एनटीपीसी
NTPC

एनटीपीसी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

NTPC/KGN/EMG/EC-MOEF/HYC/2024

Date: 16/12/2024

To
Additional Principal Chief Conservator of Forests (C),
Ministry of Environment, Forest and Climate Change,
Regional Office (WZ), Kendriya Paryavaran Bhawan,
E-5 Arera Colony, Link Road-3,
Ravishankar Nagar,
Bhopal-462016, Madhya Pradesh
Email id- rowz.bpl-mef@nic.in

Sub: Submission of 19th Half Yearly Environmental Clearance Compliance Report of Khargone Super Thermal Power Project (2x660 MW) at Village Selda & Dalchi, Khargone, Madhya Pradesh by NTPC Ltd.

EC Ref: J-13012/54/2010-1A. II (T), Dated-31.03.2015

Dear Sir,

With reference to the above-mentioned subject matter and EC reference, please find enclosed the half yearly compliance status report to the stipulated conditions of Environmental Clearance for the period **(Apr'2024-Sep'2024)**.

Submitted for your kind information and records please

Thanking you,

Yours sincerely,

(Ashish Kumar Agarwal)
AGM (Ash & Envt. Mgmt.)

Encl. as above

Copy to:

1. The Member Secretary,
Central Pollution Control Board,
Email-mscb.cpcb@nic.in

2. The Member Secretary,
Madhya Pradesh Pollution Control Board,
Email- ms-mppcb@mp.gov.in

KHARGONE SUPER THERMAL POWER PROJECT (2x660 MW)

HALF YEARLY COMPLIANCE REPORT OF ENVIRONMENTAL CLEARANCE CONDITIONS

(For the period April'2024 - September'2024)

(EC Ref.-MOEF&CC Letter No. J- 13012/54/2010-IA. II (T) Dated 31st March 2015)

A	MOEF & CC- Specific Conditions:	Status as on Implementation
i	Coal transportation shall be by Rail only. An additional EIA shall be carried out and an EMP shall be prepared for laying down the rail line and alternate mode of transportation, in case rail line gets delayed. The EIA/EMP shall be submitted to the Ministry within one year of issuing the EC.	Complied Rail network for NTPC-Khargone has been established and entire coal is being transported by railway route only.
ii	The Sulphur and Ash content of coal shall not exceed 0.5% and 43% respectively. In case of variation of quality at any point of time, fresh reference shall be made to the Ministry for suitable amendments in the environmental clearance.	Compliance assured MOEF&CC Vide Office Memorandum dated 11.11.2020 has modified this condition. The project proponent has to only inform to the Regional Office of MOEF&CC regarding the change in coal source and quality. Please refer Annexure-1 for change in coal source and quality
iii	Latest authenticated satellite imagery shall be submitted to the Regional Office of the Ministry on an annual basis to monitor the environmental alterations of the area.	Complied Satellite imagery of NTPC-Khargone and its vicinity land area is regularly submitted to the Regional Office of the MOEF&CC annually. Please refer Annexure-2 for the latest satellite imagery.
iv	Vision document specifying prospective plan for the site shall be formulated and submitted to the Regional Office of the Ministry within six months.	Complied Vision document specifying prospective plan of the project was submitted to the Regional Office of the MOEF&CC at Bhopal vide NTPC letter dated 07.09.2015.
v	Harnessing solar power within the premises of the plant particularly at available roof tops shall be carried out and status of implementation including actual generation of solar power shall be submitted along with half yearly monitoring report.	Complied For harnessing solar power, Roof-top and Land mounted solar power plants of total capacity of 1654 KW installed & operational within plant & township premises Actual generation of solar power during the FY 2024-25 up to Sep'24 is 1049615 KWH.
vi	One twin flue stack of 275 m height shall be provided with continuous on-line monitoring system of $S0_x$, $N0_x$ and **PM2.5 & *PM10.* Exit velocity of flue gases shall not be less than 22 m/sec. In addition to	Complied One twin-flue stack of 275 m height provided for both units. Continuous online emission monitoring system (CEMS) facilities also provided for monitoring of SO2, NOx and PM.

	the regular parameters, Mercury emission form stack shall also be monitored of six-monthly basis. *As per EC Amendment letter by MOEF & CC dated 22.01.2022 the condition is modified as *"PM in stack emission" in place of PM2.5 & PM10*	Separate stacks of height 150 m also provided for FGD units of respective Unit-1 & Unit-2. Continuous online emission monitoring system (CEMS) facilities also provided for monitoring of SO2, NOx and PM at FGD Stacks. Exit velocity of flue gases being maintained above 22 m/sec. Mercury emission form stack also being monitored periodically. Please refer Annexure-3, for Mercury emission report from stack for the reporting period.
vii	High Efficiency Electrostatic Precipitators (ESPs) shall be installed to ensure that particulate emission does not exceed 50 mg/Nm^3. Adequate dust extraction system such as cyclones/bag filters and water spray system to control fugitive emissions in dusty areas such as in coal handling and ash handling points, transfer areas and other vulnerable dusty areas shall be provided.	Complied High Efficiency Electrostatic Precipitators (ESPs) designed for a guaranteed efficiency of 99.97% provided and operational. The particulate emissions are controlled and maintained within prescribed norms of 30 mg/Nm^3 in compliance to MOEF&CC notification dated 07.12.2015, for revised emission norms for TPPs. Adequate dust extraction system and water spray system also provided to control fugitive emissions at coal handling, coal stockyard, ash handling area, transfer points and other vulnerable dusty areas. Please refer Annexure-3, for Particulate Matter emission from stack for the reporting period.
viii	COC of at least 5.0 shall be adopted.	Compliance assured Closed cycle cooling water re-circulation system is implemented to meet prescribed COC, for the conservation/optimization of water requirement.
ix	Monitoring of surface water quantity and quality shall be conducted regularly and records shall be maintained. The monitoring points shall be located between the plant and drainage in the direction of flow of ground water and records shall be maintained. The monitored data shall be submitted to the Ministry every six months.	Complied Regular monitoring of surface water being carried out through MOEF&CC accredited and NABL certified third party laboratory. Records are being maintained and monitoring reports regularly submitted to Regional Office of the MOEF&CC at every six months. Please refer Annexure-3 for Surface water reports for the reporting period.
x	Monitoring for heavy metals in ground water in the vicinity of plant shall also be undertaken and monitoring report shall be submitted to the ministry every six months.	Complied Regular monitoring of heavy metals in ground water are being carried out through MOEF&CC accredited and NABL certified third party laboratory. Monitoring reports

		regularly submitted to Regional Office of the MOEF&CC at every six months. Please refer Annexure-3 for Heavy metals in ground water reports for the reporting period.
xi	A well-designed rainwater harvesting system shall be put in place within six months, which shall comprise of rainwater collection from the built up and open area in the plant premises and records shall be kept for the quantity of water harvested every year and its use.	Complied Well-designed, CGWA approved rainwater harvesting system, comprise of rainwater collection from the built-up area, open area & storm water of the capacity 0.36 MCM is installed at plant premises. Records for the harvested quantity of water every year being maintained. Rainwater harvested is fully used to recharge the ground water through recharge pits as per the approved scheme.
xii	No water bodies including natural drainage system in the area shall be disturbed due to activities associated with the setting up/ operation of the power plant.	Complied No water body including natural drainage system of the area have been disturbed.
xiii	Hydro geology of the area shall be reviewed annually through an institute/ organization of repute to assess impact of surface water and ground water (especially around ash dyke). In case, any deterioration is observed specific mitigation measures shall be undertaken immediately. Reports/data of water quality shall be submitted to the Regional Office of the Ministry every six months.	Complied Baseline Hydro-geological study was carried out through National Institute of Hydrology (NIH), Roorkee. Annual review of hydro geology to assess impact of surface water and ground water (especially around ash dyke) has been also carried out through an institute/ organization of repute. Please refer Annexure-4 for the Final interim report of hydrogeology review study submitted by M/s IIT-Roorkee for year 2024. Reports of surface and ground water quality are regularly submitted to Regional Office of the MOEF&CC at every six months. Please refer Annexure-3 for Surface & Ground water quality reports for the reporting period.
xiv	Wastewater generated from the plant shall be treated before discharge to comply with the standards prescribed by the SPCB/CPCB.	Complied Effluent Management Scheme has been designed and implemented with the objective to treat the entire wastewater as per the prescribed statutory standards of MPPCB/CPCB. It is to be submitted that during normal course of operations, zero liquid discharge being adopted based on maximum recycle/reuse of wastewater for various plant usage.
xv	Additional soil for leveling of the proposed site, if require shall be taken from within the sites (to the extent	Complied For leveling of site all additional soil being taken from within the sites only (to the extent

	possible) so that natural drainage system of the area is protected.	possible) with all necessary precautions to protect natural drainage system of the area.
xvi	Fly ash shall be collected in dry from and storage facility (silos) shall be provided. Un-utilized fly ash shall be disposed-off in the ash pond in the form of slurry. Mercury and other heavy metals (As, Hg, Cr, Pb etc.) will be monitored in the effluents emanating from the ash pond and in the bottom ash also. No ash shall be disposed-off in low-lying area.	Complied An ash management & disposal scheme is implemented consisting of dry ash extraction system (DAES) for dry collection of fly ash with adequate storage facility (silos) to supply ash to entrepreneurs for utilization. Un-utilized ash is being safely disposed in the ash pond in the form of slurry. Two different systems are being provided for ash disposal: Conventional wet slurry disposal system with ash water re-circulation for bottom ash and High Concentration Slurry Disposal (HCSD) system for fly ash disposal. Mercury & other heavy metals (As, Hg, Cr, Pb etc.) are regularly monitored in the ash water emanating from ash pond and in the bottom ash. No ash is being disposed-off in low-lying area at present. Prior permission shall be obtained for ash disposal in low-lying area. Please refer Annexure-3 for Mercury & Heavy metals report in ash water & bottom ash for the reporting period.
xvii	Fugitive emission of fly ash (dry or wet) shall be controlled such that no agricultural or non-agricultural land is affected. Damage to any land shall be mitigated and suitable compensation shall be provided in consultation with the local Panchayat.	Complied & Noted Dust suppression system comprising of water spray nozzles are provided all around the ash ponds for effective control of fugitive emission of fly ash. Further, closed trucks/ bulkers/covered vehicle/closed BLC container railway wagons are being used for transportation of fly ash to avoid fugitive dust emission.
xviii	Ash pond shall be line with HDPE/LDPE lining or any other suitable impermeable media so that no leaching takes place at any point of time. Adequate safety measures shall also be implemented to protect the ash dyke from getting breached.	Complied To avoid any leaching and ground water contamination from ash slurry, suitable impermeable media lining provided in ash dyke. Bottom ash lagoons are lined with suitable impermeable media i.e., bentonite blended clay in order to achieve the required permeability. In HSCD lagoon the disposed layers of ash are solidified and there is very less free water. Overflow lagoon of ash dyke is also lined with impervious thick liner of 300 mm at bottom. The structure of ash dykes has been designed, constructed, and being operated as per state-

		of-the-art engineering practices for the design and construction of earth dams with adequate factor of safety. Ash dyke being constructed considering the seismic parameters in its design. Regular monitoring and inspection of ash dykes and an emergency response system will ensure that there are no risks of failure as apprehended. Further, in compliance to MOEF&CC Gazette Notification dtd. 31.12.2021, an annual certification of ash dyke also being done as per guidelines issued by Central Pollution Control (CPCB) & Central Electricity Authority (CEA). Certification report submitted to the MOEF&CC, CPCB, CEA & MPPCB.
xix	A long-term study of radioactivity and heavy metals contents of coal to be used shall be carried out through a reputed institute and results shall be analyzed every two years and shall be reported to the Ministry along with the monitoring reports. Thereafter, mechanism for * *in-built continuous monitoring* for radioactivity and heavy metals in coal and fly ash (including bottom ash) shall be put in place. *As per EC Amendment letter by MOEF & CC dated 22.01.2022 the condition is modified as *"regular periodical monitoring"* in place of in-built continuous monitoring.	Complied Annually, monitoring of Radioactivity content of coal has been carried out through Board of Radiation & Isotope Technology (BRIT) under Dept. of Atomic Energy, Govt. of India. Reports of Radioactivity content analysis in coal & ash samples are regularly submitted along with Half-yearly compliance report. Latest Radioactivity content analysis report was already submitted along with Half-yearly compliance report submitted on 15.05.2024. Further, Regular periodical monitoring of Heavy metals content of coal has been also carried out through MOEF&CC accredited and NABL certified third party laboratory. Reports are regularly submitted to the Regional office of MOEF&CC along with half-yearly compliance reports. Please refer Annexure-3 for Heavy metals content report for the reporting period.
xx	Green belt of least 50m width consisting of three tiers of plantations of native species around the plant shall be raised. Wherever 50m width is not feasible, an adequate justification shall be submitted to the Ministry and appropriate width not less than 20m shall be planted. Tree density shall not be less than 2500 per ha with survival rate not less than 80%.	Compliance assured Green belt development along with additional tree plantations is being carried out at all available spaces inside and outside the plant and township premises. Further tree plantation being taken up at external forest land and Govt. land to enhance the green cover. Avenue plantation along the approach roads and ash dyke also being taken up. Cumulative 4.9 lakhs tree have been planted till date at inside and outside the NTPC-Khargone premises through Govt. agencies i.e. Madhya Pradesh Rajya Van Vikas Nigam Ltd. and Rural Engineering Services depts. under Govt. of Madhya Pradesh.

xxi	Green belt shall also be developed around the ash pond over and above the Green Belt around the plant boundary.	Compliance assured Tree plantation at the vicinity of ash pond sites along peripheral roads is also being planted.
xxii	CSR schemes identified based on need-based assessment shall be implemented in consultation with the village Panchayat and the District Administration starting from the development of project itself. As part of CSR, prior identification of local employable youth the eventual employment in the project after imparting relevant training shall be also undertaken. Company shall provide separate budget for community development activities and income generation programs.	Compliance assured Need Assessment Survey (NAS) has been completed in Dec'2022 by M/s Grant Thornton. NTPC Khargone entered CSR phase from mid of May'2024. The total budget sanctioned is of INR 5.43 Cr for various CSR activities. Out of 5.43 Cr. total approved budget of CSR an amount of 37.03 Lakhs was utilized while activities of 2.35 Cr. in progress, while the work of balance amount utilization is under progress. Please refer to Annexure-5 for the list of CSR activities undertaken in during the reporting period
xxiii	For periodic monitoring of CSR activities, a CSR Committee or a Social Audit committee or a suitable credible external agency shall be appointed. CSR activities shall also be evaluated by an independent external agency. This evaluation shall be both concurrent (every six months) and final.	Compliance assured The Social Impact Evaluation (SIE) Study has been completed in Aug23 by Indian Institute of Corporate Affairs.
xxiv	An Environmental Cell comprising of at least one expert in environmental science/ engineering, ecology, occupational health, and social science shall be created preferably at the project site itself and shall be headed by an officer of appropriated seniority and qualification. It shall be ensured that the Head of the cell shall directly report to the Head of the Plant who would be accountable for implementation of environmental regulations and social impact improvement/ mitigation measures.	Complied An Environment Management Group (EMG) with qualified team, headed by AGM (Ash & Envt. Mgmt.) is already functional at the Khargone station. EMG is responsible for implementation and compliance of environmental stipulations and ensure mitigation measures.
B	**MOEF & CC- General Conditions:**	**Status as on Implementation**
i	Space for FGD shall be provided for future installation, if required.	Complied Space kept for FGD is utilized in FGD installation. FGD installation completed and available for both Units. Date of Operations (ODe) for FGD: Unit-1 and FGD: Unit-2 are 25.05.2023 & 08.12.2023 respectively.

ii	The treated effluents conforming to the prescribed standards under Environment (Protection) Act 1986 only shall be re-circulated and reused within the plant. Arrangements shall be made that effluents and storm water do not get mixed.	Complied Effluent treatment system comprising of effluent treatment plant, neutralization pit, oil & grease separator, settling ponds and cooling towers etc. provided to treat effluents conforming the prescribed standards. An integrated scheme for treatment, recycle and reuse of effluents is implemented. Cooling water blow down is reused in CHP, AHP, FGD and firefighting. Ash water effluent recirculation also being provided for reuse in ash handling purpose. Provision also made for treatment, recirculation & reuse of effluents from coal handling plant. Further, Zero Liquid Discharge (ZLD) scheme is implemented for recycle & reuse of wastewater generated, thereby reducing, and optimizing the quantities of water requirement. Independent plant effluent drainage system provided to ensure that plant effluents do not mix with storm water drainage.
iii	A sewage treatment plant shall be provided (as applicable) and the treated sewage shall be used for raising greenbelt/plantation.	Complied Sewage treatment plant (STP) provided to treat sewage effluents emanating from plant and township. The STP treated water, conforming to prescribed standards utilized for plantation & raising greenbelt/plantation.
iv	Adequate safety measures shall be provided in the plant area to check/ minimize spontaneous fires in coal yard, especially during summer season. Copy of these measures with full details along with location, plant layout etc. as and when finalized, shall be submitted to the ministry as well as to the regional office of the Ministry.	Complied Adequate no. of Fire Spray & Hydrant system covering the entire power station including all the auxiliaries and buildings in the plant area is provided as per fire safety requirements. The system is adequately equipped with piping, hydrants, valves, instrumentation, hoses, nozzles, hose boxes/stations etc. Safety measures details already submitted along with Half-yearly compliance dated 22.04.2019.
v	Separate storage facilities for auxiliary liquid fuel such as LDO/HFO/LSHS shall be made in the plant area in consultation with Department of Explosives, Nagpur. Sulphur content in the liquid fuel will not exceed 0.5%. Provisions of the Manufacture, Storage and Import of	Complied Storage facility designed and provided for LDO as auxiliary liquid fuel, inside plant area conforming to the adequate safety standard and where risk is minimal. Necessary license has been obtained from Department of

	Hazardous Chemical Rules and the Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996 shall be applicable as per the quantity stored. Disaster Management System shall be established as per the Disaster Management Plan to meet any eventuality in case of an accident taking place due to storage of oil.	Explosives. Sulphur content in LDO being ensured within limits. Detailed Disaster Management Plan (DMP) & Risk assessment including fire and explosion issues is prepared and finalized in consultation with Department of Explosives. Regular mock drills being conducted as per plan in order to address any eventuality in case of an accident.
vi	First Aid and sanitation arrangements shall be made for the drivers and other contract workers during construction phase.	Complied Adequate arrangements for first aid, health & safety, and sanitation for workers have been provided and compliance ensured.
vii	Noise levels from turbines in work zone shall be limited to 85 dB (A) from source. For people working in the high noise area, requisite personal protective equipment like earplugs/earmuffs etc. shall be provided. Workers engaged in noisy areas such as turbine area, air compressors etc. shall be periodically examined to maintain audiometric record and for treatment for any hearing loss including shifting to non-noisy/less noisy areas.	Complied Design specification for the equipments has been made to comply with the stipulations. Noise levels from turbines in work zone being maintained within prescribed limits of 85 dB (A) from source. Personal Protective Equipment (PPE's) are also being provided to personnel working in high noise areas. Workers of turbine generator area, compressor area and other high noise area being provided with appropriate ear protection devices. Periodic health examination of workers also being done.
viii	Regular monitoring of ambient air ground level concentration of SO_2, $N0_x$, $PM_{2.5}$ & PM_{10} and Hg shall be carried out in the impact zone of the project and record shall be maintained. In case these levels exceed the prescribed limits, necessary control measures shall be taken immediately. The location of the monitoring stations and frequency of monitoring shall be decided in consultation with SPCB. Monitoring reports shall be submitted to the Regional Office of this Ministry every six months. The data shall also be uploaded on the website of the company.	Complied Three nos. of CAAQMS stations have been installed at main-plant and township locations in consultation with MPPCB for regular monitoring of ambient air quality and record is maintained. Adequate control measures have also been ensured to control the exceedance if any. Additionally, one CAAQMS station is also installed at Khargone city as per directions from MPPCB. Regular monitoring of ambient air quality also carried out periodically through MOEF&CC accredited and NABL certified third party laboratory. Reports are regularly submitted to the Regional Office of MOEF&CC. Please refer Annexure-3 for ambient air quality reports for the reporting period. Online ambient air monitoring data also being uploaded on NTPC-Khargone Intranet webpage.
ix	Fly Ash generated shall be utilized 100% from the 4th year of operation of the power plant. Status of fly ash utilization	Complied Ash utilization plan has been prepared and all efforts are being made to achieve the targets

	shall be reported each year to the Regional Office of the Ministry.	in compliance to MOEF&CC, Fly ash Gazette Notification dated 03.11.2009, 31.12.2021 and its amendments, notifications thereafter. Annual compliance status of fly ash utilization being submitted regularly to the Regional office of MOEF&CC. Annual compliance report (ACR) of Ash Utilization for the FY 2023-24 already submitted along with Half-yearly compliance report dated 15.05.2024
x	Provision shall be made for the housing of construction labor (as applicable) within the site with all necessary infrastructures and facilities such as fuel for cooking, mobile toilets, mobile STP, safe drinking water, medical health care, crèche etc. The housing may be in the form of temporary structure to be removed after the completion of the project.	Compliance assured Labor colony with necessary infrastructure facilities had been provided for construction labor during construction phase and was kept under the scope of EPC contractor. Whereas NTPC ensures effective compliance of the said stipulations.
xi	The project proponent shall advertise in at least two local newspapers widely circulated in the region around the project, one of which shall be in the vernacular language of the locality concerned within seven days from the date of receipt of this clearance letter, informing that the project has been accorded environmental clearance and copies of clearance letter are available with the State Pollution Control Board/Committee and may also be see at Website of the Ministry of Environment and Forests at http://envfor.nic.in.	Complied The information of Environmental Clearance was published in two newspapers widely circulated in the region are- 1. Hindustan Times (English) on dated 04.04.2015. and 2. Nai-Dunia (Hindi) on dated 04.04.2015.
xii	A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zila Parisad/ Municipal Corporation, urban local body and the Local NGO, if any, from whom suggestions/representations, if any, received while processing the proposal. The clearance letter shall also be put on the website of the Company by the proponent.	Complied Copy of clearance letter were sent vide our letter dated 06.04.2015 to Sarpanch of village Panchayat of Selda & Dalchi village, CEO of Khargone Distt & CEO of Khargone Municipal Corporation. The Environmental Clearance is uploaded on the NTPC Ltd. website.
xiii	The proponent shall upload the status of compliance of the stipulated environmental clearance conditions, including results of monitored data on their website and shall update the same every six months. It shall simultaneously	Complied The latest status report of Compliance to the stipulated Environmental Clearance (EC) conditions is regularly uploaded on NTPC website. Compliance status report also submitted to the Regional Office of the

	be sent to the Regional Office of MOEF, the respective Zonal Office of CPCB and the SPCB.	MOEF&CC and offices of CPCB & MPPCB regularly at every six months.
v	The criteria pollutant levels namely; SPM, RSPM ($PM_{2.5}$ & PM_{10}), SO_2, NO_x (ambient levels as well as stack emissions) shall be displayed at a convenient location near the main gate of the company in the public domain.	Complied The criteria pollutant levels as prescribed, for ambient air as well as stack emissions are displayed at a convenient location near the main gate of the company in the public domain.
xv	The environment statement for each financial year ending 31st March in Form-V as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall be submitted by the project proponent to the concerned State Pollution Control Board. The same shall also be uploaded on the website of the company along with the status of compliance of environmental clearance conditions and shall also be sent to the respective Regional Offices of the Ministry by e-mail.	Complied Environment Statement for each financial year ending 31st March in Form-V has been regularly submitted to the M.P. Pollution Control Board & Regional Office of the MOEF&CC timely by September every year. Environmental Clearance along with annual environment statement is regularly updated on the NTPC website. Annual Environment Statement (Form-V) of the FY 2023-24 already submitted along with Half-yearly Compliance report dated 15.05.2024
xvi	The project proponent shall submit six monthly reports on the status of the implementations of the stipulated environmental safeguards to the Ministry of Environment and Forests, its Regional Office, Central Pollution Control Board and State Pollution Control Board. The project proponent shall upload the status of compliance of the environment of the environmental clearance conditions on their website and update the same every six months and simultaneously send the same by email to the Regional office, Ministry of Environment and Forests.	Complied Six monthly compliance status report of EC conditions regularly submitted to the Regional Office of MOEF&CC, CPCB & MPPCB. Reports are also uploaded on the NTPC website periodically.
xvii	Regional office of the Ministry of Environment & Forests will monitor the implementation of the stipulated conditions. A complete set of documents including Environmental Impact Assessment Report and Environment Management plan along with the additional information submitted from time to time shall be forwarded to the Regional Office for their use during monitoring.	Complied A complete set of documents including Environmental Impact Assessment (EIA) Report and Environment Management Plan (EMP) along with the additional information/clarifications was already submitted to Regional Office (Western Zone) of the MOEF&CC at Bhopal on 05.10.2015

xviii	The details of the funds along with item-wise break-up of Rs.1421.2 crores allocated for implementation of environmental protection measures shall be submitted to the Ministry. This cost shall be included as part of the project cost. The funds earmarked for the environment protection measures shall not be diverted for other purposes and year-wise expenditure shall be reported to the Ministry.	Compliance assured The requisite funds for environmental mitigation measures have been included in the project cost. Financial provision stipulated towards environmental mitigate measures shall not be diverted for other purposes.
xix	The project authorities shall inform the Regional Office as well as the Ministry regarding the date of financial closure and final approval of the project by the concerned authorities and the dates of start of land development work and commissioning of plant.	Complied Site leveling/ Land development work started on July 17th, 2015. Trial operation commissioning of Unit#1 (660 MW) achieved on 29/09/2019 and Commercial Date of Operation (COD) declared from 01/02/2020. Trial operation commissioning of Unit#2 (660 MW) achieved on 24/03/2020 and Commercial Date of Operation (COD) declared from 04/04/2020.
xx	Full cooperation shall be extended to the Scientists/officers from the Ministry / Regional Office of the Ministry/ CPCB /SPCB who would be monitoring the compliance of environmental status.	Noted

COMPLIANCE REPORT OF ADDITIONAL CONDITIONS

(EC Amendment vide MOEF&CC Letter Dated 22nd August 2019)

A	**MOEF & CC- Specific Conditions:**	**Status of Implementation**
1	While commissioning the proposed project, the compliance of revised emission norms vide Notification dated 07.12.2015 for the parameters PM: 30 mg/Nm3; S02: 100 mg/Nm3; NOx: 100 mg/Nm3 and Hg: 0.03 mg/Nm3 shall be achieved along with specific water consumption as per the notification vide dated 28.06.2018. The FGD System, NOx control measures such as SCR/ SCNR/ DeNOx burners shall be installed to achieve the revised emission norms.	Compliance assured NTPC-Khargone ensures compliance to all standards as stipulated in the revised emission norms vide referred MOEF&CC Notification dated 07.12.2015 and its amendments thereafter. Particulate Matter (PM) emissions from boiler stacks being controlled within prescribed new emission norms (30 mg/Nm3) FGD plants installed, commissioned & available for both Unit-1 & Unit-2 for SO2 emission control within prescribed new emission norms (100 mg/Nm3) Low NOx burners with Over Fire Air (OFA) combustion system also provided in both Units, for NOx emission control.

		Specific water consumption (SWC) being maintained within prescribed norms of 3.0 m3/mwhr as per the MOEF&CC notification dated 28.06.2018. SWC in the FY: 2024-25 for the reporting period is 2.84 m3/mwh. Whereas CPCB-Task Force vide his letter dtd. 13.12.2021, for the categorization of TPPs in line with MOEF&CC Notification dated 31/03/2021, has classified both units of NTPC-Khargone under Category-C. Accordingly, as per referred notification above, revised emission norms compliance shall be ensured by Dec'2024 for Category-C power plants including NTPC-Khargone. Whereas, as per MOEF&CC Notification dtd.05.09.2022, SO2 emissions timeline for compliance (Non-retiring units) is extended up to Dec'2026 for Category-C TPPs includes both units for NTPC-Khargone.
2	The status of installation of FGD and De-NOx/SCR/SNCR control systems to comply with new emission norms for both units shall be submitted.	Complied assured For SO2 emission control, installation of FGD plant package was awarded to M/s L&T for both units. Erection & Commissioning of FGD plants completed and available for both Units. Dates of Operation (ODe) for FGD: Unit-1 and FGD: Unit-2 are 25.05.2023 & 08.12.2023 respectively. Status of installation of FGD control system is regularly submitted to the Regional Office of the MOEF&CC at every six months along with Half-yearly EC compliance report. For NOx emission control, Low NOx Burners with Over Fire Air (OFA) combustion control system (air/fuel ratio optimization around the burner) is provided in both units. However, the matter for NOx emission compliance by TPPs commissioned after 2017 is under subjudice at Hon'ble Supreme Court.
3	The detailed progress report of construction of proposed project shall be submitted to the Ministry and its Regional Office along with six monthly compliance report till both units are commissioned.	Complied Both Unit#1 and Unit#2 were commissioned and under commercial operation from 01/02/2020 & 04/04/2020 respectively.
4	As per the Revised Tariff Policy notified of Ministry of Power issued vide dated 28.01.2016, project proponent shall	Noted & Compliance assured

	explore the use of treated sewage water from the Sewage Treatment Plant of Municipality/ local bodies/ similar organization located within 50 km radius of the proposed power project to minimize the water drawl from surface water bodies. The details of Sewage Treatment Plants located within 50 km radius along with the capacities shall be submitted.	
5	Daily quantity of (Average, minimum and maximum) fresh water withdrawn from Narmada River at Omkareshwar Dam for the plant purpose shall be submitted along with six monthly compliance report.	Noted & Compliance assured Please refer Annexure-6 for fresh water withdrawn data for the reporting period.
COMPLIANCE REPORT OF ADDITIONAL CONDITIONS *(EC Amendment vide MOEF&CC Letter Dated 22nd January 2022)*		
A	**MOEF & CC- Specific Conditions:**	**Status of Implementation**
i	24x7 online Continuous monitoring system for ambient air quality parameters SOx, NOx and PM shall be established with connected server to CPCB and SPCB.	Complied Realtime Continuous Ambient Air Quality Monitoring Stations (CAAQMS) have been installed. Further, 24x7 online connectivity of the same also provided up to the MPPCB and CPCB.

ANNEXURE-1

Reporting Format for Change in Coal Source

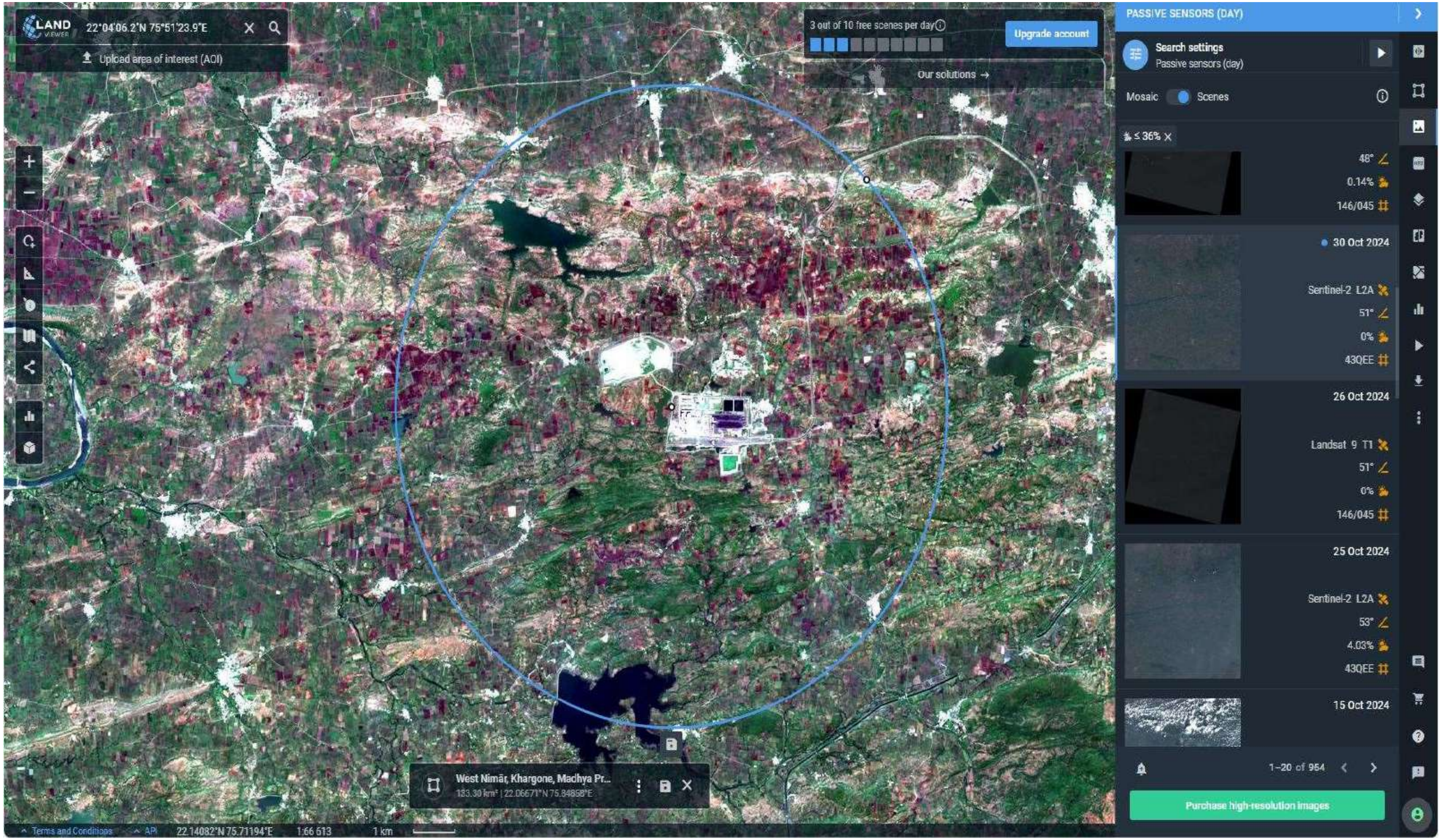
Name: Khargone Super Thermal Power Project (2x660 MW), NTPC Limited
Dates of EC & Amendments: EC Ref.-J- 13012/54/2010-IA. II (T) Dated 31.03.2015,
Amendment Dtd.22.08.2019 & 22.01.2022

Compliance Reporting Period: Apr’24 to Sep’24

S.No.	Description	Detials of Coal Source (As per EC)	Detials of Coal Source (As per FSA)	Change in Coal Source, if any
1	Coal Linkage Source (Coalfeild/Coalmine)	Pakri Barwadih	For U#1- MCL For U#2- WCL/SECL	For U#1- 17.01.2023 For U#2- 06.06.2024
2	Annual Contracted Quantity (MMT)	6.5 MMT	For U#1- MCL 3.33 MMT For U#2- WCL/SECL 2.62/2.82 MMT	
3	Distance of Coal Source from the Plant (Km)	1326 Km (Avg)	For U#1- MCL 1185 Km (Avg) For U#2- WCL/SECL 634 Km (Avg)/896Km(Avg)	
4	Mode of Trasportation (Rail/Road/Others)	Rail	Rail	
5	Total Quantity of Domestic Coal received during the period (MMT)		2.27 MMT	
6	Average Coal Quality of Domestic Coal Consumed during period:-			
a)	*Ash Content (%)*		43.9	
b)	*Sulphur (%)*		0.4	
c)	*Moisture (%)*		5.33	
d)	*Calorific Value (kcal/kg)*		3120	
7	% Blending of Imported Coal, if any and Averrage Coal Quality of Imported Coal Consumed:-		8.99%	
a)	*Ash Content (%)*		5.45	
b)	*Sulphur (%)*		0.44	
c)	*Moisture (%)*		5.99	
d)	*Calorific Value (kcal/kg)*		4924	

ANNEXURE-2 : Latest Satellite Image; 30.10.2024

NTPC Ltd, Khargone Super Thermal Power Station



ANNEXURE-3

Environment Monitoring Report

Industry: NTPC Ltd. Khargone Super Thermal Power Project
Period: April'2024 to September'2024
Laboratory M/s Hubert Enviro Care Systems Pvt. Ltd
(MOEF&CC Accredited and NABL Lab)/Online CEMS

Stack Emission Monitoring Report

For the period of Apr'24-Sep'24

Boiler-Stacks	Parameter	PM	SO2	NOx	Hg
	Unit	mg/Nm3	mg/Nm3	mg/Nm3	mg/Nm3
Unit-1	Avg	22	1370	327	<0.01
	Min	19	1241	311	<0.01
	Max	25	1615	353	<0.01
Unit-2	Avg	23	1379	331	<0.01
	Min	20	1282	288	<0.01
	Max	26	1491	373	<0.01

FGD-Stacks	Parameter	PM	SO2	NOx	Hg
	Unit	mg/Nm3	mg/Nm3	mg/Nm3	mg/Nm3
FGD-1: Unit-1	Avg	13	41	295	<0.01
	Min	12	30	254	<0.01
	Max	14	52	336	<0.01
FGD-2: Unit-2	Avg	11	15	293	<0.01
	Min	11	15	293	<0.01
	Max	11	15	293	<0.01

Ambient Air Monitoring Report

For the period of Apr'24-Sep'24

Location	Nr. Main Gate				
Parameter	S0x	NOx	PM10	PM2.5	CO
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	14.1	21.7	43.4	20.0	0.5
Min	9.3	18.4	35.4	16.8	0.4
Max	19.7	24.2	53.2	24.7	0.5
Location	Nr. DM Plant				
Parameter	S0x	NOx	PM10	PM2.5	CO
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	14.2	22.7	44.4	19.1	0.5
Min	9.0	20.4	37.0	12.7	0.4
Max	19.6	25.0	53.9	25.1	0.5
Location	At Township				
Parameter	S0x	NOx	PM10	PM2.5	CO
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	12.8	25.6	43.9	18.8	0.5
Min	8.8	17.9	30.9	13.1	0.4
Max	18.9	38.6	56.8	24.4	0.5
Location	At Selda Village				
Parameter	S0x	NOx	PM10	PM2.5	CO
Unit	ug/m3	ug/m3	ug/m3	ug/m3	mg/m3
Avg	10.7	22.2	37.9	17.9	0.5
Min	8.2	19.4	32.1	12.4	0.5

Max	13.2	27.0	45.3	21.8	0.5

Surface Water Analysis Report					
For the period of Apr'24-Sep'24					
Parameter	**Location**	**Vill.-Selda**	**Vill.-Dalchi**	**Vill.-Katora**	**Vill.-Jirbhar**
PH	_	7.62	7.63	7.82	7.69
TDS	mg/L	521	703	401	451
TSS	mg/L	24.0	25	5	8
BOD	mg/L	3.0	2	<2	<2
COD	mg/L	24.0	16	<4	<4
O&G	mg/L	<4	<4	<4	<4
Chlorides	mg/L	94.0	108.9	64.3	74.2
Sulphates	mg/L	23.3	44.4	41.3	66.5
Ca	mg/L	88.2	104.2	68.1	72.1
Mg	mg/L	51.0	58.3	34.0	38.9
Cd	mg/L	<0.001	<0.001	<0.001	<0.001
As	mg/L	<0.005	<0.005	<0.005	<0.005
Hg	mg/L	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	<0.005	<0.005	<0.005	<0.005

Ground Water Analysis Report					
For the period of Apr'24-Sep'24					
Parameter	**Location**	**Vill.-Dalchi (Nr. Ash Dyke)**	**Vill.-Selda**	**Vill.-Khedi**	**Vill.-Aarsi**
PH	_	7.7	7.8	7.7	7.9
TDS	mg/L	359	537	705	448
COD	mg/L	<4	<4	<4	<4
Chlorides	mg/L	49.5	103.9	138.6	84.1
Sulphates	mg/L	91.6	122.5	102.5	46.3
Ca	mg/L	44.1	64.1	100.2	56.1
Mg	mg/L	21.9	34.0	60.8	31.6
Cd	mg/L	<0.001	<0.001	<0.001	<0.001
As	mg/L	<0.005	<0.005	<0.005	<0.005
Hg	mg/L	<0.005	<0.005	<0.005	<0.005
Pb	mg/L	<0.005	<0.005	<0.005	<0.005

Ash Effluent Water Analysis Report					
For the period of Apr'24-Sep'24					
Parameter	**Unit**	**Avg**	**Min**	**Max**	
PH		7.5	7.2	7.9	
TDS	mg/L	830	759	874	
TSS	mg/L	14.0	11.0	18.0	
As	mg/L	<0.005	<0.005	<0.005	
Hg	mg/L	<0.01	<0.01	<0.01	
Cr	mg/L	<0.01	<0.01	<0.01	
Pb	mg/L	<0.1	<0.1	<0.1	
Cd	mg/L	<0.01	<0.01	<0.01	

Bottom Ash Analysis Report-Heavy Metals		
For the period of Apr'24-Sep'24		
Parameter	**Unit**	**Result**
Pb	mg/L	<0.1
Cr-T	mg/L	0.31

Cu	mg/L	<0.1	
Zn	mg/L	<0.1	
Ni	mg/L	<0.1	
As	mg/L	<0.1	
Hg	mg/L	<0.1	
Cd	mg/L	<0.1	
Mg	mg/L	<0.1	
Co	mg/L	<0.1	

Coal Analysis Report-Heavy Metals			
For the period of Apr'24-Sep'24			
Parameter	**Unit**	**Result**	
Pb	mg/kg	19.6	
Cr-T	mg/kg	8.4	
Cu	mg/kg	102.4	
Zn	mg/kg	46.4	
Ni	mg/kg	9.6	
As	mg/kg	0.3	
Hg	mg/kg	0.10	
Co	mg/kg	1.7	

Draft Final Report – 2nd year

Review of Hydrogeology to Assess Impact of NTPC Khargone on Surface and Ground Regime (Especially around Ash Dyke) and Propose Specific Mitigation Measures

(After completion and incorporation of Pre and Post-monsoon analysis for 2023 and pre-monsoon analysis for 2024)

Submitted to

NTPC Khargone Super Thermal Power Station

Village: Selda & Dalchi, Tehsil: Badwah, District: Khargone, Madhya Pradesh

Submitted by

Prof. Manoj Kumar Jain (PI)

Prof. Brijesh Kumar Yadav (Co-PI)

DEPARTMENT OF HYDROLOGY

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

ROORKEE (UTTARAKHAND), INDIA

SEPTEMBER 2024

Title	Review of Hydrogeology to Assess Impact of NTPC Khargone on Surface water and Ground Regime (Especially around Ash Dyke) and Propose Specific Mitigation Measures. A study conducted by Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee – 247667 (Uttarakhand)
Client	NTPC Limited
Disclaimer	While every opportunity has been taken to ensure the accuracy of the material presented in this document, IIT-Roorkee cannot be held responsible for errors or omissions but reserve the right to provide further clarification or consultation. The opinion contained in this report is our personal, professional opinion and should not be considered as the opinion of IIT Roorkee.
Document No.	HYD-6009/22-23/D-IR2
NTPC PO No.	4000294217-037-1019
Consultants	Prof. Manoj Kumar Jain, Department of Hydrology Prof. Brijesh K. Yadav, Department of Hydrology Indian Institute of Technology, Roorkee, Uttarakhand 247667, India
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Date	3 September 2024

EXECUTIVE SUMMARY

The study team from the Department of Hydrology, IIT Roorkee visited the NTPC Khargone, and its nearby areas along with the required instruments during April 25 – 30, 2023, October 9 – 13, 2023 and May 5 – 9, 2024, to undertake a survey of the power station area, ash dyke and other surrounding areas of the power station. The team identified relevant observation points in all directions for sample collection of surface and groundwater resources. Water samples were collected from the identified existing open wells, handpumps, tube wells, piezometers, ponds, reservoirs, rivers within a 10 km radius and ash dyke, NTPC station area, surface water reservoirs etc. The depth of the groundwater table was also measured using the existing open wells and piezometers available in and around the power station boundary. Some water quality parameters were measured in-situ during the field visit, and the remaining were analysed in the laboratories of the Department of Hydrology and Institute instrumentation centre (IIC) of IIT Roorkee. A summary of the field survey and a detailed analysis of collected data for the pre-and post-monsoon 2023 seasons, and pre-monsoon 2024 season are presented in this draft final report for the second year.

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1 INTRODUCTION AND OBJECTIVES OF THE STUDY

NTPC Limited is operating Khargone Super Thermal Power Station (KhSTPS) of capacity 1320 MW (2x660 MW), near villages Selda and Dalchi in Sanawad Tehsil of Khargone District of Madhya Pradesh to meet the power demand of Western Region states like MP, Gujrat, Chhattisgarh, Maharashtra, Goa and daman & Diu. It is a coal based thermal power station based on environment friendly Ultra Supercritical Technology.

The coal requirement of 6.6 MTPA for the power station is brought from the CIL Subsidiaries, SECL, NCL & NTPC Captive mines through a railway line.

The makeup water requirement for the power station is about 3700 cum/hr with an ash water recirculation system. The water requirement is being met from the Omkareshwar dam, located at a distance of about 45 km from the power station. The Govt. of Madhya Pradesh has accorded a commitment for 40 MCM of water from the Narmada River for the project.

The major objective of this power project is power supply improvement in Madhya Pradesh State. 50% of the power generated from the station has been allocated to Madhya Pradesh State, 16.5% to Maharastra, 13.3% to Gujarat, 4% to Chhattisgarh, 0.7 % to Goa, DD & DNH. 15% of power is kept as unallocated at the disposal of the Government of India (GoI) to meet short-term emergencies, deficits of beneficiary states and allocation to other willing states of Western Region. This is subject to the approval of GoI.

The Khargone Super Thermal Power Station (KhSTPS) is located at a distance of about 105 Kms from Indore, about 30 Kms from Sanawad town, about 42 km from Barwah and at a distance of about 15 km from Bedia (on Sanawad-Khargone Road).

Khargone city is about 40 km from the project site. The KhSTPS is approachable from Sanawad on Indore – Khandwa State Highway through the PWD road. The nearest Railway Station is Sanawad on Indore – Khandwa which is about 32 Km. Khandwa is on the main line of the Central Railway on the Mumbai-Itarsi section. The Airport at Indore is located about 105 km from the study site.

Narmada River is passing at about 15 Km (North) from the project site. The KhSTPS is located geographically at (Lat 22°04'06.6" N; Long 75°51'18.4" E) on Survey of India (SoI) toposheet No. 46N/16.

The specific condition no. (xiii) under Environmental Clearance (EC) accorded by The Ministry of Environment, Forest and Climate Change (MoEF&CC) vide letter Ref. No. J-13012/54/2010-IA.II(T), dtd. 31/03/2015 stipulates, "Hydrogeology of the area shall be reviewed annually through an institute/organisation of repute to assess the impact of surface water and groundwater (especially around ash dyke). In case, any deterioration is observed, specific mitigation measures shall be undertaken immediately. Reports/data of water quality shall be submitted to the Regional Office of the Ministry every six months. "In view of the above, NTPC issued an NIT No. NTPC/USSC-CPG2/9900248178 dated 15.10.2022 for Review of hydrogeology to assessment to assess impact of NTPC-Khargone on surface water and ground regime (especially around ash dyke). The Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee participated in the tender process and the consultancy was successfully awarded to IITR by NTPC Khargone vide PO No. 4000294217-037-1019.

1.1 ***Objectives***

The objectives of the study shall be as follows:

a. To assess and review the impact of Khargone STPS (2x660 MW) on soil, surface water and groundwater regime (especially around the ash dyke).
b. To suggest mitigation measures for remediation of surface water and groundwater regime, if any.

1.2 ***Extent & Scope of the Study***

The geographical extent of the study area shall consist of an area within 10 km from the periphery of the project components (Main plant, Ash Pond area & Township). In addition, the source of water, location of the intake point, and type of intake structures (barrage, dam, intake well, intake channel etc.) shall also be covered in the study, even if located beyond 10 km and significant for identification of the impact due to NTPC Khargone. Further, any significant surface or groundwater body located within 10-15 Km which is likely to influence the project/get influenced from the project shall also be covered.

The scope of the project will be as follows.

1.2.1 Literature Review

The consultant has to undertake a detailed literature search for the documents/ reports already available for the study area with various agencies such as the Geological Survey of India, the State Department of Geology and Mining, Central and State Water Boards, State Water Resources/Irrigation departments, Central Water Commission, India Meteorological Department etc. Based on the review of the literature available, the consultant shall make a detailed plan for the study covering all the objectives.

1.2.2 Field Studies

1.2.2.1 Hydro-geological investigations

i. Preparation of groundwater flow direction map in Pre-monsoon and post-monsoon periods.
ii. Analysis of soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, CO_3, HCO_3, Cl, SO_4, NO_3, F^-, and PO_4), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) at 10 selected locations at surface, 30 cm and 60 cm depth.

1.2.2.2 Surface water quality monitoring around the Ash-pond

i. Water quality parameters like pH, EC, DO, BOD, COD, major cations (Na, K, Ca, Mg, and Fe etc.), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F^-, and PO_4 etc.) and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) during Pre and Post monsoon seasons at 16 locations (including water bodies i.e. streams and ponds especially near ash pond, water bodies within 10 km, samples from ash ponds and raw water reservoir).

1.2.2.3 Groundwater monitoring network around the Ash-pond

(To check leachability from ash pond):

i. Design of the groundwater level and quality observation network.

ii. Regular monitoring of groundwater level shall be carried out in network of existing wells and piezometers in the vicinity of the ash pond for Pre-monsoon and post-monsoon. Water table monitoring and depletion status in and around the project area.

iii. Water quality parameters like, pH, EC, TDS, DO, Major cations (Na, K, Ca, Mg, and Fe etc.), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F^-, and PO_4.), heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.) and isotope monitoring during Pre & Post monsoon seasons at 16 locations (including 6 piezometers and 10 existing hand pumps and/or bore wells).

2 DESCRIPTION OF THE STUDY AREA

2.1 General

Khargone Super Thermal Power Station (KhSTPS) is a coal-based thermal power project located at villages Selda and Dalchi in the Khargone district of Madhya Pradesh. It is the country's first ultra-supercritical thermal power project generating 1.32GW power using 2X660MW ultra-supercritical coal-fired units. It is the first ultra-supercritical coal-fired unit in the country built on engineering, procurement, and construction (EPC) basis. The project received environmental clearance in March 2015, while site preparation works were started in July 2015. NTPC commissioned the first 660MW unit of the Khargone power station in August 2019, and the second unit of similar capacity was commissioned in April 2020.

The total quantum of land acquired for the power station, ash dyke and township is 428.899 Hectares (1059.498 Acres), comprising of 317.19 Hectares (783.7904 Acres) of private land and 111.709 Hectares (276.039 Acres) Govt. land and is in NTPC possession. In addition, land of about 115 Hectares (about 284 acres) has been acquired for the makeup water pipeline corridor.

While developing the details of water system for the project, utmost care has been taken to minimise water requirement as well as effluent generation. The main features of the water system shall include: (i) Re-circulating type C.W. system with cooling towers / Open System complying with MOEF requirements. (ii) In case of Cooling Towers, utilisation of Cooling Tower blow down for Coal dust suppression and extraction system, Service water system, Ash handling and Firefighting. (iii) Recycle and reuse of effluents from coal dust suppression and extraction system and service water system. (iv) Ash water recirculation system, and (v) Recirculation of filter backwash to clarifier inlet. An effluent management scheme consisting of collection, treatment, recirculation, and disposal of effluents has been implemented in order to optimise the makeup water requirement as well as liquid effluent generation.

2.2 *Location and Extent of Study Area*

The study area for this study consists of an area within 10 km of distance from the periphery of the power station, ash pond, and township. In addition, the source of water and location of the intake point, type of intake structures (barrage, dam, intake well, intake channel etc.) shall also be covered for the study, even if located beyond 10 km and significant for identification of the impact due to NTPC Khargone. Further, any significant surface or groundwater body located within 10-15 km which is likely to influence the project/get influenced from the project shall also be covered. The index map showing the location of the NTPC Khargone power station is depicted in Figure 1. An image showing the NTPC Khargone power station is shown in Figure 2, and the 10 km radius from the NTPC power station marked on a topographic map is shown in Figure 3.

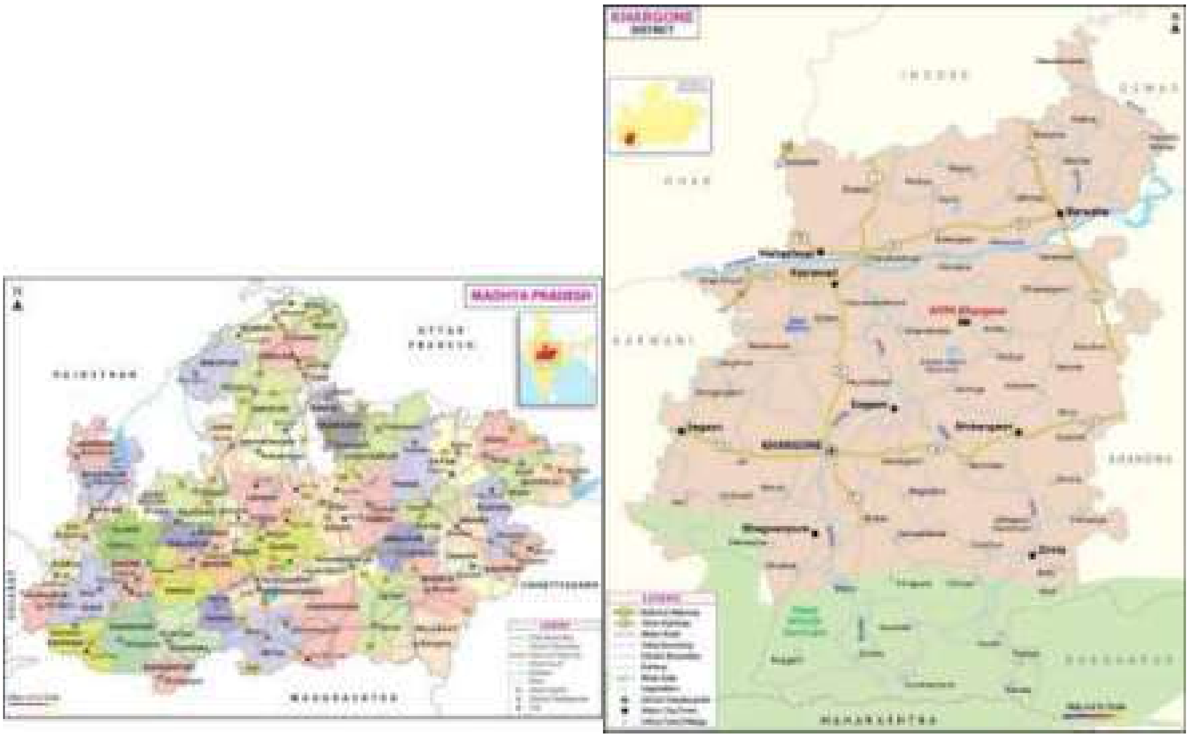

Figure 1. Index map showing location of NTPC Khargone STPP.

Figure 2. Image showing NTPC Khargone Super Thermal Power Station

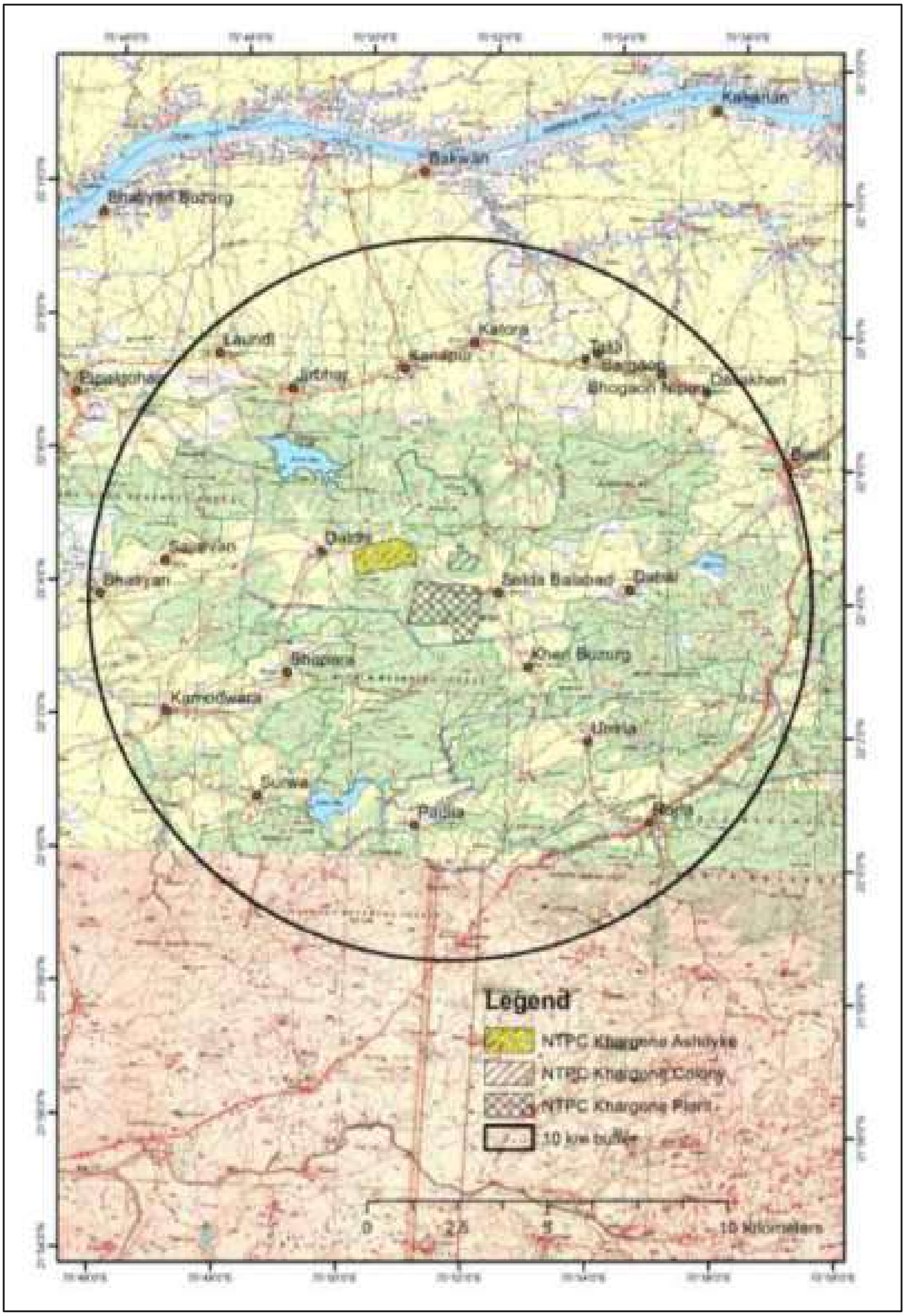

Figure 3. The boundary of NTPC Khargone Super Thermal Power Station along with a 10 km buffer marked on Survey of India toposheets.

2.3 *Topography of the Study Area*

The general topography of the study area was studied using the Survey of India toposheets 46O/13 & 46N/16, shown in Figure 3 and 1 arc second SRTM Digital Elevation Model (DEM) obtained from the Earth Explorer Website (https://earthexplorer.usgs.gov/). The DEM was processed in ArcGIS 10.8. The DEM of the study area is shown in Figure 4. The topography of the area is fairly undulating. The maximum and minimum elevation ranges between 240 and 260 m above mean sea level (amsl). The project area is a part of North Khargone tehsil, District Khargone, MP, which lies on the Deccan Plateau and has an average altitude of 250 m. The general slope of the area is towards the northwest. The general gradient of the area is towards NNW. The slope map of the study area is shown in Figure 5, which clearly shows the undulating topography of the area.

2.4 *Drainage of the Study Area*

The drainage map of the study area has been prepared using SRTM DEM, shown in Figure 4. The DEM was processed in ArcGIS 10.8 to generate the drainage map of the study area. The generated drainage map of the area is shown in Figure 6. In general, the drainage pattern of the study area is dendritic in nature. The Narmada River flows about 11.5 km in the North direction from the power station area. The Vamsali and Ambak Rivers, both tributaries of the Narmada River, mainly drain the area. The flow pattern in the 10 km circle of the study area is seen to have two distinct patterns. One flows towards the eastern side and the other towards the western side. The NTPC power station is located in the watershed draining towards the eastern watershed, while the ash dyke is located in the watershed draining towards the western side. Few water bodies could also be seen in the study area, mostly used for agricultural purposes by local farmers.

2.5 *Soil and Vegetation*

Generally, there are five types of soils, namely Kali I, (0-1 metre below ground level (mbgl)) and Kali II (1-2 mbgl) (2-3 mbgl) Halkikhardri and Bardi. These soils are classified as medium black cotton soils containing 50% silt and clay together. Alluvial soil is found on both sides of the river Narmada and has some patches along its tributaries.

The study area has sparse vegetation, mainly open scrub type. The land area around the NTPC Khargone project does not have dense vegetation cover. Various kinds of trees, herbs, shrubs, climbers and grasses surround the area near the project.

*2.6 **Land use / Land Cover***

The Main Land use pattern of the district comprises agricultural land, Forest, Fallow and settlement. Most part of the surrounding area of the project is covered by agricultural land, supporting single to multi crop pattern.

Broadly, the various land uses of the study area could be grouped under five categories, namely, Agricultural land (51.6%), Forest (27.7%), Settlement (2.3%), Waterbodies (3.6%), and barren land (14.8%).

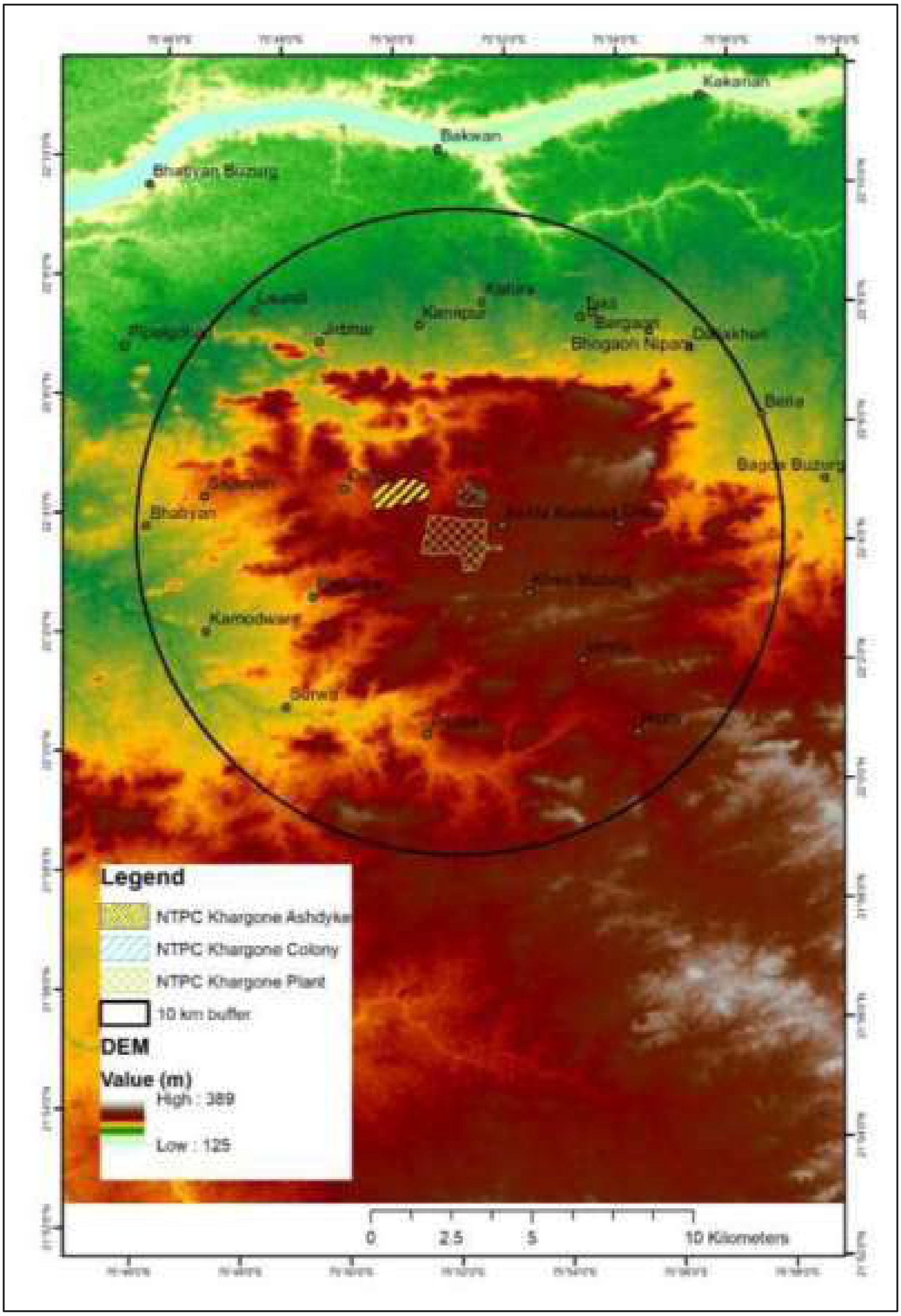

Figure 4. DEM of the Study Area

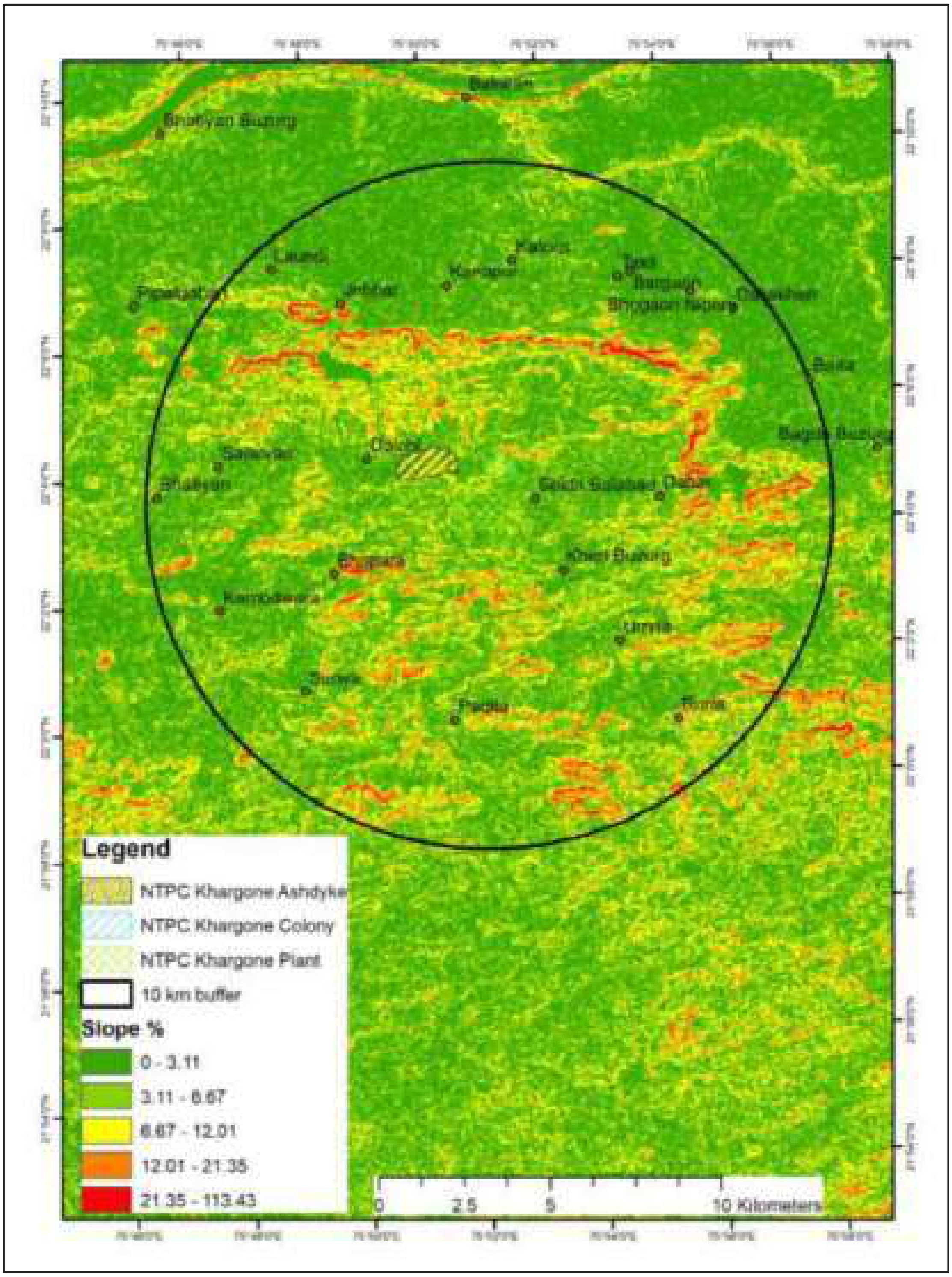

Figure 5. Slope map of the study area.

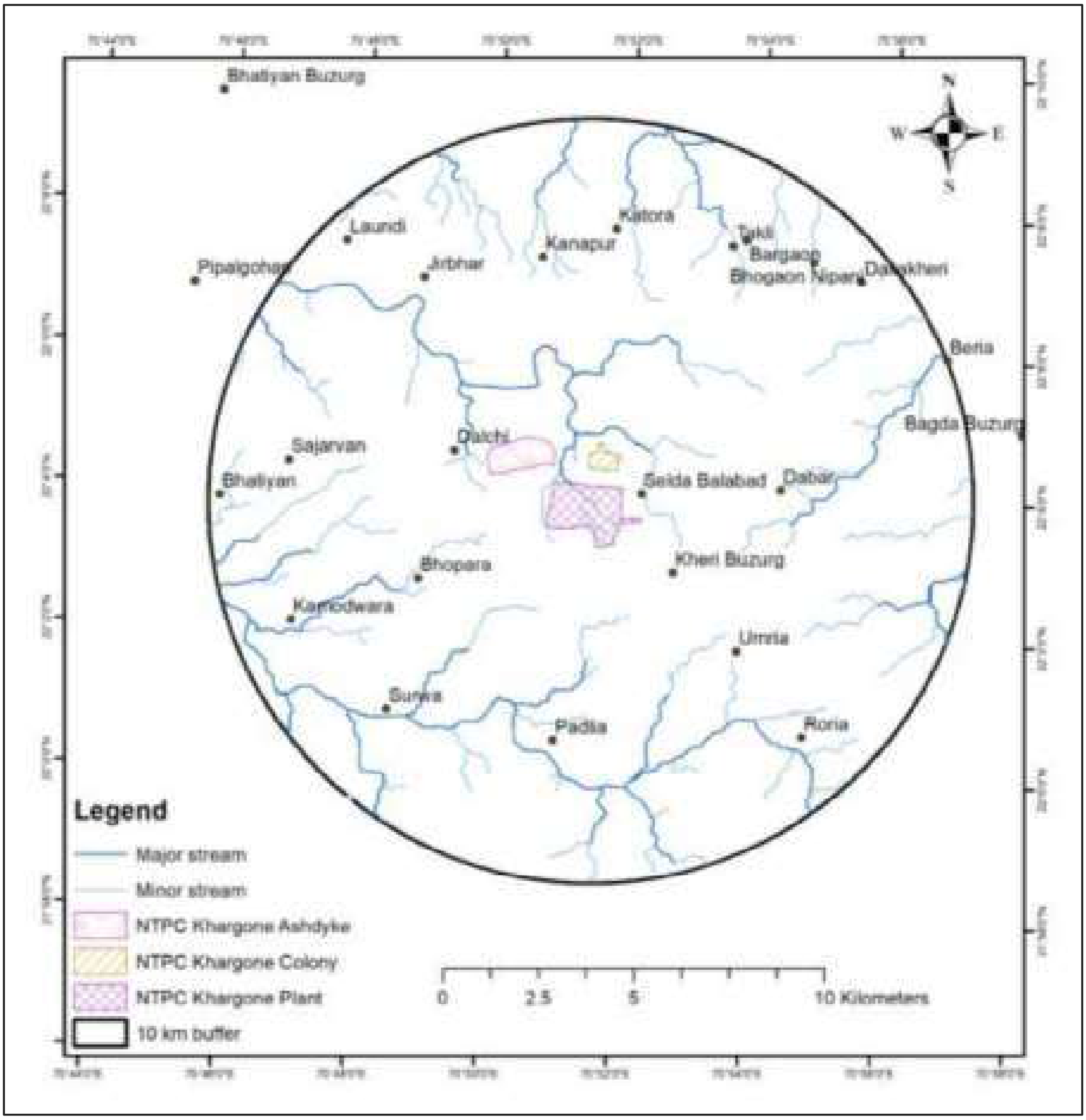

Figure 6. Drainage map of the study area.

3 RECONNAISANCE SURVEY

A field visit to the NTPC Khargone was undertaken by Professor of IIT Roorkee during February 2023. A reconnaissance survey of the study area was undertaken during this visit. A meeting was also held with officials of NTPC to discuss the fieldwork, proposed methodology and upcoming pre-monsoon visit. Some photographs of the reconnaissance field visit are shown in Figure 7.

Figure 7. Some field photographs of reconnaissance survey during February 2023

4 FIELD INVESTIGATIONS

4.1 Pre-monsoon 2023 field investigations

A site visit was undertaken for pre-monsoon sampling and field investigations by the IIT Roorkee team during April 25 – 30, 2023. During this field visit, the following field works were undertaken.

i. Surface water sampling from 12 locations of surface water, including samples from various sources such as river water, lagoons, raw water reservoirs and ponds/lakes for studying surface water quality.
ii. Ground water sampling from 18 locations, including samples from various sources such as hand pumps, tube wells, open wells, and seepage nalah.
iii. Ground water levels monitoring at 16 locations, including hand pumps, tube wells, and open wells.
iv. Collection of soil samples from 11 locations.
v. In-situ determination of latitude, longitude, and elevation (altitude) for the various sampling locations.
vi. Site photograph during sampling. The site photographs are provided in Appendix-I.

4.2 Post-monsoon 2023 field investigations

A site visit was undertaken for post-monsoon 2023 sampling and field investigations by the IIT Roorkee team during October 9 – 13, 2023. During this field visit, the following field works were undertaken.

vii. Surface water sampling from 12 locations of surface water, including samples from various sources such as river water, lagoons, raw water reservoirs and ponds/lakes for studying surface water quality.
viii. Ground water sampling from 18 locations, including samples from various sources such as hand pumps, tube wells, open wells, and seepage nalah.
ix. Ground water levels monitoring at 16 locations, including hand pumps, tube wells, and open wells.

x. Collection of soil samples from 11 locations.

xi. In-situ determination of latitude, longitude, and elevation (altitude) for the various sampling locations.

xii. Site photograph during sampling. The site photographs are provided in the Appendix-I.

4.3 Pre-monsoon 2024 field investigations

A site visit was undertaken for pre-monsoon 2024 sampling and field investigations by the IIT Roorkee team during May 5 – 9, 2024. During this field visit, the following field works were undertaken.

xiii. Surface water sampling from 12 locations of surface water, including samples from various sources such as river water, lagoons, raw water reservoirs and ponds/lakes for studying surface water quality.

xiv. Groundwater sampling from 18 locations, including samples from various sources such as hand pumps, tube wells, open wells, and seepage nalah.

xv. Groundwater level monitoring at 16 locations, including hand pumps, tube wells, and open wells.

xvi. Collection of soil samples from 11 locations.

xvii. In-situ determination of latitude, longitude, and elevation (altitude) for the various sampling locations.

xviii. Site photograph during sampling. The site photographs are provided in Appendix-I.

5 GROUNDWATER LEVEL AND FLOW DIRECTION

The groundwater level is a key parameter for evaluating spatial and temporal changes in groundwater environments. The groundwater level is governed by various factors. Any phenomenon that produces pressure change within an aquifer result in the change of groundwater level. These changes in groundwater level can be a result of changes in storage, amount of discharge and recharge, variation of stream stages and evaporation. To define the present hydro-geological scenario of the study area, the groundwater table is measured directly at various locations available within the study area to prepare the water table contour and flow direction maps.

5.1 Groundwater level observations during Pre-Monsoon 2023 season

In the present study, groundwater level monitoring for the pre-monsoon season of 2023 was carried out during April 25 – 30, 2023, at 20 locations in existing open/tube wells and piezometers. Figure 9 provides the location map of the groundwater level monitoring stations used for measuring water levels during the pre-monsoon 2023 visit. The details of the monitoring stations are provided in Table 1.

Table 1. Details of groundwater level monitoring stations during pre-monsoon of 2023.

S.No.	Site Code	Latitude (˚E)	Longitude (˚N)	Location and source	Ground Elevation (m amsl)
1	KHR-5	22.12494	75.8952	Inside Primary School, Vill Badgaon, Handpump	192
2	KHR-5A	22.12407	75.89518	Adjacent to main road, Vill Badgaon, open well	190
3	KHR-7A	22.12314	75.7963	Londhi village, open well	189
4	KHR-7B	22.12126	75.79317	Londhi village, open well	192
5	KHR-13	22.06608	75.87139	Adjoining of NTPC Community Centre Near New Hanumaan Temple, open well	263
6	KHR-15A	22.07092	75.85599	Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well	247
7	KHR-16A	22.07912	75.80412	Adjacent to Gangour thermal power station road	238
8	KHR-18	22.06295	75.85256	Well inside power station, open well	249
9	KHR-20A	22.0833	75.8515	Maal Singh Jhapdiya Well, Jamniya village, open well	231
10	KHR-21 (N1)	22.12321	75.90812	Adjacent to pipalgone road, open well	198
11	KHR-22 (N2)	22.11305	75.92877	Adjacent to pipalgone road, open well	206
12	KHR-23 (N3)	22.10902	75.93549	Adjacent to pipalgone road, open well	198
13	KHR-24 (N4)	22.04485	75.87855	Adjacent to Umaria road, open well	273
14	KHR-26 (N6)	21.99242	75.86363	in the field adjacent to Padaliya road, open well	228
15	KHR-Pz1	22.07826	75.8367	Peizometer 1, Ash Dyke	241

16	KHR-Pz2	22.07721	75.83306	Peizometer 2, Ash Dyke	239
17	KHR-Pz3	22.07476	75.83177	Peizometer 3, Ash Dyke	234
18	KHR-Pz4	22.07289	75.83233	Peizometer 4, Ash Dyke	230
19	KHR-Pz5	22.07055	75.83277	Peizometer 5, Ash Dyke	236
20	KHR-Pz6	22.07089	75.83548	Peizometer 6, Ash Dyke	238

The water level below the ground surface was measured using a dip-meter with a water level indicator. DGPS Survey was carried out in the earlier study by NIH at most of these locations, and based on the DGPS data, elevation of the location was determined. The elevation data was used to determine the water level elevation above the mean sea level (amsl). The water level data (both below the ground level and above mean sea level) is presented in Table 2. The spatial variation of water depth below the ground surface is also shown in Figure 8.

The measured depth to the groundwater table has been used as a base parameter to delineate the groundwater flow pattern in and around the NTPC power station. The groundwater contour map (Figure 9) was prepared by using measured water table depth data listed in Table 2 pre-monsoon 2023 season. Figure 9 was produced using the feature of ArcMap in which vector field rendering (arrow representation) was performed for better visualisation of flow direction. The thinning method uses a vector averaging procedure to calculate the direction and magnitude for each pixel to generate the flow map. Figure 9 suggests that the groundwater generally flows in two distinct patterns. The groundwater flow in the area to the north of the power station flows northwards towards Narmada River, and the groundwater in the area to the southern side of the power station flows towards south and southwest direction. A slight variation in the movement of groundwater around the power station site seems to be due to a dense network of measuring wells. Secondary porosities like weathering, fracturing, faulting, and other lineaments in the study area can also cause such flow variations. The groundwater table contour map of the area is found mostly in line with its surface drainage pattern.

Table 2. Measured groundwater level at identified locations in the area during the pre-monsoon season (April 2023).

S.No.	Site Code	Latitude (˚E)	Longitude (˚N)	Location and source	Depth to water table (m)	Water Table Elevation (m amsl)
1	KHR-5	22.12494	75.8952	Vill Badgaon, Handpump	2.2	189.8
2	KHR-5A	22.12407	75.89518	Adjacent to main road, Vill Badgaon, open well	3.6	186.4
3	KHR-7A	22.12314	75.7963	Londhi village, open well	6.6	182.4
4	KHR-7B	22.12126	75.79317	Londhi village, open well	6.78	185.22
5	KHR-13	22.06608	75.87139	Adjoining of NTPC Community Centre Near New Hanumaan Temple, open well	7.9	255.1
6	KHR-15A	22.07092	75.85599	Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well	1.55	245.45
7	KHR-16A	22.07912	75.80412	Adjacent to Gangour thermal power station road	12.4	225.6
8	KHR-18	22.06295	75.85256	Well inside power station, open well	4.56	244.44
9	KHR-20A	22.0833	75.8515	Maal Singh Jhapdiya Well, Jamniya village, open well	1.5	229.5
10	KHR-21 (N1)	22.12321	75.90812	Adjacent to pipalgone road, open well	5.2	192.8
11	KHR-22 (N2)	22.11305	75.92877	Adjacent to pipalgone road, open well	5.4	200.6
12	KHR-23 (N3)	22.10902	75.93549	Adjacent to pipalgone road, open well	2.3	195.7
13	KHR-24 (N4)	22.04485	75.87855	Adjacent to Umaria road, open well	9	264
14	KHR-26 (N6)	21.99242	75.86363	in the field adjacent to Padaliya road, open well	2.9	225.1
15	KHR-Pz1	22.07826	75.8367	Peizometer 1, Ash Dyke	2.7	238.3
16	KHR-Pz2	22.07721	75.83306	Peizometer 2, Ash Dyke	12.33	226.67
17	KHR-Pz3	22.07476	75.83177	Peizometer 3, Ash Dyke	3.3	230.7
18	KHR-Pz4	22.07289	75.83233	Peizometer 4, Ash Dyke	3.5	226.5
19	KHR-Pz5	22.07055	75.83277	Peizometer 5, Ash Dyke	9.4	226.6
20	KHR-Pz6	22.07089	75.83548	Peizometer 6, Ash Dyke	9.5	228.5

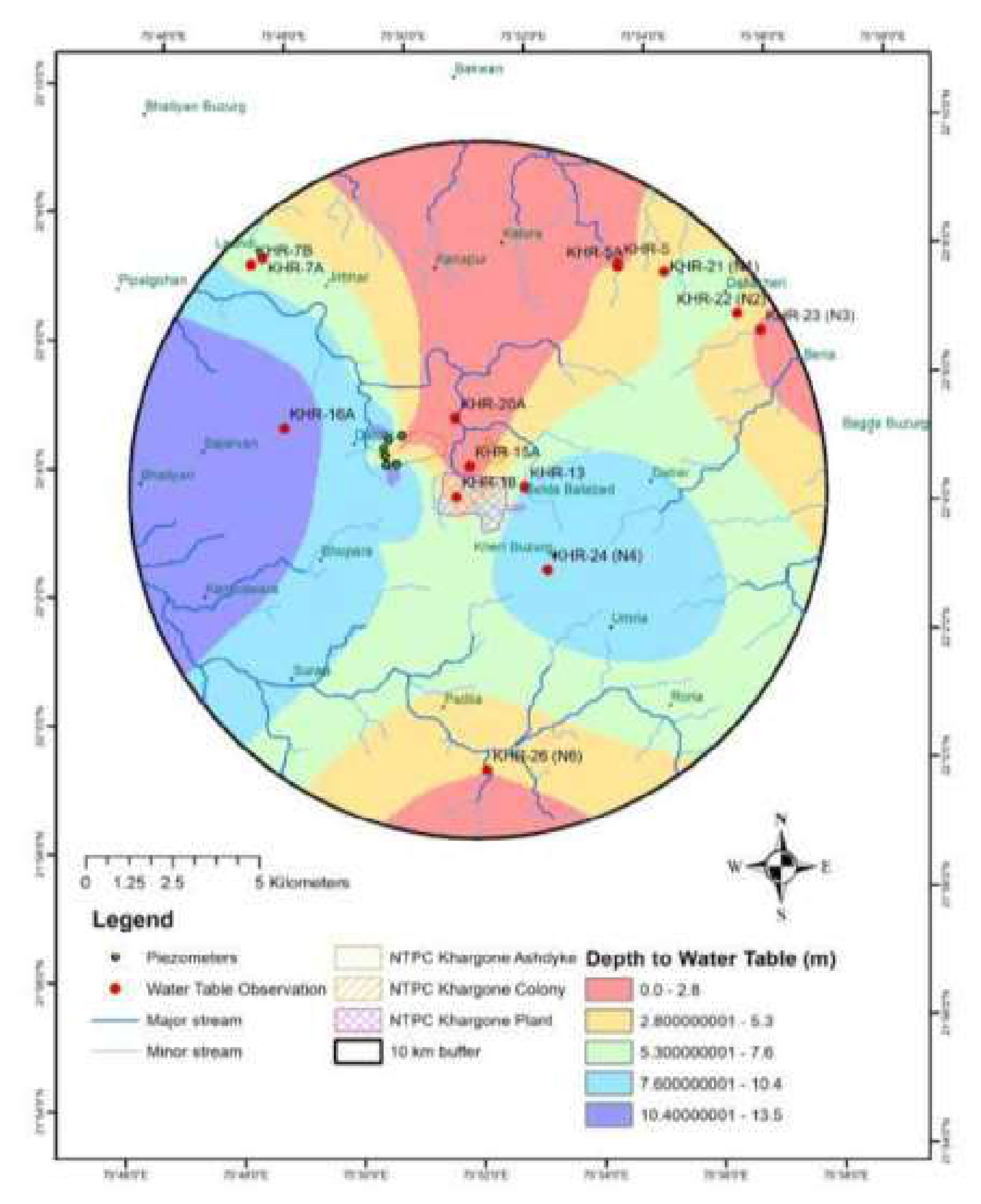

Figure 8. Map showing spatial variation of water table depth below ground level for pre-monsoon 2023 season.

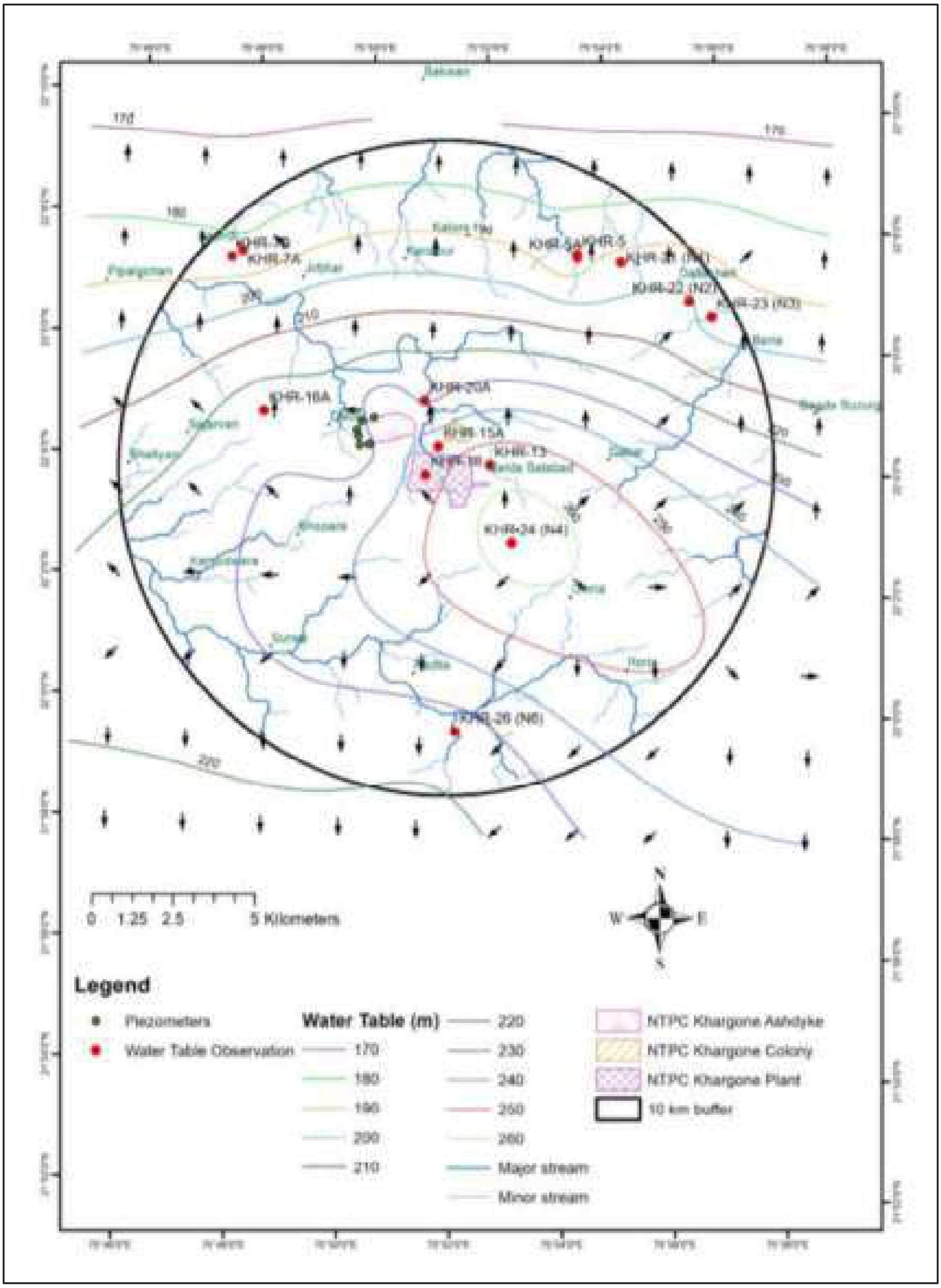

Figure 9. Map depicting ground water table contours and flow direction in the study area during Pre-monsoon 2023.

5.2 *Groundwater level observations during the post-monsoon 2023 season*

The groundwater level monitoring for the post-monsoon season of 2023 was carried out during October 9-13, 2023, at 29 locations using existing open/tube wells and piezometers. Two of the existing open wells (KHR-15 and KHR-61AE) were skipped during this post-monsoon season due to an unforeseen situation at the sampling time. Figure 10 provides the location map of the groundwater level monitoring stations used for measuring water levels during the post-monsoon 2023 visit. The details of the monitoring stations are provided in Table 3.

Table 3. Details of groundwater level monitoring stations during the post-monsoon 2023 season.

S.No.	Site Code	Latitude (˚E)	Longitude (˚N)	Location and source	Elevation
1	KHR-4	22.068803	75.862023	Between NTPC & Town ship, opposite to Boundary Pillar S.N. 230-240	254
2	KHR-5	22.12494	75.8952	Vill Badgaon, Handpump	192
3	KHR-5A	22.12407	75.89518	Adjacent to main road, Vill Badgaon, open well	190
4	KHR-6A	22.12545	75.84165	Well in the field, Vill Kanapur	188
5	KHR-7A	22.12314	75.7963	Londhi village, open well	189
6	KHR-7B	22.12126	75.79317	Londhi village, open well	192
7	KHR-8A	22.10271	75.75548	Karan Gangle Handpump, Pipalgone village.	185
8	KHR-10A	22.04086	75.81116	Near Anganwadi Kendra, Bhopada	219
9	KHR-13	22.06608	75.87139	Adjoining of NTPC Community Centre Near New Hanumaan Temple, open well	Discarded
10	KHR-15A	22.07092	75.85599	Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well	247
11	KHR-16A	22.07912	75.80412	Adjacent to Gangour thermal power station road	Discarded
12	KHR-18	22.06295	75.85256	Well inside power station, open well	249
13	KHR-20A	22.0833	75.8515	Maal Singh Jhapdiya Well, Jamniya village, open well	231
14	KHR-21	22.12321	75.90812	Adjacent to pipalgone road, open well	198
15	KHR-22	22.11305	75.92877	Adjacent to pipalgone road, open well	206
16	KHR-23	22.10902	75.93549	Adjacent to pipalgone road, open well	198
17	KHR-24	22.04485	75.87855	Adjacent to Umaria road, open well	273

18	KHR-25	22.02839	75.89527	In front of Rewa Gurjar Dharamshala, Gram panchayat office, Umaria	251
19	KHR-26	21.99242	75.86363	In the field adjacent to Padaliya road, open well	228
20	KHR-27	22.00855	75.90918	Rodiya Bus Stop, Near Teashop	245
21	KHR-28	21.97891	75.86348	Ahirkheda, Near Patrol pump	244
22	KHR-29	22.02219	75.87928	Sala Village, Shivram well	248
23	KHR-30	22.04405	75.85148	Umardad, Adjacent to road	270
24	KHR-31	22.065	75.88535	Dabar	269
25	KHR-32	22.10956	75.96084	Bediya	192
26	KHR-Pz1	22.07826	75.8367	Peizometer 1, Ash Dyke	241
27	KHR-Pz2	22.07721	75.83306	Peizometer 2, Ash Dyke	239
28	KHR-Pz3	22.07476	75.83177	Peizometer 3, Ash Dyke	234
29	KHR-Pz4	22.07289	75.83233	Peizometer 4, Ash Dyke	230
30	KHR-Pz5	22.07055	75.83277	Peizometer 5, Ash Dyke	236
31	KHR-Pz6	22.07089	75.83548	Peizometer 6, Ash Dyke	238

The measured depth to the groundwater table has been used as a base parameter to delineate the groundwater flow pattern in and around the NTPC power station. The depth to groundwater table map is depicted in Figure 10. The groundwater contour map (Figure 11) was produced using the feature of ArcMap, in which vector field rendering (arrow representation) was performed to better visualise flow direction. Figure 11 suggests that the groundwater generally flows in two distinct patterns, similar to the pre-monsoon period. The groundwater flow in the area to the north of the power station flows northwards towards the Narmada River, and the groundwater in the southern side of the power station flows towards the south and southwest direction. A slight variation in the movement of groundwater around the power station site is due to different water use/recharge through a dense network of measuring wells. In general, the groundwater table contour map of the area is found mostly in line with its surface drainage pattern. Table 4 shows the measured groundwater level at identified locations in the area during the post-monsoon season (October 2023). Figure 11 shows the map depicting ground water table contours and flow direction in the study area during the post-monsoon 2023.

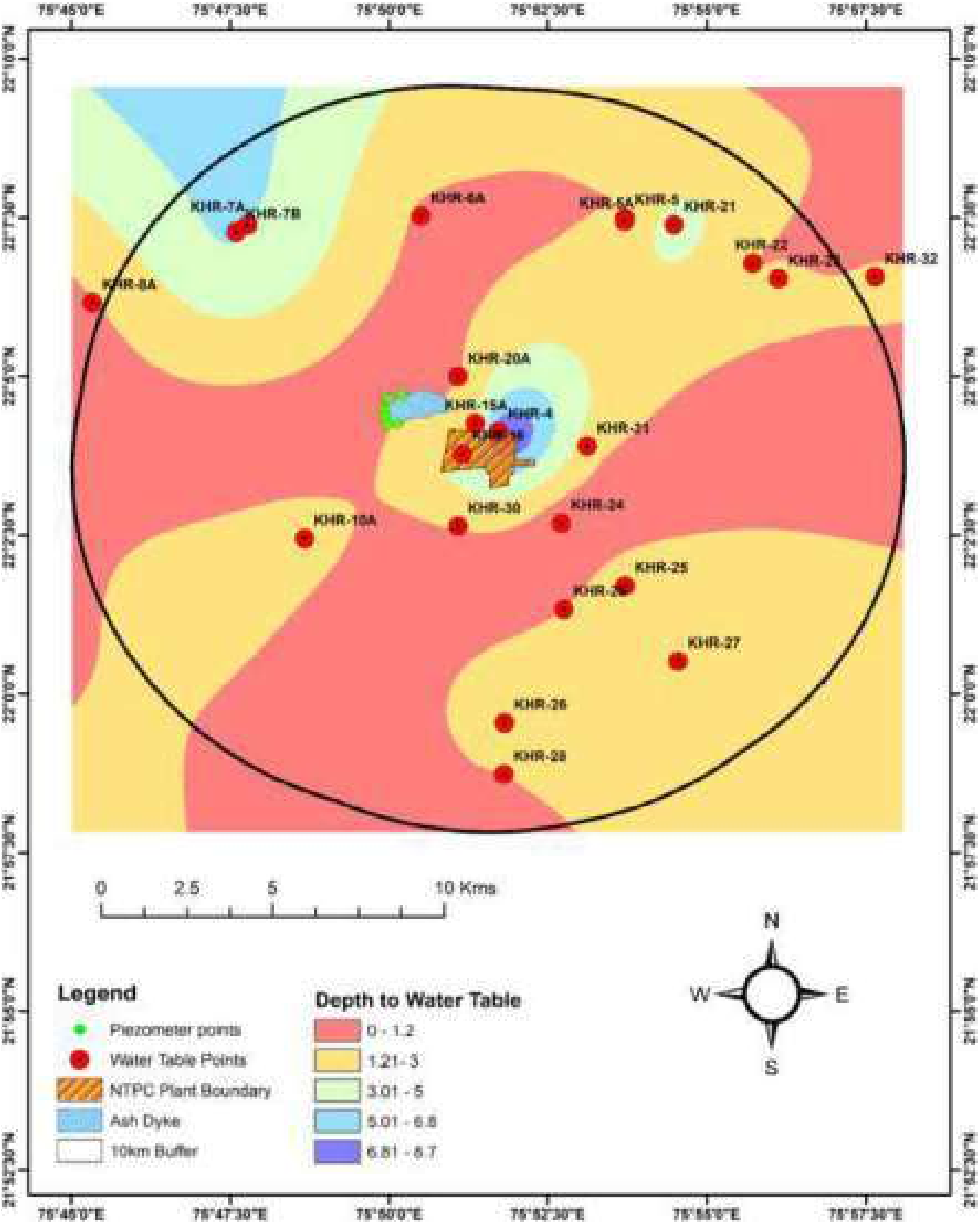

Figure 10. Map showing the spatial variation of water table depth below ground level for the post-monsoon 2023 season.

Table 4. Measured groundwater level at identified locations in the area during the post-monsoon season (October 2023).

S.No.	Site Code	Latitude (˚E)	Longitude (˚N)	Depth to water table (m)	Water Table Elevation (m amsl)
1	KHR-4	22.068803	75.862023	8.68	245.32
2	KHR-5	22.12494	75.8952	1.1	190.9
3	KHR-5A	22.12407	75.89518	2.25	187.75
4	KHR-6A	22.12545	75.84165	1.02	186.98
5	KHR-7A	22.12314	75.7963	5	184
6	KHR-7B	22.12126	75.79317	5.2	186.8
7	KHR-8A	22.10271	75.75548	1.09	183.91
8	KHR-10A	22.04086	75.81116	1.8	217.2
9	KHR-13	22.06608	75.87139	**Discarded**	
10	KHR-15A	22.07092	75.85599	1.78	245.22
11	KHR-16A	22.07912	75.80412	**Discarded**	
12	KHR-18	22.06295	75.85256	4.1	244.9
13	KHR-20A	22.0833	75.8515	1.1	229.9
14	KHR-21	22.12321	75.90812	3.38	194.62
15	KHR-22	22.11305	75.92877	1.22	204.78
16	KHR-23	22.10902	75.93549	1.42	196.58
17	KHR-24	22.04485	75.87855	0.3	272.7
18	KHR-25	22.02839	75.89527	2	249
19	KHR-26	21.99242	75.86363	2.62	225.38
20	KHR-27	22.00855	75.90918	2.6	242.4
21	KHR-28	21.97891	75.86348	1.2	242.8
22	KHR-29	22.02219	75.87928	1.2	246.8
23	KHR-30	22.04405	75.85148	1.3	268.7
24	KHR-31	22.065	75.88535	2	267
25	KHR-32	22.10956	75.96084	1.3	190.7
26	KHR-Pz1	22.07826	75.8367	2.1	238.9
27	KHR-Pz2	22.07721	75.83306	9.27	229.73
28	KHR-Pz3	22.07476	75.83177	2.42	231.58
29	KHR-Pz4	22.07289	75.83233	1.2	228.8
30	KHR-Pz5	22.07055	75.83277	7.1	228.9
31	KHR-Pz6	22.07089	75.83548	5.5	232.5

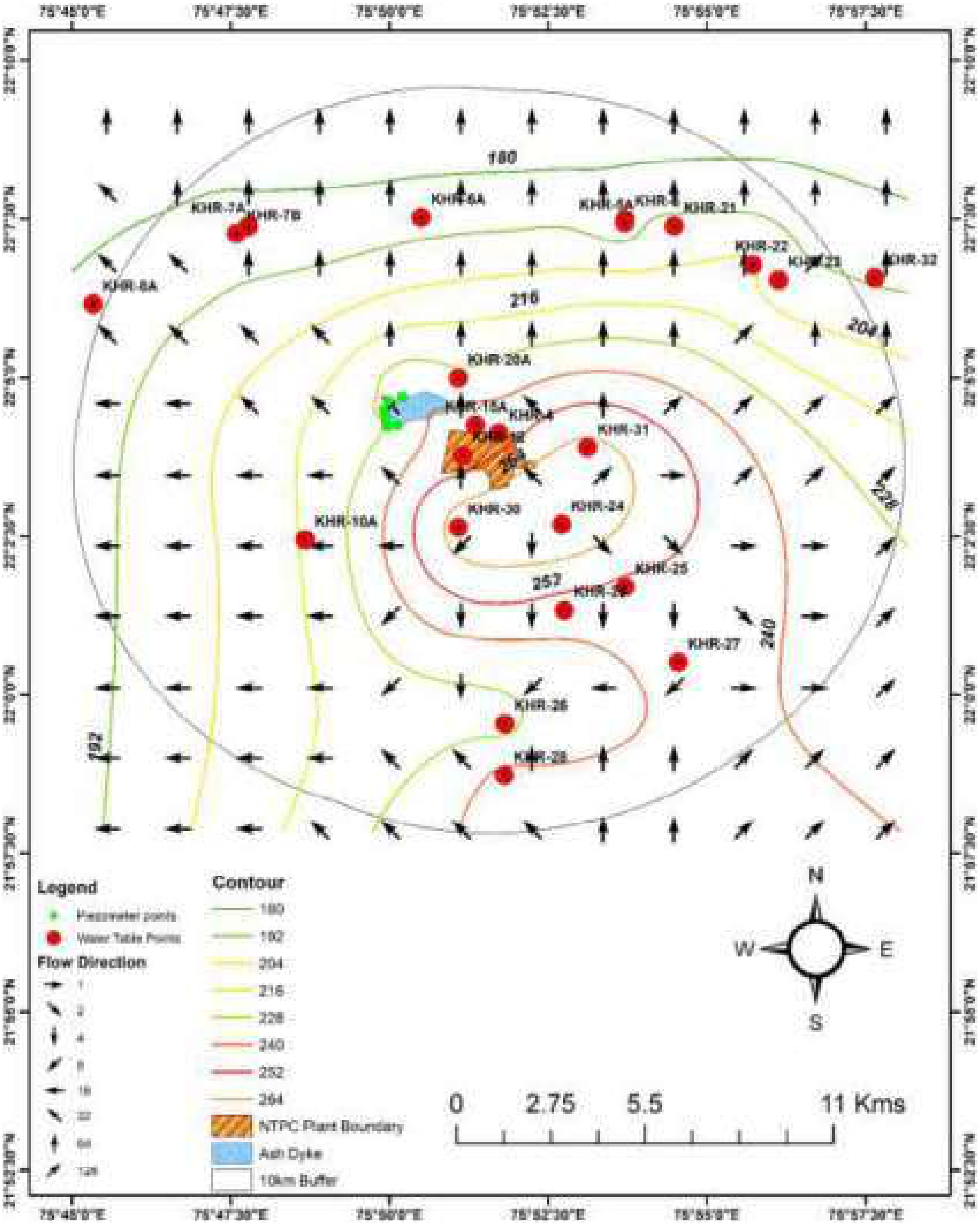

Figure 11. Map depicting groundwater table contours and flow direction in the study area during the post-monsoon 2023 season.

5.3 *Groundwater level observations during pre-monsoon 2024 season*

In the present study, groundwater level monitoring for the pre-monsoon season of 2024 was carried out during May 5 – 9, 2024, at 28 locations in existing open/tube wells and piezometers. Figure 12 provides the location map of the groundwater level monitoring stations used for measuring water levels during the pre-monsoon 2024 visit. The details of the monitoring stations are provided in Table 5.

Table 5. Details of groundwater level monitoring stations during the pre-monsoon 2024 season.

S. No.	Site Code	Latitude (˚E)	Longitude (˚N)	Location and source	Elevation
1.	KHR-2	22.06227	75.76610	Aanganwadi & School Compound Near Hanuman Mandir, Vill Bhatyaan Khurd	201
2.	KHR-4	22.068803	75.862023	Between NTPC & Town ship, opp Boundary Piller S.N. 230-240	254
3.	KHR-5A	22.12407	75.89518	Adjacent to main road, Vill Badgaon, open well	190
4.	KHR-6A	22.12545	75.84165	Well in the field, Vill Kanapur	188
5.	KHR-7A	22.12314	75.7963	Londhi village, open well	189
6.	KHR-7B	22.12126	75.79317	Londhi village, open well	192
7.	KHR-10	22.04086	75.81116	Near Anganwadi Kendra, Bhopada	219
8.	KHR-15A	22.07092	75.85599	Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well	247
9.	KHR-16A	22.07912	75.80412	Adjacent to Gangour thermal power station road	238
10.	KHR-18	22.06295	75.85256	Well inside power station, open well	249
11.	KHR-20	22.0833	75.8515	Mall Singh Jhapdiya Well, Jamniya village, open well	231
12.	KHR-21	22.12321	75.90812	Adjacent to pipalgone road, open well	198
13.	KHR-22	22.11305	75.92877	Adjacent to pipalgone road, open well	206
14.	KHR-23	22.10902	75.93549	Adjacent to pipalgone road, open well	198
15.	KHR-24	22.04485	75.87855	Adjacent to Umaria road, open well	273
16.	KHR-25	22.02839	75.89527	In front of Rewa Gurjar Dharamshala, Gram panchayat office, Umaria	251
17.	KHR-26	21.99242	75.86363	in the field adjacent to Padaliya road, open well	228
18.	KHR-27	22.021429	75.879967	Adjacent to road nimori	245
19.	KHR-28	21.97891	75.86348	Adjacent to Padaliya road, open well	244
20.	KHR-29	21.978471	75.862909	Adjacent to Khargone Sanawad Road Near IOC Petrol Pump	248
21.	KHR-30	22.04404	75.85192	Adjacent to Umerdad road	250
22.	KHR-31	22.065	75.88535	Adjacent to Gangour Thermal Plant Rd	269
23.	KHR-32	22.10956	75.96084	Adjacent to Khargone - Sanawad Rd, Amarpura	192
24.	KHR-Pz1	22.07826	75.8367	Piezometer 1, Ash Dyke	241
25.	KHR-Pz2	22.07721	75.83306	Piezometer 2, Ash Dyke	239
26.	KHR-Pz3	22.07476	75.83177	Piezometer 3, Ash Dyke	234
27.	KHR-Pz4	22.07289	75.83233	Piezometer 4, Ash Dyke	230
28.	KHR-Pz5	**Piezometer was Damaged**			
29.	KHR-Pz6	22.07089	75.83548	Piezometer 6, Ash Dyke	238

The water level below the ground surface was measured using a dip-meter with a water level indicator. DGPS Survey was carried out in the earlier study by NIH at most of these locations, and based on the DGPS data, elevation of the location was determined. The elevation data were used to determine the water level elevation above the mean sea level (amsl). The water level data (both below the ground level and above mean sea level) is presented in Table 5. The spatial variation of water depth below the ground surface is also shown in Figure 12.

The measured depth to the groundwater table has been used as a base parameter to delineate the groundwater flow pattern in and around the NTPC power station. The groundwater contour map (Figure 13) was prepared by using measured water table depth data listed in Table 5 for the pre-monsoon 2024 season. Figure 13 was produced using the feature of ArcMap in which vector field rendering (arrow representation) was performed for better visualisation of flow direction. The thinning method uses a vector averaging procedure to calculate the direction and magnitude for each pixel to generate the flow map. Figure 13 suggests that the groundwater generally flows in two distinct patterns. The flow pattern was similar to the observed pattern of previous year (2023) pre-monsoon season as discussed in section 5.1.

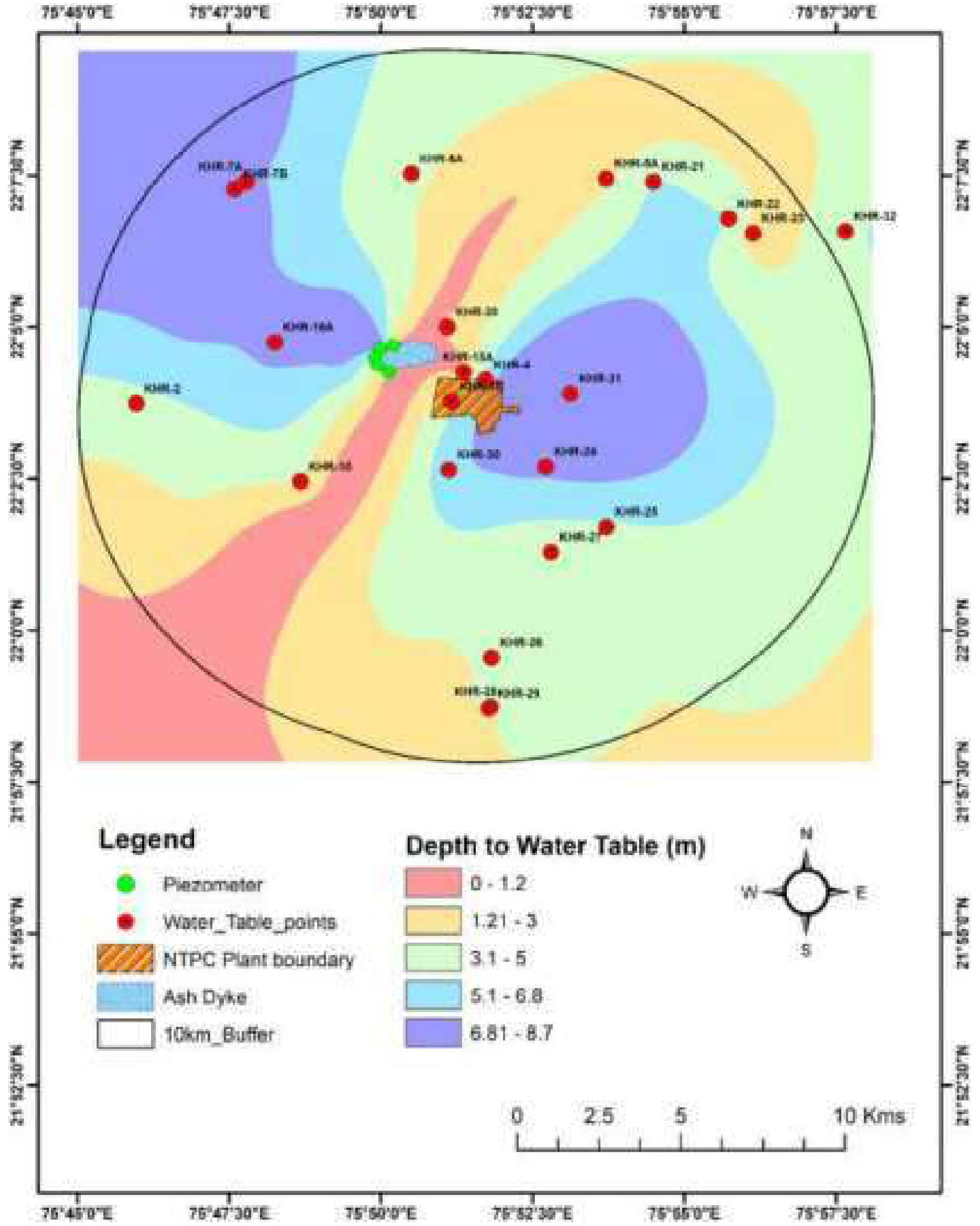

Figure 12. Map showing the spatial variation of water table depth below ground level for the pre-monsoon 2024 season.

Table 6. Measured groundwater level at identified locations in the area during the pre-monsoon season of 2024).

S. No.	Site Code	Latitude (˚E)	Longitude (˚N)	Location and source	Depth to water table (m)	Water Table Elevation (m amsl)
1.	KHR-2	22.06227	75.76610	Aanganwadi & School Compound Near Hanuman Mandir, Vill Bhatyaan Khurd	4.48	196.52
2.	KHR-4	22.068803	75.862023	Between NTPC & Town ship, opp Boundary Piller S.N. 230-240	6	248
3.	KHR-5A	22.12407	75.89518	Adjacent to main road, Vill Badgaon, open well	2.74	187.26
4.	KHR-6A	22.12545	75.84165	Well in the field, Vill Kanapur	3.42	184.58
5.	KHR-7A	22.12314	75.7963	Londhi village, open well	7.4	181.6
6.	KHR-7B	22.12126	75.79317	Londhi village, open well	8.25	183.75
7.	KHR-10	22.04086	75.81116	Near Anganwadi Kendra, Bhopada	2.95	216.05
8.	KHR-15A	22.07092	75.85599	Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well	1.50	245.5
9.	KHR-16A	22.07912	75.80412	Adjacent to Gangour thermal power station road	7.12	230.88
10.	KHR-18	22.06295	75.85256	Well inside power station, open well	4.3	244.7
11.	KHR-20	22.0833	75.8515	Mall Singh Jhapdiya Well, Jamniya village, open well	1.42	229.58
12.	KHR-21	22.12321	75.90812	Adjacent to pipalgone road, open well	4.94	193.06
13.	KHR-22	22.11305	75.92877	Adjacent to pipalgone road, open well	4.68	201.32
14.	KHR-23	22.10902	75.93549	Adjacent to pipalgone road, open well	2.2	195.8
15.	KHR-24	22.04485	75.87855	Adjacent to Umaria road, open well	7.3	265.7
16.	KHR-25	22.02839	75.89527	In front of Rewa Gurjar Dharamshala, Gram panchayat office, Umaria	4.7	246.3
17.	KHR-26	21.99242	75.86363	in the field adjacent to Padaliya road, open well	3.42	224.58
18.	KHR-27	22.021429	75.879967	Adjacent to road nimori	3.85	241.15
19.	KHR-28	21.97891	75.86348	Adjacent to Padaliya road, open well	4.1	239.9
20.	KHR-29	21.978471	75.862909	Adjacent to Khargone Sanawad Road Near IOC Petrol Pump	2.5	245.5
21.	KHR-30	22.04404	75.85192	Adjacent to Umerdad road	6.1	243.9
22.	KHR-31	22.065	75.88535	Adjacent to Gangour Thermal Plant Rd	10.42	258.58
23.	KHR-32	22.10956	75.96084	Adjacent to Khargone - Sanawad Rd, Amarpura	4.59	187.41
24.	KHR-Pz1	22.07826	75.8367	Piezometer 1, Ash Dyke	1.50	239.5
25.	KHR-Pz2	22.07721	75.83306	Piezometer 2, Ash Dyke	8.90	230.1
26.	KHR-Pz3	22.07476	75.83177	Piezometer 3, Ash Dyke	3.14	230.86
27.	KHR-Pz4	22.07289	75.83233	Piezometer 4, Ash Dyke	4.32	225.68
28.	KHR-Pz5	**Piezometer was Damaged**				
29.	KHR-Pz6	22.07089	75.83548	Piezometer 6, Ash Dyke	1.02	236.98

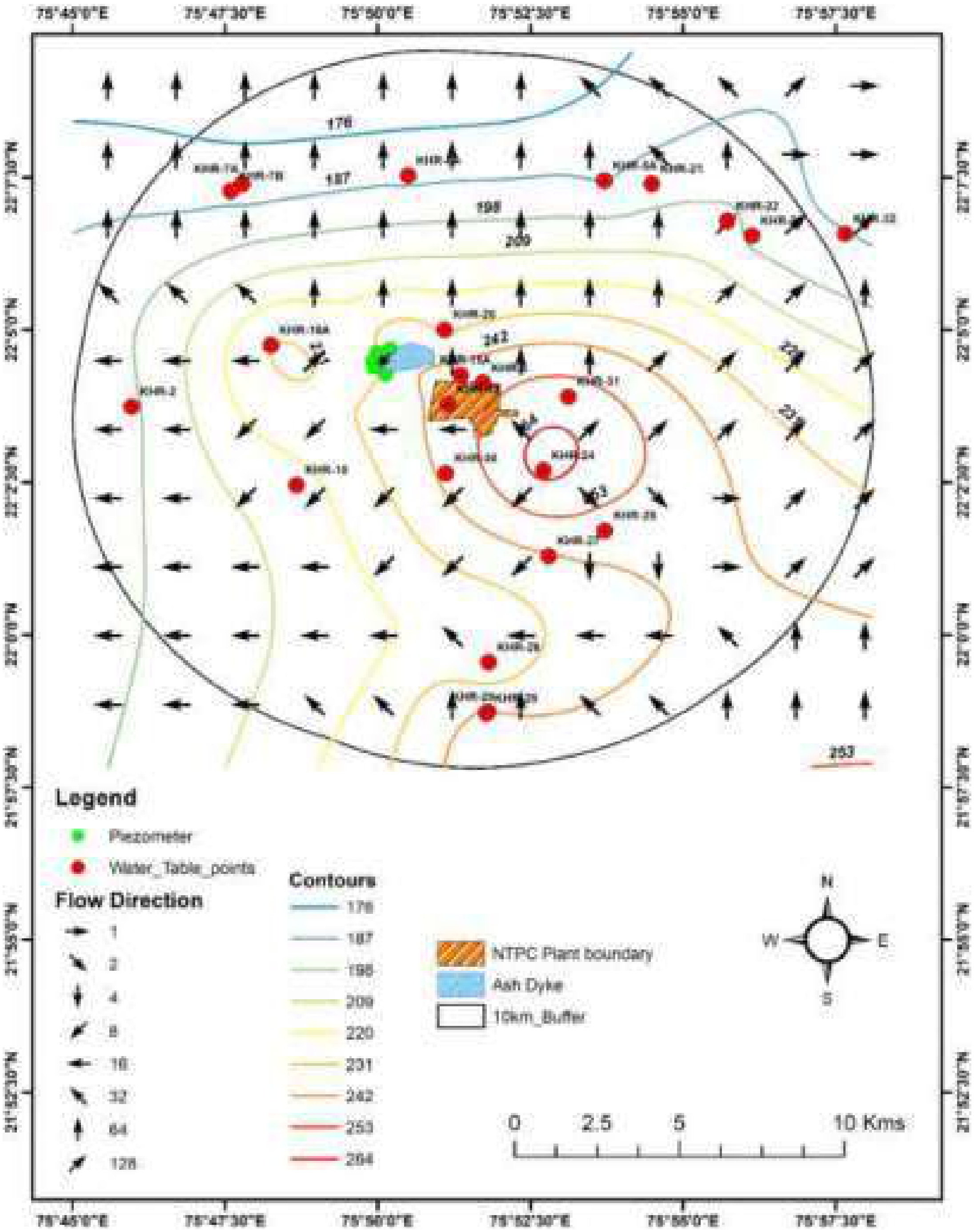

Figure 13 Map depicting groundwater table contours and flow direction in the study area during the pre-monsoon season of year 2024.

5.4 ***Analysis of Groundwater level trend with previous reports***

The comparison of groundwater level data between pre and post-monsoon periods is essential for hydrogeological studies. This comparative analysis provides valuable insights into the seasonal fluctuations and dynamics of groundwater resources. By examining the changes in water levels before and after the monsoon, we may determine trends and identify potential influences on aquifer recharge or depletion, and assess the overall health of groundwater systems. This assessment is particularly crucial for understanding the impact of seasonal variations on water availability and can help in adopting sustainable water resource management strategies. The analysis involves collecting groundwater level data during both pre-monsoon and post-monsoon seasons, calculating the differences or fluctuations between these periods, and interpreting the results to draw meaningful conclusions about groundwater storage and flow regimes.

The groundwater table data presented in the Table 7 pertains to various monitoring sites, each identified by a unique site code, latitude and longitude coordinates for the year 2023. The dataset encompasses measurements during both pre-monsoon (PreM) and post-monsoon (PostM) seasons, with associated fluctuation values denoting the difference between these seasons. Fluctuation in groundwater can be positive to negative, representing rise and decline in groundwater levels, respectively. KHR-5 demonstrates a rise in groundwater levels from PreM (2.2 m) to PostM (1.1 m). Similarly, KHR-7A and KHR-7B both experience a rise in groundwater levels post-monsoon, with fluctuations of 1.6 and 1.58 meters, respectively. On the other hand, KHR-15A observes a minor fall with a fluctuation of -0.23 m. These diverse trends underscore the complex and heterogeneous nature of groundwater dynamics of the study area.

Groundwater level fluctuation in the buffer zone and trend based secondary data were also collected by National Institute of Hydrology (NIH)- Roorkee in year 2018 during pre-and post-monsoon periods. Amba site experiences a substantial fluctuation of 16.8 m, signalling a noteworthy increase. Similarly, Dabhad, Dalchi, Bhatyan Khurd, Pipalgon, Londhi, Kanapur, Badgaon, Satkhali, Padliya Gawli, and others locations showcase substantial fluctuations, all indicative of a rise in groundwater level during the post-monsoon season. Notably, Satkhali demonstrates the highest fluctuation of 24.7 m. This positive trend suggests an overall rise in the water table over the specified period. However, it is crucial to note a significant limitation in the interpretation of the findings. The data sets presented in Table 8 were collected from diverse sources, including tube wells, bore wells, and handpumps, by the NIH Roorkee in 2018. This heterogeneity in data collection methods and sources introduces a notable challenge in directly comparing the water level measurements for precise assessment. The variability in measurement techniques and instrument types used for tube wells, bore wells, and handpumps can lead to some other disparities in the reported data, making it difficult to establish a direct and meaningful comparison. Moreover, the data collected by NIH in year 2022 is available only for the pre -monsoon period. Therefore, a meaningful comparison could not be established among the years.

Table 7. Groundwater level fluctuation in the buffer zone and trend based on pre and post monsoon water table data observed in year 2023.

S.No.	**Site Code**	**Latitude**	**Longitude**	PreM	Post M	Fluctuation	Trend
1	KHR-4	22.068803	75.862023	NA	8.68	-	-
2	KHR-5	22.12494	75.8952	2.2	1.1	1.1	Rise
3	KHR-5A	22.12407	75.89518	3.6	2.25	1.35	Rise
4	KHR-6A	22.12545	75.84165	NA	1.02	-	-
5	KHR-7A	22.12314	75.7963	6.6	5	1.6	Rise
6	KHR-7B	22.12126	75.79317	6.78	5.2	1.58	Rise
7	KHR-8A	22.10271	75.75548	NA	1.09	-	-
8	KHR-10A	22.04086	75.81116	NA	1.8	-	-
9	KHR-13	22.06608	75.87139	7.9	Discarded	-	-
10	KHR-15A	22.07092	75.85599	1.55	1.78	-0.23	fall
11	KHR-16A	22.07912	75.80412	12.4	Discarded	-	-
12	KHR-18	22.06295	75.85256	4.56	4.1	0.46	Rise
13	KHR-20A	22.0833	75.8515	1.5	1.1	0.4	Rise
14	KHR-21	22.12321	75.90812	5.2	3.38	1.82	Rise
15	KHR-22	22.11305	75.92877	5.4	1.22	4.18	Rise
16	KHR-23	22.10902	75.93549	2.3	1.42	0.88	Rise
17	KHR-24	22.04485	75.87855	9	0.3	8.7	Rise
18	KHR-25	22.02839	75.89527	NA	2	-	-
19	KHR-26	21.99242	75.86363	2.9	2.62	0.28	Rise
20	KHR-27	22.00855	75.90918	NA	2.6	-	-
21	KHR-28	21.97891	75.86348	NA	1.2	-	-
22	KHR-29	22.02219	75.87928	NA	1.2	-	-
23	KHR-30	22.04405	75.85148	NA	1.3	-	-
24	KHR-31	22.065	75.88535	NA	2	-	-
25	KHR-32	22.10956	75.96084	NA	1.3	-	-
26	KHR-Pz1	22.07826	75.8367	2.7	2.1	0.6	Rise
27	KHR-Pz2	22.07721	75.83306	12.33	9.27	3.06	Rise
28	KHR-Pz3	22.07476	75.83177	3.3	2.42	0.88	Rise
29	KHR-Pz4	22.07289	75.83233	3.5	1.2	2.3	Rise
30	KHR-Pz5	22.07055	75.83277	9.4	7.1	2.3	Rise
31	KHR-Pz6	22.07089	75.83548	9.5	5.5	4	Rise

Table 8. Groundwater level fluctuation in the buffer zone and trend based secondary data collected in year 2018 during pre and post monsoon period.

S.No.	Site	Latitude	Longitude	PreM	PosM	Fluctuation	Trend
1	Amba	75.94472	22.0434	20.192	3.392	16.8	Rise
2	Dabhad	75.90045	22.06681	26.234	8.934	17.3	Rise
3	Dalchi	75.82992	22.07724	38.317	16.817	21.5	Rise
4	Bhatyan Khurd	75.76541	22.05257	26.288	7.888	18.4	Rise
5	Pipalgon	75.7546	22.10257	26.027	5.327	20.7	Rise
6	Londhi	75.79397	22.12351	21.228	3.828	17.4	Rise
7	Kanapur	75.84291	22.12278	24.51	3.71	20.8	Rise
8	Badgaon	75.89517	22.125	19.947	1.447	18.5	Rise
9	Satkhali	75.88277	21.99955	49.277	24.577	24.7	Rise
10	Padliya Gawli	75.85117	22.00762	23.197	5.597	17.6	Rise
11	Ahirkheda	75.86368	21.97928	26.463	9.163	17.3	Rise
12	Umariya	75.89675	22.02771	34.067	14.067	20	Rise
13	Bhopada	75.81374	22.0421	27.499	5.499	22	Rise
14	Khedi Buzurg	75.87746	22.04958	29.144	14.344	14.8	Rise
15	Bakava	75.85374	22.16816	26.807	9.107	17.7	Rise
16	Bhatud	75.93065	22.10305	30.998	0.798	30.2	Rise
17	Peer Baba Mazar	75.83866	22.1375	24.489	6.089	18.4	Rise
18	Lachhora	75.92346	22.07634	22.696	3.696	19	Rise
19	Pokhar	75.83076	21.99802	24.14	6.34	17.8	Rise
20	Sala Khurd	75.87948	22.02154	38.346	17.146	21.2	Rise
21	Dudgaon	75.945	22.1024	18.934	2.434	16.5	Rise
22	Kharadi	75.84705	22.02258	47.172	8.072	39.1	Rise
23	Mardaliya	75.95227	22.0791	48.978	3.078	45.9	Rise
24	Bet Dabhad-Selda	75.88542	22.065	25.68	12.48	13.2	Rise
25	Plant Area	75.862	22.06884	21.856	8.656	13.2	Rise

6 SURFACE WATER QUALITY AT IDENTIFIED LOCATIONS AND CURRENT SOURCES OF CONTAMINATION, IF ANY.

The study team visited KhSTPS Khargone to collect surface water samples in 10 km buffer zone from the power station area, ash dyke and surrounding area during pre- and post-monsoon periods. During the site survey, the team identified several observation points for data collection of surface water within a 10 km radius of the power station area.

6.1 Surface Water Quality during Pre-monsoon 2023 Season

The team visited KhSTPS Khargone during April 25 – 30, 2023, to undertake a pre-monsoon survey and collection of surface water samples in 10 km buffer zone from the power station area, ash dyke and surrounding area. Surface water samples were collected from identified locations to identify the current sources of contamination, if any. Salient details such as sample code, station name, location, and type of analysis for which surface water sample is collected during the pre-monsoon 2023 visit are listed in Table 9. The geographical location of surface water sampling points for pre-monsoon 2023 sampling points is shown in Figure 14. The collected samples were analysed for required water quality parameters. COD and BOD are measured through the oxidation-titration method. In the In-situ analysis of the samples, pH, TDS (Total dissolved solids), EC (Electrical Conductivity), DO (Dissolved Oxygen), and temperature were measured at the water collection site using a multi-meter electrode. Measured values of physical parameters like DO, TDS, EC, pH, Temperature, COD, BOD, and Hardness (COD, BOD, Hardness, DO, and TDS in mg/L; EC in mS/cm; pH in the standard unit and temperature in °C) during the pre-monsoon season are listed in Table 10. The pH values ranged from 6.86 to 8.58, with a mean value of 7.9. The sample collected from the Ambak reservoir has the highest pH level, i.e., 8.58. TDS concentrations ranged from 120 mg/L to 570 mg/L, with an average value of 287.9 mg/L. DO concentrations ranged from 3.8 mg/L to 15 mg/L, with a mean value of 7.2 mg/L. The EC concentration ranged from 0.25 ms/cm to 1.16 ms/cm, with an average value of 0.6 ms/cm. Hardness ranged from 162.9 mg/L to 625.1 mg/L in the pre-monsoon 2023 period, with an average value of 321.4 mg/L. COD and BOD are also determined in surface water samples during the pre-monsoon season, where the BOD ranged from 4 mg/L to 16 mg/L with a mean value of 10.1mg/L while COD ranged from 36 mg/L to 112 mg/L with an average of 66.4 mg/L. The temperature of the surface water samples ranged from 27.1°C to 34.2°C with a mean value of 30.5°C.

Table 9. Surface water sampling sites in a 10 km buffer (pre-monsoon 2023)

S.No	Code	Latitude	Longitude	Station Name	Type of Analysis	Type of Site
1	KHR-51	22.07047	75.858149	Pond Between NTPC Power station & Township	In-situ and Ex-situ	Surface water
2	KHR-52	22.12206	75.842803	Near Health Centre along Main road, Vill Kanapur	In-situ and Ex-situ	Surface water
3	KHR-53	22.104185	75.812277	Jirbhar lake	In-situ and Ex-situ	Surface water
4	KHR-54A	22.158804	75.76167	Narmada River Downstream	In-situ and Ex-situ	Surface water
5	KHR-55	22.006354	75.848828	Ambak Resevoir	In-situ and Ex-situ	Surface water
6	KHR-56	22.075493	75.927687	Lachhora Talab	In-situ and Ex-situ	Surface water

7	KHR-57	22.115246	75.866087	Kattora Pond, Shelda Power station-Kattora Road	In-situ and Ex-situ	Surface water
8	KHR-58	22.07323	75.833941	OFL Ash Dyke	In-situ and Ex-situ	Surface water
9	KHR-59	22.073978	75.839568	Lagoon 1 Ash Dyke	Dried up	Surface water
10	KHR-60	22.07661	75.8332	Lagoon 2 Ash Dyke	In-situ and Ex-situ	Surface water
11	KHR-61	22.06741	75.860638	Raw water reservoir inside power station	In-situ and Ex-situ	Surface water
12	KHR-61Ae	22.063462	75.855098	Aerated water from raw water reservoir	In-situ and Ex-situ	Surface water
13	KHR-62	22.07441	75.850902	Below tower line on road crossing near power station	In-situ and Ex-situ	Surface water
14	KHR-63	22.1927	75.97763	Narmada River upstream, Toksar	In-situ and Ex-situ	Surface water
15	KHR-64	22.00772	75.90917	Ambak River, Khargone-Sanawad road	In-situ and Ex-situ	Surface water

Table 10. Physical parameters in surface water samples during the pre-monsoon season of April (2023); pH in standard units.

S.No.	Code	DO (mg/L)	TDS (mg/L)	EC mS/cm)	pH (Range)	Temp (°C)	BOD (mg/L)	COD (mg/L)	Hardness (mg/L)
1	KHR-51	9.62	400	0.81	8.45	34.2	9	39	532
2	KHR-52		450	0.9	8.45	32.5	14	103	401
3	KHR-53	3.78	300	0.61	7.66	28.4	15	68	400
4	KHR-54A	6.36	140	0.29	6.86	29.8	6	65	193
5	KHR-55	8.48	120	0.25	**8.58**	32.3	9	52	172
6	KHR-56	5.28	220	0.45	8.12	30.2	6	59	281
7	KHR-57	6.46	160	0.33	8.08	32.9	10	66	215
8	KHR-58	7.04	570	1.16	8.06	30	16	48	300
9	KHR-59				**Dried**				
10	KHR-60	7.02	540	1.08	8.32	29.7	14	65	392
11	KHR-61	5.85	130	0.27	8.2	28.6	7	41	163
12	KHR-61Ae	8.3	160	0.33	7.87	28.7	4	36	203
13	KHR-62	5.98	470	0.95	7.45	32.9	14	112	625
14	KHR-63	7.3	150	0.32	7.72	27.1	9	84	222
15	KHR-64	4.82	220	0.44	7.44	30	8	91	401
BIS Limits	**AL**	**NS**	**500**	**NS**	**6.5-8.5**	**NS**	**NS**	**NS**	**200**
	PL		**2000**		**NR**				**600**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

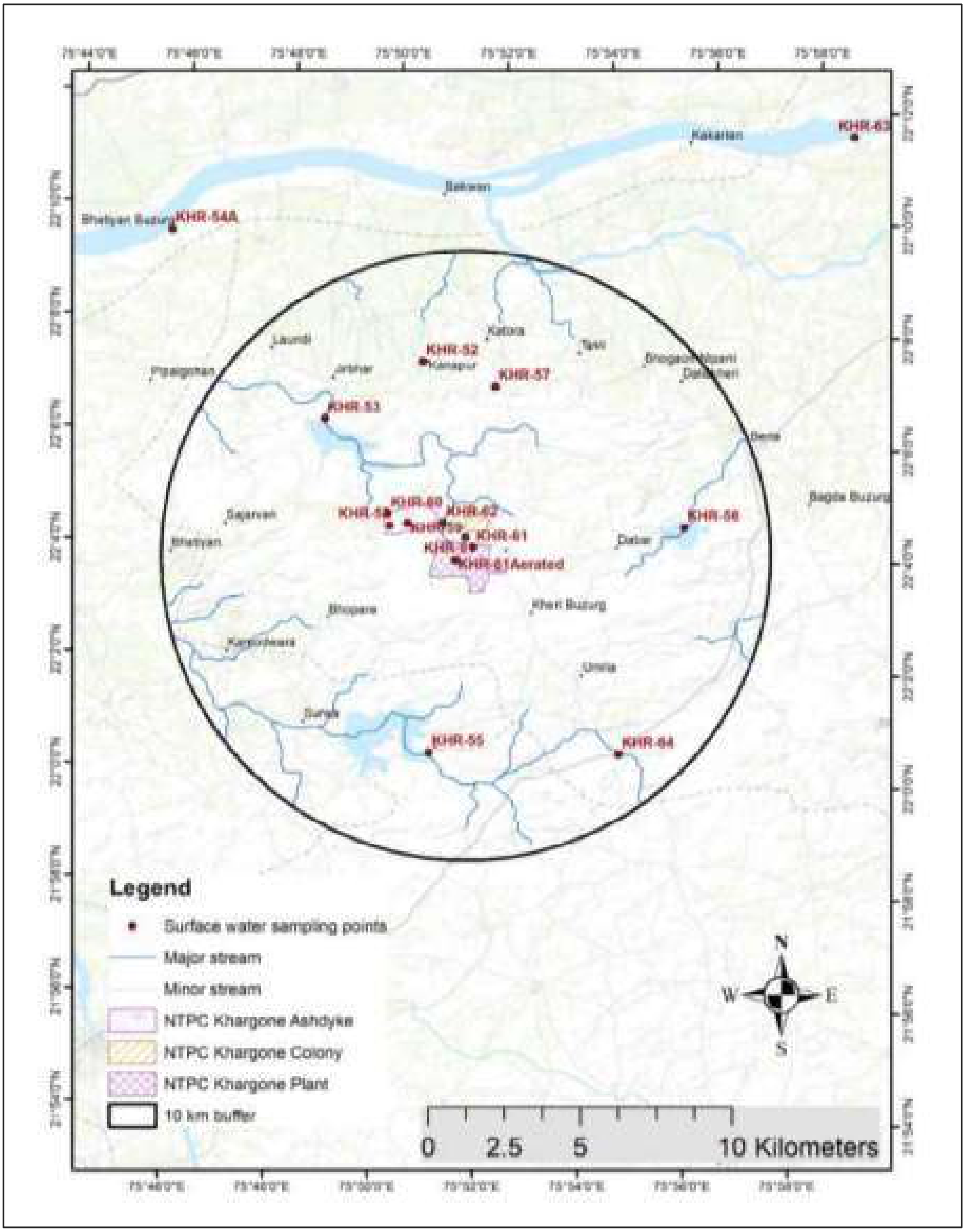

Figure 14. Map depicting the location of surface water sampling points during pre-monsoon 2023.

The mean concentration of heavy metals in the collected surface water samples and their comparison with BIS limits 10500:2012 during the pre-monsoon season (April 2023) is listed in Table 11. The concentration of arsenic (As) ranged from 0.005 ppm to 0.02 ppm, with an average value of 0.008 ppm. Pb concentration varied between 0.001-0.002 ppm with an almost insignificant mean value. The concentration of Cd, Cr, Cu, Zn, Se, and Fe ranged between 0.0003- 0.0004 ppm, 0.006-0.011 ppm, 0.031-0.043 ppm, 0.062-0.105 ppm, BDL-0.014, 0.1-2.1, respectively. Mercury (Hg) was below detectable limits in the surface water samples in the pre-monsoon 2023 period.

Table 11. Mean concentration (in ppm) of heavy metals in the surface water samples and their comparison with BIS limits 10500:2012 during pre-monsoon season of April (2023)

S.No.	Code	As	Hg	Pb	Cd	Cr	Cu	Zn	Se	Fe
1	KHR-51	0.006	BDL	0.001	0.0004	0.01	0.04	0.08	0.001	**1.1**
2	KHR-52	0.009	BDL	0.002	0.0003	0.01	0.04	0.08	0.002	**1.2**
3	KHR-53	0.008	BDL	0.002	0.0003	0.01	0.04	0.11	BDL	0.1
4	KHR-54	0.006	BDL	0.001	0.0003	0.01	0.03	0.08	0.002	0.1
5	KHR-55	0.007	BDL	0.002	0.0004	0.01	0.04	0.09	0.001	0.1
6	KHR-56	0.008	BDL	0.002	0.0003	0.01	0.04	0.10	0.001	**0.5**
7	KHR-57	0.005	BDL	0.001	0.0003	0.01	0.03	0.08	BDL	**0.4**
8	KHR-58	0.014	BDL	0.002	0.0003	0.01	0.04	0.06	0.011	0.1
9	KHR-59					**Dried**				
10	KHR-60	**0.020**	BDL	0.002	0.0003	0.01	0.04	0.09	**0.014**	**2.1**
11	KHR-61	0.007	BDL	0.001	0.0003	0.01	0.04	0.09	0.001	0.1
12	KHR-61Ae	0.007	BDL	0.002	0.0004	0.01	0.04	0.07	0.001	0.1
13	KHR-62	0.007	BDL	0.001	0.0003	0.01	0.03	0.09	0.003	0.1
14	KHR-63	0.007	BDL	0.002	0.0003	0.01	0.04	0.08	0.002	0.1
15	KHR-64	0.006	BDL	0.001	0.0003	0.01	0.03	0.08	0.001	0.5
BIS (IS:10500-2012)	**AL**	**0.01**	**0.001**	**0.01**	**0.003**	**0.05**	**0.05**	**5**	**0.01**	**0.3**
	PL	**0.05**	**NR**	**NR**	**NR**	**NR**	**1.5**	**15**	**NR**	**NR**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit

Ion Chromatography (IC) analysis was performed to measure the concentration of anions such as nitrate (NO_3^-), phosphate (PO_4^-), chloride (Cl^-), fluoride (F^-), bromide (Br^-) and sulfate (SO_4^{2-}). Prior to IC analysis, samples were diluted to a suitable degree with MQ water. After that, the samples were filtered through a 0.2µm filter before their analysis. Moreover, cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) were measured using MPAES at the Institute Instrumentation

Center (IIC) of IIT Roorkee. The concentrations of major ions in surface water samples and their comparison with BIS limits is listed in Table 12. In the pre-monsoon 2023 season, F^- concentration ranges between 0.2-3.1 mg/L with an average value of 0.7 mg/L. The concentration of Cl^- ranged from 7.9 to 91.9 mg/L, with an average value of 36.3 mg/L. The concentration of NO_3^- ranged from BDL to 25.6 mg/L, with an average value of 4.5 mg/L. SO_4^{2-} levels ranged from 15.3 to 942.3 mg/L with an average value of 185.9 mg/L. Ca^{2+} levels ranged from 40.1 mg/L to 190.8 mg/L, with an average value of 79.2 mg/L. The concentration of K^+ ranged from 1.8 mg/L to 97.6 mg/L with an average value of 11.7 mg/L. The concentration of Mg^{2+} ranged from 11.4 mg/L to 57.5 mg/L with an average value of 30.1 mg/L. Na^+ level ranged from 21.5 mg/L to 142.7 mg/L with an average value of 59.1 mg/L. The HCO_3 concentration ranged from 101 mg/L to 542 mg/L, with an average value of 205.5 mg/L.

Table 12. Mean concentration (in mg/L) of major ions in surface water samples and their comparison with BIS limits of IS 10500:2012 during pre-monsoon season of April (2023)

Sr. No.	Code	F^-	Cl^-	Br^-	NO_3^-	PO_4^-	SO_4^{2-}	Ca^{2+}	K^+	Mg^{2+}	Na^+	HCO_3^-	CO_3^-
1	KHR-51	0.4	85.3	ND	1.8	ND	304.5	118.3	9.0	57.5	99.9	175	ND
2	KHR-52	0.4	90.1	ND	1.0	ND	67.4	74.8	97.6	51.9	142.7	365	ND
3	KHR-53	0.4	31.2	ND	8.6	ND	128	100.9	4.0	36.1	58.4	154	ND
4	KHR-54	0.2	10	ND	2.7	ND	15.3	56.7	3.6	12.5	25.2	193	ND
5	KHR-55	0.3	7.9	ND	1.5	ND	19.5	43.1	2.7	15.6	26.6	159	ND
6	KHR-56	0.5	20.6	ND	3.5	ND	57.3	61.0	4.1	31.2	57.6	542	ND
7	KHR-57	0.5	8.9	ND	4.0	ND	26.8	57.9	2.3	17.1	28.8	210	ND
8	KHR-58	**3.1**	77.0	ND	3.2	ND	**942.3**	40.1	13.3	48.6	87.8	112	ND
9	KHR-59						**DRIED**						
10	KHR-60	**2.3**	37.5	ND	1.6	ND	**566.9**	75.4	14.7	49.4	91.2	101	ND
11	KHR-61	0.3	8.7	ND	BDL	ND	29.1	46.4	2.0	11.4	31.8	153	ND
12	KHR-61Ae	0.3	8.7	ND	BDL	ND	22.1	58.9	2.6	13.6	21.5	136	ND
13	KHR-62	0.5	91.9	ND	7.8	ND	378	190.8	1.8	36.1	88.5	182	ND
14	KHR-63	0.3	9.1	ND	2.1	ND	15.5	66.5	2.9	13.6	26.5	210	ND
15	KHR-64	0.5	21	ND	25.6	ND	29.5	117.5	3.0	26.0	40.2	185	ND
BIS limits (IS:10500-2012)	**AL**	**1**	**250**	**NS**	**45**	**NS**	**200**	**75**	**NS**	**30**	**NS**	**NS**	**NS**
	PL	**1.5**	**1000**		**NR**		**400**	**200**		**100**			

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

6.2 *Surface Water Quality during Post-monsoon 2023 Season*

Surface water samples were collected from identified locations to identify the current sources of contamination in the post-monsoon 2023 season. Salient details such as sample code, station name, location, and type of analysis for which surface water samples were collected during the post-monsoon 2023 visit are listed in Table 13. The collected samples were analysed for required surface water quality parameters. Measured values of physical parameters like DO, TDS, EC, pH, Temperature, along with COD, BOD, and Hardness (in mg/L) else EC in mS/cm; pH in the standard unit and temperature in °C, during the post-monsoon season are listed in Table 14.

Table 13. Surface water sampling sites in a 10 km buffer (post-monsoon 2023)

S.No	Code	Latitude	Longitude	Station Name	Type of Analysis	Type of Site
1	KHR-51	22.07047	75.858149	Pond Between NTPC Power station & Township	In-situ and Ex-situ	Surface water
2	KHR-52	22.12206	75.842803	Near Health Centre along Main road, Vill Kanapur	In-situ and Ex-situ	Surface water
3	KHR-53	22.104185	75.812277	Jirbhar lake	In-situ and Ex-situ	Surface water
4	KHR-54A	22.158804	75.76167	Narmada River Downstream	In-situ and Ex-situ	Surface water
5	KHR-55	22.006354	75.848828	Ambak Resevoir	In-situ and Ex-situ	Surface water
6	KHR-56	22.075493	75.927687	Lachhora Talab	In-situ and Ex-situ	Surface water
7	KHR-57	22.115246	75.866087	Kattora Pond, Shelda Power station-Kattora Road	In-situ and Ex-situ	Surface water
8	KHR-58	22.07323	75.833941	OFL Ash Dyke	In-situ and Ex-situ	Surface water
9	KHR-59	22.073978	75.839568	Lagoon 1 Ash Dyke	Dried up	Surface water
10	KHR-60	22.07661	75.8332	Lagoon 2 Ash Dyke	In-situ and Ex-situ	Surface water
11	KHR-61	22.06741	75.860638	Raw water reservoir inside power station	In-situ and Ex-situ	Surface water
12	KHR-62	22.07441	75.850902	Below tower line on road crossing	In-situ and Ex-situ	Surface water
13	KHR-63	22.1927	75.97763	Narmada River upstream, Toksar	In-situ and Ex-situ	Surface water
14	KHR-64	22.00772	75.90917	Ambak River, Khargone-Sanawad road	In-situ and Ex-situ	Surface water

The pH values ranged from 6.94 to 8.32, with a mean value of 7.75. TDS concentrations ranged from 100 mg/L to 970 mg/L, with an average value of 337.69 mg/L. DO concentrations ranged from 3.8 mg/L to 10.08 mg/L, with a mean value of

7.41 mg/L. The EC concentration ranged from 0.21 ms/cm to 1.94 ms/cm, with an average value of 0.69 ms/cm. Hardness ranged from 84.42 mg/L to 338.50 mg/L in the post-monsoon period, with an average value of 168.50 mg/L. COD and BOD are also determined in surface water samples during the post-monsoon season, where the BOD ranged from 4 mg/L to 14 mg/L with a mean value of 8.38 mg/L while COD ranged from 26 mg/L to 111 mg/L with an average of 56.46 mg/L. The temperature of the surface water samples ranged from 26.70°C to 32.45°C with a mean value of 30.16°C.

Table 14. Physical parameters in surface water samples during the post-monsoon season of 2023; pH in standard units.

S.No.	Code	DO (mg/L)	TDS (mg/L)	EC (mS/cm)	pH (Range)	Temp (°C)	BOD (mg/L)	COD (mg/L)	Hardness (mg/L)
1	KHR-51	9.53	410	0.86	8.32	32.45	5	26	91
2	KHR-52	7.87	240	0.5	7.75	30.9	11	111	161
3	KHR-53	3.8	150	0.31	7.63	26.7	9	70	127
4	KHR-54A	7.23	160	0.32	6.94	27.3	5	60	135
5	KHR-55	8.74	220	0.45	7.89	32.2	10	35	155
6	KHR-56	10.08	130	0.26	8.12	29.2	4	33	84
7	KHR-57	7.57	120	0.24	7.99	30.7	12	41	106
8	KHR-58	7.2	970	1.95	7.51	30.4	14	46	262
9	KHR-59				**DRIED**				
10	KHR-60	7.21	970	1.95	7.66	30.5	10	56	338
11	KHR-61	6.2	100	0.21	8.27	31.7	9	39	88
12	KHR-62	6.32	410	0.83	7.43	29.6	6	92	320
13	KHR-63	6.5	230	0.47	7.41	29.3	5	67	210
14	KHR-64	8.09	280	0.57	7.8	31.1	9	58	113
BIS Limits	**AL**	**NS**	**500**	**NS**	**6.5-8.5**	**NS**	**NS**	**NS**	**200**
	PL		**2000**		**NR**				**600**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

The mean concentration of heavy metals in the collected surface water samples and their comparison with BIS limits for post-monsoon 2023 season is listed in Table 15. The concentration of arsenic (As) ranged from 0.001 ppm to 0.004 ppm, with an average value of 0.001 ppm. Pb concentration varied between 0.002-0.007 ppm with an almost insignificant mean value of 0.003. The concentration of Cd, Cr, Cu, Se, and Fe ranged between 0.001- 0.002 ppm, 0.018-0.023 ppm, 0.003-0.150 ppm, BDL-0.010, 0.15-0.37, respectively.

Table 15. Mean concentration (in ppm) of heavy metals in the surface water samples and their comparison with BIS limits 10500:2012 during post-monsoon season of 2023

S.No.	Code	As	Hg	Pb	Cd	Cr	Cu	Zn	Se	Fe
1	KHR-51	0.001	ND	0.002	0.002	0.02	ND	ND	BDL	0.18
2	KHR-52	0.001	ND	0.007	0.002	0.02	0.01	ND	BDL	0.31
3	KHR-53	0.001	ND	0.003	0.002	0.02	0.01	ND	BDL	0.25
4	KHR-54	0.001	ND	0.003	0.001	0.02	0.01	ND	BDL	0.37
5	KHR-55	0.001	ND	0.003	0.002	0.02	0.15	ND	BDL	0.23
6	KHR-56	0.001	ND	0.004	0.002	0.02	ND	ND	BDL	0.20
7	KHR-57	0.001	ND	0.002	0.001	0.02	0.01	ND	BDL	0.21
8	KHR-58	0.003	ND	0.002	0.002	0.02	ND	ND	0.01	0.18
9	KHR-59				DRIED					
10	KHR-60	0.004	ND	0.002	0.002	0.02	ND	ND	0.01	0.18
11	KHR-61	0.001	ND	0.003	0.002	0.02	0.01	ND	BDL	0.23
12	KHR-62	0.001	ND	0.002	0.002	0.02	ND	ND	BDL	0.20
13	KHR-63	0.001	ND	0.002	0.002	0.02	0.01	ND	BDL	0.18
14	KHR-64	0.001	ND	0.002	0.001	0.02	0.01	ND	BDL	0.15
BIS (IS:10500-2012)	**AL**	**0.01**	**0.001**	**0.01**	**0.003**	**0.05**	**0.05**	**5**	**0.01**	**0.3**
	PL	**0.05**	**NR**	**NR**	**NR**	**NR**	**1.5**	**15**	**NR**	**NR**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit

The concentrations of major ions in surface water samples and their comparison with BIS limits for the post-monsoon season of 2023 is listed in Table 16. In the post-monsoon 2023 season, F^- concentration ranges between 0.3-8.4 mg/L with an average value of 1.2 mg/L. The concentration of Cl^- ranged from 30 to 280 mg/L, with an average value of 124.6 mg/L. The concentration of NO_3^- ranged from 1.6 to 6.7 mg/L, with an average value of 3.9 mg/L. SO_4^{2-} levels ranged from 6 to 386.2 mg/L with an average value of 80.4 mg/L. Ca^{2+} levels ranged from 15.75 mg/L to 81.45 mg/L, with an average value of 33.31 mg/L. The concentration of K^+ ranged from 0.04 mg/L to 3.07 mg/L with an average value of 0.5 mg/L. The concentration of Mg^{2+} ranged from 9.75 mg/L to 82.2 mg/L with an average value of 24.9 mg/L. Na^+ level ranged from 31.5 mg/L to 185.1 mg/L with an average value of 78.98 mg/L. The HCO_3^- concentration ranged from 105 mg/L to 450 mg/L, with an average value of 201.2 mg/L.

Table 16. Mean concentration (in mg/L) of major ions in surface water samples and their comparison with BIS limits of IS 10500:2012 during post-monsoon 2023 season.

Sr. No.	Code	F^-	Cl^-	Br^-	NO_3^-	PO_4^-	SO_4^{2-}	Ca^{2+}	K^+	Mg^{2+}	Na^+	HCO_3^-	CO_3^-
1	KHR-51	0.5	80	ND	1.6	ND	22.3	20.4	0.06	9.75	31.5	160	ND
2	KHR-52	0.3	90	ND	2.0	ND	6	30.9	1.55	20.4	88.8	340	ND
3	KHR-53	0.8	60	ND	2.3	ND	22.3	31.65	0.09	11.55	39.75	185	ND
4	KHR-54	0.6	100	ND	5.6	ND	188.9	23.4	3.07	18.6	185.1	190	ND
5	KHR-55	0.5	30	ND	6.7	ND	20.0	29.55	0.11	19.65	62.25	145	ND
6	KHR-56	0.8	240	ND	2.7	ND	9.1	15.75	0.07	10.95	40.65	450	ND
7	KHR-57	0.3	60	ND	3.7	ND	10.3	25.05	0.07	10.5	37.2	205	ND
8	KHR-58	**8.4**	170	ND	2.7	ND	198.6	24.1	0.43	63.6	119.55	125	ND
9	KHR-59						DRIED						
10	KHR-60	0.9	280	ND	4.1	ND	386.2	65.3	0.65	82.2	149.25	105	ND
11	KHR-61	0.9	110	ND	4.6	ND	8.0	18.9	0.1	9.9	43.35	165	ND
12	KHR-61Ae	0.6	200	ND	2.7	ND	90.9	81.45	0.05	28.35	99.45	195	ND
13	KHR-62	0.5	90	ND	5.1	ND	17.1	43.2	0.16	24.75	91.05	190	ND
14	KHR-63	0.5	110	ND	7.0	ND	65.4	23.4	0.04	13.35	38.85	160	ND
15	KHR-64	0.5	80	ND	1.6	ND	22.3	20.4	0.06	9.75	31.5	160	ND
BIS limits (IS:10500-2012)	**AL**	**1**	**250**	**NS**	**45**	**NS**	**200**	**75**	**NS**	**30**	**NS**	**NS**	**NS**
	PL	**1.5**	**1000**		**NR**		**400**	**200**		**100**			

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

6.3 Surface Water Quality during Pre-monsoon 2024 Season

The team visited KSTPS Khargone during May 5 – 9, 2024, to undertake a pre-monsoon survey and collection of surface water samples in 10 km buffer zone from the power station area, ash dyke and surrounding area. Surface water samples were collected from identified locations to identify the current sources of contamination, if any. The collected samples were analysed for required water quality parameters. COD and BOD are measured through the oxidation-titration method. In the In-situ analysis of the samples, pH, TDS (Total dissolved solids), EC (Electrical Conductivity), DO (Dissolved Oxygen), and temperature were measured at the water collection site using a multi-meter electrode. Measured values of physical parameters like DO, TDS, EC, pH, Temperature, COD, BOD, and Hardness (COD, BOD, Hardness, DO, and TDS in mg/L; EC in mS/cm; pH in the standard unit and temperature in °C) during the pre-monsoon season are listed in Table 17.

The pH values ranged from 7.55 to 8.38, with a mean value of 7.96. The sample collected from the Lachhora Talab (KHR-56) has the highest pH level, i.e., 8.38. TDS concentrations ranged from 120.00 mg/L to 1030.00 mg/L, with an average value of 364.17mg/L. DO concentrations ranged from 5.17 mg/L to 8.92 mg/L, with a mean value of 6.90mg/L. The EC concentration ranged from 0.26 ms/cm to 2.07 ms/cm, with an average value of 0.74 ms/cm. Hardness ranged from 150.00 mg/L to 520.00 mg/L in the pre-monsoon 2024 period, with an average value of 307.75 mg/L. COD and BOD are also determined in surface water samples during the pre-monsoon season, where the BOD ranged from 4.00 mg/L to 14.00 mg/L with a mean value of 11.83mg/L while COD ranged from 38.00 mg/L to 80.00 mg/L with an average of 55.33mg/L. The temperature of the surface water samples ranged from 27.5 °C to 33.9°C with a mean value of 30.32°C. The mean concentration of heavy metals in the collected surface water samples and their comparison with BIS limits 10500:2012 during the pre-monsoon season (May 2024) is listed in Table 18. The concentration of arsenic (As) ranged from 0.001 ppm to 0.010 ppm, with an average value of 0.003 ppm. Pb mean, min and max concentration 0.001 ppm. The concentration of Cd, Cr, Cu, Zn, Se, and Fe ranged between 0.0002 - 0.0004ppm, 0.008 -0.011ppm, 0.020 - 0.027ppm, 0.121- 0.152 ppm, BDL-0.01, 0.10-0.21, respectively. Mercury (Hg) was below detectable limits in the surface water samples in the pre-monsoon 2024 period.

Ion Chromatography (IC) analysis was performed to measure the concentration of anions such as nitrate (NO_3^-), phosphate (PO_4^-), chloride (Cl^-), fluoride (F^-), bromide (Br^-) and sulphate (SO_4^{2-}). Moreover, cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) were measured using MPAES at the Institute Instrumentation Centre (IIC) of IIT Roorkee. The concentrations of major ions in surface water samples and their comparison with BIS limits is listed in Table 19. In the pre-monsoon 2024 season, F^- concentration ranges between 0.00- 3.52 mg/L with an average value of 0.73mg/L.

The concentration of Cl^- ranged from 8.21- 106.13mg/L, with an average value of 38.18mg/L. The concentration of NO_3^- ranged from 0.00- 7.59 mg/L, with an average value of 2.18mg/L. SO_4^{2-} levels ranged from 9.95- 977.53 mg/L with an average value of 162.65mg/L. Ca^{2+} levels ranged from 0.00- 96.30mg/L, with an average value of 33.81mg/L. The concentration of K^+ ranged from 1.20- 48.00 mg/L with an average value of 7.03mg/L. The concentration of Mg^{2+} ranged from 12.45- 96.15 mg/L with an average value of 35.95 mg/L. Na^+ level ranged from 6.30 - 30.60 mg/L with an average value of 15.04 mg/L. The HCO_3 concentration ranged from 98.00 536.00 mg/L, with an average value of 209.58 mg/L.

Table 17.Physical parameters in surface water samples during the pre-monsoon season of 2024; pH in standard units

S. No.	Code	DO (mg/L)	TDS (mg/L)	EC mS/cm)	pH (Range)	Temp (°C)	BOD (mg/L)	COD (mg/L)	Hardness (mg/L)
1	KHR -51	8.58	430	0.89	7.89	28.8	8	28	520
2	KHR -52	8.92	450	0.91	7.96	31.4	12	38	411
3	KHR -53	5.94	260	0.52	7.92	29.1	14	52	420
4	KHR -54	5.92	150	0.3	7.96	28.3	4	48	200
5	KHR -55	5.25	130	0.27	7.89	33.9	12	48	180
6	KHR -56	7.41	160	0.32	8.15	31.3	10	56	270
7	KHR -57	8.54	190	0.38	8.38	30.1	14	56	220
8	KHR -58	8.30	530	0.97	8.15	31.6	18	54	290
9	KHR -60	8.08	500	0.93	8.19	30.7	14	46	380
10	KHR -61	7.30	120	0.26	7.76	29.4	8	42	150
11	KHR -62	5.73	560	0.99	7.72	29.2	14	80	520
12	KHR -63	5.17	200	0.42	7.84	31.3	12	64	224
13	KHR -64	6.28	190	0.39	7.55	27.5	10	80	428
BIS Limits	**AL**	**NS**	**500**	**NS**	**6.5-8.5**	**NS**	**NS**	**NS**	**200**
	PL		**2000**		**NR**				**600**

Table 18. Mean concentration (in ppm) of heavy metals in the surface water samples and their comparison with BIS limits 10500:2012 during pre-monsoon season 2024

S. No.	Code	As	Hg	Pb	Cd	Cr	Cu	Zn	Se	Fe
1	KHR -51	0.001	ND	0.001	0.0004	0.01	0.02	0.14	0.001	0.1
2	KHR -52	0.003	ND	0.001	0.0003	0.01	0.02	0.13	0.001	0.2
3	KHR -53	0.001	ND	0.001	0.0004	0.01	0.02	0.15	0.001	0.1
4	KHR -54	0.002	ND	0.001	0.0003	0.01	0.02	0.12	0.001	0.1
5	KHR -55	0.001	ND	0.001	0.0004	0.01	0.03	0.12	0.001	0.1
6	KHR -56	0.002	ND	0.001	0.0004	0.01	0.03	0.14	0.001	0.1
7	KHR -57	0.002	ND	0.001	0.0003	0.01	0.02	0.12	0.000	0.1
8	KHR -58	0.005	ND	0.001	0.0003	0.01	0.02	0.13	0.001	0.1
9	KHR -60	0.010	ND	0.001	0.0003	0.01	0.02	0.15	**0.015**	0.2
10	KHR -61	0.002	ND	0.001	0.0003	0.01	0.02	0.13	0.001	0.1
11	KHR -62	0.001	ND	0.001	0.0002	0.01	0.02	0.15	0.003	0.2
12	KHR -63	0.002	ND	0.001	0.0003	0.01	0.02	0.13	0.002	0.1
13	KHR -64	0.002	ND	0.001	0.0004	0.01	0.02	0.13	0.001	0.1
BIS (IS:10500-2012)	**AL**	**0.01**	**0.001**	**0.01**	**0.003**	**0.05**	**0.05**	**5**	**0.01**	**0.3**
	PL	**0.05**	**NR**	**NR**	**NR**	**NR**	**1.5**	**15**	**NR**	**NR**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

Table 19. Mean concentration (in mg/L) of major ions in surface water samples and their comparison with BIS limits of IS 10500:2012 during pre-monsoon season 2024

Sr. No.	Code	F^-	Cl^-	Br^-	NO_3^-	PO_4^-	SO_4^{2-}	Ca^{2+}	K^+	Mg^{2+}	Na^+	HCO_3^-	CO_3^-
1	KHR -51	0.28	75.28	ND	0.00	ND	199.26	45.45	4.50	47.85	22.65	168	ND
2	KHR -52	0.25	106.13	ND	0.00	ND	60.63	25.20	48.00	43.35	30.60	356	ND
3	KHR -53	0.31	31.29	ND	2.56	ND	88.64	39.30	2.25	25.50	10.50	150	ND
4	KHR -54	0.00	10.94	ND	3.37	ND	13.28	27.90	3.45	12.45	6.90	208	ND
5	KHR -55	0.19	8.21	ND	2.18	ND	9.95	21.90	2.40	13.20	6.30	158	ND
6	KHR -56	0.38	18.14	ND	3.17	ND	22.75	21.30	2.25	22.80	12.30	536	ND
7	KHR -57	0.31	9.10	ND	0.00	ND	14.62	54.15	2.25	29.10	10.95	200	ND
8	KHR -58	**3.52**	86.08	ND	2.47	ND	**977.53**	0.00	7.95	96.15	27.75	110	ND
9	KHR -60	**2.53**	76.23	ND	1.49	ND	**679.48**	0.00	8.70	93.15	25.65	98	ND
10	KHR -61	0.50	12.47	ND	0.31	ND	41.53	51.90	2.40	24.45	7.80	148	ND
11	KHR -62	0.24	81.34	ND	0.00	ND	21.52	96.30	1.20	38.10	24.00	176	ND
12	KHR -63	0.58	8.31	ND	7.59	ND	10.91	37.05	1.35	15.60	8.85	200	ND
13	KHR -64	0.00	9.94	ND	3.04	ND	10.92	30.75	2.10	17.55	8.85	175	ND
BIS limits (IS:10500-2012)	**AL**	**1**	**250**	**NS**	**45**	**NS**	**200**	**75**	**NS**	**30**	**NS**	**NS**	**NS**
	PL	**1.5**	**1000**		**NR**		**400**	**200**		**100**			

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit

6.4 *Overall Analysis of Surface Water Quality during the study period*

Overall, the water quality of most of the surface water samples was found to be well within the prescribed limits of BIS standards during the pre and post-monsoon 2023 season as well as pre-monsoon season 2024. The concentration of a few elements such as fluoride, sulphate and some heavy metals such as Fe, Se, and As was found to be slightly higher than the prescribed BIS limits of drinking water in ash dyke samples. They might get seep into the subsurface area and ultimately pollute the groundwater in the near future if not managed properly. Also, the pH values were slightly high in samples collected from the ash dyke area; however, the overall pH range suggests that the surface water quality is slightly of alkaline nature in the present study area.

7 GROUNDWATER QUALITY AT IDENTIFIED LOCATIONS AND CURRENT SOURCES OF CONTAMINATION.

Groundwater sampling locations were identified based on the reconnaissance site survey of the power station area. The identified locations and probable sources of contamination were assessed thoroughly based on the groundwater chemical analysis of the study area. The groundwater samples were collected from existing handpumps, tube wells, piezometers and bore wells. Prior to collecting the samples, the purging of sources was performed for 10-15 minutes. Also, the sampling bottles were rinsed with the same water thrice while sampling. During the In-situ analysis of the groundwater samples, pH, TDS (Total dissolved solids), EC (Electrical Conductivity), DO (Dissolved Oxygen), and temperature were measured at the sample collection site using a multi-meter electrode. Thereafter, collected water samples were brought to the groundwater laboratory of IIT Roorkee for further analysis to determine its quality for domestic purposes.

7.1 Groundwater Quality for Pre-monsoon 2023 Season

The groundwater sampling for the pre-monsoon season was undertaken during April 25 – 30, 2023. Salient details such as sample code, station name, location, and type of analysis for which groundwater samples were collected are given in Table 20. The geographical location of groundwater sampling points during the pre-monsoon 2023 season is shown in Figure 15.

Table 20. Location of collected groundwater samples in the study area during the pre-monsoon period (April 2023) for In-situ/Ex-situ analyses.

S.No.	Code	Latitude	Longitude	Station Name	Type of Analysis	Type of Site
1	KHR-1	22.07775	75.83155	Vill. Dalchi	In-situ and Ex-situ	Hand pump
2	KHR-2	22.0609	75.7653	Vill. Bhatyaan Khurd	In-situ and Ex-situ	Hand pump
3	KHR-3	22.06926	75.85789	Near NTPC opp Bhilal Baba Temple, Gate No. 1	In-situ and Ex-situ	Hand pump
4	KHR-4	22.0688	75.86202	Between NTPC & Township	In-situ and Ex-situ	Hand pump
5	KHR-5	22.12494	75.8952	Inside Primary School, Vill Baddgaon	In-situ and Ex-situ	Hand pump
6	KHR-6	22.12242	75.84251	Opp. Madhya Pradesh Gramin Bank, Vill Kanapur	In-situ and Ex-situ	Hand pump
7	KHR-7	22.1235	75.794	In House of sh. Daya Ram, Vill Londhi (Jhirbar)	In-situ and Ex-situ	Hand pump
8	KHR-8A	22.10271	75.75548	Karan Gangle Handpump, Pipalgone village.	In-situ and Ex-situ	Hand pump
9	KHR-9A	22.10857	75.75845	Lokesh Rathore Tubewell, Pipalgaon	In-situ and Ex-situ	Tube well
10	KHR-10A	22.04086	75.81116	Near Roop Singh house, Bhopada	In-situ and Ex-situ	Hand pump

11	KHR-11	22.00759	75.85122	Near KHR 12, Hanuman Temple, Padaliya village	In-situ and Ex-situ	Hand pump
12	KHR-12	22.00728	75.85394	Padaliya village	In-situ and Ex-situ	Hand pump
13	KHR-13	22.06608	75.87139	Adjoining of NTPC Community Centre	In-situ and Ex-situ	Hand pump
14	KHR-14	22.0493	75.87783	Opp Gram Panchayat office. Vill Kheri Bujurg	In-situ and Ex-situ	Hand pump
15	KHR-15	22.06923	75.85798	Near Bhilal Baba Temple, Near NTPC Gate No. 1	In-situ and Ex-situ	Hand pump
16	KHR-17	22.06947	75.85227	Below Tower Line, North side of Power station,	In-situ and Ex-situ	Seepage
17	KHR-18	22.06295	75.85256	Well inside power station	In-situ and Ex-situ	Open well
18	KHR-19	22.07518	75.82482	Near Baba Ramdev Mandir, Dalchi	In-situ and Ex-situ	Hand pump
19	KHR-20	22.09205	75.84918	Below Tower Line, North side of Power station,	In-situ and Ex-situ	Hand pump
20	KHR-25	22.02839	75.89527	Rewa Gurjar Dharamshala, Umaria	In-situ and Ex-situ	Hand pump
21	KHR-Pz1	22.07826	75.8367	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
22	KHR-Pz2	22.07721	75.83306	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
23	KHR-Pz3	22.07476	75.83177	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
24	KHR-Pz4	22.07289	75.83233	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
25	KHR-Pz5	22.07055	75.83277	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
26	KHR-Pz6	22.07089	75.83548	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer

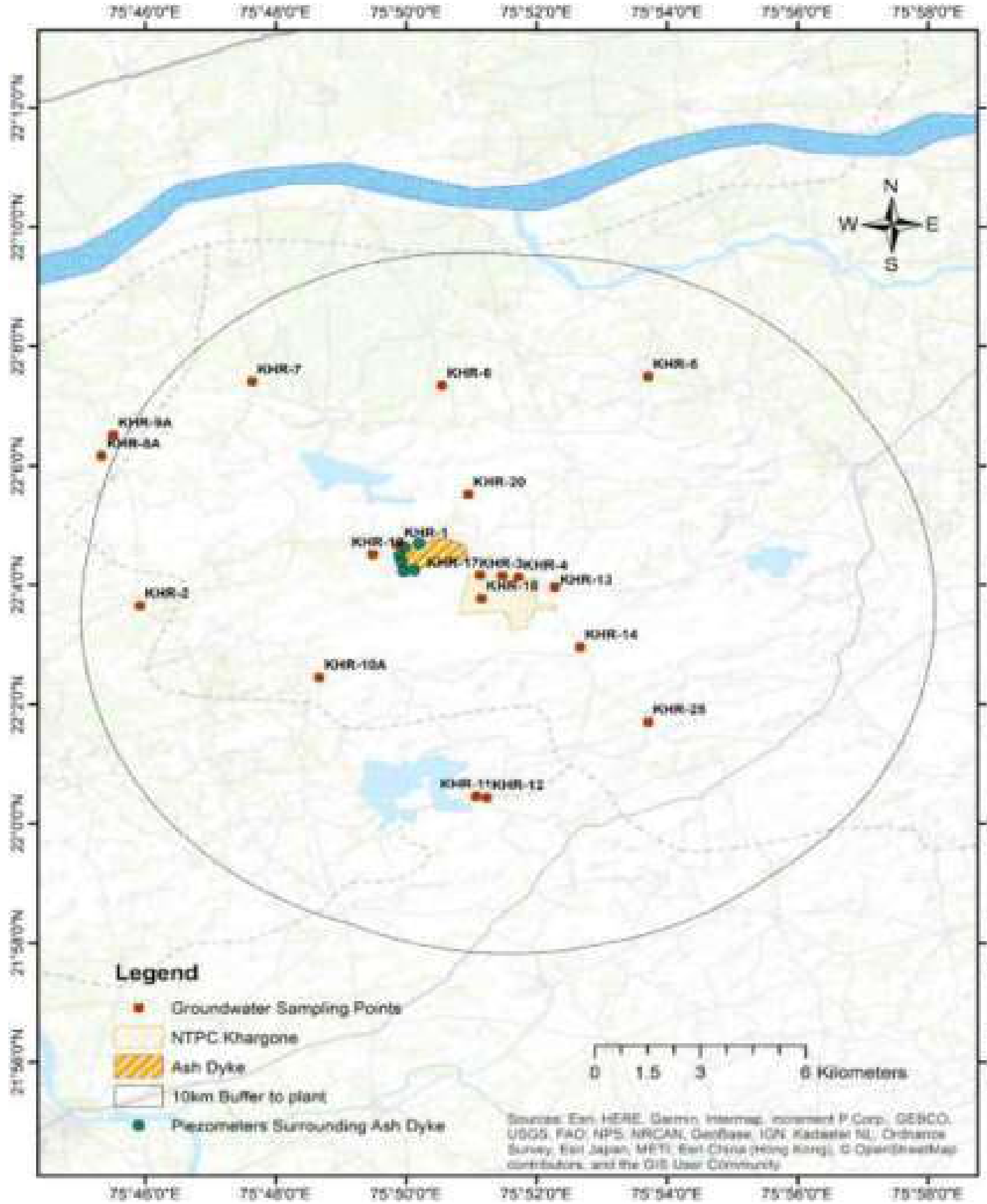

Figure 15. Groundwater sampling points during the pre-monsoon 2023 season.

The mean value of in-situ parameters for the pre-monsoon period is listed in Table 21. The DO concentrations ranged from 1.1 mg/L to 5.9 mg/L, with a mean value of 3.2 mg/L. TDS concentrations range from 230 mg/L to 730 mg/L in the pre-monsoon period, with an average value of 466.6 mg/L. The EC concentration ranged from 470 µs/cm to 1460 µs/cm, with an average value of 940 µs/cm. The pH value ranged between 5.7-8, with an average value of 7 in the pre-monsoon period. The temperature of groundwater in pre-monsoon ranged from 28.6°C to 32.8°C with an average value of 30.5°C. The Hardness ranged from 57.6 mg/L to 789.9 mg/L in the pre-monsoon period, with an average of 511.3 mg/L.

Table 21. Measured values of physical parameters (DO, TDS, EC, pH, Hardness and Temperature) in the groundwater samples during the pre-monsoon 2023 season from In-situ analysis.

S.No.	Code	DO (mg/L)	TDS (mg/L)	EC (µS/cm)	pH	Temp (°C)	Hardness
1	KHR-1	3.35	630	1260	6.74	31.3	**657**
2	KHR-2	1.5	540	1090	**5.65**	31.7	433
3	KHR-3	2.84	480	980	6.98	30.7	511
4	KHR-4	5.88	320	650	7.16	28.9	395
5	KHR-5	1.14	300	610	8.03	31	58
6	KHR-6	2.85	520	1030	6.74	29.1	**635**
7	KHR-7	1.6	410	820	6.91	29.8	569
8	KHR-8A	2.59	230	470	6.9	32.1	245
9	KHR-9A	4.29	410	840	6.97	31.3	325
10	KHR-10A	1.46	260	530	7.37	32.8	272
11	KHR-11	3.36	355	650	7.23	32.3	303
12	KHR-12	3.51	380	700	6.83	29.3	204
13	KHR-13	1.41	440	880	6.91	32.4	**606**
14	KHR-14	4.25	450	920	6.68	29.9	433
15	KHR-15	3.8	440	900	6.98	31.8	542
16	KHR-17	4.79	480	970	7.05	29.8	**698**
17	KHR-18	5.58	690	1390	7.16	29	**778**
18	KHR-19	1.94	570	1140	6.98	30	246
19	KHR-20	2.8	390	800	6.78	31.8	**623**
20	KHR-25	2.19	600	1210	6.65	30.1	**790**
21	KHR-Pz1	4.72	407	920	6.98	28.7	**747**
22	KHR-Pz2	3.03	620	1250	7.11	29.7	**627**
23	KHR-Pz3	3.16	730	1460	7.11	29	521
24	KHR-Pz4	4.36	430	870	7.7	28.6	**723**
25	KHR-Pz5	2.88	480	960	6.64	30.4	**691**
26	KHR-Pz6	3.82	570	1140	6.78	31.4	**663**
BIS Limits (IS:10500-2012)	**AL**	**NS**	**500**	**NS**	**6.5-8.5**	**NS**	**200**
	PL		**2000**		**NR**		**600**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

Concentrations of major ions and other elements measured in groundwater samples and their comparison with BIS limits for the pre-monsoon season are shown in Table 22. The concentration of F- ranged from 0.3 mg/L to 3.3 mg/L, with an average value of 0.6 mg/L. Only one sample collected from inside the primary school in the village of Baddgaon showed an elevated level of fluoride. This might be due to the presence of traces of substances or minerals that include fluoride. These substances may be released into the groundwater when they are burned (coal) or dissolved (rock). The concentration of Cl- ranged from 16.4 mg/L to 125.4 mg/L, with an average value of 59.8 mg/L. NO3- levels ranged from BDL mg/L to 139.7 mg/L, with an average of 36.1 mg/L. Out of 26 samples, approximately 34% of the samples have increased nitrate levels. This could be a result of heavy usage of nitrogenous fertilisers by local farmers, which leak into the groundwater table. SO42- levels ranged from 19.6 mg/L to 996.8 mg/L, with an average of 312.7 mg/L. About 31% of the samples showed elevated levels of SO42-. This could be a result of SO42- spontaneously entering groundwater as a result of mineral disintegration from geological formations. Also, anthropogenic activities, such as the use of sulphate-based fertilisers or animal waste, can add sulphate to the soil, which eventually reaches the groundwater table through leaching or runoff might be the possible reasons for elevated SO42- concentration in the study area. In the pre-monsoon season, the Ca2+ concentration ranged from 13.6 mg/L to 241 mg/L, averaging 151.6 mg/L. Likewise, K+ concentration ranged from 0.33 mg/L to 13.06 mg/L, with a mean value of 2.25 mg/L. The Mg concentration ranged from 3.42 mg/L to 72.21 mg/L, with an average value of 32.25 mg/L. Na values varied between 1.46-149.2 mg/L with a mean value of 84.4 mg/L in the pre-monsoon season. The concentration of HCO3- varied between 91-546 mg/L with a mean value of 309.5 mg/L.

The mean concentration of heavy metals in the collected groundwater samples and their comparison with BIS limits are listed in Table 23. The concentration of arsenic (As) ranged from 0.005 ppm to 0.010 ppm, with a mean value of 0.006 ppm. Mercury (Hg) was not detected in any groundwater sample in the current pre-monsoon 2023 season. Pb levels ranged from 0.001 to 0.008 ppm, averaging 0.002 ppm. The rest of the elements, such as Cd (BDL-0.001), Cr (0.006-0.015), Cu (0.029-0.116), Zn (0.07-

1.002), Se (BDL-0.015), and Fe (0.007-4.97) varied with average values of 0.001, 0.008, 0.04, 0.23, 0.003, and 0.47 ppm, respectively. About 29% of the groundwater samples showed an elevated concentration of Fe in the present study area. This may be due to localized corrosion in the casing pipes of hand pumps. Moreover, natural geological processes may also be attributed to the release of iron into groundwater from iron-bearing minerals and rocks in the study area.

Table 22. Mean concentration (in mg/L) of major ions in Groundwater samples and their comparison with BIS limits during pre-monsoon 2023 season.

Sr. No.	Code	F^-	Cl^-	Br^-	NO_3^-	PO_4^-	SO_4^{2-}	Ca	K	Mg	Na	CO_3^-	HCO_3^-
1	KHR-1	0.3	71.1	ND	5.4	ND	**803**	185	1	47.3	36.1	ND	245
2	KHR-2	0.5	85.1	ND	41.4	ND	57.6	133.5	13.1	24.3	125.0	ND	91
3	KHR-3	0.6	72.6	ND	13.2	ND	**414.1**	142.8	0.5	37.5	86.2	ND	170
4	KHR-4	0.5	50.1	ND	34.4	ND	219.8	111	0.7	28.6	34.8	ND	254
5	KHR-5	**3.3**	48.8	ND	12.4	ND	98.9	17.4	0.9	3.4	135.7	ND	312
6	KHR-6	0.5	72.7	ND	**111.8**	ND	131.8	164.8	7.7	54.2	88.7	ND	546
7	KHR-7	0.4	42.3	ND	**63.0**	ND	68.3	168.8	1.4	35.7	41.8	ND	390
8	KHR-8A	0.5	18.6	ND	22.5	ND	19.6	69.2	0.3	17.6	74.4	ND	267
9	KHR-9A	0.4	71.7	ND	**65.4**	ND	53.5	70	0.9	36.5	91.5	ND	379
10	KHR-10A	0.5	38.9	ND	32.2	ND	67.6	98.7	0.7	6.3	123.5	ND	395
11	KHR-11	0.6	24.3	ND	**63.0**	ND	60.8	76.8	3	27	1.5	ND	410
12	KHR-12	0.7	16.4	ND	**62.7**	ND	48.6	13.6	1.1	41.2	45.5	ND	405
13	KHR-13	0.5	30.6	ND	12.4	ND	135.8	209.2	1.3	20.2	131.8	ND	315
14	KHR-14	0.9	62.3	ND	**139.7**	ND	47.2	115	0.7	35.3	39.9	ND	290
15	KHR-15	0.6	58.7	ND	**58.2**	ND	284.7	189	0.8	17.1	120.3	ND	265
16	KHR-17	0.6	100.4	ND	7.7	ND	**429.5**	212.5	2.2	40.7	104.0	ND	220
17	KHR-18	0.6	39.7	ND	15.8	ND	**921.1**	192.6	0.3	72.2	67.8	ND	324
18	KHR-19	0.5	78.6	ND	6.2	ND	**787.3**	75.4	3.1	14	149.2	ND	345
19	KHR-20	0.4	43.6	ND	**45.7**	ND	117.9	195.8	0.6	32.5	68.9	ND	416
20	KHR-25	0.3	43.9	ND	**75.2**	ND	56.6	225.6	5	55	134.1	ND	110
21	KHRPz-1	0.4	125.4	ND	27.6	ND	116.7	241	1.6	35.4	60.8	ND	415
22	KHRPz-2	0.3	72.5	ND	1.4	ND	**996.8**	202	0.9	29.7	80.0	ND	286
23	KHRPz-3	0.3	68.0	ND	4.8	ND	**983.7**	190.1	1.1	11.2	126.1	ND	315
24	KHRPz-4	0.8	86.3	ND	ND	ND	**585.5**	222	7.3	41	87.2	ND	264
25	KHRPz-5	0.5	46.1	ND	ND	ND	187.2	235.7	1.8	24.7	101.2	ND	324
26	KHRPz-6	0.4	86.1	ND	16.4	ND	**436.2**	183.4	0.6	49.8	38.5	ND	295
BIS limits (IS:10500-2012)	**AL**	**1**	**250**	**NS**	**45**	**NS**	**200**	**75**	**NS**	**30**	**NS**	**NS**	**NS**
	PL	**1.5**	**1000**		**NR**		**400**	**200**		**100**			

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

About 46% of groundwater samples show hard water quality. This might be due to the presence of excess Ca and Mg concentration in the groundwater samples. Only one sample collected from the village of Bhatyaan Khurd has the lowest pH value. This might be due to any mineral dissolution or leaching of surface water. Overall, the groundwater quality in the pre-monsoon season is suitable for domestic use, indicating that it meets the standards and requirements necessary to provide safe and clean water for households.

Table 23. Mean concentration (in ppm) of heavy metals in the groundwater samples and their comparison with BIS limits during the pre-monsoon 2023 season.

S. No.	Code	As	Hg	Pb	Cd	Cr	Cu	Zn	Se	Fe
1	KHR-1	0.008	ND	0.002	0.001	0.01	0.04	0.97	ND	**0.39**
2	KHR-2	0.005	ND	0.002	0.001	0.01	0.04	0.98	ND	**1.35**
3	KHR-3	0.007	ND	0.002	0.001	0.01	0.03	0.16	ND	0.08
4	KHR-4	0.005	ND	0.002	0.001	0.01	0.03	0.07	ND	0.13
5	KHR-5	0.010	ND	0.002	BDL	0.01	0.04	0.15	ND	**0.52**
6	KHR-6	0.005	ND	0.002	BDL	0.01	0.05	0.13	ND	**0.36**
7	KHR-7	0.006	ND	0.001	0.001	0.01	0.03	0.14	ND	0.27
8	KHR-8A	0.008	ND	0.002	0.001	0.01	0.04	0.21	0.01	0.23
9	KHR-9A	0.009	ND	0.002	0.001	0.01	0.04	0.15	0.01	0.13
10	KHR-10A	0.008	ND	0.002	0.001	0.01	0.04	0.23	**0.02**	**0.38**
11	KHR -11	0.006	ND	0.002	0.001	0.01	0.04	0.08	ND	0.15
12	KHR -12	0.006	ND	0.002	BDL	0.01	0.03	0.09	ND	0.18
13	KHR -13	0.006	ND	0.002	0.001	0.01	0.04	0.13	0.01	0.09
14	KHR -14	0.006	ND	0.002	0.001	0.01	0.07	0.48	ND	0.21
15	KHR -15	0.005	ND	0.002	0.001	0.01	0.03	0.13	0.01	0.17
16	KHR-17	0.006	ND	0.002	BDL	0.01	0.03	0.08	ND	0.17
17	KHR-18	0.006	ND	0.002	0.001	0.01	0.03	0.07	ND	0.20
18	KHR-19	0.006	ND	0.002	0.001	0.01	0.03	0.08	ND	0.12
19	KHR-20	0.006	ND	0.002	0.001	0.01	0.03	0.11	ND	0.10
20	KHR-25	0.007	ND	0.005	0.001	0.01	0.06	1.00	ND	**4.97**
21	KHR PZ-1	0.006	ND	0.003	0.001	0.01	0.03	0.09	ND	0.13
22	KHR PZ-2	0.006	ND	0.002	0.001	0.01	0.04	0.07	ND	0.13
23	KHR PZ-3	0.006	ND	0.002	0.001	0.01	0.03	0.11	ND	0.17
24	KHR PZ-4	0.007	ND	0.005	0.001	0.02	0.03	0.13	ND	**0.33**
25	KHR PZ-5	0.007	ND	0.008	0.001	0.01	0.12	0.10	ND	**0.98**
26	KHR PZ-6	0.006	ND	0.002	0.001	0.01	0.03	0.09	ND	0.20
BIS (IS:10500-2012)	**AL**	**0.01**	**0.001**	**0.01**	**0.003**	**0.05**	**0.05**	**5**	**0.01**	**0.3**
	PL	**0.05**	**NR**	**NR**	**NR**	**NR**	**1.5**	**15**	**NR**	**NR**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

7.2 Groundwater Quality for Post-monsoon 2023 Season

The groundwater sampling for the post-monsoon 2023 season was undertaken during October 9 – 13, 2023. Salient details such as sample code, station name, location, and type of analysis for which groundwater samples were collected are given in Table 24.

Table 24. Location of collected groundwater samples in the study area during the post-monsoon 2023 season for In-situ/Ex-situ analyses.

S.No.	Code	Latitude	Longitude	Station Name	Type of Analysis	Type of Site
1	KHR-1	22.07775	75.83155	Vill. Dalchi	In-situ and Ex-situ	Hand pump
2	KHR-2	22.0609	75.7653	Vill. Bhatyaan Khurd	In-situ and Ex-situ	Hand pump
3	KHR-3	22.06926	75.85789	Near NTPC opp Bhilal Baba Temple, Gate No. 1	In-situ and Ex-situ	Hand pump
4	KHR-4	22.0688	75.86202	Between NTPC & Township	In-situ and Ex-situ	Hand pump
5	KHR-5	22.12494	75.8952	Inside Primary School, Vill Baddgaon	In-situ and Ex-situ	Hand pump
6	KHR-6	22.12242	75.84251	Opp. Madhya Pradesh Gramin Bank, Vill Kanapur	In-situ and Ex-situ	Hand pump
7	KHR-7	22.1235	75.794	In House of sh. Daya Ram, Vill Londhi (Jhirbar)	In-situ and Ex-situ	Hand pump
8	KHR-8A	22.10271	75.75548	Karan Gangle Handpump, Pipalgone village.	In-situ and Ex-situ	Hand pump
9	KHR-9A	22.10857	75.75845	Lokesh Rathore Tubewell, Pipalgaon	In-situ and Ex-situ	Tube well
10	KHR-10A	22.04086	75.81116	Near Roop Singh house, Bhopada	In-situ and Ex-situ	Hand pump
11	KHR-11	22.00759	75.85122	Near KHR 12, Hanuman Temple, Padaliya village	In-situ and Ex-situ	Hand pump
12	KHR-12	22.00728	75.85394	Padaliya village	In-situ and Ex-situ	Hand pump
13	KHR-13	22.06608	75.87139	Adjoining of NTPC Community Centre	In-situ and Ex-situ	Hand pump
14	KHR-14	22.0493	75.87783	Opp Gram Panchayat office. Vill Kheri Bujurg	In-situ and Ex-situ	Hand pump
15	KHR-15	22.06923	75.85798	Near Bhilal Baba Temple, Near NTPC Gate No. 1	In-situ and Ex-situ	Hand pump
16	KHR-17	22.06947	75.85227	Below Tower Line, North side of Power station,	In-situ and Ex-situ	Seepage
17	KHR-18	22.06295	75.85256	Well inside power station	In-situ and Ex-situ	Open well
18	KHR-19	22.07518	75.82482	Near Baba Ramdev Mandir, Dalchi	In-situ and Ex-situ	Hand pump
19	KHR-20	22.09205	75.84918	Below Tower Line, North side of Power station,	In-situ and Ex-situ	Hand pump
20	KHR-25	22.02839	75.89527	Rewa Gurjar Dharamshala, Umaria	In-situ and Ex-situ	Hand pump
21	KHR-Pz1	22.07826	75.8367	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
22	KHR-Pz2	22.07721	75.83306	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
23	KHR-Pz3	22.07476	75.83177	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
24	KHR-Pz4	22.07289	75.83233	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
25	KHR-Pz5	22.07055	75.83277	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
26	KHR-Pz6	22.07089	75.83548	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer

The mean value of in-situ parameters for the post-monsoon period is listed in Table 25. The DO concentrations ranged from 1.35 mg/L to 6.58 mg/L, with a mean value of 2.9 mg/L. TDS concentrations range from 225 mg/L to 1060 mg/L in the post-monsoon period, with an average value of 452.7 mg/L. The EC concentration ranged from 460 µs/cm to 2140 µs/cm, with an average value of 913.8 µs/cm. The pH value ranged between 6.85 -7.98, with an average value of 7.2 in the post-monsoon period. The temperature of groundwater in post-monsoon ranged from 27.7°C to 32.9°C with an average value of 30.3°C. The Hardness ranged from 29 mg/L to 870 mg/L in the pre-monsoon period, with an average of 390 mg/L.

Table 25. Measured values of physical parameters (DO, TDS, EC, pH, Hardness and Temperature) in the groundwater samples during the post-monsoon 2023 season from In-situ analysis.

S.No.	Code	DO (mg/L)	TDS (mg/L)	EC (µS/cm)	pH	Temp (°C)	Hardness
1	KHR-1	2.9	590	1160	6.9	29.1	625
2	KHR-2	1.9	470	950	7.1	29.3	549
3	KHR-3	3.6	460	940	7.34	30.3	245
4	KHR-4	6.58	490	1000	7.63	27.7	406
5	KHR-5	1.9	280	570	7.98	29.4	29
6	KHR-6	2.2	550	1130	7.1	28.4	457
7	KHR-7	1.9	420	850	6.9	31.3	397
8	KHR-8A	2.7	225	460	7.1	30.4	120
9	KHR-9A	3.9	410	820	7.04	32.9	375
10	KHR-10A	1.7	275	550	7.3	30.2	234
11	KHR-11	2.18	350	720	7.6	32.3	155
12	KHR-12	2.96	360	750	7.02	30.1	330
13	KHR-13	1.9	550	1100	7.24	30.7	620
14	KHR-14	2.82	590	1190	6.9	32.1	435
15	KHR-15	4.1	410	850	7.1	29.4	491
16	KHR-17	4.97	470	960	7.3	29.3	297
17	KHR-18	4.23	270	550	7.34	31.8	736
18	KHR-19	2.3	540	1020	7.21	28.21	253
19	KHR-20	3.1	430	870	6.9	32.1	365
20	KHR-25	1.35	510	1020	7.18	30.9	331
21	KHR-Pz1	3.6	400	810	7.52	29.1	332
22	KHR-Pz2	2.3	1060	2140	7.08	29.2	793
23	KHR-Pz3	2.6	270	550	7.42	29.9	230
24	KHR-Pz4	1.6	770	1550	7.28	30.1	871
25	KHR-Pz5	2.7	350	700	6.85	30.8	341
26	KHR-Pz6	3.7	270	550	7.34	31.8	135
BIS Limits (IS:10500-2012)	**AL**	**NS**	**500**	**NS**	**6.5-8.5**	**NS**	**200**
	PL		**2000**		**NR**		**600**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

Concentrations of major ions and other elements measured in groundwater samples and their comparison with BIS limits during the post-monsoon 2023 season are listed in Table 26. The concentration of F^- ranged from BDL to 7.6 mg/L, with an average value of 0.9 mg/L. The concentration of Cl^- ranged from 50 mg/L to 439.9 mg/L, with an average value of 147.8 mg/L. NO_3^- levels ranged from BDL mg/L to 206 mg/L, with an average of 60.9 mg/L. SO_4^{2-} levels ranged from BDL to 284.7 mg/L, with an average of 82.9 mg/L. In the post -monsoon season, the Ca^{2+} concentration ranged from 8.4 mg/L to 215.8 mg/L, averaging 104.2 mg/L. Likewise, K^+ concentration ranged from 0.02 mg/L to 26.85 mg/L, with a mean value of 1.9 mg/L. The Mg concentration ranged from 1.95 mg/L to 80.55 mg/L, with an average value of 31.6 mg/L. Na values varied between 49.35-300.15 mg/L with a mean value of 141.4 mg/L in the post-monsoon season. The concentration of HCO_3^- varied between 110-455 mg/L with a mean value of 286.2 mg/L.

The mean concentration of heavy metals in the collected groundwater samples and their comparison with BIS limits 10500:2012 during the post-monsoon 2023 season is listed in Table 27. The concentration of arsenic (As) ranged from BDL to 0.004 ppm with a mean value of 0.001 ppm. The concentration of Mercury (Hg) ranged from BDL to 0.012 ppm with a mean value of 0.001 ppm. Pb level ranged from BDL to 0.024 ppm with an average of 0.004 ppm. The rest of the elements, such as Cd (BDL-0.007), Cr (BDL-0.151), Cu (BDL-0.037), Zn (BDL- 0.707), Se (BDL-0.011), and Fe (BDL-0.837) varied with average values of 0.002, 0.024, 0.008, 0.113, 0.001, and 0.255 ppm, respectively.

Table 26. Mean concentration (in mg/L) of major ions in Groundwater samples and their comparison with BIS limits of IS 10500:2012 during post-monsoon 2023 season.

Sr. No.	Code	F^-	Cl^-	Br^-	NO_3^-	PO_4^-	SO_4^{2-}	Ca	K	Mg	Na	CO_3^-	HCO_3^-
1	KHR-1	0.3	140	ND	20.5	ND	199.3	158	1.2	55.95	49.4	ND	210
2	KHR-2	0.7	210	ND	62.1	ND	42.1	147	0.9	44.1	93.3	ND	110
3	KHR-3	0.7	100	ND	22.6	ND	142	70.35	26.85	16.95	237.3	ND	165
4	KHR-4	BDL	120	ND	BDL	ND	BDL	99.45	1.05	38.25	85.1	ND	250
5	KHR-5	**7.6**	150	ND	10	ND	27	8.4	1.5	1.95	270.3	ND	295
6	KHR-6	0.4	150	ND	86.5	ND	30.9	97.05	9.3	52.05	120.8	ND	455
7	KHR-7	0.6	80	ND	79.3	ND	14.2	101.4	1.5	34.95	64.7	ND	350
8	KHR-8A	0.7	50	ND	16.5	ND	5.7	43.65	0.9	2.7	141.3	ND	265
9	KHR-9A	0.3	90	ND	135.4	ND	17	94.65	1.05	33.6	104.7	ND	310
10	KHR-10A	0.7	120	ND	94.4	ND	47.1	71.1	0.9	13.65	218.4	ND	410
11	KHR-11	0.6	100	ND	48.4	ND	7.9	53.55	0.09	5.1	284.6	ND	390
12	KHR-12	0.4	70	ND	118.9	ND	42.4	77.4	1.8	33.15	73.2	ND	375
13	KHR-13	0.6	180	ND	187.5	ND	75.2	190.1	2.55	35.4	171	ND	290
14	KHR-14	0.5	180	ND	200.6	ND	58.5	105.6	0.06	41.55	72.8	ND	275
15	KHR-15	0.4	65	ND	45	ND	284.7	145	0.2	31.2	96.4	ND	245
16	KHR-17	0.6	140	ND	26.5	ND	65.4	91.8	0.03	16.5	54.6	ND	245

17	KHR-18	**1.6**	160	ND	54	ND	197.7	180.7	0.03	69.15	97.8	ND	310
18	KHR-19	0.5	100	ND	14.6	ND	184.6	82.4	0.11	11.4	300.2	ND	290
19	KHR-20	0.3	140	ND	101.8	ND	184.6	96.3	0.03	30.3	100.4	ND	390
20	KHR-25	0.8	140	ND	100.2	ND	59	88.95	0.12	26.4	287	ND	150
21	KHRPz-1	0.4	360	ND	25.7	ND	41.5	92.55	0.08	24.45	98.4	ND	310
22	KHRPz-2	0.3	120	ND	12.2	ND	31.1	196.1	0.04	73.65	115.7	ND	310
23	KHRPz-3	0.5	440	ND	16.1	ND	188	71.4	0.06	12.45	77.1	ND	290
24	KHRPz-4	**2.9**	160	ND	15.4	ND	12.4	215.8	0.13	80.55	210.8	ND	245
25	KHRPz-5	0.7	120	ND	72	ND	163.9	87.9	0.06	29.55	71.4	ND	265
26	KHRPz-6	0.6	160	ND	16	ND	34	42.3	0.02	7.05	180.5	ND	240
BIS limits (IS:10500-2012)	**AL**	**1**	**250**	**NS**	**45**	**NS**	**200**	**75**	**NS**	**30**	**NS**	**NS**	**NS**
	PL	**1.5**	**1000**		**NR**		**400**	**200**		**100**			

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

Table 27. Mean concentration (in ppm) of heavy metals in the groundwater samples and their comparison with BIS limits 10500:2012 during post-monsoon 2023 season

S.No.	Code	As	Hg	Pb	Cd	Cr	Cu	Zn	Se	Fe
1	KHR-1	0.002	0.004	0.003	0.003	0.02	0.005	0.46	BDL	0.18
2	KHR-2	0.001	0.001	0.002	0.004	0.02	0.006	0.06	0.002	0.15
3	KHR-3	0.001	BDL	0.003	0.002	0.02	0.010	0.71	0.002	0.43
4	KHR-4	0.001	BDL	0.003	0.002	0.02	0.004	0.06	BDL	0.25
5	KHR-5	0.004	BDL	0.003	0.002	0.02	0.003	0.02	BDL	0.45
6	KHR-6	0.001	0.012	BDL	0.007	0.15	0.015	BDL	0.001	0.53
7	KHR-7	0.001	BDL	0.005	0.002	0.02	0.013	0.02	BDL	0.26
8	KHR-8A	0.001	BDL	0.002	0.001	0.02	0.004	0.06	0.011	0.34
9	KHR-9A	0.001	BDL	0.004	0.002	0.02	0.009	0.01	BDL	0.20
10	KHR-10A	0.001	BDL	0.003	0.002	0.02	0.004	0.55	0.005	0.29
11	KHR -11	0.001	BDL	0.003	0.002	0.02	0.005	BDL	BDL	0.17
12	KHR -12	0.001	BDL	0.003	0.002	0.02	0.008	0.01	BDL	0.21
13	KHR -13	0.002	BDL	0.003	0.002	0.02	0.007	BDL	BDL	0.19
14	KHR -14	0.001	BDL	0.002	0.002	0.02	0.037	0.43	BDL	0.25
15	KHR -15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
16	KHR-17	0.001	BDL	0.002	0.002	0.02	0.002	BDL	BDL	0.21
17	KHR-18	0.001	BDL	0.003	0.003	0.02	0.005	BDL	BDL	0.21
18	KHR-19	0.001	0.002	0.002	0.002	0.02	0.005	BDL	BDL	0.20
19	KHR-20	0.001	BDL	0.002	0.001	0.02	0.004	0.04	BDL	0.26
20	KHR-25	0.001	BDL	0.003	0.002	0.02	0.007	0.45	BDL	0.84
21	KHR PZ-1	0.001	BDL	0.024	0.002	0.02	0.011	0.05	0.001	0.18
22	KHR PZ-2	0.001	BDL	0.002	0.001	0.02	0.004	0.01	BDL	0.16
23	KHR PZ-3	0.001	BDL	0.010	0.002	0.02	0.009	BDL	BDL	0.15
24	KHR PZ-4	0.001	BDL	0.009	0.001	0.02	0.005	BDL	0.002	0.23
25	KHR PZ-5	0.001	BDL	0.003	0.001	0.02	0.014	BDL	BDL	0.16
26	KHR PZ-6	0.001	BDL	0.008	0.001	0.02	0.007	BDL	0.009	0.14
BIS (IS:10500-2012)	**AL**	**0.01**	**0.001**	**0.01**	**0.003**	**0.05**	**0.05**	**5**	**0.01**	**0.3**
	PL	**0.05**	**NR**	**NR**	**NR**	**NR**	**1.5**	**15**	**NR**	**NR**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

7.3 *Groundwater Quality for Pre-monsoon 2024 Season*

The groundwater sampling for the pre-monsoon season was undertaken May 5 – 9, 2024. The mean value of in-situ parameters for the pre-monsoon period is listed in Table 28. The DO concentrations ranged from 1.80 mg/L to 7.01 mg/L, with a mean value of 4.15 mg/L. TDS concentrations range from 280mg/L to 950mg/L in the pre-monsoon period, with an average value of 531.82mg/L. The EC concentration ranged from 0.58 ms/cm to 1.91 ms/cm, with an average value of 1.07 ms/cm. The pH value ranged between 7.07 to 8.32, with an average value of 7.46 in the pre-monsoon period. The temperature of groundwater in pre-monsoon ranged from 28.30 to 34.80°C with an average value of 30.60 °C. The Hardness ranged from 64 mg/L to 788 mg/L in the pre-monsoon period, with an average of 483.09 mg/L. Concentrations of major ions and other elements measured in groundwater samples and their comparison with BIS limits for the pre-monsoon season are shown in Table 29. The concentration of F- ranged from 0.000mg/L to 0.887mg/L, with an average value of 0.276 mg/L. The concentration of Cl- ranged from 16.59mg/L to 113.70mg/L, with an average value of 53.16 mg/L. NO_3^- levels ranged from 1.55mg/L to 85.64 mg/L, with an average of 25.13mg/L. Out of 23 samples, approximately 9.96% of the samples have increased nitrate levels. This could be a result of heavy usage of nitrogenous fertilisers by local farmers, which leak into the groundwater table. SO_4^{2-} levels ranged from 12.35mg/L to 811.67mg/L, with an average of 165.93mg/L. About 9.96% of the samples showed elevated levels of SO_4^{2-}. This could be a result of SO_4^{2-} spontaneously entering groundwater as a result of mineral disintegration from geological formations. Also, anthropogenic activities, such as the use of sulphate-based fertilisers or animal waste, can add sulphate to the soil, which eventually reaches the groundwater table through leaching or runoff might be the possible reasons for elevated SO_4^{2-} concentration in the study area. In the pre-monsoon season, the Ca^{2+} concentration ranged from 0.00 mg/L to 196.65mg/L, averaging 87.72mg/L. Likewise, K^+ concentration ranged from 0.30mg/L to 10.80mg/L, with a mean value of 1.81 mg/L. The Mg concentration ranged from 3.45mg/L to 66.00 mg/L, with an average value of 32.56 mg/L. Na values varied between 12.45 to 68.70 mg/L with a mean value of 27.44 mg/L in the pre-monsoon season. The concentration of HCO^{3-} varied between 98 to 528 mg/L with a mean value of 315 mg/L. The mean concentration of heavy metals in the collected groundwater samples and their comparison with BIS limits are listed in Table 30. The concentration of arsenic (As) ranged from 0.000 ppm to 0.003 ppm, with a mean value of 0.001ppm. Mercury (Hg) was not detected in any groundwater sample in the current pre-monsoon 2024 season. Pb levels ranged from 0.002 to 0.003 ppm, averaging 0.002ppm. The rest of the elements, such as Cd (BDL-0.001), Cr (0.0007-0.0015), Cu (0.018-0.04), Zn (0.000-0.241), Se (BDL-0.014), and Fe (0.067-0.769) varied with average values of 0.001, 0.001, 0.031, 0.030, 0.002, and 0.122ppm, respectively. Overall, the groundwater quality in the pre-monsoon season is suitable for domestic use, indicating that it meets the standards and requirements necessary to provide safe and clean water for households.

Table 28. Measured values of physical parameters (DO, TDS, EC, pH, Hardness and Temperature) in the groundwater samples during the pre-monsoon. May 2024 season from In-situ analysis

S.No.	Code	DO (mg/L)	TDS (mg/L)	EC (mS/cm)	pH	Temp (°C)	Hardness
1	KHR-1	2.44	850	1.71	7.30	28.7	**644**
2	KHR-2	2.44	420	0.84	7.71	29.0	424
3	KHR-3	1.80	310	0.63	8.32	30.8	502
4	KHR-4	6.75	450	0.90	7.49	29.5	385
5	KHR-5	1.80	310	0.63	7.32	30.8	64
6	KHR-6	3.78	530	1.07	7.22	30.8	**624**
7	KHR-7	2.15	510	1.03	7.16	29.6	554
8	KHR-8	2.52	350	0.71	7.46	29.9	236
9	KHR-9	5.77	450	0.90	7.41	30.0	312
10	KHR-10	3.10	310	0.64	7.63	32.1	286
11	KHR-11	4.22	280	0.58	7.89	32.4	310
12	KHR-12	4.08	370	0.74	7.46	29.1	212
13	KHR-13	4.44	730	1.46	7.43	34.8	**616**
14	KHR-14	3.04	450	0.91	7.32	29.5	418
15	KHR-17	5.37	530	1.07	7.56	30.5	**718**
16	KHR-18	5.83	450	0.91	7.32	29.7	**788**
17	KHR-19	2.50	880	1.76	7.20	28.3	236
18	KHR-20	2.45	420	0.84	7.38	29.7	**646**
19	KHR-Pz1	4.65	880	1.77	7.07	31.1	**756**
20	KHR-Pz2	4.50	950	1.91	7.40	32.1	**647**
21	KHR-Pz3	6.27	590	1.19	7.61	31.0	518
22	KHR-Pz4	6.75	890	1.78	7.52	31.3	**720**
23	KHR-Pz6	7.01	640	1.29	7.29	31.1	**656**
BIS Limits	**AL**	**NS**	**500**	**NS**	**6.5-8.5**	**NS**	**200**
	PL		**2000**		**NR**		**600**

(IS:10500-2012)	

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit

Table 29. Mean concentration (in mg/L) of major ions in Groundwater samples and their comparison with BIS limits during pre-monsoon May 2024 season

Sr. No.	Code	F^-	Cl^-	Br^-	NO_3^-	PO_4^-	SO_4^{2-}	Ca	K	Mg	Na	CO_3^-	HCO_3^-
1	KHR-1	0.00	42.92	ND	2.87	ND	121.70	**221.25**	1.05	51.75	39.15	ND	258
2	KHR-2	0.35	82.99	ND	14.70	ND	47.26	60.90	2.70	10.95	51.15	ND	98
3	KHR-3	0.25	61.13	ND	1.55	ND	**408.06**	126.45	0.75	48.15	26.25	ND	180
4	KHR-4	0.53	43.16	ND	18.83	ND	73.07	98.70	1.05	40.95	14.70	ND	244
5	KHR-5	0.89	58.99	ND	31.35	ND	135.74	21.60	0.60	9.00	47.25	ND	290
6	KHR-6	0.22	29.26	ND	42.10	ND	36.70	47.55	1.95	24.30	17.25	ND	528
7	KHR-7	0.00	71.35	ND	**82.73**	ND	40.95	105.90	1.20	40.80	13.20	ND	376
8	KHR-8	0.19	31.57	ND	9.65	ND	27.81	41.85	0.30	25.65	22.50	ND	276
9	KHR-9	0.35	76.78	ND	**72.62**	ND	62.51	84.30	0.45	32.10	28.05	ND	386
10	KHR-10	0.00	31.01	ND	33.77	ND	20.50	47.25	0.30	6.00	33.45	ND	410
11	KHR-11	0.48	34.73	ND	20.14	ND	30.96	31.05	0.60	3.45	39.45	ND	408
12	KHR-12	0.40	16.59	ND	**58.76**	ND	30.33	86.40	0.75	39.90	13.50	ND	412
13	KHR-13	0.00	26.86	ND	4.73	ND	**400.84**	136.35	0.90	17.70	68.70	ND	328
14	KHR-14	0.00	61.93	ND	**85.64**	ND	36.53	118.05	1.95	29.70	18.30	ND	288
15	KHR-17	0.52	102.02	ND	7.53	ND	366.06	108.15	1.05	40.05	25.80	ND	256
16	KHR-18	0.53	37.45	ND	2.71	ND	171.11	102.00	0.60	44.85	14.25	ND	240
17	KHR-19	0.00	66.22	ND	7.51	ND	224.49	155.70	10.80	38.25	41.85	ND	320
18	KHR-20	0.37	55.70	ND	32.18	ND	137.00	93.90	7.80	28.35	19.80	ND	344
19	KHR-Pz1	0.42	113.70	ND	1.87	ND	12.35	0.00	1.80	46.35	33.30	ND	412
20	KHR-Pz2	0.15	43.05	ND	4.19	ND	**811.67**	0.00	0.75	55.35	20.25	ND	118
21	KHR-Pz3	0.00	39.82	ND	5.01	ND	304.49	116.10	0.90	15.00	14.85	ND	422
22	KHR-Pz4	0.45	44.29	ND	4.33	ND	219.50	196.65	1.80	66.00	27.30	ND	276
23	KHR-Pz6	0.00	41.02	ND	10.95	ND	52.54	151.05	0.90	53.55	12.45	ND	318
BIS limits (IS:10500-2012)	**AL**	**1**	**250**	**NS**	**45**	**NS**	**200**	**75**	**NS**	**30**	**NS**	**NS**	**NS**
	PL	**1.5**	**1000**		**NR**		**400**	**200**		**100**			

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit

Table 30. Mean concentration (in ppm) of heavy metals in the groundwater samples and their comparison with BIS limits during the pre-monsoon May 2024 season.

S. No.	Code	As	Hg	Pb	Cd	Cr	Cu	Zn	Se	Fe
1	KHR-1	0.001	0.0000	0.002	0.001	0.001	0.02	0.002	0.00	0.06
2	KHR-2	0.003	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.07
3	KHR-3	0.001	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.07
4	KHR-4	0.002	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.07
5	KHR-5	0.003	0.0000	0.002	0.000	0.001	0.02	0.004	0.00	0.10

6	KHR-6	0.002	0.0000	0.002	0.000	0.001	0.02	0.001	0.00	0.08
7	KHR-7	0.000	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.09
8	KHR-8	0.001	0.0000	0.002	0.001	0.001	0.03	0.001	**0.01**	0.07
9	KHR-9	0.001	0.0000	0.002	0.001	0.001	0.03	0.001	**0.01**	0.09
10	KHR-10	0.000	0.0000	0.002	0.001	0.001	0.04	0.001	**0.01**	0.08
11	KHR-11	0.001	0.0000	0.002	0.001	0.001	0.04	0.001	0.00	0.08
12	KHR-12	0.001	0.0000	0.002	0.001	0.001	0.04	0.001	0.00	0.08
13	KHR-13	0.001	0.0000	0.002	0.001	0.001	0.05	0.001	0.00	0.09
14	KHR-14	0.000	0.0000	0.002	0.001	0.001	0.04	0.001	0.00	**0.77**
15	KHR-17	0.001	0.0000	0.002	0.001	0.001	0.05	0.001	0.00	0.10
16	KHR-18	0.001	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.10
17	KHR-19	0.001	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.11
18	KHR-20	0.001	0.0000	0.002	0.001	0.001	0.04	0.001	0.00	0.14
19	KHR-Pz1	0.001	0.0000	0.003	0.001	0.001	0.02	0.000	0.00	0.07
20	KHR-Pz2	0.001	0.0000	0.002	0.001	0.001	0.02	0.137	0.00	0.07
21	KHR-Pz3	0.001	0.0000	0.002	0.001	0.001	0.02	0.241	0.00	0.20
22	KHR-Pz4	0.000	0.0000	0.003	0.001	0.001	0.02	0.118	0.00	0.08
23	KHR-Pz6	0.001	0.0000	0.020	0.001	0.001	0.02	0.154	0.00	0.07
BIS (IS:10500-2012)	**AL**	**0.01**	**0.001**	**0.01**	**0.003**	**0.05**	**0.05**	**5**	**0.01**	**0.3**
	PL	**0.05**	**NR**	**NR**	**NR**	**NR**	**1.5**	**15**	**NR**	**NR**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit

8 Estimated Contribution of Rainwater harvesting done at NTPC plant to the groundwater recharge

The comprehensive assessment of rainwater harvesting potential across different areas, as outlined in the report from the National Institute of Hydrology (NIH) in 2018, revealed an intricate understanding of the catchment type, climatic conditions, and surface characteristics. The calculated potential for rainwater harvesting from the main plant area, township, and green belt regions amounts to 0.844 million cubic meters (MCM) for enrichment of water resources of nearby plant areas.

As a contribution to this, an initiative has been undertaken at the NTPC plant at Khargone, specifically addressing the impact on groundwater recharge. NTPC has implemented a rainwater harvesting system consisting of 44 recharge pits strategically installed within the main plant premises. These recharge pits are designed to capture rainwater from various sources, including rooftop surfaces, open areas, and stormwater runoff. The rainwater collected from these sources is directed into the recharge pits, facilitating water infiltration into the underlying groundwater resource. This process contributes to the recharge of subsurface unconfined aquifers, enhancing the overall groundwater levels in the region. The collective recharge capacity of these 44 pits is specified as 0.36 million cubic meters (MCM). However, the successful implementation of the rainwater harvesting system at the NTPC plant in Khargone, coupled with the insights gained from the comprehensive assessment by NIH Roorkee in 2018, paves the way for further impactful contributions to water resource enrichment. The calculated potential of 0.844 million cubic meters (MCM) highlights the substantial capacity for rainwater harvesting across the main plant area, township, and green belt regions. Indeed, there is a scope for expanding and improving the existing rainwater harvesting structures and methodologies. This could involve identifying additional strategic locations for recharge pits, optimizing capture mechanisms, and implementing advanced technologies for efficient rainwater utilisation. Furthermore, ongoing monitoring and periodic reassessments of rainwater harvesting potential will enable adaptive strategies, ensuring continuous improvement and resilience in addressing local water needs.

8.1 *Monitoring of groundwater level and quality for observation points inside and adjacent to the plant*

A subset of data on groundwater level observation and groundwater quality observed inside the plant and adjacent to the plant area is present in this section specifically to understand the influence of the rainwater harvesting scheme implemented in the plant. Two observation wells (KHR-13, KHR-15A, KHR-18 and 6 piezometers) were monitored for groundwater level, and seven observation points (KHR-1, KHR-3, KHR-4, KHR-13, KHR-17, KHR-18, KHR-19 and 6 piezometers) were monitored to assess water quality parameters. A detailed analysis of groundwater level and quality in an area of a 10-km radius from the plant is presented in sections 5 and 7. A subset of the data for identified points inside and adjacent to the plant is presented in this section again. The salient information about groundwater table observation points is given in Table 31. The observed groundwater levels below ground level at observation points mentioned in Table 31 are given in Table 32.

Table 31. Salient details of observation wells for groundwater level monitoring inside and adjacent to the plant

S.No.	Site Code	Latitude (˚E)	Longitude (˚N)	Location and source	Ground Elevation (m amsl)
1	KHR-13	22.06608	75.87139	Adjoining of NTPC Community Centre Near New Hanumaan Temple, open well	263
2	KHR-15A	22.07092	75.85599	Near Bhilal Baba Temple, opp cooling tower, Near NTPC Gate no. 1, below mango tree, open well	247
3	KHR-16A	22.07912	75.80412	Adjacent to Gangour thermal power station road	238
4	KHR-18	22.06295	75.85256	Well inside power station, open well	249
5	KHR-Pz1	22.07826	75.8367	Piezometer 1, Ash Dyke	241
6	KHR-Pz2	22.07721	75.83306	Piezometer 2, Ash Dyke	239
7	KHR-Pz3	22.07476	75.83177	Piezometer 3, Ash Dyke	234
8	KHR-Pz4	22.07289	75.83233	Piezometer 4, Ash Dyke	230
9	KHR-Pz5	22.07055	75.83277	Piezometer 5, Ash Dyke	236
10	KHR-Pz6	22.07089	75.83548	Piezometer 6, Ash Dyke	238

Table 32. Measured groundwater level at identified locations inside and adjacent to the plant

S.No.	Site Code	Depth to the water table (m)			
		Pre-monsoon		Post-monsoon	
		2023	2024	2023	2024
1	KHR-13	7.9	NA	NA	
2	KHR-15A	1.55	1.5	1.78	
3	KHR-16A	12.4	7.12	NA	
4	KHR-18	4.56	4.3	4.1	
5	KHR-Pz1	2.7	1.5	2.1	
6	KHR-Pz2	12.33	9.8	9.27	
7	KHR-Pz3	3.3	3.14	2.42	
8	KHR-Pz4	3.5	4.32	1.2	
9	KHR-Pz5	9.4	NA	7.1	
10	KHR-Pz6	9.5	1.02	5.5	

NA=Not available

The salient information about groundwater quality observation points inside and adjacent to the plant is given in Table 33. Measured values of physical parameters (DO, TDS, EC, pH, Hardness and Temperature) in the groundwater samples inside and adjacent to the plant are given in Table 34.

Table 33. Salient information of the groundwater quality observation points inside and adjacent to the plant.

S.No.	Code	Latitude	Longitude	Station Name	Type of Analysis	Type of Site
1	KHR-1	22.07775	75.83155	Vill. Dalchi	In-situ and Ex-situ	Hand pump
2	KHR-3	22.06926	75.85789	Near NTPC opp Bhilal Baba Temple, Gate No. 1	In-situ and Ex-situ	Hand pump
3	KHR-4	22.0688	75.86202	Between NTPC & Township	In-situ and Ex-situ	Hand pump
4	KHR-13	22.06608	75.87139	Adjoining of NTPC Community Centre	In-situ and Ex-situ	Hand pump
5	KHR-14	22.0493	75.87783	Opp Gram Panchayat office. Vill Kheri Bujurg	In-situ and Ex-situ	Hand pump
6	KHR-15	22.06923	75.85798	Near Bhilal Baba Temple, Near NTPC Gate No. 1	In-situ and Ex-situ	Hand pump
7	KHR-17	22.06947	75.85227	Below Tower Line, North side of Power station,	In-situ and Ex-situ	Seepage
8	KHR-18	22.06295	75.85256	Well inside power station	In-situ and Ex-situ	Open well
9	KHR-19	22.07518	75.82482	Near Baba Ramdev Mandir, Dalchi	In-situ and Ex-situ	Hand pump
10	KHR-Pz1	22.07826	75.8367	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
11	KHR-Pz2	22.07721	75.83306	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
12	KHR-Pz3	22.07476	75.83177	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
13	KHR-Pz4	22.07289	75.83233	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
14	KHR-Pz5	22.07055	75.83277	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer
15	KHR-Pz6	22.07089	75.83548	Piezometer 1, Ash Dyke	In-situ and Ex-situ	Piezometer

Table 34. Measured values of physical parameters (DO, TDS, EC, pH, Hardness and Temperature) in the groundwater samples inside and adjacent to the plant

S.No.	Code	Season	DO (mg/L)	TDS (mg/L)	EC (µS/cm)	pH	Temp (°C)	Hardness
1	KHR-1	Pre-monsoon 2023	3.35	630	1260	6.74	31.3	**657**
		Post-monsoon 2023	2.9	590	1160	6.9	29.1	625
		Pre-monsoon 2024	2.44	850	1.71	7.30	28.7	**644**
		Post-monsoon 2024						
2	KHR-3	Pre-monsoon 2023	2.84	480	980	6.98	30.7	511
		Post-monsoon 2023	3.6	460	940	7.34	30.3	245
		Pre-monsoon 2024	1.80	310	0.63	8.32	30.8	502
		Post-monsoon 2024						
3	KHR-4	Pre-monsoon 2023	5.88	320	650	7.16	28.9	395
		Post-monsoon 2023	6.58	490	1000	7.63	27.7	406
		Pre-monsoon 2024	1.80	310	0.63	8.32	30.8	502
		Post-monsoon 2024						
4	KHR-13	Pre-monsoon 2023	1.41	440	880	6.91	32.4	**606**
		Post-monsoon 2023	1.9	550	1100	7.24	30.7	620
		Pre-monsoon 2024	4.44	730	1.46	7.43	34.8	**616**
		Post-monsoon 2024						
5	KHR-14	Pre-monsoon 2023	4.25	450	920	6.68	29.9	433
		Post-monsoon 2023	2.82	590	1190	6.9	32.1	435
		Pre-monsoon 2024	3.04	450	0.91	7.32	29.5	418
		Post-monsoon 2024						
6	KHR-15	Pre-monsoon 2023	3.8	440	900	6.98	31.8	542

		Post-monsoon 2023	4.1	410	850	7.1	29.4	491
		Pre-monsoon 2024	NA	NA	NA	NA	NA	NA
		Post-monsoon 2024						
7	KHR-17	Pre-monsoon 2023	4.79	480	970	7.05	29.8	**698**
		Post-monsoon 2023	4.97	470	960	7.3	29.3	297
		Pre-monsoon 2024	5.37	530	1.07	7.56	30.5	**718**
		Post-monsoon 2024						
8	KHR-18	Pre-monsoon 2023	5.58	690	1390	7.16	29	**778**
		Post-monsoon 2023	4.23	270	550	7.34	31.8	736
		Pre-monsoon 2024	5.83	450	0.91	7.32	29.7	**788**
		Post-monsoon 2024						
9	KHR-19	Pre-monsoon 2023	1.94	570	1140	6.98	30	246
		Post-monsoon 2023	2.3	540	1020	7.21	28.21	253
		Pre-monsoon 2024	2.50	880	1.76	7.20	28.3	236
		Post-monsoon 2024						
10	KHR-Pz1	Pre-monsoon 2023	4.72	407	920	6.98	28.7	**747**
		Post-monsoon 2023	3.6	400	810	7.52	29.1	332
		Pre-monsoon 2024	4.65	880	1.77	7.07	31.1	**756**
		Post-monsoon 2024						
11	KHR-Pz2	Pre-monsoon 2023	3.03	620	1250	7.11	29.7	**627**
		Post-monsoon 2023	2.3	1060	2140	7.08	29.2	793
		Pre-monsoon 2024	4.50	950	1.91	7.40	32.1	**647**
		Post-monsoon 2024						
12	KHR-Pz3	Pre-monsoon 2023	3.16	730	1460	7.11	29	521
		Post-monsoon 2023	2.6	270	550	7.42	29.9	230
		Pre-monsoon 2024	6.27	590	1.19	7.61	31.0	518
		Post-monsoon 2024						
13	KHR-Pz4	Pre-monsoon 2023	4.36	430	870	7.7	28.6	**723**
		Post-monsoon 2023	1.6	770	1550	7.28	30.1	871
		Pre-monsoon 2024	6.75	890	1.78	7.52	31.3	**720**
		Post-monsoon 2024						
14	KHR-Pz5	Pre-monsoon 2023	2.88	480	960	6.64	30.4	**691**
		Post-monsoon 2023	2.7	350	700	6.85	30.8	341
		Pre-monsoon 2024	NA	NA	NA	NA	NA	NA
		Post-monsoon 2024						
15	KHR-Pz6	Pre-monsoon 2023	3.82	570	1140	6.78	31.4	**663**
		Post-monsoon 2023	3.7	270	550	7.34	31.8	135
		Pre-monsoon 2024	7.01	640	1.29	7.29	31.1	**656**
		Post-monsoon 2024						
BIS Limits (IS:10500-2012	**AL**		NS	**500**	NS	**6.5-8.5**	NS	**200**
	PL			**2000**		**NR**		**600**

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit, NA: Not Available.

The groundwater samples collected from inside and adjacent to the plant were further assessed for major ions, and heavy metals. The mean concentration of major ions in groundwater samples and their comparison with BIS limits is listed in Table 35. The mean concentration of heavy metals in groundwater samples and their comparison with BIS limits is listed in Table 36.

Table 35. Mean concentration (mg/l) of major ions in groundwater samples inside and adjacent to the plant and their comparison with BIS limits

Code	Season	F^-	Cl^-	Br^-	NO_3^-	PO_4^-	SO_4^{2-}	Ca	K	Mg	Na	CO_3^-	HCO_3^-
KHR-1	S1	0.3	71.1	BDL	5.4	BDL	**803**	185	1	47.3	36.1	BDL	245
	S2	0.3	140	BDL	20.5	BDL	199.3	158	1.2	55.95	49.4	BDL	210
	S3	0.00	42.92	BDL	2.87	BDL	121.70	**221.25**	1.05	51.75	39.15	BDL	258
	S4												
KHR-3	S1	0.6	72.6	BDL	13.2	BDL	**414.1**	142.8	0.5	37.5	86.2	BDL	170
	S2	0.7	100	BDL	22.6	BDL	142	70.35	26.85	16.95	237.3	BDL	165
	S3	0.25	61.13	BDL	1.55	BDL	**408.06**	126.45	0.75	48.15	26.25	BDL	180
	S4												
KHR-4	S1	0.5	50.1	BDL	34.4	BDL	219.8	111	0.7	28.6	34.8	BDL	254
	S2	BDL	120	BDL	BDL	BDL	BDL	99.45	1.05	38.25	85.1	BDL	250
	S3	0.53	43.16	BDL	18.83	BDL	73.07	98.70	1.05	40.95	14.70	BDL	244
	S4												
KHR-13	S1	0.5	30.6	BDL	12.4	BDL	135.8	209.2	1.3	20.2	131.8	BDL	315
	S2	0.6	180	BDL	187.5	BDL	75.2	190.1	2.55	35.4	171	BDL	290
	S3	0.00	26.86	BDL	4.73	BDL	**400.84**	136.35	0.90	17.70	68.70	BDL	328
	S4												
KHR-14		0.9	62.3	BDL	**139.7**	BDL	47.2	115	0.7	35.3	39.9	BDL	290
	S2	0.5	180	BDL	200.6	BDL	58.5	105.6	0.06	41.55	72.8	BDL	275
	S3	0.00	61.93	BDL	**85.64**	BDL	36.53	118.05	1.95	29.70	18.30	BDL	288
	S4												
KHR-15	S1	0.6	58.7	BDL	**58.2**	BDL	284.7	189	0.8	17.1	120.3	BDL	265
	S2	0.4	65	BDL	45	BDL	284.7	145	0.2	31.2	96.4	BDL	245
	S3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	S4												
KHR-17	S1	0.6	100.4	BDL	7.7	BDL	**429.5**	212.5	2.2	40.7	104.0	BDL	220
	S2	**1.6**	160	BDL	54	BDL	197.7	180.7	0.03	69.15	97.8	BDL	310
	S3	0.00	66.22	BDL	7.51	BDL	224.49	155.70	10.80	38.25	41.85	BDL	320
	S4												
KHR-18	S1	0.6	39.7	BDL	15.8	BDL	**921.1**	192.6	0.3	72.2	67.8	BDL	324
	S2	**1.6**	160	BDL	54	BDL	197.7	180.7	0.03	69.15	97.8	BDL	310
	S3	0.53	37.45	BDL	2.71	BDL	171.11	102.00	0.60	44.85	14.25	BDL	240
	S4												
KHR-19	S1	0.5	78.6	BDL	6.2	BDL	**787.3**	75.4	3.1	14	149.2	BDL	345
	S2	0.5	100	BDL	14.6	BDL	184.6	82.4	0.11	11.4	300.2	BDL	290
	S3	0.00	66.22	BDL	7.51	BDL	224.49	155.70	10.80	38.25	41.85	BDL	320
	S4												
KHRPz-1	S1	0.4	125.4	BDL	27.6	BDL	116.7	241	1.6	35.4	60.8	BDL	415
	S2	0.4	360	BDL	25.7	BDL	41.5	92.55	0.08	24.45	98.4	BDL	310
	S3	0.42	113.70	BDL	1.87	BDL	12.35	0.00	1.80	46.35	33.30	BDL	412

	S4												
KHRPz-2	S1	0.3	72.5	BDL	1.4	BDL	**996.8**	202	0.9	29.7	80.0	BDL	286
	S2	0.3	120	BDL	12.2	BDL	31.1	196.1	0.04	73.65	115.7	BDL	310
	S3	0.15	43.05	BDL	4.19	BDL	**811.67**	0.00	0.75	55.35	20.25	BDL	118
	S4												
KHRPz-3	S1	0.3	68.0	BDL	4.8	BDL	**983.7**	190.1	1.1	11.2	126.1	BDL	315
	S2	0.5	440	BDL	16.1	BDL	188	71.4	0.06	12.45	77.1	BDL	290
	S3	0.00	39.82	BDL	5.01	BDL	304.49	116.10	0.90	15.00	14.85	BDL	422
	S4												
KHRPz-4	S1	0.8	86.3	BDL	BDL	BDL	**585.5**	222	7.3	41	87.2	BDL	264
	S2	**2.9**	160	BDL	15.4	BDL	12.4	215.8	0.13	80.55	210.8	BDL	245
	S3	0.45	44.29	BDL	4.33	BDL	219.50	196.65	1.80	66.00	27.30	BDL	276
	S4												
KHRPz-5	S1	0.5	46.1	BDL	BDL	BDL	187.2	235.7	1.8	24.7	101.2	BDL	324
	S2	0.7	120	BDL	72	BDL	163.9	87.9	0.06	29.55	71.4	BDL	265
	S3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	S4												
KHRPz-6	S1	0.4	86.1	BDL	16.4	BDL	**436.2**	183.4	0.6	49.8	38.5	BDL	295
	S2	0.6	160	BDL	16	BDL	34	42.3	0.02	7.05	180.5	BDL	240
	S3	0.00	41.02	BDL	10.95	BDL	52.54	151.05	0.90	53.55	12.45	BDL	318
	S4												
BIS limits (IS:10500-2012)	**AL**	**1**	**250**	**NS**	**45**	**NS**	**200**	**75**	**NS**	**30**	**NS**	**NS**	**NS**
	PL	**1.5**	**1000**		**NR**		**400**	**200**		**100**			

Notations: S1: Pre-monsoon2023; S2: Post-monsoon 2023; S3: Pre-monsoon 2024; S4: Post-monsoon 2024, *NS-Not specified; NR-No relaxation; NA- Not Available; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit*

Table 36. Mean concentration (in ppm) of heavy metals in groundwater samples inside and adjacent to the plant and their comparison with BIS limits

Code	Season	As	Hg	Pb	Cd	Cr	Cu	Zn	Se	Fe
KHR-1	S1	0.008	BDL	0.002	0.001	0.01	0.04	0.97	BDL	**0.39**
	S2	0.002	0.004	0.003	0.003	0.02	0.005	0.46	BDL	0.18
	S3	0.001	0.0000	0.002	0.001	0.001	0.02	0.002	0.00	0.06
	S4									
KHR-3	S1	0.007	BDL	0.002	0.001	0.01	0.03	0.16	BDL	0.08
	S2	0.001	BDL	0.003	0.002	0.02	0.010	0.71	0.002	0.43
	S3	0.001	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.07
	S4									
KHR-4	S1	0.005	BDL	0.002	0.001	0.01	0.03	0.07	BDL	0.13
	S2	0.001	BDL	0.003	0.002	0.02	0.004	0.06	BDL	0.25
	S3	0.002	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.07
	S4									
KHR -13	S1	0.006	BDL	0.002	0.001	0.01	0.04	0.13	0.01	0.09
	S2	0.002	BDL	0.003	0.002	0.02	0.007	BDL	BDL	0.19
	S3	0.001	0.0000	0.002	0.001	0.001	0.05	0.001	0.00	0.09
	S4									
KHR -14	S1	0.006	BDL	0.002	0.001	0.01	0.07	0.48	BDL	0.21
	S2	0.001	BDL	0.002	0.002	0.02	0.037	0.43	BDL	0.25
	S3	0.000	0.0000	0.002	0.001	0.001	0.04	0.001	0.00	**0.77**
	S4									
KHR -15	S1	0.005	BDL	0.002	0.001	0.01	0.03	0.13	0.01	0.17

	S2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	S3	NA	NA	NA	NA	NA	NA	NA	NA	NA
	S4									
KHR-17	S1	0.006	BDL	0.002	BDL	0.01	0.03	0.08	BDL	0.17
	S2	0.001	BDL	0.002	0.002	0.02	0.002	BDL	BDL	0.21
	S3	0.001	0.0000	0.002	0.001	0.001	0.05	0.001	0.00	0.10
	S4									
KHR-18	S1	0.006	BDL	0.002	0.001	0.01	0.03	0.07	BDL	0.20
	S2	0.001	BDL	0.003	0.003	0.02	0.005	BDL	BDL	0.21
	S3	0.001	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.10
	S4									
KHR-19	S1	0.006	BDL	0.002	0.001	0.01	0.03	0.08	BDL	0.12
	S2	0.001	0.002	0.002	0.002	0.02	0.005	BDL	BDL	0.20
	S3	0.001	0.0000	0.002	0.001	0.001	0.02	0.001	0.00	0.11
	S4									
KHR PZ-1	S1	0.006	BDL	0.003	0.001	0.01	0.03	0.09	BDL	0.13
	S2	0.001	BDL	0.024	0.002	0.02	0.011	0.05	0.001	0.18
	S3	0.001	0.0000	0.003	0.001	0.001	0.02	0.000	0.00	0.07
	S4									
KHR PZ-2	S1	0.006	BDL	0.002	0.001	0.01	0.04	0.07	BDL	0.13
	S2	0.001	BDL	0.002	0.001	0.02	0.004	0.01	BDL	0.16
	S3	0.001	0.0000	0.002	0.001	0.001	0.02	0.137	0.00	0.07
	S4									
KHR PZ-3	S1	0.006	BDL	0.002	0.001	0.01	0.03	0.11	BDL	0.17
	S2	0.001	BDL	0.010	0.002	0.02	0.009	BDL	BDL	0.15
	S3	0.001	0.0000	0.002	0.001	0.001	0.02	0.241	0.00	0.20
	S4									
KHR PZ-4	S1	0.007	BDL	0.005	0.001	0.02	0.03	0.13	BDL	**0.33**
	S2	0.001	BDL	0.009	0.001	0.02	0.005	BDL	0.002	0.23
	S3	0.000	0.0000	0.003	0.001	0.001	0.02	0.118	0.00	0.08
	S4									
KHR PZ-5	S1	0.007	BDL	0.008	0.001	0.01	0.12	0.10	BDL	**0.98**
	S2	0.001	BDL	0.003	0.001	0.02	0.014	BDL	BDL	0.16
	S3	NA	NA	NA	NA	NA	NA	NA	NA	NA
	S4									
KHR PZ-6	S1	0.006	BDL	0.002	0.001	0.01	0.03	0.09	BDL	0.20
	S2	0.001	BDL	0.008	0.001	0.02	0.007	BDL	0.009	0.14
	S3	0.001	0.0000	0.020	0.001	0.001	0.02	0.154	0.00	0.07
	S4									
BIS (IS:10500-2012)	**AL**	**0.01**	**0.001**	**0.01**	**0.003**	**0.05**	**0.05**	**5**	**0.01**	**0.3**
	PL	**0.05**	**NR**	**NR**	**NR**	**NR**	**1.5**	**15**	**NR**	**NR**

Notations: S1: Pre-monsoon2023; S2: Post-monsoon 2023; S3: Pre-monsoon 2024; S4: Post-monsoon 2024, *NS-Not specified; NR-No relaxation; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit, NA: Not Available.*

9 ANALYSIS OF SOIL CHEMICAL PROPERTIES

Typically, the elements found in natural soil are represented by soil chemistry. However, many natural and anthropogenic processes alter the natural soil chemistry, including leaching of chemical elements by flood irrigation, chemical reactions, different patterns of land use, intense fertiliser usage, and biological processes. Depending on how the soil will be used in the future, these changes may be deemed to have either beneficial or adverse effects. In order to monitor the environment and determine potential effects on the local ecology, it is crucial to examine the soil components close to thermal power stations.

Various heavy metals (mercury, lead, cadmium, and arsenic), and other ions (nitrate) are among the many pollutants that thermal power stations frequently emit into the atmosphere. These emissions have the potential to pollute the soil when they settle onto it. These metals can build up in the soil over time and get into plants and animals, which then get into the food chain. Also, soil-borne pollutants have the potential to seep into groundwater and contaminate sources of drinking water. The possible migration of contaminants from the soil to groundwater can be better understood with the soil element analysis. Monitoring changes in soil quality over time is possible with routine soil element analyses. This ongoing observation provides the detailed characterisation which can be used to implement pollution control strategies. As per the scope of the present study, 36 soil samples were collected from 12 locations, and three samples from each location, i.e., from the surface, 30 cm and 60 cm depth from the surface were collected using an auger. The samples were appropriately tagged and placed in polythene bags for analysis in the laboratory. The samples were brought to IIT Roorkee Laboratory for further chemistry-based analysis.

9.1 *Soil Chemical Properties during pre-monsoon 2023 season*

The geographical location of soil sampling locations in the study area is shown in Figure 16. Table 37 presents the details of the sampling locations. The results of laboratory analysis for physical parameters and major ions (F^-, Cl^-, HCO_3^-, SO_4^{2-}, NO_3, PO_4^{3-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, and Fe^{2+}) are listed in Table 38.

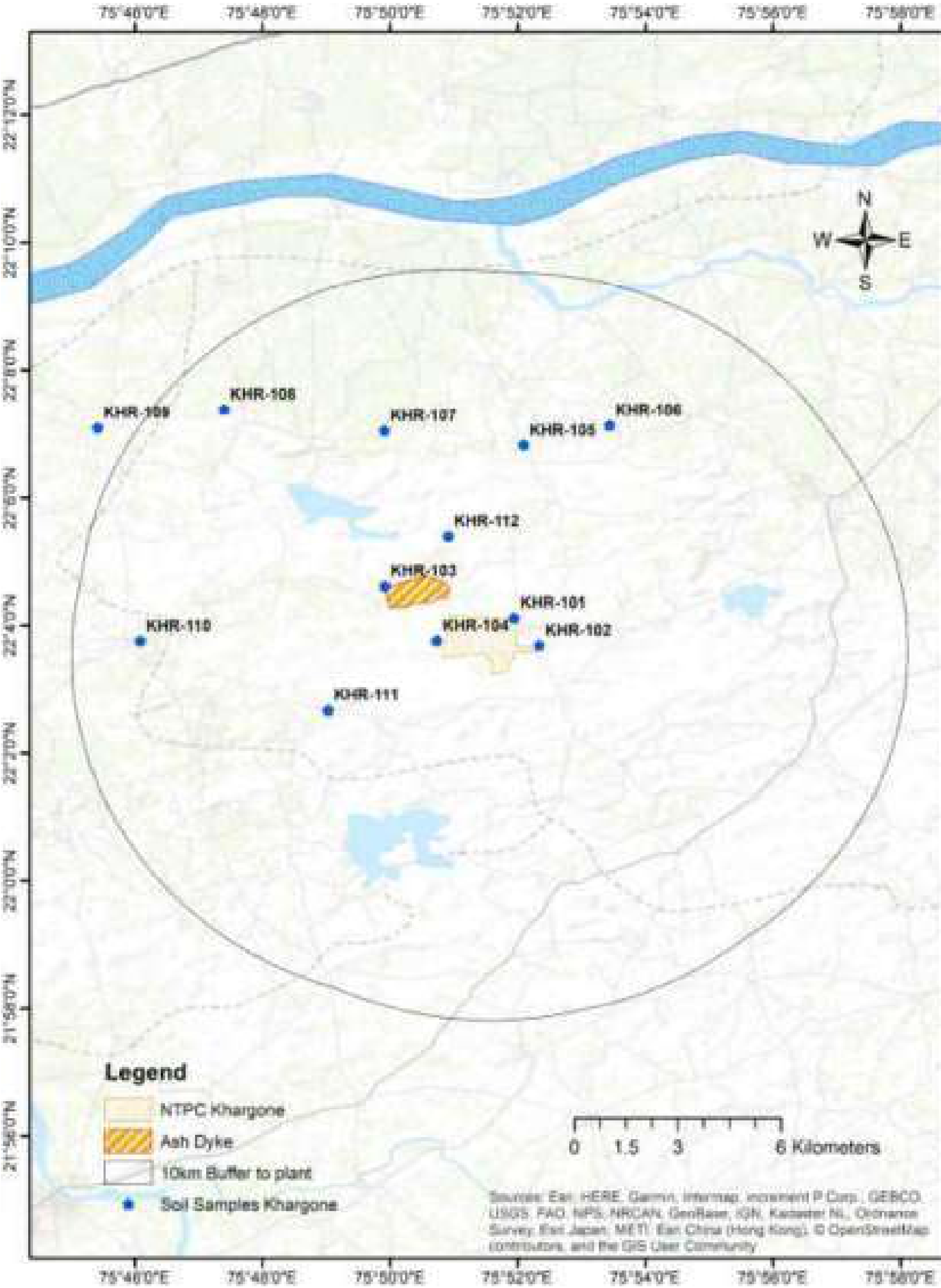

Figure 16. Soil sampling points within the 10 km buffer zone of power station site in the study area

Table 37. Details of soils samples and their location name with geo-coordinates in the study area

S.No.	Site Code	Location name	Latitude	Longitude
1	KHR-101	NTPC Plantation Land near Shelda Village	22.068686	75.865808
2	KHR-102	NTPC Power station to Kheri road along NTPC Railway line	22.061526	75.87233
3	KHR-103	Near NTPC Boundary inside Dalchi along Power station AshDyke - Dalchi road	22.077065	75.832013
4	KHR-104	Power station to Bhopada side single Chimney side	22.062734	75.845571
5	KHR-105	Opp side of Kottara Pond, Power station to Kattora Village	22.113848	75.868283
6	KHR-106	Near Badgaon Village, Near Papu Dhaba	22.119023	75.890667
7	KHR-107	Kanhapur- Pipalgaon Road, Along Road site outside Kanhapur	22.117732	75.83194
8	KHR-108	Pipalgaon Londi road, Londi along road side Near Hand Pump	22.123119	75.790038
9	KHR-109	Opp Sant Siya ram Auto Parts & Garrage	22.118459	75.757034
10	KHR-110	Village Bhatiyan On Power station road Near Overhead water tank opp side	22.062688	75.768112
11	KHR-111	Village Bhopada Shalda Road	22.044646	75.817312
12	KHR-112	Vill Jamnia	22.090059	75.848602

The pH range for most soils varies between 3.5 and 10. The natural pH of soils normally ranges from 5 to 7 in areas with more rainfall and from 6.5 to 9 in dry regions. According to their pH value, soils can be categorized as neutral (pH range: 6.5 to 7.5), alkaline (pH over 7.5), or acidic (pH less than 6.5). Strongly acidic soils have a pH of less than 5.5. The pH range of the soil samples analysed in this study ranged from 6.05 to 7.5, with an average value of 6.8 when all sample depths were taken into account. The soil is frequently found to be neutral (34 out of 36 samples) within the pH range of 6.5 to 7.5. Only two samples showed acidic nature at 0 cm depth and 30 cm depth, respectively.

Soil electrical conductivity (EC), also known as the electrical conductivity of soil, is a measure of the soil's ability to conduct an electric current. It provides useful information about the physical and chemical qualities of the soil, as well as its moisture content and salinity. Soil EC monitoring is useful in a variety of sectors, including agriculture, environmental research, and geology. The value of EC for soil in the study area during the pre-monsoon period (April 2023) ranged from 150 μS/cm to 460 μS/cm with an average value of 262.9 μS/cm. Considering all the samples at various depths. Furthermore, no specific trend of depth-wise increase or decrease in EC values has been detected in the majority of soil samples. Moreover, the mean concentration of essential ions in soil samples at various depths (at the surface, at 30 cm depth, and at 60 cm depth) during the pre-monsoon 2023 season (April 2023) is listed in Table 38.

Table 38. Mean concentration of major ions in soil samples during the pre-monsoon 2023 season (April 2023) (ions in mg/g, EC in µs/cm, pH in standard unit)

S.No.	Site Code	pH	EC	CO_3^-	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	PO_4^-	F^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Br^-
1	KHR 101(0)	6.9	230	ND	0.28	0.06	0.38	0.06	ND	0.001	ND	0.0004	0.02	0.006	ND
2	KHR 101(30)	6.7	240	ND	0.41	0.06	0.37	0.02	ND	0.001	0.015	0.0003	0.01	0.004	ND
3	KHR 101(60)	6.9	240	ND	0.36	0.05	0.22	0.02	ND	0.003	0.001	0.0012	0.02	0.007	0.001
4	KHR 102 (0)	6.8	170	ND	0.34	0.03	0.11	0.00	ND	0.005	ND	0.0009	0.02	0.007	ND
5	KHR 102 (30)	6.8	200	ND	0.49	0.02	0.16	0.01	ND	0.005	ND	0.0010	0.02	0.007	ND
6	KHR 102(60)	6.9	210	ND	0.34	0.02	0.15	0.02	ND	0.005	ND	0.0013	0.05	0.009	0.001
7	KHR 103 (0)	6.7	150	ND	0.66	0.03	0.22	0.04	ND	0.001	0.000	0.0009	0.01	0.004	ND
8	KHR 103 (30)	6.6	150	ND	0.73	0.03	0.25	0.03	ND	0.001	0.005	0.0009	0.01	0.004	ND
9	KHR 103 (60)	6.8	190	ND	0.92	0.04	0.25	0.04	ND	0.001	ND	0.0012	0.01	0.004	ND
10	KHR 104(0)	6.5	410	ND	0.31	0.05	0.28	0.21	ND	0.005	ND	0.0007	0.02	0.006	0.001
11	KHR 104(30)	6.8	280	ND	0.25	0.03	0.14	0.06	ND	0.005	0.006	0.0004	0.02	0.007	0.001
12	KHR 104(60)	6.9	260	ND	0.47	0.03	0.11	0.04	ND	0.007	0.001	0.0005	0.02	0.009	0.001
13	KHR 105 (0)	7.5	360	ND	0.14	0.07	0.30	0.28	ND	0.004	0.001	0.0004	0.02	0.005	0.003
14	KHR 105 (30)	7.3	230	ND	0.34	0.02	0.11	0.02	ND	0.004	0.001	0.0004	0.06	0.006	0.001
15	KHR 105 (60)	7.5	180	ND	0.37	0.02	0.14	0.01	ND	0.005	0.001	0.0002	0.07	0.006	ND
16	KHR 106 (0)	6.1	360	ND	0.50	0.06	0.15	0.44	0.02	0.002	0.001	0.0006	0.02	0.010	ND
17	KHR 106 (30)	6.6	220	ND	0.26	0.06	0.08	0.05	ND	0.004	ND	0.0005	0.01	0.009	ND
18	KHR 106 (60)	6.5	190	ND	0.30	0.11	0.07	0.14	0.11	0.005	ND	0.0004	0.02	0.009	ND
19	KHR 107 (0)	6.9	350	ND	0.67	0.02	0.04	0.16	0.01	ND	0.004	0.0007	0.02	0.006	ND
20	KHR 107 (30)	6.8	310	ND	0.45	0.03	0.06	0.10	ND	ND	0.001	0.0006	0.04	0.006	ND
21	KHR 107 (60)	6.8	305	ND	0.51	0.02	0.09	0.13	0.01	ND	0.038	0.0003	0.04	0.008	ND
22	KHR 108(0)	6.4	310	ND	0.70	0.15	0.09	0.01	ND	ND	0.001	0.0005	0.02	0.006	ND
23	KHR 108(30)	6.3	190	ND	0.37	0.13	0.04	0.08	0.01	ND	0.006	0.0003	0.01	0.004	ND
24	KHR 108(60)	6.7	210	ND	0.40	0.14	0.12	0.08	ND	ND	0.002	0.0006	0.04	0.005	ND
25	KHR 109 (0)	6.5	330	ND	0.59	0.10	0.16	0.09	0.01	0.004	ND	0.0012	0.03	0.008	0.001
26	KHR 109 (30)	6.9	360	ND	0.73	0.09	0.20	0.03	0.01	0.005	0.001	0.0022	0.04	0.012	0.001
27	KHR 109 (60)	7.2	320	ND	0.51	0.10	0.11	0.09	0.01	0.008	0.001	0.0012	0.03	0.007	0.001
28	KHR 110 (0)	6.6	460	ND	0.47	0.12	0.33	0.21	ND	0.003	0.005	0.0030	0.02	0.005	ND
29	KHR 110 (30)	6.6	300	ND	0.23	0.05	0.13	0.08	ND	0.002	ND	0.0038	0.02	0.007	ND
30	KHR 110 (60)	6.6	230	ND	0.30	0.04	0.12	0.05	ND	0.004	0.001	0.0025	0.02	0.006	ND
31	KHR 111 (0)	6.8	210	ND	0.58	0.07	0.16	0.03	ND	0.003	0.001	0.0029	0.02	0.009	ND
32	KHR 111 (30)	6.8	150	ND	0.30	0.07	0.16	0.01	ND	0.004	0.003	0.0018	0.04	0.011	ND
33	KHR 111 (60)	6.7	200	ND	0.35	0.06	0.13	0.04	ND	0.004	0.002	0.0039	0.03	0.015	ND
34	KHR112 (0)	6.9	340	ND	0.63	0.15	0.01	0.09	ND	ND	ND	0.0009	0.01	0.006	ND
35	KHR112 (30)	6.8	310	ND	0.14	0.10	0.07	0.01	0.01	0.009	0.002	0.0008	0.03	0.008	ND
36	KHR112 (60)	6.9	310	ND	0.63	0.19	0.08	0.08	ND	ND	0.003	0.0008	0.03	0.007	ND

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

Heavy metals (HMs) are naturally occurring minerals found in soil; however, human activities can contribute considerably to high amounts of these metals in the soil. Moreover, heavy metals can enter the soil through the use of certain fertilizers, insecticides, and animal dung. Also, they are released into the soil by the degradation of rocks and minerals in the Earth's crust. However, the presence of these metals is influenced by soil composition, local geology, and geological processes. Heavy metal pollution in the soil can harm ecosystems, human health, and agricultural output. Therefore, various HMs have been analyzed in the soil samples collected from the power station area. The mean concentration of heavy metals in the soil samples at various depths during the pre-monsoon season of April (2023) is listed in Table 39.

Table 39. Mean concentration of heavy metals in the soil samples during the pre-monsoon 2023 season (April 2023).

Sr. No.	Site Code	Cr (mg/g)	Fe (mg/g)	Cu (mg/g)	Zn (mg/g)	As (mg/g)	Se (mg/g)	Cd (mg/g)	Hg (mg/g)	Pb (mg/g)
1	KHR 101 (0)	0.002	2.7	0.007	0.005	ND	ND	ND	ND	ND
2	KHR 101 (30)	0.001	1.6	0.004	0.003	ND	ND	ND	ND	ND
3	KHR 101 (60)	0.002	3.1	0.008	0.004	ND	ND	ND	ND	ND
4	KHR 102 (0)	0.003	2.5	0.008	0.005	ND	ND	ND	ND	ND
5	KHR 102 (30)	0.003	2.4	0.008	0.006	ND	ND	ND	ND	ND
6	KHR 102 (60)	0.003	2.4	0.008	0.004	ND	ND	ND	ND	ND
7	KHR 103 (0)	0.002	3.6	0.011	0.006	ND	ND	ND	ND	ND
8	KHR 103 (30)	0.002	3.7	0.011	0.006	ND	ND	ND	ND	ND
9	KHR 103 (60)	0.002	3.9	0.012	0.005	ND	ND	ND	ND	ND
10	KHR 104 (0)	0.002	2.1	0.006	0.005	ND	ND	ND	ND	ND
11	KHR 104 (30)	0.002	2.2	0.006	0.005	ND	ND	ND	ND	ND
12	KHR 104 (60)	0.002	2.6	0.007	0.004	ND	ND	ND	ND	ND
13	KHR 105 (0)	0.001	1.2	0.002	0.003	ND	ND	ND	ND	ND
14	KHR 105 (30)	0.001	1.4	0.002	0.003	ND	ND	ND	ND	ND
15	KHR 105 (60)	0.001	1.2	0.002	0.002	ND	ND	ND	ND	ND
16	KHR 106 (0)	0.001	2.0	0.003	0.005	ND	ND	ND	ND	ND
17	KHR 106 (30)	0.001	2.5	0.003	0.003	ND	ND	ND	ND	ND
18	KHR 106 (60)	0.001	2.4	0.005	0.002	ND	ND	ND	ND	ND
19	KHR 107 (0)	0.002	1.5	0.003	0.003	ND	ND	ND	ND	ND
20	KHR 107 (30)	0.002	1.4	0.003	0.006	ND	ND	ND	ND	ND
21	KHR 107 (60)	0.001	1.5	0.003	0.003	ND	ND	ND	ND	ND
22	KHR 108 (0)	0.002	2.0	0.005	0.004	ND	ND	ND	ND	ND
23	KHR 108 (30)	0.001	1.6	0.004	0.003	ND	ND	ND	ND	ND
24	KHR 108 (60)	0.001	1.5	0.005	0.005	ND	ND	ND	ND	ND
25	KHR 109 (0)	0.002	2.2	0.006	0.003	ND	ND	ND	ND	ND
26	KHR 109 (30)	0.003	3.0	0.008	0.005	ND	ND	ND	ND	ND
27	KHR 109 (60)	0.002	1.8	0.005	0.003	ND	ND	ND	ND	ND
28	KHR 110 (0)	0.001	1.5	0.005	0.003	ND	ND	ND	ND	ND
29	KHR 110 (30)	0.001	2.2	0.008	0.005	ND	ND	ND	ND	ND
30	KHR 110 (60)	0.001	1.9	0.006	0.004	ND	ND	ND	ND	ND
31	KHR 111 (0)	0.002	3.9	0.012	0.007	ND	ND	ND	ND	ND
32	KHR 111 (30)	0.006	5.5	0.016	0.010	ND	ND	ND	ND	ND

33	KHR 111 (60)	0.003	5.9	0.020	0.010	ND	ND	ND	ND	ND
34	KHR 112 (0)	0.001	1.8	0.008	0.002	ND	ND	ND	ND	ND
35	KHR 112 (30)	0.004	4.0	0.012	0.009	ND	ND	ND	ND	ND
36	KHR 112 (60)	0.003	2.8	0.014	0.006	ND	ND	ND	ND	ND

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit.

9.2 *Soil Chemical Properties during the post-monsoon 2023 season*

The soil sampling at the desired depth for the post-monsoon 2023 season was undertaken during October 9 – 13, 2023. The results of laboratory analysis for physico-chemical parameters and major ions (F^-, Cl^-, HCO_3^-, SO_4^{2-}, NO_3, PO_4^{3-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, and Fe^{2+}) are listed in Table 40. The pH range of the soil samples analyzed in the post monsoon study ranged from 6.08 to 7.5, with an average value of 6.88 when all sample depths were considered. The nature of the soil does not shown variation during post monsoon period as compared to pre monsoon season. The value of EC for soil in the study area during the post-monsoon period ranged from 180 µS/cm to 390 µS/cm with an average value of 262.22 µS/cm. Considering all the samples at various depths. Furthermore, no specific trend of depth-wise increase or decrease in EC values has been detected in the majority of soil samples, similar to the pre-monsoon period. The mean concentration of heavy metals in the soil samples at various depths during the post-monsoon 2023 season is listed in Table 41.

Table 40. Mean concentration of major ions in soil samples during the post-monsoon season of 2023 (ions in mg/g, EC in µs/cm, pH in standard unit)

S.No.	Site Code	pH	EC	CO_3^-	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	PO_4^-	F^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Br^-
1	KHR 101(0)	6.75	280	ND	0.26	0.10	0.31	0.06	ND	0.01	0.0010	0.0002	0.002	0.0004	ND
2	KHR 101(30)	6.43	180	ND	0.39	0.10	0.29	0.12	ND	BDL	0.0003	0.0001	0.001	0.0001	ND
3	KHR 101(60)	6.24	270	ND	0.33	0.08	0.16	0.11	ND	BDL	0.0010	0.0001	0.002	0.0005	ND
4	KHR 102 (0)	6.35	180	ND	0.28	0.10	0.19	0.08	ND	0.01	0.0009	0.0002	0.001	0.0003	ND
5	KHR 102 (30)	6.50	270	ND	0.45	0.08	0.11	0.07	ND	0.01	0.0009	0.0002	0.002	0.0004	ND
6	KHR 102(60)	6.55	240	ND	0.32	0.10	0.17	0.10	ND	0.01	0.0010	0.0002	0.002	0.0004	ND
7	KHR 103 (0)	6.57	280	ND	0.59	0.04	0.24	0.10	ND	BDL	0.0011	0.0002	0.002	0.0005	ND
8	KHR 103 (30)	6.67	260	ND	0.66	0.16	0.26	0.17	ND	BDL	0.0011	0.0002	0.002	0.0005	ND
9	KHR 103 (60)	6.68	270	ND	0.46	0.10	0.24	0.08	ND	BDL	0.0011	0.0002	0.002	0.0005	ND
10	KHR 104(0)	6.64	330	ND	0.28	0.18	0.18	0.50	ND	0.01	0.0008	0.0003	0.003	0.0005	ND
11	KHR 104(30)	6.08	290	ND	0.29	0.18	0.14	0.15	ND	0.01	0.0012	0.0003	0.002	0.0006	ND

12	KHR 104(60)	7.07	250	ND	0.34	0.08	0.17	0.02	ND	0.01	0.0014	0.0001	0.001	0.0004	ND
13	KHR 105 (0)	6.92	390	ND	0.24	0.20	0.18	0.04	ND	BDL	0.0008	0.0002	0.003	0.0004	ND
14	KHR 105 (30)	7.06	180	ND	0.29	0.14	0.19	0.07	ND	BDL	0.0006	0.0001	0.001	0.0002	ND
15	KHR 105 (60)	7.00	240	ND	0.32	0.16	0.18	0.08	ND	0.01	0.0008	0.0002	0.002	0.0003	ND
16	KHR 106 (0)	6.90	300	ND	0.49	0.12	0.05	1.43	ND	BDL	0.0008	0.0002	0.002	0.0005	ND
17	KHR 106 (30)	7.50	180	ND	0.28	0.14	0.04	0.15	ND	BDL	0.0008	0.0001	0.001	0.0003	ND
18	KHR 106 (60)	7.03	190	ND	0.62	0.12	0.05	0.09	ND	BDL	0.0008	0.0001	0.001	0.0003	ND
19	KHR 107 (0)	6.92	360	ND	0.46	0.26	0.06	0.11	ND	BDL	0.0013	0.0002	0.003	0.0008	ND
20	KHR 107 (30)	7.05	280	ND	0.29	0.14	0.40	0.10	ND	BDL	0.0014	0.0002	0.002	0.0007	ND
21	KHR 107 (60)	7.08	250	ND	0.41	0.16	0.07	0.12	ND	BDL	0.0011	0.0001	0.002	0.0005	ND
22	KHR 108(0)	7.07	300	ND	0.49	0.24	0.06	0.10	ND	BDL	0.0012	0.0003	0.002	0.0006	ND
23	KHR 108(30)	7.27	260	ND	0.65	0.16	0.05	0.02	ND	BDL	0.0014	0.0001	0.002	0.0005	ND
24	KHR 108(60)	7.24	220	ND	0.37	0.12	0.08	0.19	ND	BDL	0.0011	0.0001	0.002	0.0004	ND
25	KHR 109 (0)	7.19	240	ND	0.39	0.24	0.11	0.14	ND	0.01	0.0018	0.0002	0.002	0.0004	ND
26	KHR 109 (30)	7.12	290	ND	0.46	0.12	0.15	0.10	ND	0.01	0.0024	0.0002	0.002	0.0005	ND
27	KHR 109 (60)	7.22	270	ND	0.49	0.12	0.14	0.10	ND	0.01	0.0031	0.0001	0.001	0.0003	ND
28	KHR 110 (0)	6.96	350	ND	0.26	0.26	0.18	0.41	ND	BDL	0.0008	0.0008	0.003	0.0006	ND
29	KHR 110 (30)	7.04	250	ND	0.64	0.22	0.19	0.04	ND	0.01	0.0010	0.0005	0.002	0.0005	ND
30	KHR 110 (60)	7.08	230	ND	0.87	0.16	0.17	0.12	ND	BDL	0.0008	0.0003	0.002	0.0005	ND
31	KHR 111 (0)	7.12	240	ND	0.49	0.16	0.22	0.12	ND	BDL	0.0011	0.0002	0.002	0.0006	ND
32	KHR 111 (30)	7.16	220	ND	0.29	0.10	0.29	0.02	ND	BDL	0.0010	0.0001	0.001	0.0004	ND
33	KHR 111 (60)	7.16	250	ND	0.27	0.16	0.24	0.04	ND	BDL	0.0011	0.0001	0.002	0.0006	ND
34	KHR112 (0)	6.70	290	ND	0.62	0.10	0.17	0.70	ND	BDL	0.0012	0.0002	0.002	0.0006	ND
35	KHR112 (30)	6.70	260	ND	0.36	0.14	0.20	0.08	ND	BDL	0.0011	0.0001	0.002	0.0005	ND
36	KHR112 (60)	6.80	300	ND	0.58	0.12	0.19	0.07	ND	BDL	0.0011	0.0001	0.002	0.0006	ND

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit

Table 41. Mean concentration of heavy metals in the soil samples during post-monsoon 2023 season.

Sr. No.	Site Code	Cr (mg/g)	Fe (mg/g)	Cu (mg/g)	Zn (mg/g)	As (mg/g)	Se (mg/g)	Cd (mg/g)	Hg (mg/g)	Pb (mg/g)
1	KHR 101 (0)	0.003	0.007	0.003	0.001	ND	ND	ND	ND	ND
2	KHR 101 (30)	0.002	0.009	0.001	ND	ND	ND	ND	ND	ND
3	KHR 101 (60)	0.003	0.012	0.003	ND	ND	ND	ND	ND	ND
4	KHR 102 (0)	0.003	0.009	0.003	0.001	ND	ND	ND	ND	ND
5	KHR 102 (30)	0.003	0.010	0.003	ND	ND	ND	ND	ND	ND
6	KHR 102 (60)	0.003	0.010	0.003	ND	ND	ND	ND	ND	ND
7	KHR 103 (0)	0.005	0.014	0.004	0.001	ND	ND	ND	ND	ND
8	KHR 103 (30)	0.003	0.009	0.003	0.001	ND	ND	ND	ND	ND
9	KHR 103 (60)	0.002	0.008	0.003	ND	ND	ND	ND	ND	ND
10	KHR 104 (0)	0.003	0.011	0.005	0.001	ND	ND	ND	ND	ND
11	KHR 104 (30)	0.004	0.011	0.003	0.001	ND	ND	ND	ND	ND
12	KHR 104 (60)	0.005	0.012	0.003	0.001	ND	ND	ND	ND	ND
13	KHR 105 (0)	0.003	0.010	0.002	0.001	ND	ND	ND	ND	ND
14	KHR 105 (30)	0.003	0.009	0.001	ND	ND	ND	ND	ND	ND
15	KHR 105 (60)	0.003	0.008	0.002	0.002	ND	ND	ND	ND	ND
16	KHR 106 (0)	0.003	0.010	0.002	0.001	ND	ND	ND	ND	ND

17	KHR 106 (30)	0.005	0.011	0.002	ND	ND	ND	ND	ND	ND
18	KHR 106 (60)	0.003	0.007	0.002	ND	ND	ND	ND	ND	ND
19	KHR 107 (0)	0.003	0.010	0.004	0.002	ND	ND	ND	ND	ND
20	KHR 107 (30)	0.003	0.012	0.003	0.003	ND	ND	ND	ND	ND
21	KHR 107 (60)	0.004	0.011	0.002	0.003	ND	ND	ND	ND	ND
22	KHR 108 (0)	0.006	0.008	0.004	0.002	ND	ND	ND	ND	ND
23	KHR 108 (30)	0.003	0.009	0.003	0.002	ND	ND	ND	ND	ND
24	KHR 108 (60)	0.003	0.010	0.002	0.002	ND	ND	ND	ND	ND
25	KHR 109 (0)	0.003	0.010	0.003	0.001	ND	ND	ND	ND	ND
26	KHR 109 (30)	0.003	0.011	0.003	0.002	ND	ND	ND	ND	ND
27	KHR 109 (60)	0.003	0.010	0.002	0.002	ND	ND	ND	ND	ND
28	KHR 110 (0)	0.003	0.010	0.005	0.002	ND	ND	ND	ND	ND
29	KHR 110 (30)	0.004	0.014	0.005	0.003	ND	ND	ND	ND	ND
30	KHR 110 (60)	0.003	0.009	0.003	0.002	ND	ND	ND	ND	ND
31	KHR 111 (0)	0.002	0.009	0.003	0.002	ND	ND	ND	ND	ND
32	KHR 111 (30)	0.003	0.007	0.002	0.002	ND	ND	ND	ND	ND
33	KHR 111 (60)	0.002	0.007	0.003	0.002	ND	ND	ND	ND	ND
34	KHR 112 (0)	0.003	0.013	0.003	0.004	ND	ND	ND	ND	ND
35	KHR 112 (30)	0.003	0.008	0.002	0.002	ND	ND	ND	ND	ND
36	KHR 112 (60)	0.003	0.007	0.002	0.002	ND	ND	ND	ND	ND

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL-Permissible Limit; BDL: Below detection limit.

9.3 *Soil Chemical Properties during pre-monsoon 2024 Season*

The results of laboratory analysis for physical parameters and major ions (F^-, Cl^-, HCO3-, SO42-, NO3, PO43-, Ca2+, Mg2+, Na+, K+, and Fe2+) are listed in Table 42. The natural pH of soils normally ranges from 5 to 7 in areas with more rainfall and from 6.5 to 9 in dry regions. According to their pH value, soils can be categorized as neutral (pH range: 6.5 to 7.5), alkaline (pH over 7.5), or acidic (pH less than 6.5). Strongly acidic soils have a pH of less than 5.5. The pH range of the soil samples analyzed in this study ranged from 6.33 to 7.49, with an average value of 6.61 when all sample depths were considered. The soil is frequently found to be neutral (26 out of 36 samples) within the pH range of 6.5 to 7.5. 10 samples showed acidic nature at 0 cm depth and 60 cm depth, respectively.

Soil electrical conductivity (EC), also known as the electrical conductivity of soil, is a measure of the soil's ability to conduct an electric current. It provides useful information about the physical and chemical qualities of the soil, as well as its moisture content and salinity. Soil EC monitoring is useful in a variety of sectors, including agriculture, environmental research, and geology. The value of EC for soil in the study area during the pre-monsoon period (May 2024) ranged from 160µS/cm to 360 µS/cm with an average value of 257µS/cm. Considering all the samples at various depths. Furthermore, no specific trend of depth-wise increase or decrease in EC values has been detected in the majority of soil samples. Moreover, the mean concentration of essential ions in soil samples at various depths (at the surface, at 30 cm depth, and at 60 cm depth) during the pre-monsoon 2024 season (May 2024) is listed in Table 42.

Heavy metals (HMs) are naturally occurring minerals found in soil; however, human activities can contribute considerably to high amounts of these metals in the soil. Moreover, heavy metals can enter the soil through the use of certain fertilizers, insecticides, and animal dung. Also, they are released into the soil by the degradation of rocks and minerals in the Earth's crust. However, the presence of these metals is influenced by soil composition, local geology, and geological processes. Heavy metal pollution in the soil can harm ecosystems, human health, and agricultural output. Therefore, various HMs have been analyzed in the soil samples collected from the power station area. The mean concentration of heavy metals in the soil samples at various depths during the pre-monsoon season of April (2024) is listed in Table 43.

Table 42. Mean concentration of major ions in soil samples during the pre-monsoon season May 2024 (ions in mg/g, EC in µs/cm, pH in standard unit)

S.No.	Site Code	pH	EC	CO_3^-	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	F^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Br^-
1	KHR 101(0)	6.78	220	ND	0.27	0.430	0.479	0.318	0.020	0.56	0.16	1.03	0.26	ND
2	KHR 101(30)	6.61	230	ND	0.31	0.492	0.646	0.243	0.019	0.69	0.23	1.05	0.48	ND
3	KHR 101(60)	6.61	230	ND	0.35	0.379	0.446	0.154	0.014	0.42	0.08	0.35	0.21	ND
4	KHR 102 (0)	6.66	200	ND	0.32	0.388	0.586	0.153	0.020	0.48	0.16	0.78	0.28	ND
5	KHR 102 (30)	6.51	210	ND	0.39	0.413	0.594	0.281	0.000	0.49	0.14	0.67	0.20	ND
6	KHR 102(60)	6.68	200	ND	0.36	0.365	0.675	0.411	0.008	0.48	0.15	0.71	0.23	ND
7	KHR 103 (0)	6.49	160	ND	0.58	0.377	1.582	0.433	0.021	0.93	0.16	1.00	0.28	ND
8	KHR 103 (30)	6.58	160	ND	0.53	0.451	1.788	0.125	0.000	0.84	0.12	0.75	0.21	ND
9	KHR 103 (60)	6.44	170	ND	0.59	0.551	2.658	0.129	0.010	0.73	0.16	0.86	0.25	ND
10	KHR 104(0)	6.38	260	ND	0.31	0.632	1.004	0.116	0.016	0.88	0.45	2.64	0.55	ND
11	KHR 104(30)	6.37	250	ND	0.29	0.396	0.504	0.171	0.018	0.74	0.18	1.40	0.37	ND
12	KHR 104(60)	6.33	270	ND	0.31	0.517	0.556	0.288	0.021	0.49	0.19	1.19	0.27	ND
13	KHR 105 (0)	7.48	260	ND	0.24	0.436	0.535	0.558	0.019	0.72	0.21	1.15	0.24	ND
14	KHR 105 (30)	7.44	240	ND	0.32	0.612	0.67	0.238	0.081	0.52	0.16	0.72	0.17	ND
15	KHR 105 (60)	7.49	230	ND	0.34	0.488	0.552	0.07	0.017	0.50	0.19	0.90	0.21	ND
16	KHR 106 (0)	6.36	320	ND	0.47	0.405	0.733	0.121	0.018	0.68	0.28	1.07	0.23	ND
17	KHR 106 (30)	6.34	280	ND	0.45	0.382	0.739	0.130	0.018	0.71	0.25	1.26	0.28	ND

18	KHR 106 (60)	6.37	200	ND	0.41	0.419	0.834	0.116	0.019	0.41	0.19	0.89	0.23	ND
19	KHR 107 (0)	6.53	320	ND	0.51	5.877	16.06	5.099	0.295	0.97	0.37	2.62	0.41	ND
20	KHR 107 (30)	6.49	300	ND	0.49	5.544	12.81	1.742	0.356	0.58	0.21	1.72	0.27	ND
21	KHR 107 (60)	6.51	300	ND	0.51	6.973	15.94	2.079	0.400	0.51	0.21	1.67	0.26	ND
22	KHR 108(0)	6.44	300	ND	0.69	8.884	10.86	4.375	0.273	0.99	0.28	1.30	0.30	ND
23	KHR 108(30)	6.48	280	ND	0.63	6.853	15.85	9.891	0.453	0.77	0.19	1.18	0.30	ND
24	KHR 108(60)	6.47	280	ND	0.41	6.736	9.601	2.290	0.266	0.55	0.16	0.85	0.20	ND
25	KHR 109 (0)	6.58	310	ND	0.48	7.654	9.621	1.414	0.311	0.68	0.21	1.06	0.28	ND
26	KHR 109 (30)	6.51	340	ND	0.51	6.759	9.913	4.706	0.165	0.62	0.19	1.05	0.30	ND
27	KHR 109 (60)	6.53	300	ND	0.50	5.653	7.558	3.559	0.000	0.48	0.16	1.04	0.30	ND
28	KHR 110 (0)	6.61	360	ND	0.44	8.011	9.433	0.894	0.000	0.89	0.71	1.49	0.32	ND
29	KHR 110 (30)	6.63	280	ND	0.31	6.373	7.10	0.000	0.000	0.64	0.63	1.39	0.30	ND
30	KHR 110 (60)	6.68	250	ND	0.30	6.012	6.38	0.000	0.000	0.57	0.69	1.58	0.33	ND
31	KHR 111 (0)	6.56	200	ND	0.49	9.502	13.97	5.109	0.335	1.75	0.46	2.12	0.61	ND
32	KHR 111 (30)	6.58	180	ND	0.38	15.634	16.48	11.452	0.427	1.48	0.47	1.97	0.57	ND
33	KHR 111 (60)	6.59	190	ND	0.32	10.289	14.23	5.775	0.374	1.20	0.42	2.18	0.62	ND
34	KHR112 (0)	6.64	320	ND	0.52	19.129	41.36	1.775	0.454	1.87	0.27	1.94	0.60	ND
35	KHR112 (30)	6.68	300	ND	0.44	10.129	22.44	1.033	0.234	1.06	0.16	1.13	0.33	ND
36	KHR112 (60)	6.66	300	ND	0.43	10.473	31.33	1.224	0.274	1.11	0.23	1.50	0.42	ND

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit

Table 43. Mean concentration of heavy metals in the soil samples during the pre-monsoon seasons of 2024.

Sr. No.	Site Code	Cr (mg/g)	Fe (mg/g)	Cu (mg/g)	Zn (mg/g)	As (mg/g)	Se (mg/g)	Cd (mg/g)	Hg (mg/g)	Pb (mg/g)
1	KHR 101 (0)	0.002	0.012	0.003	0.008	0.00	0.00	0.00	0.00	0.00
2	KHR 101 (30)	0.002	0.010	0.003	0.006	0.00	0.00	0.00	0.00	0.00
3	KHR 101 (60)	0.002	0.010	0.002	0.006	0.00	0.00	0.00	0.00	0.00
4	KHR 102 (0)	0.002	0.012	0.005	0.007	0.00	0.00	0.00	0.00	0.00
5	KHR 102 (30)	0.003	0.013	0.005	0.009	0.00	0.00	0.00	0.00	0.00
6	KHR 102 (60)	0.003	0.012	0.007	0.008	0.00	0.00	0.00	0.00	0.00
7	KHR 103 (0)	0.002	0.013	0.007	0.009	0.00	0.00	0.00	0.00	0.00
8	KHR 103 (30)	0.002	0.012	0.004	0.008	0.00	0.00	0.00	0.00	0.00
9	KHR 103 (60)	0.002	0.011	0.005	0.010	0.00	0.00	0.00	0.00	0.00
10	KHR 104 (0)	0.002	0.012	0.015	0.009	0.00	0.00	0.00	0.00	0.00
11	KHR 104 (30)	0.003	0.012	0.011	0.009	0.00	0.00	0.00	0.00	0.00
12	KHR 104 (60)	0.003	0.013	0.008	0.008	0.00	0.00	0.00	0.00	0.00
13	KHR 105 (0)	0.003	0.012	0.006	0.008	0.00	0.00	0.00	0.00	0.00
14	KHR 105 (30)	0.003	0.012	0.009	0.009	0.00	0.00	0.00	0.00	0.00
15	KHR 105 (60)	0.002	0.012	0.008	0.008	0.00	0.00	0.00	0.00	0.00
16	KHR 106 (0)	0.003	0.015	0.008	0.009	0.00	0.00	0.00	0.00	0.00
17	KHR 106 (30)	0.002	0.012	0.006	0.007	0.00	0.00	0.00	0.00	0.00
18	KHR 106 (60)	0.003	0.015	0.006	0.009	0.00	0.00	0.00	0.00	0.00
19	KHR 107 (0)	0.003	0.021	0.015	0.013	0.00	0.00	0.00	0.00	0.00
20	KHR 107 (30)	0.003	0.020	0.011	0.010	0.00	0.00	0.00	0.00	0.00
21	KHR 107 (60)	0.003	0.018	0.010	0.010	0.00	0.00	0.00	0.00	0.00
22	KHR 108 (0)	0.003	0.017	0.010	0.010	0.00	0.00	0.00	0.00	0.00
23	KHR 108 (30)	0.003	0.020	0.011	0.010	0.00	0.00	0.00	0.00	0.00

24	KHR 108 (60)	0.003	0.020	0.010	0.011	0.00	0.00	0.00	0.00	0.00
25	KHR 109 (0)	0.003	0.020	0.008	0.010	0.00	0.00	0.00	0.00	0.00
26	KHR 109 (30)	0.003	0.019	0.010	0.010	0.00	0.00	0.00	0.00	0.00
27	KHR 109 (60)	0.002	0.015	0.009	0.007	0.00	0.00	0.00	0.00	0.00
28	KHR 110 (0)	0.002	0.021	0.007	0.007	0.00	0.00	0.00	0.00	0.00
29	KHR 110 (30)	0.003	0.018	0.007	0.008	0.00	0.00	0.00	0.00	0.00
30	KHR 110 (60)	0.002	0.014	0.008	0.007	0.00	0.00	0.00	0.00	0.00
31	KHR 111 (0)	0.003	0.021	0.014	0.011	0.00	0.00	0.00	0.00	0.00
32	KHR 111 (30)	0.002	0.016	0.015	0.010	0.00	0.00	0.00	0.00	0.00
33	KHR 111 (60)	0.003	0.018	0.012	0.010	0.00	0.00	0.00	0.00	0.00
34	KHR 112 (0)	0.003	0.021	0.012	0.011	0.00	0.00	0.00	0.00	0.00
35	KHR 112 (30)	0.003	0.016	0.011	0.008	0.00	0.00	0.00	0.00	0.00
36	KHR 112 (60)	0.006	0.045	0.010	0.022	0.00	0.00	0.00	0.00	0.00

Notations: NS-Not specified; NR-No relaxation; ND- Not Detected; AL-Acceptable Limit; PL- Permissible Limit; BDL: Below detection limit.

10 ISOTOPE DATA ANALYSIS

Isotopes can play a significant role in studying the origin, age, occurrence, and distribution of groundwater in a region, recharge mechanism, determination of groundwater flow direction and velocity, interconnections and interaction between aquifers, and identification of recharge areas and sources. Isotopes can also be applied to study surface water and groundwater interaction, among others.

In the present study, groundwater and surface water samples were collected from different sources such as hand pumps, tube wells, and open wells for isotopic characterisation of the waters of the study area. Water samples were collected from different sources for analysis of stable isotopes. For the analysis of δ^2H, δ^{18}O, a 20 ml sample was collected in pre-cleaned Polypropylene bottles (Tarsons make). The bottles were rinsed and filled with water samples, and tightly capped (to prevent evaporation and exchange with air). On-site measurements like sample temperature, pH, and conductivity, along with all other relevant site information, were also recorded.

The stable isotope ratio is the molar ratio of heavy to light isotopes and is known as the abundance ratio. It is denoted by δ(x) and given by

$$\delta\ \mathbf{(x)} = \left\{\frac{R_{SAMPLE}}{R_{STANDARD}} - \mathbf{1}\right\} * \mathbf{1000}\ \text{(in permil / ‰)} \ldots\ldots\ldots (1)$$

where δ(x) is the delta value of the sample for element' x' in permil (‰), and R is the molar ratio of the heavy-to-light isotope in the sample. Different isotope standards can determine the isotopic compositions, the most common being VSMOW (Vienna Standard Mean Ocean Water). Water isotope ratios vary with the season, and groundwater isotope values differ from GMWL and LMWL due to (i) natural intermittent processes such as evaporation, infiltration, and percolation and (ii) anthropogenic-driven processes. A small fraction of rain percolates through the soil to become groundwater; however, significant modifications in signatures are observed in meteoric water, particularly in arid and semi-arid regions.

10.1 *Isotope Analysis for Pre-monsoon Season*

For the study, 16 representative groundwater samples were collected from semi-arid regions in the Khargone district of Madhya Pradesh during the pre-monsoon season. Six groundwater samples were collected from the piezometer, seven from the handpump, two from the tube well, and one from the open well. The ratios of heavy stable isotopes were measured using Dual Inlet Isotope Ratio Mass Spectrometer-DI IRMS. The results of $\delta^{18}O$ varied from -0.69 to -4.84 ‰ with an average value of -2.61 ‰, whereas $\delta\ ^{2}H$ varied from -9.11 to - 37.07 ‰ with an average value of -19.43 ‰. The characteristic isotope lines of groundwater samples are very closely related to the LMWL (as shown in Table 44), indicating that meteoric water is the primary source of recharge in groundwater. The slight variation in the slope of GMWL (8) and LMWL (7.68) may be due to differences in the source of moisture and climatic and geographic conditions. The overall slope of the groundwater sample (5.74) is less steep than the LMWL (7.68), indicating the occurrence of evaporation before water infiltration in the vadose zone. The individual trends of piezometer samples (06), handpump (07), tube wells (02), and the open well (01) are showing the similar patterns. Figure 17 represents isotopic characterization for groundwater samples based on plots between $\delta^{2}H$ and $\delta^{18}O$.

Table 44 Characteristic isotope lines of GMWL, LMWL, and groundwater samples for Pre-monsoon 2023

S. No.	Component type	Regression equation
1	Global meteoric water line (Craig, 1961)	$\delta^2H = 8\delta^{18}O + 10$
2	Local meteoric water line (Deshpande et al., 2013)	$\delta^2H = \mathbf{7.68}\delta^{18}O + 5.77$
3	Groundwater representative samples	$\delta^2H = \mathbf{5.74}\delta^{18}O - 4.54$

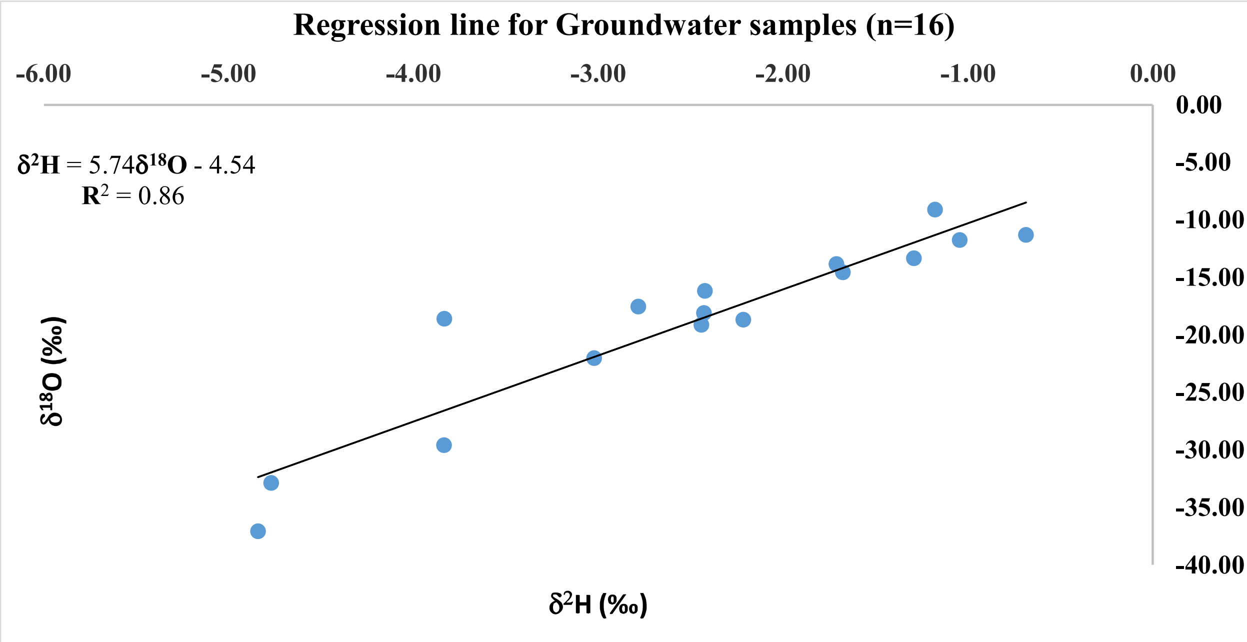

Figure 17. Isotopic characterization for Groundwater samples collected from piezometers (06), handpump (07), tube-wells (02), and the open well (01) for Pre-monsoon 2023.

10.2 *Isotope Analysis for Post-monsoon Season*

The δ ⁸O varied from -0.64 to -9.02 ‰ with an average value of -3.62 ‰, whereas δ^2H varied from -9.04 to – 48.71 ‰ with an average value of -21.93 ‰. The characteristic isotope lines of groundwater samples are very closely related to the LMWL (as shown in Table 45 Characteristic isotope lines of GMWL, LMWL, and groundwater samples for post-monsoon 2023 season.). The overall slope of the post-monsoon groundwater samples (5.09) is less steep than the LMWL (7.68) and pre-monsoon groundwater samples (5.74), indicating meteoric water to be the primary source of groundwater recharge. The individual trends of piezometer samples (06), handpump (07), tubewells (02), and the open well (01) show similar patterns as in the case of the pre-monsoon season. The variation in intercept is due to differences in the source of moisture and climatic conditions. The contribution from each factor cannot be equal and it can be negligible in some places. Some rapid changes are likely linked to poor well integrity and anulus flow, highlighting the risk to groundwater sources from surface water intrusion. Moreover, the suggested predominance of evaporation in both pre- and post-season due to semi-arid conditions was also observed.

Figure 18 shows Isotopic characterization for Groundwater samples collected from piezometers (06), handpump (07), tube-wells (02), and the open well (01) in the post-monsoon season.

Table 45 Characteristic isotope lines of GMWL, LMWL, and groundwater samples for post-monsoon 2023 season.

S. No.	Component type	Regression equation
1	Global meteoric water line (Craig, 1961)	$\delta^2H = 8\delta^{18}O + 10$
2	Local meteoric water line (Deshpande et al., 2013)	$\delta^2H = \mathbf{7.68}\delta^{18}O + 5.77$
3	Groundwater representative samples	$\delta^2H = \mathbf{5.09}\delta^{18}O - 0.05$

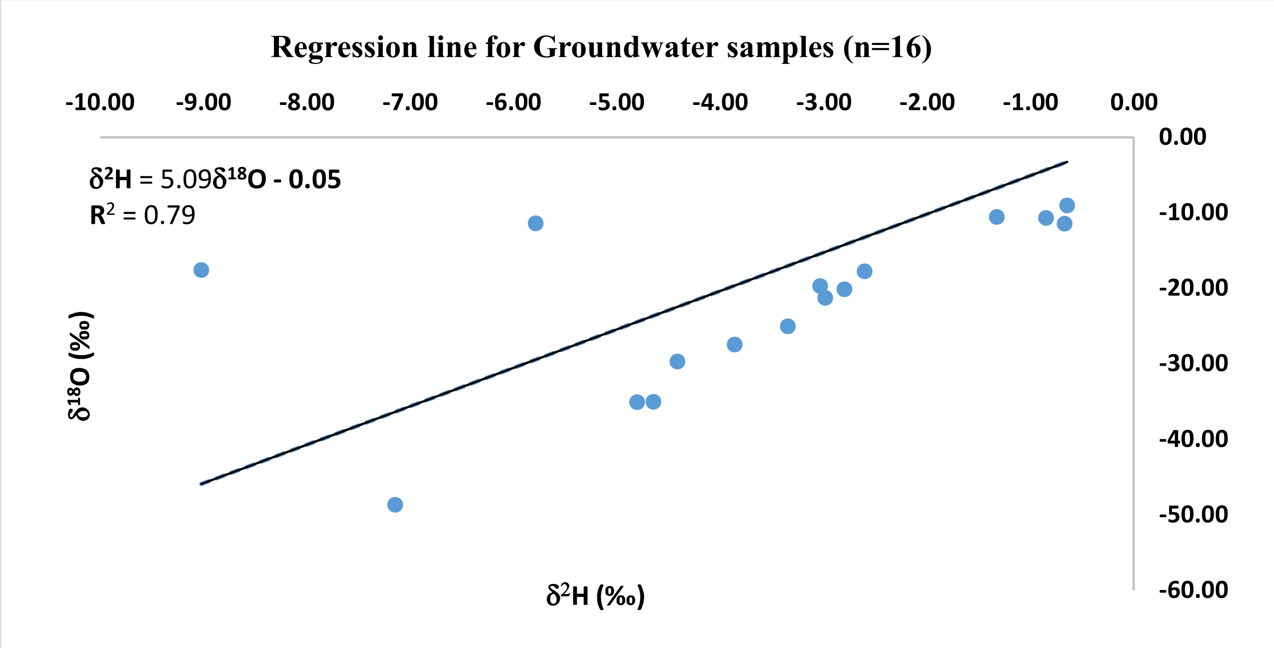

Figure 18. Isotopic characterization for Groundwater samples collected from piezometers (06), handpump (07), tube-wells (02), and the open well (01) for Post-monsoon 2023.

11 SUMMARY AND CONCLUSION

Site visits to NTPC Khargone power station, located near villages Selda, Balabad and Dalchi in Barwah tehsil of Khargone district of Madhya Pradesh, and the surrounding 10 km area were undertaken for pre-monsoon season during April 25 – 30, 2023, for post-monsoon season during October 9 – 13, 2023 and for pre-monsoon season during May 5 – 9, 2024 by the survey team of IIT Roorkee. During these site visits, groundwater and surface water samples were collected from different sources such as hand pumps, tube wells, open wells, ponds, reservoirs, rivers, ash dyke and piezometers etc. Groundwater table depth was also measured in existing open wells and piezometers to prepare groundwater table and flow direction maps. Soil samples at the surface, 30 cm, and 60 cm from the ground were also collected and brought to

IIT Roorkee for the analysis of soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, CO_3, HCO_3, Cl, SO_4, NO_3, F-, and PO_4), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.). Collected surface and groundwater samples were analysed to measure water quality parameters like pH, EC, DO, BOD, COD, major cations (Na, K, Ca, Mg, and Fe etc.), major anions (CO3, HCO3, Cl, SO4, NO3, F-, and PO4 etc.) and Heavy metals (Cd, Zn, Hg, As, Cr, Pb etc.). Some water quality parameters were determined using in-situ probes, and major cations, anions and heavy metals were determined using laboratory facilities available at IIT Roorkee. The following conclusions are made based on the analysis of 1st & 2nd year of sampling (pre and post-monsoon 2023 data) and pre-monsoon 2024 sampling.

1. Analysis of groundwater table observation reveals that, in general, the groundwater is flowing in two distinct patterns. The groundwater in the area to the north of the power station flows northwards towards Narmada River, and the groundwater in the area to the southern side of the power station flows towards the south and southwest direction.
2. The groundwater table contour map of the area is found mostly in line with its surface drainage pattern.
3. The water quality of most of the surface water samples was found to be well within the prescribed limits of BIS standards during the pre-monsoon 2023 season. The concentration of a few elements such as fluoride, sulphate and some heavy metals such as Fe, Se, and As was found to be slightly higher than the prescribed BIS limits of drinking water in ash dyke samples. Also, the pH values were slightly high in surface water samples collected from the ash dyke area.
4. The water quality of most of the groundwater samples was found to be well within the prescribed limits of BIS standards during the pre-monsoon 2023 season. The concentration of a few elements such as fluoride, nitrate, sulphate, and some heavy metals such as Fe, and Se was found to be slightly higher than the prescribed BIS limits of drinking water in a few groundwater samples during pre-monsoon 2023 season, which will be ascertained further during upcoming post-monsoon visit. Overall, the groundwater quality in the pre-

monsoon season is suitable for domestic use, indicating that it meets the standards and requirements necessary to provide safe and clean water for households.

5. The pH range of the soil samples analyzed in this study ranged from 6.05 to 7.5, with an average value of 6.8 when all sample depths were considered. The soil is frequently found to be neutral (34 out of 36 samples) within the pH range of 6.5 to 7.5. Only two samples showed acidic nature at 0 cm depth and 30 cm depth, respectively. Other soil chemical properties were found well within the prescribed limits.
6. The overall slope of the post- monsoon groundwater samples (5.09) is less steep than the LMWL (7.68) and pre- monsoon groundwater samples (5.74), indicating meteoric water to be primary source of groundwater recharge. The individual trends of piezometer samples (06), handpump (07), tubewells (02), and the open well (01) are showing the similar patterns as in case both pre-monsoon season and post-monsoon season.

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Appendix-A: Photographs of Sampling Sites

Sl. No.	Site Details	Location Details	Location Photograph
Ground Water Sites			
1.	Site Code: KHR1 Latitude: 22.077748 Longitude: 75.831549	In House of Sh. Rai Singh S/O Sh. Jai Sing. On Road of Pipalgaon to NTPC Power station, Near Electric Triangle pole of HT Line, Vill Dalchi	
2.	Site Code: KHR2 Lat: 22.060904 Long: 75.765297	Anganwadi & School Compound Near Hanuman Mandir, Vill Bhatyaan Khurd Remarks: Nearby well depth was also taken	
3.	Site Code: KHR3 Lat: 22.069258 Long: 75.857885	Near NTPC opp Bhilal Baba Temple, Gate No. 1,opp Cooling Towers, Below Bargad Tree	

4.	Site Code: KHR4 Lat: 22.068803 Long: 75.862023	Between NTPC & Town ship, opposite to Boundary Pillar S.N. 230-240	
5.	Ste Code: KHR5 Lat: 22.124938 Long: 75.895198	Inside Primary School, Vill Baddgaon Remarks: Nearby well depth also measured	
6.	Site Code: KHR5A Lat: 22.12407 Long: 75.89518	Adjacent to main road, Vill Badgaon	

7.	Site Code: KHR6 Lat: 22.122422 Long: 75.842507	opp Madhya Pradesh Gramin Bank, opp Health Centre. Vill Kanapur Remarks: Indiamarka Handpump	
8.	Site Code: KHR6A Lat: 22.12545 Long: 75.84165	Well in the field, Vill Kanapur	
9.	Site Code: KHR7 Lat: 22.123495 Long: 75.794	In House of sh. Daya Ram, Vill Londhi (Jhirbar)	

10.	Site Code: KHR7A Lat: 22.12314 Long: 75.7963	Londhi village Remarks: Motor was running at time of measurement	
11.	Site Code: KHR7B Lat: 22.12126 Long: 75.79317	Londhi village	
12.	Site Code: KHR8A Lat: 22.10271 Long: 75.75548	Karan Gangle Handpump, Pipalgone village. Remarks: Nearby well depth also measured	

13.	Site Code: KHR9A Lat: 22.10857 Long: 75.75845	Lokesh Rathore Tubewell, Pipalgaon	
14.	Site Code: KHR10 Lat: 22.04166 Long: 75.81254	Near Anganwadi Kendra, Bhopada	
15.	Site Code: KHR10A Lat: 22.04086 Long: 75.81116	Near Roop Singh house, Bhopada Remarks: Indiamarka handpump	

16.	Site Code: KHR11 Lat: 22.007591 Long: 75.851219	Near KHR 12, Hanuman Temple, Padaliya village	
17.	Site Code: KHR12 Lat: 22.007275 Long:75.853942	Padaliya village Remarks: Gawali samaj Dharamshala	
18.	Site Code: KHR13 Lat: 22.066083 Long: 75.871388	Adjoining of NTPC Community Centre Near New Hanumaan Temple Remarks: Measurement of nearby well also done	

19.	Site Code: KHR14 Lat: 22.049303 Long: 75.877826	Opp Gram Panchayat office. Vill Kheri Bujurg	
20.	Site Code: KHR15 Lat: 22.069233 Long: 75.857978	Near Bhilal Baba Temple, opposite cooling tower, Near NTPC Gate No. 1	
21.	Site Code: KHR15A Lat: 22.07092 Long: 75.85599	Near KHR 15 and KHR 3, Below Mango tree	

22.	Site Code: KHR16A Lat: 22.07912 Long: 75.80412	Adjacent to Gangour thermal power station road	
23.	Site Code: KHR17 Lat: 22.069467 Long: 75.852274	Below Tower Line, North side of Power station, Side of NTPC Road Remarks: Seepage water from below power station	
24.	Site Code: KHR18 Lat: 22.062953 Long: 75.852559	Well inside power station	

25.	Site Code: KHR19 Lat: 22.075184 Long: 75.824819	opp Community Centre Near Primary School, Near Baba Ramdev Mandir, Dalchi	
26.	Site Code: KHR20 Lat: 22.092052 Long: 75.849177	Below Tower Line, North side of Power station, Side of NTPC Road	
27.	Site Code: KHR20A Lat: 22.0833 Long:75.8515	Maal Singh Jhapdiya Well, Jamniya village	

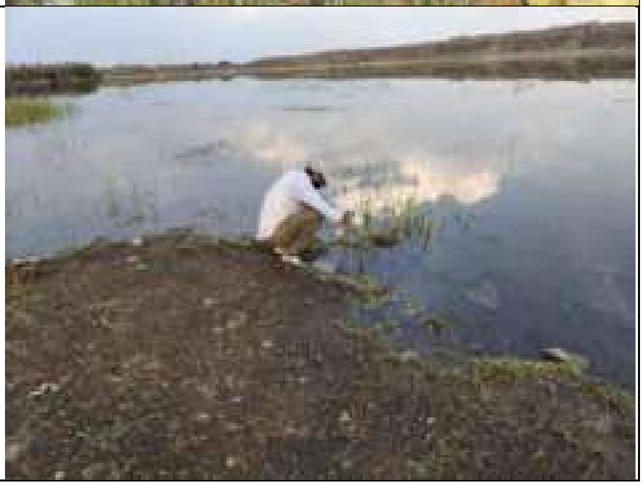
28.	Site Code: KHR21 Lat: 22.12321 Long:75.90812	Adjacent to pipalgone road	
29.	Site Code: KHR22 Lat: 22.11305 Long: 75.92877	Adjacent to Pipalgone road	
30.	Site Code: KHR23 Lat: 22.10902 Long: 75.93549	Adjacent to Pipalgone road	

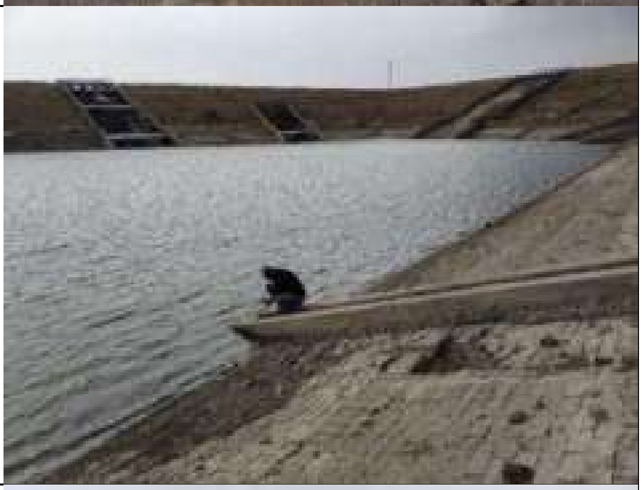
31.	Site Code: KHR24 Lat: 22.04485 Long: 75.87855	Adjacent to Umaria road	
32.	Site Code: KHR25 Lat: 22.02839 Long: 75.89527	In front of Rewa Gurjar Dharamshala, Gram panchayat office, Umaria Remarks: Nearby handpump measurement was also done	
33.	Site Code: KHR26 Lat: 21.99242 Long: 75.86363	In the field adjacent to Padaliya road	

34.	Site Code: KHR-27 Lat: 22.021429 Long: 75.879967	Adjacent to road nimori	
35.	Site Code: KHR-28 Lat: 21.97891 Long: 75.86348	Adjacent to Padaliya road, open well	
36.	Site Code: KHR-29 Lat: 21.978471 Long: 75.862909	Adjacent to Khargone Sanawad Road Near IOC Petrol Pump	

37.	Site Code: KHR-30 Lat: 22.04404 Long: 75.85192	Adjacent to Umerdad road	
38.	Site Code: KHR-31 Lat: 22.06500 Long: 75.88535	Adjacent to Gangour Thermal Plant Rd	
39.	Site Code: KHR-32 Lat: 22.10956 Long: 75.96084	Adjacent to Khargone - Sanawad Rd, Amarpura	

Surface Water Sites			
34.	Site Code: KHR51 Lat: 22.07047 Long: 75.858149	Pond Between NTPC Power station & Township	
35.	Site Code: KHR52 Lat: 22.12206 Long: 75.842803	Pond near Health Centre at Main Road, Vill Kanapur	
36.	Site Code: KHR53 Lat: 22.104185 Long: 75.812277	Jirbhar lake	

37.	Site Code: KHR54A Lat: 22.158804 Long: 75.76167	Narmada River Downstream	
38.	Site Code: KHR55 Lat: 22.006354 Long: 75.848828	Ambak Reservoir	
39.	Site Code: KHR56 Lat: 22.075493 Long: 75.927687	Lachhora Talab	

40.	Site Code: KHR57 Lat: 22.115246 Long: 75.866087	Kattora Pond, Shelda Power station-Kattora Road	
41.	Site Code: KHR58 Lat: 22.07323 Long: 75.833941	OFL Ash Dyke	
42.	Site Code: KHR59 Lat: 22.073978 Long: 75.839568	Lagoon 1 Ash Dyke Remarks: Dried up	

43.	Site Code: KHR60 Lat: 22.07661 Long: 75.8332	Lagoon 2 Ash Dyke	
44.	Site Code: KHR61 Lat: 22.06741 Long: 75.860638	Raw water reservoir inside power station	Photo not taken
45.	Site Code: KHR61A Lat: 22.063462 Long: 75.855098	Aerated water from raw water reservoir	
46.	Site Code: KHR62 Lat: 22.07441 Long: 75.850902	Nala flowing as groundwater drainage below tower line on road crossing near power station.	

47.	Site Code: KHR63 Lat: 22.1927 Long: 75.97763	Narmada River upstream, Toksar	
48.	Site Code: KHR64 Lat: 22.00772 Long: 75.90917	Ambak River, Khargone-Sanawad road	

Soil Sampling Sites			
49.	Site Code: KHR101 Lat: 22.068686 Long: 75.865808	NTPC Plantation Land near Shelda Village	
50.	Site Code: KHR102 Lat: 22.061526 Long: 75.87233	NTPC Power station to Kheri road along NTPC Railway line	
51.	Site Code: KHR103 Lat: 22.077065 Long: 75.832013	Near NTPC Boundary inside Dalchi along Power station AshDyke - Dalchi road	

52.	Site Code: KHR104 Lat: 22.062734 Long: 75.845571	Power station to Bhopada side single Chimney side	
53.	Site Code: KHR105 Lat: 22.113848 Long: 75.868283	opp side of Kottara Pond, Power station to Kattora Village	
54.	Site Code: KHR106 Lat: 22.119023 Long: 75.890667	Near Badgaon Village, Near Papu Dhaba	

55.	Site Code: KHR107 Lat: 22.117732 Long: 75.83194	Kanhapur-Pipalgaon Road ,Along Road site outside Kanhapur	
56.	Site Code: KHR108 Lat: 22.123119 Long: 75.790038	Pipalgaon Londi road, Londi along road side Near Hand Pump	
57.	Site Code: KHR109 Lat: 22.118459 Long: 75.757034	opp Sant Siya ram Auto Parts & Garrage	

58.	Site Code: KHR110 Lat: 22.062688 Long: 75.768112	Village Bhatiyan On Power station road Near Overhead water tank opp side	
59.	Site Code: KHR111 Lat: 22.044646 Long: 75.817312	Village Bhopada Shalda Road	
60.	Site Code: KHR112 Lat: 22.090059 Long: 75.848602	Vill Jamnia	

Piezometers around ash dyke			
61.	Site Code: KHR PZ1 Lat: 22.07826 Long: 75.8367	Piezometer 1, Ash Dyke	
62.	Site Code: KHR PZ2 Lat: 22.07721 Long: 75.83306	Piezometer 2, Ash Dyke	
63.	Site Code: KHR PZ3 Lat: 22.07476 Long: 75.83177	Piezometer 3, Ash Dyke	

64.	Site Code: KHR PZ4 Lat: 22.07289 Long: 75.83233	Piezometer 4, Ash Dyke	
65.	Site Code: KHR PZ5 Lat: 22.07055 Long: 75.83277	Piezometer 5, Ash Dyke	
66.	Site Code: KHR PZ6 Lat: 22.07089 Long: 75.83548	Piezometer 6, Ash Dyke	

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Annexure-5

CSR Works by NTPC-Khargone STPS

FY: 2024-25 (April 2024 to September 2024)

Girl Empowerment mission Workshop 2024 by NTPC Khargone.

Organization of Mega Health checkup camp at Dalchi Village

Education- Stationery and School Bag Distribution to PAV Govt. Schools

Distribution of Sweet packets to PAV schools under CSR on Independence Day- 2024

Organization of District Level Kabaddi at NTPC Khargone Stadium in which more than 500 students participated.

Organization of District Level Kabaddi at NTPC Khargone Stadium in which more than 800 students participated.

Distribution of school kits to 14 GEM Girls in BBPS

ANNEXURE-6

Water withdrawal data at NTPC-Khargone STPS

Source- Omkareshwar Dam on Narmada River

Period- Apr'24 to Sep'24' in FY: 2024-25

Water withdrawal data at NTPC Khargone STPP from Omkareshwar Dam on Narmada River				
Month	**Start date**	**Finish date**	**Days**	**Water Drawn, M3**
Apr-24	01-04-2024	30-04-2024	30	1840588
May-24	01-05-2024	31-05-2024	31	1901860
Jun-24	01-06-2024	30-06-2024	30	2068092
Jul-24	01-07-2024	31-07-2024	31	1153064
Aug-24	01-08-2024	31-08-2024	31	1253286
Sep-24	01-09-2024	30-09-2024	30	1794039
			Total Water Drawn, M3	**10010929**

Total Water Withdrawal from Apr'24 to Sep'24= 10010929 m3