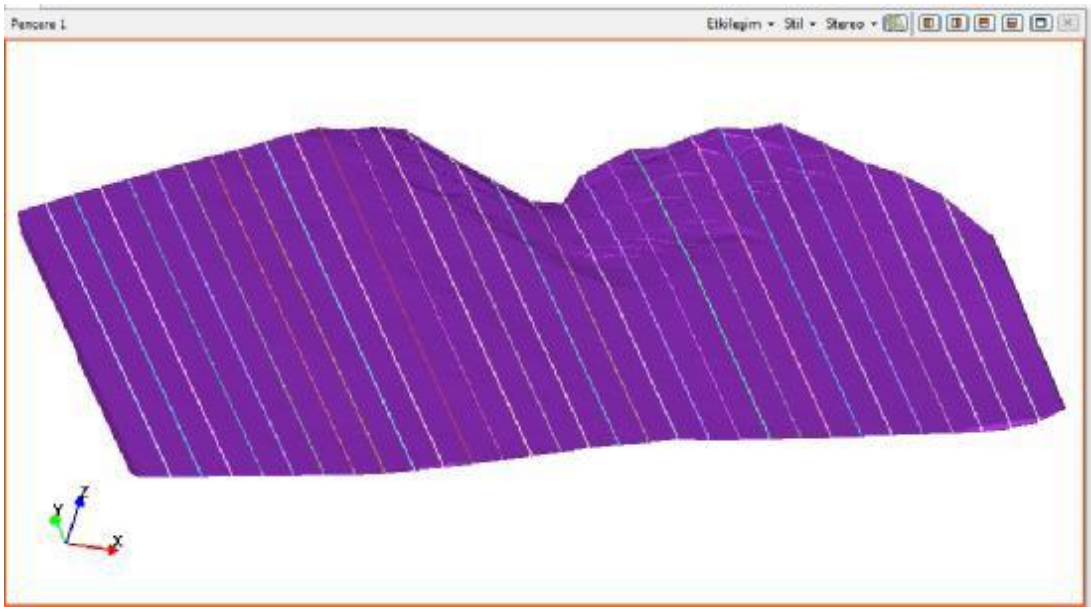


Figure 4.14. Obtained solid model of the overburden

4.4.2. Solid Model of Coal

A solid model for lignite coal is created by selected all cross-sections obtained for the lignite horizon with "create solid model from cross-sections" command. (Figure 4.15).

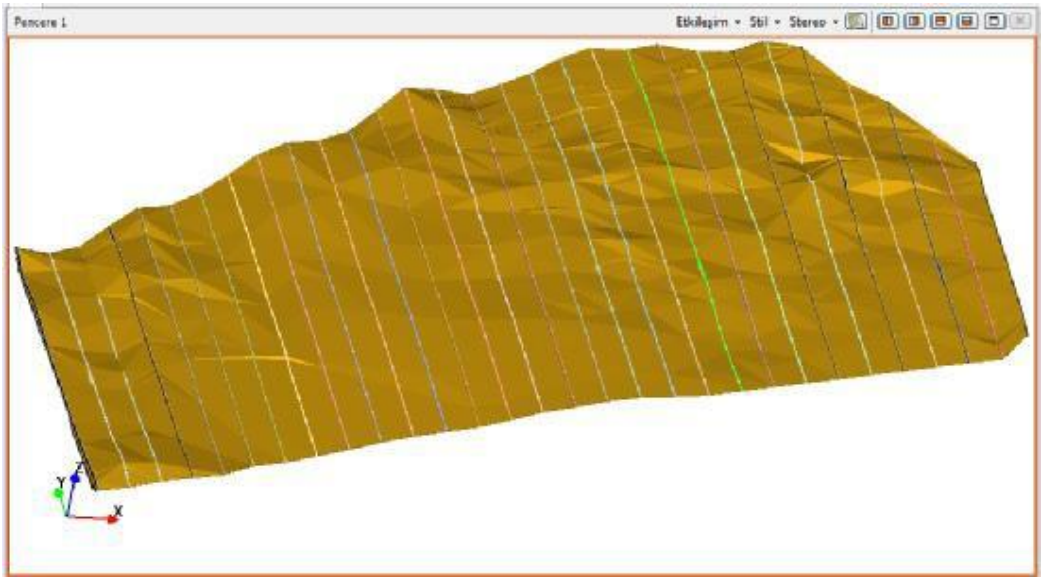
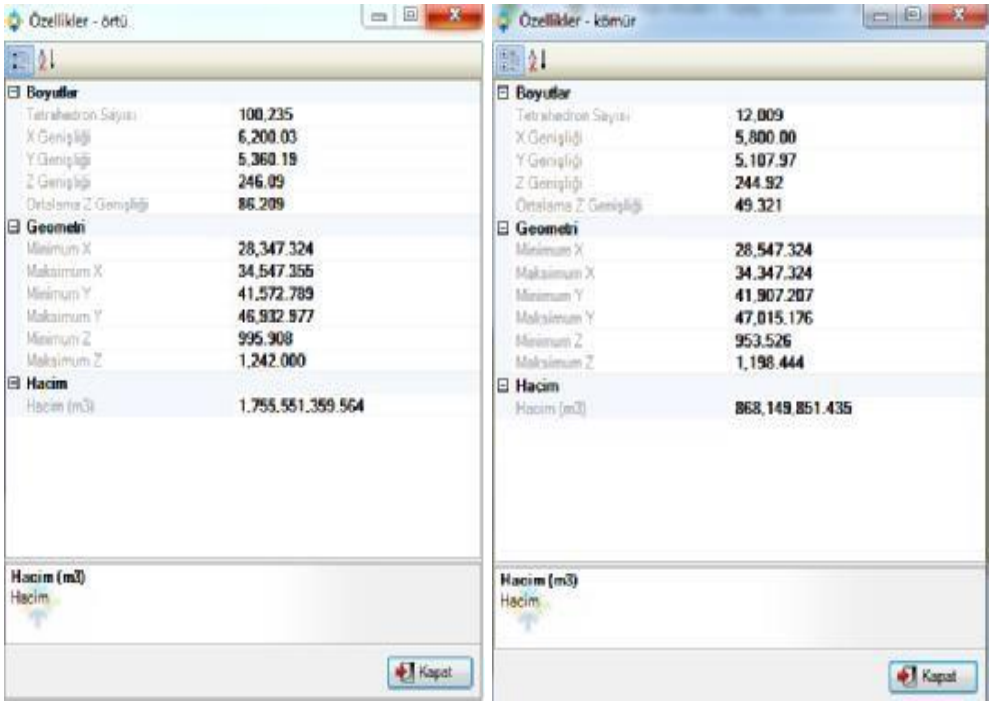


Figure 4.15. Obtained solid model of the coal horizon

4.4.3. Solid Model Properties

Solid model properties of both overburden and lignite coal are examined and some of the information obtained (Figure 4.16) is given in Table 4.2.



(a) (b)

Figure 4.16. Properties of the solid model a) Overburden, b) Coal

Table 4.2. Solid model information

Solid Model	Solid Model Volume (m^3)
Overburden	1755551359
Lignite (including partings)	868149851

4.5. Creating the Block Model

Small block sizes as much as possible will increase accuracy, on the other hand, as the block size becomes smaller, estimation errors increase and memory problems arise depending on the characteristics of the computer used. Therefore, the block parameters specified in Figure 4.17 are used for both overburden and lignite coal.

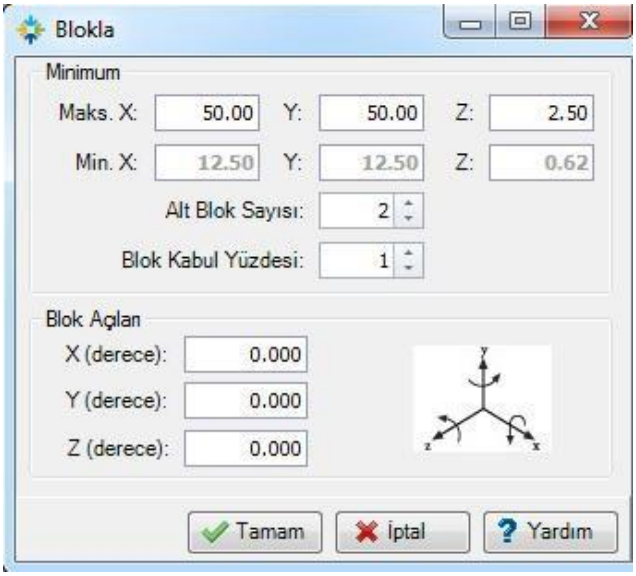


Figure 4.17. Block parameters used in the study

4.5.1. Overburden Block Model and its Properties

The blocks obtained for overburden based on the block parameters given in Figure 4.17 are shown in Figure 4.18. When the property report given in Figure 4.19 of this block model is examined, it is seen that the difference between the total volume of the blocks and the total volume of the solid model is 0.69%.

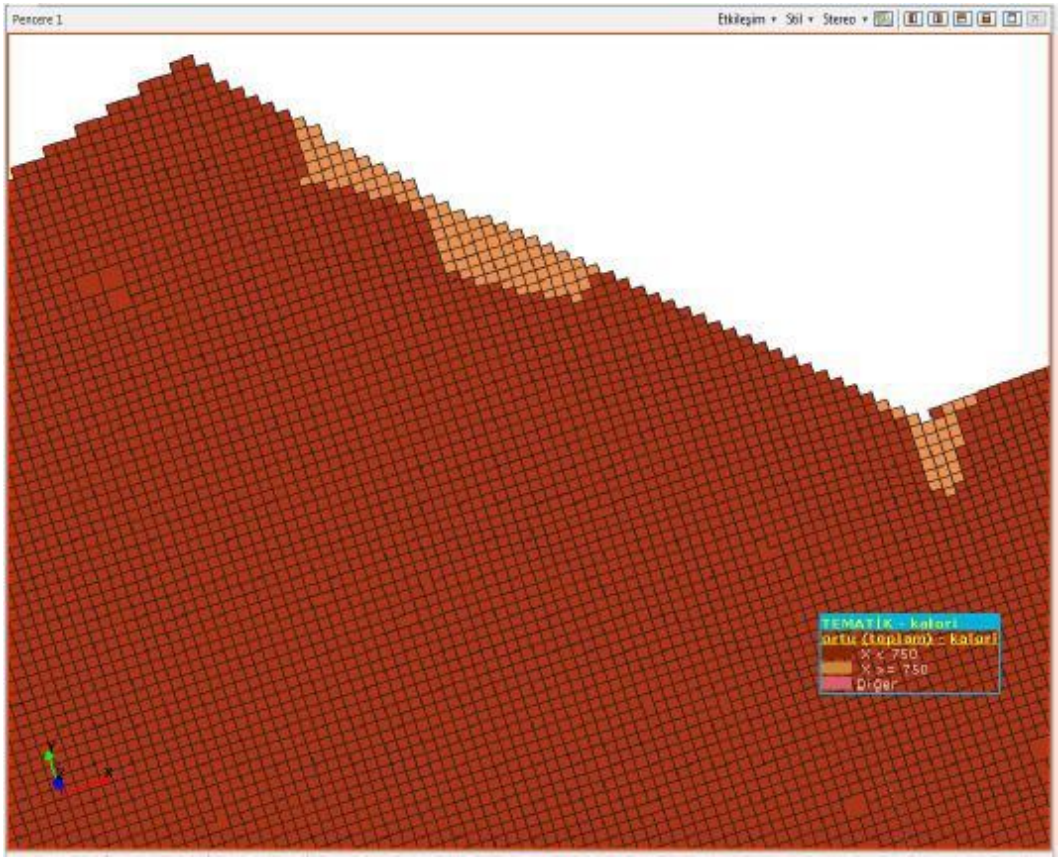
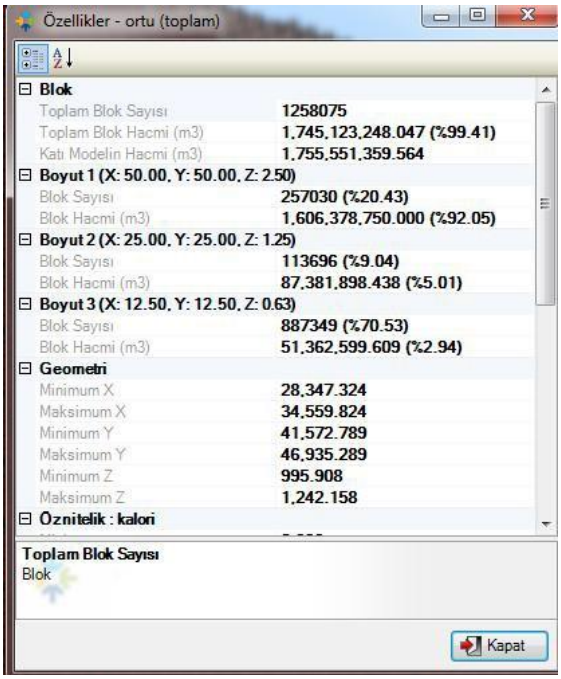


Figure 4.18. View of the overburden block model



Özellikler - ortu (toplam)

Blok	
Toplam Blok Sayısı	1258075
Toplam Blok Hacmi (m3)	1,745,123,248.047 (%99.41)
Katı Modelin Hacmi (m3)	1,755,551,359.564
Boyut 1 (X: 50.00, Y: 50.00, Z: 2.50)	
Blok Sayısı	257030 (%20.43)
Blok Hacmi (m3)	1,606,378,750.000 (%92.05)
Boyut 2 (X: 25.00, Y: 25.00, Z: 1.25)	
Blok Sayısı	113696 (%9.04)
Blok Hacmi (m3)	87,381,898.438 (%5.01)
Boyut 3 (X: 12.50, Y: 12.50, Z: 0.63)	
Blok Sayısı	887349 (%70.53)
Blok Hacmi (m3)	51,362,599.609 (%2.94)
Geometri	
Minimum X	28,347.324
Maksimum X	34,559.824
Minimum Y	41,572.789
Maksimum Y	46,935.289
Minimum Z	995.908
Maksimum Z	1,242.158
Öznitelik : kalori	

Toplam Blok Sayısı
Blok

Kapat

Figure 4.19. Overburden block model report

4.5.2. Coal Block Model and its Properties

The blocks obtained for lignite coal based on the block parameters given in Figure 4.17 are shown in Figure 4.20. When the property report given in Figure 4.21 of this block model is examined, it is seen that the difference between the total volume of the blocks and the total volume of the solid model is 1.08% (Table 4.3).

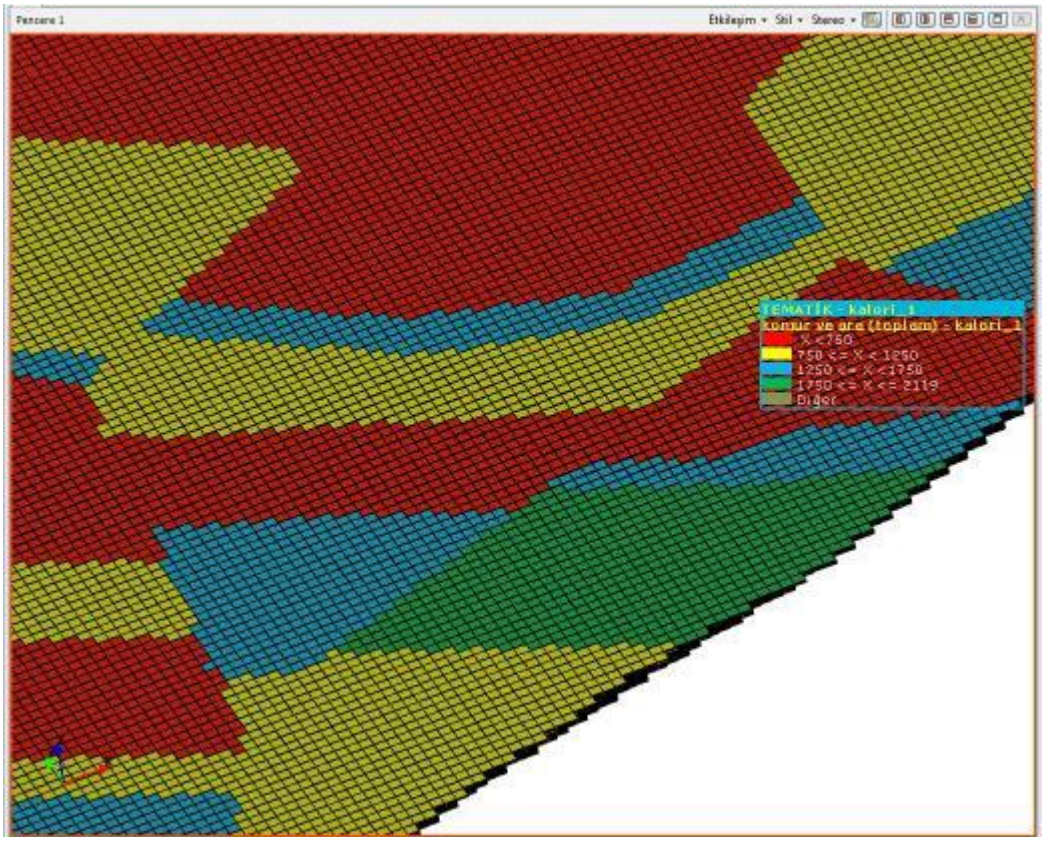


Figure 4.20. View of the coal block model

4.6. Assigning Calorific Value to the Blocks

Due to the presence of numerous and irregular partings in the lignite horizon, solid models for partings could not be obtained correctly. As the solid model and block model of the lignite horizon were obtained including partings, estimation of the calorific value for these blocks could not be made with Kriging method that is commonly used in estimation process. Estimations were made by using the nearest neighbor method.

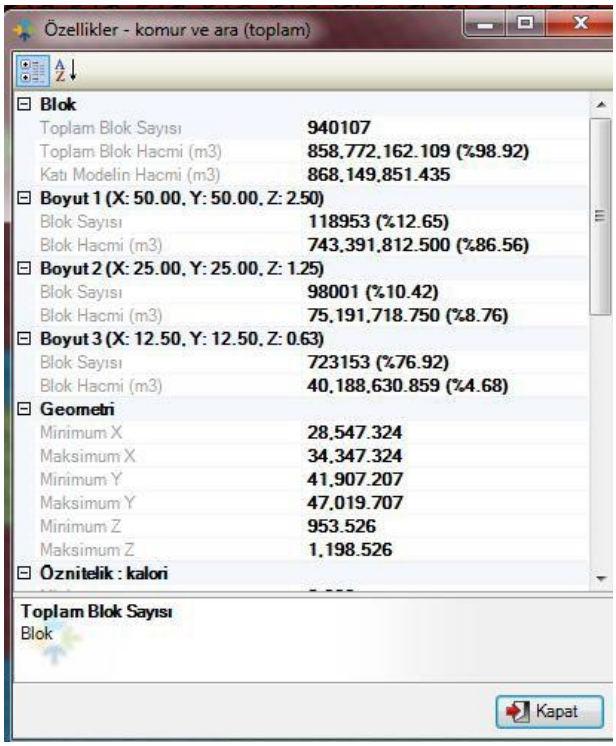


Figure 4.21. Coal block model report

Table 4.3. Block model information

Solid Model	Solid Model Volume (m^3)	Block Model Volume(m^3)
Overburden	1755551359.564	1745123248.047
Lignite (including partings)	868149851.435	858772162.109

Cut-off grade is the minimum grade required for a mineral or metal to be economically mined. No production is performed for material below this value. The estimation of the production in this field was carried out by considering the calorific value, being the main variable. 750 kcal / kg calorific value is taken as cut-off grade for lignite. The blocks with a calorific value below this value are considered parting (wall rock of the coal) and the blocks above this value are considered coal and the resulting volumes are given in Table 4.4-5.

Table 4.4. Volumes calculated for lignite horizon

Cut-Off Calorific Value (kcal/kg)	Volume (m^3)	Average Calorific Value (kcal/kg)
< 750	323655365.23	-
750	535116796.87	1102.27

Table 4.5. Volumes calculated for overburden horizon

Cut-Off Calorific Value (kcal/kg)	Volume (m^3)
< 750	1708002973.633
750	37120274.414*

* It is the overburden blocks that is close to the lignite horizon and assigned calorific value with nearest neighbor method, and these blocks are included in the stripping.

4.7. Block Constraint

The blocks that is constrained by a surface are extracted from the existing block model and a new block model is obtained. Volume inquiry can be made by thematizing this new model.

4.7.1. Production Inquiry Based on Benches

The properties of the restrained blocks were queried by the help of the existing overburden and coal block models (Figure 4.18 and Figure 4.20) obtained by the April 2008 dated excavation surface, and the level surfaces (The blocks to be produced in level 1 are obtained by sorting the blocks that are above the level surface; the blocks to be produced in level 2 are obtained by sorting the blocks that are under the level 1 and above level 2; the blocks to be produced in level 3 are obtained by sorting the blocks that are under the level 2 and above level 3; the blocks to be produced in level 4 are obtained by sorting the blocks that are under the level 3 and above level 4; the blocks to be produced in level 5 are obtained by

sorting the blocks that are under the level 4 and above level 5; and the blocks to be produced in level 6 are obtained by sorting the blocks that are under the level 5) given in Figure 4.9. The production amounts for the levels within the final pit limit were determined and given in Table 4.6. The blocks to be produced in level 2 (Figure 4.22) and their properties (Figure 4.23) are given below.

Table 4.6. Excavations calculated according to benches

Level	Overburden (m^3)	Coal (m^3)	Total Amount of Excavation (m^3)
1	343650945	0	343650945
2	418874551	238706	419113257
3	399364596	3906179	403270774
4	391050670	41347113	432397783
5	266398200	138392888	404791088
6	178265129	373557272	551822401
Total	1997604091	557442158	2555046249

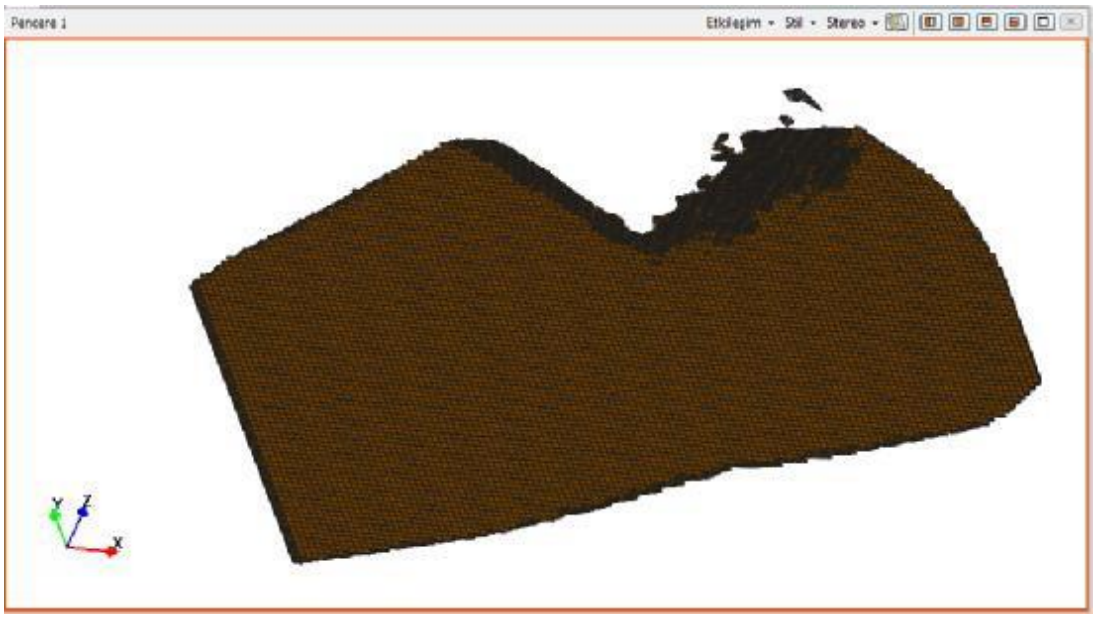
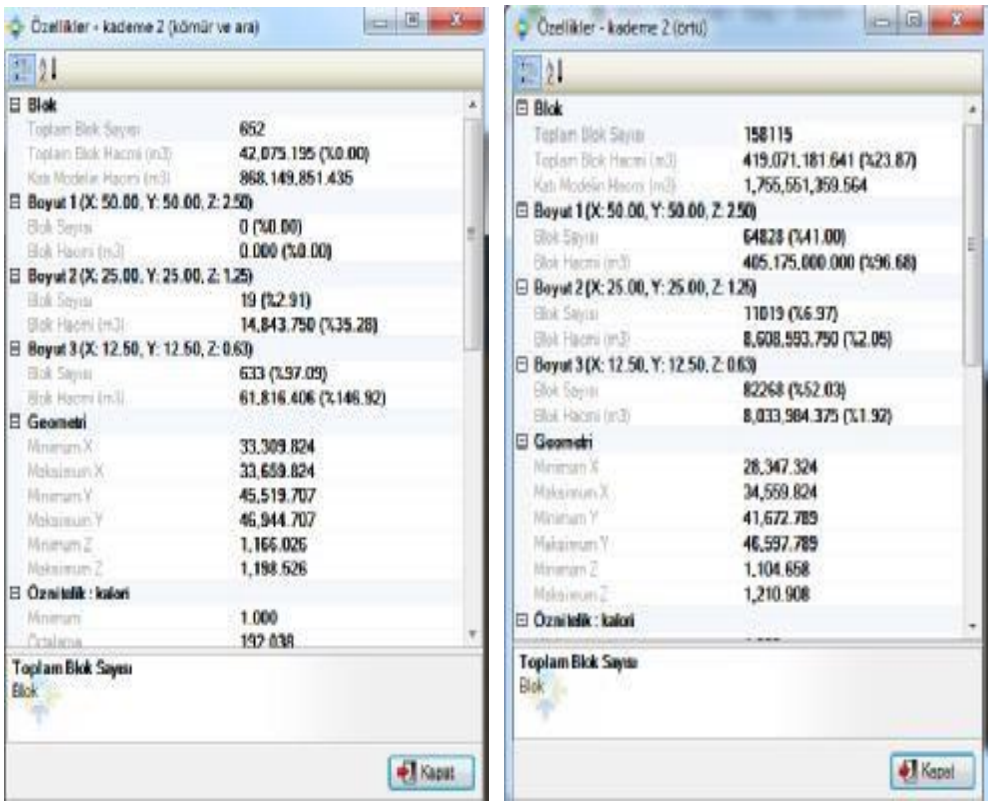


Figure 4.22. The blocks to be produced in the 2nd level



a b

Figure 4.23. Properties of the blocks to be produced in the 2nd level a) for coal seam b) for overburden

4.7.2. Production Inquiry Based on Desired Excavation Plan

The existing overburden and coal block models (Figure 4.18 and Figure 4.20) obtained with excavation surface as of April 2008 and the blocks limited with excavation surface (Figure 4.24) at the end of 2013 are sorted out, and overburden and coal blocks obtained are given in Figure 4.25 and Figure 4.26.

Produced (extracted) overburden and lignite coal block model characteristics are examined and some obtained information obtained (Figure 4.27) are given in Table 4.7.

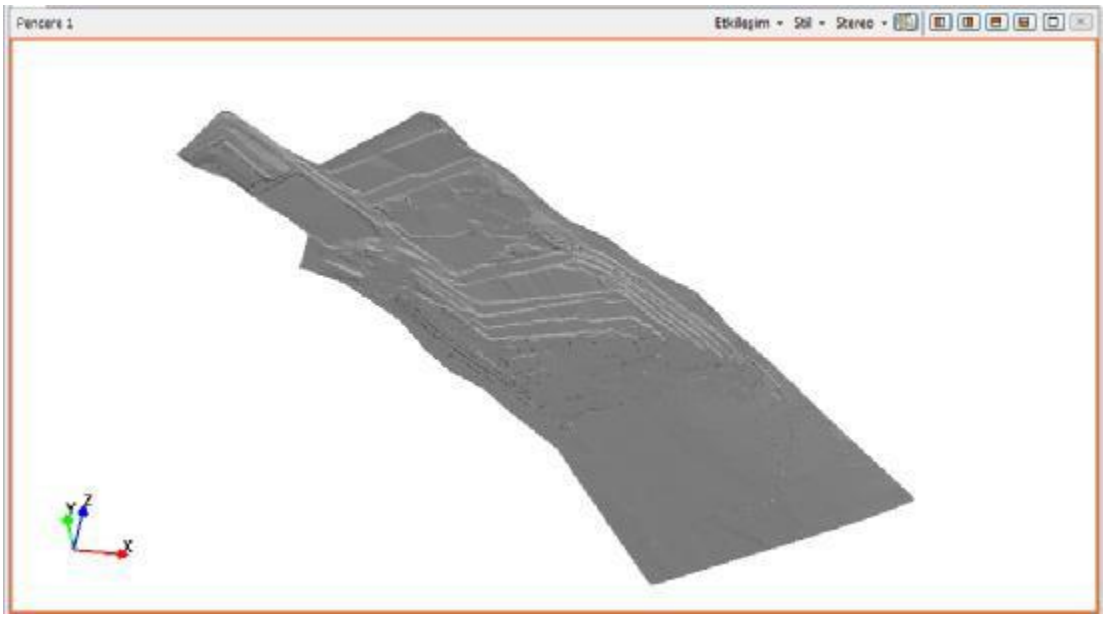


Figure 4.24. Excavation surface at the end of 2013

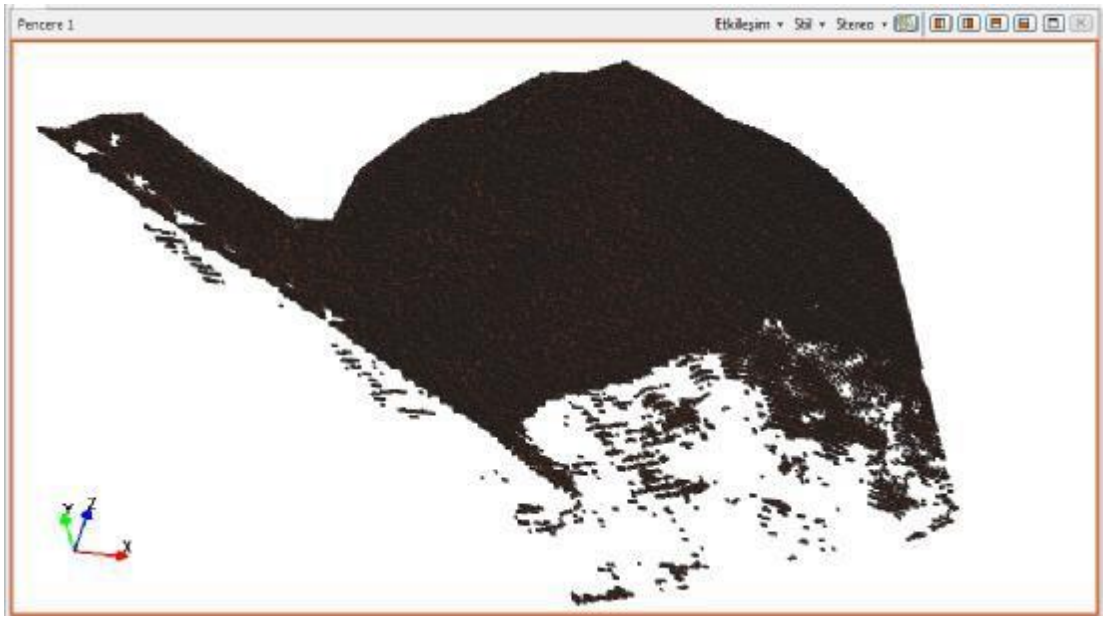


Figure 4.25. Overburden blocks produced at the end of 2013

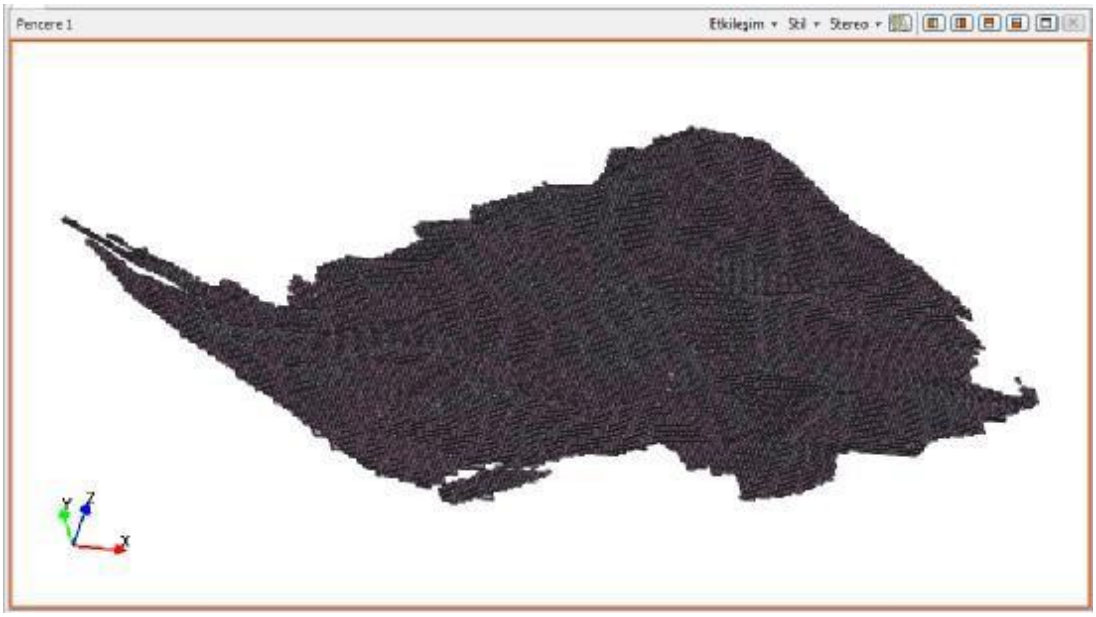
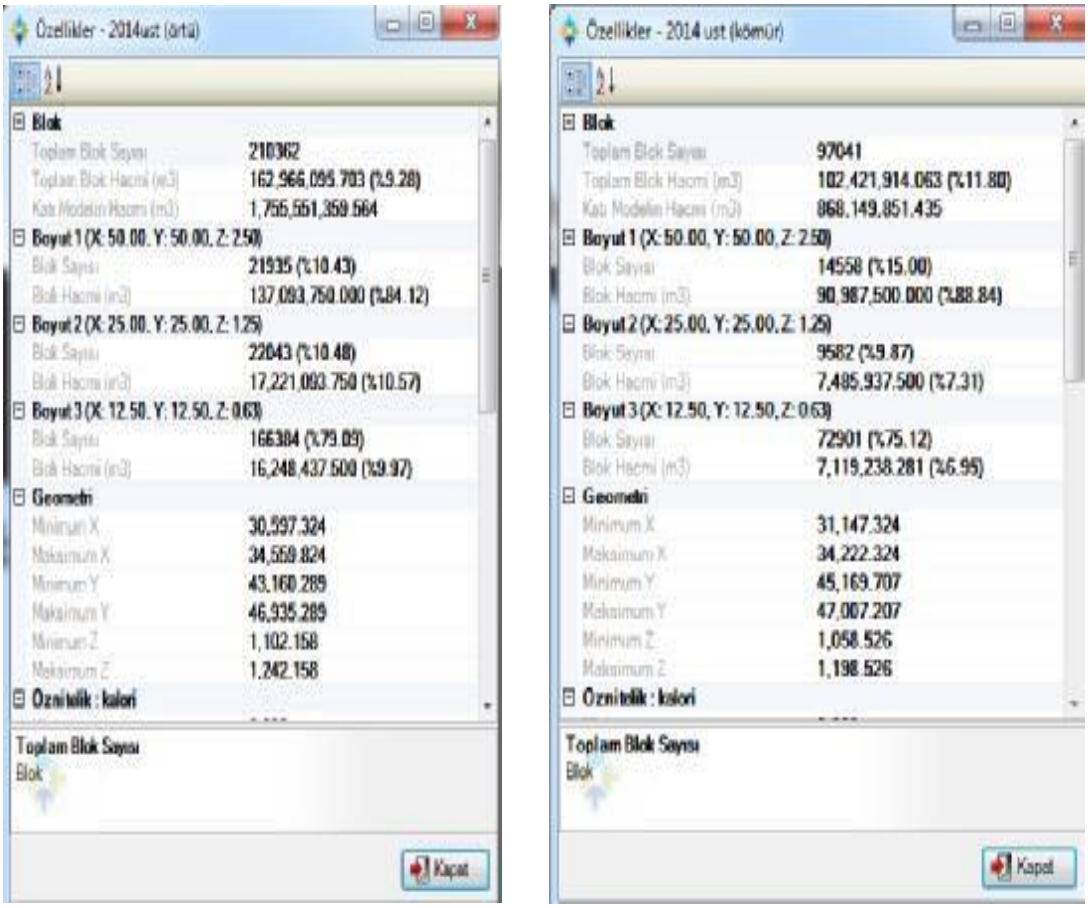


Figure 4.26. Coal blocks produced at the end of 2013



(a) (b)

Figure 4.27. The characteristics of the block model produced at the end of 2013 a) Overburden, b) Coal

Table 4.7. Information of block model produced between April 2008 and end of 2013.

Model	Block Model Volume (m^3)
Overburden	162966096
Coal (including partings)	102421914

4.8. Evaluation of the Results

The total amount of excavations within the pit limits with the existing block model and the total amount of excavations determined by the calculations made by BWE (2008) are given in Table 4.8.

Table 4.8. Total excavation in the pit limits as of April 2008

Work	Overburden (m^3)	Coal (m^3)	Total Excavation (m^3)
BWE (2008)	2118223000	413596000	2531819000
This study	2068778613	535116797	2603895410
Difference	**-49444387**	**121520797**	**72076410**

Based on the calculations made in this study as shown in Table 4.8, more coal (121520797 m^3) and less overburden (49444387 m^3) have been calculated, compared to the BWE's study (2008).

The block model to compare actual amount of excavation performed between April 2008 and the end of 2013 is generated and the blocks limited by the excavation surfaces between these dates are sorted out. The obtained block volumes are calculated theoretically, and the results are given in Table 4.9.

Table 4.9. Theoretically calculated excavation amount and actual excavation amount between April 2008-2013.

	Excavation Amount (Overburden + Coal) (m^3)
Afşin-Elbistan Lignite Obtained	287557519
Theoretically Calculated	265388010
Difference	**-22169509**

From Table 4.9, it is found that the difference is 8.3% of the excavation amount calculated theoretically and approximately 1.3% of this difference is obtained when the block model is created from the solid model (Figure 4.19-4.21). Therefore, the error percentage is determined as approximately 7%.

5. CONCLUSIONS AND RECOMMENDATIONS

With the help of Netpro/Mine software, evaluation and editing of the drillings, surface constructing, solid modeling, block modelling, calorific value estimation and production and quality estimations have been made by using drill-hole data of the Afşin-Elbistan Kışlaköy field. The results of the study are summarized below.

1. Netpro / Mine software has a simple user interface that puts all mining designs under a single framework and is powerful in combining 2D / 3D design processes (CAD) and Geographic Information Systems (GIS) with extensive reporting options.
2. The characteristics of the variable (calorific value) were determined by looking at the descriptive statistics of the drilling data.
3. The overburden and coal zone solid models under the excavation and topography surface as of April 2008 were successfully obtained.
4. The volume was inquired over the solid models obtained.
5. The optimum block sizes with the lowest estimation error and representing the field best were determined and the block dimensions were taken as 50x50x 2.5m.
6. Various composite lengths are tried and 2.5 m is chosen as the composite length which best represents the original data.
7. The calorific value of each block within the coal model is estimated by using composited drilling logs and the nearest neighbor technique. In Kışlaköy field, 2068778613 m3 overburden and 535116796 m3 coal with average calorific value of 1102.272 kcal/kg above the 750 Kcal/kg cut-off calorific value were calculated. It is seen that these results are similar with the results of RWE (2008) by using same data.
8. To check the accuracy of the current block model, excavation performed between April 2008 and end of 2013 year were calculated (265388010 m^3) and this result was found close to the actual amount of excavation (287557519 m^3) performed by Afşin-Elbistan Lignite Coal Enterprises.

REFERENCES

ARIÖZ, D., 2011. Afşin-Elbistan linyit sahası Çöllolar sektörünün Netpro/Mine yazılımı ile değerlendirilmesi. Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Adana, 91s.

AYDOĞAN, M., 1978. K.Maraş-Elbistan-Çöllolar Kömür Yatağı Fizibilite Araştırması. MTA Raporu. Derleme No: 6413, Ankara (Yayınlanmamış).

DAĞ, A., 1997. Döner Kepçeli Ekskavatör Açık İşletme Yönteminde Bilgisayar Destekli Üretim Planlaması: Afşin-Elbistan Linyit İşletmesi Çöllolar Sahasına Uygulanması. Çukurova Üniv., Fen Bil. Ens., Doktora Tezi, s.184, Adana.

ERGÜDER, G., KIZILDAĞ, G. ve GÜNKEL, G., 2000. AEL Kışlaköy Açık İşletmesi Doğu Nihai Şevi Jeofizik Rezistivite Etüdü raporu. TKİ Genel Müdürlüğü, Ankara.

GÖKMEN, V., MEMİKOĞLU, O., DAĞLI, M., ÖZ, D., TUNCALI, E., 1993. Türkiye Linyit Envanteri. MTA, s. 269-272, Ankara.

GÜRSOY, E., ÖZCAN, K., YÜCEL, A.R., 1981. K.Maraş Elbistan D1 Sektörü Kömür Yatağı Jeoloji Raporu. MTA Raporu, Ankara.

KILIÇ, A. M., 1996. Analyse de la Stabilité Des Talus de la Mine de Lignite D'Afşin-Elbistan. Pour Obtenir la Grade de Docteur de I'école Nationale Supérieure Des Mines de Paris en Géologie de L'ingéieur, Paris.

KILIÇ, A. M.,ve ONUR, A. H., 2001. Afşin-Elbistan Linyitleri Açık İşletmesi İç Döküm Sahası Dinamik Duraylılık Analizi. Türkiye 17. Uluslar arası Madencilik Kongresi ve Sergisi Bildiriler Kitabı, s. 11-16.

KOÇAK Ç., 2000. Afşin-Elbistan Linyit Havzasının Yeniden Değerlendirilmesi. Enerji Dünyası Dergisi, Sayı:32.

KOÇAK, Ç., KÜRKÇÜ, S. N., ve YILMAZ, S., 2003. Afşin-Elbistan Linyit Havzasının Yeniden Değerlendirilmesi ve Linyit Kaynakları Arasındaki Yeri. 24-27 Eylül 2003, Türkiye 9. Enerji Kongresi, İstanbul.

KÜRKÇÜ, S.N., ERSOY M., ERSUN, E., 1993. Jeoistatiksel Yöntem Kullanılarak A fşin-Elbistan Havzası Çöllolar B Sektörü Rezerv Belirleme Çalışması. Türkiye 13. Madencilik Kongresi, Ankara.

MERT, B.A. 2004. Jeoistatiksel Analiz Üzerine Bir Bilgisayar Programı: Antalya- Akseki-Kızıltaş Boksit Yatağına Uygulanması. Çukurova Üniv., Fen Bil. Ens., Yüksek Lisans Tezi, Adana, Turkey, s.26.

MERT, B.A., 2010. Afşin-Elbistan Kömür Havzasındaki Madencilik Faaliyetlerinde Coğrafi Bilgi Sistemleri ile Küresel Konumlama Sistemlerinin Kullanım Olanaklarının Araştırılması, Çukurova Üniveristesi, Fen Bilimleri Enstitüsü, Doktora Tezi, s.1,

Adana.

NETCAD, 2010. NETCAD Netpro/Mine Operatörler, ss.27, Ankara.

NETCAD, 2012. NETCAD Netpro/Mine Kullanım Klavuzu, ss.392, Ankara.

OTTO GOLD, 1969. Lignite Deposit of Afşin-Elbistan Feasibility Report. Vol 1, Köln, p.123

ÖNEN, N., 1936. Orta Anadolu Linyit Yatakları Hakkında Rapor. MTA, Ankara.

ÖZBEK, T., ve GÜÇLÜER, S., 1977. K.Maraş Elbistan Çöllolar – B Linyit Sektörü 1977 Yılı Faaliyet Raporu. MTA Raporu, Ankara.

ÖZDEMİR, A.. 2013. Yüzey Modelleme Teknikleri Ve Kömür Yatağına Uygulanmas. Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Adana, 83s.

ÖZTÜRK, T., 1994. A.E.L. İşletmesi Kazı Sahasında Karşılaşılan Sert Kayaçların Kazı Yöntemlerinin İncelenmesi, İatanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, s.4-5, İstanbul.

PERİNÇEK, D., and KOZLU, H., 1984. Stratigraphy and Structural Relations of the Units in the Afşin-Elbistan-Doğanşehir Region (Eastern Taurus): in Tekeli. O. and Göncüoğlu, M.C. (Eds), Geology of Taurus Belt, Ankara- Turkey, p.181-198.

RHEINBRAUN CONSULTING, 1976. Quality and Quantity Calculations For Kışlaköy Open Cast Mine. Cologne (yayınlanmamış).

RWE, 2008. Maden Planlaması – Aşama I: Uzun Vadeli Maden Planlaması Projesi, Proje Numarası: P-0636, Versiyon:2.0.

SAYDAM, S., 1995. Blok boyutu seçiminin kömür rezerv tahminine etkisi. Dokuz Eylül Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, İzmir, 58s.

TURHAN, H., 1993. Bir linyit yatağında rezerv modelleme yöntemlerinin karşılaştırılması. Orta Doğu Teknik Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Ankara, 150s.

URAL, S., 1999. Afşin-Elbistan Linyitlerinin Sınıflandırılarak Termik Santralin Performansı Üzerindeki Etkilerinin Araştırılması, Çukurova Üniversitesi Fen Bilimleri Enstitüsü, Proje No: FBE. 96.97, Doktora Tezi, s.140, Adana.

URAL, S., ve YUKSEL, F., 2004. Geotechnical Characterization Of Lignite-Bearing Horizons In The Afşin-Elbistan Lignite Basin, SE Turkey. Engineering Geology 75 (2004), 129-146.

YÖRÜKOĞLU, M., 1991. Afşin-Elbistan Projesi ve TKİ Kurumu AELÎ Müessesesinde Madencilik Çalışmaları. Madencilik Dergisi, Eylül 1991, Sayı No:3, s.13-29, Ankara.

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