PROCUREMENT OF CONSULTING SERVICES

Royal Government of Bhutan

Ministry of Infrastructure and Transport

Department of Human Settlement

Project Reference #: BT-MWHS-511859-CS-CQS

PROJECT TITLE: Strengthening Risk Information for Disaster Resilience

Project (RIR project, P175081)

TITLE OF CONSULTING SERVICE

SHEAR-WAVE VELOCITY (Vs30) TESTING

AND

SEISMIC SITE CLASSIFICATION

FOR

DZONGKHAG THROMS / THROMDES, RURAL

TOWN AND YENLAG THROM FOR UPDATING

SEISMIC ASPECT OF THE BUILDING CODE -PACKAGE B

PROCURING AGENCY

Department of Human Settlement
Ministry of Infrastructure and Transport
Thimphu

(Sept 2025)

TERMS OF REFERENCE (TOR)

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TERMS OF REFERENCE

1 Background

Bhutan, situated along the seismically active Himalayan belt, faces considerable seismic risk due to its proximity to the convergent boundary between the Indian and Eurasian tectonic plates. Although no large-scale catastrophic earthquakes have struck the country in recent decades, scientific studies and regional seismic records consistently indicate that Bhutan remains highly vulnerable to moderate-to-severe ground shaking. With the increasing pace of urbanization and infrastructure development across all Dzongkhags, the need to integrate accurate, location-specific seismic risk information into planning, design, and construction practices has become both timely and essential.

In response to this national priority, the Department of Human Settlement (DHS), under the Ministry of Infrastructure and Transport, is currently implementing the component C (Professionalization of Construction Industry for Green and Resilient Infrastructure Development" under the World Bank-supported project titled "Strengthening Risk Information for Disaster Resilience in Bhutan (RIR)".

Under this project, one of the core components is to develop and integrate scientifically grounded seismic design parameters into the Building Code of Bhutan, based on the country's seismic risk conditions. To support this objective, a fundamental requirement is the development of an evidence-based seismic site classification framework through the systematic assessment of shear-wave velocity in the upper 30 meters of the ground profile (V_s30). V_s30 is internationally recognized as the standard metric for characterizing local site stiffness and is directly used in defining seismic site classes- ranging from very hard rock to very soft soil- under established international codes such as the NEHRP Provisions and Eurocode 8.

Accurate V_s30 measurements are, therefore, critical for deriving site-specific ground motion parameters and developing response spectra that support performance-based earthquake-resistant design. Without such data, national building codes may rely on generalized assumptions, which can result in unsafe, uneconomical, or overly conservative design outcomes.

Recognizing the specialized nature of geophysical field investigations, the Department of Human Settlement intends to engage a qualified and experienced geotechnical or geophysical consulting firm to undertake detailed V_s30 testing across urban settlement boundaries in the country. These areas have been prioritized in the initial phase due to their higher concentration of population and built infrastructure. Future phases are anticipated to expand coverage to rural and peri-urban areas as additional resources become available.

The successful implementation of this assignment will directly support Bhutan's efforts to develop a hazard-informed, site-specific building code aligned with international seismic design standards. The resulting Vs30 data will serve as a critical input for site classification and will support the future development of nationwide Probabilistic seismic Hazard Assessments maps.

2 Objectives

The objective of this assignment is to generate reliable shear-wave velocity (V_s30) data and seismic site classifications for the Dzongkhag Throm/Thromde, Rural town and Yenlam Throm settlements to support the development and integration of seismic provisions in the National Building Code.

Specifically, the assignment aims to:

1. Acquire in-situ V_s30 measurements using internationally recognized geophysical testing methods.

2. Classify local site conditions into standard seismic site classes (NEHRP) based on measured V_s30 values.

3. Develop spatial datasets and produce V_s30 map and Seismic Site Classification Maps using appropriate geospatial analysis methods.

4. Provide data, outputs and site-specific seismic parameters compatible for integration with the Revision of Building Code and the development of Probabilistic Seismic Hazard Assessment (PSHA) map.

5. Deliver comprehensive technical reports and data packages documenting methodology, results, and interpretations in suitable formats.

3 Test Locations and Boundaries

The table below presents the distribution of test points within each designated Dzongkhag Throm/ Rural town and Yenlag Throm boundary, highlighting geographic coverage and test-point density to ensure adequate spatial representation for seismic site characterization. Test points are uniformly distributed based on a predetermined grid size, and the field team must strictly follow these locations as designated by the Client. Minor adjustments may be proposed only if a location coincides with permanent structures or inaccessible areas, subject to prior approval by the Client.

Sl. No.	Dzongkhag	Throm			Test Points	Grid Size
		Name	Km^2	Acre		
1	Bumthang	Bumthang Throm & Periphery	18.41	4,548.33	19	1000m
		Chhumey	0.44	108.73	2	500m
2	Lhuentse	Lhuentse Throm	1.24	306.29	9	500m
		Gorgan	0.02	4.94	1	500m

		Autsho	0.41	101.31	2	700m
3	Mongar	Mongar Throm	3.05	752.59	10	700m
		Dramedtse	0.58	143.32	3	500m
		Lingmethang	0.67	165.56	3	500m
		Yadi	0.18	44.48	2	500m
4	Pemagatshel	Denchi Throm	0.46	113.25	3	500m
		Nangkor	0.26	64.25	1	700m
		Old Pemagatshel town	0.97	239.7	2	700m
		Nganglam	9.81	2424.104	21	700m
5	S-Jongkhar	S-Jongkhar Thromde	4.94	1,219.76	35	500m
		Jomotshangkha	0.8	197.7	2	700m
		Samdrupcholing	1.5	370.66	4	700m
6	Trashigang	Trashigang Throm	2.74	675.95	14	500m
		Kanglung	1.14	281.7	2	700m
		Khaling	0.52	128.5	2	500m
		Wamrong	0.13	32.12	2	250m
		Resarbu	0.14	34.6	2	250m
		Rangjung	0.74	182.86	3	700m
7	Trashiyangtse	Trashiyangtse Throm	3.31	818.62	8	700m
		Duksum	0.42	103.8	2	500m
8	Trongsa	Trongsa Throm	2.05	506.51	9	500m
		Kuengarabten	0.24	59.3	2	700m
9	Zhemgang	Zhemgang Throm	1.66	410.40	9	500m
		Sonamthang	2.16	533.75	4	700m
		Panbang	2.62	647.42	8	700m
		Total:	61.61	15220.5	186	

* Note:
For Bumthang Ura and Sarpang, the Vs30 test has already been conducted by DGM.The Consultant shall integrate these existing DGM dataset and data acquired under this assignment to generate a continuous Vs30 Distribution Map and a corresponding Seismic Site Classification Map. The existing DGM dataset will be provided by the Client for this purpose. All data integration, processing, and mapping must ensure consistency in methodology, georeferencing, and quality control to support uniform and reliable interpretation across all Dzongkhag Throms/Thromde, Rural town and Yenlam Throm.

4 Scope of Work

The consulting firm shall be responsible for carrying out a comprehensive program of field investigations, data processing, seismic site classification, and spatial mapping to generate shear-wave velocity (V_s30) data and associated seismic site classifications within the designated urban settlement boundaries.

The assignment shall include all activities necessary to deliver technically valid and spatially referenced outputs in accordance with internationally accepted geophysical site characterization practices.

4.1: Project Planning, Mobilization and Site Reconnaissance

Review the initial testing locations and grid spacing to ensure they meet project requirements. Conduct preliminary site visits to evaluate accessibility and identify any obstructions and carry out environmental and social screening using the given standard form. Before testing, ensure complete site access and compliance with the Environmental and Social Management Framework (ESMF). Obtain prior approval from the relevant agency to facilitate a smooth testing process. Finally, create a comprehensive fieldwork schedule that outlines the timing and sequence of activities, taking into account specific site conditions to minimize disruptions. Refer to the annex for the environmental and social requirements to be compiled before the selection of specific sites for the test and during implementation.

4.2: Geophysical Testing Methods

The Multichannel Analysis of Surface Waves (MASW) method shall serve as the primary and preferred technique for this assignment, due to its proven reliability, resolution, and adaptability across varied geologic and topographic settings. This method is internationally accepted for characterizing near-surface shear-wave velocity profiles and deriving Vs30 values.

In settings where MASW deployment is constrained due to limited linear space, traffic, surface obstructions, or elevated ambient noise levels- the firm shall implement alternative methods consistent with international best practices for seismic site characterization - including:

- Refraction Microtremor (ReMi): A passive seismic method appropriate for constrained urban corridors or high-noise environments. ReMi is internationally recognized for estimating 1D Vs profiles where active sources are impractical.

- Modified MASW Arrays: Adapted configurations of the MASW method, such as shortened, reduced-offset, or curved arrays, suitable for locations where standard linear deployments are infeasible.

- Horizontal-to-Vertical Spectral Ratio (HVSR): May be used only as a supplementary method to identify site resonance frequencies or to support the interpretation of MASW or ReMi results. It shall not be used as a standalone method for Vs30 determination unless supported by additional subsurface data.

The Consultants shall assess and justify the selected method at each site based on terrain, environmental constraints, expected subsurface conditions, and required data quality. Where appropriate, a hybrid approach combining multiple techniques may be employed to enhance data reliability and spatial resolution.Where feasible, the Consultant is encouraged to perform multi-method testing (e.g., MASW + ReMi or MASW + HVSR) at 10~20% of sites, regardless of deployment constraints. These tests will serve to benchmark inter-method variability, support uncertainty quantification, and enhance overall confidence in Vs30 estimation. Significant discrepancies shall be documented and justified

In an event the data obtained are found to be inaccurate, the firm shall be liable to carry the necessary rectification at their own expenses and final payment and/or retention money shall be withheld.

4.3: Data Acquisition Procedures

(1) Multichannel Analysis of Surface Waves (MASW)

- Use active-source MASW with vertical geophones and impact sources (sledgehammer or weight drop) to generate surface wave data suitable for shear wave velocity profiling.

- Design arrays to achieve a minimum investigation depth of 30 meters, with clearly resolved dispersion curves.

- Geophone spacing shall be fixed at 4 meters, providing an effective array length of 92 meters using a 24-channel system. This configuration is required to achieve acceptable vertical resolution, minimize aliasing and enhance the clarity of dispersion curve extraction.

- Use a 24-channel seismograph, ensure a high signal-to-noise ratio through proper coupling,

adequate source impacts, and appropriate gain control.

- Capture near- and far-offset shots to include broad frequency content.
- Field logs must include: array layout, number and positions of shots, site conditions, and photographs.
- The source must be placed at offset distances sufficient to capture a wide frequency bandwidth, typically including near-offset and far-offset shots to ensure low- and high-frequency content.
- Field acquisition notes must include the number and location of shots, array layout diagrams, and site photos.
- Record test center coordinates and elevation using RTK-GNSS for high positional accuracy.
- Ensure all procedures align with international standards for shear-wave velocity profiling.

(2) Refraction Microtremor (ReMi)

- Use ReMi in narrow or noisy urban environments where MASW is impractical.
- A geophone spacing of 5 to 6 meters shall be adopted with a 24-channel system, yielding an effective array length of approximately 115 to 138 meters. This configuration is required to achieve reliable Vs30 results to a depth of at least 30 meters, with adequate resolution of deeper velocity structures under passive ambient noise conditions.
- Ambient vibration data shall be recorded for a minimum of 20 minutes per site to ensure adequate capture of the microtremor energy spectrum.
- Ensure uniform coupling and unobstructed array alignment; maintain consistent noise sources.
- Target shear-wave velocity profiles resolving depths of 30 meters or more.
- RTK-GNSS for site geolocation.
- Process data with industry-standard software and apply recognized inversion and quality control protocols (ASTM D8299-19).

(3) Modified MASW Arrays

- In constrained locations, implement adapted MASW configurations (shortened, curved, or offset-reduced).

- Maintain minimum 30-meter depth penetration and reliable resolution.
- Justify each adaptation and demonstrate data quality equivalent to standard MASW.
- Follow same acquisition and processing protocols as standard MASW where applicable.

(4) Horizontal-to-Vertical Spectral Ratio (HVSR)

- Use three-component seismometers with 20-30 minutes of ambient noise recording under low-disturbance conditions.
- Co-locate HVSR measurements with MASW or ReMi survey locations wherever feasible, to allow integrated interpretation of site resonance frequency and shear-wave velocity structure.
- HVSR data shall be processed using the Nakamura method (1989), or equivalent internationally recognized procedures, to identify site resonance frequencies. Interpretation shall be supported by MASW or ReMi results wherever possible.
- Use HVSR solely for resonance frequency estimation or supporting interpretation, not for standalone Vs30 estimation unless otherwise validated.

4.4: Data Processing and Vs30 Computation

The firm shall be responsible for processing all acquired field data using internationally recognized geophysical techniques to derive reliable shear-wave velocity profiles and calculate Vs30 values. All data processing must be traceable, reproducible, and adequately documented.

The Consultant shall:

1. Process raw field data using licensed or validated software capable of extracting dispersion curves, performing inversion, and generating shear-wave velocity models applicable to MASW, ReMi, and other employed methods.
2. Conduct quality control throughout the processing workflow, including inspection of signal quality, validation of dispersion images, and checks for inversion stability. Dispersion images must demonstrate coherent surface wave energy and cover a frequency range sufficient to resolve shear-wave velocities to a minimum depth of 30 meters.
3. Apply inversion procedures that reflect realistic geophysical conditions and follow internationally accepted best practices. The Consultant shall clearly document model assumptions, layer constraints, and initial velocity models for each site.
4. Calculate Vs30 from finalized 1D velocity models using the standard time-averaged harmonic mean method in accordance with NEHRP or equivalent international guidelines.

5. Assess uncertainty in the computed Vs30 values based on sensitivity analysis, data quality, and the reliability of field measurements and inversion results.

6. Maintain detailed processing documentation and metadata for each site, including:

    - Extracted dispersion curves and inversion results
    - Final shear-wave velocity profiles (1D Vs Models)
    - Vs30 calculation sheets or summaries
    - Software and methods used
    - Inversion constraints and error estimates

7. Ensure consistency and quality assurance across all datasets by applying standardized processing workflows, uniform file naming conventions, consistent coordinate systems (Bhutan National Grid), and reporting formats as approved by the Client.

4.5: Seismic Site Classification, Spatial Data Integration and Mapping

The Consultant shall classify all test locations and develop geospatial outputs that integrate classification results across the designated settlements. The classification shall support the adoption within the national building codes and inform future seismic hazard assessments.

The following tasks shall be performed:

1. Seismic Site Classification.

    - Classify each tested location based on computed Vs30 values in accordance with the NEHRP (2003/2015/2020) Site Class definitions (Classes A-E).
    - Ensure consistency by applying uniform classification thresholds across all datasets.
    - Validate results with available borehole/geological data.
    - Document the classification rationale for each location, including:
        - Final $Vs_3$30 value and assigned Site Class,
        - Reference classification standard used,
        - Subsurface description and any relevant geological constraints,

- Any uncertainty due to data quality or stratigraphic variability.

2. Spatial Mapping.

- Generate spatially referenced thematic maps for each settlement, including:
  - Vs30 distribution maps,
  - Seismic Site Class zoning maps (Classes A through E),
  - Measurement point locations, annotated with test method and Vs30 values.
  - The Consultant shall also document and report the interpolation method used, including input parameters and cross-validation accuracy metrics (e.g., mean error, RMS error, etc.) for each thromdes
- Apply standardized cartographic elements: legends, north arrow, color schemes, map scale, and layout consistent with seismic mapping conventions.

3. Geospatial Output Standards.

- All outputs shall be delivered in GIS-compatible formats such as:
  - Layered shapefiles or File Geodatabases (.gdb),
  - Attribute tables formatted as per Annex-I: Attribute Table Specification for Shapefile / Geodatabase Outputs.
  - Maintain spatial accuracy using georeferenced field data collected with RTK-GNSS or equivalent high-precision positioning.

4. Metadata and Documentation.

- Provide complete metadata for all spatial outputs, including:
  - Coordinate reference system and projection (Bhutan National Grid),
  - Methodology for spatial representation of Vs30 and associated assumptions,
  - Classification thresholds and symbology conventions.
- Ensure that all datasets are fully reproducible, internally consistent, and suitable for integration into the national seismic risk geodatabase in future.

5. Attribute Table Specification for Shapefile/Geodatabase Outputs.

Test_ID	Text	Unique identifier for each test
Throm_Name	Text	Name of the Throm or Urban Settlement
Dzongkhag_Name	Text	Dzongkhag in which the test point is located
Latitude	Decimal	Coordinates in Bhutan National Grid (based on RTK Observations)
Longitude	Decimal	
Elevation_m	Decimal	Elevation in meters (based on RTK Observations)
Grid_Size_m	Integer	Based on source Test Point Distribution
Vs30_Value	Decimal	Computed Vs30 value (in meters per second)
Site_Class	Text	Seismic Site Class (based on NEHRP)
Test_Method	Text	Method used: MASW, ReMi, Modified MASW, HVSR (if supplementary)
Depth_Penetration_m	Decimal	Maximum reliable depth of velocity model
Array_Length_m	Decimal	Effective geophone array length in meters
Spacing_m	Decimal	Geophone spacing used in the test
Data_Quality	Text	Qualitative flag (High, Medium, Low) based on data reliability
Date_of_Test	Date	Date of test conducted
Inversion_Software	Text	Software used for dispersion processing and inversion
Dispersion_Quality	Text	Qualitative assessment of dispersion image (e.g., Clear, Noisy)
HVSR_Used	Text	Yes / No (whether HVSR was used at this location)
Site_Geology	Text	Brief description of general surface geology (if available)

Remarks	Text	Any relevant field notes (e.g., traffic, obstructions, soft fill etc. observed)

5 Field Operation and HSE Compliance

A qualified geophysical survey team, including trained technicians and a designated site supervisor, shall be deployed to conduct the field-testing operations. All field activities must be supervised and directed by a competent Geotechnical Expert or Geophysical Engineer or Engineering Seismologist to ensure adherence to internationally recognized procedures for surface wave testing- MASW, ReMi, HVSR techniques or any approved supplementary methods.

- All test sites shall be restored to their original condition following completion of field measurements. Any temporary disturbance caused by equipment setup or access must be addressed by the Consultant, including safe removal of materials and ensuring no residual hazards.

- The Consultant shall prepare and implement a Site-Specific Health, Safety, and Environmental (HSE) Plan prior to mobilization. This plan shall outline safety protocols, use of appropriate personal protective equipment (PPE), hazard identification, risk mitigation strategies, emergency procedures, and access control for field staff and the public.

- The Consultant shall ensure that all personnel are trained in safety protocols and are adequately insured. The safety and well-being of field staff and third parties shall be the sole responsibility of the Consultant. The Procuring Agency shall bear no liability for injuries, damages, or losses incurred during field execution.

6 Reporting and timing of the assignment

The duration of this contract is Four Months [One Twenty Days (120) Days], within which all activities outlined in the scope of work must be completed. This period includes Ninety (90) days fieldwork, followed by Thirty (30) days for data processing, interpretation, geospatial analysis, mappings and reporting. Any extensions or modification to this timeline must be approved in consultation with the Client, based on unforeseen site conditions or technical complexities.

The following deliverables shall be submitted in accordance with the specified schedule:

(i) Inception Report (2 color hard copies and 1 softcopy) shall be submitted within Ten (10) days from the date of contract award. It shall outline the overall work plan, methodologies, and designated key personnel. The report shall define the implementation strategy, outline the roles and responsibilities of the project team, and summarize key site coordination (site access, scheduling, and local coordination) and technical considerations (method selection, data quality control, and equipment calibration) necessary for effective execution of the assignment.

(ii) The Interim Progress Report (2 color hard copies and 1 soft copy) shall be submitted within Sixty (60) days from the date of contract award. This report shall provide an update on field activities, data quality assessment, and remaining tasks, including:

- Status of field investigations and associated deliverables.
- Progress of each test location relative to the work plan.
- List of outstanding tasks with updated timelines.
- Proposed submission plan for draft and final reports.
- Identification of any deviations from the original scope with justifications.
- Recommended adjustments to the work plan, if necessary.
- Updates on team mobilization, equipment status, and site coordination activities.

❖ The consultant shall present the Interim Progress Report to the DHS for discussion and feedback. The participants' logistics shall be arranged by the client.

(iii) Draft Report (2 color hard copies and 1 softcopy, including datasets) shall be submitted within One hundred Ten (110) days from the date of contract award. It shall present complete findings and analyses in a structured manner.

❖ The consultant shall conduct a daylong seminar/workshop/discussion to present and discuss the findings with the Client. The participants' logistics shall be arranged by the client. Feedback received from the discussion must be incorporated into the Final Report.

(iv) Final Deliverable (2 color hard copies and 1 softcopy) including the final report and all other deliverables, shall be submitted within Ten (10) days after the receipt of final comments from the Client.

7 Report Contents and Deliverables

The Consultant shall submit a comprehensive technical report that presents the scope of work, field procedures, data processing, analysis, interpretations, conclusions, and recommendations of the Vs30 testing and seismic site classification program. The report shall begin with an Executive Summary and include detailed documentation of the adopted methodologies and results.

A complete and well-organized dataset shall be provided, comprising both raw and processed

geophysical data, with appropriate metadata and documentation to enable independent verification and future reference. Data files and documentation shall be logically organized, consistently labelled and accompanied by clear metadata explaining the content, units of measurement, data dictionaries (if applicable) and any relevant contextual information.

All deliverables- report, datasets and supporting materials, shall be submitted in both hard copy (color-printed) and digital formats including working format wherever applicable. All submissions must conform to internationally recognized standards and the Client's technical specifications.

1. Technical Report:
    - Executive Summary- summarizing key findings and recommendations.
    - Detailed description of field procedures, equipment specifications, data acquisition parameters, and processing workflows.
    - Presentation of Vs30 profiles, site classifications, and relevant spatial maps with interpretation.
    - Assessment of data quality, limitations, uncertainties, and recommendations for future work.
    - Clear referencing of applicable technical standards, guidelines, and protocols followed.
2. Data Deliverables:
    - Processed Vs30 datasets with associated metadata, quality flags, and explanatory documentation.
    - GIS-compatible spatial data layers, including:
        - Test locations.
        - Vs30 Maps.
        - Seismic Site Classification Maps.
        - Other agreed spatial outputs.
    - Raw and processed geophysical data files in open or widely accepted formats (SEG2, TXT, CSV & GIS Shape or Geodatabase) accompanied by a master index file listing test ID, data, method and filename.

3. Supporting Materials:

    - Dispersion Curve Plots, Shear Wave Velocity Inversion Models, and other relevant Quality Control Graphics.

    - Field notes, site photographs, and equipment calibration records.

4. Digital Submissions

    - All reports and data shall be submitted electronically in formats compatible with the Client's systems:
        - PDF for narrative reports.
        - Shapefiles or Geodatabases for GIS data.
        - Excel and CSV for Tabular data.

8 Quantitative Breakdown of Activities

The Quantitative Breakdown of Activities is provided to guide Consultants in preparing realistic and well-substantiated financial proposals. Although this is a Lump-Sum Contract, and payments shall not be made on an itemized basis, this breakdown enables the Client to assess the reasonableness and completeness of the proposed costs.

The financial proposal (Form FIN-4) shall include a detailed breakdown by activity, corresponding to the scope of work described in the above sections. Each activity shall be treated as a built-up unit, with the proposed cost incorporating all associated sub-components, including but not limited to personnel inputs, equipment usage, field logistics, data processing, analysis, reporting, and overheads.

All activities and associated costs must be consistent with the technical specifications and standards outlined in the Scope of Work. Consultants are expected to ensure that their cost estimates reflect the full resource requirements for the successful and timely execution of each activity.

Sl. No.	Description of Activities	Built-up Components	Qty	Unit
1	V_s30 Testing, Data Processing and Interpretation	● MASW Test (per point) using 24-channel geophone array (spacing = 4 m; array length ≈ 92 m); including equipment mobilization and setup, geophones and acquisition system, field crew, local logistics, daily subsistence, travel, site coordination, data quality control, field documentation etc. ● Generation of dispersion curves, inversion, 1D Vs profile creation, Vs30 computation, and seismic site classification; including signal analysis, inversion modeling, quality assurance/quality control, interpretative notes etc.	116	Point
2	GIS Mapping and Spatial Analysis	● GIS-based preparation of Vs30 data, spatial analysis for all test points and generation of Thematic Maps across 9 Dzongkhag Throms / Thromdes: ▪ Vs30 Distribution Maps ▪ Seismic Site Classification Maps	9	Throm
3	Technical Report Preparation	● Comprehensive reporting, documentation of methodologies, procedures, results including colour printing and presentation.	Lump Sum	

Note:
If more test points are needed, the firm will be notified of up to 24 additional points after work begins. The unit price for each will be based on Table mentioned above, Items 1 (Vs30 Testing, Data Processing and Interpretation) and 2 (GIS Mapping and Spatial Analysis) based on Pro-Rata.

9 Qualifications and Experience of Key Personnel

The qualifications and experience criteria are defined to ensure the engagement of competent and practically experienced professionals capable of delivering high-quality outputs. While specialized experience in seismic site classification and earthquake engineering is desirable, relevant experience in geophysical investigations such as MASW, Seismic Refraction Tests (SRTs), Downhole Seismic Tests, or other subsurface characterization techniques shall also be acceptable.

Firms are encouraged to propose experts with strong practical experience in geophysical fieldwork, data interpretation, and geospatial analysis, particularly those who have contributed to ground investigations under geotechnical or infrastructure development projects in Bhutan or similar settings.

The qualification requirements outlined below shall serve as the basis for assessing the suitability of proposed personnel in relation to their ability to fulfill the defined roles and responsibilities of this assignment.

9.1 Qualifications

Sl. No.	Experts	Qualifications
1	Team Leader Geotechnical Expert / Engineering Seismologist / Geophysical Expert	● Master's degree in Geotechnical Engineering, Engineering Geology, Engineering Seismology, or related discipline with a minimum of 5 years professional experience in the relevant field. OR ● Bachelor's degree in Geotechnical Engineering, Engineering Geology, Engineering Seismology, or related discipline with a minimum of 8 years professional experience in the relevant field.
2	Field Geophysicist / Geotechnical Engineer/Geologist/ Geological Engineer/Civil Engineer	● Bachelor's degree in Geophysics, Earth Sciences, Civil Engineering with a minimum of 5 years professional experience in the relevant field. OR ● Diploma in Geophysics, Earth Sciences, Civil Engineering with a minimum of 8 years professional experience in the relevant field.

3	GIS Specialist (Geospatial Analyst)	● Master's degree in Geoinformatics, Geo-Information Science, Geo-Information Management with a minimum of 3 years professional experience in the relevant field. OR ● Bachelor's degree in Geoinformatics, Geo-Information Science, Geo-Information Management with a minimum of 5 years professional experience in the relevant field.
4	Field Technician(s): (3 nos)	● Diploma or relevant technical training in surveying, civil technology, or geosciences with a minimum of 2 years of professional experience in the relevant field.
5	Field Manager	● Class X or XII Pass with a minimum of 3 years demonstrated experience in coordinating field logistics and managing operational teams in any projects.

9.2 Experience

Sl. No.	Experts	Experience
1	Team Leader Geotechnical Expert / Engineering Seismologist / Geophysical Expert	● Leading and managing geophysical projects, specifically with significant direct experience in data acquisition, processing, and interpretation for Vs30 determination. ● Proven Experience in application of wave propagation theory, inversion methodologies, seismic site classification (NEHRP/IBC), and the limitations of geophysical methods. ● Proven ability in project management including plan, schedule, budget, manage resources, and oversee all phases of a complex technical project. ● Proven experience in synthesizing technical findings into clear, comprehensive reports and actionable recommendations.

2	Field Geophysicist / Geotechnical Engineer/Geologist/ Geological Engineer/Civil Engineer	● Direct experience in conducting geophysical surveys, MASW or other similar methods. ● Equipment Operation: Proficient in operating MASW seismographs, geophones, and seismic sources. ● Field Data Quality: Strong understanding of field parameters, noise identification, and real-time data quality control. ● GPS Proficiency: Skilled in using high-precision GPS units for accurate location recording. ● Demonstrated ability to implement inversion QC, assess signal quality, and perform uncertainty quantification in Vs30 determination.
3	GIS Specialist (Geospatial Analyst)	● Hands-on experience in geospatial data management, spatial analysis, and cartographic production. ● Software Proficiency: Expert-level proficiency with industry-standard GIS software (e.g., ArcGIS Pro, QGIS). ● Spatial Analysis: Strong understanding of geostatistical interpolation methods (Kriging, Inverse Distance Weighting) and their appropriate application. ● Database Management: Experience in designing, creating, and managing geodatabases.
4	Field Technician(s):	● Experience in supporting fieldwork for geophysical or surveying projects. ● Experience in array setup and site preparation.
5	Field Manager	● Experience in coordinating field logistics and managing operational teams in any projects.

10 Key Experts and Their Roles and Responsibilities

The successful implementation of this assignment relies on the clear identification and assignment of responsibilities to appropriately designated key experts. Clearly defined roles ensure technical coherence across all components of the project, from field data acquisition and seismic analysis to geospatial

processing and reporting.

This role-based structure promotes accountability, minimizes duplication of effort, and enables effective coordination among multidisciplinary team members. It also facilitates systematic quality assurance and control throughout the assignment life cycle.

By establishing well-articulated responsibilities for each expert, the Consultant can maintain workflow efficiency, uphold methodological consistency, and ensure that all deliverables meet the technical requirements and performance standards outlined in this Terms of Reference.

Sl. No.	Key Personnel	Roles and Responsibilities
1	Team Leader Geotechnical Expert / Engineering Seismologist / Geophysical Expert	Overall project planning, execution and quality assurance. Ensuring adherence to the Environmental and social compliance Requirement (ECSP) *(Details mentioned in Annexure 1*) . Reviewing and approving all technical methodologies, data analysis and final deliverables. Preparation of the final technical report. This includes documentation of field methodologies, data processing workflows, analysis results, interpretation, conclusions, and recommendations as specified in the scope of work.
2	Field Geophysicist / Geotechnical Engineer/Geologist/ Geological Engineer/Civil Engineer	Responsible for conducting Vs30 field testing using MASW (or ReMi) or any other relevant techniques. This includes site setup, geophone array configuration, seismic wave acquisition, and quality assurance of field data. Maintaining detailed and accurate field logs and photographic documentation. Ensuring field operations comply with safety protocols and ECSP.
3	GIS Specialist (Geospatial Analyst)	Conducts geospatial analysis and prepares thematic maps of Vs30 values and seismic site classifications. Responsible for integrating geophysical data into the GIS environment and generating final deliverables covering all project locations (8 Dzongkhag Throms/Thromdes). Ensure map accuracy, proper symbology and compliance with cartographic standards.

4	Field Technician(s):	Assisting the Field Geophysicist in deploying and retrieving geophones and cables. Operating the seismic source (e.g., sledgehammer). Assisting with site clearing and preparation activities. Marking survey points and ensuring accurate measurements. Ensuring field safety and proper handling of equipment. Assisting with basic equipment maintenance and calibration.
5	Field Manager	Oversees field operations including coordination of transport, logistics, local labour deployment, daily field scheduling, and ensuring timely execution of field activities.

11 Support services to be provided by the Client:

To facilitate the successful execution of the assignment, the Client will provide the following support services and resources:

1) Boundaries of Dzongkhag Throms/Thromdes and Test Point Locations: The Client will provide delineated boundaries of Throms/Thromdes and designated test point locations, both shapefile (.shp) and KMZ (.kmz) formats.

2) Facilitation: The Client will issue letters for the following for facilitation:
    a. Work and Route Permits: The client will provide recommendation letters to facilitate the issuance of work permits and special route permits for foreign nationals engaged in this assignment.

    b. Local Government's Support: The client will support smooth fieldwork operations by providing letters addressed to local government authorities, enabling consultants to inform local authority and community regarding project activities in their vicinity.

3) Logistic arrangement :The Client will arrange and bear the expenses for all logistics related to the Interim Progress Report and Draft Report workshop. This includes the conference hall, participants' TA/DA (for those nominated by the Client), working lunch, refreshments, and stationery, all in accordance with RGoB norms.

12 Curriculum Vitae (CV), Academic & Training Certificates

Comprehensive Curriculum Vitae (CVs) for all proposed professionals are mandatory. These must be accompanied by verifiable copies of all academic qualifications and relevant training certificates. If certificates are not in English, attested translations must be provided alongside a copy of the original document. Please note that qualifications or certificates mentioned in a CV will not be considered during evaluation unless supported by corresponding, verifiable documentation.

13 Documents that are required for the Evaluation of Technical Proposals

13.1 Evidence of Relevant Work Experience

The following documentary evidence(s) must be submitted to fulfill the requirement of work experience for both firms and professional key experts.

- Work Completion Certificate(s) from the previous client(s) shall be relevant to the assignment.
- As prescribed in the form TECH-2, assignments completed by the Consultant's individual experts working privately or through other consulting firms cannot be claimed as the relevant experience of the Consultancy firm, but can be claimed by the Experts themselves in their CVs.
- For works completed as a sub-consultant, the firm should obtain a letter of attestation from the procuring agency to attest that the work was done and sub-consulting was allowed. Failing to produce such a letter of attestation, the work shall not be considered as the firm's experience.
- Letter of Reference/Experience from the employer(s). This letter shall be an official document printed on the letterhead of the previous firm(s) / organization(s) with contact information. The letter must state the details of work/project undertaken including date, type, and name of work completed successfully. The experience/reference letter(s) must be supported by work completion certificate(s) from the previous client(s) for the accomplished project(s). Without work completion certificate(s), the 'experience or reference letters' will be treated as invalid.

13.2 Commitment letter/Undertaking letter

Proposals for joint ventures, consortia, or associations with international firms are permitted and encouraged. For any such collaboration, the submitting entity must clearly designate the lead firm and explicitly state each partner's financial stake in the project, expressed as a percentage.

In addition, a comprehensive Joint Venture (JV) Agreement, Consortium Agreement, or Association Agreement with *sign and seal of all parties* must be submitted. This agreement should clearly define the purpose and scope including the specific *objectives, activities,* and *duration* of the collaboration.

13.3 Stock Ledger/Inventory List for the Field Equipment

- A duly signed copy of the stock ledger/ inventory list/ invoices of bills for the equipment described above in the ToR, must be submitted. Similarly, if firms intend to hire/borrow from another organization/agency/business entity, a borrowing agreement duly signed by both parties shall be submitted. Failure to submit such documents shall result in zero (0) score/point against each equipment during the evaluation of technical proposals.

13.4 Number of permissible work

- To promote competitive bidding, consultants are not restricted by the volume of their existing work in hand. However, to ensure the timely and quality completion of the awarded work, each consultant must declare all their ongoing projects. Crucially, they must demonstrate that they

possess sufficient dedicated manpower and equipment for both packages[1], Package A and Package B. The manpower and equipment committed in Package A shall not be allowed in Package B.

- The firms shall give a detailed explanation of their current work in hand and how their engagements are with the current work. They should clearly justify that they can carry the work along with their current engagements. Failure to complete the project on time by false declaration shall be dealt with as per the Prevailing Law of the Kingdom of Bhutan.

13.5 Rejection of Proposals

- During the evaluation of technical proposals, bid(s) shall be rejected if the bidder is found to have submitted fraudulent statements, false or fake information viz. reference letters, work completion certificate, or any other information.

14 Terms and condition of payment

Deliverable	Quantity	Payment (%)	Timeline
Inception Report	2 hard copies + soft copy	10%	10th day
Interim Progress Report	2 hard copies + soft copy	40%	60th day
Draft Report with GIS database and maps.	2 hard copies + soft copies	25%	110th day
Final Report: Submission of all related project data and documents.	2 hard copies + soft copy	25%	120th day

A 10% retention will be withheld from each payment. This amount will be released following the completion of the one-year defect liability period (commencing from the date the final report is submitted) and upon the client's issuance of completion letter.

15 Intellectual Property, Compliance, and Ethics

- All intellectual property rights for the data and reports produced during the consultancy will belong to the Department of Human Settlement, MoIT.

[1]The project includes two separate tenders, **Package A** and **Package B**. This Terms of Reference (ToR) specifically applies to **Package B**

- The consultancy firm must ensure compliance with all relevant laws and regulations during the execution of the assignments.

16 Professional Liability and Accountability

- The consultant is expected to carry out the assignments with due diligence and in accordance with prevailing standards of the professions. The accountability of the consultant shall be as in the following.

16.1 Timely Project Completion:

- Delay in the final project report submission beyond the contract duration shall be liable for a penalty of 0.1% of the contract amount for every 24 hours delay from the project deadline or approved extension deadline up to the maximum of 10% of the initial contract amount. Submission of the incomplete final report and re-submission shall be also considered a delay.

16.2 Gross Negligence:

A. In case of gross negligence or wilful misconduct on the part of the consultant or on the part of any person acting on behalf of the consultant, observed even after the end of the contract period, the consultant shall be responsible for rectifications in entirety at its own cost within the agreed reasonable time frame.
B. Consultant not fulfilling the requirements shall be excluded from future participation in any of the tenders of the client for at least two years and the relevant authorities shall be accordingly informed.

17 Duration and Timeline

- The project shall be completed within 120 days from the date of issue of work order.

18 Collaboration

- If the Project's packages are awarded to two different firms, both firms are required to collaborate. Their joint effort will produce a single, continuous Vs30 Distribution Map and a corresponding Seismic Site Classification Map for the entire country. This collaborative mapping effort is in addition to the individual scopes already defined in Section 4.

- In light of upcoming activities under the project, specifically the development of the Probabilistic Seismic Hazard Assessment (PSHA) map and the revision of the Bhutan Building Code 2018, the firm awarded the current assignment (Packages A and B) shall provide requisite collaboration with firm(s), consultant(s) and professionals working on these activities, wherever necessary.

19 Knowledge transfer and capacity building

1. The firm shall provide knowledge transfer on the adopted methodology and field testing. This includes a demonstration of the geophysical testing methodology, data acquisition, processing, and Vs30 computation. This training will be delivered to a maximum of 15 participants nominated by the Client.

2. The Client will be responsible for all workshop logistics and associated expenses, including the conference hall, participants' TA/DA (for Client-nominated attendees), working lunch, refreshments, and stationery, all in accordance with RGoB norms.

20 Annex: Environmental and Social Compliance Requirement

This compliance matrix integrates World Bank ESS requirements for Vs30 Testing and Seismic Site Classification, including site-specific conditions and mitigation actions.

ESS	Relevance	Required Actions / Mitigation Measures (Including Site-Specific Conditions)	Responsibility
ESS1: Assessment and Management of Environmental and Social Risks	All sites	- Conduct specific site risk screening prior to testing. - Document all mitigation in Inception Report. **If site is within dense settlement: ** Ensure early (at least 2 weeks prior) community notification, restrict equipment use during peak hours. **If site is within or near schools/hospitals: ** Schedule testing after school hours, and ensure noise control. **If site is on public road: ** Implement a traffic management plan with local authorities.	Consultant, DHS

ESS2: Labor and Working Conditions	Field operations	- Ensure worker safety: PPE, safety induction, emergency contacts. - Implement worker grievance mechanism. - Maintain first aid kits at all sites. **If site is remote: ** Ensure satellite phone or alternative communication. **If high-risk terrain: ** Conduct stability check before setup, provide harnesses if necessary.	Consultant
ESS3: Resource Efficiency & Pollution Prevention	All sites	- Avoid contamination of soil and water. - Optimize routes to reduce fuel consumption. - Collect and dispose of all types of waste properly, especially the site preparation waste. **If site is near water body: ** Prevent spillage of fuels, avoid equipment washing near streams. **If site has soft ground: ** Use protective mats to prevent ground damage.	Consultant
ESS4: Community Health and Safety	High population zones	- Inform the public through local leaders and thromde offices before testing. - Consultants and all workers will need to sign code of conduct in English/local language - Set up warning signs and barricades. - Assign a field safety officer. **If site is within dense settlement:** Use smaller arrays or ReMi methods to minimize disruption. **If site is in traffic corridor:** Deploy traffic controllers or coordinate with traffic police.	Consultant, DHS
ESS8: Cultural Heritage	Sites near religious or heritage areas	- Screen all test points for cultural sensitivity. - Implement Chance Finds Procedure. **If site is near monastery/chorten:** Maintain a buffer (≥10 m), avoid noisy testing during prayer times. **If sacred tree or landmark present:** Shift test point with DHS approval. **If heritage site is unavoidable:** Obtain local approval and work under supervision.	Consultant, DHS
ESS10: Stakeholder Engagement and Disclosure	All sites	- Notify communities before testing begins. - Maintain a grievance mechanism for complaints. **If site affects access:** Discuss schedule with affected households. **If community objects:** Escalate to DHS and reschedule with consultation.	Consultant, DHS
Cross-Cutting	All sites	- Implement EHS Plan with site-specific measures: ✔ Risk assessment for each site. ✔ Daily safety briefing and monitoring. ✔ Emergency response plan. **If site is in a protected area:** No vegetation clearance; avoid disturbing wildlife. **If site is near schools/markets:** Implement crowd control with barricades and local authority.	Consultant

		If night work is needed: Ensure proper lighting and safety signage.	