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A PRAGMATIC APPROACH FOR APPLYING SSHAC LEVEL 3 PSHA TO A SPECIFIC SITE

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ABSTRACT

The assessment of the seismic hazards at a nuclear installation site is one of the most critical and difficult activities of the site-evaluation process for determining the design bases of a new installation against natural hazards or, in case of operating facilities, for evaluating its safety margins. For this assessment, there is a need to deal with the uncertainties embedded in the complexity of tectonic environments and the limited data available for seismic source and ground motion characterizations, as well as with the multiple expert's judgments, to achieve a final output for the design bases or for the re-evaluation purposes.

The aim of the paper is to present the planning and preparation of all activities required for performing a full scope assessment of all geo-hazards, including the application of a streamlined and optimized SSHAC Level 3 approach for the probabilistic assessment of the ground motion hazards, on the example of a nuclear installation site under early stages of development in Turkey. The paper emphasizes the prioritization on the timing collection of reliable data with respect to performing desktop analyses, which will proceed after the collection of reliable and sufficient data. This was an essential condition of the approach to comply with before to start the SSHAC phase in order to avoid the issues of similar previous studies regarding overrun costs and schedules.

INTRODUCTION

As a Turkish company, Elektrik Üretim Anonim Şirketi (EÜAŞ) has founded EUAS International Incorporated Cell Company (EUAS International ICC). The mandate of the EUAS International ICC firm comprises the execution of Turkey's nuclear-related programs in collaboration with its international partners. The main duties of the EUAS International ICC were: (1) managing the nuclear power plant (NPP) new build projects, (2) establishing the required specific know-how, and (3) enabling the built-up of a local nuclear industry. Consistent with that mandate, EUAS International ICC[1] is currently executing all activities related to the 3rd NPP new build project in the Thrace Region in Turkey.

After preforming a preliminary feasibility study, EUAS IICC launched in 2019 a project aimed to perform the assessment of the seismic hazards at the site of the planned 3rd NPP in Turkey, located on the Black Sea coast of the Thrace region (see Figure 1). As a fundamental principle, it was established that this Project should be performed in full compliance with applicable national regulatory requirements (TAEK 2009), international safety standards and recognized updated engineering practice for the design of nuclear installations.

The Project established that all hazards generated by the occurrence of earthquakes have to be evaluated. The earthquake generated hazards include:

[1] In the following, only for his paper, EUAS International ICC is noted as "EUAS IICC".

1. Vibratory ground motion hazards
2. Surface fault displacement phenomena
3. Slope instability associated hazards
4. Collapse associated hazards due to cavities and subsidence phenomena
5. Soil liquefaction associated hazards
6. Concomitant events as floods caused by earthquake generated tsunamis

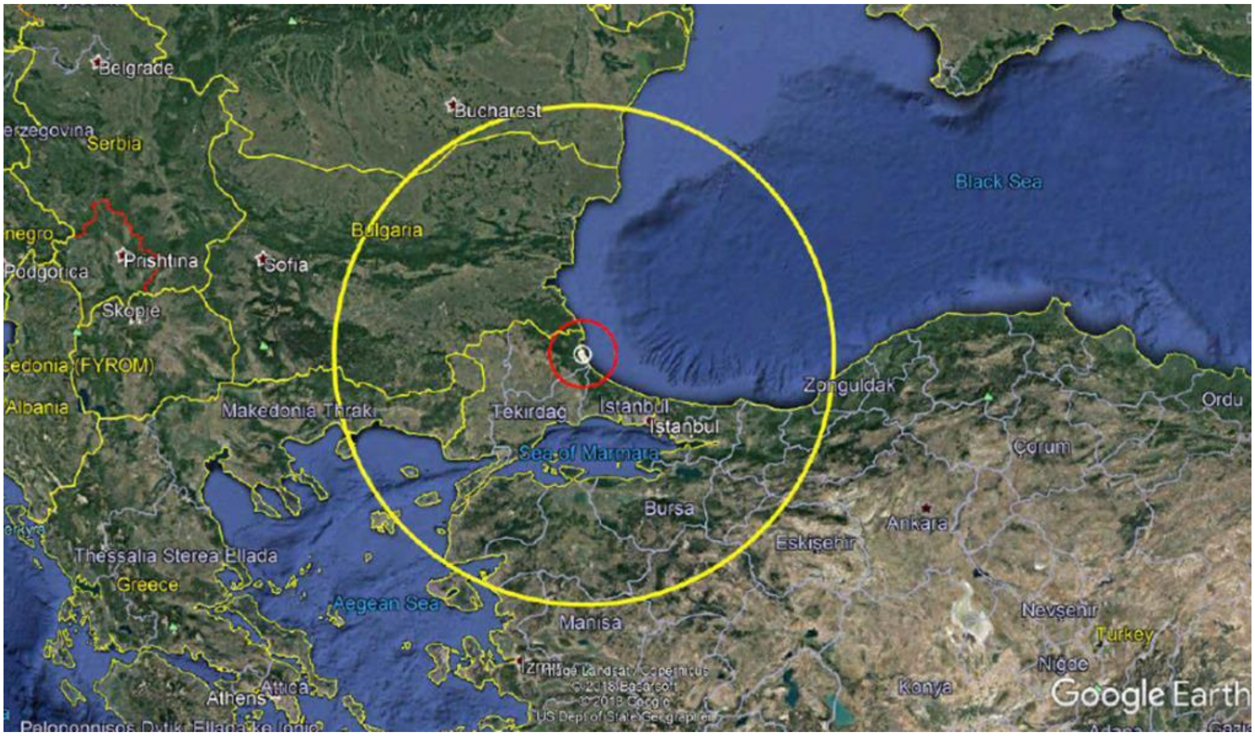

Figure 1: General view of location of 3rd NPP site in Turkey. The yellow circle has a radius of 300 km and the red circle of 50 km.

In addition, it was indicated that a volcanic hazard assessment should also be performed aimed to fulfil the safety requirements established by IAEA SSR-1 (2019). Therefore, the outcome of the assessment of the seismic and other hazards indicated above would fulfil the following specific safety requirements:

- Demonstration of the acceptability (or suitability) of the selected site in relation to the established exclusionary screening criteria regarding:
  - surface fault displacement phenomena,
  - massive slope instability,
  - collapse phenomena associated to earthquakes,
  - massive soil liquefaction phenomena, and
  - volcanic hazards.

It was agreed that the specific exclusionary screening criteria including the corresponding attributes, will be established before the beginning of the Project and, if possible, in agreement with the Turkish Regulatory Authority (NDK - Nükleer Düzenleme Kurumu; formerly named TAEK - Türkiye Atom Enerjisi Kurumu (Turkey Atomic Energy Agency)).

- Derivation of the site related design parameters for seismic vibratory ground motion and tsunami flood level hazards.

Therefore, the outcome of the Project will include:

(i) Development of the hazard curves or assessment of the potential for occurrence of each of the indicated hazards (1 to 6 above). Specifically, in relation to seismic hazards, EUAS IICC requested to perform the assessment through the application of the SSHAC Level 3 approach.

(ii) Derivation of the associated site-related design parameters required for the design and safety evaluation of the NPP. Discussion and definition of beyond design basis parameters are not part of the Project.

(iii) Derivation of the site related design parameters for volcanic hazards, if required by the specific related assessment.

PLANNING OF THE PROJECT

Fundamental Premises and Assumptions

As well known, the assessment of the seismic hazards involves dealing with a significant number of uncertainties which are embedded in the complexity of tectonic environments, in the limited data usually available – mainly for seismic source and ground motion characterizations - and in the need to properly consider the multiple expert's judgments. The lack of availability of reliable and enough data as required for performing an assessment of hazards with an adequate identification and reasonable control of the involved uncertainties is also the case for the studied site of Turkey, even if it could be assumed that in Turkey - as a country with high seismicity - a lot of seismic data would be available.

Literature and practice are plenty of long and expensive assessments before to achieve a final reliable output. Since the inception of the nuclear power, almost seven decades ago, the seismic hazard assessment methodologies have evolved from pure deterministic to probabilistic approaches nowadays. In many nuclear power plant sites in the world, the original seismic hazard evaluations have been updated and revised during the operational lifetime of the installations. The conducted re-evaluation processes have proved in almost all cases that the newly determined seismic demands differ (and, in almost all cases, exceed) the original values, which have required to perform complex and expensive capacity assessment of structures, systems and components and, alternatively, physical upgrades and retrofits at the plant.

EUAS IICC decided to put together an expert team with recognized expertise on project management as well as on engineering seismology in order to carry out a very efficient project. Based on the long experience of the Project Team members in international projects on the subject, it was formulated the fundamental premise that for keeping the Project within the estimate budget and the expected schedule it was essential to proceed in a sequential step-by-step approach, as summarized below:

1. Organization of a clear project structure with well-defined roles and responsibilities
2. Formulation of a full scope Project Plan, approved by EUAS IICC
3. Definition of all disciplines and tasks to carry out
    a. Prioritization of the tasks based on the criteria to give first priority to collection of specific site data for all disciplines involved in the assessments.
    b. Demonstrate the acceptability of the selected site based on established exclusionary criteria.

4. Preparation of all required technical specifications and selection and contracting of contractors and subcontractors.
5. Execution of field, laboratory and in-office activities related to data collection
6. Assessment of all earthquake and volcanic related hazards:
   The assessment of the seismic hazards applying SSHAC Level 3 approach (US NUREG/CR-6372, NUREG-2117, NUREG/CR-2213),- which include all expensive activities related to conduct of several workshops with numerous teams of international experts - will start after completion of steps 3.b) and 5) above.
7. Integration of results, conclusions and final reporting.

The main assumptions for the formulation of the Project were not considered to be of technological or scientific character. Rather, they were related to managerial aspects linked to the following critical aspects:

a) A sound estimates of the required budget
b) A committed and sufficiently provided fund allocation and the timely availability of funds
c) A selection of highly qualified and reliable contractors and subcontractors for critical tasks, especially for those corresponding to collecting new data
d) An effective coordination between all specific tasks, particularly, between data collection tasks and assessment tasks
e) Collaboration of (or at minimum no hindrance from) locals
f) The selected site complies with exclusion criteria conditions and its suitability is demonstrated
g) Permits and authorizations obtained without undue delays
h) No occurrence of force-majeure events

Project Organization Structure and Project Plan

The organizational structure of the Project was established as follows (see Figure 2 below):

- A Project Sponsor (PS), a role that is fulfilled by the Chief Executive Officer (CEO) of EUAS IICC.
- A Project Steering Committee (PSC), constituted and aimed to project governance, control and monitoring. It was formed by the CEO, the Director of Engineering and the Director of Projects of EUAS IICC, including the future participation of members of the investor partner.
- The Project Management Team (PMT), managing and executing the Project. This PMT shall report to the PSC and, ultimately, to the PS. The PMT is composed of a Project Manager (PM), a Deputy Project Manager (DPM), a Senior Advisor, the Project Assistants (PA) and supporting staff. The PMT will take the full responsibility of the Project and will work as a one united single body. Note that three of the authors of this paper formed the PMT.
- A consultancy firm with the role of Owner's Engineer (OE), contracted to provide the necessary additional resources and specialized expertise to support the PMT to manage and execute the Project.
- The Data Manager (DM), responsible from management of all the Project's data and document management and ensuring that all the work being done is performed in compliance with EUAS IICC's procedures and standards.
- The Quality Manager (QM), in charge of quality management of the Project. The QM ensures that all the work being done is performed in compliance with and Contractor's Quality Management System where applicable.

The organizational structure follows the concept of a clear and defined responsibility for performing three different types of tasks: (i) collection of all required data and information related to the geological, geotechnical and geophysics disciplines (i.e., Sub-Project 2), (ii) collection of all required data and information related to the seismological database (i.e., Sub-Project 3), and (iii) assessment of the seismic hazards (i.e., Sub-Project 1).

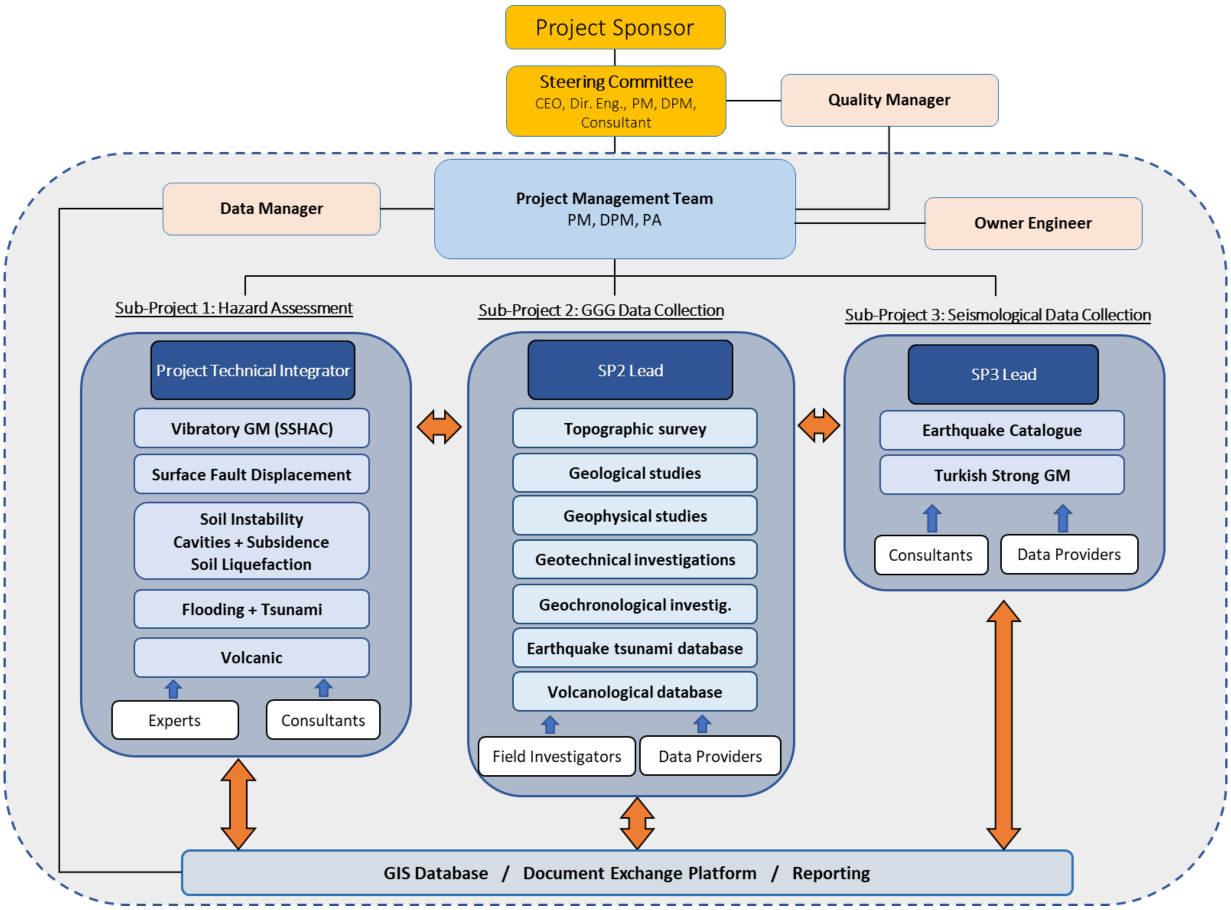

Figure 2: Project Organization Chart

It is worth mentioning that the OE was selected to provide independent advice, highly qualified and specific services to the PMT during all stages of the Project. Engaging an independent owner's engineer can ensure that the Project complies with international and national standards using world best updated engineering practices, thereby reducing the risk of liabilities and allowing to timely address potential quality issues. The OE will provide resources, expertise and execution skills to define and specify the services required for the Project within the scope of the defined Work Packages.

In this regard, the OE should have expertise in broad-based engineering, contractor selection, procurement review, vendor oversight for specification of design, risk management, project management assessment, project management and interface issues. Thus, selecting an OE requires great care and a proper selection will save money to the PS in the long term. In line with those considerations, a Joint Team constituted by Lettis Consultants International Inc. and Annie Kammerer Consulting was selected for the Project and attributed this role.

A specific organization chart was defined in relation to the tasks related to assessing the earthquake vibratory ground motion using the US SSHAC Level 3 approach, which is one of the parts of the Sub-Project 1, as shown in Figure 3.

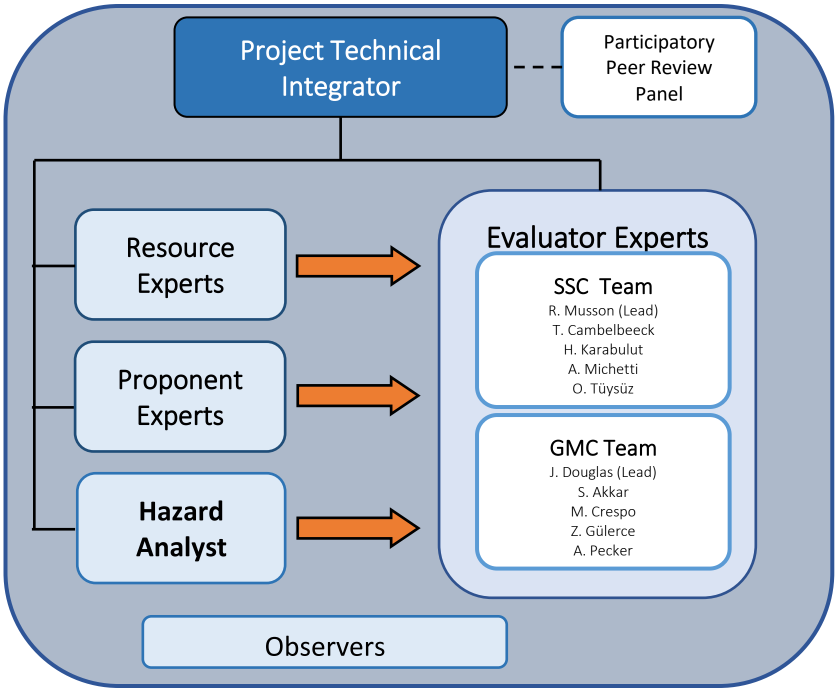

Figure 3: Project organizational chart for SSHAC process of vibratory GM hazard assessment. (SSC = Seismic Source Characterization, GMC = Ground Motion Characterization).

As part and in parallel to the definition of the project structure organization, it was prepared, discussed, reviewed and approved by the PSC a very detailed Project Plan that describes the objectives, the outcome and the planning of the whole Project was prepared, discussed, reviewed and approved by the PSC. It is briefly summarized in this paper. It includes a detailed description of the objectives, approaches, output and deliverables for each of the identified tasks in order to establish the bases for preparing the technical specifications for selection of contractors and procurement activities.

Planning and Definition of all Tasks and Activities

A phased approach to reach the Project objectives, with four phases and clear milestones, was formulated in line with the fundamental premises. Consequently, a preliminary time schedule was prepared to comply with the Project duration requested by the PSC, which in principle was estimated to be of 18 months. The phases and status were as follows:

Phase 1: "Preparatory Phase" done and completed in 2019 (with a duration of <6 months)
Phase 2: "Contracting Phase" started in 2019 and suspended in 1Q of 2020 (with a duration of <6 months)
Phase 3: "Data collection and site suitability demonstration" started in 2019 and suspended
Phase 4: "Assessment of Seismic and Other Hazards" not initiated due to Project suspension

Often in practice, the Phase 1 is underestimated by the PS management and not much attention is paid to it and the consequences of incomplete planning are suffered later in the process. Thus, in order to set up a solid and robust project, the Project invested the necessary resources in the conception and selection of team members and external experts to contract. Furthermore, a detailed preparatory phase allows to identify synergies in the data collection tasks to satisfy the different requirements of the full scope project, as within one campaign multiple datasets can be gathered, avoiding sequential deployment of personnel and equipment. This results also in cost savings for the PS, as the data collection task (both old existing and new data) is usually the most expensive part of the project.

The Phase 1, here called the contracting phase, requires a dedicated attention and to spend a proper period of time, as needed, in order to arrange that highly specialised experts, with usually numerous commitments and previous engagements, be able to accept participating and book the required dates for the workshops and meetings. Thus, experts need to be contacted well in advance and beside their general acceptance to participate, it is even more important to align the project schedule with the availability schedule of the experts. Furthermore, this phase also contains also the available data compilation and setting up the IT infrastructure for the project.

It was formulated that the Project and the three sub-projects be conducted through the execution of four categories of Work Packages (WP), which were identified as follows:

WP Category 1 Collection of available data and preparatory tasks, divided in 5 specific work packages,

WP Category 2 Compilation and processing of geological, geophysical, geotechnical, seismological, tsunami and volcanological databases, divided in 13 specific work packages,

WP Category 3 Assessment of hazards, divided in 7 specific work packages,

WP Category 4 Reporting and documentation, divided in 4 specific work packages.

Each of the WP Categories comprises a number of specific WPs. Thus, 29 specific WPs were identified in order to be implemented within the three Sub-projects indicated above. The detailed list of the 29 specific WPs is presented below:

WORK PACKAGE CATEGORY 1: COLLECTION OF AVAILABLE DATA AND PREPARATORY TASKS

The WP Category 1 includes the collection and organization of all data available from *past performed stages and preparatory tasks,* any of which can be performed in parallel:

WP1.1: Collection of available geological, geophysical, geotechnical, seismological, volcanological, and flooding data.
WP1.2: Organization of the Geographic Information System (GIS), including procurement, delivery, installation and testing of the software, organization of the group, definition of the data and metadata structure and the uploading of the available data.
WP1.3: Procurement, installation, and organization of web-based document exchange platform, including backup-system and user specific access privileges.
WP1.4: Definition, selection, procurement of equipment and installation of required monitoring networks:
- WP1.4.1: Geodetic Monitoring Network (GMN).
- WP1.4.2: Local Microearthquake Monitoring Network (LMMN) at the near region area.

WORK PACKAGE CATEGORY 2: GEOLOGICAL, GEOPHYSICAL, GEOTECHNICAL, SEISMOLOGICAL AND VOLCANOLOGICAL DATABASES

The WP Category 2 includes the collection of *new* site-specific data organized according to the geographical (region, near-region, site vicinity and site area) and temporal (prehistorical and historical) scales. The following specific WPs are defined:

WP2.1: Permits and Authorizations
WP2.2: Topographic survey – LiDAR campaign
WP2.3: Bathymetry survey
WP2.4: Geological studies
WP2.5: Geophysical studies:
- WP2.5.1: Onshore geophysics investigations
- WP2.5.2: Offshore geophysics investigations

WP2.6: Geotechnical investigations

WP2.7: Geochronological investigations
WP2.8: Integrated Geological, Geophysical and Geotechnical Database
WP2.9: Seismological database
WP2.10: Earthquake generated tsunami database
WP2.11: Volcanological database
WP2.12: Additional data collection (if necessary)

WORK PACKAGE CATEGORY 3: ASSESSMENT OF HAZARDS

The WP Category 3 covers the assessment activities for all hazards defined in the scope of the Project using all collected databases and in accordance with the established methods and approaches. In principle, the following seven specific WPs are considered:

WP3.1: Assessment of vibratory ground motion hazards (using the SSHAC L3 approach)
WP3.2: Assessment of surface fault displacement phenomena
WP3.3: Assessment of hazards associated to soil instability
WP3.4: Assessment of potential of collapse due to cavities and subsidence phenomena
WP3.5: Assessment of potential of soil liquefaction
WP3.6: Assessment of external flood hazard: earthquake generated tsunami
WP3.7: Assessment of the potential for volcanic hazards

Regarding the methodology for assessing the hazards generated by the occurrence of earthquakes the approaches summarized in Table 1 will be used. For the assessment of the potential volcanic hazard related phenomena, mainly screening criteria have been adopted and for tephra fallout assessment appropriate probabilistic methods will be applied.

Table 1: Overview of assessment methods (Det. = Deterministic, Prob. = Probabilistic) for the different geo hazards, as required by the TAEK regulation on nuclear power plant sites (No: 27176).

Assessment of:	**Det.**	**Prob.**
Vibratory ground motion hazards	×	×*
Potential of surface fault displacement phenomena	×	
Slope instability associated hazards	×	
Collapse associated hazards due to cavities and subsidence phenomena	×	
Potential for soil liquefaction associated hazards	×	
External floods caused by earthquake generated tsunamis	×	×

(*) For the probabilistic assessment of vibratory ground motion hazards the PS decided to use the SSHAC Level 3 procedure as defined in the latest US NUREG SSHAC guidelines. The deterministic seismic hazard analysis follows the classical approach, as described in the IAEA Specific Safety Guide No SSG-9.

WORK PACKAGE CATEGORY 4: REPORTING AND DOCUMENTATION

The WP Category 4 covers the activities related to integrating and reporting the results of the studies, investigations and analyses conducted within the scope of the Project. This WP category includes the preparation, review, revision and approval of all reports. In principle, this WP is split in the following specific WPs (or activities), considering the timing and phasing for production of each type of reports:

WP4.1: Topical technical reports for each of the activities

WP4.2: Final report of the Project
WP4.3: Organization of Site Data in the GIS in accordance with QA/MS requirements
WP4.4: Project Quality Management System

The mentioned specific WPs are assigned to the three defined sub-projects according to a matrix of responsibilities, indicating:

PR (Primary Responsibility):	Sub-project in charge of fulfilling the objectives of the work package.
SR (Secondary Responsibility):	Sub-project in charge of supply data to fulfil the objectives of the work package which is under the primary responsibility of another Sub-project.
PSR (Primary Shared Responsibility):	When two Sub-projects are assigned with PSR, both are responsible to fulfil the objectives of the work package, since as part of that work package, different activities are to be performed for each of the Sub-projects.

The PMT defined a “freezing point” for input data after the foreseen data collection (right before the SSHAC Workshop #1) in order to avoid an unnecessary long delay of the start of the evaluation and hazard assessment phase (Phase 3). This “freezing point” has to be endorsed and understood by all participating parties as a snapshot in time of the actual state of knowledge. This does not mean that the outcome of the Project cannot be adjusted after the completion of this Project as soon as new data or models become available. Nevertheless, for the purpose of the demonstration of the acceptability (or suitability) it is deemed to be sufficient and is a management constraint in order to keep the Project on foreseen time and budget.

Project Risks

Also, upon request from the PSC, the Project Team evaluated the risks the Project could face in its implementation. The identified and evaluated risks were mainly related to:

- Ensuring budget allocation and payment delivery on time
- Contracting contractors and individual consultant experts on time
- Obtaining the necessary authorizations and permits from authorities
- Performing the field and laboratory testing program without interruption
- Collecting and compiling sound and reliable databases.

It was also considered that the scope and objectives of the Project correspond strictly to the assessment of the natural hazards indicated above. It should be noted that hazards derived from human induced hazards and other natural hazards, as well as other safety and non-safety aspects covered in site characterization studies (e.g., related to dispersion in air, atmosphere and soil, feasibility of implementing emergency response action, environmental and socio-economic aspects, site preparation), were not included in the scope of the Project. However, the studies and investigations conducted by the Project are important and they are a relevant part of such site characterization. The obtained results and the collected data and information will be integrated into the Site Evaluation Report and Site Data Report as part of the required documentation for obtaining the site permit during the licensing process of the NPP.

CONCLUSIONS

This paper summarized the planning and execution (partial, because of Project suspension) of a modern full scope hazard assessment for a new nuclear installation site. The scope of the Project covered seven critical natural hazards (direct, associated and concomitant) generated by earthquakes and volcanoes. The expected duration of the Project was required to be 18 months. The requested outcome was (i) the demonstration of site suitability against established exclusionary criteria and (ii) the derivation of related design bases.

This paper emphasis the need to prepare, first, a comprehensive and detailed project plan as the starting point in order to achieve the goals on time, within the budget and with the required quality, trying to overcome and avoid the issues and delays of similar natural hazard assessment projects for nuclear installations, which are very well-known and reported in the specialized literature.

The Project was structured in four phases, from which often the first two ones (preparation and contracting) are not well considered in terms of time demand and careful detailing. Furthermore, this phasing approach allows an efficient and optimal allocation of resources and budget considering two critical priorities: 1) to demonstrate, first, that the site is suitable (if not demonstrated, the Project is to be re-formulated, but no further resources are spent useless or unnecessary), and 2) to conduct, first, field and laboratory investigations as required for compiling sound and reliable databases for assessing, later, the hazards. This sequence of priorities is considered as key for successful reaching the Project objectives.

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