CHAPTER-6
LIGNITE MINING & ASSOCIATED HYDROGEOLOGICAL PROBLEMS
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LIGNITE MINING AND ASSOCIATED HYDROLOGICAL PROBLEMS

Lignite is a low grade, immature coal of low calorific fossil fuel (2000-3000 Kcal/ Kg), popularly known as Brown Diamond / brown coal. Lignite belongs to geologically younger member in coal family (i.e. tertiary age). Coal is the primary source of energy and become a cornerstone in power generation. Presently, coal based thermal energy has lion share in the total energy production in the world as estimated by the World Coal Institute (WCI, December, 2001) The countries mostly dependent on coal for electricity generation in 2000 includes Poland (96%), south Africa (90%), Australia (84%), China (80%), India (74%), Czech Republic (71%), Greece (70%), USA (56%), Denmark (52%) and Germany (51%).

In India, coal reserves (i.e. geological reserves) estimated 234 billion tones as on 1/1/2002 and produced 327.78 million tones during 2001-2002. Indian coal has high ash content ranges from 20 to 80% or more ash. Even though coking coal contain 25 to 30% ash, which is generally perceived to be good quality. The average ash content for coal based fire thermal power plant varies from 30 to 40% in India. The thermal power plants are the single largest coal-consuming sector, which consumed 78% of the total coal production in India. Besides this, other major coal consuming industries includes iron and steel, cement and fertilizer. Therefore, India’s industrial economy is largely coal centric.

Lignite is predominantly occurring in all the European countries as well as in Australia, Rumania, USA, China, Canada, India, Thailand,
Indonesia, Philippines, etc., with a total geological reserves estimated more than 6500 billion tones, of which about 5 to 7% are economically mineable reserves and produced 895 million tones during -2002. Presently, lignite is the primary source of energy in countries like Germany, Greece, Turkey, Spain, Australia, USA, etc., because of fast depleting hard coal resources and lack of other alternative cheap source of energy have enforced to exploit lignite, to meet the growing demand of electricity. Germany topped in lignite production and lignite based thermal power generation in the world. Almost 80.00% of the total energy production in Germany is based on lignite resources. Thereby, lignite play a vital role in Germany’s industrial development. The German industrial economy, therefore, is lignite oriented.

India’s southern states (i.e. Tamil Nadu, Kerala and Karnataka) and union territory of Pondichery were devoid of hard coal deposits and of limited potential of hydel power resource development and existing potential had already tapped to maximum extents. The transportation of coal from Northern states (i.e. Jharkhand, West Bengal and Orissa) to southern states by railways is economically not viable. While use of coal having more than 34% ash content in thermal power plants located more than 1000Kms away from coal mines and near ecologically sensitive areas has already prohibited by Ministry of Environment and Forest, Government of India (2001). Hence, no option left other than to exploit the treasure buried 25 million years ago underneath a village, called Neyveli in the Cuddalore district, Tamil Nadu. To cater the burgeoning demands of power in the southern India, the exploitation of Neyveli deposits provided cornerstone in power generation and has contributed in a big way to economic growth of the nation in general and Tamil Nadu in particular.
1. LIGNITE DEPOSITS IN INDIA

The lignite deposits of India mostly occur as sub-surface deposits except in the states of Jammu and Kashmir, Gujarat, and Kerala in Tertiary formations. The lignite occurs in a distinct and widely varying in nature, especially with regards to their lateral and vertical structured disposition, multiplicity of seams, quality, nature of occurrences, associated overburden and interburden formation, etc. The principal states of lignite deposits in India are Tamil Nadu, Rajasthan, Gujarat, and Jammu and Kashmir. The important known occurrences of lignite deposits in India are given in Table-XVII.

Table-XVII: Lignite deposits in India

<table>
<thead>
<tr>
<th>States</th>
<th>Geological reserves (MT)</th>
<th>Percentage( %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamil Nadu and Pondechery</td>
<td>26154.81</td>
<td>89.07</td>
</tr>
<tr>
<td>Gujarat</td>
<td>1504.81</td>
<td>5.12</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>1466.99</td>
<td>5.00</td>
</tr>
<tr>
<td>Jammu and Kashmir</td>
<td>127.84</td>
<td>0.44</td>
</tr>
<tr>
<td>Kerala</td>
<td>108.30</td>
<td>0.37</td>
</tr>
<tr>
<td>Total</td>
<td>29362.75</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Lignite Resources in India estimated 29362.75 million tones, of which Tamil Nadu alone accounts for 89%, and followed by Gujarat (5.12%) and Rajasthan (5%). In India, lignite based thermal power plants share only 4.00% of the total power generation at present.
1.1 LIGNITE DEPOSITS IN TAMIL NADU

Lignite deposits in Tamil Nadu are mainly confined in Cuddalore, Tanjaur, Trichirapalli and Bahur lignite field in Pondichery, which partly lies in Cuddalore district. A total of 26154.81 million tones of geological reserves of lignite are estimated by March 1997, out of which about 74.45% lies in Mannargudi field in Tanjour district. It is the largest known geological reserve of lignite in India occurs at depth of more than 400.00m (MECL-2001) and splitting nature of lignite seam has not yet been exploited.

However, Nayveli lignite deposits occur at shallow depth of 50 to 120 m below ground level (bgl). It is the biggest source of lignite in India, which is fully exploited mainly for electricity generation and also used in Briquetting and Carbonization plants and Urea manufacturing.

1.1.1. NEYVELI LIGNITE FIELD

The lignite deposits in this area was known through memoirs of Geological Survey of India (G.S.I., 1969). Which made the first mention of this deposit in 1884. The lignite deposits were found while drilling wells for irrigation purposes in late 1930. Geological Survey of India (GSI) further proved the occurrence of lignite deposits at Neyveli in 1943. The Government of Madras under took the preliminary investigation for the exploration of lignite in 1947 and the Government of India later took it in September 1955. The Neyveli Lignite Corporation was setup as a company in 1956 for commercial exploration of lignite. Shri Jawaharlal Nehru, the first Prime Minister of India who inaugurated the Mine-1 in May 1957, laid down the foundation stone.
The Neyveli Lignite Field spread over an area of about 480.00 sq. Km. and total geological reserves estimated to be about 3300.00 million tones. Lignite deposits at Neyveli occurs in a single seam with an average thickness of 14.00 m. The Neyveli mine is one of the Asia’s largest open cast lignite mine and produce 18.36 million tones of lignite during 2001-2002. It is the biggest lignite mine and largest producer of lignite in India, and constitutes more than 95.00% of the total lignite production in India. The two pit head gigantic lignite based thermal power plants produced 14451.32 million unit of electricity during 2001-2002 which meets the growing demand of power in southern states of India. The extensive lignite reserves are sufficient to sustain over 5000 MW power project for more than 80 years.

2. NEYVELI INDUSTRIAL COMPLEX

It is the legacy of the Tertiary era, which has transformed Neyveli, a small-unknown hamlet five decades ago into a renowned Mine-cum-Industrial complex of South India.

From the very modest beginning, when a pilot open cast project for lignite exploitation was launched near the hamlet, Neyveli in 1953. Initially Neyveli lignite project consist of an opencast mine with a capacity of 3.50 million tones of lignite per annum to feed a thermal power plant of 300 MW (5 x 50 MW) capacity, a fertilizer plant with a capacity of 152,000 tones of Urea per annum, a briquetting and carbonization plant with a capacity of 327,000 tones of leco per year and also a clay washing plant with a capacity of 6000 tones per annum. The project over the year has been expanded and enlarged to cater the increased power demand of India in general and southern region of India in particular.
Neyveli Lignite Corporation, presently operating, two opencast lignite mines; two pit head thermal power plants, a fertilizer plant and Briquetting and Carbonization plant.

2.1 MINE-I

The mine-I is situated on the northern part of village, Neyveli and was commissioned in 1957. The lignite seam was first exposed in August 1961 and regular lignite mining was commenced in May 1962. Initially, the area of the open cast mine was 15 sq. Km and had mineable reserves of 240 Million Tones with a capacity of 3.50 MT/Y. The mine-I was expanded to 6.50 MT/annum covering an area of 16.69 sq. Km with mineable reserves of 287 MT to sustain the supply of lignite to the expanded thermal power plant-I (TPS-I) with a capacity of 600 MW.

In December 2001, Government of India had further sanctioned the expansion of Mine-I from its present capacity of 6.50 MT to 10.50MT with corresponding expansion of Thermal Power Station-I (TPS-I) from the existing 600 MW to 1020 MW capacity. At present, Mine-I occupied an area of 18.36 sq. km. with mineable reserves of 365MT. During 2001-02, the Mine-I produced 7.65MT of lignite, which is highest since its inception.

2.2 MINE-II

It is located 5 km south of mine-I, spread over an area of 27.74 sq. Km with 398MT of lignite reserves. The Mine-II was opened in 1981 with a capacity of 4.70MT/Y linked to Thermal Power Plant–II (TPS-II) with a capacity of 630 MW. In February 1983, the Government of India had sanctioned for the expansion of mine-II to a capacity of 10.50 MT/ Y to feed
the Thermal Power Station-II (TPS-II) expansion of 840 MW (4 x 210 MW), and the present total installed capacity of TPS-II has reached to 1470 MW.

2.3 THERMAL POWER STATION-I (TPS-I)

   The first unit of Thermal Power Plant-I (TPS-I) with a capacity of 600 MW (6 x 50 MW) was synchronized in May 1962 and the last unit (3 x 100 MW) in September, 1970. In February 1996, Government of India had sanctioned the expansion of TPS-I of 420MW (22 x 210MW). Thus, TPS-I has total installed capacity of 1020 MW and generated 4182.36 million unit (MU) of electricity during 2001-2002. The power generation from TPS-I is fed into Tamil Nadu Electricity Board.

2.4 THERMAL POWER STATION-II (TPS-II)

   In February 1978, Government of India had sanctioned the expansion of TPS-II to 630 MW (3 x 210MW). Further Government of India had sanctioned for the expansion of TPS-II from 630 MW to 1470 MW with the addition of 840 MW (4 x 210 MW) in February 1983. The TPS-II had generated 10268.96 million unit (MU) of electricity during 2001-2002. The power generated from TPS-II is shared by all the southern states of India viz. Tamil Nadu (33.54%), Andhra Pradesh (22.78%), Karnataka (14.56%), Kerala (11.39%) and Pondichery (1.91%).

2.5 FERTILIZER PLANT

   Fertilizer plant at Neyveli is unique in the world as it is the plant only of this kind, which used lignite as a raw material for manufacturing of urea. The fertilizer plant with an installed capacity of 1,52000 tones of urea per annum had started production in 1996 with lignite as feedstock. The plant was designed to utilize raw lignite for the production of synthesis gas and at
the time it was the only plant in India to adopt direct solid fuel gasification for synthesis gas production. However, production of urea decline at alarming rate from 1.09 lakh tones in 1992-1993 to 0.62 lakh tones during 2001-2002.

2.6 BRIQUETTING AND CARBONIZATION PLANT

The Briquetting and Carbonization plant was commissioned in 1965 with an installed capacity of 4,36000 tones of coke (i.e. leco) per annum. In 1983-1984, Government of India had reduced the achievable capacity of this plant to 2,62000 tonnes of coke per annum. The B & C plant used lignite as raw material to produce coke, coke fine and phenolic chemical as a by-product. While production of coke (leco) falling rapidly from 1.21 lakh tones (1998-1999) to 0.04 lakh tones in 2001-2002. The coke is sold under the trade name of Leco. It is a useful fuel for domestic and industrial uses.

2.6.1 BY-PRODUCTS

In the process of briquetting and carbonization of lignite, several useful by-products like carbon acid, multivalent phenol, orho-cresol, meta-para cresol, xylenol, tar and neutral oil are produced. The productions of these by-products are given in Table XVIII.
Table-XVIII: By-Products of Briquetting and Carbonisation of Lignite

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Production (tones/annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbolic acid</td>
<td>1470.00</td>
</tr>
<tr>
<td>Multivalent phenol</td>
<td>480.00</td>
</tr>
<tr>
<td>Ortho-cresol</td>
<td>200.00</td>
</tr>
<tr>
<td>Metacresol</td>
<td>990.00</td>
</tr>
<tr>
<td>Xylenol</td>
<td>220.00</td>
</tr>
<tr>
<td>Tar</td>
<td>49100.00</td>
</tr>
<tr>
<td>Neutral oil</td>
<td>4820.00</td>
</tr>
</tbody>
</table>

2.7 CLAY WASHING PLANT

The clay occurs just above the lignite seam with an average thickness of 0.05m and is whitish in colour, termed as White clay. The White clay obtains along with the mining of lignite and later sends to clay washing plant. The washed clay is dried and sold under the trade name of Nekolin. It is used in ceramic industry, paper mills, and Porcelain factory and for manufacturing of insulators. At present this plant is closed.

2.8 ONGOING PROJECTS

1. Mine-I expansion from 6.50MT/Y to 10.50MT/Y.
2. TPS-I expansion from 600.00MW to 1020.00MW.
3. Mine IA: Neyveli lignite corporation has opened a new Mine known as Mine-IA in 2003, having mineable reserves of 120MT and located east of mine-I with a capacity of 3MT/Y to feed the zero unit of 210MW.

5. Mine-11 expansion from 10.50MT/Y to 15.00 MT/Y to be linked to TPS-II expansion (2 x 250MW).

6. Thermal power station-II expansion from 1470MW to 1970MW (2 x 250 MW).

2.9 PROPOSED PROJECTS

* To open the Mine-III with capacity of 8.00MT/Y to feeds the TPS-III with the capacity of 1000 MW (2 x 250MW).

From the very modest beginning when pilot open casts project for lignite mining was launched near the hamlet, Neyveli, today, Neyveli lignite corporation (NLC) has emerged as Hub of the vast and expanding industrial complex and became the power and industrial center of south India. The rapid transformations of the relatively backward Cuddalore district over the last few decades both socially and economically are due to the lignite mining and associated industrial plants at Neyveli.

Neyveli Lignite Corporation (NLC), however is more than just a lignite mining and electricity generation, ecological ramification have helped to stimulate and nurture a new industrial ethos worthy of being emulated. Over the years, the spectrum of widening interaction of NLC with the society and economy at large have helped in the rapid transformation of a predominantly agrarian economy to that of a vibrant industrial society.
3 MINING METHODS

Discovery of any mineral should be followed by intensive exploration and to assess the occurrence, nature, characteristics, aerial extents, reserves estimation, depth of occurrence, nature of overburdens, quality, utility, etc. pertaining to the mineral deposits. Further, a comprehensive idea about field of occurrence of the mineral deposits such as land use pattern, morphological features, hydrological phenomenon, ecological aspects, etc. should be gathered and analyzed as these have major bearing on the location, design, type of mining, benefit-cost ratio, ecological vulnerability, etc.

The prevalent practices in vague for mineral exploration is mining. Mining in turn broadly categorized into two classes: open cast mining and underground mining depending upon nature, occurrence, overburden, associated hydrological aspects and geology of the mineral deposits.

3.1 TECHNOLOGICAL OPTIONS AND CHOICE OF MINING METHODS AT NEYVELI

The geological and hydrological conditions of the Neyveli Lignite Field were analyzed with regards to their suitability for methods of mining. Unstable nature of the overburden, immediate weak roof over the lignite seam and floor conditions, the existence of high pressure confined aquifer below the lignite seam and semi-confined aquifer above the lignite seam (Mine-II area) and spontaneous combustible nature of the lignite have favored to opt opencast lignite mining at Neyveli. The lignite mining is carried out through open cast method only. Today, opencast mining has increasingly resorted globally to increase the volume of production with the growing demand of raw material for fuelling the Industrial society. Of the estimated 28 BT of raw mineral currently exploited worldwide, the share of
opencast mining is over 80%. However, open cast mining accounts 90% of the total mineral production in India. Surface mining has certain advantages over the underground method such as higher production rate, higher percentage of recovery, low production cost, safe mining conditions, etc. has resorted to open cast mining today.

3.2 MINING TECHNOLOGY AT NEYVELI MINES

The continuous surface mining technologies adapted at present include Bucket Wheel Excavator (BWE), belt conveyers, and spreader for removing of overburden and mining lignite. These machines are ideally suited for higher overburden lignite ratio and of soft formation.

The Neyveli lignite deposits, however, have certain unique features peculiar only to this area, which offered major technological challenges in lignite exploitation. Lignite mining conditions at Neyveli are extremely difficult and very much different from European and other world lignite deposits. Some of the main features are given below:

1. Hard, abrasive, thick overburden strata, which presents severe and strenuous duty condition for the mining equipment at Mine-I and some part of Mine-II. Neyveli people have been successfully adopted certain modifications in BWE and forward preparation of overburden through blasting.

2. Problem of sticky and marshy surface clays occurring in more than 65% of Mine-II area.

3. Presence of powerful confined aquifer below lignite seam and semi-confined aquifer above lignite seam.

4. Fall in cyclonic belt.
5. Comparatively higher overburden - lignite ratio.

These problems encounter in the Neyveli lignite mining has been successfully tackled by Neyveli Lignite Corporation (NLC).

4. **EXCAVATION OF OVERBURDEN**

The continuous surface mining technology adopted at Neyveli mines using Bucket Wheal Excavation (BWE), Conveyers and Spreader for removing the overburden and mining lignite resources. The overburden in the Neyveli lignite region varies from 50 to 100m, which is increasing towards dip direction (i.e. towards south east). The major part of overburden consists of hard and abrasive Cuddalore sandstone with beds of clay except in the southern and eastern part of Mine-II area, where soft alluvial deposits overlie Cudallore sandstones. The thickness of lignite seam varies from 11 to 25m and occurs in a single seam. Overburden lignite ratio in at Neyveli ranges from 9 : 1 to 15 : 1 (tones : tones basis) have involved higher quantum of overburden removal. The open cast mining at Neyveli disturbed 3679.81 hectares of fertile land and currently disturbing about 120 hectares land/year. It is anticipated that fertile soil over an area of about 6250 hectares would be disturbed and vegetation affected by opencast lignite mining.

The NLC, since it inception in 1957, has exploited a total of 324.66 MT of lignite and removed more than 1807.24 MCM of overburden. The details of annual production of lignite, overburden and lignite/overburden ratio of Mine-I and Mine-II is given in Appendix-VIII. The NLC has produced 18.36 MT of lignite and removed 122.25 MCM of overburden during 2001-2002, which is the highest since the inception of mining.
In opencast mining, it is imperative to reserve some area outside the mine boundary for dumping the initial mine out overburden. The initial outside dump cannot be avoided unless and until there is some other abundant mine pit nearby. The dumping of overburden can be diverted into mined out area, known as a backfilling.

4.1. MINE-I

The thickness of overburden varies from 50.00 to 95.00m and the lignite seam varies in thickness from 11 to 25m. The overburden material consists of mostly hard mottled Cuddalore sandstones lies below the top loamy and lateritic soil with varying percentage of clay material, fire clay and white clay.

Top portion of overburden consist of 2.00 m thick loamy and lateritic soil followed by lateritic sandstones, mottled clayey sandstone and sandstones, where fire clay and white clay are noticed at depth of about 20 to 25m and 50.00m below ground level respectively.

In the open cast mining, overburden has to be removed before reaching lignite seam. The overburden to lignite ratio is 5.50 m$^3$ to one tones of lignite. The overburden excavation carried out in four benches (viz. surface, top, middle and bottom) to increase the lignite production. Since 1957, overburden removal has been worked out and removed 1109.07 MCM of overburden. Whereas, lignite production begins in 1962, exploited a total of 206.11 MT of lignite. The details of annual removal of overburden material are shown in Fig. 23 & Appendix-VIII.
Fig. 23: Overburden production From Mine-I
4.1.1. OVERBURDEN DUMPING

Initially the overburden excavated from the Mine-I was taken out of the lignite boundary on the northern side and dumped over an area of 195.00 hectares. The volume of overburden has been estimated 80 MCM and dumped up to the height of 45m above ground level in different stages, which look like a mountain range in a featureless plain and developed gigantic crater.

Since 1965, backfilling was started along with the outside dumping and by 1970, outside dumping was almost stopped. Currently, the volume of overburden backfilling in Mine-I is in the order of 33 MCM over an area of about 50.00 hectares per year. With the implementation of Mine-I expansion scheme in 1978, soil of the top most benches was again taken outside the mine boundary of about 45 MCM and dumped in the eastern side of mine over an area of 135 hectare up to a height of 55 m. In 2003, again outside dumping is carried out over the old dumping yard with the opening of Mine-IA and implementation of expansion programme of Mine-I in December 2001.

Dumping of overburden on the dumping yard carried out in stages and has attained a height of about 60m from the ground level. Currently Neyveli lignite mining has disturbed 17.69 sq. Km of fertile land and projected to 28.07 sq. Km. by 2017.

The topmost dump was highly irregular with development of massive ravines, pit, gullies and vallies resulting spread of loose material into adjacent cultivated land, settlement area, subsidence of dumping yard, silting of drainage system during rainy season in the study area.
4.1.2 CHARACTERISTIC OF OVERBURDEN

i) Cuddalore Sandstones

The Cuddalore sandstones constituting a major portion of the overburden materials are predominantly argillaceous and in places ferruginous. They are partly fine grained and partly coarse grained. The hard and compact ferruginous clayey, mottled variegated Cuddalore sandstone form part of the surface bench and top bench. A typical physical, mechanical and chemical analysis was done by NLC and mineralogical composition of Cuddalore sandstones are given in Table-XIX, XX & XXI respectively.

Table-XIX: Physical Analysis of Cuddalore Sandstones

1. Grain Size %
   I) Coarse sand 16.00%
   II) Medium sand 26.00%
   III) Fine sand 13.00%
   IV) Silt and clay 45.00%
2. Porosity 27.00%
3. Liquid limit 21.00
4. Plastic limit 14.00
5. Normal moisture content 7.00
6. Bulk density(gm/cc) 2.1
7. Specific gravity 2.5
8. Void ratio 0.28
Table-XX: Chemical Analysis of Cuddalore Sandstones

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>76.00%</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>14.50%</td>
</tr>
<tr>
<td>Fe₂O₃ + FeO</td>
<td>4.25%</td>
</tr>
<tr>
<td>CaO</td>
<td>0.50%</td>
</tr>
<tr>
<td>MgO</td>
<td>1.00%</td>
</tr>
<tr>
<td>Na₂O</td>
<td>Trace</td>
</tr>
<tr>
<td>TiO₂</td>
<td>Trace</td>
</tr>
<tr>
<td>Loss of weight on ignition</td>
<td>6.00</td>
</tr>
</tbody>
</table>

Table-XXI: Mechanical Analysis of Cuddalore Sandstones

1. Compressive strength
   I) Top bench     15 - 25Kg/m²
   II) Middle bench 20 - 25 Kg/m²
   III) Bottom bench 10 - 20Kg/m³

2. Hardness: Because of the heterogeneity, which various with medium of binding, hardness can be adjudged by the penetrating rate of drilling equipments which ranges from 0.13 m/minute to 0.233 m/minute.

3. Specific cutting resistance: 2 Kg/cm to 50.6 Kg/cm.

4. Abrasiveness: overburden is very abrasive on all digging elements and on account of hardness, it is very difficult to cut into clayey
sandstone continuous fine quartz grains, which causes heavy abrasion.

MINERAL CONSTITUENTS OF CUDDALORE SANDSTONES

The Cuddalore sandstones are mostly consisting of quartz (38.50%) and feldspars (5.50%) and cementing material, which is mostly argillaceous and/or ferruginous (55.50%). Hard ferruginous concretions nodular in shape also occur sporadically in the overburden. The typical mineral composition of Cuddalore sandstones is given in Table-XXII.

Table-XXII: Mineral constituents of Cuddalore Sandstones

<table>
<thead>
<tr>
<th>Mineral constituents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>38.50</td>
</tr>
<tr>
<td>Feldspare</td>
<td>5.50</td>
</tr>
<tr>
<td>Magnetite</td>
<td>0.60</td>
</tr>
<tr>
<td>Accessory minerals</td>
<td>0.40</td>
</tr>
<tr>
<td>Cementing medium</td>
<td>55.00</td>
</tr>
</tbody>
</table>

Microscopic and heavy mineral analysis of Cuddalore sandstones shows that heavy minerals like Zircon, kyanite, magnetite, rutile, etc. are present in minor quantities in the sandstone with predominance of magnetite. Quartz grains are mostly angular to sub angular.

4.1.2(b) CLAYS

There are distinct beds of fire clay and white clay occurring above lignite seam at depth of 35 to 40 m and 75 to 80m respectively. They are
fairly continuous and extensive in mining area and constitute parts of overburden material.

i) **MOTTLED CLAY (OR FIRE CLAY)**

It is predominantly yellow or violet in colour, occurs between the top and middle bench of overburden and of 2m thick. The physical and chemical characteristic of fire clay was analyzed by NLC is given in Table-XXIII & XXIV.

**Table-XXIII: Physical characteristic of Mottled Clay**

1. Bulk density (gm/cc)  
   1.60-1.90  
2. Specific gravity  
   2.60 to 2.70  
3. Plastic limit( %)  
   23.00 to 30.00  
4. Liquid limit(%)  
   33.00 to 52.00  
5. Atterberg number  
   10.00 to 20.00  
6. Dry linear shrinkage  
   3.00 to 4.00  
7. Total firing shrinkage (12000C)  
   -  
8. Water of plasticity  
   27.00-35.00  
9. Particle size(%)  
   -  
   I) Above 20 microns  
      10.00-25.00  
   II) Between 20 and 10 microns  
      4.00-8.00  
   III) Between 10 and 2 microns  
      10.00-15.00  
   IV) Below 2 microns  
      60.00-90.00
Table-XXIV: Chemical Properties of Mottled Clays

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>45.00-62.00</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>26.00-38.00</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.20-4.00</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.80-1.20</td>
</tr>
<tr>
<td>CaO + MgO</td>
<td>0.75-1.50</td>
</tr>
<tr>
<td>Alkalies(Na₂O + K₂O)</td>
<td>0.20-0.40</td>
</tr>
</tbody>
</table>

ii) WHITE CLAY

White clay occurs just above the lignite seam with average thickness of 0.50m. The physical and chemical characteristic of white clay was analyzed by NLC is given in Table-XXV and XXVI.

Table-XXV: Physical characteristics of White Clay

1. Bulk density (gm/cc) 1.50-1.70
2. Specific gravity 2.60 to 2.70
3. Plastic limit (%) 20.00 to 28.00
4. Liquid limit (%) 31.00 to 45.00
5. Atterberg number 11.00 to 13.00
6. Dry linear shrinkage -
7. Total firing shrinkage (12000C) -
8. Water of plasticity 23.00-25.00
9. Particle size (%) -
I) Above 20 microns 3.00-10.000
II) Between 20 and 10 microns 2.00-5.00
III) Between 10 and 2 microns 7.00-15.00
IV) Below 2 microns 65.00-75.00

Table-XXVI: Chemical Characteristics of White Clay

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>44.00-59.00</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>28.00-38.00</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.90-1.50</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.40-1.50</td>
</tr>
<tr>
<td>CaO + MgO</td>
<td>0.80-1.60</td>
</tr>
<tr>
<td>Alkalies (Na₂O + K₂O)</td>
<td>0.2-0.3</td>
</tr>
<tr>
<td>Loss on ignition w/m</td>
<td>10.00-14.00</td>
</tr>
</tbody>
</table>

4.2 MINE-II

In the Mine-II area, greyish black clay alluvial deposits in the southern part and in the northern part cover nearly three-fourth portion by Cuddalore sandstones. The Quaternary alluvium (i.e. greyish black clay) forms the top portion of the overburden and ranging in thickness from 0.50 to 10m, which overlies the Cuddalore sandstones. Below Cuddalore sandstones occurs clay seam fallow by water bearing sands of 5 to 10m in thickness. The overburden consists of clays, sandy clays, sandstones, clayey sandstones and medium to coarse sands (semi-confined aquifers) of varying in thickness from 50 to 103m with an average thickness of 75 m. The
thickness of overburden increasing towards south, south east (i.e. dip
direction). The thickness of lignite seam varies form 12 to 22m except in
small portion, where it is only 8 to 9 m. The average thickness of lignite
seam is about 16.00 m. Where lignite seam occurs at depth of -50 to -80 m
below sea level (bmsl) and average overburden to lignite ratio is 5 m³: 1
tonnes in the area.

In the Mine-II, process of overburden excavation is similar to that of
Mine-I and carried out in 1982. The total overburden removed and lignite
excavated is 702.93 MCM and 108.35 MT since inception. Currently Mine-
II exploiting 10.71MT lignite and 61.33 MCM of overburden, it is the
highest since its inception. The detail of annual excavation of overburden in
the Mine-II area is given in Fig. 23 & Appendix-VIII.

4.2.1 OVERBURDEN DUMPING

In the case of Mine-II, overburden from the initial mine cut also has to
be dumped out side the lignite boundary till enough space is created inside
the mined out area for back filling. The out side spoil bank capacity has been
calculated to be 260 MCM, which accounts for 20% of the overburden. It
has been divided into north and south segments with a capacity of 50 and
160MCM over an area of 6 sq. Km and attained a height of 60m. Back
filling was worked out in 1983 and gradually outside dumping were stopped
in 1997. The total of 255.34 MCM of overburden had been dumped outside
up to a height of 60m since the inception of Mine-II.

4.2.2 CHARACTERISTICS OF OVERBURDEN

Overburden material consists of hard and abrasive Cuddalore
sandstones in the north and sticky alluvial clay occurring as a capping
material over the Tertiary Cuddalore sandstones in ⅓th of mine area up to a
depth of 2.00m in the south. The sands and unconsolidated sandstone
constitute 5 to 20% of the overburden material, whereas clay content of the
mine-II is generally similar to Mine-I area.

Dumping of overburden materials from the mine to outside dumping
yard was started during April, 1983 and continued without any apparent
disturbance up to a height of about 33m above the ground surface. When
further dumping was taken up over a small stretch to a height of 44m,
suddenly series of deep and wide tensional cracks were developed that
followed by heavy subsidence on the top of the dump. Simultaneous heavy
subsidence and upheaval on southern slope as well as adjacent ground
surface has caused deep-seated disturbances at several places in the area. At
places disturbances was as much as 10m. The disturbance problem was
observed only on the southern side of the Quaternary alluvial deposits /
Tertiary Boundary and conspicuously absent on the northern side. It is
believed that it may be due to weak alluvial clay foundation.

The excavated overburden, dumped over large area that too up to a
substantial height, creates major problems of erosion, resulting development
of massive ravines, gullies, vallies, and crept off dumped materials into
adjoining cultivated land and simultaneous siltation of rivers, nallas, tanks,
ponds, etc. Currently Mine-II has disturbed 19.10 sq. Km of productive land
and projected to disturb up to 34.54 sq. Km by 2028.

(a) **Cuddalore Sandstones:** The Cuddalore sandstones in
the Mine-II area is almost similar in physical, mechanical and chemical
characteristics as well as mineralogical composition to that of Mine-I area.
(b) **ALLUVIAL CLAYS:** The Quaternary alluvial soil is grayish and black in colour and associated with large quantity of Kankar nodules, having poor infiltration, very low conductivity, poor aeration porosity and calcareous in nature. They swell, when it get wet and become plastic, soft and slushy. In dry season, the clay get shrink in volume and consequently large cracks were developed due to loss of water and becomes friable, week and powdery. They have developed a tendency to collapse and slide down. The sticky characteristic of the soil created operational constraints in this area. The typical physical characteristics of alluvial clay of Mine-II area were analyzed by NLC are given in Table- XXVII.

**TABLE-XXVII: Physical Characteristic of Alluvial Clays**

1. Bulk density - 2.02gm/cc
2. Plasticity index - 35.00 to 40.00 (high)
3. Dry linear shrinkage - 9.00 %
4. Soil moisture - 20.00 to 24.00%
5. Angle of internal fraction - < 10.00(very low)
6. Swell factor - 1.60 to 1.70 (high)
7. Average shear strength - 37.00 tonnes/m$^2$

**4.2.5 SANDS AND UNCONSOLIDATED SANDSTONES**

It constitutes 5 to 20% of the overburden material and composed of very friable, soft semi-consolidated sands and unconsolidated sandstones. They generally vary in thickness from 2 to 10m and medium to coarse grain sands lies just above lignite seam in Mine-II while absent in Mine-I area.
4.2.6 CLAYS

In the Mine-II also two clay beds (i.e. fire clay and white clay) occurring above lignite seam, having same physical and chemical characteristics to that of Mine-I have been noticed.

5. LIGNITE MINING AND PRODUCTION

The lignite deposits are not exposed anywhere in the Neyveli lignite field and occurs at depth of about 45 to 120m below the ground level. The depth of lignite seam progressively increasing toward south, south-east and east (i.e. dip direction) which in turn to increase the lignite/overburden ratio in the Mine-II area. The thickness of lignite seam varies from 8 to 25m with an average thickness of about 16m. The lignite generally occurs as a single seam except in the eastern sector of Mine-II and south eastern block of the Mine-I where it is split into two or more seam by sand and clays as intercalations and even though one single seam of 16m occurs in the area. The general dip of lignite is 1 in 100.

Mining of lignite could not be possible without removing of hard overburden material above the lignite seam and depressurization of confined aquifer below the lignite seam. Mining of lignite carried out through continuous surface mining technology with Bucket Wheal Excavator (BWE) and Conveyers.

Production of lignite began with capacity of 3.50MT/Y from Mine-I in 1962 and from Mine-II with a capacity of 4.70MT/Y in 1984. Currently Mine-I has a capacity of 10.50MT/Y and Mine-II also has same capacity. In 2003, NLC has open new mine known as Mine-IA with the capacity of 3 MT/Y to feed the thermal power plant (Zero Unit). During 2001-2002,
Fig. 24: Lignite production from Mine-I & II
Mine-I and Mine-11 has produced 7.65MT and 10.5MT of lignite respectively. A total of 18.15MT of lignite produced during 2001-2002, which is highest since the inception of lignite mining.

The Neyveli lignite corporation (NLC) has exploited a total of 324.66MT of lignite, of which 216.99Mt from Mine-I and 107.67MT from Mine-II since its inception. The detail of annual production of lignite is furnished in Fig. 24 and Appendix-VIII.

6. QUALITY OF LIGNITE

Neyveli lignite is a dark brown, geologically young, immature and low-grade coal. When it is exposed, lignite brake into small uneven blocks or flakes or even get crumpled when slight pressure of the hand is used. It has a low calorific value (2460 to 3200 KCal/Kg), high moisture i.e. 45 - 60%, ash content varying from 2 to 8% and free from inherent impurities. Being of low calorific value, high moisture content, fragile nature, spontaneous combustion characteristics and poor pulverization, long distance transportation of lignite is not feasible. That is why lignite fired thermal power stations are usually located very close to mines.

6.1 LIGNITE ANALYSIS

Quality assessment of lignite is most important from utility point of view. The lignite at Neyveli, principally utilized for the production of electricity and also for manufacturing of coke and urea. A typical proximate and ultimate analysis of Neyveli lignite is given in Table-XXVIII.
Table- XXVIII: The Typical Proximate and Ultimate Analysis of Lignite.

<table>
<thead>
<tr>
<th>Proximate Analysis (as received basis)</th>
<th>Ultimate Analysis (Moisture and Ash free basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulars</td>
<td>Range (%)</td>
</tr>
<tr>
<td>Moisture</td>
<td>45.00-60.00</td>
</tr>
<tr>
<td>Ash</td>
<td>2.00-8.00</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>21.00-26.00</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>18.50-22.50</td>
</tr>
<tr>
<td>Grass calorific value (KCal/Kg)</td>
<td>2460-3200</td>
</tr>
<tr>
<td>Bulk density(t/m$^3$)</td>
<td>0.80-1.28</td>
</tr>
<tr>
<td>Hardgrove Grindability index</td>
<td>127-167</td>
</tr>
</tbody>
</table>

6.2 CHEMICAL ANALYSIS OF LIGNITE ASH

Ash content in lignite occurs as a mineral matter in the initial vegetal growth and extraneous material deposited with coal forming vegetal matter and also material caught up during mining. It is the incombustible material present in coal/ lignite.

Ash analysis is of paramount importance in boiler design of thermal power plants and of environmental concern. The flyash generated by burning of lignite for electricity production containing various amount of toxic elements, which poses great threat to environment. High ash content in coal /lignite invites variety of problems: such as wear and tear of the
machineries, heat loss, fouling and choking of material surface, ducts and chutes, slag depositions on boiler tubes, generation of a large quantity of combustion residues with consequent heavy load on collectors and precipitators. Thereby, handling and disposal task of these combustion residues are very much associated with adverse environmental impacts. The chemical analysis of Neyveli lignite ash is given in Table-XXIX.

**Table-XXIX: Chemical Analysis of Lignite Ash (Majumdar, et al, 1974)**

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Average value(%)</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>24.80</td>
<td>10.40-38.80</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>9.48</td>
<td>2.10-19.80</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>20.16</td>
<td>11.00-27.30</td>
</tr>
<tr>
<td>CaO</td>
<td>17.45</td>
<td>10.60-25.30</td>
</tr>
<tr>
<td>MgO</td>
<td>5.52</td>
<td>3.70-9.40</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.54</td>
<td>0.09-0.81</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.09</td>
<td>0.01-0.18</td>
</tr>
<tr>
<td>SO₃</td>
<td>22.03</td>
<td>11.70-30.80</td>
</tr>
<tr>
<td>CaO+MgO / Fe₂O₃</td>
<td>2.42</td>
<td>1.75-6.80</td>
</tr>
<tr>
<td>SiO₂ / Al₂O₃</td>
<td>1.23</td>
<td>0.94-1.42</td>
</tr>
</tbody>
</table>

Fusion Temperature(°C)
- a) Initial deformation
- b) Final

| 1012-1187                    | 1220-1300        |

Neyveli lignite causes no significant slugging and fouling.
7. MARCASITE (FeS₂):

Marcasite is an uneconomic mineral and occurs as co-mineral in lignite deposits. It occurs in lignite deposits in different shape such as massive, globular, lenticular, veins, wadges, boulders and platty and also as enrichment segregations with variation in quality.

Marcasite is found sporadic, intermittent and irregularly distributed throughout the lignite seam and also found in aquifer sands. In the lower part of Mine-II, marcasite occurs as cleft and cracks fillers. Marcasite in Mine-11 is more abundant than mine-I and does not show any preferred orientation. The chemical and general property of marcasite is given in Table-XXX & XXXI.

**Table-XXX: Physical Characteristics of Marcasite**

- **Chemical composition**: FeS₂
- **Colour**: dirty metallic yellow
- **Shape**: boulder, lenticular, veins, platty and massive
- **Appearance**: metal like
- **Magnetic properties**: not magnetic.
- **Hardness (hard groove index)**: 5.00 to 7.50
- **Specific gravity**: 3.00 to 4.50
- **Compressive strength**: 150.00 to 800.00 kg/cm²
Table-XXXI: Chemical properties of Marcasite

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>0.60 to 26%</td>
</tr>
<tr>
<td>Aluminum</td>
<td>traces to 2%</td>
</tr>
<tr>
<td>Iron (as Fe)</td>
<td>60 to 86%</td>
</tr>
<tr>
<td>FeO₂</td>
<td>0.30 to 0.40%</td>
</tr>
<tr>
<td>CaO₂</td>
<td>0.30 to 1.50%</td>
</tr>
<tr>
<td>MgO</td>
<td>0.20 to 2.00%</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.10 to 2.00%</td>
</tr>
<tr>
<td>K₂O</td>
<td>traces</td>
</tr>
<tr>
<td>SO₃</td>
<td>2 to 20%</td>
</tr>
<tr>
<td>Moisture</td>
<td>up to 7%</td>
</tr>
</tbody>
</table>

Due to the high hardness and compressive strength of marcasite poses problems in excavation causing abrasion, wear and tear and it damages the jaws and rollers of the crushers at thermal power stations. It also causes ash melting and sintering problems in the power plant boilers. Due to presence of combination of several slagging agents like Fe, Na, k and S in the marcasite at various combustion condition in the boiler from slagging and alter the ash melting behaviors cause enormous problems in Thermal Power Plants.

8. HYDROLOGICAL PROBLEMS ASSOCIATED WITH LIGNITE MINING

Hydrology plays predominant role in the excavation of Neyveli lignite deposits. This is due to the fact that exploitation of lignite is subjected to
stupendous hydrological problems. They are in the form of powerful confined aquifer below the lignite seam and semi-confined aquifer above the lignite seam of lesser magnitude, storm water in the mine sumps and lies in the cyclonic belt. It may hamper the mining operation if proper measures are not been taken during mining operation.

8.1 SOURCES OF WATER IN OPENCAST NEYVELI LIGNITE MINES AND ITS POTENTIAL HAZARDS

For any subterranean activities, water plays potential hazards. Neyveli lignite opencast mining is one of them. The Neyveli mines have two huge open pit of 2.50km (mine-I) and 3.50 (mine-II) in length. The catchments area of mine-I and mine-II is 13.83 sq. Km and 16.30sq.km respectively. The water from different sources is accumulated in the deepest portion of mine pits that hamper the mining operations during rainy period.

The sources of water, which are necessary to be controlled for safe and economic exploitation of lignite at Neyveli, include:

a) Extraneous water

b) Unconfined water

c) Confined water

Neyveli opencast lignite mines are exposed to above sources of water related problems. But problems related to confined aquifer are paramount and to a lesser extent the other sources. They may pose potential hazards to mine safety and progress of mining operations such as bursting of mine floor, dislocation of the stability of slopes, sliding of the spoil bank, bogging of machines and vehicles, water logging, erosion of benches, etc. Hence
water has to be controlled and tackled during mining operation otherwise it may jeopardize the mining activities.

Difficulties and dangers that could arise from the confined aquifer are termed as groundwater problems and that from extraneous water may be termed as Storm Water Problems.

8.2 STORM WATER PROBLEM AND SOLUTION

All problems and difficulties arising from rain water, subsoil water from overburden benches, aquifer water flowing out through cracks and fissures due to positive pressure head, flowing well, leak water from ground water control lines, oozing of water from exposed semi-confined in the mine pits are termed “Storm Water Problem.”

Neyveli lignite mines hardly lies 40 kms away from Bay of Bengal and falls in the cyclonic belt. The North-east monsoon (October to December) account 80% of the total rainfall, whereas average rainfall estimated is about 1200mm in the Neyveli Lignite Field.

Being opencast lignite mines and having large catchments area of about 13.03 sq km (mine-1) and 16.03sq km (mine-11) have received water from different sources. The water from different sources are accumulated in the deeper part of mines pits and ultimately water level reached above the lignite seam resulting in flooding of mines floor that paralyzes the mining operations, if pumping of Storm Water stopped even for an hour.

The solution for controlling the storm water is to drain the entire water into mine sumps i.e. lowest part of mines floor and then pumped out to the surface by high capacity floating pontoons established in the mine sumps to bring the water level below lignite seam. At present there are 25 pontoons
working with individual pumping capacity of 400 GPM and a total installed capacity of pumping is 1000 GPM. Currently, the rate of Storm Water pumping is in the order of 25000GPM in mine-I and 3500GPM in mine-II. In case of heavy rainfall on certain days, Storm Water required to pump out at the rate of nearly 30000GPM (mine-I) to maintain the water level in the sumps.

Since the inception of Storm Water pumping operation in mine-I (1961), had pumped out a total of 1114.51MCM of Storm Water and more volume of Storm Water pumped from mine-II.

The rate of pumping of Storm Water has increased at alarming rate since it inception, 1961. It was estimated to be 1750GPM in 1961 and reached to 25620PM in 2000 from mine-I and rate of pumping in the mine-II is also increasing at alarming rate since it inception in, 1982. The huge volume of storm water pumped out from mine pits to the surface into agricultural field, drains, nallas, ponds, etc. in a down slope direction. The mines water used by down stream villagers for irrigation since 1961, has adversely affected the soil quality and causing waterlogging problems in the downstream areas. The storm water and effluent from industrial complex draining into Paravanar river and finally discharge into Walaza and Perumal lakes in the east of mines results deterioration of lakes water and ponds ecosystem.

8.3 GROUNDWATER PROBLEMS

Mining of lignite from the Neyveli lignite field is subjected to stupendous hydrological problems. It is due to presence of multi-layers powerful confined aquifers below the lignite seam exerting tremendous upward pressure of about 5 to 9 Kg/cm$^2$ and if not controlled could
jeopardize the mining operations. While presence of semi-confined and unconfined aquifers occurring above the lignite seam may also pose potential hazard in mining operations and have to be tackled judiciously for safe and economic mining of lignite.

i) **CONFINED AQUIFERS**

In the Neyveli mining area lignite seam is underlain by a series of powerful confined aquifers and are separated by parting clay beds. These confined aquifers pose potential hazard to mining of lignite. It could jeopardize the mining operations if pressure of confined aquifers has not been brought below the lignite seam.

The confined aquifers exert an upward pressure of about 5 to 9 Kg/cm² and its hydrostatic head was 30 m above mean sea level in the mining area. The only force which arrests confined aquifer from bursting of lignite seam is the downward pressure (10 to 12Kg/cm²) exerted by the overlying strata comprising of overburden and lignite seam. But when overburden is removed in stages in order to exploit the lignite resources and progressively reduced the down thrust pressure a stage will come when upward pressure increases over the downward pressure resulting in the bursting of mine floor that may disturb the equilibrium conditions.

The hydrogeological investigation and pumping test conducted before and after have provided the most practical-cum-economic solution to this problem is to depressurize the upper confined aquifer. Thereby, maintain the pressure head below the lignite seam by continuous large scale pumping of groundwater by constructing series of pumping wells at hydrogeologically calculated distances over lignite bed. Where depressurization of aquifer restricted to upper confined aquifers up to depth of 35 to 40m below the
lignite bed. Below it, probably a continuous clay bed of 5m thick exists, termed as parting clay, which present the movement of water entering from lower confined aquifer to depressurized aquifer (i.e. upper confiner aquifer).

The depressurization of confined aquifers in the Mine-I started on 6th July 1961 with initial discharge of 26712 GPM from 27 wells with capacity of 1000 GPM each. With the expansion of Mine-I, additional pumping wells were established to keep the pressure surface below the lignite seam. The number of wells increased to 48 with a total discharge of 47934 GPM in 1964 and gradually the number of wells and corresponding discharge from them reduced to 21569 GPM (i.e. 51.49CMC) in 2000. The detail of annual pumping of groundwater from upper confined aquifer at Mine-I is given in Fig 25 and Appendix-IX of Mine-I. Since the commencement of depressurization of upper confined aquifer at Mine-I in 1961, a total of 2815.32 MCM of groundwater discharged from confined aquifer alone.

In the Mine-II, depressurization of confined aquifers started in 1982 with the discharge of 1000 GPM and progressively increased to 33481 GPM in 1987, which gradually reduced to 27000 GPM in 2000. It may be due to mutual interference effects of pumping wells and also impact of depressurization from Mine-I since 1961. Since the inception of groundwater control at Mine-II has estimated a total of about 1195.03 MCM of groundwater withdrawal from upper confined aquifer. Since, the commencement of pumping operations, a total of 4010.35MCM of water discharged from both mines. On an average 115MCM/Y of groundwater has been pumped out for depressurization of confined aquifer from both the mines and significant quantity of groundwater also extracted for other uses such as irrigation, domestic supply, etc. Thereby, huge volume of
Fig. 25. Average annual pumping of groundwater from upper confined aquifer (1961-2001)
groundwater discharged from the confined aquifer since the commencement of pumping operations in 1961, which adversely affected the groundwater balance of the Neyveli basin. The groundwater budget deficit has estimated to be 25MCM for the year, 2000. The problem and solution of high pressure of confined aquifers below lignite seam is given in Fig 25

ii) SEMI-CONFINED AQUIFERS

The unconsolidated sand formation of 5-10m thick, occurring immediately above lignite seam in the Mine-II area is termed semi-confined aquifer, while it is absent in Mine-I area. The groundwater in this zone occurs under partially confined conditions exerting an upward pressure but of lesser magnitude than the confined aquifers below the lignite seam. This aquifer may also have to be tackled by pumping of groundwater. Initially depressurizations of these aquifers were carried out by commission 9 wells of 500GPM capacity each and 16 wells of 100GPM capacity each with a total capacity of 6100GPM (27.72M3/min). Annually approximately 14MCM of groundwater discharged from semi-confined aquifers. Since inception of depressurization of semi-confined aquifers, a total of 254.00MCM of groundwater discharged. It has reduced the pressure surface at the bottom bench level of overburden by 24m (+18 to -6m) and brought down the seepage to the bottom bench considerably. Further dewatering of these aquifers is carried out through bench toe drains where through its own hydraulic gradients become desaturated. The drain water is accumulated in the mine sumps and from there it is pumped to the surface.
PROBLEM

Static Pressure Surface + 16 M
Alluvial clay

Flooded Mine Cut
Calculated Limit Of

10 to 15 Kg/sq.cm (downward pressure)

5 to 8 Kg/sq.cm (upward pressure)
Upward Pressure Exceeding The Downward Pressure
If Mining Proceeds Below The Limit Of Excavation
Sand
Artesian Aquifer (Upper)
Sand
Clay
Artesian Aquifer (Lower)

Fig.25A: Problem and solution of high pressure confined aquifer at Neyveli
iii) **UNCONFINED AQUIFER**

The unconfined aquifer occurs at shallower depth i.e. near the ground surface where water level ranges from 2 to 10 meter below the ground level. The dewatering of this zone is also tackled before mining of lignite through pumping. Thus entire saturated zones are dewatered to prevent the seepage into the mines during excavations.