Mine Closure Planning Issues and Strategies in Neyveli Mines by using open Source Software

Atun Roy Choudhury
M.E. Scholar: dept. of Civil Engineering
Annamalai University
Annamalai Nagar, Chidambaram,
India-608002

Dr. V. Arutchelvan
Professor & Head: dept. of Civil Engineering
Annamalai University
Annamalai Nagar, Chidambaram,
India-608002

***Abstract*— Planning for mine closure is a critical component of environmental management in the mining industry. Nationally and internationally, industry-leading practice requires that planning for mine closure should start before mining commences and should continue throughout the life of the mine until final closure and relinquishment. The study indicates, somewhat surprisingly, that most mine closures are unplanned, with only 30% of mines closing when the economic resource has been extracted. The oldest mine closure technique was adopted in India is known as bibliometric mapping. But recently the transition from isolated specialties to a mature discipline, complete with higher level management process, continuing growth in technical fields and new interests in stakeholders and sustainability issues makes mine closure planning more complicated. This paper comprehensively discusses the legal framework for mine closure in Indian context besides highlighting the environmental and safety issues resulting from unplanned mine closure in Neyveli by using Quantum-GIS.**

Keywords*—Bibliometric Mapping; Quantum-GIS; Google Earth Pro; Artesian Pressure; Post Project Monitoring.

I. INTRODUCTION

Mine closure occurs as a result of the total extraction of the mineral reserves within the physical limits of a deposit or unworkability of the deposit due to technical/economic reasons [1] & [2]. The legacy of abandoned mines and their associated adverse environmental and safety problems have contributed to an increased emphasis on mine closure planning in recent years [3]. Both in the developed and developing countries, the mine closure issue has been a challenging and Herculean task and requires good planning, monitoring and execution as well financial commitments and hence to be exercised correctly [4] & [5]. Consultation with all external stakeholders and their participation are vital for the successful closing of each mine and to ensure social and economic activities are maintained [6] & [7]. The main concerns for decommissioning and rehabilitation are to ensure public safety and health, environmentally stable conditions compatible with the surrounding environment are achieved and to minimize environmental impacts made by mining [8] & [9]. The overall objective is to have a social, economical and environmental sustainable development [10]. There is a pressing need all over the world to confront the issue of mine closure. The pollution legacy makes difficult the sustainability of the mining activity and it is imperative to set up comprehensive mine closure systems [11]. With these planned closures, Federal, State and Local Governments have no doubt maximized their benefits in the form of taxes and royalties and should be working in the mine to ensure that environmental outcomes are optimum and in line with the closure or environmental management plan [12]. There is a plethora of reasons why mines close prematurely. Detailed study has shown that almost 70 per cent of mines that have closed in the past 25 years have closed for reasons other than exhaustion or depletion of reserves [13]. Main political decisions have to be made and this requires the involvement of governments, mining companies, NGOs and the organized civil community [14]. Policy issues, in its broadest meaning, are core to the understanding of the situation and thus, a research is needed beyond the technical aspects of mine closure [15] & [16]. Specifically, a research should include legal, institutional, economic, and public participation considerations [17]. There is much to learn from each other and from countries with mature systems on mine closure [18] & [19]. The main objective of this study is to know the implementation of technology intended for the development of Neyveli mine closure planning system by using open source software [20] & [21].

II. STUDY AREA

Neyveli Thermal Power Station is a set of power plant situated near lignite mines of Neyveli (*Fig. 1*). The study area of Neyveli open cast mines, Neyveli is located in Tamilnadu, approximately lies with latitude 11.5927°N and 79.4713°E (*Fig. 2 & 3*). NLC operates the largest open pit lignite mines in India presently mining 24MT of lignite and has an installed capacity of 2740MW of electricity [22]. The union government holds 93% shares of NLC and is administered through the Ministry of coal. The township covers 53 Km^2 provide around 18000 houses for the employees. It consists of two distinct units (Neyveli Thermal Power Station I and Neyveli Thermal Power Station II) capable of producing 1020 MW and 1,970 MW is respectively including their expansion units [23].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 11, November-2016

Fig. 1. Location of study area

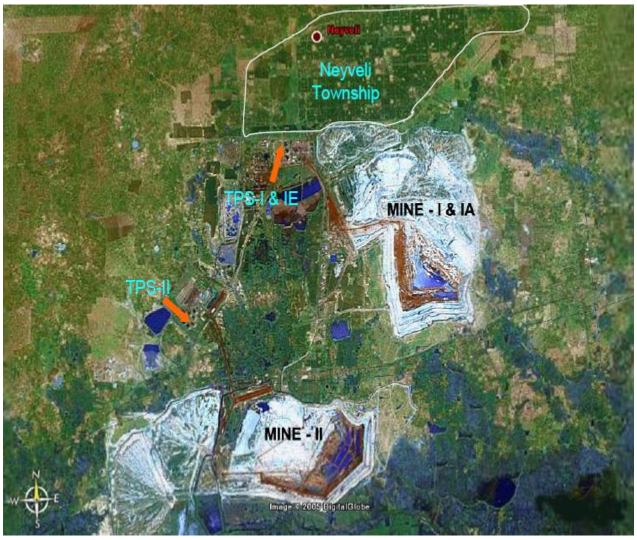

Fig. 2. Area of interest from Google earth pro

UTM CO-ORDINATES FOR DIFFERENT CORNERS OF NEYVELI MINES

CORNER 01 - 326280.69 m E
1283539.84 m N

CORNER 02 - 341606.42 m E
1283434.72 m N

CORNER 03 - 325933.52 m E
1270459.68 m N

CORNER 04 - 342727.81 m E
1270588.85 m N

Fig. 3. UTM Co-ordinates of Neyveli mines

III. METHODOLOGY

The following methodology includes creation of 2D mine map, Geo- referencing, shape files, contouring & drainage pattern, comparative study with other mines.

A. Technical, Environmental and Safety Issues Associated with Mine Closure in Neyveli

The technical aspects of mine closure planning deals with management of pit slopes, hydrology and hydro-geology, closure of entries, decommissioning of infrastructure, etc. The social impacts of mine closure involve: redeployment of the workforce, PAPs, minimize community and socioeconomic risk. The mine closure costs normally take into account: cost of closure activities, cost of organization for execution of closure related activities, the cost of post-project monitoring and bond/insurance [1].

B. Guidelines for Preparation of Mine Closure Plan in India

The Central Government vides Notification No. GSR 329 (E) dated 10.04.2003 and No. GSR 330 (E) dated 10.04.2003 amended the Mineral Concession Rules, 1960 and Mineral Conservation and Development Rules, 1988 respectively. As per these amendments all the existing mining lessees are required to submit the "Progressive Mine Closure Plan" along with prescribed financial sureties within 180 days from date of notification. Further, the mining lessee is required to submit "Final Mines Closure Plan" one year prior to the proposed Closure of the mine. In the notification it has been enumerated that the "Progressive Closure Plan" and "Final Closure Plan" should be in the format and as per the guidelines issued by the Indian Bureau of Mines [1].

C. Probable Closure Reasons of Neyveli Mines

C.1. Closure due to resource depletion

NLC mines are Tasmanian base coal mines and may be closed once the resource is exhausted (Table I).

C.2. Closure Due to Economic Reasons

Until around 2005, the mining industry was subjected to a continued steady decline in worldwide commodity prices. In the last couple of years, due mainly to unprecedented demand from China and to a lesser extent, India, most commodity prices have strengthened. This has implications, of course, for mine closure.

C.3. Closure Due to Cessation of Open Pit or Underground Workings

The resource continues at depth and in a number of cases, the mines were reopened as underground mines, with a portal and decline driven from a lower bench of the open pit. This can be a probable reason for mine closure.

C.4. Closure Due to Geological or Geotechnical Reasons

Ore reserves are estimates based on the best available data provided by geological, geophysical, geochemical, and drilling techniques, and by other relevant means. An over-estimation of the grade and tonnage of a deposit is a common reason for a mine to close prematurely [24].

C.5. Closure Due to Flooding

Flooding was the primary cause of 5 mine closures in Australia in recent years. They include both underground and open pit mines in WA and elsewhere and included the Bannockburn and the Emu mine in the Eastern Goldfields with the resultant loss of 6 lives. Inrush also caused the deaths of four coal miners and the closure of the Gretley Coal Mine in NSW in 1996 [12 & 24].

TABLE I. GENERAL REASONS OF MINE CLOSURE

Primary reason for closure	Numbers	Percent
Resource depletion/exhaustion (includes)	55	30.7
High cost/low prices/low grades	52	29.1
Open pit resource depletion (but with underground reserves) or underground reserves depleted (but plans to open cut remainder)	15	8.4
Depletion of oxide ore (but sulphide reserves)	3	1.7
Geological/geotechnical	6	3.4
Receivership/voluntary administration	9	5.0
Government actions/decisions	5	2.8
Flooding	5	2.8
Closure downstream industry or loss of markets	7	3.9
Major safety and health issue	4	2.3
Technical/equipment difficulties	2	1.1
Environmental issue	1	0.5
Industrial dispute	1	0.5
Landowner objections	1	0.5
Metallurgical recovery	3	1.7
Commissioning difficulties	2	1.1
Mine design or planning issue	4	2.3
Resource to be mined by others/ownership change	4	2.2
Total	**179**	**100%**

D. Status of Mine Closure in Indian Coal Mines

Coal mines in India have no statutory requirement to prepare mine closure plans or to furnish financial assurance to ensure decommissioning and reclamation of the mined out areas. The coal industry on its own has started preparing mine closure plans and incorporating it in EIA/EMPs prepared these days (*Fig. 4*). The coal companies also have started earmarking contribution based on per tone coal produced to cover closure cost [1].

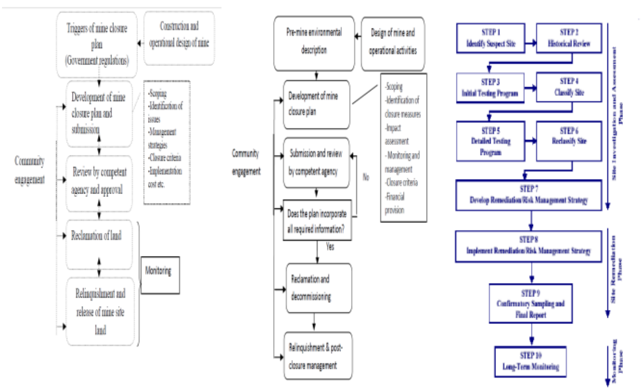

Fig. 4. Comparative study of mine closure policy in Australia, Canada and India

E. Contouring to Ensure Drainage

Digital elevation modelling contains all the 3D information about the terrain, but it doesn't look like a 3D object. To get a better look at the terrain, it is possible to calculate a hillshade, which is a raster that maps the terrain using light and shadow to create a 3D-looking image. To work with DEMs, QGIS all-in-one ***DEM (Terrain models)*** analysis tool has been used [25]. Generation of contour at an interval of 10 m has been carried out (*Fig. 5*).

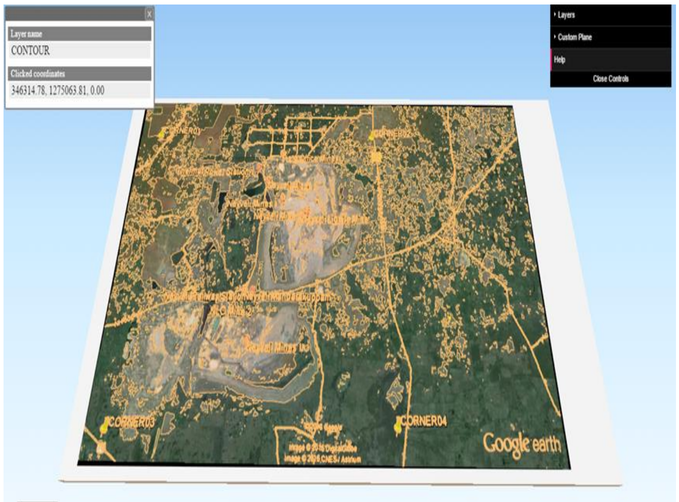

Fig. 5. Contours with geo referenced UTM co-ordinates

F. Existing Conditions of NLC Mines

F.1. Ground Water Aquifer

A huge reservoir of ground water occurs below the entire lignite bed, exerting an upward pressure of 6 to 8 kgf/cm^2. Unless this water pressure is reduced before mining, it will burst the lignite seam and flood the Mines (*Fig. 6*). This problem was overcome by continuously pumping out water round the clock through bore wells located at predetermined points and thereby reducing the water pressure at the lignite excavation area [22]. Ground water pumping from mines takes place at the rate of 110 Mm^3 / annum. 45 numbers of 1000 GPM pumps (20" dia) has generally been used for successful execution of the work [26]. Over the years, through continuous study and implementation of new methods, the quantity of water pumped out has been reduced from 50,000 GPM to 32,000 GPM [22].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 11, November-2016

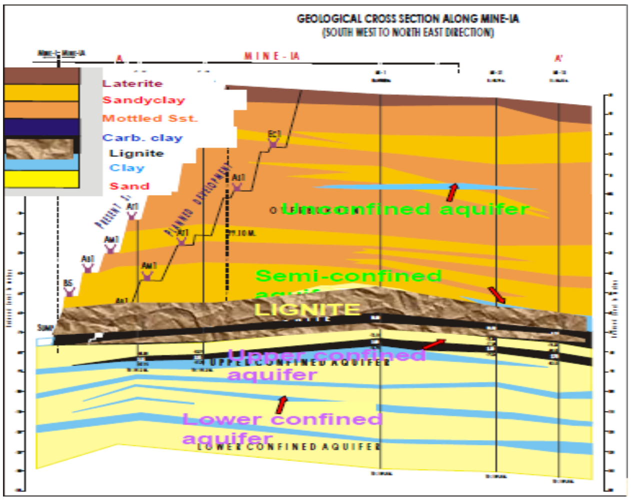

Fig. 6. Vertical cross section of NLC soil profile

F.2 Prevailing Climatic Condition

The Mine is mainly located in a monsoon and cyclonic area. The average rainfall in a year comes to about 1200 mm and the wind velocity goes up to 160 KM per hour [22].

G. Design Drainage

Here the drainage facility has been designed by using QGIS software with existing ground conditions and available hydraulic gradient (*Fig. 7*).

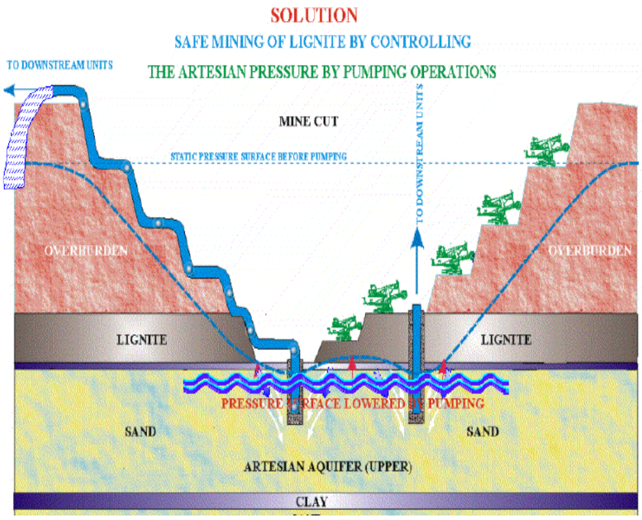

Fig. 7. Probable Drainage direction according to variation in gradient

H. Ground Water & Storm Water Control Operations

Ever since July 1961, the pressure surface is being controlled through pumping from large diameter wells (Drilling: 36 inches/Casing: 20inches) strategically located at pre-determined places. Effective pressure control is achieved from the upper confined aquifer alone, constituting the first 30 to 40 m of the aquifer zone immediately below lignite. Neyveli receives an average rainfall of 1200 to 1400 mm / annum through North-East monsoon (October-December). The pumps are of varying capacities Viz. 1000, 2000, 4000 and 5000GPM are used for dewatering the storm water and seepage water (*Fig. 8*) [26].

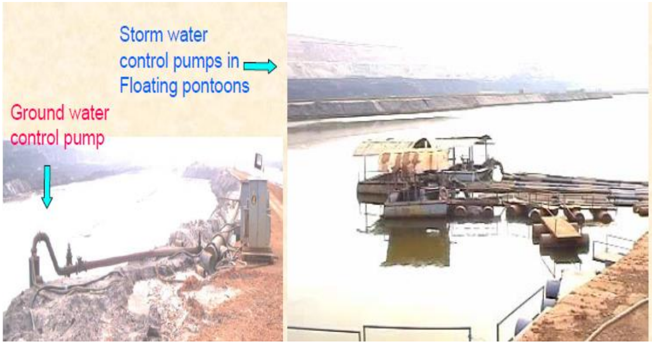

Fig. 8. Water pumping system

IV. RESULTS AND DISCUSSION

The mine closure objective for Neyveli may be to prevent access to former underground openings [1] and arrest the artesian pressure exerted by the underlying water table. Semi confined aquifer occurs just above lignite seam in the southern parts of Mine-I and is predominant in Mine-II and further south [26], exerts minimal pressure of about 3 to 5 kgf/cm^2 (*Fig. 9*). In case of confined aquifer, it exerts 50-100 $tones/m^2$ on the existing upper lignite base stratum. It's absolute to results in flooding of both the mine. Study shows this mine could be closed after a flood carried away the peat resource downstream.

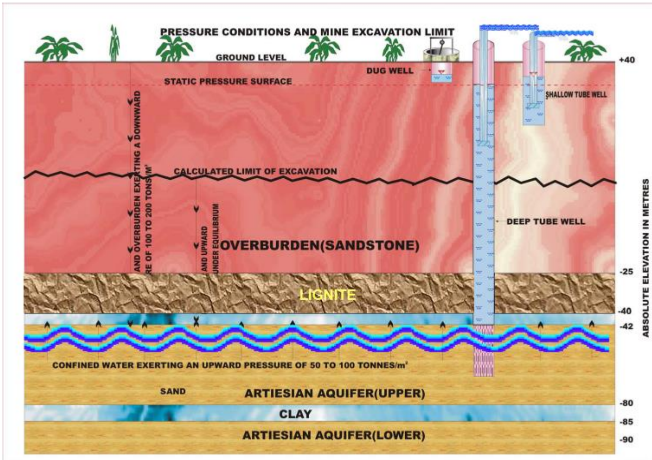

Fig. 9. Caution of flooding due to artesian phenomenon

The general drainage pattern, which is being adopted by NLC, is a temporary pressure removal solution which is carried out by the enormous number of heavy duty pumps. That system can be redesigned by using this GIS based technique, by finding the proper relief (*Fig. 10*). Here one suitable pathway has been designed to match the following criteria [8] & [9].

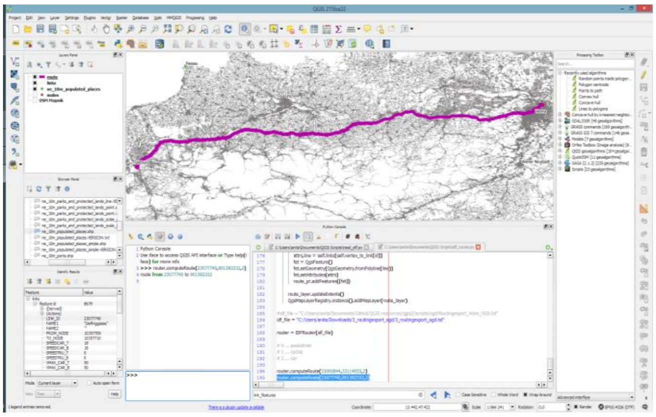

Fig. 10. Drainage path according to relief

If proper pressure relief and drainage is not simultaneously executed, then the colossal amount of upward water table pressure can submerge the whole mine area (*Fig. 11*).

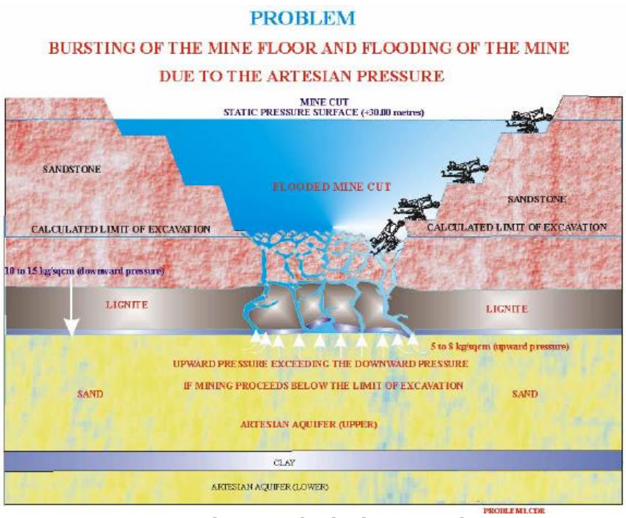

Fig. 11. Final catastrophe, leads to mine closure

In order to achieve the objective of this work and to develop a monitoring based pumping model, several important issues are essential and has to be taken into consideration, to provide satisfactory results like: proper planning and study of the region of interest, geological data collection and processing etc. [20] & [21].

CONCLUSION

Comprehensive mine closure for abandoned mines, operating mines and the future mines remain a major challenge for every mining nation in the world. Planned decommissioning, closure and reclamation planning have in recent years become a legal necessity in India since 2003 as pragmatic business approach and an environmental responsibility are viewed as an integrated part of the mining cycle. Studies on environmental impacts of mining post closure are very rare. Hence considerable efforts are needed to be directed towards the environment and safety risk assessment of mines after mine closure. The analysis of Neyveli mines was performed with the aim of extracting useful information for planning interventions towards the improvement of the existing pressure relief system. In this paper, the complete workflow has been discussed, starting from the generation of contours to the designing of appropriate drainage pathway. OSM and Google satellite has been used to bring the model into reality. Now, after taking all the probable reasons under consideration of the above study, a conclusion has been arrived that the bursting of the mine floor and submergence of the mineral ore under water could be the appropriate reason for Neyveli mine closure.

ACKNOWLEDGMENT

We sincerely express the gratitude to the technical team of Geological department, NLC India Limited for providing us such handy information & enabled us to complete the research work.

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