सत्यमेव जयते

भारत सरकार
Government of India
विद्युत मंत्रालय
Ministry of Power
केन्द्रीय विद्युत प्राधिकरण
.Central Electricity Authority
जल परियोजना आयोजन एवं अन्वेषण प्रभाग
Hydro Project Planning & Investigation Division

To,

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12. Chairman and Managing Director, SJVN Ltd., Shakti Sadan, Corporate Office Complex, Shanan, Shimla Himachal Pradesh -171006.
13. Managing Director, M/s Adani Green Energy Limited, Shanti Gram, S.G. Highway, Ahmedabad, Gujrat-382421
14. Managing Director, M/s JSW Energy Limited, Bandra Kurla Complex, Bandra East, Mumbai, Maharashatra - 400051.
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Subject: Guidelines on advanced methodologies for adoption during investigation, tender and construction stages of hydel projects for minimizing geological uncertainties in long water conductor systems-reg.

महोदय/महोदया,

Tunnels, particularly headrace, tailrace and diversion are essential components of hydropower infrastructure, but their construction is deeply sensitive to subsurface geological conditions. Geological surprises in tunneling projects in Himalaya such as ingress of groundwater, thrust zones, shear zones, folded rock sequence, stress induced deformations like rock bursting and squeezing, shallow rock cover, geothermal gradient, ingress of toxic gases, high level of seismicity etc. often result in significant time and cost overruns, which in turn trigger contractual disputes, variation claims and erosion of stakeholder confidence.

To address these issues, MoP vide letter dated 12.06.2026 requested CEA to formulate and issue guidelines on the subject. Accordingly, guidelines have been formulated by CEA on "New Methodologies for Adoption during Investigation, Tender and Construction Stage of Hydel Projects for Minimizing Geological Uncertainty in Hydro Tunnels". The guideline is enclosed as **Appendix** for kind information and necessary action. These guidelines will help in mitigating geological surprises and accordingly time and cost overrun.

This issues with the approval of the Competent Authority.

Encl.: As above.

भवदीय

Digitally signed by
Shrey Kumar
Date: 26-06-2026
15:16:15

(श्रेय कुमार)
उप निदेशक

Copy To:
1. Director(Hydel-II), MoP.

Copy for Information:
1. SA to Chairperson, CEA.
2. SA to Member (Hydro), CEA.

Appendix

GUIDELINES ON ADVANCED METHODOLOGIES FOR ADOPTION DURING INVESTIGATION, TENDER AND CONSTRUCTION STAGES OF HYDEL PROJECTS FOR MINIMIZING GEOLOGICAL UNCERTAINTIES IN LONG WATER CONDUCTOR SYSTEMS

1. Introduction

Tunnels, particularly headrace, tailrace and diversion are essential components of hydropower infrastructure, but their construction is deeply sensitive to subsurface geological conditions. Unlike surface structures, tunnels traverse unknown and often unpredictable ground, where geological surprises can derail even the most meticulously planned projects. Tunneling in weak geology is more challenging in terms of stability and application of support. Geological surprises in tunneling projects often result in significant time and cost overruns, which in turn trigger contractual disputes, variation claims and erosion of stakeholder confidence.

Diverse geological problems are being faced during tunneling activity in various projects in Himalaya such as ingress of groundwater, thrust zones, shear zones, folded rock sequence, stress induced deformations like rock bursting and squeezing, shallow rock cover, geothermal gradient, ingress of toxic gases, high level of seismicity etc. These geological phenomena are not isolated; they often interact, compounding risks and complicating mitigation efforts. For example, squeezing ground may be exacerbated by water ingress, fault zones may trigger both deformation and rock bursts while negotiating shear zones may become more difficult due to associated ground water ingress.

Due to the geotechnical hazards often encountered during tunneling, 90% of infrastructure and hydro-power projects globally exceed their budgeted cost and tunneling project on an average exceed their expected costs by 50% (Beckers et al, 2013).

Quoting for example the ITA WG17 reports on Long Tunnels (2010) "… *at great depth … very little is known about the geological, hydrogeological and geotechnical conditions: the deeper the tunnel, the larger the uncertainties; the higher the probability of encountering adverse or unforeseen conditions for tunneling, the greater the effort and the cost for site investigations to reduce the uncertainties*" and in the following revision (2017) "*The timely identification of the geotechnical hazards and the understanding of their consequences are essential … to minimize the risks during construction.*"

2. Objective and Scope

Taking cognizance of past geological hazards encountered during construction of long water conductor system, a guideline applicable to hydro power project developers in Himalayan terrains has been prepared which recommends advanced methodologies for adoption during investigation, new information to incorporate in tender document and suggested improvement in construction stage geological activities of hydel projects. The guideline may help in the preparation of a bankable DPR during S&I stage, preparation of comprehensive bid document and improvement in construction stage geological activities.

For implementation of the suggested advanced methodologies, the paramount requirement is to increase the budgetary allotment for site geological investigation of the hydro-power projects based on their installed capacity, capital cost and length of the water conductor system. Presently, the expenditure on site investigation especially along the water conductor system as a percentage of project capital cost is often low. Thus, only miniscule percentage of the total capital and construction cost are spent for survey and investigation along the water conductor system in the DPR stage. This leads to incomplete investigation, thereby leaving significant gap areas.

Based on the examples and case studies of advanced methodologies adopted worldwide in various infrastructure and hydro-power projects for minimizing geological uncertainties in long tunnels/ water conductor system, Standard Operating Procedures (SOP) suggesting implementation of these methodologies during investigation, tender and construction stages of hydro-power projects in Himalayan geology have been prepared.

A proposed increase in the range of estimated expenditure under “A-Preliminary works” which covers Survey & Investigation works in CEA/CWC guidelines has also been suggested in the subsequent section.

“Guidelines for Preparation of Detailed Project Reports of Irrigation and Multipurpose Projects” issued by Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti (erstwhile Ministry of Water Resources), “Guidelines for Formulation of Detailed Project Reports for Hydro Electric Schemes” issued by Central Electricity Authority, “Guidelines for Investigations and Explorations required at Detailed Project Report (DPR) stage of proposed Hydroelectric Project in Himalayan Terrains” issued by Geological Survey of India (GSI) and Indian Standard “IS 17883:2022- Geological Exploration for Tunnels — Guideline” may be referred for S&I and preparation of DPRs of hydro power projects.

Standard Operating Procedures for implementation of advanced methodologies during investigation stage and improvement in tender and construction stage geological activities of long water conductor systems in hydro-power projects in Himalaya are suggested for inclusion in the existing CEA Guidelines in the following sections.

3. Standard Operating Procedure for subsurface geological and geophysical investigations of long Head Race Tunnel/Tail Race Tunnel (> 1000 m) and Diversion tunnel

A. Practices to be adopted during Detailed Investigation Stage

1. Head Race Tunnel/Tail Race Tunnel with Vertical cover <300 m

a) Sub-surface investigations suggested in existing guidelines and standards as mentioned above should be followed.

b) Additionally, one drill hole every 500 m or part thereof along the length (excluding portals) of the water conductor system should be carried out.

2. Head Race Tunnel/Tail Race Tunnel with Vertical cover >300 m

a) Advanced Remote sensing techniques through satellites, aircrafts and drones using both optical-infrared and radar sensors, e.g. light-detection and ranging (LIDAR) systems, synthetic aperture radar (SAR) systems, multispectral and hyperspectral scanners and the NASA Aster sensor, characterized by different spatial and spectral resolutions are required to carry out high resolution surface geological mapping (lithological and structural mapping and hydro-mechanical monitoring) and develop a 3-D Digital Terrain Model of the proposed tunnel alignment incorporating major geological features (Joints/Faults/Shears/ Lineaments).

b) Aerial / Heliborne Electromagnetic survey (AEM) in inaccessible terrain along HRT/TRT for delineation of potential geo-hazards like subsurface aquifers and weak zones along the entire length of the tunnel with reasonable accuracy upto a depth of 500 m.

c) Two to three drill holes with core recovery in low cover region and lithological contacts. The drill holes should puncture at least 10 m below the desired depth.

d) Combined Active & Passive Seismic Tomography should be carried out for detailed ground survey of the critical geological zones as identified by Remote Sensing/AEM studies within a short length of <1 km with higher resolution and up to the tunnel grade at large depth (> 1 km).

e) Directional Core Drilling with core recovery along the tunnel alignment using wireline operated core barrel and rotary steerable tools in the geologically problematic zones as identified from Remote Sensing/AEM/Combined Active-Passive Seismic Tomography studies should be carried out.

f) One drill hole per kilometer with core recovery along the length of HRT/TRT should be drilled to the extent feasible (subject to accessibility). For locations with superincumbent cover > 1 km, it may be dropped.

g) Geo-hydrological studies in the form of conducting ground water survey based on natural springs, wells, deep valleys, gully crossings, faults, valleys formed by fault/joint connected to uphill and ground water condition identified by site investigations such as geophysical survey (ERT/AEM study) and drilling results. Drilling in major nala crossings should be conducted and piezometers should be installed in selected critical areas identified by the field survey and geophysical investigations for monitoring hydraulic head. Ground water table should be mapped based on piezometer readings and water bearing zone along each underground structures should be identified and marked on the geological section along water conductor system.

3. Diversion Tunnel

a) Geophysical survey like Seismic Refraction Tomography (SRT) should be carried out throughout the length of Diversion tunnel.

b) Three drill holes-one at each portal, one in low cover area or as per topography. The drill holes should puncture at least 10 m below the desired depth. Piezometers should be installed in drill holes in major nala crossings.

c) Additional drill holes every 500 m or part thereof should be drilled to validate geologically critical zones identified from Seismic Refraction Tomography.

d) Diversion tunnels are often designed to cater high discharge during construction of Dam enabling safe and efficient construction by isolating the work area from the natural river flow, especially during high water events. To enhance the construction life of Diversion tunnel and avoid its failure due to geologically unfavorable conditions, preventive measures like lining of the Diversion tunnel with high grade concrete of increased thickness in the overt portion and reinforced lining in the invert portion and in the areas of poor geological conditions may be practiced to reduce the risk of cavity formation and damage/scouring of invert.

Based on comprehensive Survey & Investigation as mentioned above, the tunnel should be aligned along most favorable geological conditions avoiding major nalas/ aquifers, optimum rock cover to avoid stress instabilities and hydro-fracturing, oblique to the weak zones and low angle to principal stress directions.

B. Practices to be adopted during preparation of bid document (Geology chapter) during pre-construction stage

1. **Anticipated geological risks along water conductor system based on conventional and advanced investigation techniques**

a) Based on the conventional and advanced geological & geophysical technologies like Remote sensing using LIDAR/SAR/Hyperspectral scanners, Aerial Electro Magnetic survey, Combined Active-Passive Seismic Tomography and Directional drilling to enhance the area of investigation covering almost the entire length of WCS and near to the tunnel depth thereby reducing the gap areas left by conventional methods and minimize geological surprises, a Geotechnical Baseline Report (GBR) showing anticipated rockmass quality, hydrogeological conditions, problematic geological zones and other relevant geo-technical properties may be made a part of tender documents.

b) Provision of in-situ rock-mechanic testing like hydro-fracturing/overcoring should be incorporated in the scope of contract for stress measurement in anticipated zones of stress induced deformations like rock bursting/ squeezing in water conductor system to determine magnitude and direction of principal in-situ stresses and design rock support in anticipated rock bursting zones accordingly. These tests should be conducted in Adits to HRT during construction stage, if not possible to drill hole along HRT alignment during DPR stage.

The results of stress measurement tests should be validated with the World Stress Map of latest version published on its website.

c) Provision of advanced ground specific instrumentations in the scope of contract like Micro-seismic monitoring, cross-hole acoustic apparatus, digital borehole camera in anticipated rock bursting zones and Survey prism targets/Tape extensometer in anticipated squeezing zones for real time monitoring of deformation should be incorporated during excavation of long tunnels.

d) Advanced ground prognostication techniques during tunnel excavation as described in **Section C (para 2b)** should be incorporated in the contract agreement**.**

2. **Anticipated rockmass classification (Q/RMR/NATM/GSI) based on ground condition and construction methodology**

a) Interpreted RD wise continuous rockmass (RMR/Q) classification along the length of water conductor system should be attempted to the best extent possible along with percentage wise rock class. Distribution of RD wise anticipated rock classes along geological section of the tunnel alignment for each underground structure should be prepared for effective design of rock support. Percentage wise rockmass classification may be provided only in the gap/gray areas along the water conductor system which could not be adequately investigated due to site constraints to provide flexibility for geological variation in the contract.

RD wise anticipated rock class shall help in estimating progress of excavation in different rock classes with higher precision and thus developing a more realistic Time schedule for completion of tunnel excavation. A comparison between anticipated vs. encountered rock class should be monitored for every 500 m length of excavation of WCS. Provision should be kept in the contract for adjusting the time, if the progress of excavation is less than the estimated progress in higher rock class or compensating the contractor by granting time extension for installation of additional rock support and treatment of weak zones if the encountered rock class is lower than the anticipated rock class in the contract.

b) Apart from conventional Q and RMR rockmass classification systems, provision of flexible and qualitative rock mass classification systems based on site geological conditions like NATM for squeezing and swelling ground conditions alongwith in-situ instrumentation program and Q_{TBM} for mechanized tunneling through Tunnel Boring Machine should be incorporated in the contract agreement.

c) Based on different empirical correlations as given in Indian standards IS 13365 (Part 1):1998 (Reaffirmed 2021) and IS 13365 (Part 2):2019, support pressure and deformation modulus should be estimated for different rock classes as per rockmass classification (Q/RMR/GSI) for adequate design of rock support system and incorporated in the contract agreement.

3. **Geological risk sharing-Probabilistic risk modelling based on anticipated extra-ordinary geological (EGO) conditions**

a) Based on the geological hazard identification using new-age technologies, quantitative risk assessment using statistical models to establish severity and probability of predicted geological hazards/uncertainties should be incorporated in the contract.

b) Risk matrix should be prepared categorizing the predicted geological risks as high, medium or low based on their probability of occurrence.

c) A predictive algorithm should be prepared to forecast the impact of anticipated geological hazards/uncertainties on overall timeline and cost of the project and incorporated in the contract.

d) Cross-sectoral learning from contract document of metro, highway, railway and mining tunnels in similar complex geological scenario should be practiced.

e) Risk allocation schedule clearly defining how the contractor will be compensated in terms of time and cost in case of geological surprise/EGO conditions should be included in the contract.

C. Practices to be adopted during construction stage geological activities

1. Assessment of the geological condition during tunnel excavation and adopting site specific rockmass classification

a) Potential stress induced deformations like rock bursting/squeezing based on encountered rock conditions, superincumbent cover above the tunnel alignment, rock mechanic testing parameters and in-situ stresses determined from empirical method in high rock cover zones (>300 m) along the tunnel alignment should be analyzed and incorporated in 3-D geological log and face log of the tunnels.

b) Kinematic analysis of encountered joint sets through stereographic projection should be carried out and incorporated in 3-D geological log for assessment of potential planar/wedge failure during excavation.

c) Apart from conventional empirical geo-mechanic rockmass classifications like RMR and Q, following site specific rockmass classifications should also be practiced during tunnel excavation:

(i) Q_{TBM} (Barton, 2000) for mechanized tunneling integrating machine parameters like Cutter Life Index based on quartz content and hardness of the rock, Average Cutter Load based on average machine thrust and number of cutters and rock mechanic parameters determined in the laboratory like hardness, abrasivity, brittleness, drilling rate index etc. and determine advance rate & penetration rate of Tunnel Boring Machine based on the empirical relationships.

(ii) Modified RMR (Laubscher & Jakubec, 2000) classification incorporating blasting damage adjustment, stress adjustment and fracture orientation adjustment parameters should be followed in rock bursting conditions.

(iii) NATM rock classes for squeezing/swelling ground conditions with flexible support system based on the deformation measured from installed instrumentation reading.

(iv) GSI classification system should be used to determine Hoek-Brown and shear strength parameters for stability analysis through finite element modelling.

2. Anticipation of geologically problematic zones ahead of tunnel face through advanced ground prognostication techniques

a) Existing ground prognostication measures like core/probe drilling/Tunnel Seismic Prediction/Cross-hole seismic tomography should be carried out in reasonable quantities & actual execution records should be transmitted to central Design team every week.

b) Apart from existing ground prediction techniques, following prognostication measures should also be implemented:

(i) Induced polarization and resistivity based BEAM (Bore Tunneling Electrical Ahead Monitoring) survey may be conducted during mechanized tunneling through Tunnel Boring Machine to predict real-time groundwater condition ahead of face.

(ii) Ground Penetrating Radar (GPR) and Transient Electromagnetic (TEM) studies should be carried out to delineate groundwater zones ahead of the face in tunnels excavated through Drill & Blast method.

(iii) Measurement While Drilling (MWD) tools should be applied during core drilling to obtain real time results and graph of the rockmass properties while drilling.

(iv) In-situ stress measurement tests like Hydro-fracturing/overcoring should be conducted in anticipated rock bursting/ squeezing zones for optimizing design support

3. Advanced stabilization and Safety measures to be implemented in encountered geologically weak zones/EGO conditions

a) Monitoring of already excavated length using standard instrumentation needs to be strictly ensured.

b) Ground specific instrumentation like Survey prism targets, Tape Convergence for monitoring squeezing ground conditions and Micro-seismic monitoring/ cross-hole acoustic apparatus/ digital borehole camera for monitoring rock bursting conditions should be implemented during tunnel excavation.

c) Specialized blasting pattern like stress-relief blasting for pre-splitting of hard and massive rock and reduce intensity of rock burst should be implemented in rock bursting zones.

d) During excavation of twin WCS running parallel, considering tunnel spacing, project layout, safety requirement and additional cost, provision of construction of a link tunnel connecting the twin tunnels with readily accessible rescue equipment should be kept to provide safe evacuation route during collapse of tunnel face/flooding /fire /toxic gases under EGO (Extra-ordinary Geological Conditions) conditions, or any other emergency situations. Link tunnel will also help in increasing progress in case of less progress in either tunnel.

e) For automatic risk assessment and improved worker safety with minimum human intervention, following practices should be implemented:

(i) Use of NATM for proactive monitoring

(ii) Digital Twin model for creating virtual tunnel replica and assessment of geology, tunnel profile, rock support and lining behaviour during excavation and

(iii) Automated TBM self-adjusting machine parameters like thrust, torques and rate of penetration based on ground conditions

Generalized flow diagrams summarizing the measures/ practices to be adopted during Survey & Investigation stage, tender stage and construction stage geological activities are enclosed as **Annexure-I, II & III**

D. Recommended enhancement of the existing permissible range of expenditure under "A – Preliminary" works in the CWC & CEA guidelines

The expenditure on site investigation as a percentage of total project cost is often low, not exceeding 1% of the estimated capital cost during CCEA stage. Thus, only miniscule percentage of the total capital/construction cost of the project is spent for survey and investigation in the DPR stage. This leads to incomplete investigation, thereby leaving significant gap areas.

As per the "Guidelines for formulation of DPR of Hydro Electric Projects" issued by CEA (2023) and "Guidelines for preparation of project estimates for river valley projects" issued by CWC (1998), expenditure on account of Survey & Investigation works is presently covered under ***Head "A – Preliminary"*** of the DPR cost estimate, which has a prescribed range of 1% to 2% of the total cost of I-Works and also includes other activities such as consultancy expenses, model studies, EIA/EMP and other specialized technical studies.

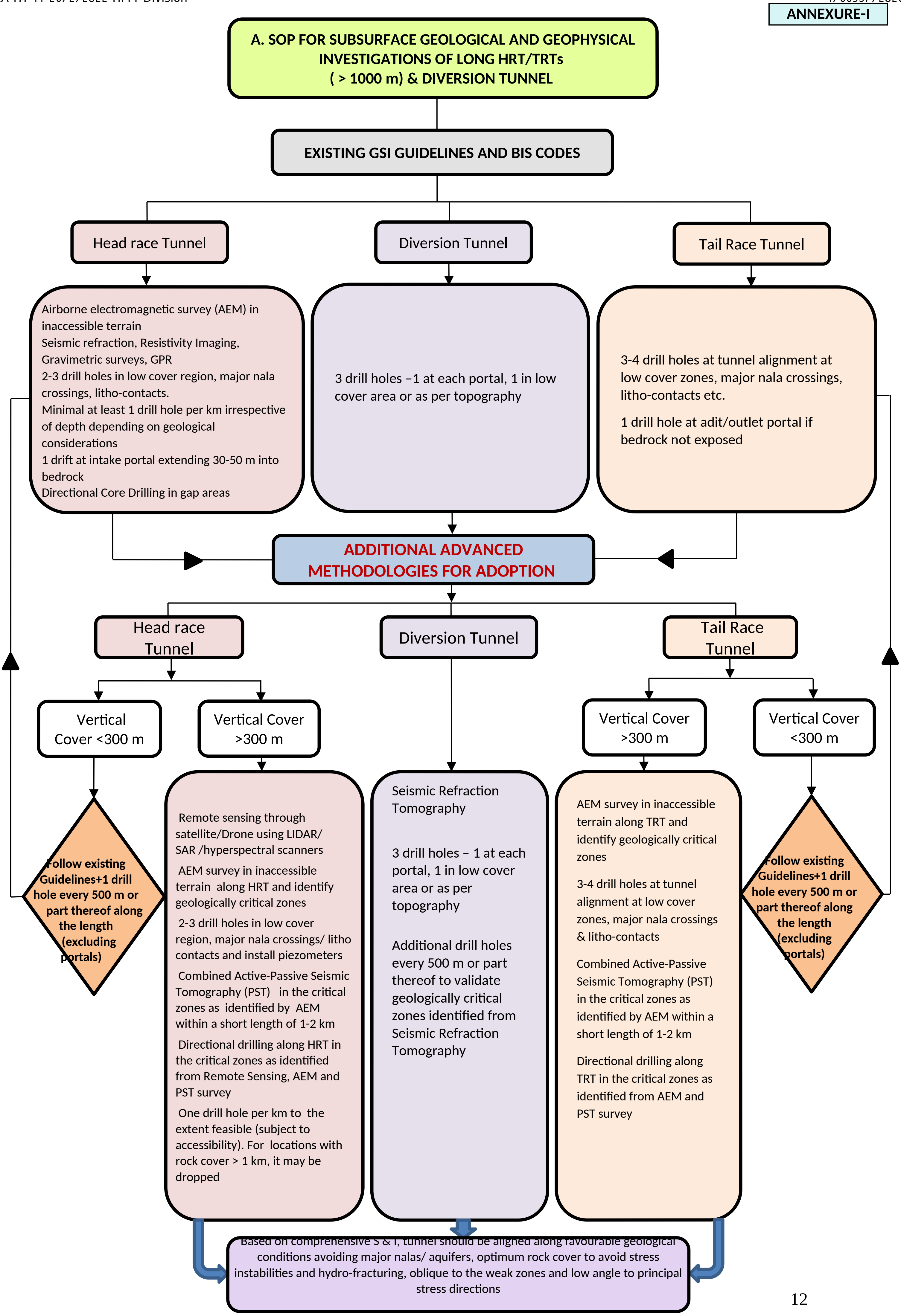
As the expenditure for survey & investigation works of long Water Conductor system in hydro power projects located in Himalayan terrain shall increase substantially due to the adoption of suggested advanced methodologies, it is recommended that a new item titled "***Advanced Geo-technical Investigations for Water Conductor System***" may be created in the Head ***"A – Preliminary"*** of the CWC & CEA Guidelines.

It is recommended that the budgetory allotment for geological investigations and site characterization in a hydro-power project may be decided based on their installed capacity, capital cost of construction and length of the water conductor system as shown in **Table-1** of **Annexure-IV.**

Based on the budgetary allotment proposed in **Annexure-IV**, the permissible range of expenditure on account of **"A – Preliminary"** works is recommended from **0.32%** of total estimated capital cost during CCEA stage for hydel power projects with installed capacity of ≥5000 MW to **1.75%** for smaller hydel power projects with installed capacity of ≤ 200 MW assuming average capital cost of construction of the project is limited to ₹12 Cr./MW as per financial year 2025-26 price level.

The present permissible expenditure on account of **"A – Preliminary"** works as per existing CWC and CEA guidelines ranges from **1%** to **2%** of the total estimated cost of I-works. The permissible range may be modified to **0.5% of I-Works** for hydel power projects with installed capacity of ≥5000 MW to **3% of I-Works** for smaller hydel power projects with installed capacity of ≤ 200 MW assuming average cost of "***I work***" is 60% of average capital cost of construction of the project limited to ₹7.2 Cr./MW as per financial year 2025-26 PL.

ANNEXURE-I


A. SOP FOR SUBSURFACE GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS OF LONG HRT/TRTs (> 1000 m) & DIVERSION TUNNEL
EXISTING GSI GUIDELINES AND BIS CODES
Head race Tunnel
Diversion Tunnel
Tail Race Tunnel
Airborne electromagnetic survey (AEM) in inaccessible terrain
Seismic refraction, Resistivity Imaging, Gravimetric surveys, GPR
2-3 drill holes in low cover region, major nala crossings, litho-contacts.
Minimal at least 1 drill hole per km irrespective of depth depending on geological considerations
1 drift at intake portal extending 30-50 m into bedrock
Directional Core Drilling in gap areas
3 drill holes –1 at each portal, 1 in low cover area or as per topography
3-4 drill holes at tunnel alignment at low cover zones, major nala crossings, litho-contacts etc.
1 drill hole at adit/outlet portal if bedrock not exposed
ADDITIONAL ADVANCED METHODOLOGIES FOR ADOPTION
Head race Tunnel
Diversion Tunnel
Tail Race Tunnel
Vertical Cover <300 m
Vertical Cover >300 m
Vertical Cover >300 m
Vertical Cover <300 m
Follow existing Guidelines+1 drill hole every 500 m or part thereof along the length (excluding portals)
Remote sensing through satellite/Drone using LIDAR/ SAR /hyperspectral scanners
AEM survey in inaccessible terrain along HRT and identify geologically critical zones
2-3 drill holes in low cover region, major nala crossings/ litho contacts and install piezometers
Combined Active-Passive Seismic Tomography (PST) in the critical zones as identified by AEM within a short length of 1-2 km
Directional drilling along HRT in the critical zones as identified from Remote Sensing, AEM and PST survey
One drill hole per km to the extent feasible (subject to accessibility). For locations with rock cover > 1 km, it may be dropped
Seismic Refraction Tomography
3 drill holes – 1 at each portal, 1 in low cover area or as per topography
Additional drill holes every 500 m or part thereof to validate geologically critical zones identified from Seismic Refraction Tomography
AEM survey in inaccessible terrain along TRT and identify geologically critical zones
3-4 drill holes at tunnel alignment at low cover zones, major nala crossings & litho-contacts
Combined Active-Passive Seismic Tomography (PST) in the critical zones as identified by AEM within a short length of 1-2 km
Directional drilling along TRT in the critical zones as identified from AEM and PST survey
Follow existing Guidelines+1 drill hole every 500 m or part thereof along the length (excluding portals)
Based on comprehensive S & I, tunnel should be aligned along favourable geological conditions avoiding major nalas/ aquifers, optimum rock cover to avoid stress instabilities and hydro-fracturing, oblique to the weak zones and low angle to principal stress directions

ANNEXURE-II

B. SOP FOR PREPARATION OF COMPREHENSIVE BID DOCUMENT FOR MINIMIZING GEOLOGICAL SURPRISES ALONG LONG HYDRO-TUNNELS > 1000 m

EXISTING GEOLOGICAL INFORMATIONS IN CONTRACT AGREEMENT-INFORMATION FOR BIDDERS

Anticipated Geological risks along Water Conductor System based on Conventional methods of Investigations (surface geological mapping, drilling and geo-physical survey)

Anticipated geologically problematic zones like thrust /shear zones, chimney formation, stress induced deformations like squeezing /rock bursting, surface cave-in or sink hole in low cover nala zone, ingress of groundwater, geothermal gradient, ingress of toxic gases, high level of seismicity etc.

Suggested support / stabilization measures to incorporate in design drawing

Suggested geological and geophysical prediction techniques during tunneling to validate geologically problematic zones anticipated during S & I stage

Anticipated rockmass classification based on Q/RMR/GSI

Anticipated rock class and support class (% wise) as per empirical (Q/RMR/GSI) classification of rock mass

Interpreted geological plan and sections along WCS incorporating litho types, litho-contacts, regional thrusts, intersecting nalas, low and high cover zones and anticipated geologically problematic zones

Geological risk sharing clauses -EGO (Extra Ordinary Geological Occurrences) conditions

Time compensation to the contractors due to following geological factors not attributable to the contractors

Weak structural conditions like fractured/shear zone of defined magnitude causing chimney formation

Ingress of groundwater or with silt/ slush /debris of defined quantum causing flooding of the tunnel

Rock Bursting/Squeezing causing rockfall/ tunnel closure of specific magnitude

Geo-thermal conditions (>50°C)

Encountering pockets of methane or other toxic gases of defined magnitude

ADDITIONAL NEW INFORMATIONS TO INCORPORATE IN THE BID DOCUMENT

Anticipated Geological risks along WCS based on Conventional and New Age Geological & Geophysical investigation technologies reducing the gap areas

Based on advanced geo-technical investigations minimizing the gap areas, a comprehensive Geotechnical Baseline Report (GBR) showing anticipated rockmass quality, hydrogeological conditions, geologically problematic zones and other relevant geo-technical properties may be made a part of tender documents.

Incorporation of provision of in-situ testing like hydro-fracturing/overcoring in the scope of contract for stress measurement in anticipated zones of stress induced deformations in WCS

Incorporation of provision of new age ground specific instrumentations in the scope of contract like Micro-seismic monitoring, cross-hole acoustic apparatus, digital borehole camera in anticipated rock bursting and Survey prism targets/Tape extensometer in anticipated squeezing zones for real time monitoring during execution

Incorporating advanced ground prognostication techniques during tunneling in the contract agreement as described in **Section C**

Anticipated Rockmass classification (Q/RMR/NATM/GSI) based on ground condition and construction methodology

Interpreted RD wise continuous rockmass (RMR/Q/GSI) classification along the extensively investigated length of WCS

Alongwith RD wise rock class, % wise rock class in gap areas of WCS left due to inadequate investigation

Apart from conventional Q and RMR, incorporate flexible and qualitative rock mass classification system based on site geological conditions like NATM for squeezing and swelling ground conditions, Q_{TBM} for mechanized tunneling through Tunnel Boring Machine and Modified RMR in rock bursting conditions in the contract agreement

Estimating support pressure and deformation modulus for different rockmass classification (Q/RMR/GSI) based on empirical correlation as per Indian standards IS 13365 (Part 1):1998 (Reaffirmed 2021) and IS 13365 (Part 2):2019 for adequate design of rock mass support system

Geological risk sharing - Probabilistic risk modelling based on anticipated EGO conditions

Based on the geological hazard identification using new-age technologies, quantitative risk assessment using statistical models to establish severity and probability of predicted geological hazards / uncertainties

Preparation of Risk Matrix and categorizing the predicted geological risks as high, medium or low based on their probability of occurrence

Predictive algorithm to forecast the impact of anticipated geological hazards/uncertainties on overall timeline and cost of the project

Cross-sectoral learning from contract document of metro, highway, railway and mining tunnels in similar complex geological scenario

Risk allocation schedule in the contract clearly defining how the contractor will be compensated in terms of time and cost in case of geological surprise/ EGO conditions

ANNEXURE-III

C. SOP ON SCOPE FOR IMPROVEMENT IN CONSTRUCTION STAGE GEOLOGICAL ACTIVITIES FOR MINIMIZING GEOLOGICAL SURPRISES ALONG LONG HYDRO-TUNNELS > 1000m

EXISTING GEOLOGICAL ACTIVITIES DURING CONSTRUCTION STAGE

Assessment of the geological condition during tunnel excavation

Preparation of progressive 3-D Geological log and Face log after each blast

Classification of encountered rockmass based on Q/RMR/GSI as defined in the contract incorporating joint and stress parameters

Advise suitable rock support based on rock class / Modify existing design support based on geological conditions

Prognostication measures for anticipation of geologically problematic zones ahead of tunnel face

Validate anticipated geologically problematic zones in the contract agreement with ground prediction techniques like probe or core drilling, Tunnel Seismic Prediction (TSP), Cross-hole Seismic Tomography etc.

Interpretation of geological conditions ahead of tunnel face from ground prediction techniques and suggest suitable support/ stabilization measures

Advise tunnel support and stabilization measures of encountered geologically problematic zones

Ensuring class wise installation of rock support within the excavation cycle/ stand up time of the rock class

Advise specialized stabilization measures as per contract agreement and standard operating procedure like forepoling, self-drilling anchors, pre-grouting, chemical grouting, pipe-roofing, pressure/stress relief holes etc. to negotiate geologically weak zones

Geological assessment of contractual issues like geological overbreak and contractor's claim for EGO conditions of contractor's claims

SUGGESTED IMPROVEMENT IN CONSTRUCTION STAGE GEOLOGICAL ACTIVITIES

Assessment of the geological condition during tunnel excavation and adopting site specific rockmass classification

Prediction of potential stress induced deformations like rock bursting/squeezing based on encountered rock conditions, rock mechanic testing parameters and in-situ stresses determined from empirical method in high rock cover zones along the tunnel alignment and incorporate in 3-D geological log and face log

Kinematic analysis of encountered joint sets through stereographic projection and incorporate in 3-D geological log for assessment of potential planar/wedge failure

Implementation of site specific rockmass classifications apart from conventional RMR and Q like:

Q_{TBM} (Barton, 2000) for mechanized tunneling integrating machine parameters like Cutter Life Index, Average Cutter Load and rock parameters like hardness, abrasivity, brittleness, Drilling rate index etc. and determine advance rate & penetration rate of Tunnel Boring Machine

Modified RMR (Laubscher & Jakubec, 2000) incorporating stress parameters for rock bursting Conditions

NATM rock classes for squeezing ground condition

Anticipation of geologically problematic zones ahead of tunnel face through advanced ground prognostication techniques

Core Drilling/TSP of reasonable quantity & actual execution records to be transmitted to central Design team every week

Apart from existing ground prediction techniques implement following prognostication measures:

Conduct induced polarization and resistivity based BEAM (Bore Tunneling Electrical Ahead Monitoring) survey during mechanized tunneling with TBM to predict real-time groundwater condition ahead of face

Conduct Ground Penetrating Radar (GPR) and Transient Electromagnetic (TEM) techniques to delineate groundwater zones ahead of the face in DBM tunnels

Apply Measurement While Drilling (MWD) tools during Core drilling to obtain real time results and graph of the rockmass properties while drilling

In-situ stress measurement tests like Hydro-fracturing/overcoring tests be conducted in anticipated rock bursting/ squeezing zones for optimizing design support

Advanced stabilization and Safety measures to be implemented in encountered geologically weak zones/EGO conditions

Monitoring of already excavated length using standard instrumentation need to be strictly ensured

Implementation of ground specific instrumentation like Survey prism targets, Tape Convergence for monitoring squeezing ground conditions and Micro-seismic monitoring/ cross-hole acoustic apparatus/ digital borehole camera for monitoring rock bursting condition

Implementation of specialized blasting pattern like stress-relief blasting in rock bursting zones for pre-splitting of hard and massive rock and reduce bursting intensity

Considering tunnel spacing, layout, safety requirement and additional cost, provision of construction of a link tunnel during excavation of parallel twin WCS for safe evacuation of site personnel during collapse of tunnel / flooding /fire / EGO conditions, or any other emergency situations. Link tunnel will also help increasing progress in case of less progress in one tunnel

Automatic risk assessment and improved worker safety with minimum human intervention through the use of NATM for proactive monitoring, Digital Twin model for creating virtual tunnel replica and assessment of geology, tunnel profile, rock support and lining behaviour during excavation and automated TBM self-adjusting machine parameters based on ground conditions

ANNEXURE-IV

Table 1. Budgetary allotment suggested in a hydro-power project

Hydro-Power Projects involving water conductor system upto 1 km (Head Race Tunnel & Tail race Tunnel)				
Length of Water Conductor System (m)	**Vertical Cover**	**Project Installed Capacity (MW)**	**Recommended budgetary allotment (A-Preliminary) based on estimated capital cost at CCEA**	**Recommended budgetary allotment (A-Preliminary) based on estimated cost of 'I works at CCEA'**
< 1000 (< 1 km)	< 300 m	Upto 200	**1.5%** of capital cost ~ ₹36 Cr.	**2.6 %** of I works ~ ₹37 Cr
		200 - <500	₹36 Cr. + 1% of capital cost above 200 MW~ ₹72 Cr. =**1.2%** for 500 MW	₹37 Cr. + 1.7% of I works above 200 MW~ ₹74 Cr.= **2%** for 500 MW
		500 - <1000	₹72 Cr.+0.5% of capital cost above 500 MW~₹102 Cr. =**0.85%** for 1000 MW	₹74 Cr. + 0.85% of I works above 500 MW ~ ₹104 Cr.=**1.5%** for 1000 MW
		1000 - <3000	₹102 Cr. + 0.25% of capital cost above 1000 MW~ ₹162 Cr.=**0.45%** for 3000 MW	₹106 Cr.+ 0.4% of I works above 1000 MW~ ₹164 Cr.= **0.75%** for 3000MW
		3000 - 5000	₹162 Cr. + 0.125% of capital cost above 3000 MW~ ₹192 Cr.=**0.32%** for 5000 MW	₹164 Cr.+ 0.2% of I works above 3000 MW~ ₹193 Cr.= **0.5%** for 5000 MW
For capacities above 5000 MW, amount will be capped at 0.32% of capital cost* and 0.5% of I works (applicable for 5000 MW)**				
*Budgetory allotment has been recommended *assuming average capital cost of construction of the project is limited to ₹12 Cr./MW* as per financial year 2025-26 price level **Average Expenditure on account of head ***'I-works'*** is taken as 60% of average capital cost of construction of the project ~ ₹7.2 Cr./MW as per financial year 2025-26 price level				

Hydro-Power Projects involving long water conductor system > 1 km (Head Race Tunnel & Tail race Tunnel)				
Length of Water Conductor System (m)	**Vertical Cover**	**Project Installed Capacity (MW)**	**Recommended budgetary allotment (A-Preliminary) based on estimated capital cost at CCEA**	**Recommended budgetary allotment (A-Preliminary) based on estimated cost of 'I works at CCEA'**
1000- 5000 (1-5 km)	> 300 m	Upto 200	**1.75%** of capital cost ~ ₹42 Cr.	**3 %** of I works ~ ₹43 Cr
		200 - <500	₹42 Cr. + 1.25% of cost above 200 MW~ ₹87 Cr.=**1.45%** for 500 MW	₹43 Cr. + 2% of I works above 200 MW~ ₹86 Cr. = **2.4 %** for 500 MW
		500 - <1000	₹87 Cr. + 1% of cost above 500 MW~ ₹147 Cr..=**1.25%** for 1000 MW	₹86 Cr. + 1.7% of I works above 500 MW~ ₹147 Cr.= **2%** for 1000 MW
		1000 - <3000	₹147 Cr. + 0.2% of cost above 1000 MW~ ₹195 Cr = **0.54%** for 3000 MW	₹147 Cr. + 0.35% of I works above 1000 MW~ ₹197 Cr. = **0.9%** for 3000 MW
		3000 - 5000	₹195 Cr. + 0.1% of cost above 3000 MW~ ₹219 Cr.=**0.37%** for 5000 MW	₹197 Cr. + 0.17% of I works above 3000 MW~ ₹221 Cr. = **0.6%** for 5000 MW
For capacities above 5000 MW, amount will be capped at 0.37% of capital cost* and 0.6% of I works (applicable for 5000 MW)**				
*Budgetory allotment has been recommended *assuming average capital cost of construction of the project is limited to ₹12 Cr./MW* as per financial year 2025-26 price level ****Average Expenditure on account of head ***'I-works'*** is taken as 60% of average capital cost of construction of the project ~ *₹7.2 Cr./MW* as per financial year 2025-26 price level				

***** For length of water conductor system (HRT + TRT only) above 5000 m, approx. ₹3 Cr./ km additional amount for Survey & Investigation along long water conductor system may be allocated.***