

SECTION-III

SURVEY & SOIL INVESTIGATION

TECHNICAL SPECIFICATIONS

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TECHNICAL SPECIFICATIONS

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SURVEY & SOIL INVESTIGATION

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TECHNICAL SPECIFICATIONS

SECTION- III

SURVEY & SOIL INVESTIGATION

1. General Information & Scope Of Work

1.1 The technical specifications cover detailed survey including route alignment, profiling, tower spotting, optimization of locations, check survey, contouring, and soil investigation for the transmission lines/ part of the transmission lines covered under this specification as included in the BPS.

1.1.1 The scope of work inter-alia shall include the following: -

- a) Detailed Survey using Total Work stations or alternatively using ALTM (Airborne Laser Terrain Modeling) techniques , inter-alia including:
 - i) Digitised profiling along the selected route along with plan details.
 - ii) Computer aided tower spotting & optimization
 - iii) Soil resistivity measurement along the route
- b) Check survey including digitised contouring at undulated / hilly tower locations.
- c) Soil Investigation
- d) Preparation of Survey reports including estimation of Bill of Quantities, identification and explanation of route constraints (like Forest, Animal/ Bird sanctuary, reserve coal belt areas, oil pipe line/ underground inflammable pipe lines etc.), infrastructure details available en-route etc.
- e) Land scheduling within the line corridor (i.e. Right of way width) & tower base for compensation.

1.2 The Provisional quantities for the scope of work are indicated in relevant Price Schedules of BPS. The final quantities for route alignment, detailed survey and check survey (quantities in “kms” unit) shall be as approved by Site Engineer-in-charge and shall be along the approved route alignment. For contouring at undulated/hilly tower locations and soil investigations (quantities in “Locs.” unit), the actual quantities to be executed shall be decided by Site Engineer-in-charge during execution stage and the final quantities shall be as approved by Site Engineer-in-charge. The route alignment, detailed survey, including profiling & tower spotting, contouring, soil investigation, check survey etc. shall be carried out by the Contractor as per the technical specifications stipulated herein. Contractor shall indemnify the Employer for any loss or damage to properties, trees etc. during the survey work.

1.3 The Contractor should note that Employer will not furnish topographical maps prepared by survey of India but will make available assistance that may be required

in obtaining these by providing letters of recommendation to the concerned authorities. Further, in case the contractor opts for use of ALTM techniques for detailed survey, he shall be responsible for obtaining necessary clearances/permissions, as may be required from concerned authorities. The Employer will provide assistance that may be required in obtaining these clearances / permissions by providing letters of recommendation to the concerned authorities.

1.4 The work shall be carried out by the contractor using modern surveying techniques. The bidder shall indicate in his offer, the detailed description of the procedure to be deployed. The details of the equipment & facilities including software for image processing, computer aided tower spotting etc. available with the bidder or his associates shall also be furnished with the bid.

1.5 The Contractor shall also engage services of a reputed geo-technical consultant or experts from independent educational/ research institutions for examining stability aspects of the selected transmission line route/ locations in hilly terrain wherever required.

1.6 After carrying out the detailed survey and soil investigations, the contractor shall submit complete BOQ of the transmission lines, Tower schedule, Profiles, Survey reports and other details as per technical specification requirements to the Employer.

2. Route Alignment

2.1 The route Alignment shall be carried out by the contractor using Survey of India topographical maps.

2.2 Requirement of Transmission Line Routing

2.2.1 The Re-alignment/ routing, if any required, of the transmission line shall be most economical from the point of view of construction and maintenance. The contractor shall identify & examine alternative route alignments and suggest to the Employer the optimal route alignment.

2.2.2 Routing/ Re-routing of transmission line through protected/reserved forest area should be avoided. In case it is not possible to avoid the forests or areas having large trees completely, then keeping in view of the overall economy, the route should be aligned in such a way that involvement of forest area and cutting of trees is minimum.

2.2.3 In case, it is not possible to avoid protected areas, the towers of the transmission line upto 400 kV level which are installed in protected areas shall be designed for Multi Circuit (4 circuits) configuration of same voltage level considering reliability level of at least two (2). The top two circuits of these multi-circuit towers shall be used for stringing of the transmission line under present scope and the bottom two circuits shall be made available for stringing of any future transmission line of any transmission service providers/ State transmission utilities/Central transmission utilities passing through the same protected area. Further, the configuration and coordinates of such transmission towers shall be submitted to CEA, CTU & BPC (In case of TBCB Projects) by POWERGRID.

- 2.2.4 The route should have minimum crossings of Major river, Railway lines, National/ State highways, overhead EHV power line and communication lines.
- 2.2.5 The number of angle points shall be kept to minimum.
- 2.2.6 The distance between the terminal points specified shall be kept shortest possible, consistent with the terrain that is encountered.
- 2.2.7 Marshy and low-lying areas, river beds and earth slip zones shall be avoided to minimize risk to the foundations.
- 2.2.8 It would be preferable to utilize level ground for the alignment.
- 2.2.9 Crossing of power lines shall be minimum. Alignment of a transmission line with respect to existing line will be kept considering ROW and tower falling distance.
- 2.2.10 Crossing of communication line shall be minimized and it shall be preferably at right angle. Proximity and parallelism with telecom lines shall be eliminated to avoid danger of induction to them.
- 2.2.11 Areas subjected to flooding such as nalah shall be avoided.
- 2.2.12 Restricted areas such as civil and military airfield shall be avoided. Care shall also be taken to avoid aircraft landing approaches.
- 2.2.13 All alignment should be easily accessible both in dry and rainy seasons to enable maintenance throughout the year.
- 2.2.14 Certain areas such as quarry sites, tea, tobacco and saffron fields and rich plantations, gardens & nurseries which will present the Employer problems in acquisition of right of way and way leave clearance during construction and maintenance should be avoided.
- 2.2.15 Angle points during survey should be selected such that shifting of the point within 100 m radius is possible at the time of construction of the line.
- 2.2.16 The line routing should avoid large habitations, densely populated areas, Forest, Animal/Bird sanctuary, reserve coal belt areas, oil pipe line/underground inflammable pipe lines etc. to the extent possible.
- 2.2.17 The areas requiring special foundations and those prone to flooding should be avoided.
- 2.3** For examination of the alternatives & identification of the most appropriate route, besides making use of information/ data/ details available/ extracted through Survey of India Topographical maps, the contractor shall also carryout reconnaissance/ preliminary survey as may be required for verification & collection of additional information/ data/ details.
- 2.4** The contractor shall submit his preliminary observations & suggestions along with various information/ data /details collected, topographical map data marked with the alternative routes etc. The final evaluation of the alternative routes shall be conducted by the contractor in consultation with Employer's representatives and

optimal route alignment shall be proposed by the contractor. Site visit and field verification shall be conducted by the contractor jointly with the Employer's representative for the proposed route alignment.

- 2.5** Final route alignment drawing with latest topographical and other details/features including all rivers, railway lines, canals, roads etc. up to 8 km on both sides of selected route alignment shall be submitted by the contractor for Employer's approval along with report containing other information/details as mentioned above.
- 2.6** Changes in the route alignment, if any, during detail survey, shall be incorporated in the final route alignment drawings.

3. Detailed Survey

- 3.1** The detailed survey shall be carried out using Total stations etc. along the approved route alignment. As an alternative, the contractor may also use ALTM (Airborne Laser Terrain Modeling) techniques of equal or better accuracy for the detailed survey.
- 3.2** Soil resistivity, along the route alignment shall be measured in dry weather by four electrode method keeping inter-electrode spacing of 50 meters. For calculating soil resistivity formula 2ρ (Where $a=50$ m and r = megger reading in ohms) shall be adopted. Measurement shall be made at every 2 to 3 km along the length of the route. In case soil characteristics changes within 2 to 3 km, values shall have to be measured at intermediate locations also. Megger reading and soil characteristics should also be indicated in the soil resistivity results.

3.3 Route Marking

- 3.3.1** The route of the transmission line shall be recorded using GPS/ DGPS of positional accuracy less than 3m.
- 3.3.2** The co-ordinates of all the angle points as well as other important crossings, landmarks etc. shall be recorded using GPS for easy relocating.
- 3.3.3** At the starting point of the commencement of route survey a suitable peg/spike shall be driven firmly into the ground to indicate location of the survey instrument. The co-ordinates of the location of the survey instrument shall also be recorded. Further, the co-ordinates at prominent position at intervals of not more than 750 meters along the transmission line to be surveyed up to the next angle point shall also be recorded. Wooden peg of 50x50x650mm size shall also be driven at prominent position at intervals of not more than 750 meters along the transmission line to be surveyed up to the next angle point. Wire nails of 50 mm length should be fixed on the top of these pegs to show the location of instrument. The pegs shall be driven firmly into the ground to project 100 mm only above ground level. Wherever the line alignment crosses the EHT line, Railway line, P&T line or roads, the contractor shall record co-ordinates on the points of crossing. Wherever line route alignment passes over permanent land marks such as rock, boulders, culverts etc. suitable white paint marks with directional and POWERGRID

markings shall be made and co-ordinates recorded.

3.4 Profiling

- 3.4.1 The complete profiling along the route shall be carried out using modern surveying equipment viz. total stations. Reference levels at every 20 meters along the route are to be recorded. RLs at other undulations along the route as well as in the route plan and other En-route details viz. crossings, building & structures, trees & other infrastructure etc. shall also be recorded. Areas along the route, which in the view of the contractor, are not suitable for tower spotting, shall also be marked in profile. Any undulation keeping conductor location as reference may also be indicated as dotted line in profile.
- 3.4.2 The complete profiling details shall be digitized and the data shall be prepared & stored in the format compatible to computer-aided tower spotting software.
- 3.4.3 A printed/ plotted output of the digitized profiling shall be submitted by the contractor to Employer's site-in-charge for review before taking up computer-aided tower spotting.
- 3.4.4 For reconductoring packages, the Contractor shall then plot the profile of the HTLS Conductor under hot and cold conditions using the above ground profile & existing tower details, verify the various statutory electrical clearances & span limitations on the profile using sag tension calculations of the HTLS Conductor.
- 3.4.5 The profile and computer aided tower spotting prepared by contractor shall also cover the following with respect to clauses mentioned in technical specification, tower spotting data and statutory requirement:
- (i) Wind and weight spans (under maximum and minimum temperature of conductor and no wind condition i.e. hot and cold condition)
 - (ii) Clearances from ground, power lines, highways, communication lines, rivers etc with conductor curves under hot and cold condition)
 - (iii) Clearances from earth wire & OPGW with top conductor at midspan for maximum and minimum temperature combination of earth wire & OPGW and top conductor.

3.5 Optimisation of Tower Location/ Tower Spotting

- 3.5.1 Optimisation of tower locations including profiling shall be done by the contractor using computer-aided tower spotting software - PLSCADD and shall furnish sample calculations and manual tower spotting drawings for some typical sections.
- 3.5.2 The sag-tension characteristics of the conductor as well as tower spotting data shall be furnished by the Employer to the contractor during execution stage. Sag template curves, if any required for tower spotting, shall be prepared by the contractor and two sets of sag-template curves shall be given to POWERGRID for checking of profile.
- 3.5.3 General description of towers is indicated in **Section-I** of this specification for

information of the Bidders.

3.5.4 **Tower Spotting**

While profiling & spotting the towers, the following shall be borne in mind:

a) Span

The number of consecutive spans between the section points shall not exceed 15 spans or 5 km in plain terrain and 10 spans or 3km in hilly terrain as well as in coastal area. A section point shall comprise of tension point with B/DB/QB type or C/DC/QC type or D/DD/QD type towers as applicable.

b) Extension/Truncation

An individual span shall be as near to the normal design span as possible. In case an individual span becomes too short with normal supports on account of undulations in ground profile, one or both the supports of the span may be extended by inserting standard body/ leg extension. In case of locations where the ground clearance is available, truncated towers may be spotted. The provisions kept in the design of towers w.r.t. body/ leg extensions, truncations shall be intimated to the contractor by the Employer during execution stage.

c) Loading

There shall not be any upward force on suspension towers under normal working conditions and the suspension towers shall support at least the minimum weight span as provided in the designs. In case uplift is unavoidable, it shall be examined if the same can be overcome by adding standard body extensions to the towers failing which tension towers designed for the purpose shall be deployed at such positions.

d) Road Crossing

At all important road crossings, the tower shall be fitted with normal suspension and tension insulator strings depending on the type of tower, but the ground clearance at roads under maximum temperature and in still air shall be such that even with conductor broken in adjacent span, ground clearance of the conductor from the road surfaces will not be less than specified minimum ground clearances.. At all national highways, any tension tower based on span and angle of crossing may be used and crossing span shall not be more than 250 meters, unless higher span is permitted by national highways authority in case of highways having more lanes.

e) Railway Crossings

All the railway crossings coming En-route the transmission line shall be identified by the Contractor. At the time of detailed survey, the railway crossings shall be finalised based on the following and also confirming to the regulation laid down by the Railway Authorities.

i) The crossings shall be supported on D/DD/QD type tower on either side.

- ii) The crossing shall normally be at right angle to the railway track.
- iii) The minimum horizontal distance measured at right angles from the center of nearest track to any part of a structure (all structures shall be rigid and well founded), carrying electrical conductors crossing a railway shall be equal to the height of the structure in meters above normal ground level plus 6 meters.
- iv) No crossing shall be located over a booster transformer, traction switching station, traction sub-station, Overlap Section or a track cabin location in an electrified area.
- v) The crossing span will be limited to 300 meters or 80% of the normal span for which the structure is designed whichever is less.
- vi) Minimum ground clearance between crossing conductor under condition of maximum sag and railway line shall maximum of following:

(I) Vertical Clearance for OHE (other than high rise OHE):

Sl. No.	Transmission line voltage level	Minimum clearances from Rail Level
		New Power Line Crossing or Crossing Planned for Alteration
1	Above 66 kV & upto 132 kV	15.56 m
2	Above 132 kV & upto 220 kV	16.46 m
3	Above 220 kV & upto 400 kV	18.26 m
4	Above 400 kV & upto 500 kV	19.16 m
5	Above 500 kV & upto 800 kV	21.86 m

(II) Vertical Clearance for high rise OHE:

Sl. No.	Transmission line voltage level	Minimum clearances from Rail Level
		New Power Line Crossing or Crossing Planned for Alteration
1	Above 66 kV & upto 132 kV	17.56 m
2	Above 132 kV & upto 220 kV	18.46 m
3	Above 220 kV & upto 400 kV	20.26 m
4	Above 400 kV & upto 500 kV	21.16 m
5	Above 500 kV & upto 800 kV	23.86 m

Note: Applicable only for electrification of routes where double stack container

having maximum height of 6809mm is plying.

(III) Minimum Clearances between Highest Traction Conductor & Lowest Crossing Conductor

1	Above 66 kV & upto 132 kV	3.05 m
2	Above 132 kV & upto 220 kV	4.58 m
3	Above 220 kV & upto 400 kV	5.49 m
4	Above 400 kV & upto 500 kV	7.94 m
5	Above 500 kV & upto 800 kV	7.94 m

f) River Crossings

In case of major river crossing, river crossing towers shall be of suspension type alongwith anchor towers of D/DD/QD type tower on either side of the main river crossing. Alternately on the basis of economics and / or site/ execution constraints crossing of rivers using normal extended angle towers (+18/+25/+30M Extensions) also shall be considered. For navigable rivers, clearance required by navigation authority shall be provided. For non-navigable river, clearance shall be reckoned with respect to highest flood level (HFL).

g) Power line Crossings

Where the line is to cross over another line, towers with suitable extensions may be used, depending upon the merit of the prevailing site condition.

For power line crossing of 400 kV or above voltage level, large angle & dead-end towers (i.e. D/DD/QD) shall be used on either side of power line crossing (i.e. D/DD/QD - D/DD/QD arrangement).

For power line crossing of 132 kV and 220 kV voltage level, angle towers (B/C/D/DB/DC/DD/ QB/QC/QD) shall be used on either side of power line crossing depending upon the merit of the prevailing site condition and line deviation requirement.

For power line crossing of 66 kV and below voltage level, suspension/ tension towers shall be provided on either side of power line crossing depending upon the merit of the prevailing site condition and line deviation requirement.

Use of D/DD/QD towers for crossing of 66kV, 132kV or 220kV voltage lines shall however be permitted for cases where more than +25 m extension are required due to site conditions.

In case of crossing with B/C/DB/DC/QB/QC towers proper guying shall be provided to facilitate stringing of the power line crossing sections separately on obtaining line shutdowns.

Clearance between lines crossing each other shall be kept in accordance with the CEA (Measures Relating to Safety and Electric Supply) Regulations, 2010 as amended up-to-date. In order to reduce the height of the crossing towers, it may be advantageous to remove the ground-wire of the line to be crossed (if this is possible and permitted by the Employer of the line to be crossed).

Minimum clearance in meters between lines when crossing each other:

Sl. No.	Nominal	110-132 kV	220 kV	400 kV	765 kV	500 kV HVDC	800 kV HVDC	1200 kV
1	110-132KV	3.05	4.58	5.49	7.94	6.86	9.04	10.44
2	220KV	4.58	4.58	5.49	7.94	6.86	9.04	10.44
3	400KV	5.49	5.49	5.49	7.94	6.86	9.04	10.44
4	765KV	7.94	7.94	7.94	7.94	7.94	9.04	10.44
5	500KV HVDC	6.86	6.86	6.86	7.94	7.94	9.04	10.44
6	800KV HVDC	9.04	9.04	9.04	9.04	9.04	9.04	10.44
7	1200 KV	10.44	10.44	10.44	10.44	10.44	10.44	10.44

h) Telecommunication Line Crossings

The angle of crossing shall be as near to 90 degree possible. However, deviation to the extent of 30 degree may be permitted under exceptionally difficult situations.

When the angle of crossing has to be below 60 degree, the matter will be referred to the authority in charge of the telecommunication System. On a request from the Contractor, the permission of the telecommunication authority may be obtained by the Employer.

Also, in the crossing span, power line support will be as near the telecommunication line as possible, to obtain increased vertical clearance between the wires.

i) Oil Pipe-Line Crossings

Wherever transmission line crosses an oil/ gas pipeline, the angle of crossing shall be as near to 90 degree possible and in no case less than 75 degrees. Further, a minimum separation of 25 m should be maintained between pipe line and transmission line footings & pipe/ counterpoise earthing.

j) Details En-route

All topographical details, permanent features, such as trees, building etc. within following distance on either side of the alignment shall be detailed on the profile plan: -

1	1200 kV Single Circuit	44.5 m
2	765 kV Double Circuit	33.5 m
3	765kV Single Circuit Delta	32 m
4	765kV Single Circuit Horizontal	37m
5	±800 kV HVDC	34.5 m
6	400kV Single Circuit	26.0 m
7	400kV Double Circuit	23.0 m
8	±500 kV HVDC	26.0 m
9	220 kV	16m
10	132 kV	12.5 m

3.6 Clearance from Ground, Building, Trees etc.

Clearance from ground, buildings, trees and telephone lines shall be provided in conformity with the CEA’s Regulations 2023 (Measures relating to Safety and Electric Supply).

3.6.1 The Contractor shall count, mark and put proper numbers with suitable quality of paint at his own cost on all the trees that are to be cut by the Employer at the time of actual execution of the work as detailed below. Contractor may please note that Employer shall not pay any compensation for any loss or damage to the properties or for tree cutting due to Contractor’s work.

3.6.2 To evaluate and tabulate the trees and bushes coming within following distance on either side of the central line alignment the trees will be numbered and marked with quality paint serially from angle point 1 (I) onwards and the corresponding number will be painted on the stem of trees at a height of 1 meter from ground level.

1	1200 kV Single Circuit	44.5 m
2	765 kV Double Circuit	33.5 m
3	765kV Single Circuit Delta	32 m
4	765kV Single Circuit Horizontal	37m

5	+800 kV HVDC	34.5 m
6	400kV Single Circuit	26.0 m
7	400kV Double Circuit	23.0 m
8	+500 kV HVDC	26.0 m
9	220 kV	16m
10	132 kV	12.5 m

The trees list should contain the following:

- a) Girth (circumstances) measured at a height of 1 meter from ground level.
- b) Approximate height of the tree with an accuracy of +2 meters.
- c) Name of the type of the species/ tree.
- d) The bushy and under growth encountered within following distance should also be evaluated with its type, height, girth and area in square meters, clearly indicating the growth in the tree/bush statement: -

1	1200 kV Single Circuit	89 m
2	765 kV Double Circuit	67 m
3	765kV Single Circuit Delta	64 m
4	765kV Single Circuit Horizontal	74 m
5	+800 kV HVDC	69m
6	400kV Single Circuit	52 m
7	400kV Double Circuit	46 m
8	+500 kV HVDC	52 m
9	220 kV	32m
10	132 kV	25m

3.6.3 The contractor shall also intimate the Employer, his assessment about the likely amount of tree & crop compensation etc. required to be paid by the Employer during execution stage. This assessment shall be done considering prevailing practices/guidelines, local regulations and other enquiries from local authorities.

- 3.6.4 The Contractor shall also identify the forest/ non-forest areas involved duly authenticated by concerned authorities.
- A statement of forest areas with survey/ compartment Number (all type of forest RF/ PF / Acquired forest/ Revenue forest/ Private forest/ Forest as per dictionary meaning of forest etc.)
 - A statement of non-forest areas with survey/ compartment nos.
 - Tree cutting details (Girth wise & specie wise)
 - Marking of forest areas with category on topo sheets 1:2,50,000 showing complete line route, boundaries of various forest divisions and their areas involved.
 - Village forest maps of affected line and affected forest area and marking of the same.
 - Forest division map showing line and affected forest area.

3.6.5 The Contractor shall finalize the forest clearance proposal on the prescribed format, as per requirements of the state/ MOE & F, duly completed in all respects for submission by the Employer to the Forest Department.

3.7 Preliminary Schedule

The profile sheets showing the locations of the towers together with preliminary schedules of quantities indicating tower types, wind & weight spans, angle of deviation, crossing & other details etc. shall be submitted by the contractor for review & approval by Employer's site-in-charge.

3.8 Check Survey of Tower Locations

3.8.1 The check survey shall be conducted to locate tower locations on ground conforming to the approved profile and tower schedule.

3.8.2 The co-ordinates of all the tower locations shall also be recorded using GPS / DGPS of positional accuracy less than 3m for easy relocating. The position of all tower locations shall be marked in the final digitized route alignment drawing with relative distances from any permanent bench mark area.

3.8.3 The contractor shall also collect required data at each tower location in respect of soil strata, ground water level, history of water table in adjacent areas/surface water, distance from permanent bench mark (these details to be furnished in a tabulated form) and classify the suitable type of foundation at each tower location based on the data collected at each location and detailed soil investigations carried out at selected locations etc.

3.9 Contouring at hilly/ undulated locations

3.9.1 The levels up or down of each pit centre with respect to centre of tower location shall be recorded at intervals of 2m using total stations/ GPS/ digital theodolite and digitized contour plans shall be made. Based on the digitized elevation plans, the

quantities of benching & protection work vis-à-vis possible unequal leg extensions shall be optimized using suitable computer-aided techniques/ software or manual method. Required tower and foundation details, cost data for comparative valuation for benching & protection work vis-à-vis unequal leg extensions shall be provided by the Employer to the Contractor during execution stage.

3.10 The changes desired by the Employer in the preliminary tower schedule or as may be required based on detailed survey of tower locations & contouring by the contractor, shall be carried out by the contractor and the final tower schedule shall be submitted for approval of Employer. The tower schedule shall show position of all type oftowers, span length, type of foundation for each tower, benching & revetment requirement, unequal leg extensions, deviation at all angles, crossings & other details etc.

3.11 Survey Methodology & Precision

3.11.1 All elevations shall be referenced to benchmarks established by the survey of India. Survey operations shall begin and end at benchmarks approved by the Employer.

3.11.2 During the leveling of the profile, check surveys will be affected at intervals not exceeding 50 km with benchmarks of known elevations. The difference in elevations as surveyed by the contractor and as declared by Survey of India for these benchmarks shall not exceed the precision required for 3rd order surveys $e \leq 24k$, where k is the distance between benchmarks in km and e is the difference between elevations in mm.

3.11.3 In the absence of suitable benchmarks, the leveling shall be done by two independent leveling parties working in opposite directions along the same line. The difference in elevations between the two surveys shall not exceed the precision required for 3rd order surveys as stated above.

3.11.4 All-important objects and features along the transmission line centerline (railways, highways, roads, canals, rivers, transmission lines, distribution lines, telephone lines etc.) shall be surveyed and located with a positional accuracy of 1:2000 between points of known horizontal position.

3.12 Survey Report

3.12.1 Complete BOQ of the transmission lines as per format enclosed with this technical specification at Annexure-A shall be furnished in the survey report.

3.12.2 Each angle point locations shall be shown with detailed sketches showing existing close by permanent land marks such as specific tree(s), cattle shed, homes, tube wells, temples, electric pole/ tower, telephone pole, canal, roads, railway lines etc. The relative distance of land marks from the angle points and their bearings shall be indicated in the sketch. These details shall be included in the survey report.

3.12.3 Information w.r.t infrastructure details available en-route, identification and explanation of route constraints, etc. shall also be furnished in the Survey report and shall inter-alia include the following:

3.12.3.1 Information regarding infrastructural facilities available along the final route

- alignment like access to roads, railway stations, construction material sources (like quarry points for stone, sand and availability of construction water), labour, existing transport facilities, fuel availability etc. shall be furnished in the survey report.
- 3.12.3.2 All observations which the Contractor thinks would be useful to the construction of the transmission lines mentioned under scope of work are to be reported.
- 3.12.3.3 Suggestions regarding the number of convenient zones (line segments/ portions) in which the entire alignment can be divided keeping in view the convenience of construction/project implementation are to be given.
- 3.12.3.4 Suggestions regarding location for setting up stores during line construction in consultation with Employer's representative shall also be provided by the contractor.
- 3.12.3.5 Working months available during various seasons along the final route alignment, with period, time of sowing & harvesting of different type of crops and the importance attached to the crops particularly in the context of way leave problems and compensation payable shall be stated by the Contractor.
- 3.12.3.6 Some portions of the line may require clearance from various authorities. The Contractor shall indicate the portion of the line so affected, the nature of clearance required and the name of concerned organizations such as local bodies, municipalities, P&T (name of circle), Inland navigation, Irrigation Department, Electricity Boards and Zonal railways, Divisional Forest Authorities etc.
- 3.12.4 All the requisite data for processing the case for statutory clearances such as PTCC, Forest and Railway shall be provided along with the report.
- 3.12.5 The contractor shall also collect & report (as per Formats enclosed at B) details pertaining to pollution levels envisaged along the transmission line.
- 3.12.6 Four copies of survey reports shall be furnished by the contractor to the Employer.

4. Land Scheduling for Compensation

4.1 The Land Scheduling required for Disbursement for compensation to the affected stake holders shall comprise of the following activities and shall be carried out after the Check survey.

1. Ownership identification
2. Assessment & Verification of Ownership details from revenue authority.
3. Rate finalization -Assessment of land compensation as per Govt. order/ resolution for each affected landowner.

4.2 Ownership identification: The Contractor shall mark the transmission line route on the geo referenced Cadastral map and identify the affected plot/Khasra no. Based on the affected plot/Khasra/Hissa/Subdivision/Podi nos the contractor shall also identify the area (Both Tower Base and Corridor) and the Ownership Details (name of the owners) from the Jamabandi/ Khasra-Khatauni/11 E Sketches/FMB (Field Measurement Book) Sketches. The cadastral map & its geo referencing shall be arranged by the Contractor. The Contractor will also arrange verified copy of cadastral map, Khatauni/11 E Sketches//FMB Sketches if demanded by revenue department.

4.3 Assessment & Verification of Ownership details from revenue authority: The Contractor shall get the above ownership details verified from the revenue authorities which may include up-dation of ownership details as well as bifurcation of areas among multiple owners in the affected area of the plot. The Contractor may be required to get the details verified by revenue authority in a statement showing tower no/ section of corridor, type of tower, Khasra number, owner's name & affected area, village and tehsil. In some of the states the contractor may also be required to prepare FMS (field measurement Sketch) based on the FMB from the revenue authority. The FMS shall show the line corridor, tower base along with name of the owner and affected area of each affected plot. The Employer shall assist the Contractor by providing letter to concerned revenue authority. (FMB & FMS sample copy attached in annexure-E1).

4.4 Rate finalization: The rate shall be finalized by the employer in association with the revenue authority if required.

Based on the above activities, statement for each plot showing the owner's name, affected area, unit rate and the total compensation to be disbursement shall be finalized and the contractor shall get the same jointly verified & signed from the revenue authority. Sample copy attached at Annexure E2. The statement shall be made for both tower base and line corridor as applicable. Further the contractor shall also collect the necessary documents from the affected parties viz Aadhar, Passbook/Account details & affidavit (if required) etc for necessary disbursement of compensation. The Contractor shall submit to the employer the detail status of Land scheduling for compensation every 15 days.

The georeferenced cadastral map with the transmission line corridor marked on it for the complete route in kml or shape file format shall be provided by the Contractor.

4.5 Payment for survey & Land Scheduling for compensation shall be paid on pro-rata basis on completion of survey & Land Scheduling and approval of the same by the Employer.

5. Geotechnical Investigations

5.1 General

5.1.1 Employer requires that a detailed Geotechnical investigation be carried out at various tower locations to provide the designer with sufficiently accurate information, both general and specific, about the substrata profile and relevant soil and rock parameters at site on the basis of which the foundation of transmission line towers can be classified and designed rationally.

5.1.2 These specifications provide general guidelines for geotechnical investigation of normal soils. Cases of marshy locations and locations affected by salt water or saltpeter shall be treated as special locations and the corresponding description in these specifications shall apply. Any other information required for such locations shall be obtained by Contractor and furnished to Employer.

5.2 Scope

- 5.2.1 The scope of work includes detail soil investigations and furnishing bore log data at various tower locations. The provisional quantities have been indicated in Bill Of Quantities. Detailed soil investigations shall be carried out as decided by site in-charge besides critical locations like railway crossing, river crossing etc. However, during actual execution of work, the quantities shall be decided by the Engineer - in - Charge, depending upon the soil strata and terrain. Based on the bore log data/ soil parameter/ soil investigation results, the Contractor shall recommend the type of foundations suitable for each location and the same shall be got approved by the Employer. For other locations, trial pit is to be done in every location for foundation classification up to foundation depth. No separate payment for trial pit shall be done.
- 5.2.2 These specifications cover the technical requirements for a detailed Geotechnical investigation and submission of a detailed Geotechnical Report. The work shall include mobilization of all necessary tools and equipment, provision of necessary engineering supervision and technical personnel, skilled and unskilled labour, etc. as required to carry out the entire field investigation as well as laboratory tests, analysis and interpretation of data collected and preparation of the Geotechnical Report. Contractor shall also collect data regarding variation of subsoil water table along the proposed line route. The aforementioned work shall be supervised by a graduate in Civil Engineering having at least 5 years of site experience in geotechnical investigation work.
- 5.2.3 Contractor shall make his own arrangements to establish the co-ordinate system required to position boreholes, tests pits and other field test locations as per the drawings/ sketches supplied by Employer. Contractor shall determine the reduced levels (RL's) at these locations with respect to benchmarks used in the detailed survey. Two reference lines shall be established based on survey data/details. Contractor shall provide at site all required survey instruments to the satisfactions of the Employer so that the work can be carried out accurately according to specifications and drawings. Contractor shall arrange to collect the data regarding change of course of rivers, major natural streams and nalas, etc., encountered along the transmission line route from the best available sources and shall furnish complete hydrological details at the tower location including maximum velocity discharge, highest flood level (H.F.L), scour depth etc. of the concerned rivers, major streams and nalas (canals).
- 5.2.4 The field and laboratory data shall be recorded on the proforma recommended in relevant Indian Standards. Contractor shall submit to Employer two copies of field bore logs (one copy each to Employer site and Corporate Office) and all the field records (countersigned by the Employer) soon after the completion of each boreholes/ test.
- 5.2.5 Whenever Contractor is unable to extract undisturbed samples, he shall immediately inform the Employer. Payment for boring charges shall be subject to Employer being satisfied that adequate effort has been made to extract undisturbed samples. Special care shall be taken for locations where marshy soils are encountered and Contractor in such cases shall ensure that specified numbers of vane shear tests are performed

and the results correlated with other soil parameters.

- 5.2.6 One copy of all field records and laboratory test results along with soil investigation report shall be sent to Employer. Employer may observe, at the laboratory testing procedures.
- 5.2.7 The Contractor shall interact with the Employer to get acquainted with the different types of structures envisaged and in assessing the load intensities on the foundation for the various types of towers in order to enable him to make specific recommendation for the depth, founding strata, type of foundation and the allowable bearing pressure.
- 5.2.8 After reviewing Contractor's geotechnical investigation draft report, Employer will call for discussions, to be held normally within one week at Employers site Office, in order to comment on the report in the presence of Contractor's Geotechnical Engineer. Any expenditure associated with the redrafting and finalising the report, traveling etc. shall be deemed included in the rates quoted for the geotechnical investigations.
- 5.2.9 Contractor shall carry out all work expressed and implied in these specifications in accordance with requirements of the specification.
- 5.2.10 The contractor shall prepare and submit soil profile along the transmission line route (in digitized form, with digitized route alignment drawing as base) indicating salient soil characteristics/ features, water table etc. based on detailed soil investigations and other details/ information collected during detailed survey.

5.3 General Requirements

- 5.3.1 Wherever possible, Contractor shall research and review existing local knowledge, records of test pits, boreholes, etc., types of foundations adopted and the behavior of existing structures, particularly those similar to the present project.
- 5.3.2 Contractor shall make use of information gathered from nearby quarries, unlined wells excavation etc. Study of the general topography of the surrounding areas will often help in the delineation of different soil types.
- 5.3.3 Contractor shall gather data regarding the removal of overburden at the tower location area either by performing test excavations, or by observing soil erosion or land slide in order to estimate reconsolidation of the soil strata. Similarly, data regarding recent landfills shall be studied to determine the characteristics of such land fill as well as the original soil strata.
- 5.3.4 The water level in neighboring streams and water courses shall be noted. Contractor shall make enquiries and shall verify whether there are abandoned underground works e.g. worked out ballast pits, quarries, old brick fields, mines, mineral workings etc.
- 5.3.5 It is essential that equipment and instruments be properly calibrated at the commencement of the work. If the Employer so desires. Contractor shall arrange for having the instruments tested at an approved laboratory at its cost and shall submit

the test reports to the Employer. If the Employer desires to witness such tests, Contractor shall arrange for the same.

5.4 Codes and Standards for Geotechnical Investigations

5.4.1 All standards, specifications and codes of practice referred to herein shall be the latest editions including all applicable official amendments and revisions. In case of conflict between the present specifications and those referred to herein, the former shall prevail. Internationally accepted standards which ensure equal or higher performance than those specified shall also be accepted.

5.4.2 All work shall be carried out in accordance with the following Indian Standards and Codes:

Indian Standards	Title	International Standard
IS 1080	Codes of Practice for Design and Construction of Shallow Foundations on soils (other than Raft, Ring & Shell)	
IS1498	Classification and Identification of Soils for General Engineering purposes.	ASTM D 2487 ASTM D2488
IS 1892	Code of Practice for Subsurface Investigation for Foundation	
IS 1904	Code of Practice for Design and Construction of foundation in Soils: General Requirements.	
IS 2131	Method of Standard Penetration Test for Soils	ASTM D 1586
IS 2132	Code of Practice for Thin Walled Tube Sampling of Soils	ASTM D 1587
IS 2720 (Part 1-39) (relevant parts)	Method of Test for Soils (Relevant Parts)	
IS 2809	Glossary of Terms and symbols Relating to Soil Engineering	ASTM D 653-14
IS 2911 (Part I-VI)	Code of Practice for Design and construction of Pile Foundations (Relevant Parts)	
IS 3043	Code of Practice for Earthing	
IS 4078	Code of Practice for Indexing and Storage of Drill Cores.	
IS 4091	Code of Practice for Design and Construction of Foundations for Transmission Line Towers and Poles	

IS 4434	Code of Practice for In-situ Vane Shear Test for Soils	ASTM D 2573(M)-15 ASTMD 4648(M)-16
IS 4453	Code of Practice for Sub-Surface Exploration by Pits, Trenches, Drifts and Shafts	
IS 4464	Code of Practice for Presentation of Drilling information and core description in Foundation investigation	
IS 4968(Part-II)	Method for Subsurface sounding for soils, dynamic method using cone and Bentonite slurry	
IS 5313	Guide for Core Drilling observations	
IS 6403	Code of Practice for Determination of Bearing Capacity of Shallow Foundation	
IS 6926	Code of Practice for Diamond Core Drilling for Site Investigation for River Valley Projects	
IS 6935	Method of Determination of Water level in a Bore Hole	
IS 2809	Glossary of Terms and symbols Relating to Soil Engineering	ASTM D 653-14
IS 2911 (Part I-VI)	Code of Practice for Design and construction of Pile Foundations (Relevant Parts)	
IS 3043	Code of Practice for Earthing	
IS 4078	Code of Practice for Indexing and Storage of Drill Cores	
IS 4091	Code of Practice for Design and Construction of Foundations for Transmission Line Towers and Poles	
IS 4434	Code of Practice for In-situ Vane Shear Test for Soils	ASTM D 2573 (M)-15 ASTMD 4648(M)-16
IS 4453	Code of Practice for Sub-Surface Exploration by Pits, Trenches, Drifts and Shafts	
IS 4464	Code of Practice for Presentation of Drilling information and core description in Foundation investigation	
IS 4968 (Part-II)	Method for Subsurface sounding for soils, dynamic method using cone and Bentonite slurry	
IS 5313	Guide for Core Drilling observations.	

IS 6403	Code of Practice for Determination of Bearing Capacity of Shallow Foundation	
IS 6926	Code of Practice for Diamond Core Drilling for Site Investigation for River Valley Projects	
IS 6935	Method of Determination of Water level in a Bore Hole	
IS 7422 Part(I-V)	Symbols and Abbreviations for use in Geological Maps Sections and subsurface Exploratory Logs (Relevant parts).	
IS 8009(Part-I)	Code of Practice for Calculation of Settlements of Foundations (Shallow Foundations subjected to symmetrical Vertical Loads).	
IS 8764	Method of Determination of Point Load Strength Index of Rocks.	
IS 9143	Method of Determination of Unconfined Compressive Strength of Rock Materials	ASTM D 7012-14e1
IS 9179	Method of Preparation of Rock Specimen for Laboratory Testing	
IS 9259	Specification for Liquid Limit Apparatus	ASTM D4318-17
IS 9640	Specification for Split Spoon Sampler	ASTM D1586-11
IS 10050	Method of Determination of Slake Durability Index of Rocks.	ASTM D4644-16
IS 11315 (Part 1-12)	Method for the Quantitative Description of discontinuities in Rock Mass	

5.5 Field Investigation for Soils

Tentative numbers of detailed soil investigation to be done is given in BPS

5.5.1 Boring

Boreholes are required for detailed soil investigations.

5.5.1.1 General Requirements

- a) Boreholes shall be made to obtain information about the subsoil profile, its nature and strength and to collect soil samples for strata identification and for conducting laboratory tests. The minimum diameter of the borehole shall be 150mm and boring shall be carried out in accordance with the provisions of IS 1892 and the present specification.
- b) All boreholes shall be 10m deep for normal soil conditions. The depth of boreholes at river crossings and special locations shall be 40m. If a strata is encountered where the Standard Penetration Test Records N values greater than 100, with characteristics of rock, the borehole shall be advanced by coring at least 3m further in normal locations and at least 7m further for the case of river crossing locations with prior approval of the Employer. When

the boreholes are to be terminated in soil strata an additional Standard Penetration Test shall be carried out at the termination depth. No extra payment shall be made for carrying out Standard Penetration Tests.

- c) Casing pipe shall be used when collapse of a borehole wall is probable. The bottom of the casing pipe shall at all times be above the test of sampling level but not more than 15 cm above the borehole bottom. In case of cohesionless soils, the advancement of the casing pipe shall be such that it does not disturb the soil to be tested or sampled. The casing shall preferably be advanced by slowly rotating the casing pipe and not by driving.
- d) In-situ tests shall be conducted and undisturbed samples shall be obtained in the boreholes at intervals specified hereafter. Representative disturbed samples shall be preserved for conducting various identification tests in the laboratory. Water table in the bore hole shall be carefully recorded and reported following IS 6935. No water or drilling mud shall be used while boring above ground water table. For cohesion less soil below water table, the water level in the borehole shall at all times be maintained slightly above the water table.
- e) The borehole shall be cleaned using suitable tools to the depth of testing or sampling, ensuring least or minimum disturbance of the soil at the bottom of the borehole. The process of jetting through an open tube sampler shall not be permitted. In cohesive soils, the borehole may be cleaned by using a bailer with a flap valve. Gentle circulation of drilling fluid shall be done when rotary mud circulation boring is adopted.
- f) On completion of the drilling, Contractor shall backfill all boreholes as directed by the Employer.

5.5.1.2 Auger Boring

Auger boring may be employed in soft to stiff cohesive soils above the water table. Augers shall be of helical or post hole type and the cuttings brought up by the auger shall be carefully examined in the field and the description of all strata shall be duly recorded in the field bore log as per IS 1498. No water shall be introduced from the top while conducting auger boring.

5.5.1.3 Shell and Auger Boring

- 5.5.1.3.1 Shell and auger boring may be used in all types of soil which are free from boulders. For cohesion less soil below ground water table, the water level in the borehole shall always be maintained at or above ground water level. The use of chisel bits shall be permitted in hard strata having SPT-N value greater than 100 Chisel bits may also be used to extend the bore hole through local obstructions such as old construction. Boulders rocky formations, etc. The requirements in **Clause 4.5.1.2** shall apply for this type of boring also.
- 5.5.1.3.2 Rotary method may be used in all types of soil below water table. In this method the boring is carried out by rotating the bit fixed at the lower end of the drill rod. Proper

care shall be taken to maintain firm contact between the bit and the bottom of the borehole. Bentonite or drilling mud shall be used as drilling fluid to stabilise and protect the inside surface of the borehole. Use of percussion tools shall be permitted in hard clays and in dense sandy deposits.

5.5.2 **Standard Penetration Test (SPT)**

- 5.5.2.1 This test shall be conducted in all types of soil deposits encountered within a borehole, to find the variation in the soil stratification by correlating with the number of blows required for unit penetration of a standard penetrometer. Structure sensitive engineering properties of cohesive soils and silts such as strength and compressibility shall not be inferred based on SPT values.
- 5.5.2.2 The test shall be conducted at every change of stratum or at interval of not more than 1.5 m whichever is less as per IS 2131, for a depth up to 10 m in case of normal soils and 40 m in case of special locations.
- 5.5.2.3 The Equipment, accessories and procedures for conducting the test shall conform to IS 2131 and IS 9640. The test shall be conducted immediately after reaching to the test depth and cleaning of bore hole.
- 5.5.2.4 The test shall be carried out by driving a standard split spoon sampler in the bore hole by means of hammer of standard weight as specified in IS 2131, having a free fall of 750 mm. The sample shall be driven using the hammer for 450 mm recording the number of blows for every 150 mm. The number of blows for the last 300 mm drive shall be reported as N value.
- 5.5.2.5 This test shall be discontinued when the blow count is equal to 100 or the penetration is less than 25 mm for 50 blows. At the level where the test is discontinued, the number of blows and the corresponding penetration shall be reported. Sufficient quantity of disturbed soil samples shall be collected from the split spoon sampler for identification and laboratory testing. The sample shall be visually classified and recorded at the site as well as properly preserved without loss of moisture content and labeled.
- #### 5.5.3 **Sampling**
- 5.5.3.1 **General**
- a) Sufficient number of soil samples shall be collected. Disturbed soil samples shall be collected for soil identification and for conducting tests such as sieve analysis, index properties, specific gravity, chemical analysis etc. Undisturbed samples shall be collected to estimate the physical bearing capacity and settlement properties of the soil.
 - b) All accessories and sampling methods shall conform to IS 2132. all disturbed and undisturbed samples collected in the field shall be classified as per IS 1498.
 - c) All samples shall be identified with date, borehole or test pit number, depth of sampling, etc. The top surface of the sample in-situ shall also be marked. Care shall be taken to keep the core and box samples vertical, with the mark directing

upwards. The tube samples shall be properly trimmed at one end and suitably capped and sealed with molten paraffin wax. The Contractor shall be responsible for packing, storing in a cool place and transporting all the samples from site to the laboratory within seven days after sampling with probe, protection against loss and damage.

5.5.3.2 Disturbed Samples

- a) Disturbed soil samples shall be collected in boreholes at regular intervals. The weight of sample as per table 2 of IS 1892 shall be collected at 0.5 m intervals starting from a depth of 0.5 m below ground level and at every identifiable change of strata to supplement the boring records. Samples shall be stored immediately in air tight jars which shall be filled to capacity as much as possible.
- b) In designated borrow areas, bulk samples, from a depth of about 0.5 m below ground level shall be collected to establish the required properties for use as a fill material. Disturbed samples weighing about 25 kg (250 N) shall be collected at shallow depths and immediately stored in polythene bags as per IS 1892. The bags shall be sealed properly to preserve the natural moisture content of the sample and placed in wooden boxes for transportation.

5.5.3.3 Undisturbed Samples

In each borehole undisturbed samples shall be collected at every change in stratum or at intervals not more than 1.5 m, whichever is less as per IS 2132, for a depth up to 10 m in case of normal soils and 40 m in case of special locations.

5.5.3.3.1 The spacing between the top levels of undisturbed sampling and standard penetration testing shall not be less than 1.0 m. Undisturbed samples shall be of 100 mm diameter and 450 mm in length. Samples shall be collected in a manner to preserve the structure and moisture content of the soil. Accessories and sampling procedures shall conform to IS 1892 and IS 2132

- a) Undisturbed sampling in cohesive soil:

Undisturbed samples in soft to stiff cohesive soils shall be obtained using a thin walled sampler. In order to reduce the wall friction, suitable precautions, such as oiling the surfaces shall be taken. The sampling tube shall have a smooth finish on both surfaces and a minimum effective length of 450 mm. The area ratio of sampling tubes shall be less than 12.5%. However, in case of very stiff soils area ratio up to 20% shall be permitted.

- b) Undisturbed sampling in very loose, saturated, sandy and silty soils and very soft clays:

Samples shall be obtained using a piston sampler consisting of a cylinder and piston system. In soft clays and silty clays, with water standing in the casing pipe, piston sampler shall be used to collect undisturbed samples in the presence of expert supervision.

Accurate measurements of the sampling depth, dimensions of sampler, stroke and length of sample recovery shall be recorded. After the sampler is pushed to the required depth, the cylinder and piston system shall be drawn up together, preventing disturbance and changes in moisture content of the sample;

c) **Undisturbed sampling in cohesion less soils**

Undisturbed samples in cohesion less soils shall be obtained in accordance with IS 8763. Sampler operated by compressed air shall be used to sample cohesion less soils below ground water table.

5.5.4 Ground Water

5.5.4.1 One of the following methods shall be adopted for determining the elevation of ground water table in boreholes as per IS 6935 and the instructions of the Employer:

- a) In permeable soils, the water level in the borehole shall be allowed to stabilize after depressing it adequately by bailing before recording its level. Stability of sides and bottom of the boreholes shall be ensured at all times.
- b) For both permeable and impermeable soils, the following method shall be suitable. The borehole shall be filled with water and then bailed out to various depths. Observations on the rise or fall of water level shall be made at each depth. The level at which neither fall nor rise is observed shall be considered the water table elevation and confirmed by three successive readings of water level taken at two hours interval.

5.5.4.2 If any variation of the ground water level is observed in any specific boreholes, the water level in these boreholes shall be recorded during the course of the field investigation. Levels in nearby wells, streams, etc., if any, shall also be noted in parallel.

5.5.4.3 Subsoil water samples

- a) Subsoil water samples shall be collected for performing chemical analysis. Representative ground water samples shall be collected when first encountered in boreholes and before the addition of water to aid boring or drilling.
- b) Chemical analysis of water samples shall include determination of pH value, turbidity, sulphate, carbonate, nitrate and chloride contents, presence of organic matter and suspended solids. Chemical preservatives may be added to the sample for cases as specified in the test methods or in applicable Indian Standards. This shall only be done if analysis cannot be conducted within an hour of collection and shall have the prior written permission and approval of the Employer.

5.5.5 Dynamic Cone Penetration Test (only at Special locations)

- a) With bentonite slurry

Dynamic cone penetration test shall be conducted to predict stratification, density, bearing capacity of granular soils, etc. The test shall be conducted to the specified depth or refusal, whichever comes first. Refusal shall be considered when the blow count exceeds 100 for 300mm penetration. Equipment, accessories test procedures, field observations and reporting of results shall conform to IS 4968 (Part-II). The driving system shall comprise of hammer of standard weight as specified in IS 4968 (Part-II), having a free fall of 750mm. The cone shall be of 60° and of 62.5mm diameter provided with vents for continuous flow of bentonite slurry through the cone and rods in order to avoid friction between the rods and soil. On completion of the test the results shall be presented as a continuous record of the number of blows required for every 300mm penetration of the cone into the soil in a suitable chart supplemented by a graphical plot of blow count for 300mm penetration vs. depth. On completion of the test, the results shall be presented on the proforma approved by the Employer.

b) Without bentonite slurry

This test shall be conducted with 50mm diameter 60° cone fitted loosely to the driving rod through a cone adopter. The cone shall be driven in to the soil by allowing hammer of standard weight as specified in IS 4968 (Part-II), having a free fall of 750mm. The number of blows for every 100mm penetrations shall be recorded. The process shall be repeated till the cone is driven to the required depth. The penetration depth shall be limited to 5m in cohesion less soil and 10m in mixed soil with some binding material. The cone driving rods, driving head, hoisting equipment shall conform to IS 10589. The test report should be prepared as per guidelines of IS 4968 (Part I).

5.5.6 Vane Shear Test. (required for boreholes where UDS is not possible) (Only at Special Locations)

Field vane shear test shall be performed inside the borehole to determine the shear strength and bearing capacity of cohesive soils, especially of soft and sensitive clays, which are highly susceptible to sampling disturbance. Equipment, accessories, test procedures, field observations shall correspond to IS 4434. Tests may also be conducted by direct penetration from ground surface. If the cuttings at the test depth in the borehole show any presence of gravel, sand shells, decomposed wood, etc., which are likely to influence the test results substantially, the test at that particular depth may be omitted with the permission of the Employer. However, the test shall be conducted at a depth where these obstructions cease to occur. On completion of the test, the results shall be reported in an approved proforma as specified in IS 4434, Appendix-A.

5.6 Field Investigation for Rock

5.6.1 Rock Drilling

5.6.1.1 If, during the investigations, large hard fragments or natural rock beds are encountered, work shall proceed with core drilling methods. The equipment and

procedures for this operation shall conform to IS 1892. The starting depth of drilling in rock shall be certified by the Employer. At the end of the investigation, the hole drilled in rock shall be backfilled with grout consisting of 1-part cement and 3-parts sand by weight.

5.6.1.2 Drilling shall be carried out with NX size tungsten carbide (TC) or diamond tipped drill bits, depending on the type of rock and according to IS 6926. Suitable type of drill bit (TC/Diamond) and core catchers shall be used to ensure continuous and good core recovery. Core barrels and core catchers shall be used for breaking off the core and retaining it when the rods are withdrawn. Double tube core barrels shall be used to ensure better core recovery and to retrieve cores from layers of bedrock. Water shall be circulated continuously in the hollow rods and the sludge conveying the rock cuttings to the surface shall be collected. A very high core recovery ratio shall be aimed at in order to obtain a satisfactory undisturbed sample. Attempt shall be made to recover cores of 1.5 m in length. Normally TC bit shall be used. Change over to a diamond bit shall require the specific written approval of the Employer, and his decision as to whether a TC or a diamond bit is to be used shall be final and binding on Contractor.

5.6.1.3 No drilling run shall exceed 1.5 m in depth. if the core recovery is less than 80% in any run, the length of the subsequent run shall be reduced to 0.75 m. During drilling operations observations on return water, rate of penetration etc. shall be made recorded and recorded as per IS 5313.

- a) The colour of return water at regular intervals, the depth at which any change of colour of return water is observed, the depth of occurrence and amount of flow of hot water, if encountered, shall be recorded.
- b) The depth through which a uniform rate of penetration was maintained, the depth at which marked change in rate of penetration or sudden fail on drill rod occurs, the depth at which any blockage of drill bit causing core loss, if any, shall be recorded.
- c) Any heavy vibration or torque noticed during the drilling should be recorded together with the depth of occurrence.
- d) Special conditions like the depth at which grouting was done during, drilling, presence of artesian conditions, loss of drilling fluid, observations of gas discharge with return water, etc., shall also be observed and recorded.
- e) All the observations and other details shall be recorded as per daily drill and reported in a proforma as given in IS 5313, Appendix-A.

5.6.2 Core Sampling

5.6.2.1 Core samples shall be extracted by the application of a continuous pressure at one end of the core with the barrel held horizontally without vibration. Friable cores shall be extracted from the barrel directly into a suitably sized half round plastic channel section. Care shall be taken to extrude the samples in the direction of coring to avoid stress reversal.

5.6.2.2 Immediately after withdrawal from the core barrel, the cores shall be placed in a tray and transferred to boxes specially prepared for this purpose. The boxes shall be made from seasoned timber or any other durably material and shall be indexed on top of the lid according to IS 4078. The cores shall be numbered serially and arranged in the boxes in a sequential order. The description of the core samples shall be recorded as instructed in IS 4464. Where no core is recovered, it shall be recorded as specified in the standard. Continuous record of core recovery and rock quality designation (RD/DD/QD) are to be mentioned in the bore log in accordance with IS 11315 (Part-II).

5.7 Laboratory Testing

5.7.1 Essential Requirements

- a) Depending on the types of substrata encountered, appropriate laboratory tests shall be conducted on soil and rock samples collected in the field. Laboratory tests shall be scheduled and performed by qualified and experienced personnel who are thoroughly conversant with the work. Tests indicated in the schedule of items shall be performed on soil, water and rock samples as per relevant IS codes. One copy of all laboratory test data records shall be submitted to Employer progressively every week. Laboratory tests shall be carried out concurrently with the field investigations as initial laboratory test results could be useful in planning the later stages of field work. A schedule of laboratory tests shall be established by Contractor to the satisfaction of the Employer within one week of completion of the first bore hole;
- b) Laboratory tests shall be conducted using approved apparatus complying with the requirements and specification of Indian Standards or other approved standards for this type of work. It shall be checked that the apparatus is in good working condition before starting the laboratory tests. Calibration of all the instruments and their accessories shall be done carefully and precisely at an approved laboratory.
- c) All samples, whether undisturbed or disturbed shall be extracted, prepared and examined by competent personnel properly trained and experienced in soil sampling. examination, testing and in using the apparatus in conformance with the specified standards;
- d) Undisturbed soil samples retained in liners or seamless tube samplers shall be removed, without causing any disturbance to the samples, using suitably designed extruders just prior to actual testing. If the extruder is horizontal, proper support shall be provided to prevent the sample from breaking. For screwtube extruders, the pushing head shall be free from the screw shaft so that no torque is applied to the soil sample in contact with the pushing head. For soft clay samples, the sample tube shall be cut by means of a high-speed hacksaw to proper test length and placed over the mould before pushing the sample into it with a suitable piston;
- e) While extracting a sample from a liner or tube, care shall be taken to assure that its direction of movement is the same as that during sampling to avoid stress reversal;

5.7.2 Tests

5.7.2.1 Tests as indicated in these specifications and as may be requested by the Employer, shall be conducted. These tests shall include but may not be limited to the following: -

a) Tests of undisturbed and disturbed samples

- Visual and engineering classification;
- Sieve analysis and hydrometric analysis;
- Liquid, plastic and shrinkage limits;
- Specific gravity;
- Chemical analysis;
- Swell pressure and free swell index determination;
- Proctor compaction test.

b) Tests of undisturbed samples:

- Bulk density and moisture content;
- Relative density (for sand),
- Unconfined compression test;
- Box shear test (for sand);
- Triaxial shear tests (depending on the type of soil and field conditions on undisturbed or remoulded samples):
 - i) Unconsolidated undrained;
 - ii) Consolidated drained test;
- Consolidation

c) Tests on rock samples

- Visual classification;
- Moisture content, porosity and density;
- Specific gravity;
- Hardness
- Stake durability
- Unconfined compression test (both saturated and at in-situ water content);
- Point load strength index;

- Deformability test (both saturated and dry samples).
- d) Chemical analysis of sub soil water.

5.7.3 Salient Test Requirement

- a) Triaxial shear tests shall be conducted on undisturbed soil samples, saturated by the application of back pressure. Only if the water table is at sufficient depth so that chances of its rising to the base of the footing are small or nil, the triaxial tests shall be performed on specimens at natural moisture content. Each test shall be carried out on a set of three test specimens from one sample at cell pressures equal to 100, 200 and 300 KPa respectively or as required depending on the soil conditions:
- b) Direct shear test shall be conducted on undisturbed soil samples. The three normal vertical stresses for each test shall be 100, 200 and 300 KPa or as required for the soil conditions;
- c) Consolidation test shall have loading stages of 10, 25, 50, 75, 100, 200, 400 and 800 KPa. Rebound curve shall be recorded for all samples by unloading the specimen at its in-situ stress. Additional rebound curves shall also be recorded wherever desired by the Employer;
- d) Chemical analysis of subsoil shaft includes determination of PH value, carbonate, sulphate (both SO₃ and SO₄), chloride and nitrate contents, organic matter, salinity and any other chemicals which may be harmful to the foundation material. Their contents in the soil shall be indicated as percentage (%);
- e) Chemical analysis of subsoil water samples shall include the determination of properties such as colour, odour, turbidity, PH value and specific conductivity, the last two chlorides, nitrates, organic matter and any other chemical harmful to the foundation material. The chemical contents shall be indicated as parts per million (PPM) based on weight.

5.8 Geotechnical Investigation Report

5.8.1 General

Contractor shall submit a formal report containing geological information of the region, procedures adopted for geotechnical investigation, field observations, summarised test data, conclusions and recommendations. The report shall also include detailed bore logs, subsoil sections, field test results, laboratory observations and test results both in tabular as well as graphical form, practical and theoretical considerations for the interpretation of test results, supporting calculations for the conclusions drawn, etc. Initially, Contractor shall submit three copies of the report in draft form for Employer's review;

- a) Contractor's Geotechnical engineer shall visit Employer's Office for a detailed review based on Employer's comments in order to discuss the nature of modifications, if any, to be done in the draft report. Contractor shall incorporate

in the report the agreed modifications and resubmit the revised draft report for approval. Ten copies of the detailed final approved report shall be submitted to Employer together with one set of reproducible of the graphs, tables etc.

- b) The detailed final report based on field observations, in-situ and laboratory tests shall encompass theoretical as well as practical considerations for foundations for different types of structures.

5.8.2 Data to be furnished

5.8.2.1 The report shall also include the following

- a) A plot plant/ location plan showing the locations and reduced levels of all field test e.g. boreholes, trial pits, static cone penetration tests, dynamic cone penetration tests, etc., property drawn to scale and dimensioned with reference to the established grid lines;
- b) A true cross section of all individual boreholes and test pits with reduced levels and co-ordinates showing the classification and thickness of individual stratum, position of ground water table, various in-situ tests conducted, samples collected at different depths and the rock stratum, if encountered;
- c) Geological information of the area including geomorphology, geological structure, lithology, stratigraphy and tectonics, core recovery and rock quality designation (RD/DD/QD), etc.,
- d) Observations and data regarding change of course of rivers, velocity, scour depths, slit factor, etc., and history of flood details for mid-stream and river bank locations;
- e) Past observations and historical data, if available, for the area or for other areas with similar soil profile, or with similar structures in the surrounding areas;
- f) Plot of Standard Penetration Test (uncorrected and corrected N values) with depth for each test site;
- g) Results of all laboratory test summarised according to Table 4.0 (i) for each sample as well as (ii) for each layer, along with all the relevant charts, tables, graphs, figures, supporting calculations, conclusions and photographs of representative rock cores,
- h) For all triaxial shear tests, stress vs. strain diagrams as well as Mohr's circle envelopes shall be furnished. If back pressure is applied for saturation, the magnitude of the same shall be indicated. The value of modulus of elasticity (E) shall be furnished for all tests along with relevant calculations;
- i) For all consolidation tests, the following curves shall be furnished
 - i) e vs. log p;
 - ii) e vs. p;
 - iii) Compression vs log t or vs $\dot{\sigma}_t$

depending upon the shape of the plot, for proper determination of coefficient of consolidation. The point showing the initial condition (e_0 , p_0) of the soil shall be marked on the curves;

- j) The procedure adopted for calculating the compression index from the field curve and settlement of soil strata shall be clearly specified. The time required for 50% and 90% primary consolidation along with secondary settlements, if significant, shall also be calculated.

Table 4.0

A) SUMMARY OF RESULTS OF LABORATORY TESTS ON SOIL

Date of Boring:						Name of the Project:										Bore hole no.:								
Ground elevation: (R.L. in m.)						Co-ordinates:						Termination Depth:				Water table:								
Soil details						Grain Size Distribution				Atterberg limits			Soil Density (kg / m³)				Moisture content		Triaxial / Direct shear Test			Remarks		
Depth	Sample nos. & type	IS Classification of soil	Description of layers	N – Value (observed)	N – Value (corrected)	Specific Gravity	Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity index	Bulk / Natural Density	Dry Density	Submerged Density	Proctor Density	Relative Density	Natural	Optimum	Confining Pressure	Co-hesion	Angle of Repose	

Following additional information should also be provided:

- (i) Maximum expected yearly rise / fall of water table
- (ii) General topography of the location: whether cultivated or barren, hilly / plain location, river bank location etc.

Note: where ever undisturbed sampling is not possible, reasons must be clearly indicated and all the tests shall be conducted on re-moulded samples.

(Signature)
Prepared by
Soil investigator

(Signature)
Checked & Reviewed by
Line Contractor

(Signature)
Checked & Approved by
POWERGRID Site / RHQ Engg.

**B) SUMMARY OF ULTIMATE BEARING CAPACITIES CONSIDERING MAXIMUM RISE OF WATER
TABLE**

Location no.	Foundation Classification	Depth of footing considered for bearing capacity calculation	Size of footing considered for bearing capacity calculation	Bearing capacity*		
				Based on settlement criteria (for 40mm total settlement)	Based on settlement criteria (for 50mm total settlement)	Based on shear failure criteria
		3.0m	3.0m x 3.0m			
		3.0m	5.0m x 5.0m			
		3.0m	7.0m x 7.0m			
		3.0m	9.0m x 9.0m			
		3.5m	3.0m x 3.0m			
		3.5m	5.0m x 5.0m			
		3.5m	7.0m x 7.0m			
		3.5m	9.0m x 9.0m			

* Detailed calculations of all the bearing capacities should be enclosed with soil investigation reports.

(Signature)	(Signature)	(Signature)
Prepared by	Checked & Reviewed by	Checked & Approved by
Soil investigator	Line Contractor	POWERGRID Site / RHQ Engg.

C) For Chemical Test

As per Specifications - Clause 4.8.4

5.8.3 Recommendations

5.8.3.1 Recommendations shall be provided for each tower location duly considering soil type and tower spotting data. The recommendations shall provide all design parameters and considerations required for proper selection, dimensioning and future performance of tower foundations and the following:-

- a) The subsurface material must provide safe bearing capacity and uplift resistance by incorporating appropriate safety factors thereby avoiding rupture under ultimate loads;

- b) Movement of the foundation, including short-term and long-term components under transient and permanent loading, shall be strictly controlled with regard to settlement, uplift, lateral translation and rotation:
- c) Co-efficient of permeability of various sub soil and rock strata based on in-situ permeability tests.

Core resistance, frictional resistance total resistance, relation between core resistance, Standard Penetration Test N value, and settlement analysis for different sizes of foundation as specified in para 4.1.8.3 (I) based on static cone penetration test.

- d) For shallow foundation the following shall be indicated with comprehensive supporting calculations: -
 - i) Net Safe allowable bearing pressure for isolated square footing of sizes 4.0, 5.0, 6.0 & 7.0 m at three different founding depths of 1,2 and 3 & 3.5m below ground level considering both shear failure and settlement criteria giving reasons for type of shear failure adopted in the calculation.
 - ii) Net safe allowable bearing pressure for raft foundations of widths greater than 5m at 2.0, 3.0 and 4.0m below ground level considering both shear failure and settlement criteria.
 - iii) Rate and magnitude of settlement expected of the structure.
 - iv) Net safe bearing capacity for foundation sizes mentioned in para(i) above, modulus of sub grade reaction, modulus of elasticity from plate load test results along with time settlement curves and load settlement curve in both natural and log graph, variation of Modulus of sub grade reaction with size, shape and depth of foundation.
- e) The stable slopes for shallow and deep excavations, active and passive earth pressure at rest and angle of repose for sandy soils shall be furnished. The loading of the foundations shall not compromise the stability of the surrounding subsurface materials and the stability of the foundation shall be ensured against sliding or overturning.
- f) Depending on the subsurface material, water table level and tower type, either reinforced concrete isolated pad and chimney, cast-in-situ bored pile of special foundations shall be installed at a given location.
- g) Net Safe allowable bearing pressure and uplift resistance shall be provided for the various sizes of isolated square footings founded at various depths below

ground level considering both shear failure and movement criteria; rate and magnitude of movement expected of the structure (settlement, uplift, rotation) shall also be given.

- h) In cases where normal open cast/ pile foundations appear to be impractical, special pile foundations shall be given due consideration along with the following:
- i) Type of pile foundation and reasons for recommending the same duly considering the soil characteristics.
 - ii) Suitable founding strata for the pile.
 - iii) Estimated length of pile for 500, 750 and 1000 KN and 4500 KN capacities; end bearing and frictional resistance shall be indicated separately.
 - iv) Magnitude of negative skin friction or uplift forces due to soil swelling.
- i) Where the subsoil water and soil properties are found to be chemically aggressive. Contractor shall take suitable precautions during construction including any protective coating to be applied on the foundations; susceptibility of soil to termite action and remedial measures for the same shall be dealt with.
- j) Suitability of locally available soils at site for filling, backfilling and adequate compaction shall be investigated.
- k) If expansive soil such as black cotton soil is encountered recommendation of removal or retainment of the same shall be given in the latter case, detailed specifications of special requirements shall also be given.
- l) Susceptibility of subsoil strata to liquefaction in the event of earthquake and remedial measures, if required, shall be considered.
- m) Any other information of special significance such as dewatering schemes, etc. which may have a bearing on the design and construction shall be provided.
- n) Recommendations for additional soil investigations, beyond the scope of the present work, shall be given if Contractor considers such investigations necessary.

5.8.4 Hydrogeological Conditions

- 5.8.4.1 The maximum elevation of ground water table, amplitudes of its fluctuations and data on water aggressivity with regard to foundation structure materials shall be reported. While preparing ground water characteristics the following parameters should be specified for each aquifer:

- a) bicarbonate alkalinity mg-eq/(deg)
- b) pH value
- c) content of aggressive carbon dioxide, mg/l;
- d) content of magnesia salts. mg/l, recalculated in terms of ions Mg^{+2} ;
- e) content of ammonia salts, mg/l, recalculated in terms of ions NH^{4+}
- f) content of caustic alkalis, mg/l, recalculated in terms of ions Na^{+} and K^{+}
- g) contents of chlorides,mg/l recalculated in terms of ions Cl^{-}
- h) contents of sulphates, mg/l, recalculated in terms of ions SO_4^{-2}
- i) aggregate content of chlorides, sulphates, nitrates, carbonates and other salts, mg/l

5.9 Rates and Measurements

5.9.1 Rates

The contractor's quoted rates shall be inclusive of making observations, establishing the ground level and co-ordinates at the location of each borehole, test pit etc. No extra payments shall be made for conducting Standard Penetration Test, collecting, packing, transporting of all samples and cores, recording and submittal of results on approved formats.

5.10 Specific Requirements for Geotechnical Investigation at River Crossings

5.10.1 The entire soil investigation work at river crossing locations (if required) shall be carried out in accordance with the relevant parts of the specifications for geotechnical investigation modified to the extent given below.

5.10.2 Requirements

5.10.2.1 Boreholes shall be executed to specified depth of 40m (refer clause 4.5.1.1 (b). If refusal strata is reached (i.e. SPT-N value is greater than 100 continuously for 5m depth) with characteristics of rock the borehole may be terminated at shallower depth i.e. at 5m in refusal strata, with prior approval of the Employer.

5.10.2.2 Laboratory testing shall be conducted on all soil samples to determine grain size distribution, liquid limit and plastic limit of the different soil strata encountered.

5.10.2.3 Geotechnical Report must furnish the following:

- a) Geotechnical investigation scheme;
- b) Bore-logs indicating soil stratification, with IS classification, sampling details and
- c) SPI 'N' values;

- d) Soil cross-sections along various boreholes in two orthogonal directions indicating soil stratification based on field and laboratory tests;
 - e) Grain size distribution curves;
 - f) IS classification of soils;
 - g) Shear tests (UU), to be done on saturated soil samples;
 - h) Bearing capacity of soil at different levels;
 - i) Highest flood level (HFL);
 - j) Maximum discharge, velocity etc. (from authenticated source such as CWC or appropriate State authorities);
 - k) Recommendations regarding type of foundation to be adopted at the location
- 5.10.3 A check list for reporting results of river crossing locational details, detailed soil investigation and river values for river crossing locations is enclosed at Annexure-C.
- 5.11 Special Terms and conditions for Geotechnical Investigation in the River bed**
- 5.11.1 Contractor is required to mobilise a suitable arrangement (floating pontoon, plant, equipment etc.) to carry out geotechnical investigation work in creek/ river locations identified by the Employer.
- 5.11.2 In the event of storm or stoppage of work, etc., Contractor shall not be paid extra for mobilization/ remobilisation of floating pontoon, plant, equipment, etc.
- 5.11.3 Contractor shall fully satisfy himself about the conditions of creek/ river (depth of water, wave currents, wind conditions, etc.) prevailing in the area of proposed investigation and plan the necessary tools and plant to be deployed before quoting. Any claim resulting from lack of data collection in this respect shall not be entertained.
- 5.11.4 Contractor shall make his own arrangements for locating the coordinates and position of boreholes in creek/ river with respect to two grid-lines indicated by Employer.
- 5.11.5 Boring in creek or river shall be payable only below the bed level and no payment shall be made for lowering the casing in water.
- 5.11.6 Contractor shall arrange for necessary transportation on water (e.g. motor boat) to facilitate the supervision of work by officials of Employer at its own cost.
- 5.11.7 Full details of the construction plant, proposed working method for boring and sampling in water shall be submitted along with the Tender.
- 5.11.8 The unit rate quoted for underwater boring shall include complete work required as per specification and no separate payment shall be made on any account.

6 Statutory Regulations and Standards

- 6.1 Contractor is required to follow statutory regulations stipulated in Electricity Act 2003, Indian Electricity Rules and other local rules & regulations.
- 6.2 The codes and standards referred to in these specifications shall govern. In case of a conflict between such codes/ standards and these specifications, the provisions of the specifications shall prevail. Such codes, standards referred to shall mean latest revisions, amendments, changes adopted and published by relevant agencies.
- 6.3 Other Internationally acceptable standards which ensure equivalent or better performance than those specified shall also be acceptable.