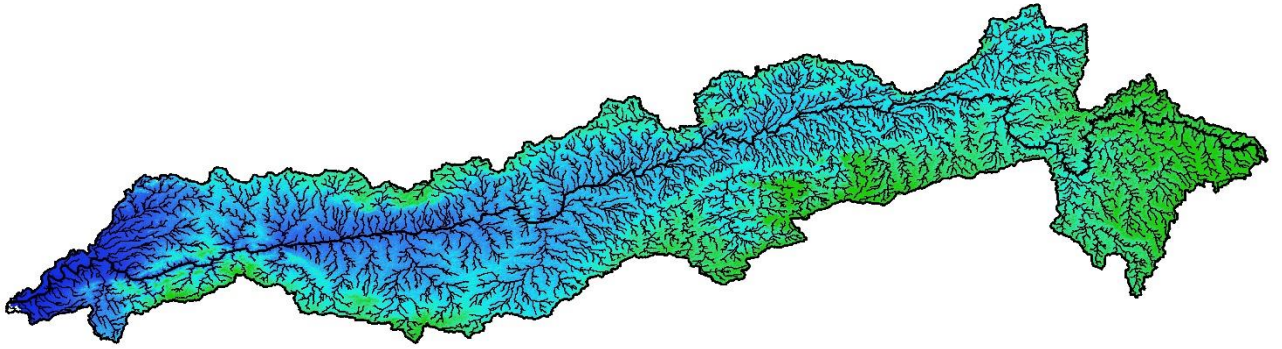


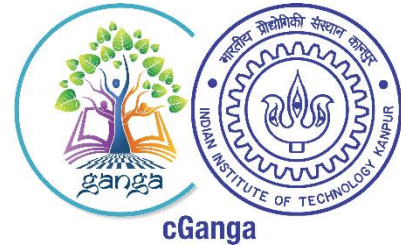


**National River Conservation Directorate**  
Ministry of Jal Shakti,  
Department of Water Resources,  
River Development & Ganga Rejuvenation  
Government of India

# Lithological Profile of Narmada River Basin



**December 2024**



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The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

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## Preface

The lithological profile of the Narmada River Basin is a cornerstone for understanding its geological evolution, tectonic framework, and hydrological dynamics. Encompassing diverse soil types, aquifers, and geological formations, the basin supports both natural ecosystems and human livelihoods. Its intricate geological history reflects the interplay between tectonic forces and sedimentary processes, shaping the basin's unique structural and stratigraphic features.

Despite the basin's significance, a cohesive understanding of its lithological characteristics has been hindered by fragmented studies and insufficient integration of geological and environmental data. This report seeks to bridge this gap by providing a comprehensive analysis of the basin's lithological profile, with a focus on its evolution, tectonics, soils, and aquifers.

Drawing from authoritative research and field surveys, the report highlights the challenges and opportunities in studying the basin's lithology. It underscores the importance of high-resolution geological data for sustainable resource management and proactive planning. Each chapter builds on critical aspects, from the basin's tectonic framework and neotectonics to its regional geology and soil distribution, offering insights into its dynamic nature.

By presenting an integrated lithological profile, this report aims to inform decision-makers, researchers, and stakeholders. It advocates for continued interdisciplinary studies, enhanced data collection efforts, and informed strategies to ensure the long-term resilience and sustainable management of the Narmada River Basin.

Centres for Narmada River Basin  
Management and Studies (cNarmada)  
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## Abbreviations and Acronyms

|               |                                         |
|---------------|-----------------------------------------|
| <b>CIS</b>    | Central Indian Shear                    |
| <b>CITZ</b>   | Central Indian Tectonic Zone            |
| <b>DEM</b>    | Digital Elevation Model                 |
| <b>DSS</b>    | Deep Seismic Sounding                   |
| <b>ENE</b>    | East-northeast                          |
| <b>FAO</b>    | Food and Agriculture Organization       |
| <b>Ga</b>     | Giga Anum                               |
| <b>GPR</b>    | Ground Penetrating Radar                |
| <b>GSI</b>    | Geological Survey of India              |
| <b>NNW</b>    | North-Northwest                         |
| <b>NSF</b>    | Narmada Son Fault                       |
| <b>SI</b>     | Steepness Index                         |
| <b>SNNF</b>   | Son-Narmada North Fault                 |
| <b>SNSF</b>   | Son-Narmada South Fault                 |
| <b>SONATA</b> | Son-Narmada-Tapi                        |
| <b>SSE</b>    | South-Southeast                         |
| <b>WSW</b>    | West-Southwest                          |
| <b>IWRIS</b>  | India Water Resource Information System |
| <b>NHP</b>    | National Hydrology Project              |
| <b>NWIC</b>   | National Water Informatic Centre        |

## 1. Introduction

The Narmada River originates from the Amarkantak plateau in the Satpura Ranges at an elevation of about 1,057 meters and flows westward for approximately 1,284 kilometers across central India before emptying into the Arabian Sea near Baroda, Gujarat. The Narmada River flows into a fertile alluvial plain and travels through a 19-kilometer-long gorge made of Marble rocks near Jabalpur. It then turns westward, moving through an alluvial region situated between the Satpura and Vindhyan hills.

Key tributaries of the Narmada include the Sher and Sakkar rivers in Narsingpur, the Tawa and Ganjal rivers in Hoshangabad, and the Gaur River in the Jabalpur-Harda section and the lower Narmada. Other notable rivers, including Madhumati, Orsang, Unch, Heran, Aswan, and Man, originate in the Satpura hills and create smaller basins that are both tectonically segmented and ecologically within the larger rift system (Khan, 2017). The Hiran River, originating from the Vindhyan hills in Jabalpur district, is the only major tributary from the north. Most of these tributaries have steep and short courses after emerging from the hills, forming on the pediment and pediplain surfaces of the Vindhyan plateau. Their courses are influenced by the area's structural setup, with faults playing a significant role. The northern tributaries join the main river at acute angles, while the southern tributaries intersect it at nearly perpendicular angles (Khan, 2017). Major landforms, including plateaus, scarps, ridges, and valleys, display a pronounced parallelism, generally aligned along an ENE-WSW direction, with plateau levels and high escarpments following this orientation. Tributaries from the Satpura range tend to carry more sediment and water, often displaying meandering and braided patterns (Khan, 2015). The Narmada basin's Quaternary flats cover about 12,950 square kilometres from west of Jabalpur to east of Harda, featuring a series of Quaternary terraces and a gradual slope of about 1 meter per kilometre towards the west.

The margins of the Narmada Valley are composed of diverse rock types such as Mahakoshals, Granites, Vindhyans, Gondwanas, Lametas, and Deccan Traps. The northern margin in the west is characterized by Vindhyans and Deccan Traps, whereas the southern margin features Mahakoshals, Gondwanas, and Deccan Traps. While the southern boundary is characterized by its straight segments, the northern margin is irregular.

The southern margin features cliffs and steep debris slopes that descend into a piedmont, whereas the northern margin includes cliffs, debris slopes, and extended pediments covered with alluvium. On the northern side of the valley, small rocky formations such as isolated mounts, buttes, mesas, and relict rock sheets are found within the alluvial area (Khan & Banerjee, 1984). In contrast, the southern side is characterized by alluvial fans, cones, and colluvium deposits. The eastern portion of the valley has an uneven southern border and a straight northern line.

The northern margin of the Narmada Valley is characterized by Mahakoshals and Vindhyan, while the southern margin includes Mahakoshals, Gondwanas, Lametas, and Deccan Traps. Vindhyan shale and sandstone form escarpments along the northern valley wall, with tablelands gently sloping away. The northern margin's slope profiles, including scarps, cliffs, and pediments, are covered by the Hiran River's floodplain and descend into the valley, forming a pediplain that merges with the alluvial plain (Khan & Sonakia, 1992). The straight valley margins



are influenced by faults separating the Vindhyan basin in the north from the Gondwana basin in the south. These margins, characterized by their cyclic and paired nature, appear to be controlled by faults. The drainage patterns and geomorphic features suggest that the southern margin fault has a Quaternary component.

Influenced by ENE-WSW to E-W tectonic lineaments, the Narmada River flows in a straight line, with the Satpura range to the south and the Vindhyan range to the north. The region has experienced repeated erosional and depositional activities, as well as asymmetric tectonic shifts, leading to the formation of diverse landforms and morphogenetic units (Khan & Banerjee, 1984). These processes have shaped the area's drainage patterns, topography, and physiography, resulting in features like erosional platforms, planation surfaces, ridges, valleys, escarpments, and river terraces (Rahate & Khan, 1985). The ongoing structural deformation, along with geothermal and hydrological activities, has also revealed underlying tectonic cycles, seismic events, and surface changes. Additionally, valley gaps and trenches have provided prime locations for sedimentation, contributing to the development of quaternary platforms, pediments, and plains.

The landscape of the Narmada Basin is characterized by distinct altitudinal classes: flat topography with erosional surfaces and valley flats below 400 meters, prominent plateaus and sharp-crested hills between 500 and 650 meters, and high hills with peaks and upper plateaus between 650 and 900 meters. The ground slopes northward from the Satpura range and southward from the Vindhyan escarpment, with the valley sloping westward. The regional slope of the Vindhyan, Gondwana, and Deccan lava plateaus is generally towards the north (Khan, 2017).

The central part of the Narmada Basin displays dendritic and sub-parallel drainage patterns, with trellis and parallel drainage systems influenced by faults and fractures in the plateaus and upland areas. While the northern tributaries of the Narmada River stay comparatively straight, the southern tributaries exhibit significant meandering and the formation of floodplains close to their confluence. Geomorphological studies suggest that the southern region has undergone repeated cycles of subsidence and uplift, in contrast to the more stable northern margin, as indicated by features such as paleo-channels, cut-off meanders, and terraces on the southern bank of the Narmada.

## **2. Evolution of the Basin**

The western continental margin of India is classified as an Atlantic-type passive margin (Biswas, 1982). The Narmada, Cambay, and Kutch basins are significant geological features on the western edge of the Indian Peninsula. All three basins evolved at different times different stages of India's northward drift after breakup from Gondwanaland in the Late Triassic-Early Jurassic. Biswas (1982) brought out the sequential development of these basins from north to south. The Kutch rifting took place in the Late Triassic-Early Jurassic, Cambay rifting in Early Cretaceous and Narmada rifting in Late Cretaceous time.

The evolution of the Narmada Basin is intricately linked to the tectonic events associated with the breakup of Gondwanaland during the Late Triassic to Early Jurassic. The basin's formation is attributed to rifting along the Narmada geofracture, which aligns with the ENE-WSW Satpura Precambrian trend and reflects a series of tectonic movements shaping the Indian subcontinent during the Mesozoic and Cenozoic eras.

### **1. Initiation of Rifting:**

During the Mesozoic era, particularly the Late Cretaceous, rifting commenced along the Narmada geofracture. This phase coincided with India's drift away from Gondwanaland and the initiation of India-Antarctica separation (Biswas, 1983). Deltaic sediments were deposited at the western end of the basin, fed by rivers flowing along the geofracture.

### **2. Marine Incursion and Sedimentation:**

The Narmada rift experienced subsidence, allowing for the deposition of marine sediments. This marked a significant phase in the basin's evolution, characterized by the interaction between tectonic subsidence and sedimentation processes.

### **3. Tectonic Uplifts and Block Movements:**

During the Late Cretaceous, intense block movements occurred along the Narmada fault system. The foreland block to the north of the fault and the peninsular block to the south were uplifted, while the Narmada graben subsided. This tectonic activity resulted in an eastward tilt of the peninsular block, leading to the drowning of eastern intracratonic grabens like the Godavari and Mahanadi.

### **4. Volcanism and Regional Uplift:**

The western part of India, including the Narmada Basin, experienced widespread volcanic activity during this period, with eruptions of Deccan Trap basalts. This phase was accompanied by regional uplift, further influencing the tectonic and sedimentation patterns in the basin.

### **5. Interaction with Adjacent Structures:**

In the Early Tertiary, the Narmada graben interacted with neighbouring tectonic features. The Cambay graben, extending southward, crossed and displaced the Narmada graben. Conjugate shearing along their bounding faults caused right-lateral movements along the Narmada faults (Rao and Talukdar, 1980).

## 6. Later Evolution and Stabilization:

As India collided with Eurasia in the Early Tertiary, the tectonic framework of the region stabilized. The eastern part of the Narmada graben was uplifted, transforming it into a rift valley once more. The present configuration of the Narmada Basin reflects a culmination of these tectonic processes.

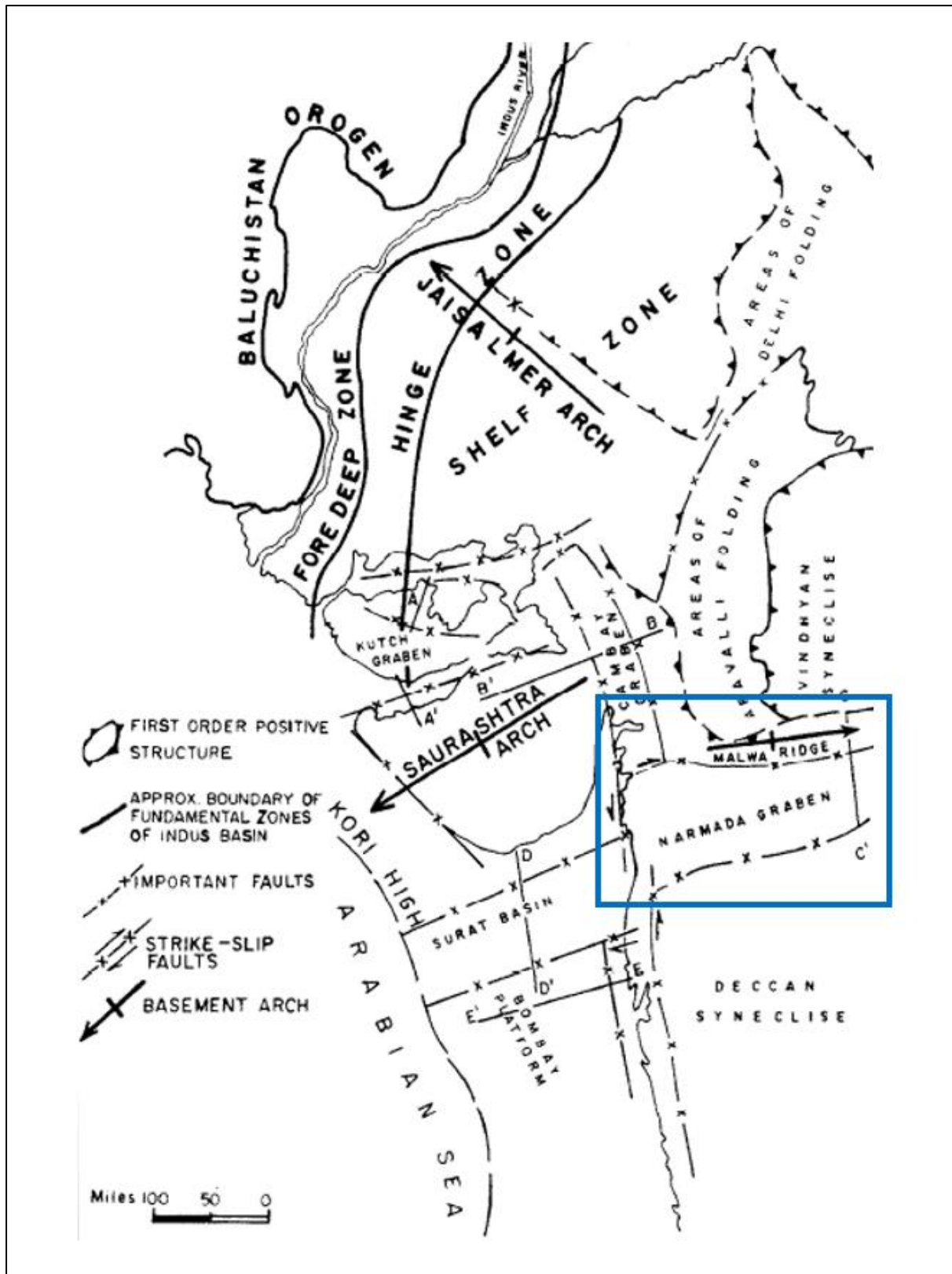
**Table 01 Summary of Evolutionary Stages**

| Time Period                | Key Evolutionary Events                                            |
|----------------------------|--------------------------------------------------------------------|
| <b>Late Cretaceous</b>     | Initiation of rifting and deposition of deltaic sediments.         |
| <b>Post-Cretaceous</b>     | Marine sedimentation and extensive volcanic activity.              |
| <b>Early Tertiary</b>      | Uplift, conjugate faulting, and interaction with adjacent grabens. |
| <b>Final Configuration</b> | Stabilization post-India-Eurasia collision.                        |

The Narmada Basin exemplifies the tectonic complexity of the western margin of India, evolving through sequential rifting, subsidence, sedimentation, and volcanic activity over millions of years. and Table 1 summarizes the evolutionary stages of the basin while Table 2 provides a summary of the generalized stratigraphy of the basin. Figure 1 shows the tectonic framework of the western margins of India with a focus on the Narmada.

**Table 02 Generalized stratigraphy of the basin (after Biswas, 1987)**

| Age                  | Lithology                             | Environment           | Event                                                   |
|----------------------|---------------------------------------|-----------------------|---------------------------------------------------------|
| Cretaceous to Eocene | Deccan Traps (> 3000 ft)              | Terrestrial           | Regression/ Uplift / Volcanicity / Major Tectonic Cycle |
| Late Cretaceous      | Limestone / Marl / Sandstone (250 ft) | Marine                | Transgression                                           |
| Early Cretaceous     | Sandstone / Shale (300 ft)            | Deltaic / Continental | Rifting                                                 |
| Pre-Mesozoic         | Sandstone / Shale / Limestone         | Marine                | Transgression                                           |
| Precambrian Basement | Metamorphic / Granitic                |                       |                                                         |



**Fig. 01 Tectonic Framework of the Western Margins of India with Emphasis on the Narmada**  
 (Source: Modified from Biswas, 1986; Eremenko et al. 1969)

### 3. Tectonic Framework of the Basin

The graben trending ENE-WSW, which is flanked by a network of nearly parallel dextral wrench faults (Das and Patel, 1984), gradually widens towards the west and constitutes the valley of the Narmada River. This fault system marks the boundary of the Narmada-Son mega lineament (Murthy et al., 1981). The Narmada-Son lineament, aligned along the Satpura trend, serves as a significant tectonic demarcation (West, 1962; Chaubey, 1971), dividing the Indian shield into a northern foreland block and a southern peninsular block and has a long tectonic history dating back to the Archaean times (Ravishankar, 1991). The Narmada–Son Fault (NSF) extends in an ENE–WSW direction and can be traced laterally for over 1,000 km. It serves as a geological boundary dividing Peninsular India into two distinct regions: the Vindhyan–Bundelkhand area to the north and the Deccan region to the south. According to Ravishankar (1991), the NSF is part of a larger tectonically active area in central India, known as the SONATA zone, which stands for the Son–Narmada–Tapti Lineament zone. These tectonic trends are followed by the Narmada and Tapti Rivers over their whole journey. The Central Indian Shear (CIS) (Jain et al., 1995), the Narmada-Son Lineament (Choubey, 1971), and the Central Indian Tectonic Zone (CITZ) (Radhakrishna and Ramakrishnan, 1988; Acharyya and Roy, 2000) are some other terms used in literature to describe this zone. The Narmada Valley Gap is an ideal location for Quaternary sedimentation, preserving Glacial, Fluvio- glacial and fluvial deposit of pleistocene to Holocene times (Khan et. al., 2017).

According to geophysical investigations conducted in the zone's centre, there is a lot of deep-seated faulting within this region (Reddy et al., 1995). Around 2.5–2.2 and 1.5–0.9 Ga, the zone had significant tectono-thermal episodes linked to major granitic intrusions (Acharyya and Roy, 2000). In the Late Cretaceous–Palaeocene, it was reactivated once more during the Deccan volcanic eruption (Agarwal et al., 1995). The zone may have served as the primary centre of eruptive activity due to the frequent occurrences of E-W trending dykes (Bhattacharji et al., 1996). High gravity anomalies, a high temperature gradient and heat flow, and an anomalous geothermal regime currently characterize the entire zone (Ravishankar, 1991). These factors imply that the zone is seismically and thermo-mechanically vulnerable within the context of modern tectonism (Bhattacharji et al., 1996).

The mega lineament represents a geofracture characterized by deep faulting, extending down to the Moho at depths of 35–40 km (Kaila et al., 1980, 1985). According to DSS profiles analysed by Kaila et al. (1980), the rift zone exhibits block faulting along a series of deep faults that displace the Moho. This zone of maximum subsidence occurs where the Godavari graben, running parallel to the Dharwar strike, intersects with the Narmada graben, forming a depocentre. Since the Godavari graben is filled with Gondwana rocks, it is likely that a significant portion of the pre-trap sediment thickness at the depocentre belongs to the Gondwana Super Group. Based on velocity data analysis by Kaila et al. (1980), it is inferred that late Cretaceous sediments are primarily found in the shallower northern side of the trough. This zone's westward expansion into the lower Narmada valley has a less intricate structural configuration. Most of the NSF data in this section comes from geophysical surveys conducted in order to commercially utilize subsurface petroleum deposits. According to the Deep Seismic Sounding (DSS) studies, it is manifested as a single deep-seated fault (NSF) in the lower Narmada basin (Kaila et al., 1981). The extent of

outcrops and sediment thickness indicates that the Cretaceous basin is confined to the western part of the rift zone, gradually widening and deepening towards the west (Biswas, 1987).

Kaila et al. (1985) highlighted the intricate nature of movements along this fault system, noting a link between basement displacements and the Moho along the deep faults. They identified a fault that serves as a tectonic boundary, separating the late Proterozoic - early Paleozoic epicontinental marine rocks of the Vindhyan Super Group in the north from the paralic Gondwana rocks in the south (Biswas, 1987). According to Kaila et al. (1958), the reversal of movements along deep faults bordering the central trough led to Permian rifting along this fault zone, which facilitated marine sedimentation in central India (Eremenko et al., 1969). The reactivation of these faults during the Cretaceous period resulted in the formation of a Mesozoic rift basin. Additionally, a Tertiary depocenter developed in the outer region of the embayment, specifically in the Broach depression, where the Narmada rift intersects with the Cambay rift.

Pal and Bhimasankaran (1976) linked the post-Jurassic drift of the Indian plate to the wrench-type Narmada-Son mega-lineament. Das and Patel (1984) noted that the dextral motion along this lineament seems unusual given India's anticlockwise rotation. This right-lateral movement is likely due to the differential transform motion between the foreland and peninsular blocks, influenced by India's continued northward motion under the Asian continent, the eastward convergence of the Bay of Bengal resulting from subduction below the Andaman-Sumatra arc, and the dextral transform motion along the northeastern plate boundary of India with the Indosinian plate (Parkar and Gealey, 1983). Roy and Kacker (1982) proposed a genetic link between the right lateral Dauki tear fault on the southern side of the northeastern cratonic wedge of India and the Narmada-Son mega-lineament and characterized the Narmada-Son-Dauki lineament as a major shear zone spanning the Indian subcontinent, formed due to a global stress system associated with the spreading of the Indian Ocean floor.

### 3.1 Neotectonics of the Basin

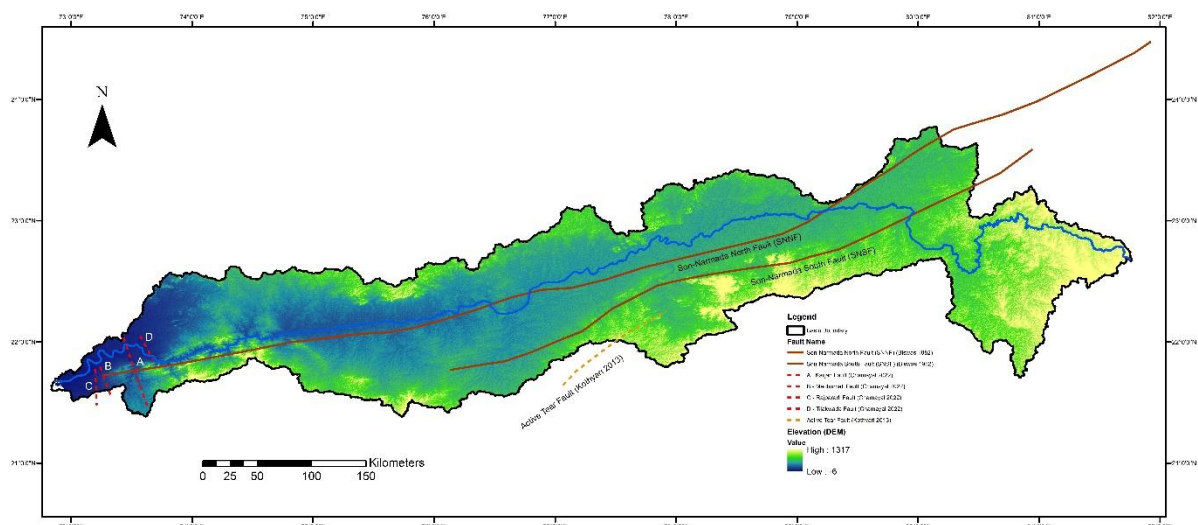


Fig. 02 Neotectonics of the Basin

The Narmada-Son Lineament has been extensively studied by numerous researchers over the years, highlighting its geological significance and complex tectonic history. Notable contributions include West (1962), who provided early insights into its structural framework, and Choubey (1971), who detailed its tectonic activity. Pal and Bhimasankaran (1976) explored its geophysical characteristics, while Katz (1978) examined its role in broader regional tectonics. Parker (1983) contributed to understanding its crustal dynamics, and subsequent studies by Das and Patel (1984) and Kaila (1985) further elaborated on its seismicity, faulting patterns, and lithospheric features.

The seismically active Narmada-Son Fault (NSF) is an ENE-WSW trending ~ 1000 km long crustal-scale fault transecting through the central part of the Indian plate (Kaila et al., 1981; Biswas, 1982). The fault has been reactivated several times since the Precambrian time, including the northward drift of the Indian plate after its breakup from Gondwanaland (Ravishankar, 1991).

According to Choubey (1971), the Narmada-Son lineament has undergone recurrent rejuvenation through a series of tectonic events, with similar differential effects recurring over time. Different segments of this rift structure developed at various periods, yet consistently aligned with the structural trends of great age.

As per the Geological Survey of India (GSI) Report (1974), conducted in parts of Bharuch and Surat districts of Gujarat, the Narmada Valley has undergone significant tectonic activity since the Pre-Deccan Trap period, marked by the formation of the Narmada rift and its intensification during the Deccan Trap eruptions. Post-Deccan Trap, faults trending ENE-WSW (Narmada fault) and NNW-SSE (Laki fault) marked continued tectonic evolution. The Quaternary period saw folding of Tertiary sediments, disrupted by cross-faults during Quaternary and Holocene times, leading to dynamic rejuvenation and reactivation of older weak planes and forming new lineaments.

The lower Narmada Valley exhibits significant evidence of subsurface tectonic activity. Features like alluvial terraces indicate river uplift and lateral swinging caused by tectonic movements. Stream capture, anastomotic channels, and new stream formations suggest block tilting. Variations in longitudinal profiles of river terraces, especially near Hansot and Bharbhata, highlight differential uplift and tilting.

Lineaments in multiple directions (e.g., E-W, ENE-WSW, NNW-SSE) influence drainage patterns and impact even the youngest alluvium. Vertical block movements, tilted terraces, and new drainage systems signify ongoing tectonic activity. The 1970 Broach (Bharuch) earthquake validated the region's tectonic instability, as fissures aligned with the Narmada fault trace provided concrete evidence of active subsurface movements.

Kothyari et al. (2013) conducted geomorphometric studies in the upper Narmada Valley, revealing significant tectonic activity along the Son-Narmada Fault (SNF) zone. Their analysis highlighted vertical uplift due to N-S compression, basin tilting toward the NNW, and activation of the Son-Narmada South Fault (SNSF) during the Quaternary period. This tectonic activity has shaped fluvial landforms, including channel shifts, gorges near Bhedaghat, waterfalls, and strath terraces. High steepness index (SL) values and morphometric data indicate ongoing vertical tectonic processes, particularly in the Shahpuri-Mandla and Jabalpur-Narsihapur segments.

Geodetic data and seismic patterns corroborate stress accumulation along the SNF, suggesting the region remains tectonically active with potential for future seismic events.

Chamyal et al. (2022) conducted a detailed investigation of the Narmada-Son Fault (NSF) zone's westernmost part in Gujarat using ground-penetrating radar (GPR) and developed nine GPR profiles across four fault segments. The study highlighted significant tectonic features, including strike-slip motion, uplift, and fault-controlled sedimentation. Segment II revealed clear NSF exposures, displaced veins, and tectonically influenced sedimentation patterns, resulting in steep escarpments and alluvial fan deposits. In segment III, neotectonic activity-controlled river dynamics, while segment IV showed uplifted Tertiary rocks and paleo-bank development due to NSF activity. Chamyal concluded that the NSF exhibits spatial variability in neotectonic activity, influenced by transverse faults and uneven stress distribution along its segmented structure.

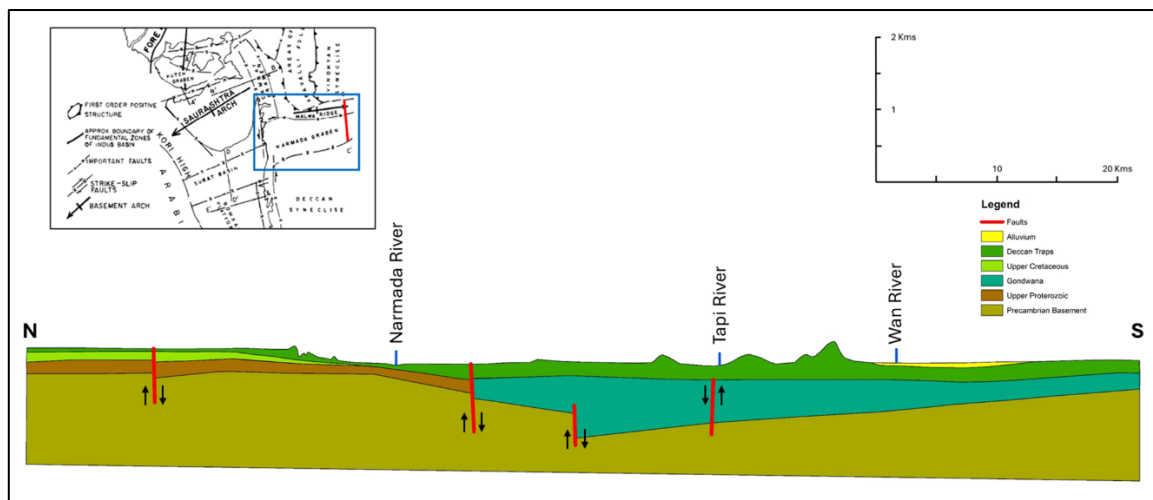
These features underscore the Narmada Valley's dynamic geological evolution, shaped by both ancient tectonic events and recent disturbances.



#### 4. Regional Geological set-up of Narmada River Basin

The Narmada Basin is a large rift valley where the Narmada River cuts through Mesozoic sediments. The Narmada-Son Lineament, paralleling the Satpura Orogenic trend, is a major tectonic boundary dividing the Indian Shield into the southern peninsular and northern foreland blocks (West, 1962; Mathur et al. 1968; Choubey, 1971). The Narmada graben, formed by faults parallel to this lineament, extends westward across the continental shelf and is offset southward by the west coast fault near the Gulf of Cambay. This fault, following the NNW-SSE Dharwar Trend, shapes the current coastline and forms the Cambay Graben.

The Western Continental Shelf has extension faults parallel to the Dharwar Rift, forming narrow linear horsts and grabens typical of a passive margin (Pratsch, 1978). Each basin evolved independently, correlating with the drifting history of the Indian subcontinent post-Gondwana breakup. Biswas (1982) demonstrated the synchrony in the development of these basins and the major events of plate tectonics. Important stages of tectonic evolution of the basins correlate with the stages of drifting history of the Indian subcontinent since the time of its breakup from Gondwana Land until its collision with Eurasia. The rifting progressed from north to south, forming the Kutch Basin in the Early Jurassic, Cambay Basin in the Early Cretaceous, and Narmada Basin in the Late Cretaceous. The Narmada Basin's complex history includes Palaeozoic origins and upper Cretaceous marine sedimentation, which was brief and ended with Late Cretaceous uplift and volcanic activity (Biswas and Deshpande, 1984).

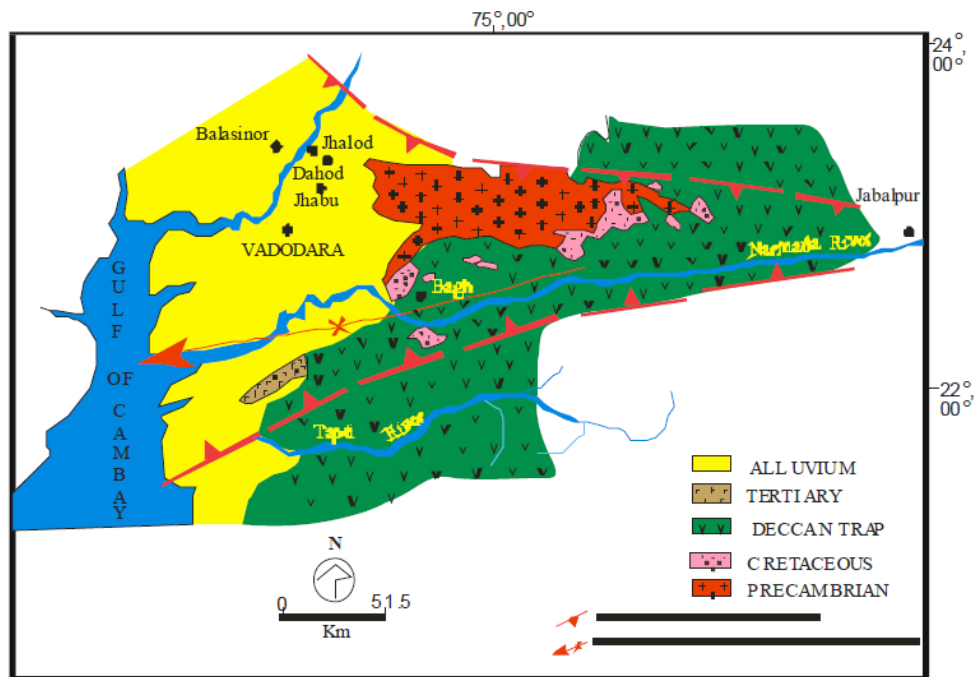


**Fig. 03 Geological Section of Narmada Basin (Modified after Biswas, 1986 and Kaila et al., 1985.)**

In the Narmada basin, scattered outcrops of shallow marine Late Cretaceous rocks (100 meters thick) lie beneath the Deccan Trap (Biswas, 1982). These rocks were deposited during a brief Turonian transgression in a narrow embayment in the western part of the basin (Jafar, 1982). Unlike the other two marginal basins, which experienced non-deposition and volcanic activity during the Late Cretaceous, the Narmada basin saw subsidence. However, the Turonian transgression was short-lived, with Late Cretaceous tectonic activity leading to uplift, erosion, and Deccan Trap volcanic flows, which limited marine sediment occurrence to a few areas. The Late Cretaceous marine sediments are found mainly in the basin's western part, lying on Upper Proterozoic metasediments, with Lower Cretaceous fluvio-deltaic sediments below and Eocene

and Miocene rocks above in coastal regions. Eastern remnants of marine Permo-Carboniferous sediments are present in the middle of the rift zone (Krishnan, 1968). In the Early Cretaceous, the Kutch-Saurashtra-Narmada region was a broad shelf receiving extensive deltaic sediments (Biswas, 1983). The Deccan Trap lavas, marking widespread volcanic activity at the end of the Cretaceous, covered the Mesozoic sedimentary rocks across these basins. This volcanic activity occurred during the late-tectonic phase at the end of the Late Cretaceous diastrophic episode in Western India (Biswas and Deshpande, 1983).

Cretaceous sediments in the Narmada Valley, oriented ENE-WSW, are exposed in various locations and often covered by the Deccan Traps, occurring as inliers. These sediments are classified into the Nimar Group, consisting of fluvial and lacustrine sandstones; the Bagh Group, composed of marine sandstones, fossiliferous marls, and coralline limestones; and the Lameta Group, featuring fluviatile sandstones and clays, reaching a maximum thickness of about 400 meters (Murty et al. 1963). Paleocurrent studies in the area indicate that from the Upper Jurassic to Lower Cretaceous, sediments originated from northern and north-eastern sources and were transported by streams flowing westward and south-westward, with increasing thickness toward the south and southeast (Shukla, 1971).

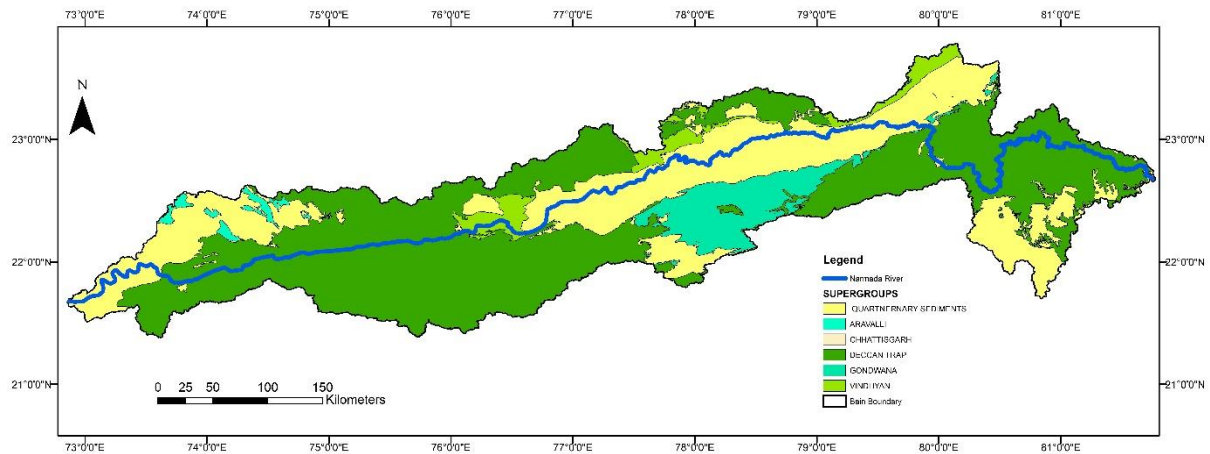


**Fig. 04 Architecture of Narmada Basin (Source: Mukhopadhyay, 2008; modified after Biswas, 1987)**

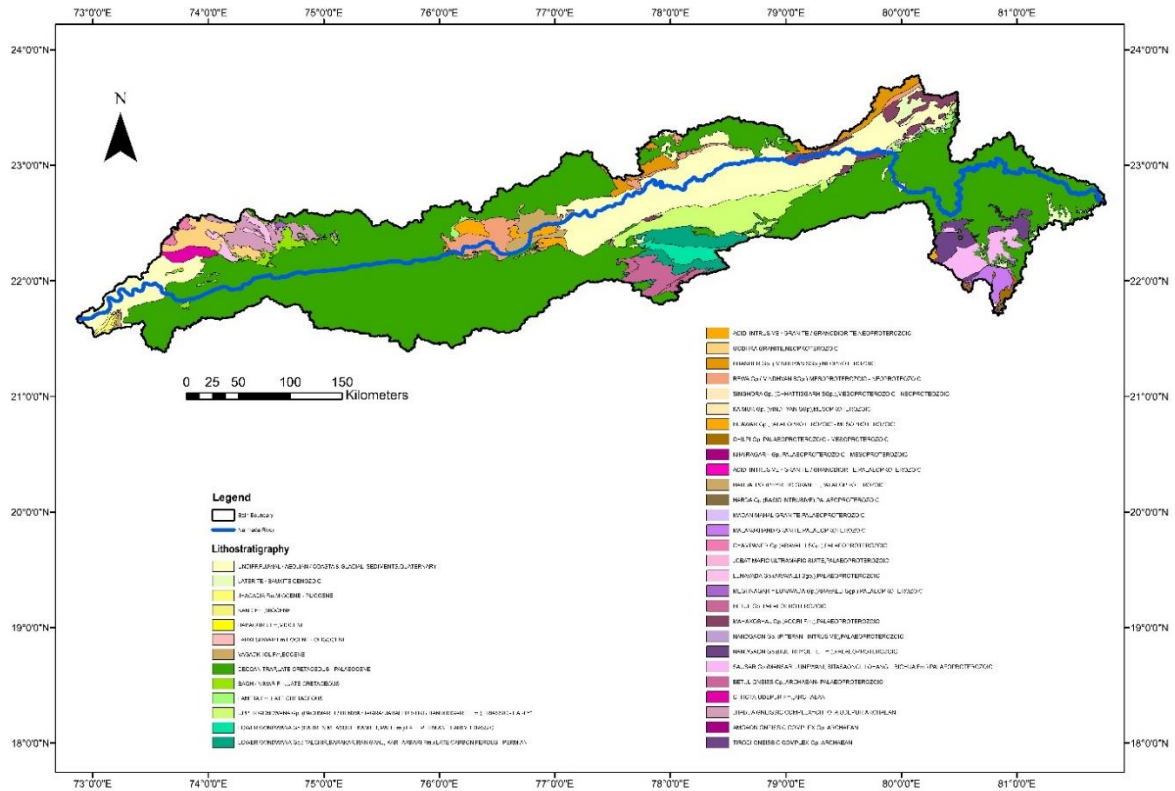
The Mesozoic basin style and stratigraphic history in the Narmada Valley are covered by thick volcanic lavas. Field investigations from the 1960s indicate that faults in the Deccan Trap and the fold axes of overlying sediments run nearly parallel to the ENE-WSW striking Narmada fault. Post-Trappean enechelon and parallel fault systems have disturbed the Mesozoic sediments, which are exposed as faulted inliers in the western basin (Babu, 1984). The regional structure is characterized by graben and horst formations.

Blandford (1869) suggested that trap lava flowed over an eroded Cretaceous topography, with sedimentary inliers representing pre-trap topographical highs. Field investigations recorded that

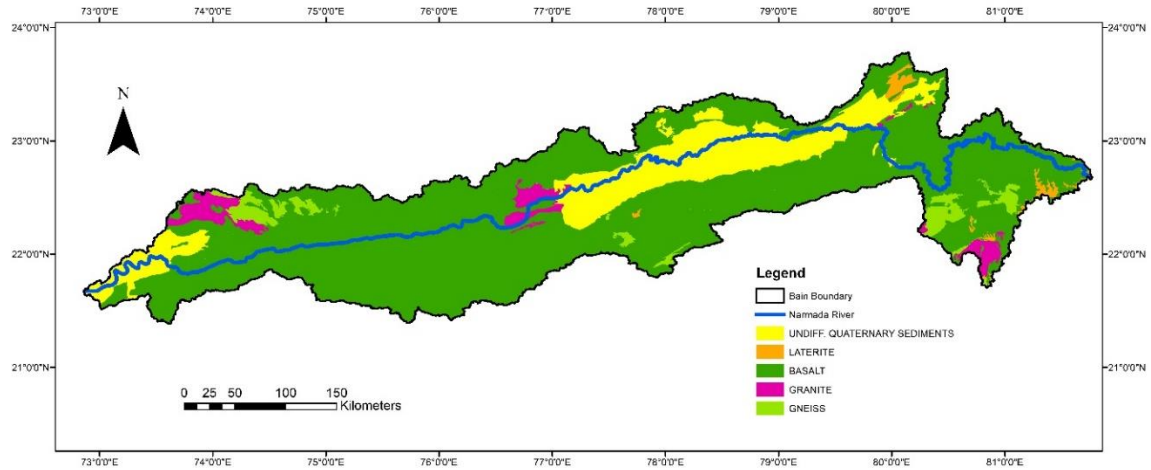
the Narmada fault, the northern boundary of the Satpura horst, caused southward tilting of sediments, forming a graben, and that the basin's southern part features numerous ENE-WSW dykes (Babu, 1984). The metamorphic terrain has a general NW-SE orientation, while Cretaceous sediments and Deccan traps follow an ENE-WSW orientation. In the coastal basin to the west, alluvium covers older rocks, and Tertiary outcrops near Jhagadia trend NE-SW and ENE-WSW.



**Fig. 05 Geological Supergroups in the Narmada River Basin (Source: Bhukosh)**



**Fig. 06 Lithostratigraphic Map of Narmada River Basin (Source: Bhukosh)**



**Fig. 07 Major Rock Types in the Basin (Source: Bhukosh)**

The basin features unclassified granite gneisses and metamorphic rocks from the Archaean basement. Above these lie sedimentary sequences from the Bijawar and Jobat formations of Precambrian age, the Vindhyan Group of Paleozoic age, the Nimar and Bagh groups of Cretaceous age, the infratrappeans and the Lameta Group, the Deccan Traps, lower and upper Tertiary sediments, laterite, and recent alluvium (Babu, 1984). Figure 06 presents the lithostratigraphic map of the Narmada River basin and figure 07 shows the major rock types found within the basin, while Table 3 outlines the general lithostratigraphic sequence of the Narmada Valley.

**Table 03 Lithostratigraphic Sequence of Narmada Valley (modified after Chiplonkar, 1982; Bose, 1984; Sahni & Bajpai, 1988)**

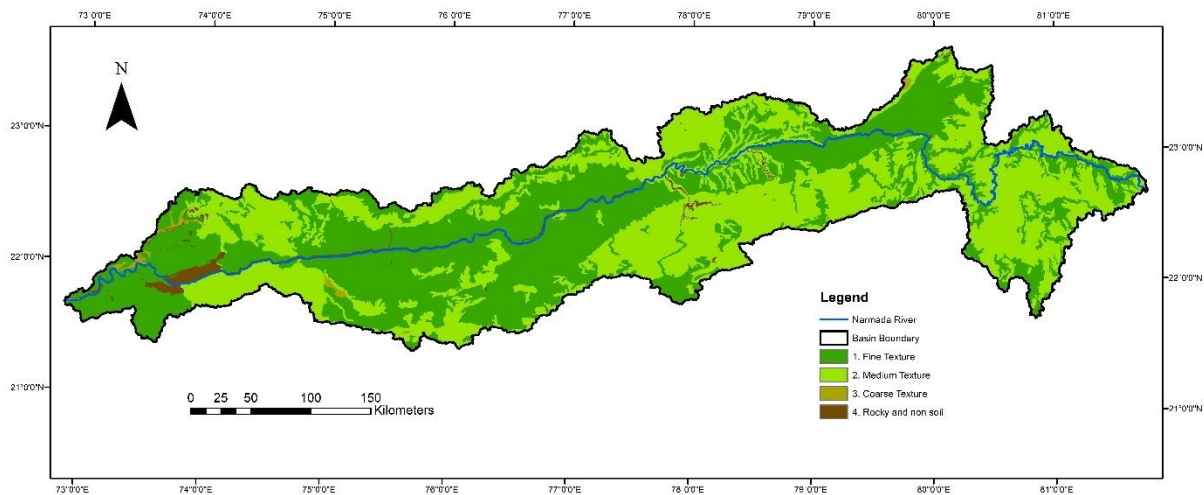
| Age                             | Formation           | Lithology                                                                    |
|---------------------------------|---------------------|------------------------------------------------------------------------------|
| Quaternary                      | Alluvium            | Alluvium and Soils                                                           |
| Cretaceous to Eocene            | Deccan Traps        | Basalt and its Varieties                                                     |
| Maestrichtian                   | Lameta Formation    | Cherty Limestones, Limestones and Sandstones                                 |
| Albian to Senonian              | Bagh Formation      | Coralline Limestone, Nodular Limestone, marls, oyster beds etc. with fossils |
| Up. Carboniferous to Cretaceous | Gondwana Formations | Sandstones, shales with plant remains                                        |
| Pre-Cambrian to Cambrian        | Vindhyan Formation  | Sandstones, Shales                                                           |
| Pre-Cambrian                    | Bijawar Formation   | Low grade metamorphics                                                       |
| Basement not exposed            |                     |                                                                              |

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## 5. Soils of the Basin

Soil is a dynamic and complex natural resource, consisting of a blend of minerals and organic matter that undergoes substantial transformation from its parent material. These transformations give soil its distinctive characteristics, including texture, structure, consistency, colour, and chemical and biological properties. Understanding the soil profile is essential for accurately modelling the hydrological characteristics of a basin.

In the upper basin, most soils are characterized as shallow black soils formed from the erosion of trap basalts. These black soils contain smectite clays, known for their high water-holding capacity. Organic matter content in black soils is typically less than 5%. These soils are predominantly in-situ or colluvial and are often interspersed with red sandy or lateritic soils. The soil profile is generally shallow, covering hilltops and plateau regions. Red soils, formed through intense chemical leaching of basalts, retain only the oxides of silica, iron, and aluminium, with other minerals being washed away. While these red soils have good drainage, they lack the nutrients required for healthy plant growth. In the middle basin near the regions of Vindhyan and Satpura plateaus, soils range from shallow to medium black types. In the lower basin, medium-deep black soils dominate the valley and southern plateau, while a mix of red and black soils is prevalent in the northern plateau. Near the mouth of the Narmada, Pliocene rocks are accompanied by recent alluvial deposits. These alluvial soils, composed mostly of sandy loams, exhibit good drainage, high fertility, and are well-suited for agriculture.



**Fig. 08 Soil Texture Map of the Basin (Data Source: NBSS&LUP, IWRIS)**

As shown in Figure 08, more than half of the basin is dominated by fine-textured soils, which play a significant role in the region's agricultural and hydrological dynamics. Medium-textured soils constitute the next largest category, providing moderate water retention and fertility properties. The remaining portions of the basin are comprised of rocky and non-soil areas, as well as coarse-textured soils, which are less favourable for cultivation but may influence drainage and erosion patterns. Detailed sub-basin characteristics of soil texture are presented in Table 04.

**Table 04 Sub-Basin wise Soil Texture Characteristics**

| Sr. No.                           | Class                                                  | Area (sq. Km) |
|-----------------------------------|--------------------------------------------------------|---------------|
| <b>Upper Narmada River Basin</b>  |                                                        |               |
| 1                                 | Clay, loamy clay, sandy clay, silty clay, sandy clay   | 16181.34      |
| 2                                 | Loam, silt loam, silt, sandy loam                      | 26506.22      |
| 3                                 | Loamy sand, sand                                       | 68.46         |
| 4                                 | Rocky, other non-soil categories (built up, waterbody) | 436.67        |
| <b>Middle Narmada River Basin</b> |                                                        |               |
| 1                                 | Clay, loamy clay, sandy clay, silty clay, sandy clay   | 24954.54      |
| 2                                 | Loam, silt loam, silt, sandy loam                      | 14811.31      |
| 3                                 | Loamy sand, sand                                       | 110.30        |
| 4                                 | Rocky, other non-soil categories (built up, waterbody) | 699.57        |
| <b>Lower Narmada River Basin</b>  |                                                        |               |
| 1                                 | Clay, loamy clay, sandy clay, silty clay, sandy clay   | 7397.27       |
| 2                                 | Loam, silt loam, silt, sandy loam                      | 154.75        |
| 3                                 | Loamy sand, sand                                       | 1241.36       |
| 4                                 | Rocky, other non-soil categories (built up, waterbody) | 295.95        |
| 5                                 | Clay, loamy clay, sandy clay, silty clay, sandy clay   | 636.07        |
| <b>Entire Narmada River Basin</b> |                                                        |               |
| 1                                 | Clay, loamy clay, sandy clay, silty clay, sandy clay   | 48533.14      |
| 2                                 | Loam, silt loam, silt, sandy loam                      | 154.75        |
| 3                                 | Loamy sand, sand                                       | 42558.88      |
| 4                                 | Rocky, other non-soil categories (built up, waterbody) | 474.71        |
| 5                                 | Clay, loamy clay, sandy clay, silty clay, sandy clay   | 1772.30       |

**DATA SOURCE: NHP, NWIC, Data downloaded from [www.indiawris.gov.in](http://www.indiawris.gov.in)**

The analysis of daily volumetric soil moisture data for the Narmada Basin from 24th July 2018 to 2nd September 2024 highlights notable variations across its upper, middle, and lower regions. In the upper basin, soil moisture ranges from 0% to a maximum of 40.25%, with an average of 24.71%. The middle basin records the highest maximum soil moisture at 41.12% and an average

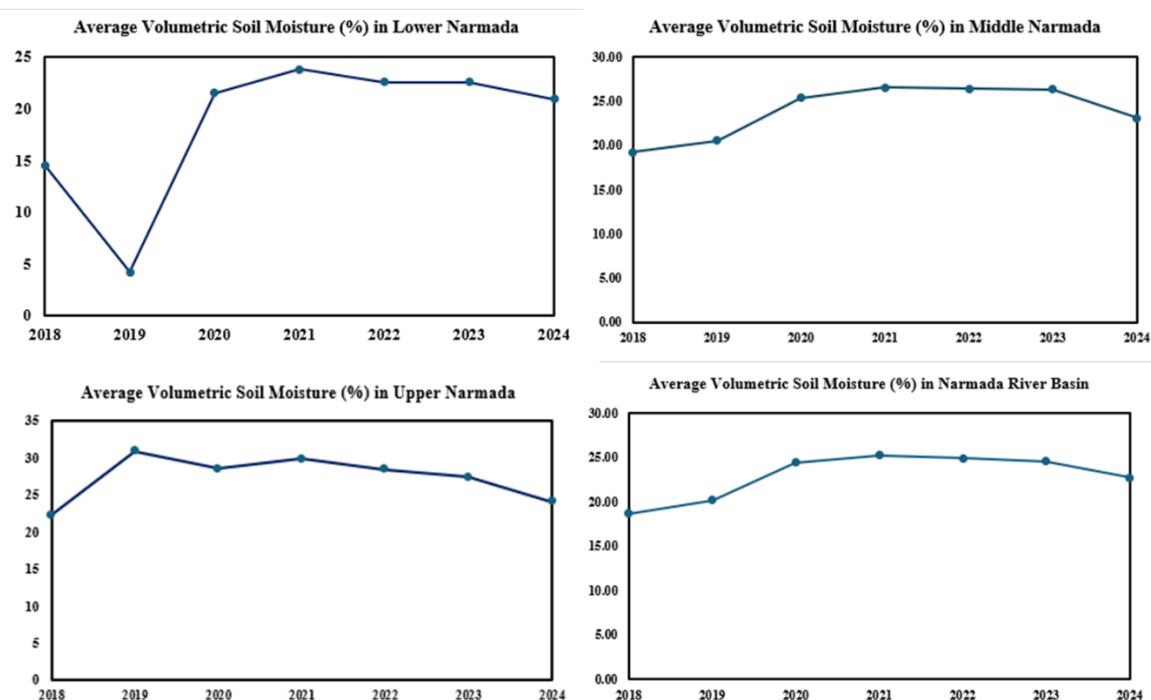
of 26.06%, indicating relatively wetter conditions compared to other regions. The lower basin, despite a maximum of 37.02%, exhibits the lowest average soil moisture at 20.87%, likely influenced by drier conditions and missing data for 2019. For the entire basin, the maximum soil moisture is 39.41%, with an average of 23.31% and moderate variability shown by a standard deviation of 8.71%. Overall, the middle basin shows better water retention or wetter conditions, while the lower basin reflects comparatively drier trends, with variability in soil moisture across all regions influenced by local factors such as rainfall, soil type, and land use patterns.

**Table 05 Characteristics of Daily Volumetric Soil Moisture (%) (24/07/2018 to 02/09/2024)**

| S. No                             | Class                             | Area (sq. Km) |
|-----------------------------------|-----------------------------------|---------------|
| <b>Upper Narmada River Basin</b>  |                                   |               |
| 1                                 | Maximum                           | 40.25         |
| 2                                 | Minimum                           | 0             |
| 3                                 | Average                           | 24.71         |
| 4                                 | Standard Deviation                | 8.22          |
| <b>Middle Narmada River Basin</b> |                                   |               |
| 1                                 | Maximum                           | 41.12         |
| 2                                 | Minimum                           | 0             |
| 3                                 | Average                           | 26.06         |
| 4                                 | Standard Deviation                | 9.43          |
| <b>Lower Narmada River Basin</b>  |                                   |               |
| 1                                 | Maximum                           | 37.02         |
| 2                                 | Minimum                           | 0             |
| 3                                 | Average (* Data Missing for 2019) | 20.87         |
| 4                                 | Standard Deviation                | 9.03          |
| <b>Entire Narmada River Basin</b> |                                   |               |
| 1                                 | Maximum                           | 39.41         |
| 2                                 | Minimum                           | 0             |
| 3                                 | Average                           | 23.31         |
| 4                                 | Standard Deviation                | 8.71          |

**DATA SOURCE: NHP, NWIC, Data downloaded from [www.indiawris.gov.in](http://www.indiawris.gov.in)**



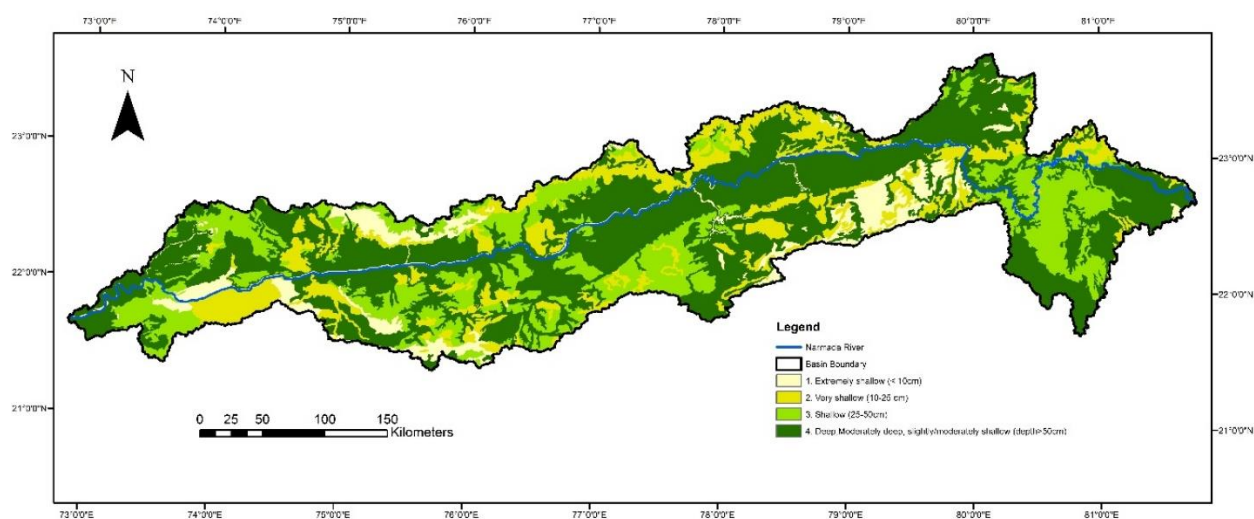


As shown in figure 09 the soil depth distribution varies significantly across the basin. In the upper basin, most of the area, approximately 25,062.57 sq. km, consists of deep soils with a depth greater than 50 cm. Shallow soils (25–50 cm) dominate with 719,490.34 sq. km, while extremely shallow soils (<10 cm) cover 3,514.33 sq. km. The middle basin also has a substantial proportion of deeper soils (18,936.77 sq. km) but includes notable areas of very shallow soils (10–25 cm) at 7,908.88 sq. km, and extremely shallow soils at 3,591.27 sq. km. The lower basin shows a smaller extent of deep soils (5,744.91 sq. km) and shallow soils (3,083.36 sq. km), with very shallow and extremely shallow soils contributing 106.14 sq. km and 636.25 sq. km, respectively. For the entire basin, deep soils (>50 cm) account for the largest area, followed by shallow soils, very shallow soils and extremely shallow soils. This distribution indicates a dominance of shallow to moderately deep soils across the basin, reflecting its varied topography and soil formation processes.

Much of the basin features gentle slopes, covering over 40% of the area. Approximately 20% of the soil in the basin is classified as highly productive, while around 28% falls into the category of moderately productive soils, as shown in Map 10.

Soil erosion is notably intense in the hilly regions and upper plains of the Narmada basin. It is also severe along the river's course through the lower plains. In contrast, soil erosion in the middle and lower plains of the basin tends to be moderate in intensity, as shown in figure 11.



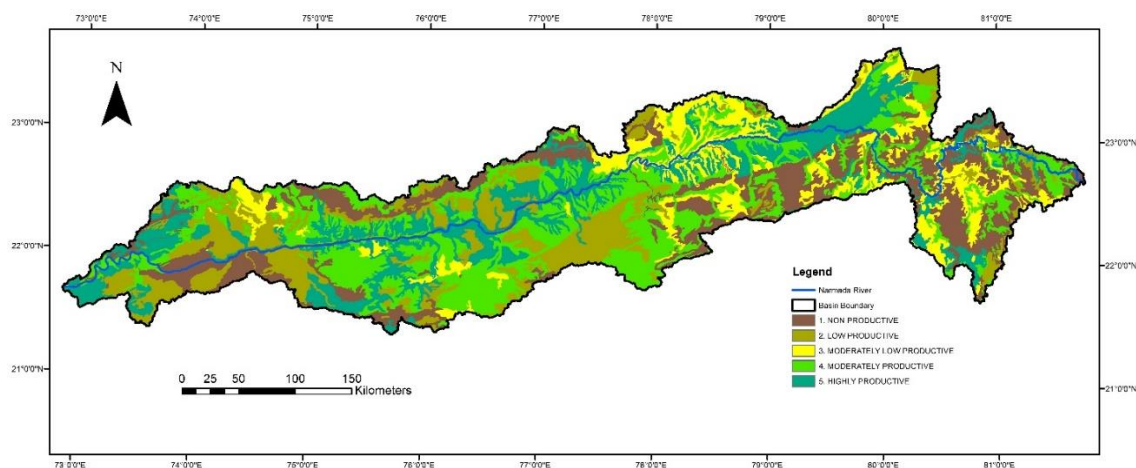


**Fig. 09 Narmada Basin Soil Depths (Data Source: NBSS&LUP, IWRIS)**

**Table 06 Soil Depth Information**

| Sr. No                            | Class                                                            | Area (sq. Km) |
|-----------------------------------|------------------------------------------------------------------|---------------|
| <b>Upper Narmada River Basin</b>  |                                                                  |               |
| 1                                 | Data Not Available                                               | 0             |
| 2                                 | Deep, Moderately Deep, Slightly/Moderately Shallow (>50cm)       | 25062.57      |
| 3                                 | Extremely Shallow (<10cm)                                        | 3514.33       |
| 4                                 | Shallow (25-50cm)                                                | 719490.34     |
| <b>Middle Narmada River Basin</b> |                                                                  |               |
| 1                                 | Deep, Moderately Deep, Slightly/Moderately Shallow (>50cm)       | 18936.77      |
| 2                                 | Extremely Shallow (<10cm)                                        | 3591.27       |
| 3                                 | Shallow (25-50cm)                                                | 10138.8       |
| 4                                 | Very Shallow (10-25cm)                                           | 7908.88       |
| <b>Lower Narmada River Basin</b>  |                                                                  |               |
| 1                                 | Data Not Available                                               | 154.75        |
| 2                                 | Deep, Moderately Deep, Slightly/Moderately Shallow (>50cm)       | 5744.91       |
| 3                                 | Extremely Shallow (<10cm)                                        | 636.25        |
| 4                                 | Shallow (25-50cm)                                                | 3083.36       |
| 5                                 | Very Shallow (10-25 cm)                                          | 106.14        |
| <b>Entire Narmada River Basin</b> |                                                                  |               |
| 1                                 | Data Not Available                                               | 154.75        |
| 2                                 | Deep, Moderately Deep, slightly/moderately Shallow (depth >50cm) | 49744.25      |
| 3                                 | Extremely Shallow (<10cm)                                        | 7741.84       |
| 4                                 | Shallow (25-50cm)                                                | 20643.03      |
| 5                                 | Very Shallow (10-25 cm)                                          | 15209.92      |

**DATA SOURCE: NHP, NWIC, Data downloaded from [www.indiawris.gov.in](http://www.indiawris.gov.in)**

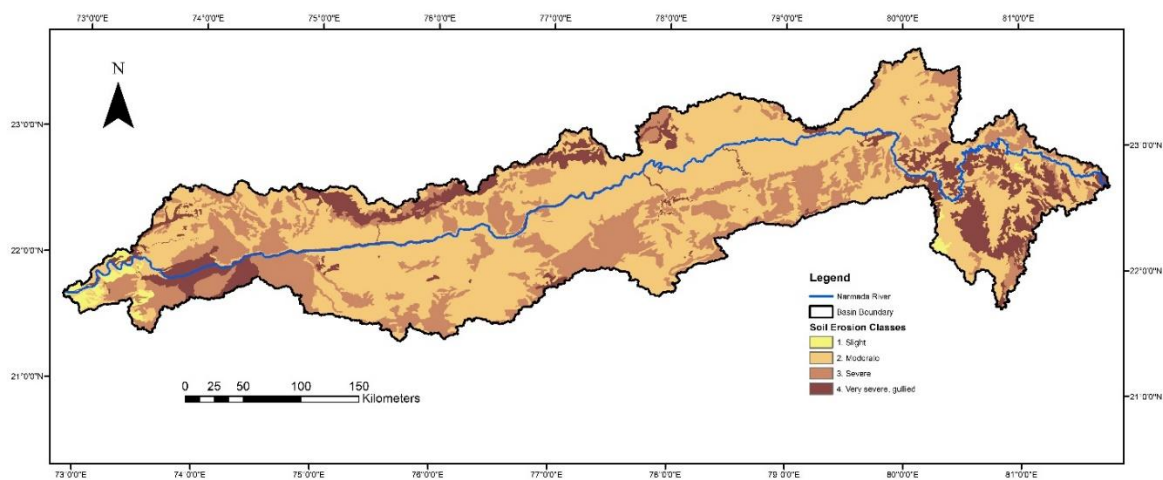


**Fig. 10 Basin Soil Productivity (Data Source: NBSS&LUP, IWRIS)**

**Table 07 Characteristics of Soil Productivity**

| Sr. No                            | Class                     | Area (sq. Km) |
|-----------------------------------|---------------------------|---------------|
| <b>Upper Narmada River Basin</b>  |                           |               |
| 1                                 | Data not available        | 0             |
| 2                                 | Highly Productive         | 6666.36       |
| 3                                 | Low Productive            | 3154.31       |
| 4                                 | Moderately Low Productive | 10029.27      |
| 5                                 | Moderately Productive     | 11665.16      |
| 6                                 | Non-Productive            | 11677.54      |
| <b>Middle Narmada River Basin</b> |                           |               |
| 1                                 | Highly Productive         | 8775.9        |
| 2                                 | Low Productive            | 10319.6       |
| 3                                 | Moderately Low Productive | 2155.96       |
| 4                                 | Moderately Productive     | 12895.57      |
| 5                                 | Non-Productive            | 6428.69       |
| <b>Lower Narmada River Basin</b>  |                           |               |
| 1                                 | Data not available        | 154.75        |
| 2                                 | Highly Productive         | 4107.6        |
| 3                                 | Low Productive            | 2833.68       |
| 4                                 | Moderately Low Productive | 13.12         |
| 5                                 | Moderately Productive     | 1674.63       |
| 6                                 | Non-Productive            | 941.6         |
| <b>Entire Narmada River Basin</b> |                           |               |
| 1                                 | Data not available        | 154.75        |
| 2                                 | Highly Productive         | 19549.87      |
| 3                                 | Low Productive            | 16307.6       |
| 4                                 | Moderately Low Productive | 12198.36      |
| 5                                 | Moderately Productive     | 26235.37      |
| 6                                 | Non-Productive            | 19047.84      |

**DATA SOURCE: NHP, NWIC, Data downloaded from [www.indiawris.gov.in](http://www.indiawris.gov.in)**



**Fig. 11 Soil Erosion Map of the Basin (Data Source: NBSS&LUP, IWRIS)**

**Table 08 Soil Erosion Status Information**

| Sr. No                            | Class                  | Area (sq. Km) |
|-----------------------------------|------------------------|---------------|
| <b>Upper Narmada River Basin</b>  |                        |               |
| 1                                 | Data Not Available     | 0             |
| 2                                 | Moderate               | 28165.45      |
| 3                                 | None to Slight, Slight | 199.94        |
| 4                                 | Severe                 | 8741.19       |
| 5                                 | Very Severe, Gullied   | 6086.08       |
| <b>Middle Narmada River Basin</b> |                        |               |
| 1                                 | Moderate               | 23937.29      |
| 2                                 | Severe                 | 12046.23      |
| 3                                 | Very Severe, Gullied   | 4592.18       |
| <b>Lower Narmada River Basin</b>  |                        |               |
| 1                                 | Data Not Available     | 154.75        |
| 2                                 | Moderate               | 3793.44       |
| 3                                 | None to Slight, Slight | 2002          |
| 4                                 | Severe                 | 2833.62       |
| 5                                 | Very Severe, gullied   | 941.52        |
| <b>Entire Narmada River Basin</b> |                        |               |
| 1                                 | Data Not Available     | 154.75        |
| 2                                 | Moderate               | 55896.19      |
| 3                                 | None to Slight, Slight | 2201.94       |
| 4                                 | Severe                 | 23621.05      |
| 5                                 | Very Severe, Gullied   | 11619.8       |

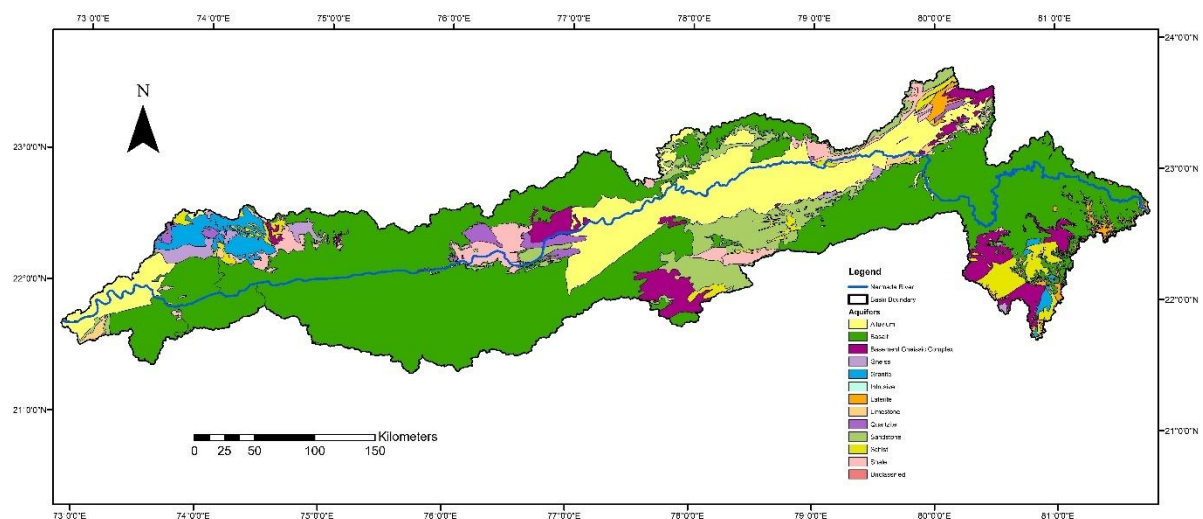
**DATA SOURCE: NHP, NWIC, Data downloaded from [www.indiawris.gov.in](http://www.indiawris.gov.in)**

## 6. Aquifers of the Basin

Aquifers are underground geological formations capable of storing and transmitting groundwater. They serve as vital components of the hydrological cycle, functioning as natural reservoirs that provide water for a wide range of uses, including agriculture, domestic consumption, and industrial activities. These formations vary widely in their characteristics, depending on their geological makeup and environmental conditions.

### 6.1 Major Aquifer Systems of the Basin

The Narmada basin hosts a variety of aquifer systems, ranging from unconsolidated alluvium to consolidated sedimentary, metamorphic, and igneous rocks, spanning geological periods from the Archean to the Quaternary. The key aquifer systems of the basin are shown in figure 12.



**Fig. 12 Major Aquifer Systems of the Basin (Data Source: CGWB)**

**1. Alluvial Aquifers:** Comprising fluvial deposits such as clay, silt, sand, and calcareous concretions, these aquifers are associated with the Quaternary period. The aquifer thickness ranges from 28 to 220 meters, with moderate to high yield potential ( $7\text{--}468\text{ m}^3/\text{day}$ ), making them a significant groundwater resource. These are mainly located in riverine plains.

**2. Laterite Aquifers:** These aquifers, formed from lateritic and ferruginous concretions, are limited in thickness (2–5 m) and exhibit moderate yields ( $5\text{--}180\text{ m}^3/\text{day}$ ). They are associated with the Quaternary to Cenozoic periods and primarily occur in plateau regions.

**3. Sandstone Aquifers:** Predominantly found in formations ranging from the Upper Palaeozoic to the Mesozoic era, sandstone aquifers exhibit substantial thickness (20–300 m) and moderate yields ( $20\text{--}2885\text{ m}^3/\text{day}$ ). These aquifers are a vital groundwater source due to their relatively high permeability and extensive distribution.

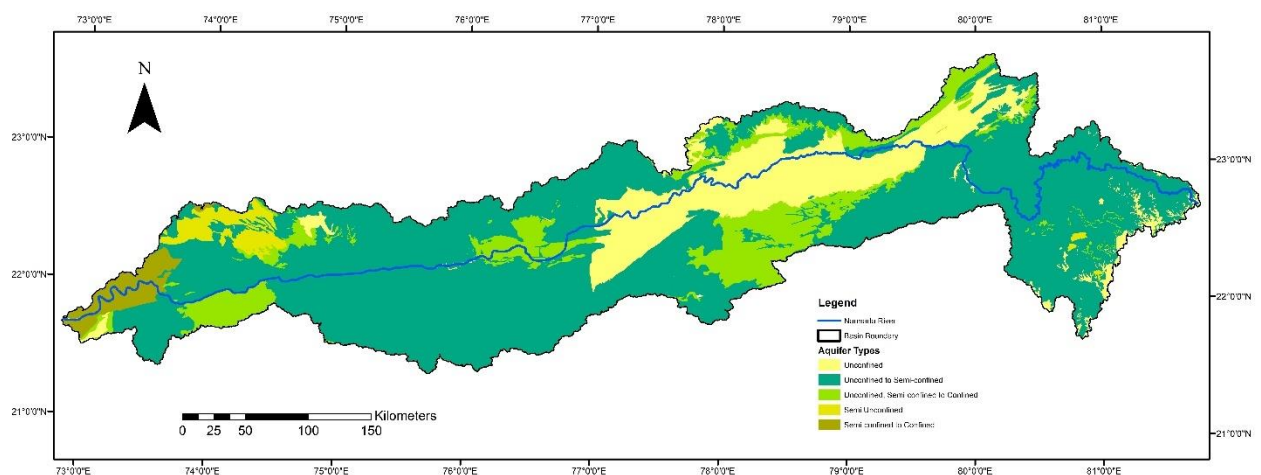
**4. Shale Aquifers:** Shale aquifers, often interbedded with sandstone or limestone, are characterized by lower permeability, limited thickness (2–50 m), and low to moderate yield potential (10–825 m<sup>3</sup>/day). These formations are primarily associated with the Proterozoic to Cenozoic periods.

**5. Limestone Aquifers:** Limestone formations, including dolomitic and jointed/fractured varieties, are critical aquifers due to their karstic nature, allowing for significant groundwater storage and movement. These aquifers, associated with the Upper Palaeozoic to Cenozoic periods, have thicknesses ranging from 3 to 150 meters and moderate to high yields (10–3485 m<sup>3</sup>/day).

**6. Granite Aquifers:** These aquifers, composed of highly fractured and weathered granitic rocks, belong to the Archean to Proterozoic periods. Despite their crystalline nature, they exhibit moderate yields (10–350 m<sup>3</sup>/day) and thicknesses of 1–18 meters due to secondary porosity created by fractures and weathering.

**7. Schist and Quartzite Aquifers:** These metamorphic formations, primarily from the Archean to Proterozoic periods, have moderate aquifer potential when weathered or fractured. Yields range from 10 to 180 m<sup>3</sup>/day, with aquifer thicknesses of up to 30 meters.

**8. Intrusives and Banded Gneissic Complex (BGC):** These formations, predominantly associated with the Precambrian era, have limited aquifer potential due to their compact nature and low permeability. Yields are generally low (10–100 m<sup>3</sup>/day), with aquifer thicknesses ranging from 2 to 15 meters.



**Fig. 13 Types of Aquifers (Source CGWB)**

## 6.2 Groundwater Occurrence

The availability and distribution of groundwater are primarily influenced by several key factors, including rainfall, drainage patterns, topography, and the geological conditions of the region. These elements determine how water infiltrates, moves, and accumulates in the subsurface.

Within the occurrence of groundwater can be seen in distinct zones or horizons, each with its own characteristics and behaviours.

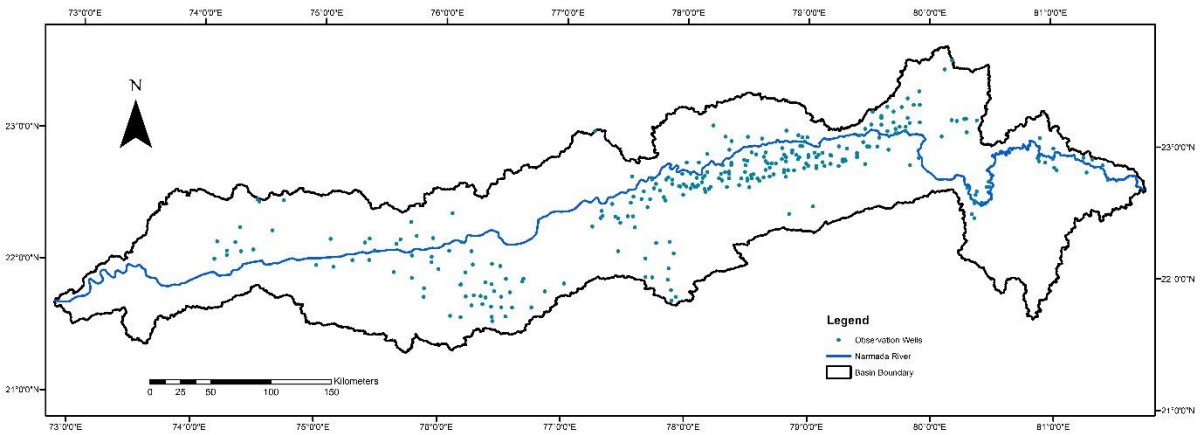
In the upper basin, the predominant geological formations are the ancient rocks of the Archaean and Vindhyan periods, which are known for their relatively high water potential. Groundwater in this area primarily resides in the weathered zones of these rocks. Both the quality and quantity of groundwater in these regions are generally good.

In the middle basin, where Gondwana rocks are most prevalent, groundwater is found in varying amounts within the pores of sandstones. The quantity of groundwater largely depends on the grain size of the rocks; coarser-grained rocks tend to have a higher groundwater yield. However, in areas where trap rocks are exposed, groundwater conditions become more unpredictable. In the trap basalts, groundwater is present in scattered aquifers, which are often isolated and not interconnected.

A large portion of the lower basin is dominated by trap basalts, where groundwater is found in patchy aquifers. However, closer to the river's mouth, coastal alluvial deposits are more prevalent. These coastal alluvials contain highly permeable aquifers that store substantial quantities of water, typically offering excellent yield and recharge characteristics. Groundwater in this region primarily exists in unconfined aquifers at varying depths but is subject to seasonal fluctuations in the water table.

### 6.3 Groundwater Scenario

A total of 465 groundwater observation wells have been installed by the Central Ground Water Board (CGWB) across the basin. The middle basin has the highest number of stations, with 192 wells, while the lower basin has the fewest, with 92. Figure 14 shows the locations of these observation wells, while Table 09 provides a breakdown of the number of stations and their corresponding water level ranges from 2020 to 2024.



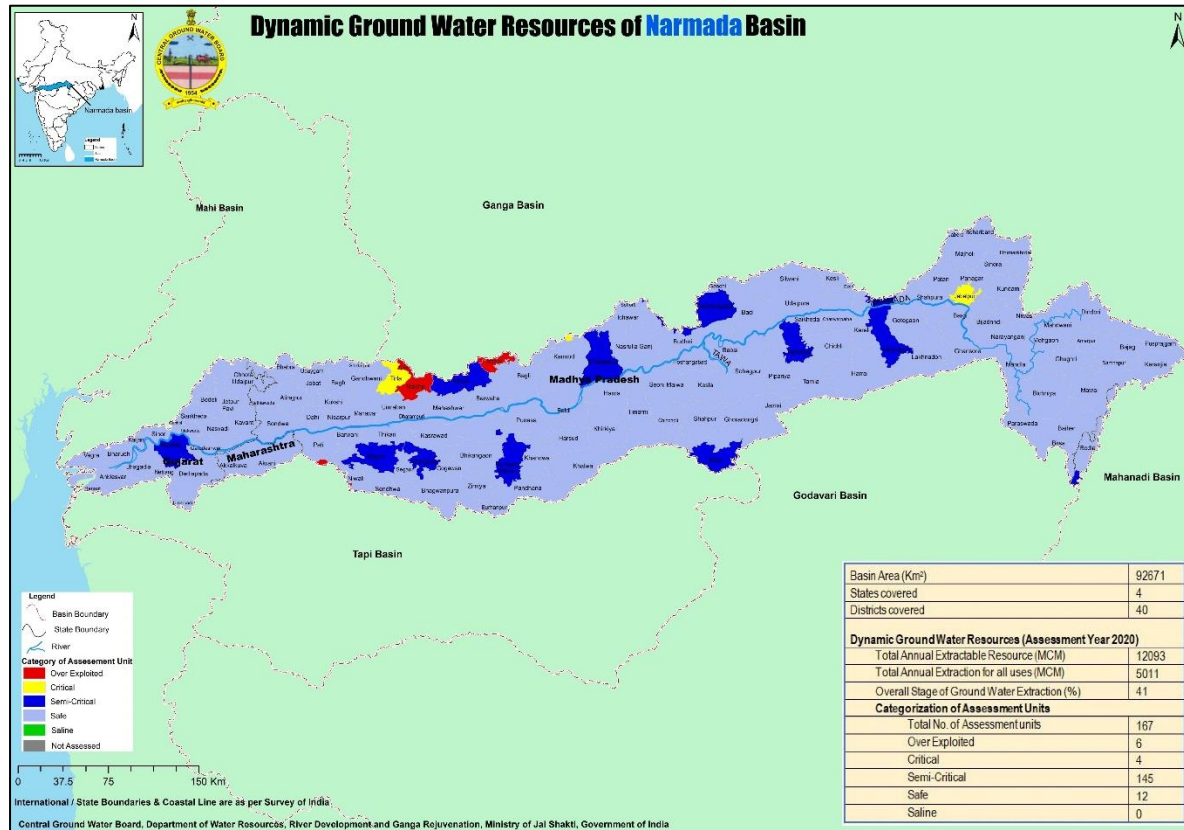
**Fig. 14 Observation Wells within the Basin**

**Table 09 Groundwater Observation Wells and Water Levels in the Basin**



| Sub Basin    | Total Number of Monitored Stations<br>(Observation Wells) | Observed Range of Water<br>Level (m bgl) |
|--------------|-----------------------------------------------------------|------------------------------------------|
| Lower Basin  | 93                                                        | 0 - 132.34                               |
| Middle Basin | 190                                                       | 0 - 50.7                                 |
| Upper Basin  | 182                                                       | 0 - 32.8                                 |

Source: [www.indiawris.gov.in](http://www.indiawris.gov.in)



**Fig. 15 Dynamic Groundwater Resources of Narmada Basin (Source: CGWB, 2020)**

Figure 15 represents groundwater conditions in the Narmada River Basin across four states—Madhya Pradesh, Gujarat, Maharashtra, and Chhattisgarh. Data for this analysis was sourced from the Central Ground Water Board (CGWB) for the assessment year 2020, as more recent data was unavailable.

The map categorizes groundwater assessment units into five groups: Over-Exploited, Critical, Semi-Critical, Safe, and Saline. According to the data:

A total of 167 assessment units were evaluated. Out of which 6 blocks (Pansemal, Dewas, Dhar, Nalcha, Indore & Indore Urban area) fall under the "Over-Exploited" category, shown in red, indicating severe groundwater depletion. 4 blocks (Pandariya, Tirla, Jabalpur and Ashta) were classified as "Critical," represented in yellow, signifying high stress levels. 12 units were labeled as "Semi-Critical" (marked in blue). The majority of blocks, 145, were categorized as "Safe" (depicted in green), implying balanced groundwater availability. No saline water zones were recorded in this assessment.

The Total Annual Extractable Resource for groundwater in the Narmada Basin was 12,093 MCM (Million Cubic Meters), while the Total Annual Extraction for all uses stood at 5,011 MCM, resulting in an overall Stage of Groundwater Extraction of 41%, which is moderate.

To evaluate the historical changes in groundwater within the basin, data from CGWB and GWRDC were obtained from IWRIS. An analysis was conducted to understand the alterations in the groundwater scenario, considering factors such as groundwater draft, availability, and the categorization of districts based on development categories from 2011 to 2020. Tables 10 and 11 present block-wise data on draft, groundwater availability, and changes in category for the years 2011 and 2020, respectively.

**Table 10 District wise Ground Water Resources Data of the Narmada Basin (In ham) of 2011**

| State          | District Name | Annual Domestic and Industry Draft | Annual Irrigation Draft | Annual Groundwater Draft | Annual Replenishable Groundwater Resources (Total) | Natural Discharge During Non-Monsoon Season | Net Groundwater Availability |
|----------------|---------------|------------------------------------|-------------------------|--------------------------|----------------------------------------------------|---------------------------------------------|------------------------------|
| Chhattisgarh   | Kabeerdham    | 1848                               | 20872                   | 22720                    | 36589                                              | 2308                                        | 34281                        |
|                | Rajnandgaon   | 3384                               | 21529                   | 24913                    | 46592                                              | 3500                                        | 43092                        |
| Gujarat        | Bharuch       | 2228                               | 16182                   | 18410                    | 40916                                              | 2046                                        | 38870                        |
|                | Dahod         | 4395                               | 13256                   | 17651                    | 37254                                              | 1863                                        | 35392                        |
|                | Narmada       | 1554                               | 4826                    | 6380                     | 22625                                              | 1131                                        | 21494                        |
|                | Panch Mahals  | 5569                               | 23568                   | 29137                    | 73939                                              | 3697                                        | 70242                        |
|                | Surat         | 6315                               | 30197                   | 36512                    | 85633                                              | 4282                                        | 81352                        |
|                | Vadodara      | 8129                               | 56601                   | 64730                    | 125982                                             | 6299                                        | 119682                       |
| Madhya Pradesh | Alirajpur     | 2162                               | 3802                    | 5964                     | 21648                                              | 1082                                        | 20565                        |
|                | Anuppur       | 1162                               | 1017                    | 2180                     | 40163                                              | 2008                                        | 38155                        |
|                | Balaghat      | 3107                               | 9620                    | 12728                    | 95825                                              | 4791                                        | 91034                        |
|                | Barwani       | 3019                               | 26800                   | 29819                    | 43475                                              | 2174                                        | 41301                        |
|                | Betul         | 3594                               | 55565                   | 59159                    | 119956                                             | 5998                                        | 113959                       |
|                | Bhopal        | 2356                               | 25719                   | 28075                    | 39227                                              | 1961                                        | 37266                        |
|                | Burhanpur     | 1147                               | 23504                   | 24651                    | 34077                                              | 1704                                        | 32373                        |
|                | Chhindwara    | 5274                               | 64955                   | 70230                    | 139607                                             | 6980                                        | 132627                       |
|                | Damoh         | 2113                               | 22861                   | 24974                    | 42217                                              | 2111                                        | 40106                        |
|                | Dewas         | 2623                               | 65523                   | 68146                    | 87646                                              | 4382                                        | 83264                        |
|                | Dhar          | 5005                               | 75257                   | 80262                    | 103017                                             | 5151                                        | 97867                        |
|                | Dindori       | 1384                               | 1857                    | 3241                     | 44853                                              | 2243                                        | 42611                        |
|                | Harda         | 976                                | 13730                   | 14706                    | 53712                                              | 2686                                        | 51026                        |
|                | Hoshangabad   | 2933                               | 35051                   | 37984                    | 213837                                             | 10692                                       | 203145                       |
|                | Indore        | 3369                               | 65109                   | 68478                    | 60089                                              | 3004                                        | 57084                        |
|                | Jabalpur      | 3141                               | 25989                   | 29130                    | 62238                                              | 3112                                        | 59126                        |
|                | Jhabua        | 2366                               | 7657                    | 10023                    | 23214                                              | 1161                                        | 22053                        |
|                | Katni         | 2549                               | 13404                   | 15953                    | 41068                                              | 2053                                        | 39015                        |
|                | Mandla        | 2248                               | 6218                    | 8465                     | 58603                                              | 2930                                        | 55672                        |
|                | Narsinghpur   | 2168                               | 85929                   | 88097                    | 122679                                             | 6134                                        | 116545                       |
|                | Raisen        | 3168                               | 37095                   | 40263                    | 95013                                              | 4751                                        | 90262                        |
|                | Sagar         | 2418                               | 69993                   | 72411                    | 129102                                             | 6455                                        | 122647                       |
|                | Sehore        | 2585                               | 55106                   | 57692                    | 78947                                              | 3947                                        | 74999                        |



|             |           |      |       |       |       |      |       |
|-------------|-----------|------|-------|-------|-------|------|-------|
|             | Seoni     | 3029 | 17504 | 20532 | 74706 | 3735 | 70970 |
|             | Umaria    | 1277 | 3661  | 4937  | 46386 | 2319 | 44067 |
| Maharashtra | Dhule     | 1784 | 34596 | 36380 | 74538 | 4334 | 70205 |
|             | Nandurbar | 2373 | 22122 | 24494 | 51437 | 2823 | 48614 |

Source: IWRIS <https://indiawris.gov.in/wris/#/GWResources>

**Table 11 District wise Ground Water Resources Data of the Narmada Basin (In ham) of 2020**

| State          | District Name | Annul Domestic and Industry Draft | Annual Irrigation Draft | Annual Groundwater Draft | Annual Replenishable Groundwater Resources (Total) | Natural Discharge During Non-Monsoon Season | Net Groundwater Availability |
|----------------|---------------|-----------------------------------|-------------------------|--------------------------|----------------------------------------------------|---------------------------------------------|------------------------------|
| Chhattisgarh   | Kabeerdham    | 2354.49                           | 33365.7                 | 35720.22                 | 53093.66                                           | 4148.27                                     | 48945.39                     |
|                | Mungeli       | 1729.45                           | 6558.95                 | 8288.4                   | 15845.23                                           | 1584.54                                     | 14260.69                     |
|                | Rajnandgaon   | 4659.91                           | 42951.8                 | 47611.7                  | 81755.7                                            | 6736.48                                     | 75019.23                     |
| Gujarat        | Surat         | 3377.62                           | 29018                   | 32395.62                 | 120453.3                                           | 9415.95                                     | 111037.35                    |
|                | Vadodara      | 2577.34                           | 54911.9                 | 57489.24                 | 105687.18                                          | 7843.33                                     | 97843.85                     |
|                | Bharuch       | 1120.51                           | 15379.4                 | 16499.91                 | 86406.75                                           | 8640.66                                     | 77766.09                     |
|                | Chhota Udepur | 1727.58                           | 18634.6                 | 20362.18                 | 54191.58                                           | 4894.98                                     | 49296.6                      |
|                | Dahod         | 4576.15                           | 8267.3                  | 12843.45                 | 51718.21                                           | 4484.34                                     | 47233.87                     |
|                | Narmada       | 463.77                            | 18038.4                 | 18502.17                 | 39578.5                                            | 3008.21                                     | 36570.29                     |
|                | Panch Mahals  | 1802.9                            | 9404.6                  | 11207.5                  | 47556.98                                           | 4201.2                                      | 43355.78                     |
| Madhya Pradesh | Alirajpur     | 2189.07                           | 6306.57                 | 8495.64                  | 23103.53                                           | 1776.22                                     | 21327.31                     |
|                | Anuppur       | 1512.23                           | 6038.97                 | 7551.2                   | 40430.92                                           | 2695.93                                     | 37734.99                     |
|                | Balaghat      | 3597.17                           | 12464.3                 | 16061.46                 | 86726.12                                           | 8672.64                                     | 78053.48                     |
|                | Barwani       | 3491.24                           | 33147.2                 | 36638.46                 | 56910.69                                           | 5165.15                                     | 51745.54                     |
|                | Betul         | 3753.32                           | 46816.3                 | 50569.57                 | 121699.28                                          | 8221.47                                     | 113477.81                    |
|                | Bhopal        | 3579.55                           | 23436.9                 | 27016.41                 | 39907.66                                           | 3042.37                                     | 36865.29                     |
|                | Burhanpur     | 1469.58                           | 22112.2                 | 23581.8                  | 40273.6                                            | 2929.68                                     | 37343.92                     |
|                | Chhindwara    | 5792.71                           | 53283.6                 | 59076.26                 | 104706.63                                          | 5919.69                                     | 98786.94                     |
|                | Damoh         | 2988.54                           | 19443.4                 | 22431.9                  | 42843.53                                           | 3545.25                                     | 39298.28                     |
|                | Dewas         | 4130.05                           | 60554.7                 | 64684.76                 | 86898.12                                           | 6096.06                                     | 80802.06                     |
|                | Dhar          | 5739.37                           | 77390.9                 | 83130.28                 | 114314.3                                           | 9401.24                                     | 104913.07                    |
|                | Dindori       | 1754.34                           | 2377.6                  | 4131.94                  | 41441.85                                           | 2604.84                                     | 38837.01                     |
|                | Harda         | 1183.32                           | 14704.6                 | 15887.95                 | 51874.18                                           | 5187.43                                     | 46686.75                     |
|                | Hoshangabad   | 2168.49                           | 39144.7                 | 41313.2                  | 207093.39                                          | 12074.2                                     | 195019.19                    |
|                | Indore        | 9617.48                           | 59180                   | 68797.43                 | 60090.65                                           | 5476.51                                     | 54614.14                     |
|                | Jabalpur      | 3543.15                           | 25507.4                 | 29050.55                 | 63816.21                                           | 4819                                        | 58997.21                     |
|                | Jhabua        | 2993.56                           | 10246.9                 | 13240.5                  | 27937.4                                            | 1703.56                                     | 26233.84                     |
|                | Katni         | 2624.73                           | 13378.9                 | 16003.66                 | 39813.86                                           | 3136.6                                      | 36677.26                     |
|                | Mandla        | 2425.78                           | 6908.22                 | 9334                     | 62670.03                                           | 3425.88                                     | 59244.15                     |
|                | Narsinghpur   | 2263.17                           | 70217.3                 | 72480.49                 | 121837.62                                          | 8296.36                                     | 113541.26                    |
|                | Raisen        | 3877.11                           | 39617.8                 | 43494.92                 | 89155.97                                           | 7206.76                                     | 81949.21                     |
|                | Sagar         | 3645.88                           | 56586.8                 | 60232.63                 | 108758.99                                          | 8828.73                                     | 99930.26                     |
|                | Sehore        | 2365.6                            | 38035.1                 | 40400.72                 | 69795.95                                           | 4608.14                                     | 65187.81                     |
|                | Seoni         | 3136.8                            | 22485                   | 25621.81                 | 72502.68                                           | 4252.85                                     | 68249.83                     |
|                | Umaria        | 1480.99                           | 8591.38                 | 10072.37                 | 46086.35                                           | 4608.62                                     | 41477.73                     |

|             |           |         |         |          |          |         |          |
|-------------|-----------|---------|---------|----------|----------|---------|----------|
| Maharashtra | Nandurbar | 3065.27 | 17367.6 | 20432.82 | 50989.36 | 3145.07 | 47844.3  |
|             | Dhule     | 1758.06 | 34082.7 | 35840.72 | 72413.01 | 4146.12 | 68266.89 |

**Source: IWRIS <https://indiawris.gov.in/wris/#/GWResources>**

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