CHAPTER-3

STUDY AREA

3.1 Introduction

The Singrauli coalfield of India is identified as one of the hot spots in the country for producing coal by the opencast mining method. Coal is also known as the "Black Gold" originating from organic matter wood. It is the main source of energy in India and it fulfills approximately 67 percent of the total commercial energy consumed in the country. Madhya Pradesh has a coal reserve of about 8 percent (25,673 million tonnes) of the country. The main coal deposits of Madhya Pradesh lie in Singrauli, Muhpani, Satpura, Pench Kanhan, and Sohagpur areas. This time, the state has produced coal which is way better than many other states. Madhya Pradesh's total coal production was 137.95 million tons in 2021-2022 and thus became the 4^{th} largest coal-producing state in India. In the Singrauli coalfield, mainly surface mining is performed. Due to this, it has many harmful impacts on the environment. So this raised many environmental challenges in the study area, including soil erosion, dust, noise, and water pollution, which severely impact adjoining biodiversity (Coal India Report 2001).

3.2 Description of the study area

The study region is located in the eastern part of Madhya Pradesh in the Singrauli district, with a few areas in the northeast Sonbhadra district of Uttar Pradesh. The study area lies between latitudes 24°3'0" to 24°14'0" N and longitude

82°30'0" to 82°48'0" E. The area was renamed Northern Coalfields Limited (NCL) in November 1985, with its headquarters in Singrauli.

The Singrauli coalfield is connected by a good rail and road network. The distance of the coalfield region by road to Siddhi is 125 km from Rewa, and 235 km from Varanasi. The nearest railway stations are Singrauli on the Chopan-Katni line, which runs parallel to the northern boundaries of the coalfields, and Renukoot, which is 47 km from Singrauli.

Singrauli Coalfield covers an area of approximately 2202 km^2. It is covered by toposheets no. 63L/12 and 63L/16 by the Survey of India. The coalfield is divided into the Moher sub-basin (312 km^2) and the Singrauli main basin (1890 km^2). The entire coal resource of NCL is 10.06 billion tonnes (BT) (6.83 BT in Moher Sub-basin and 3.23 BT in the Main Basin). Most of the Moher sub-basin is located in the Madhya Pradesh district of Singrauli, with a small portion in the Uttar Pradesh district of Sonebhadra. NCL's coal mining operations are currently concentrated on the Moher Sub-basin via eleven opencast mining blocks: Kakri, Bina, Marak, Khadia, Dudhichua, Jayant, Nigahi, Amlohri, Moher, and Gorbi block-B. They contributed 113 million tons (MT) in 2020-21 approx. 14% of the total coal production through mechanized opencast mining. The Singrauli main basin is located in the western part of the coalfield and is mainly unexplored (http://nclcil.in/detail/647634/ncl-overview). The location map of the study area is shown in Figure 3.1.

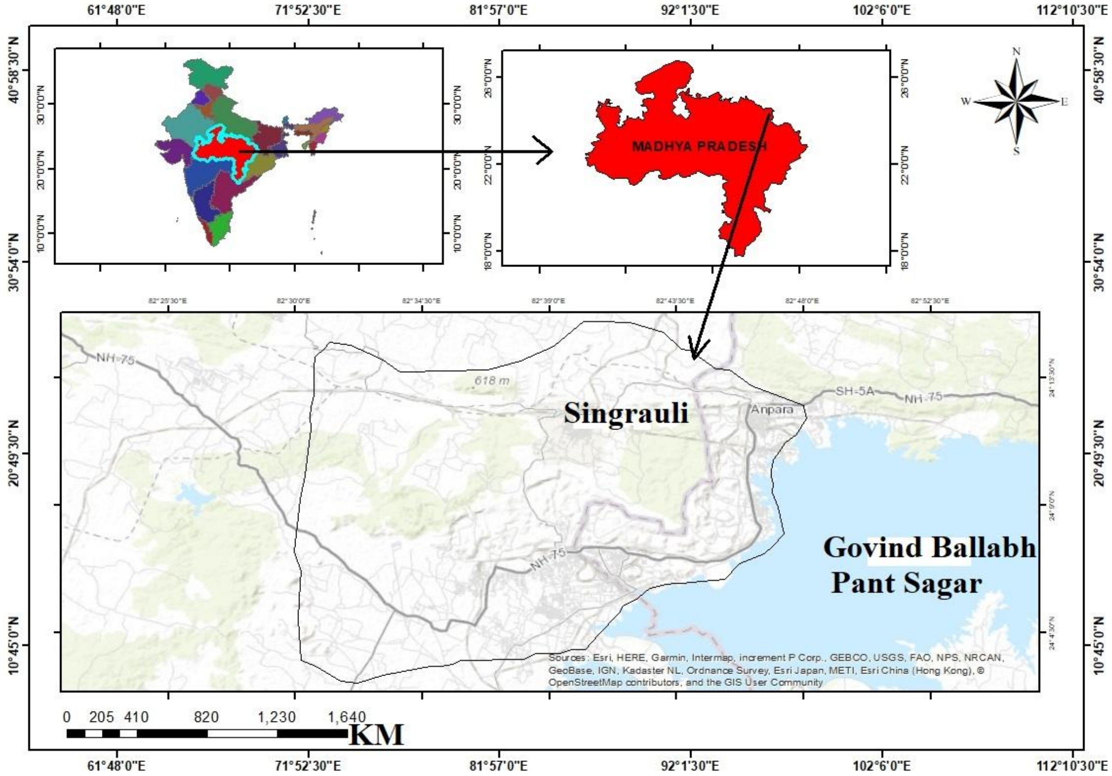

Figure 3.1 Location map of the study area

Several energy-producing industries, including Singrauli super thermal power plant, Vindhyachal super thermal power plant, Northern Coal India, Essar Power Limited, and Kanoria chemicals, are regularly increasing the amount of pollution in the local environment by disposing of organic, inorganic, degradable, and non-degradable materials.

The major towns in the study area are Nigahi Colony, Amlohri Colony, Gorbi Colony, Jayant Colony, Dudhichua Colony, Teldha, Waidhan, Majan, Nawagaon, Pipra, Tusa, Kasar, and Kota Basti. However, Waidhan is the main town and the administrative center of Singrauli. According to the 2011 census, the district has a population of 11,78132 people, representing 1.62% of the state's total population. Between 2001 and 2011, Singrauli's population grew by roughly 28%. In 2011, the district's 728 villages had a population density of 208 people per km^2. The average literacy rate in Singrauli is 62.4%, which is lower than the national average of 74.04%, while the literacy rates for males and females are 73.8% and 49.9%, respectively (http://censusindia.gov.in, https://en.wikipedia.org/wiki/Singrauli).

3.3 Geology and Tectonic Setting

The geological map was acquired from the research and development institute Central Mine Planning and Design Institute Limited (CMPDI), Singrauli, a subsidiary of Coal India Limited, and the further map was digitized in the ArcGIS platform. Various researchers and institutes have studied the geology of Singrauli coalfield in detail such as Mishra and Singh (1990); Choubey and Shankaranarayana (1990); Majumdar and Sarkar (1994); CMPDI (2005); Singh et al. (2017); and others. The geological map of the study area is shown in Figure 3.2.

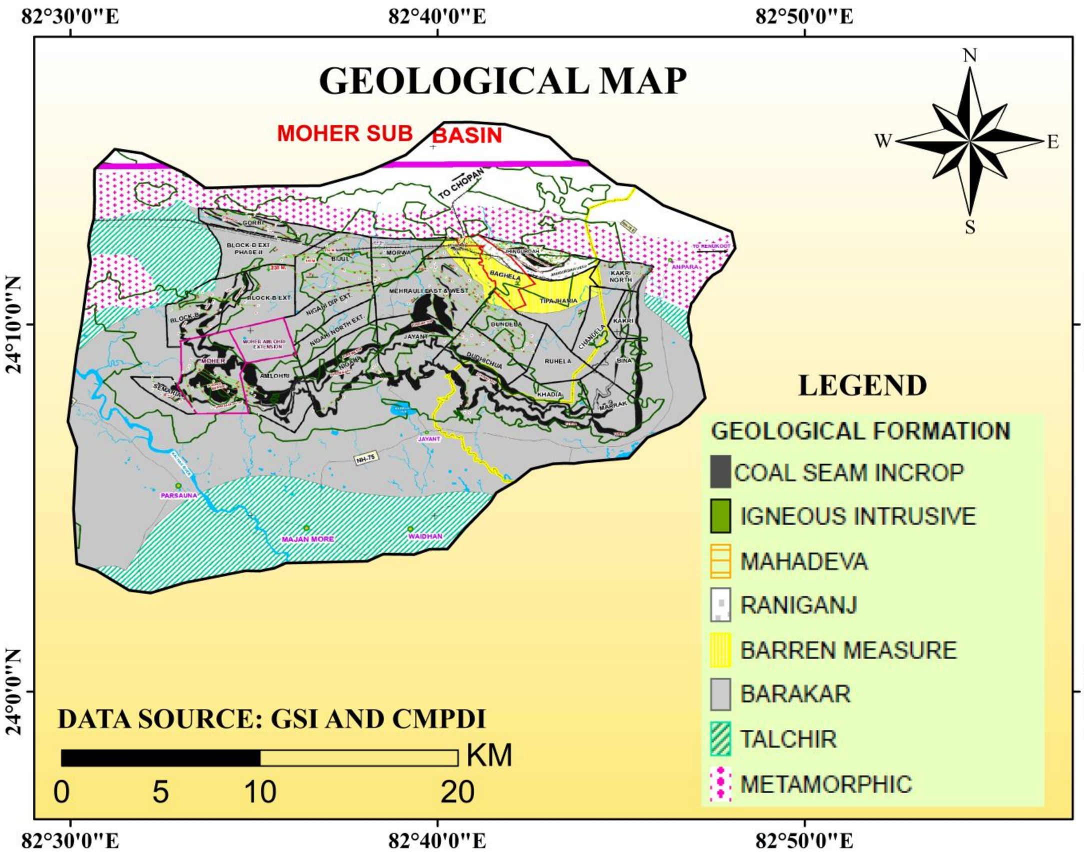

Figure 3.2 Geological map of the study area

The Singrauli coalfield, lying in the Son and Rihand Rivers drainage area, is the northernmost part of the Son-Mahanadi, Gondwana basin. It occupies the connecting regions between the NW-SE treading rift zone of the Son-Mahanadi valley basin and the east-west trending Tatopani-keol graben. The Gondwana sediments were deposited by northwesterly drainage fluvial network. The Singrauli coalfield, having an aerial extent of about 2202 km^2 in the Son and Rihand Rivers drainage area, is the northern part of the Son-Mahanadi Gondwana basin. It is spread over two states; the major part, 2122 km^2 approx, lies in Madhya Pradesh, while the 80 km^2 area falls within Uttar Pradesh. The general stratigraphic succession of the coalfields is given in **Table 3.1**.

Table 3.1. Stratigraphic succession of the Singrauli coalfields (after GSI unpublished report)

Age	Formation/Group	Thickness	General Lithology
Recent Alluvium			Alluvium
Cretaceous	Basic intrusive		Dolerite dykes and sills
Late Triassic	Parasora	500 m+	Medium-to-coarse-grained ferruginous quartzose sandstone
Early Triassic	Pali	700 m+	Greenish yellow to reddish yellow, medium-to-coarse-grained sandstone with variegated siltstone and clay
Late Permian	Raniganj	215–400 m	Fine-to-medium grained dirty to buff-colored subarkose to feldspathic wacke with alternation of thin lamination of grey and carbonaceous shale along with impersistent coal seams
Middle Permian	Barren Measures	110–300 m	Dark brown to brownish yellow to greenish grey, medium-to-coarse-grained flaggy sandstone with thin

			grey clay bands in between
Early Permian	Barakar	325–550 m	Dirty white fine-to-coarse grained sub-arkosic to arkosic sandstone along with siltstone, shale, carbonaceous shale, and coal seams
Early Permian	Talchir	75–230 m	Dark greenish grey to grey shale, fine-grained sandstone diamictite, siltstone pebbly sandstone, and boulder bed
-- Unconformity--			
Precambrian	Mahakoshal	Granite, gneiss, quartzite, phyllite, schist, and pegmatite	

It is a composite basin composed of the Moher Sub-basin in the east and the Main basin in the west, separated by an NW-SE trending fault. The Moher sub-basin is known for developing the thick coal seams in which extensive opencast mining operations are in progress. The Main basin is spread over a huge area, where the Barakar coal seam (comparatively less thick & multi seams) of the lower Gondwana sequence is overlain by younger Barren measures, Raniganj, and Mahadeva formation (Tripathi et al., 2012).

3.3.1 Moher sub-basin

The Moher-sub basin is the eastern part of the Singrauli coalfield, covering an area of about 312 km^2 containing thick potential coal seams, Turra, Purewa, and Jhingurdah. It is the most potential coalfield area and contributes around 65 million tonnes of coal annually. A total of six series of formations have been recognized within the Gondwana rocks, namely Talchir, Barakar, Barren Measures, Raniganj, Panchet, and Mahadeva. Barākar and Raniganj are coal-bearing formations of the Moher sub-basin.

3.3.2 Moher main basin

The main basin is spread over an area of 1890 km^2 the west of the Kachani River, where the Barakar coal seam (comparatively less thick and multi seams) of the lower Gondwana sequence is overlain by younger barren measures, Raniganj and Mahadeva formations. Earlier, the main basin was regionally mapped and partially explored by GSI; hence, less information was known regarding its potentiality. The entire main basin offers underground potentiality except for some coal seams, which offer quarriable potentiality on the eastern fringe where Amelia North, Chhatrasal, and Mahan blocks are located. Generally, coal seams are thin and impersistant, but contain superior-grade coal.

The basin has an undulating structure and several normal faults comprise coal seams of Barakar and Raniganj formation with strike trending in N-S and NW-SE to NE-SW direction having a dip of 3-10° westerly. The major part of the basin is affected by igneous activities. The regional exploration was initially started by GSI and then by MECL.CMPDIL also conducted a detailed exploration of the Mahan, Chhatrasal, and Gondbahera-Ujheni blocks.

3.4 Stratigraphic description

The general stratigraphic succession of the coalfields is described in **Table 3.1**

3.4.1 Precambrian Basement

The Precambrian basement on which the Gondwana sediments rest over unconformity comprises gneisses and schist in the south, while phyllites and quartzite are also observed in the northern region. A series of ridges demarcates the basin's northern boundary in the northeastern part of the Singrauli coalfield.

3.4.2 Talchir Formation

The oldest sediments of the Gondwana group, unconformably overlying the basement, are well exposed over a large area of the plain land on the easternmost and southernmost part of the coalfield. Many of the Talchir exposures have been submerged under the Rihand reservoir (Rao, 1983). A narrow strip of the Talchir formation also occurs around Parari village in the North-Western part of the Moher Sub-basin. It consists of shale, siltstone, sandstone, and boulder beds. The boulder bed at the base is successively overlain by shale, siltstone, and sandstone. The maximum thickness of the formation has been estimated as 130 meters.

3.4.3 Barakar Formation

The most significant Gondwana formation is Barakar because it contains the coal seams and covers a broad area on the eastern side of the coalfield. It is made up of coarse to fine-grained grey, pink, and white sandstones, grey and carbonaceous shale strata, and coal seams. There is a high garnet concentration in the area, which gives the sandstones a pinkish color. Coal-bearing strata are found in the upper Barakar, whereas there are no coal seams in the lower formations. The Barakar formation contains six coal seams known as Kota, Turra, Purewa Bottom, Purewa Top, Turra, Khadia, and Pani Pahari seams. These seams are arranged from bottom to top and are separated by layers of sandstone and shale (Tripathi et al., 2012). Among these seams, Kota, Khadia, and Pani Pahari are relatively thinner, measuring approximately 2 meters in thickness. On the other hand Turra, Purewa Bottom, and Purewa Top seams are significantly thicker, ranging from 10 to 18 meters. On average, the composition of the Barakar Formation consists of approximately 68% sandstone, 6% shale, and 26% coal (Hota et al., 2012).

The Barakar formation covers an area of 515.18 Km^2. In GSI boreholes, a maximum thickness of 585 to 600 meters has been encountered in the eastern part of the coalfield, while it has been reduced to 325 to 400 meters in the western part of the coalfield. The following coal seam occurs in the Barakar formation.

3.4.3.1 Kota seam

The Kota seam is the lowest coal seam in the Moher basin and is inconsistent and erratic in both lateral and horizontal extremes. The thickness of the seam lies between 0.35 to 3.16 meters. The composition of the seam ranges from interbanded coal to carbonaceous shale. Coals are present in the form of patches in these formations, so it is uneconomical to mine them.

3.4.3.2 Turra seam

Turra seam is the most prominent coal seam of the Moher basin and is found in all blocks of Singrauli coalfields, ranging from Kakri in the east to block B in the west. Its thickness varies between 12 to 26 meters. The upper part of the seam is interbanded with dirt, while the lower part is free from dirt, and its composition varies from block to block.

3.4.3.3 Prewa seam

The Purewa seam is found in two parts in the Moher basin: Purewa Bottom and Purewa top seam. The Purewa bottom seam thickness ranges from 8 to 15 meters. Purewa seams are highly interbanded. Purewa top seam occurs as a top portion with thicknesses ranging from 5 to 9 meters. The two parts of the Purewa seam have combined into one seam in the western portion of the basin, particularly in Moher and

Block-B region, and are known as the Purewa merged seam. The overall seam thickness is about 25 meters.

3.4.3.4 Khadia seam

This seam occurs above the Purewa top at about 40 meters. This seam is not workable but is a locally developed seam in Khadia ranging from 1 to 2 meters in thickness.

3.4.3.5 Pani Pahari seam

As the Khadia seam, this seam is local, and a workable section is also unavailable. This seam has a thickness of 1 to 2 meters and is 150 meters above the Purewa top (Singh and Jha, 2018).

3.4.4 Barren Measures

The formation was first identified around Jhingurdah village in the northeastern part of the coalfields. It consists of a sequence of coarse-grained, pebbly, ferruginous, and yellow sandstone with greenish sandstone and red and green clay bands, generally devoid of carbonaceous material. Towards the western part of the coalfields, in the Ujheni and Jhaleri-Majhauli area, the barren measure covers the large tract. Barren measures with an estimated maximum thickness of 300 meters are represented by coarse-grained white to yellowish feldspathic Sandstone (Rao, 1983).

3.4.5 Raniganj Formation

The Raniganj formation covers a large area in the western part of the Singrauli coalfields. A semi-circular outcrop of this formation is also recorded in the

Jhingurdah area, which attains a thickness of about 400 meters. In the Jhingurdah area, this formation is represented by sandstone of varying grain size, white and grey clays, carbonaceous shale, and two coal seams such as the Jhingurdah top seam (maximum 159 meters), which is known to be the thickest Gondwana coal seam so far known in the country, and Jhingurdah bottom seam (up to 19 meters). In the Jhaleri-Majhauli area, in the western part of the Singrauli coalfield, the Raniganj formation is usually composed of fine-grained sandstone, shale, and a thin section of the coal seam (Tripathi et al., 2012).

3.4.6 Panchet Formation

The Panchet rock formations are exposed in the Latajharia, Harari Nala, and Gopad rivers in the southern part of the coalfields. The rock outcrops are found in the deep gorges cutting across the Mahadeva ranges. The Panchet beds rest conformably over the Raniganj sediments and overlap the Mahadeva sandstones with an angular discordance. The Panchet sediments comprise coarse-grained sandstones with bands of yellowish and reddish clay and siltstone. The sandstone is interbedded with conglomerates, which contain rock pebbles from the underlying formation. Towards the base of the sequence, silt, shale, greenish and brown mudstone, and greenish shale are observed.

3.4.7 Mahadeva Formation

It covers a large tract in the southern and southwestern parts of the coalfield up to the south periphery. In many places, they occur as an outlier within the coalfields. The Mahadeva beds are generally found in high hillocks. They are mainly horizontal, with a regional dip towards the south. It is composed of massive, thickly bedded medium to coarse-grained sandstone with a yellow to dark brown color. The sandstone is hard and resistant to weathering. Impersistant bands of chert, siderite, and conglomerates with clay pellets are quite common in the Mahadeva sequence.

3.4.8 Igneous intrusive bodies

The basic Igneous intrusive bodies are quite common in the western and southern parts of the coalfields and are confined to the Pre-Panchet formation. Most intrusive outcrops are located near the contact of the lower Gondwana and Mahadeva formations. These igneous bodies occur as dikes and sills, forming elongated ridges and mounds after weathering. These basic rocks comprise dark-colored dolerite showing a sub-ophitic texture.

3.5 Field Description

The rocks are fine to coarse-grained sandstone, white and grey clays with ferruginous bands, and carbonaceous shallow coal seams. The northern limit of the area is defined by a prominent east-west trending fault along which the rocks consist of gneisses, schists, quartzite, and phyllites of the Precambrian age. The sedimentary lithic pile shows sandstone-dominated cycles of the Son basin belt, and sediments rest unconformably on the Precambrian rocks. The area describes the following three zones:

1. Central Region
2. Western Region
3. Eastern Region

3.6 Geomorphology

The study area has a typical topographic landscape with plains and plateaus. The general elevation above mean sea level varies from 280 meters on the plains to over 500 meters on the plateau. The steep escarpment dissects the southern, eastern, and western boundaries. At the same time, the northern part of the plateau gradually slopes down towards the north but against the structural linear ridges. The different platforms are of the remnant type, resulting from the erosion of gently inclined sedimentary strata of various compactness. Physiographically, the eastern part of the area in Uttar Pradesh is characterized by a cluster of hills and plateau to the north and an undulating plain to the south (Sengupta et al., 2018).

3.7 Drainage

The drainage pattern of the study area is dendritic, totally controlled by lithology and topography as shown in Figure 3.3. Southern flowing streams join the Kachan and Mayar, which meet near Tusa and eventually meet at Govind Ballabh Pant Sagar. The streams that maintain the study area's perennial flow are Mehrauli Nala in the north and Baliya Nala and Matwani Nala in the south (Khan et al., 2013). Many seasonal nallas in the region control the drainage. The southern draining streams are following

1. Tippa Jharia near Jhingurdah-Perennial,
2. Kakria near Kakri,
3. Gorbandha near Bina
4. Jamtihua near Bina Mine-II,
5. Hadwaria, Senduri near Khadia

6. Ballia, close to Dudhichua
7. Motwani in Jayant
8. Amjhar Near Amlohri
9. Karahia Nalla, close to Block-B
10. Kachani River- Perennial.

The Son River flows north in the Sidhi district, parallel to the Kaimur ridges. The Rihand River flows through the immense open plain in the southeastern part of the Singrauli Coalfield area. The Nallas and all drainage of the area are controlled by the catchment area of the Son and Rihand Rivers.

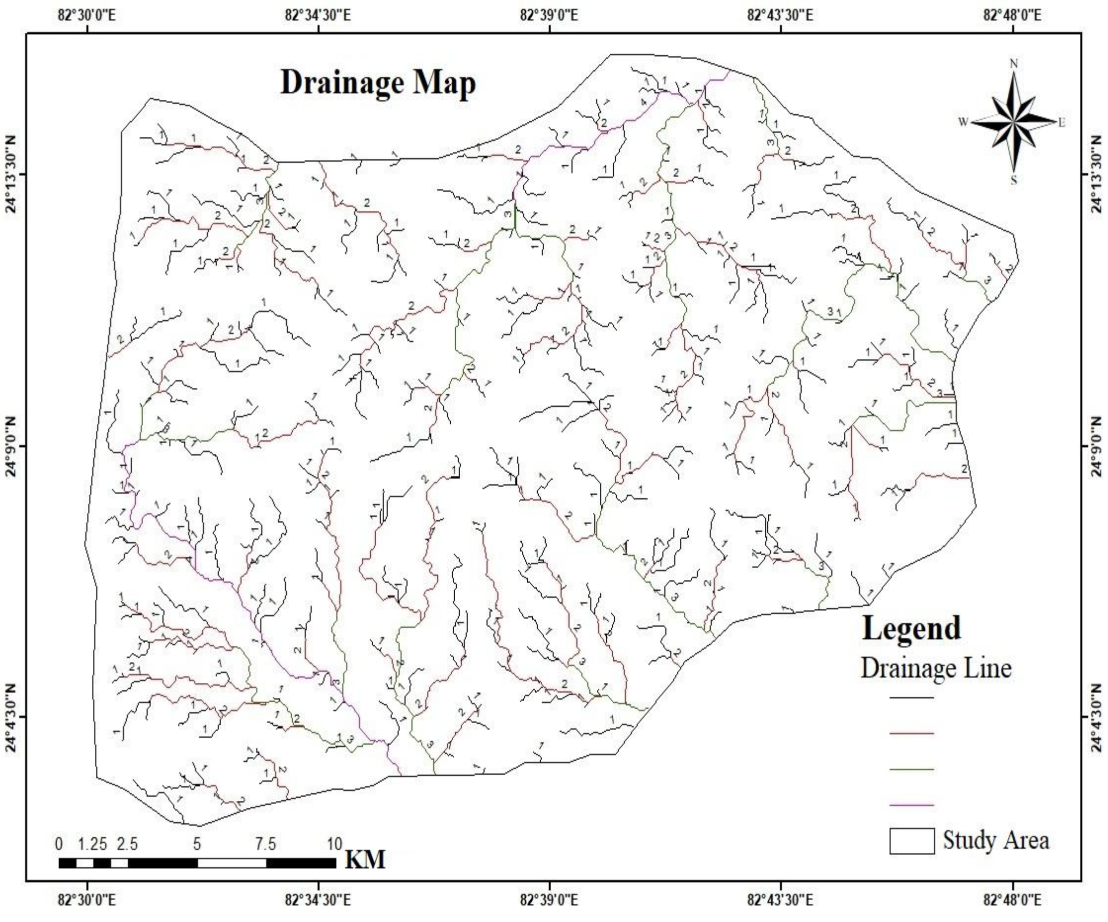

Figure 3.3 Drainage map of the study area

3.8 Hydrogeology

Groundwater information for hydrological studies includes, (1) The areal distribution of aquifer units, (2) The position of the aquifer in the stratigraphic section, and (3) The vertical relationship between the coal and aquifer units above and below the seam. The aquifer was characterized by evaluating the logs of drilled wells in the region, as shown in Figure 3.4. It is seen from the drilling data that the rocks in the area are covered by a thin soil layer of 2 m, which increases in thickness to 10 m in some boreholes. The primary lithological water-bearing unit is Barakar sandstone which is medium to coarse and easily susceptible to erosion (Choubey and Shankaranarayana, 1990). The Singrauli Plateau was developed by erosional processes of gently dipping strata of varying resistance (Ahmed, 1950). Sandstones have loose texture, high porosity, and are less compact; hence they are very susceptible to weathering and erosion. The water table varies from 8 to 10 m below the ground surface in the subsurface aquifer (Choubey and Shankaranarayana, 1990). From the drill hole studies, the area comprised three aquifers (Figure 3.4), but the second one is of little importance due to its small thickness.

Yadav, (1995) carried out groundwater studies in the Jayant block of Singrauli Coalfield have observed two principal aquifers. One is unconfined and situated above the Purewa bottom seam, and another is confined in nature and located between the Purewa bottom and Turra seam of medium to coarse sandstone.

In the Jayant block average transmissivity value is 84 m^2/day, storativity is $4.4x10^{-4}$, and hydraulic conductivity is $4.2x10^{2}$ m/s (Choubey and Shankaranarayana, 1990). Thus are sufficient to extract groundwater to a specific limit. This data will help to evaluate the impacts of mines on groundwater resources and the constructibility of mines due to seepage. Choubey and Shankaranarayana, (1990) concluded that the unconfined aquifer is not feasible to exploit groundwater; therefore, water-supply wells should be completed in the confined aquifer.

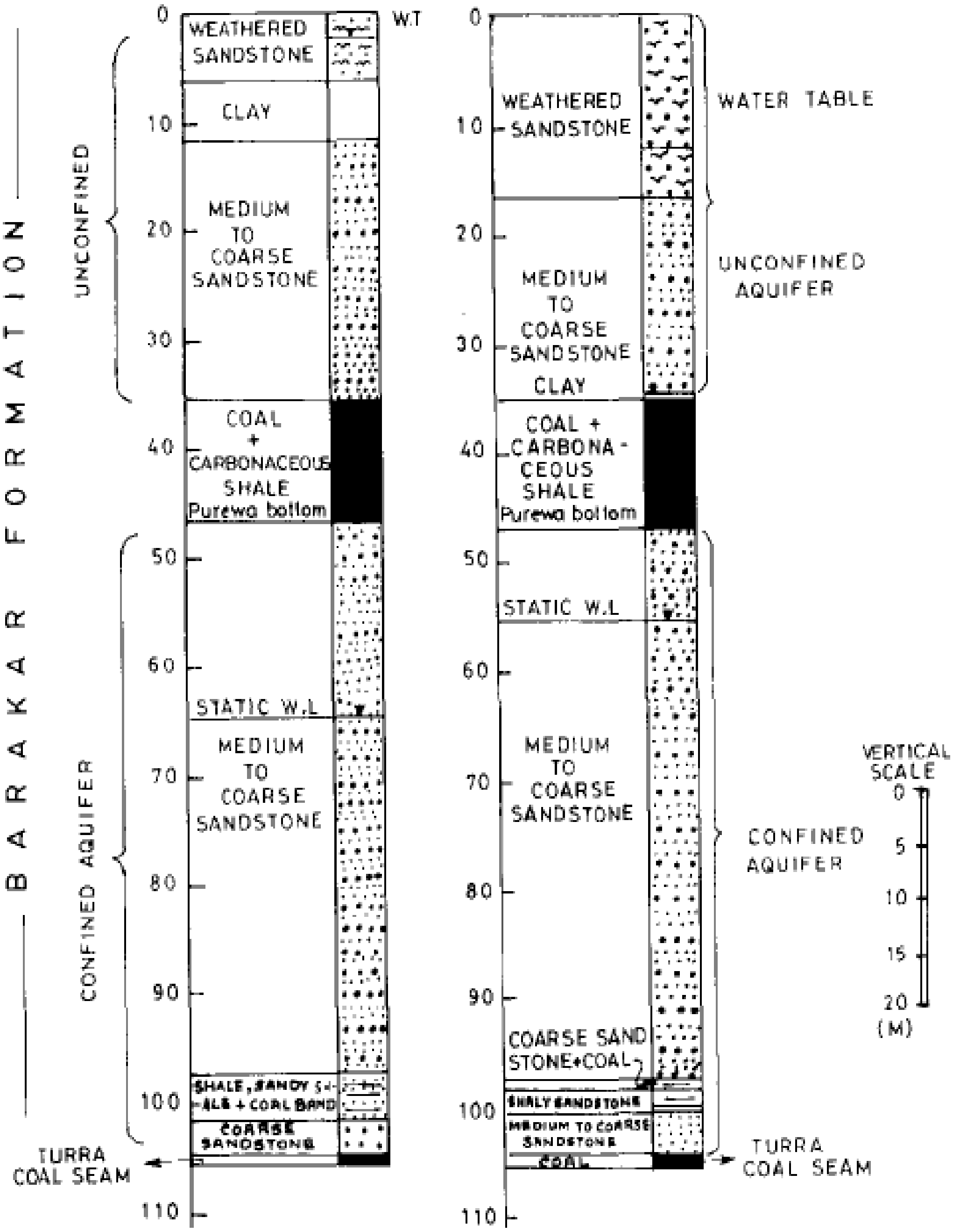

Figure 3.4 (a) Lithology of the test boreholes, (b) Lithology of observation boreholes (Choubey and Shankaranarayana, 1990).

3.9 Soil

Soil is the primary resource formed by the disintegration, decomposition, and erosion of parent materials through natural agents like climate, water, vegetation cover, etc. The area consists of fragile coarse sand or gravelly soil having low water holding capacity and less fertility (Mishra et al., 2022). The valley and lowland have high water holding capacity with fine-textured, thick, dark, and more fertile soils. The uplands and hilly areas consist of thin, gravelly, and porous soil having low productivity and severely affected by erosion activities, soils of the region are altered residues of underlying parent materials after eroding the soluble constituents of the top surface (CGWB North central Bhopal region report, 2013). The Department of Agriculture, U.P and M.P Govt has classified the region's soil into the following groups:

3.9.1 Jungail soil: In the north and northeastern parts of the Bijul, the Jingail soil series covers a significantly small area. Jingail soil developed over undulating uplands of the Son-Bijul divide with a red tinge due to sandstone and red shale basement. The area is primarily hilly and not suitable for cultivation.

3.9.2 Clay loam soil: This type of soil is found over a triangular patch of land between the Rihand and Deohar. It also contains some Kewal soil, the alluvial soil that is black in color and slightly alkaline. It has developed due to the decomposition of carboniferous parent materials. Most of the area has been submerged under the Govind Ballabh Pant reservoir.

3.9.3 Aundhi Clay: This soil is found in a narrow triangular strip of land and is locally called ‘Setuta’.It occurs along the northern boundary of the Govind Ballabh Pant reservoir. The Aundh clay soil is brown and slightly acidic.

3.9.4 Carboniferous soil: This soil is spread over an area of 320 sq. km. It is formed due to the decomposition of Gondwana rocks on the whole Singrauli Coalfields belt. It is grey in color and exhibits high fertility.

3.9.5 Kachani-Mayar soil: It lies mostly in the south and southwestern part of the area. The color of this soil is brown and slightly acidic in nature. It also contains some Kewal soil. The soil of the Kachani stream extends along its left and right banks, the right bank having coarse sandy soil and the left bank having clay loam and coarse sandy soil.

3.10 Flora and Fauna

The forests in the area are mostly dry deciduous types. The vegetation density varies with the topography, being relatively thick in the valleys and poor on hills. The principal species found are Sal, Saja, Tendu, Dhara, Salai, Shisam, Mahua, Palas, Bhira, etc (Rani et al., 2014). The area's main types of forest encountered are (1) Sal forests and (2) Mixed forests. The Sal forests are found in areas where moisture content is relatively high. Whereas mixed forests are found on dry rocks.

3.10.1 Dry Sal-bearing deciduous forests: In these mixed deciduous forests, low-grade Sal (Shorearobusta) predominates, growing up to 20 meters tall, with chiraunji as the main associate. Interspersed pure patches of Sal are also found to a limited extent. Sal's regeneration is fair but slow.

3.10.2 Dry mixed deciduous forests: Dry mixed deciduous forests are widely distributed throughout the area and are severely affected by artificial activities. The remaining part of the forest consists of trees with low spreading crowns and an almost complete canopy. The entire canopy consists of a large number of tree species, amongst which the most conspicuous are axe wood (Anogeissuslatfolia) Bidde (Diospyrosmalanoxylon), Jelingan (Lanneacoromandelica, Bijasar (Pterocarpus marsupium), etc.

3.10.3 Dry deciduous scrub forest: Dry deciduous scrub forest is distributed in the southwestern part of the study area. The land space has been dominated by 3 to 6 meters high scrubby growth, including many tree species, mostly small-leaved trees such as Katha(Acacia catechu), Bauchi(Flacourtiaindica), Ber(Zizyphusjujuba), and Karanda(Oarrissa Spinarum) are common, The area has been rich in wildlife, including tigers, panthers, bears, elephants, sambhar, bison, hyenas, etc. The degradation of forests, industrialization, and extensive coal mining activities in the area are significant threats to wildlife.

This chapter presented the general geology, stratigraphy, hydrogeology, drainage, and soil condition of the study area which will support further detailed study. The basic principle and application of Geospatial techniques (Remote sensing and Geographical Information Systems) have been presented in the fourth chapter.