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DEFENCE SYSTEM FROM WATER OF THE OPEN PIT GRAČANICA – GACKO**

Abstract

The open pit Gračanica - Gacko has very complex conditions of watering with occurrences of significant inflow of water as the result of short-term precipitation of high-intensity. This paper presents a review of the influential parameters on size of watering and review a defense system of the open pit from water.

Keywords: open pit Gračanica - Gacko, influential factors of watering, defense system from water

INTRODUCTION

Selection of technical - technological solution for defense the open pit Gračanica with a part of the Field C and roof zone from surface and groundwater depends on the natural and technical - technological factors. The natural factors important in terms of drainage include the morphological features of the terrain, hydrographic features of the terrain, climatic characteristics of the area, hydrological characteristics of the area and hydrological characteristics of the terrain. The technical - technological factors include the available complex of equipment and general conditions of exploitation [1].

The concept of defence from water must provide a reliable protection of mining facilities in compliance with the legislation for this area, with maximum use of the existing equipment at the open pit [4, 5, 6, 7].

INFLUENTIAL FACTORS

The Gatačko field represents the intermountain depression filled with the Neogene

sediments formed in the phase of terrain relaxation upon cessation of directed tectonic pressures (Oligocene - Miocene). Now, it represents, for the most part, the alluvial surface of very slight decline from entering the river Mušnica in the field east of Avto-
vac to the mouth of the Gojkovića stream in Mušnica in the west.

Right tributaries of Mušnica, Gračanica i Gojkovića stream, with tributaries the Rajića stream Trnovac, flow as well as Mušnica from north to south to entering the field, cutting off diagonally prominently expressed decametric calcarenite packages in the Upper Cretaceous, mainly calcareous flysch. Tributaries of these three flows usually have orientation the northwest - southeast, parallel with calcarenite packages carved in softer marls or major and minor water flows form a rectangular hydrographic network conditioned by lithology of flysch formation in the northeast of the formacije severoistočno of Gatačko field.

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Mušnica, Gračanica and Gojkovića stream with their lower parts flow directly through the productive part of the coalbearing Gatački basin and their flows and amount of water in them have a significant impact on the surface coal mining and protection of the open pit from surface and partly ground water. Maximum and minimum flow rates in all three surface flows are a direct consequence of climatic conditions in the region or varying amounts of precipitation in certain seasons.

At the time of flood, periodically, from late autumn to early spring, the lowest southern and southwestern parts of the field are flooded with the water pillar, depth of up to 0.6 m, which decreases with a steep gradient immediately after cessation of heavy rainfall. Flooding occur due to the formation of natural prechasm retention, because there is no a usual chasm zone at the lowest southwestern part of the field due to the exi-

sting geological situation and the gorge near in Srdjevića cannot miss in a short period the big storm water collected by Mušnica.

Climate of wider area of Gacko is a continental - mountainous which means a long and cold winters (in the period November - April with temperatures as low as -30°C) and relatively short summers (June - August) with temperature of up to 30°C . With a temperature range at annual level are also typical and heavy snowfall causing disruption of traffic on the roads to the northern and rarely western areas. It should be also counted on the occasional storm surges of strong winds, which can reach speeds of up to 150 km/h, and jeopardize the transmission electricity systems, as well as heavy rains in a short period when the open pit is threatened by abundant inflows of surface and partly groundwater. Precipitation amounts for return period of 60 years are given in Table 1 [2].

Table 1 *Precipitation amounts for a period of 60 years*

	l / m^2
Maximum hourly rainfall amounts	56.0
Maximum daily rainfall amounts	198.4
Maximum monthly rainfall amounts	636.0
Maximum annual rainfall amounts	3 012.5

Deposition of Neogene sediments with coal was performed in inter-mountain depression formed in the karst area. Coal deposit is entirely located below the alluvial surface with several streams drained by the largest flow in the field by the small river Mušnica. Mušnica through the Srdjevic gorge drains the Gatačko field on its southwestern edge, and a few kilometers away ends up in the chasm zone below Videz. In the period of heavy rainfall, the lowest part of the Gatačko field is blue, because a back pressure is created in the Srdjevic gorge. And in the southeastern and southwestern edge, there are several sources, whose water flows out by small streams across the alluvial surface into Mušnica. The conditions from previous described statements, lithology of the Neogene coal-bearing formation, as well as the overall geological characteristics of its older substrate, influenced the formation of

several aquifers - water-bearing horizons, both in the coal-bearing formation and in its immediate environment. The coal deposit Gacko deposit in terms of hydrogeological characteristics belongs to very complex deposits.

In the coalbearing formation of Gacko, the extremely most common lithological member are marls (coaly, sandy, limed, tufaceous) then clay, coal, subordinate tuffs and very rarely weakly bonded sandstones and conglomerates. The basic collector in the geological pillar of above the sediment, more than 450 m thick, is a coal seam, especially coal in the main and the first foot wall of coal seam. Coals are medium to low water permeable rocks, depending on the depth of distribution. The category of low water permeable rocks also includes sandy marls as well as marls above the main coal seam but only if they have poorly developed frac

ture system. There is a datum that tuffs can be partly water permeable in some places. All other listed lithological members are watertight.

According to the extensive detailed hydrogeological explorations in the West Field of the open pit Gračanica, it was concluded that the rivers Mušnica i Gračanica participate in the recharge of aquifers in the Neogene coalbearing formation with 80%, since 10% of water comes from the flysch formation and 10% from the field rim and of rainfall [2]. In some areas, the recharge is also done from the Jurassic formations, where they are in a direct contact with the coal seams as it is the case in the northeastern part of the Central and East Fields. Emptying of aquifers in the Jurassic and Cretaceous units takes place in the northeastern and southwestern rim of the basin through a number of sources (much higher yields are those on the northeastern contact with the Neogene sediments). The aquifers in the area of syncline axis have sometimes the artesian and sometimes sub-artesian character.

In the area of the Central Field, the groundwater flows from northeast to the southwest with gradient of underground flow $I = 0.007 - 0.01$ [2]. In the East field, the flow direction is toward the northwest, nearly parallel to a flow of Musnica gradient the flow gradient $I = 0.006 - 0.005$ [2]. Recharge of aquifers in the roof coal seams is mainly from rainfall (infiltration through the thin Quaternary cover) and from surface flows, mainly Musnica. The direction of flow is as in the previous case and with a small flow gradient. Bearing in mind the previously given as well as displays on the geological map and geological - accounting profiles, the interconnections of individual aquifers can be observed, their interconnections with the terrain surface as well as connections to the divisions that were transgressed by the Neogene sediments.

The system of coal and overburden exploitation at the open pit Gračanica in a part of the Field C and elevated zone is defined as a function of geological - structural conditions, engineering - geological and hydrogeological characteristics of the working envi-

ronment, disposable complex of equipment and general operating conditions. A continuous, mixed and discontinuous technology of exploitation is applied on overburden production. Combined technology of exploitation involves a discontinuous overburden excavation with hydraulic shovels, loaders, as well as continuous excavation the solid parts using combine and internal transport by trucks to the crushing plants for waste. A part of discontinuous equipment is engaged to the requirements of technological process and coal production. Disposal of overburden is carried out on the West outer landfill and internal landfill of the Field B at the open pit Gračanica. A combined technology of selective excavation is applied for coal production. Coal excavation is carried out by hydraulic shovels. Transportation of coal excavated by hydraulic excavators to the primary crusher is carried out by trucks. From the primary crushers, coal is transported by conveyor belts to the secondary crusher of the power plant.

DEFENCE SYSTEM FROM WATER

In accordance with the work progress on the excavation of overburden and coal, the defense from water will be carried out in two locations: a part of the Field C, and a part of the Roof zone.

The concept of defense a part of the Field C is that, where possible, water from atmospheric precipitation gravitating towards the open pit to be accepted by lateral canals with dams and gravity taking out of the open pit area, and groundwater and water from atmospheric precipitation falling directly on the area of the open pit to be accepted into the water collectors and to be taken by pumps and pipelines into the river Gračanica [1]. Protection of the Field C of the water due to the atmospheric precipitation gravitating towards the open pit will be done with two circumferential canals: the channel OK1 on the north side of the open pit, and the the channel OK2 which extends parallel to the front line of mining works in progress and on the south side of the open pit flows into the old riverbed of Musnica.

Protection of the Field C on groundwater and water from atmospheric precipitation falling directly on the area of the open pit will be done with the current system, which includes two water-collectors: the VS-C1 and VS-C2 from which the water is lead by pumps and pipes into the river Gracanica. For groundwater occurring in the northern part of the Field C, the two holes will be made below the transport route for coal transport. For regulation the water flow on the working front, the storey channels EK0 - EK4 will be made which are connected by transverse channels PK1 and PK2.

Protection of the Roof zone on water due to atmospheric precipitation gravitating towards the open pit will be done by a peripheral canal and a dam OK3 around the entire open pit. Water from this canal will partly go into the old river bed Musnica and partly in the canal OK4. Protection of the Roof zone on groundwater and water from atmospheric precipitation falling directly on the area of open pit will be done by creating a water collector where the pumps and pipeline will be set which will be led through the peripheral embankment to the canal OK4 on the southwest side of the open pit. The water flows into this canal from the canal OK3. Water from canal OK4 are drained by the old river bed Musnica outside the area of the open pit. The storey canals EK5 - EK9 and transverse canal PK3 - PK5 are predicted at the open pit.

Due to the stability, a part of the old riverbed Musnica from the bridge on the south side of the Field C, distance of 200 m, will be covered with a protective foil. Position of the water protection facilities is shown in Figure 1.

The positions and volume of water collectors VS-C1 and VS-C2 in the final stage in a part of the Field C are determined by the available space in these locations. The available volumes of water collectors are VS-C1: 166 665 m³ and VS-C2: 65 985 m³[3]. Calculation of the required volumes of water collectors is done according to maximum eight-hour rainfalls for a return period of 50 years. According to the hydrogeological characteristics of the area, the obtained value

will be increased by 5% due to the influx of groundwater into the open pit. Required volumes of water collectors are VS-C1: 236 680 m³ and VS-C2: 146 740 m³[3]. Volumes of water collectors are lower than calculated. Due to large sizes of water collectors that would accept maximum water from rainfalls for the fifty-year-period, the sinking of the lowest level is allowed except that there is no equipment on it, and there is no interruption in production. During precipitation of high intensity (which are of short duration), the space is predicted for temporary accumulation in the water-collector VS-C1 at the bottom of the open pit. The space on the lowest elevation E870 to the level K875 is 380 000 m³ [3] what is larger volume than needed. During precipitation of high intensity, it is necessary to remove the machinery and manpower from the space allocated for temporary accumulation.

The water-collector VS-PZ in the final stage of works on the Roof zone is made on the level E905 and the depth of water collector is 5 m. The position and sizes of water collectors are conditioned by development of works at the open pit. Volume of this water collector is 10 975 m³ [3]. The area authoritative for sizing the water collector is a complete surface inside the dike. Required volume of water collector VS-PZ is 78 890 m³ [3]. Volume of water collector is lower than calculated. Due to large sizes of water collectors that would accept maximum water from rainfalls for the fifty-year-period, the sinking of the lowest level is allowed except that there is no equipment on it, and there is no interruption in production. During precipitation of high intensity (which are of short duration), the space is predicted for temporary accumulation in the water-collector VS-C1 at the bottom of the open pit. The space on the lowest elevation E905 K915 is 270 000 m³ [3] what is larger volume than needed. During precipitation of high intensity, it is necessary to remove the machinery and manpower from the space allocated for temporary accumulation.

Sizing of pumping systems in a part of the Field C was carried out according to the condition that maximum eight-hour water

inflows have to be reduced for the amount of water that can be accepted by water-collectors and pumped for 36 hours. The amount of water that needs to be pumped out is: PS-C1: 236 680 m³, PS-C2: 146 740

m³ [3]. The required pumping capacity is: PS-C1: 0.54 m³/s, PS-C2: 0.62 m³/s[3]. Height pumping for both pumping stations is H_g = 70 m. Pump head is increased by 10% for local resistance and is H = 77 m [3].

Figure 1 Position of water protection facilities

At the pump station PS-C1 the existing pumps Flygt 2250 HT and pump Flygt 3240 CS are retained with moving to a new location and extension of the pipeline. The additional pipeline length needed for pumps in development phase of works is 100 m for every existing pipeline. The new pump which is set is Flygt CS 3240 connected to the pipeline $\phi 300$ mm. The first 30 meters of the pipeline is flexible and the rest is steel pipeline. Pipeline length is 800 m. At the pump station PS-C2 the existing pumps Flygt 2250 HT and pump Flygt 3240 CS are retained with moving to a new location and extension of the pipeline. The additional pipelines needed for pumps in development phase of works is 350 m for every existing pipeline. The new pump Flygt CS 3240 is set connected to the pipeline $\phi 300$ mm. The first 30 m of this pipeline is flexible and the rest is steel pipeline. Pipeline length is 750 m.

Sizing the pumping plants in a part of the Roof was carried out according to the condition that maximum eight-hour inflow of water to be pumped for 24 hours. As the

volume of water to be pumped is 78 890 m³, required hour pumping capacity is 0.91 m³/s. Height of pumping is H_g = 40 m. Pump head is increased by 10% for local resistance and is H = 44 m. For these conditions pumping will be done by Flygt 2250 MT pumps. One section consists of two pumps of this type, which are arranged in series. Five such sections are needed, each with individual pipeline $\phi 300$ mm. The investor has the required number of pumps. The acquisition of a plastic piping length of 200 m for each of the three new sections is required.

Circumferential dike is made of marl. The height of dike is 1.5 m, width of crown 1 m, and a slope of lateral sides 1: 2. Length of dike is 1 830 m. Plugs in the old riverbed Musnica are made of marl, length of 100 m for plug 1 and 50 m for plug 2.

Protective foil in the old riverbed Musnica is set from the bridge on the south side of the Field C upstream in length of 200 m. Required minimum thickness of foil is 2 mm. The foil surface is 520 m². Profile with the set foil is shown in Figure 2.

Figure 2 Profile with set foil

CONCLUSION

Sizing a defense system from water at the open pit Gračanica - Gacko is particularly a complex issue. Particularly important is determination the inflow of precipitation and groundwater. Properly defined inflow and hydraulic connections determine the type and number of facilities for defense from water [4, 5, 6, 7].

The present defense system from water at the open pit Gračanica - Gacko has primarily a function to provide a reliable protection of mining facilities in the case of large inflows as a consequence of maximum precipitation of a short intensity.

A significant feature of this defense system from water is also maximum utilization the existing pumping plants and pipelines with minimizing procurement of a new equipment, which is extremely important in terms of investments.

In designing the defense system of the open pit from water, the experience of the open pit Gračanica - Gacko, with additional measures of bringing the water quality within the prescribed limits, should be also used at the open pits of RTB Bor. By combination and proper selection of facilities for defense from water and maximum utilization of the existing resources, the presented system is an optimal solution in terms of safety, investment, maintenance, energy consumption and required workforce.

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SISTEM ODBRANE OD VODA POVRŠINSKOG KOPA GRAČANICA – GACKO**

Izvod

Površinski kop Gračanica Gacko ima izuzetno složene uslove ovodnjenosti uz pojave značajnih priliva voda kao posledice kratkotrajnih padavina velikog intenziteta. Ovim radom je dat prikaz uticajnih parametara na veličinu ovodnjenosti i prikaz sistema za odbranu kopa od voda.

Ključne reči: Površinski kop Gračanica – Gacko, uticajni faktori ovodnjenosti, sistem odbrane od voda

UVOD

Izbor tehničko - tehnološkog rešenja odbrane površinskog kopa Gračanica sa delom Polja C i Povlatne zone od površinskih i podzemnih voda zavisi od prirodnih i tehničko - tehnoloških faktora. U prirodne faktore bitne sa aspekta odvodnjavanja spadaju morfološke odlike terena, hidrografske odlike terena, klimatske odlike područja, hidrološke karakteristike područja i hidro-geološke karakteristike terena. U tehničko - tehnološke faktore spadaju raspoloživi kompleks opreme i opšti uslovi eksploatacije[1].

Koncepcija odbrane od voda mora da pruži pouzdanu zaštitu rudarskih objekata, uz pridržavanje zakonske regulative za ovu oblast, uz maksimalno korišćenje postojeće opreme na kopu [4, 5, 6, 7].

UTICAJNI FAKTORI

Gatačko polje predstavlja među planinsku depresiju ispunjenu neogenim sedi-

mentima, formiranu u fazi relaksacije terena po prestanku usmerenih tektonskih pritisaka (oligocen-miocen). Sada predstavlja, najvećim delom, aluvijalnu površ veoma blagog pada od ulaska reke Mušnice u polje istočno od Avtovca do ušća Gojkovića potoka u Mušnicu na zapadu.

Desne pritoke Mušnice, Gračanica i Gojkovića potok, sa pritokama Rajića potok i Trnovac, teku, kao i Mušnica, od severa ka jugu do ulaska u polje, presecajući dijagonalno markantno izražene dekameterske pakete kalkarenita u gornjokrednom, pretežno karbonatnom flišu. Pritoke ova tri toka uglavnom imaju orijentaciju severozapad – jugoistok, paralelno sa pružanjem kalkarenitskih paketa usečene su u mekše laporce, odnosno glavni i manji vođeni tokovi čine pravougaonu hidrografsku mrežu uslovljenu litologijom flišne formacije severo-istočno od Gatačkog Polja.

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Mušnica, Gračanica i Gojkovića potok svojim donjim delovima tokova teku direktno preko produktivnog dela ugljonosnog Gatačkog basena pa njihovi tokovi i količina voda u njima imaju značajan uticaj na površinsku eksploataciju uglja i zaštitu kopa od površinskih i delom podzemnih voda. Maksimalni i minimalni proticaji u sva tri navedena površinska tokadirektna su posledica klimatskih prilika u regionu, odnosno različite količine padavina u pojedinim godišnjim dobima.

U vreme povodanja, periodično, od kasne jeseni do ranog proleća, najniži južni i jugozapadni delovi polja su poplavljeni stubom vode dubine do 0,6 m, koji se strmim gradijentom smanjuje odmah posle prestanka obilnih padavina. Plavljenja nastaju usled formiranja prirodne pretonorske retezije, jer na najnižem jugozapadnom delu polja nema, zbog postojeće geološke situacije, uobičajene ponorske zone, pa tesnac

kod Srđevića ne može u kratkom periodu da propusti velike oborinske vode koje je prikupila Mušnica.

Klima šireg područja Gacka je kontinentalno – planinska što podrazumeva duge i hladne zime (u periodu novembar – april sa temperaturom i do -30°C) i relativno kratkim letima (juni - avgust) uz temperaturu i do 30°C. Uz velik raspon temperatura na godišnjem nivou karakteristične su i velike snežne padavine što uzrokuje prekide saobraćaja na komunikacijama prema severnim i ređe zapadnim područjima. Treba računati i na povremene snažne olujne udare vetrova, koji mogu dostizati brzinu i do 150 km/h i ugroziti i prenosne elektrosisteme, kao i obilne kiše u kratkom vremenskom periodu kada je ugrožen površinski kop obilnim doticajima površinske i delom podzemne vode. Količine padavina za povratni period od 60 godina date su tabelom 1 [2].

Tabela 1. Količine padavina za period od 60 godina

	l / m ²
Maksimalna časovna količina padavina	56,0
Maksimalna dnevna količina padavina	198,4
Maksimalna mesečna količina padavina	636,0
Maksimalna godišnja količina padavina	3 012,5

Depozicija neogenih sedimenata sa ugljem izvršena je u međuplaninskoj depresiji formiranoj u karsnom okruženju. Ležište uglja se u celini nalazi ispod aluvijalne površi sa nekoliko potoka, koje drenira najveći tok u polju – rečica Mušnica. Mušnica kroz Srđevića klanac odvodnjava Gatačko Polje na njegovom jugozapadnom obodu i nekoliko kilometara dalje završava u ponorskoj zoni ispod Videža. U period obilnih padavina najniži deo Gatačkog Polja se plavi, jer se stvara uspor u Srđevića klanacu. I na jugoistočnom i na jugozapadnom obodu nalazi se po nekoliko izvora, čije vode malim potocima preko aluvijalne površi odlaze u Mušnicu. Uslovi iz napred iznetih konstatacija, litologija neogene ugljonošne formacije, kao i ukupne geološke karakteristike

njene starije podloge, uticali su na formiranje nekoliko izdani - vodonosnih horizonata, kako u samoj ugljonošnoj formaciji tako i u njenom neposrednom okruženju. Ležište uglja Gacko u pogledu hidrogeoloških osobina spada u veoma složena ležišta.

U ugljonošnoj formaciji Gacka izrazito najzastupljeniji litološki član su laporci (ugljeviti, peskoviti, vapnoviti, tufitični), zatim gline, ugalj, podređeno tufovi i sasvim retko slabo vezani peščari i konglomerati. Osnovni kolektor u geološkom stubu navedenih sedimenata, debelom preko 450 m, predstavljaju ugljeni slojevi, posebno ugalj u glavnom i prvom podinskom ugljenom sloju. Ugljevi su srednje do slabovodopropusne stene, u zavisnosti od dubine rasprostranjenja. U kategoriji slabo-vodopropusnih

stena mogu doći i peskoviti laporci, kao i laporci iznad glavnog ugljenog sloja ali samo ukoliko imaju slabo razvijen pukotinski sistem. Postoji podatak da mestimično i tufovi mogu biti delom vodopropusni. Svi ostali navedeni litološki članovi su vodonepropusni.

Prema obimnim detaljnim hidrogeološkim istraživanjima na Zapadnom polju površinskog kopa Gračanica, zaključeno je da reke Mušnica i Gračanica učestvuju u prihranjivanju izdani u neogenoj ugljonoj formaciji sa 80%, dok 10% vode potiče iz flišne formacije a 10% sa oboda polja i od padavina [2]. U nekim područjima prihranjivanje se vrši i iz jurskih formacija, tamo gde su u direktnom kontaktu sa ugljenim slojevima kao što je slučaj na severoistočnom delu centralnog i istočnog polja. Pražnjenje izdani u jurskim i krednim jedinicama vrši se na severoistočnom i jugozapadnom obodu basena preko nekoliko izvora (znatno veće izdašnosti su oni na severoistočnom kontaktu sa neogenim sedimentima). Izdani u području ose sinklinale imaju ponegde arteški a ponegde subarteški karakter. U području Centralnog Polja podzemne vode teku od severoistoka ka jugozapadu sa gradijentom podzemnog toka $I=0.007 - 0.01$ [2]. U Istočnom polju smer toka je ka severozapadu, skoro paralelno toku Mušnice, sa gradijentom toka $I=0.006 - 0.005$ [2]. Prihranjivanje izdani u krovinskim ugljenim slojevima je uglavnom od pada-vina (infiltracija kroz tanak kvartarni pokrivač) i od površinskih tokova, uglavnom Mušnice. Smer toka je kao i u prethodnom slučaju i sa malim gradijentom toka. Imajući u vidu do sada izneto, kao i prikaze na geološkoj karti i geološkim – obračunskim profilima, mogu se uočiti međusobne veze pojedinih izdani, njihove veze sa površinom terena, kao i veze sa jedinicama na koje su neogeni sedimenti transgredirali.

Sistem eksploatacije uglja i otkrivke na površinskom kopu Gračanica u delu Polja C i povlatnoj zoni definisan je u funkciji geološko - strukturnih uslova, inženjersko – geoloških i hidrogeoloških karakteristika

radne sredine, raspoloživog kompleksa opreme i opštih uslova eksploatacije. Na proizvodnji otkrivke se primenjuje kontinualna, kombinovana i diskontinualna tehnologija eksploatacije. Kombinovana tehnologija eksploatacije podrazumeva diskontinualno otkopavanje otkrivke sa hidrauličnim bagerima kašikarima, utovaračem, kao i kontinualno otkopavanje čvrstih delova kombajnom i unutrašnji transport kamionima do drobilinih postrojenja za jalovinu. Deo diskontinualne opreme se angažuje prema zahtevima tehnološkog procesa i na proizvodnji uglja. Odlaganje otkrivke se vrši na Zapadno spoljašnje odlagalište i na unutrašnja odlagalište Polja B površinskog kopa Gračanica. Na proizvodnji uglja se primenjuje kombinovana tehnologija selektivnog otkopavanja. Otkopavanje uglja se vrši hidrauličnim bagerima kašikarima. Transport uglja otkopanog hidrauličnim bagerima do primarnih drobilica je kamionima. Od primarnih drobilica, ugalj se transporterima sa trakom transportuje do sekundarne drobilice termoelektrane.

SISTEM ODBRANE OD VODA

Saglasno dinamici izvođenja radova na otkopavanju otkrivke i uglja, odbrana od voda vršiće se na dva lokaliteta: deo Polje C, i deo Povlatna zona.

Koncepcija odbrane dela Polje C je da se, gde je to moguće, vode od atmosferskih padavina koje gravitiraju ka kopu prihvate obodnim kanalima sa nasipima i gravitacijski odvedu van područja kopa, a podzemne vode i vode od atmosferskih padavina koje padnu direktno na područje kopa prihvate u vodosabirnice i pumpama i cevovodima odvedu u reku Gračanicu[1]. Zaštita dela Polje C od voda usled atmosferskih padavina koje gravitiraju ka kopu, vršiće se sa dva obodna kanala: kanal OK1 sa severne strane kopa, i kanal OK2 koji se pruža paralelno sa frontom napredovanja radova i sa južne strane kopa se uliva u staro korito reke Mušnice. Zaštita dela Polje C od voda podzemnih voda i voda od atmo-

sferskih padavina koje padnu direktno na područje kopa vršiće se postojećim sistemom koji obuhvata dva vodosabirnika: VS-C1 i VS-C2 iz kojih se voda pumpama i cevovodima dovodi u reku Gračanicu. Za podzemne vode koje se javljaju u severnom delu Polja C, napraviće se dva propusta ispod transportnog puta za transport uglja. Za regulaciju kretanja vode na radnom frontu, biće urađeni etažni kanali EK0 – EK4 koji su spojeni poprečnim kanalima PK1 i PK2.

Zaštita dela Povlatna zona od voda usled atmosferskih padavina koje gravitiraju ka kopu, vršiće se obodnim kanalom i nasipom OK3 oko celog kopa. Vode iz ovog kanala delom će ići u staro korito reke Mušnice a delom u kanal OK4. Zaštita dela Povlatna zona od podzemnih voda i voda od atmosferskih padavina koje padnu direktno na područje kopa vršiće se izradom vodosabirnika u koji će biti postavljene pumpe i cevovodom će se preko obodnog nasipa dovoditi do kanala OK4 na jugozapadnoj strani kopa. U ovaj kanal dospevaju i vode iz kanala OK3. Vode iz kanala OK4 odvođe se starim koritom reke Mušnice van područja kopa. Na kopu su predviđeni etažni kanali EK5 – EK9 i poprečni kanali PK3 – PK5.

Zbog stabilnosti, deo starog korita reke Mušnice od mosta sa južne strane Polja C u dužini od 200 m biće obložen zaštitnom folijom. Položaj objekata zaštite od voda prikazan je na slici 1.

Položaji i zapremina vodosabirnika VS-C1 i VS-C2 u završnoj fazi u delu Polja C uslovljeni su raspoloživim prostorom na ovim lokacijama. Raspoložive zapremine vodosabirnika su VS-C1: 166.665 m³ i VS-C2: 65.985 m³ [3]. Proračun potrebnih zapremina vodosabirnika vrši se prema maksimalnim osmočasovnim padavinama za povratni period od 50 godina. Prema hidrogeološkim karakteristikama područja, dobijena vrednost će se uvećati za 5% usled priliva podzemnih voda u kop. Potrebne zapremine vodosabirnika su VS-C1: 236 680 m³ i VS-C2: 146 740 m³ [3]. Zapremine vodosabirnika su manje od proračunatih. Zbog velikih dimenzija vodosabirnika koji bi prihvatili maksimalne vode od padavina

za pedesetogodišnji period, dozvoljava se potapanje najniže etaže s tim da se na njoj ne nalazi oprema, i ne dolazi do prekida u proizvodnji. U vreme padavina velikog intenziteta (koje su kratkog trajanja) predviđen je prostor za privremenu akumulaciju kod vodosabirnika VS-C1 na dnu kopa. Prostor na najnižoj otvorenoj etaži E870 do kote K875 iznosi 380.000 m³ [3] što je veća zapremina od potrebne. U vreme padavina velikog intenziteta potrebno je mehanizaciju i ljudstvo skloniti iz prostora predviđenog za privremenu akumulaciju.

Vodosabirnik VS-PZ u završnoj fazi radova na Povlatnoj zoni se izrađuje na etaži E905 a dubina vodosabirnika je 5 m. Položaj i dimenzije vodosabirnika uslovljene su razvojem radova na kopu. Zapremnina ovog vodosabirnika iznosi 10.975 m³ [3]. Površina merodavna za dimenzionisanje vodosabirnika je kompletna površina unutar odbrambenog nasipa. Potrebna zapremina vodosabirnika VS-PZ iznosi 78.890 m³ [3]. Zapremina vodosabirnika je manja od proračunate. Zbog velikih dimenzija vodosabirnika koji bi prihvatili maksimalne vode od padavina za pedesetogodišnji period, dozvoljava se potapanje najniže etaže s tim da se na njoj ne nalazi oprema, i ne dolazi do prekida u proizvodnji. U vreme padavina velikog intenziteta (koje su kratkog trajanja) predviđen je prostor za privremenu akumulaciju na dnu kopa. Prostor na najnižoj otvorenoj etaži E905 do kote K915 iznosi 270.000 m³ [3] što je veća zapremina od potrebne. U vreme padavina velikog intenziteta potrebno je mehanizaciju i ljudstvo skloniti iz prostora predviđenog za privremenu akumulaciju.

Dimenzionisanje pumpnih postrojenja u delu Polje C izvršeno je prema uslovu da se maksimalni osmočasovni prilivi vode umanjeni za količinu vode koju mogu da prihvate vodosabirnici ispumpaju za 36 h. Količina vode koja treba da se ispumpa je: PS-C1: 236 680 m³, PS-C2: 146 740 m³ [3]. Potrebni kapacitet ispumpavanja iznosi: PS-C1: 0,54 m³/s, PS-C2: 0,62 m³/s [3]. Visina ispumpavanja za obe pumpne stanice iznosi H_g = 70 m. Napor pumpi je uvećan za 10% za lokalne otpore i iznosi H = 77 m [3].

Sl. 1. Položaj objekata zaštite od voda

Na pumpnoj stanici PS-C1 zadržavaju se postojeće pumpe Flygt 2250 HT i pumpa Flygt 3240 CS uz seljenje na novu lokaciju i produženje cevovoda. Dodatna dužina cevovoda potrebna za pumpe iz faze razvoja radova iznosi 100 m za svaki postojeći cevovod. Nova pumpa koja se postavlja je Flygt 3240 CS vezana na cevovod Ø300 mm. Prvih 30 m ovog cevovoda je fleksibilno a ostali deo čelični cevovod. Dužina cevovoda iznosi 800 m. Na pumpnoj stanici PS-C2 zadržavaju se postojeće pumpe Flygt 2250 HT i pumpa Flygt 3240 CS uz seljenje na novu lokaciju i produženje cevovoda. Dodatna dužina cevovoda potrebna za pumpe iz faze razvoja radova iznosi 350 m za svaki postojeći cevovod. Postavlja se nova pumpa Flygt 3240 CS vezana na cevovod Ø300 mm. Prvih 30 m ovog cevovoda je fleksibilno a ostali deo čelični cevovod. Dužina cevovoda iznosi 750 m.

Dimenzionisanje pumpnih postrojenja u delu povlatne zone izvršeno je prema uslovu da se maksimalni osmočasovni prilivi vode ispumpaju za 24 h. Kako je količina vode

koja treba da se ispumpa 78.890 m^3 , potreban časovni kapacitet ispumpavanja iznosi $0,91 \text{ m}^3/\text{s}$. Visina ispumpavanja iznosi $H_g = 40 \text{ m}$. Napor pumpi je uvećan za 10% za lokalne otpore i iznosi $H = 44 \text{ m}$. Za ove uslove ispumpavanje će se vršiti pumpama Flygt 2250 MT. Jedna sekcija se sastoji od dve pumpe ovog tipa koje su redno vezane. Potrebno je 5 ovakvih sekcija, svaka sa pojedinačnim cevovod Ø300 mm. Investitor poseduje potreban broj pumpi. Potrebna je nabavka plastičnog cevovoda dužine 200 m za svaku od tri nove sekcije.

Obodni nasip se izrađuje od laporca. Visina nasipa je 1,5 m, širina krune 1 m a nagib bočnih strana 1:2. Dužina nasipa iznosi 1.830 m. Čepovi u starom koritu reke Mušnice izrađuju se od laporca dužina čepova iznosi 100 m za čep 1 i 50 m za čep 2.

Zaštitna folija u starom koritu reke Mušnice postavlja se od mosta sa južne strane dela Polja C uzvodno u dužini od 200 m. Potrebna je folija minimalne debljine 2 mm. Površina folije iznosi 520 m^2 . Profil sa postavljenom folijom prikazan je na slici 2.

Sl. 2. Profil sa postavljenom folijom

ZAKLJUČAK

Dimenzionisanje sistema odbrane od voda kod površinskog kopa Gračanica – Gacko je posebno složeno pitanje. Izuzetno je značajno određivanje priliva od padavina i podzemnih voda. Pravilno određen priliv i hidrauličke veze opredeljuju vrstu i broj objekata za odbranu od voda [4, 5, 6, 7].

Prikazani sistem zaštite od voda površinskog kopa Gračanica – Gacko prvenstveno ima funkciju da obezbedi pouzdanu zaštitu rudarskih objekata u slučaju velikih priliva koji su posledica maksimalnih padavina kratkog intenziteta.

Značajna karakteristika ovog sistema zaštite od voda je i maksimalno iskorišćenje postojećih pumpnih postrojenja i cevovoda uz minimiziranje nabavke nove opreme, što je izuzetno važno sa aspekta investicionih ulaganja.

Pri projektovanju sistema odbrane kopa od voda, iskustva sa površinskog kopa Gračanica – Gacko, uz dodatne mere dovođenja kvaliteta vode u propisane granice, trebaju da se iskoriste i na površinskim kopovima RTB-a Bor. Kombinacijom i pravilnim izborom objekata zaštite od voda i maksimalnim iskorišćenjem postojećih resursa prikazani sistem je optimalno rešenje sa aspekta sigurnosti, ulaganja, održavanja, potrošnje energije i potrebne radne snage.

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