To: ENSI
CC: ENSI-RT
From: TFI, SP1 Leader and PMT

ADMINISTRATIVE NOTE **PMT-AN-1150**

PEGASOS Refinement Project

Position on the ENSI late stage review observations of the PRP entitled: "ENSI Final Report: Review Approach and Comments Concerning the PEGASOS Refinement Project (PRP) and the PRP Summary Report" (ENSI-AN-9060)

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Introduction

ENSI has submitted on 24. August 2015 to swissnuclear the ENSI review team (ENSI-RT) report *"ENSI Final Report: Review Approach and Comments Concerning the PEGASOS Refinement Project (PRP) and the PRP Summary Report"* in its final version (dated 22.04.2015, Ref. ENSI-AN-9060). This document describes the observations of the ENSI-RT, their criticism and judgement on the validity of the PRP final result. There are in total 38 late stage review items (consisting of strengths and areas of improvements), which can be divided in SP1: 8 comments, SP2: 4 comments, SP3: 13 comments, SP4: 4 comments and Interfaces: 9 comments. Relevant significant "areas of improvement" were expressed by the ENSI-RT only for 6 SP1 items (Nb. 3-8), which are related to one procedural point and 5 technical points. According to the ENSI-RT, the SP1 results are not suitable for computing hazard results. The 6 aspects that apparently invalidated the SP1 results identified by the ENSI-RT (Section 4.2.1(a - f)) are the following: 1) Overall scope of SP1 elicitation; 2) SP1 elicitation of Mmax; 3) Issues related to the application of the ECOS11 seismic catalog; 4) SP1 elicitation of activity rates; 5) SP1 derivation and use of hypocentral depths; and 6) Assessment of epistemic uncertainty. Based on these criticisms, the ENSI-RT arrived at the conclusion that the PRP hazard results are not acceptable and not suitable for use in safety-relevant applications for nuclear power plants in Switzerland.

A key role of a Participatory Peer Review Panel (PPRP) in a SSHAC level 4 study is to follow the activities of the project as they occur and the related documentation made available in the project data base. In the course of the PRP, there was a lack of continual monitoring of the project progress and expert interactions by the RT. Because the RT was not aware of all of the expert evaluations and feedback that occurred, the RT concluded that the SSHAC process was not adequately followed and that a late-stage technical review of the submitted PRP summary report was required.

This note summarizes the positions taken by the technical leaders of both the PEGASOS project and the PRP relative to the criticisms offered by the ENSI-RT. Such positions have been offered previously in writing to ENSI, as summarized in Attachment D *Position of PRP Project Management Team on Issues 1 to 4* in ENSI's letter to the SP1 Expert Teams "PEGASOS Refinement Project (PRP): Question-Based Survey Regarding SP1" dated 20 April 2015. This information was also presented and discussed in detail at the ENSI meeting on 18 September 2014[1]. Despite the fact that this information and documentation was provided by the PRP to ENSI, no significant changes were made to the Draft ENSI-RT report and the final report is essentially unchanged and does not acknowledge the PRP position regarding the criticisms posed. The position of the PRP is that the criticisms are unfounded and can be shown by evidence in the project documentation to be incorrect. Further, criticisms offered by the ENSI-RT regarding procedural shortcomings of the project are not supported by consideration of existing SSHAC regulatory guidance for such studies and the documented steps and activities taken during the PRP. The ENSI-RT report explains that the RT does not endorse NUREG-2117 [2] and instead relies on the original SSHAC report where NUREG-2117 expands and updates definitions and concepts. In contrast, the technical leaders of the project relied on the lessons learned from previous SSHAC studies that are described in NUREG-2117. This is part of the cause of the differences in the expectations of the RT and execution of the project.

This document is structured to first provide the PRP's positions relative to the 6 aspects cited by the ENSI-RT as invalidating the SP1 results, then to provide the implications of the PRP models to seismic hazard results relative to the PEGASOS models and to post-PRP hazard analyses by the SED, and finally to summarize the PRP position relative to the ENSI-RT's criticisms of the SP1 assessments and the decision that they should not be used for hazard calculations and risk assessments. Appendices to this note provide additional documentation and technical support for the positions taken in the text. Appendix 1 provides detailed information regarding the timelines during which the SP1 expert team considered important catalogue-related issues. Appendix 2 summarizes key advantages of the PRP assessments over the PEGASOS study. Appendix 3 provides a comparison of post-PRP hazard results from the SED 2015 model with the PRP 2013 results. Appendix 4 and 5 provide a summary of the main issues raised by the ENSI-RT and issues raised by the ENSI-RT that are not considered to be significant to the PRP.

PRP Response to ENSI-RT Criticism of SP1

As noted above, the ENSI-RT report identifies 6 areas of criticism of the SP1 aspect of the PRP in Section 4.2.1 (a – f) and these areas are again cited in Section 5 of the Review Team report in drawing the conclusion that the SP1 results are not valid and not suitable for use in hazard calculations. The first criticism is related to the scope and procedural aspects of the project and the remaining five relate to technical aspects of the assessments made by the SP1 expert teams. The positions of the PRP related to each of these criticisms are given below.

1. Overall scope of SP1 elicitation

The fundamental criticism of the process of conducting the SP1 aspect of the project relates to conclusion by the ENSI-RT that the scope of the SP1 activities was limited by the project management team (PMT) because the importance of the issue of magnitude conversion in the earthquake catalogue was not foreseen, the importance of the issue was not known to the experts until it was too late for consideration by the experts, and inadequate feedback was provided to the experts early enough to allow them to understand the issue, its importance to hazard, and to ensure that their models addressed the issue.

At the time that the Project Plan for PRP was put together, the expectation was that an update to the catalogue would have a minor effect on hazard. However, as differences in the ECOS-02 and ECOS-09 catalogues [Note: throughout the PRP, the catalogue was referred to as the "ECOS-09" catalogue so that terminology is used in this document] became clear, the project evolved, the scope expanded to accommodate catalogue-related issues, and the SP1 Teams focused on the implications of those differences to their models. Examples of consideration by the Teams of the new ECOS-09 catalogue on seismic source characteristics are given below and are documented in the PRP Final Report (Vol.1, Ch.2; Vol.3). Topics discussed at the various workshops and working meetings related to the earthquake catalogue, magnitude conversions, and importance to recurrence and hazard are identified:

- Workshop #1 /2 September 2008): Summary of work for ECOS-09 update by SED.
- SP1/SP3 Interface Workshop /8 December 2008): SED's need to convert all magnitudes to a common moment magnitude was identified.
- Workshop #2 /28 April 2009): SED indicates the M_L-M_w conversion was not linear for all magnitudes and discussion that this could have hazard significance; potential significance of the catalogue to Mmax (of the Bayesian and Kijko approaches had been used) and the hazard significance of Mmax was also identified.
- Working Meeting /1-2 Nov 2009): Non-linearity in M_L-M_w for magnitudes smaller than about 3 and influence on b-value in recurrence discussed; sensitivity analyses identified by each team to evaluate the importance of the issue and an approach to addressing it.
- ECOS/SP1 Working Meeting /26 Jan 2010): Comparison of the magnitudes, locations, and depths in ECOS-02 and ECOS-09; Impacts of new catalogue on estimates of catalogue completeness, as function of time and space, including M_L-M_w conversion; Calculations of catalogue completeness, recurrence parameters (a-, b-values, exponentiality), and Mmax for all SP1 seismic sources using ECOS02 and ECOS09; identification of additional sensitivity analyses requested by expert teams.

- ECOS/SP1 Working Meeting /22 Feb 2010}: Comparative catalog completeness plots for all teams using (1) their PEGAOS magnitude intervals for both catalogs and (2) adjusted magnitude intervals for the ECOS-09 catalog based on the difference in the ECOS-02 and ECOS-09 ML-Mw conversions; Comparative recurrence calculations for large or regional source zones for each team based on ECOS-02 and ECOS-09 catalogs, using teams initial assessments for: (1) Adjustment to catalog completeness (time periods and magnitude intervals), (2) Truncated exponential and a modified truncated exponential model incorporating the curvature in the ECOS-09 M_L-M_w conversion relationship.
- Workshop #3 /23 Feb 2010}: Presentation and discussion of all Team assessments including completeness using new non-linear M_L-M_w relationship; recurrence using alternative magnitude distributions and Mmin, and recalculations of Mmax using Team-specified approaches; discussion across all teams of catalogue-change impacts and approaches to address uncertainties in a-, b-values, Mmax, magnitude frequency distributions and their hazard significance; Identification of additional sensitivity analyses and calculations to assist each team in the finalization of their models
- Extended TFI-Team interactions (incl. Bob Youngs & Kevin Coppersmith) (24 Feb 2010 to Aug 2011): Numerous calculations and exploratory analyses conducted at requests of each team: comparisons of catalogs in historical vs. instrumental periods; b-values for various regions and time periods for use as prior distribution; recurrence calculations for various magnitude intervals, time periods, completeness regions; Mmax distributions for Bayesian and Kijko approaches for all recurrence parameters.

In summary, although early planning for the PRP did not anticipate significant changes in the SP1 models due to updating the earthquake catalogue, the importance of the M_L- M_w conversion issue to recurrence estimation was recognized early in the PRP project and the scope of the PRP was expanded to provide for a complete evaluation of the implications of this issue to seismic source characterization. The catalogue and magnitude conversion issue was the subject of numerous discussions amongst the SP1 Teams, presentations at workshops, interactions during working meetings, and interactions between the Teams and the TFI team over the course of more than two years (see pp. 9-11 in [1]). The detailed SP1 timeline and identification of topics and issues addressed at all workshops and working meetings is given in Appendix 1 and confirms that the catalogue-related issues were given high priority throughout the PRP and that the expert teams were provided with extensive feedback and information to assist the teams in understanding the issues and developing their SP1 models to capture their assessments and uncertainties. The documentation of the Evaluation Summaries developed by each Team provides the technical justification for the approaches taken to deal with the conversion issue (PRP, Vol. 3).

2. SP1 elicitation of Mmax

The criticisms offered by the ENSI-RT related to the assessments of Mmax by the SP1 teams relate to an understanding of the SSHAC process by the RT that all of the expert assessments should be representing the “views of the informed technical community (ITC).” As a result, the RT expects that the Mmax assessments should show significant overlap amongst the four teams and should be the same (or certainly not lower Mmax values) than Mmax values for regional hazard studies such as SHARE. Examples are given in which the overlaps between particular teams for certain source zones have little to no overlap and, the RT concludes, this violates the SSHAC concept that each team represents the “community view. The RT also notes that the Mmax values assessed by the teams are lower than the values implied by paleoseismic studies.

The notion that a SSHAC process is designed to reflect or represent the "community view' is incorrect. In the original SSHAC guidelines of NUREG/CR-6732, the "informed technical community (ITC)” had a very specific definition based on the hypothetical situation in which one imagines that members of technical community had become “informed” by having gone through the evaluation and integration processes that the TI Teams had gone through . This concept was difficult to understand, so it was clarified in the detailed SSHAC implementation guidance given in NUREG-2117 [2] (p. 33-36):

> "In practice, however, the term "informed" is often either ignored or misinterpreted as simply meaning "expert in the field of interest." Thus, some view the process of capturing or representing the CBR of the ITC as a process of somehow conducting a poll or surveying the larger community for its opinions. ….. In light of these definitions, we propose that it is clearer to refer to the CBR of the "technically defensible interpretations" (TDI) instead of CBR of the ITC."
>
> "Similarly, we propose to replace the term "community distribution" that is used frequently in the original SSHAC guidelines to describe the outcome from a SSHAC assessment process with the term "integrated distribution." This change of terms will remove any perception that one arrives at the final assessments and models through a mere poll of the community."

Therefore, the requirement in a SSHAC process is that the Teams evaluate all relevant data, models, and methods in the technical community, they then build models (logic trees, etc.) that capture the CBR of the TDI, and they document those models. The Teams are responsible for defending their models technically, including the expressions of uncertainty in their logic trees. There is no requirement or expectation that all data, models, or methods proposed by the technical community will be found by the experts to be technically defensible. Likewise, there is no expectation that the Mmax distribution developed by any given Team must "represent the community view" or reflect the distribution of any other team. One reason for using a SSHAC level 4 rather than a SSHAC level 3 approach is to have multiple teams develop models so that the sensitivity of the results to the selection of the expert team can be evaluated. The latter increases robustness and defensibility of the final results.

In the ENSI-RT report it is stated that the RT was aware of the SSHAC guidance given in NUREG-2117, which is the standard by which SSHAC projects are currently evaluated, but did not rely on it. This is a severe shortcoming of the review provided by the RT and reflects an apparent lack of understanding of SSHAC principles and process. It also raises questions regarding the ENSI-RT's ability to act in the role of a Participatory Peer Review Panel, as specified in NUREG-2117 (p.49), given the apparent lack of recognition of the essential implementation guidance issued for all SSHAC processes in NUREG-2117.

Other studies such as the SHARE project were well-known by the experts (many of them are participants). However, Mmax is an assessment that is specific to the particular seismic source being characterized by the expert team and the seismic sources in those studies do not necessarily pertain to each Team's PRP sources. Likewise, the paleoseismic evidence for large earthquake occurrence is subject to interpretation and considerable uncertainties exist regarding the magnitude of paleo-earthquakes that were interpreted (see PMT-TN-1294 [3][4]). The PRP Teams considered this evidence and concluded that it did not provide compelling constraints on the Mmax for their source zones.

Because the approaches used by the SP1 Teams to assess Mmax (e.g., Bayesian and Kijko approaches) incorporate recurrence, it was recognized as early a Workshop #2 on 28 Apr 2009 (see timeline in Appendix 1 of this document) that Mmax had hazard significance and that it would need to be reassessed as part of the PRP. As discussed in Issue #1 of this document, feedback regarding the impacts of various team assessments to Mmax was provided throughout the project. Mmax is a characteristic that is specific to a given source zone and, because the source zones developed by the four teams are different, comparison of Mmax distributions across the teams is not very meaningful. Nevertheless, the range of estimates of Mmax is large and is indicative of uncertainties that are typical for source zones in other PSHAs in stable continental regions, such as the CEUS-SSC project [5] and as compared in Fig. 3 of TFI-TN-1292 [6].

As summarized in the PRP position for Issue #1 above, the SP1 teams reviewed their Mmax assessments and were provided sufficient feedback multiple times in order to understand why team-to-team differences existed. In the end, each team expressed large uncertainties in Mmax for their source zones, and they were technically justified in the Evaluation Summaries (PRP, Vol.3), as required by the SSHAC process.

3. Issues related to the application of the ECOS-09 seismic catalogue

The criticisms offered by the ENSI-RT with regard to the earthquake catalogue relate to whether or not the TI Teams were aware of the importance of the magnitude conversions, particularly the M_L – M_w conversion, whether alternative regression approaches should have been used to assess the conversion relationship, and whether multiple catalogues should be included in the hazard analysis as epistemic uncertainties. With regard to the conversion approaches, the RT makes suggestions for alternative ways that the regression could have been done with different minimum magnitudes, etc. With respect to alternative catalogues, the RT suggests that the ECOS-02 and ECOS-09 catalogues should be considered as weighted alternatives in a logic tree to express epistemic uncertainty. In addition, it is also suggest that the catalogues developed for other projects, such as SHARE and ISC-GEM, should likewise be considered as weighted alternatives.

From the standpoint of the SSHAC process, it is important to first note that the issue raised here by the ENSI Review Team is inappropriate if the RT considers itself to be a PPRP as defined in the SSHAC regulatory guidance. In that guidance, the defined role of the PPRP is not to offer their own technical interpretations, but, rather, to provide their review of the adequacy of the technical justifications provided by the expert teams. As stated in NUREG-2117 [2] (p. 49):

> “Beyond completeness, it is not within the remit of the PPRP to judge the weighting of the logic-trees in detail but rather to judge the justification provided for the models included or excluded, and for the weights applied to the logic-tree branches.”

Therefore, the RT's review of the SP1 assessments should entail a careful consideration of whether or not the teams were aware of the importance of the M_L - M_w conversion issue and the adequacy of the technical justification given by each team for the approach taken to address the conversion issue (PRP, Vol.3). Further, the RT should not be offering alternative technical interpretations (e.g., alternative approaches to regressing the data to arrive at a conversion relationship). Likewise, regarding the epistemic uncertainty in magnitudes, the RT should review the approaches taken by the SP1 teams to address the issue and the adequacy of the technical justifications for the approaches given in each team's Evaluation Summary (PRP, Vol.3). It should not be offering the RT’s interpretation of how epistemic uncertainties should be handled by weighting multiple earthquake catalogues.

From the first presentation made by the SED at Workshop #1, the ECOS-09 catalogue was portrayed and intended to be an update and revision to the ECOS-02 catalogue. As such, the SP1 Teams did not consider the catalogue to be another viable, mutually exclusive branch of a logic tree that expressed the epistemic uncertainties in the magnitudes of identified earthquakes. Rather, the ECOS-09 catalogue was considered to be the new PRP project catalogue replacing the ECOS-02 catalogue (see also PMT-AN-1145) [7] p. 111). Similarly, it is common practice for PSHAs to be based on a project-specific catalogue that provides the information specified for the project (e.g., M_w for all earthquakes). Other catalogues, such as those prepared for the SHARE or ISC-GEM projects are not relevant to the PRP project, since they fulfill their own project requirements.

Importantly, the epistemic uncertainties of importance to the PRP assessments are the uncertainties in the moment magnitudes defined for each earthquake in the catalogue, which includes the uncertainties associated with conversion from the native size measures for each event. The identification and quantification of these uncertainties was a major change from the ECOS-02 to

ECOS-09 catalogues. These epistemic uncertainties were discussed in detail by the SP1 teams, and were appropriately propagated through the analysis of SP1 parameters, such as recurrence parameters (a- and b-values) and Mmax. The approach taken to propagate the epistemic uncertainties in each magnitude estimate for each earthquake in the catalogue into the recurrence calculations is conceptually the same as that taken in the CEUS-SSC project (NUREG-2115 [5], Chp. 3.3.1). This issue of properly capturing epistemic uncertainties is also discussed in item #6 below.

4. SP1 elicitation of activity rates

The principal criticism of the manner in which activity rates (recurrence rates) were assessed during the PRP is the assertion that feedback was not provided to the expert teams early enough in the project for the experts to understand the importance of their recurrence assessments to the hazard at each NPP site. It is stated that the cumulative recurrence plots that show the summed recurrence rates within 50 km of each NPP site were shown to the expert teams only at the PRP Sumamary Meeting. It is implied that because these plots were not shown earlier, the experts were not aware of what their assessments of recurrence might have been or of their importance to hazard. The RT notes that the earthquake recurrence rates derived from paleoseismic evidence are not consistent with the recurrence rates developed by the SP1 teams. The RT also compares the recurrence assessments between the PEGASOS results and the PRP and notes that in some cases there is a large increase in the range of recurrence estimates. There is an implication that such an increase reflects that a proper procedure was not followed or that of sufficient feedback was not provided to the teams.

Primary inputs to the PSHA are the characteristics of seismic sources defined by each SP1 team, including source geometries, recurrence rates, and Mmax. The considerations by the teams for the PRP began with the sources defined in PEGASOS and moved into a full consideration of the impacts of new data, models, and methods on each team's SSC model. As discussed in the PRP position on Issue #1 of this document, once the importance of the M_L - M_w conversion was identified in April 2009, the implications to each team's assessments was thoroughly explored in the subsequent years of the project. All of these explorations are summarized in the PRP Report Section 1.2 *Supporting Computations* of PRP Vol.3 and in each Team's respective sections in Chapters II, Ill, IV, and V *Supporting Calculations by R. Youngs.* For example, R. Youngs provided to the RT a *Backup b-value Assessment in PRP* [8] that summarizes the various approaches taken by each team to address the narrow, but important, issue of assessing b-values for their seismic source zones in light of the non-linearity of the magnitude conversion. Similar summaries could be extracted from PRP Vol. 3 to show the manner in which other aspects of recurrence were evaluated by each SP1 team (e.g., catalogue completeness as a function of magnitude, location, and time; spatial smoothing; recurrence for different magnitude intervals; comparison of historical and instrumental periods; etc.).

The document PMT-TN-1294 [3] and its *Addendum* [4] summarize the assessments made by the SP1 Teams for the Basel earthquake region. Like all seismic sources in the PRP model, the Basel earthquake source region is characterized by a recurrence distribution that spans a range from small magnitudes up to maximum magnitudes equal to or larger than the estimated magnitude of the 1356 Basel earthquake [~Mw 6.6]. Each team evaluated available seismicity, tectonic, and paleoseismic data and developed seismic sources that included the Basel earthquake source as an explicit Basel source zone (with alternative configurations) or as source zones that included the Basel earthquake region within zones having preferred and alternative boundary locations. Historically, only one moderate-to-large earthquake—the 1356 earthquake—has occurred in the Basel area. As a result, assessments of future earthquake recurrence rates needed for purposes of PSHA require expert judgment regarding the extent to which the rate of small-to-moderate magnitude earthquakes derived from the historical and instrumental earthquake catalog can be extrapolated up to large-magnitude earthquakes, and the degree of belief that paleoseismic data developed for the Reinach fault provides a defensible recurrence rate for the Basel earthquake source. The Basel earthquake source, as defined by the ECOS-09 earthquake catalogue, is marked by a persistent zone of elevated seismicity relative to adjacent regions and the seismicity from this zone was used in combination with other seismotectonic evidence in the Upper Rhine Graben region to define source zone boundaries and/or spatial smoothing that incorporates this zone of seismicity. In the end, most teams judged that the Reinach fault interpretations did not provide a fundamental and reliable constraint on Basel recurrence rate, but developed models that included the central estimates of the paleoseismic interpretations, and also included significant weight to the lower recurrence rates derived from analysis of the historical seismicity.

The primary purpose for developing the virtual 50 km circle representation shown by R. Youngs at the PRP Summary Meeting was to allow post-facto comparisons of the integrated recurrence rates among the SP1 teams over the same area (rather than for seismic source zones, which would not have the same geometry) and in a region proximal to the sites of interest for hazard calculations. However, the 50 km circles were not considered or characterized directly by the expert teams and, because they are part of a post-facto analysis, they have no particular relevance to the experts' seismic source characterization models, per se, and they do not provide much insight into the experts' models other than the integrated rates. For example, the circles cut through seismic source zone boundaries defined by each expert team and include irregular parts of multiple seismic sources (see PMT-TN-1294 [3]). With respect to the large ranges of recurrence seen in the team-to-team comparisons for the 50 km regions, this is not surprising given the large uncertainties in the assessments of recurrence made by each team. Similar differences were seen in the comparisons made for the PEGASOS assessments (e.g., TP1-RF-0388 [9], TP1-TN-0334 to 0337 [10]) and, taken across all Teams, merely represent the epistemic uncertainties in assessing earthquake recurrence within non-plate boundary regions lacking high levels of observed seismicity.

Throughout the project, the SP1 teams were provided with recurrence curves and hazard sensitivity analyses that allowed them to understand fully the implications of their assessments for their source zones. The recurrence rates in the 50 km circles represent an aggregated intermediate feedback product. The full feedback is the hazard sensitivity which was provided to the SP1 teams early in the project. Further, at Workshop #3 and other meetings, the various teams were able to examine the assessments made by the other teams to gain an understanding of the implications of alternative methods and models being considered by each team.

5. SP1 derivation and use of hypocentral depths

The ENSI-RT offer their criticism that the SP1 experts used the same approach to assessing the depths of rupture as used previously in the PEGASOS and did not consider the restriction on rupture to the surface in their elicitations. The RT notes that the PRP followed the same convention adopted by PEGASOS to derive the depth distributions of hypocenters for different magnitudes and styles of faulting. It is stated that the determination of the minimum depth of rupture is not satisfactorily addressed because the depth distribution model approved by the EG1 teams does not allow significant seismic rupture to occur in the first 2 to 3 km below the surface and, as a result, near-fault hazard has not been assessed.

As part of the PRP, the magnitude-dependent hypocentral depth distribution model was reviewed and affirmed by all of the teams. The model accounts for the seismogenic thickness assessed by the teams and provides the nucleation depth of ruptures as a function of magnitude. The same model has been adopted in other PSHAs, such as the CEUS-SSC project (NUREG-2115 [5]). The relationship of nucleation depth, magnitude, and rupture were all reviewed by experts as part of their assessments and the technical basis for the experts’ assessments are given in their Elicitation Summaries in the PRP report (Vol. 3). There is no restriction on the minimum depth to the top of rupture and larger earthquakes would be expected to rupture to the surface. This is accounted for as well in the ground motion models of SP2. Hazard sensitivity analyses confirm that this depth distribution model is important only for the smaller magnitudes and that it has very minor hazard significance.

6. Assessment of epistemic uncertainty

This criticism by the ENSI-RT states that epistemic uncertainties among various earthquake catalogues was not considered, including uncertainty in ML-Mw conversion, and other features of ongoing SSC studies were also not considered in the assessment of epistemic uncertainties. It is claimed by the RT that epistemic uncertainty in the earthquake catalog and the magnitude conversions applied was not taken into account because both the ECOS-02 and ECOS-09 catalogues were not included as weighted epistemic alternatives. Other catalogs like SHARE and ISC-GEM also weren't included as alternative branches of a logic tree. The RT claims that epistemic uncertainty in the functional form of the M_L - M_w conversion was not included or even considered. Finally, the RT claims that zoneless approaches and non-Poissonian approaches were not considered or included, although they are being considered in the technical community.

The PRP response to all of the RT's criticisms related to epistemic uncertainty have been addressed previously in this document in the context of discussions of the scope of the assessments, earthquake catalogue, and magnitude conversions (see Issues #1 through 4 above). Specific responses to the criticisms made are summarized here.

A new project earthquake catalog developed specifically for a PSHA project is an update that supersedes previous project catalogues, and this is the case with the ECOS-02 and the ECOS-09 catalogues. The new catalogue includes the latest earthquakes and updated information regarding the size of each event. The differences between the latest catalogue and the previous catalogue are not epistemic uncertainties and are never treated as such in PSHA. Other catalogs were not developed specifically for the PRP project and are therefore not applicable, although all of the SP1 experts were aware of the SHARE and GEM catalogs (many are participants in developing those catalogues) and they were free to use any data, models, or methods deemed applicable to PRP. For example, any special studies of the size of individual earthquakes could be considered by the experts as they evaluated the uncertainties in the magnitude estimates given in the ECOS-09 catalogue. As discussed above in Issue #3, the approach taken by the SP1 expert teams to address epistemic uncertainties was to consider the uncertainties in the magnitude estimates in individual earthquakes due to the conversion process to arrive at moment magnitudes for each earthquake. Developing models that represent the current estimates of the uncertainty in the underlying data is preferred over applying weights to previous interpretations of out-of-date data sets that may be incomplete and contain errors. This is a much more defensible approach than weighting alternative catalogues.

As discussed extensively in Issues #1 and 3 above, the documentation of workshops and working meetings confirms that careful consideration was given by the SP1 teams to the importance, functional forms, and approaches to the M_L-M_w conversion issue. Indeed, the broad uncertainties in recurrence parameters derived for the sources in the SP1 models reflects the broad range of epistemic uncertainties included in the teams' assessments. The expert teams were keenly aware of the significance of the magnitude conversion issue early in the project and devoted a major effort to ensuring that the aleatory and epistemic uncertainties associated with the issue and its manifestation in earthquake recurrence rates was carefully done and fully documented in the PRP report.

Zoneless approaches to source zones were considered and the smoothing approaches and consideration of zone boundaries by the SP1 teams confirms this. As documented in the SP1 Elicitation Summaries (Vol. 3), non-Poissonian temporal models were considered and not adopted for the PRP seismic sources due to the fact that such models have been principally advocated for use with fault sources and are not part of the state-of-practice for characterizing the earthquake rates for areal source zones.

Hazard Implications

The robustness of the new PRP results compared to the old PEGASOS results can best be assessed when comparing the median and range of variability of the results. As can be seen from the illustrative example in Figure 1 the median hazard results are very consistent (also concluded by the ENSI-RT, see 5.1.3, page 40 in ENSI-AN-9060) and the range given by the fractiles demonstrate the achieved reduction of uncertainties.

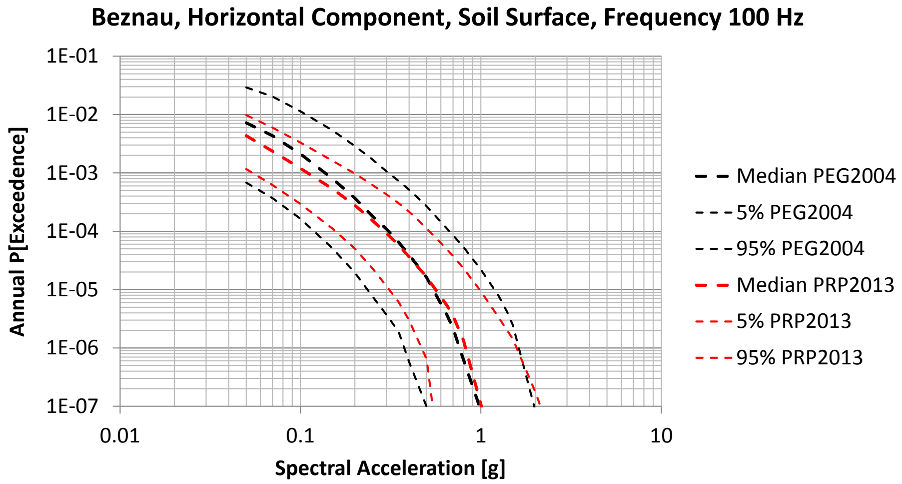

Figure 1 Comparison of PEGASOS and PRP median hazard and fractiles.

Another support of the robustness of the PRP is the consistency between the PRP hazard results and the latest Swiss hazard model 2015 developed by the Swiss Seismological Service (SED), which were evaluated at all four sites in term of mean, median and fractiles (see Appendix 3). As can be seen in the comparisons, the mean hazard values and fractile hazard curves are quite similar. In this context, the PRP hazard results are robust and suitable for use in probabilistic and deterministic assessments for nuclear power plants in Switzerland.

Conclusions

After detailed review of the ENSI-RT final report, discussion with the RT at the meeting in September 2014, consideration of all relevant information, the technical leadership of the PRP offers the following conclusions regarding the Late Stage Review Comments of the ENSI-RT:

- Relevant criticism and significant concerns were expressed by the ENSI-RT in six SP1 items: 1) Overall scope of SP1 elicitation, 2) SP1 elicitation of Mmax ; 3) Issues related to the application of the ECOS-09 seismic catalog; 4) SP1 elicitation of activity rates; 5) SP1 derivation and use of hypocentral depths; and 6) Assessment of epistemic uncertainty. These six aspects all relate to the development and use of using an improved catalog EOCS-09 (as recognized by ENSI, see Page 21 in review report) that by design replaced the old EOCS-02 catalog. Rather than considering SP1 as weak (as defined by ENSI-RT) it should be considered as an improvement with respect to PEGASOS.

- Systematic consideration of the criticisms offered by the ENSI-RT with respect to the six areas of concern indicate that the criticisms posed are incorrect and are not based on the documented record of the PRP as evidenced by the PRP final report and associated documentation. The criticisms given in the ENSI-RT draft report were each systematically and completely addressed and refuted in written materials and presentations to ENSI during the late-stage review. However, the ENSI-RT final report is essentially unchanged from the draft report, reflecting a disregard for the factual evidence and documentation brought to bear by the PRP in 2014-2015. It can only be concluded that that ENSI-RT has developed its position with regard to the PRP without resorting to the written project record or to subsequent documentation of the technical bases for the assessments made on the project or the procedure followed.

- As was the PEGASOS project, the PRP was conducted to be consistent with a SSHAC Level 4 process, as defined in the original SSHAC guidance (NUREG/CR-6372) and the practical implementation guidelines (NUREG-2117, Rev.1). This has also been recognized by ENSI-RT in the review report (see 5.2.1, page 42 in ENSI-AN-9060). As such, the roles and responsibilities of all project participants were consistent with that guidance, including the Expert Teams, TFI, Proponent Experts and Resource Experts. One exception is the Participatory Peer Review Panel (PPRP), which is the role to be assumed by the ENSI-RT for the PRP just as it was for the PEGASOS project. As discussed in existing regulatory guidance for SSHAC Level 3 and 4 projects, the PPRP is responsible for reviewing both *process* and *technical* aspects of the project. To do so, it is required that members of the PPRP be thoroughly familiar with all SSHAC guidance and that the Panel includes members with SSHAC experience.

  The written criticisms offered by the ENSI-RT in its review report related to *process* issues do not reflect a familiarity or working knowledge of SSHAC concepts or implementation practice. For example, SSHAC regulatory guidance prohibits the PPRP from offering its own technical interpretations or viewpoints; rather, the Panel is responsible for ensuring that the technical assessments made by the expert teams are technically defensible with adequate justification provided. From the project side, it was expected that the review report on the PRP would be consistent with this SSHAC concept and not include expert judgments or recommendations beyond the SSHAC process. Comments made by the ENSI-RT do not honor the boundaries set for a PPRP and *technical* assessments are offered that differ from those assessed by the expert teams. Examples include technical directions by the RT related to a preferred approach to obtaining a regression for the M_L – M_w relationship, or insistence by the RT that expressions of epistemic uncertainty in the expert models include alternative earthquake catalogues as logic tree branches. In addition, references to SSHAC process issues made by the ENSI-RT do not show evidence that the Panel is familiar with current SSHAC guidance. Examples include insistence by the RT that non-overlapping Mmax distributions is a sign that the expert teams did not capture the view of the informed technical community (a concept that was abandoned in NUREG-2117 in favor of the CBR of the TDI), and the RT calling for a third SP1 workshop (ENSI-RT report, p. 24) when, in fact, a third workshop was actually held more than two years before the PRP Summary Meeting and is documented in the PRP report and associated documentation (see summary in Appendix 1 to this document). The lack of experience and familiarity of the RT with SSHAC concepts, regulatory guidance, and the PRP documentation itself questions if the RT is in the position to provide a meaningful peer review of the PRP as a SSHAC Level 4 study.

- Despite the criticisms leveled by the ENSI-RT regarding SP1, the seismic hazard calculations show a remarkable agreement in median hazard between the PRP and PEGASOS. As expected, reduction of uncertainties primarily in the SP2 and SP3 parts of the model have led to reductions of uncertainty in the hazard results, as reflected by smaller range in the fractiles of the hazard distribution for PRP. Remarkably, the hazard results from the new Swiss hazard model 2015 developed independently from the PRP by the SED in light of all SP1 related criticisms by ENSI-RT show a remarkable consistency with the PRP 2013 hazard results at the four NPP sites. This conclusion supports the project position that the impact of the stated criticisms in SP1 on the overall hazard results is minor.

- Rejecting PRP would mean rejecting numerous (55) peer reviewed journal articles published by the participating experts, based on their work within PRP (incl. specifically 4 on the M_L-M_W relationship and the ECOS-09 itself). This would be against the intent and spirit of the study to consider all available state-of-the-art information and data.

In summary, the PRP project leaders have considerable experience in the conduct of SSHAC Level 3 and 4 projects worldwide and do not share the conclusions of the ENSI-RT regarding deficiencies in the technical assessments made by the expert teams, nor the claims that a proper SSHAC process was not followed. The response to those criticisms is provided in summary form in this document and is backed by documented evidence in the PRP project documentation. It is concluded that the technical assessments made by the SP1 expert teams capture the center, body, and range of technically defensible interpretations. Likewise, the PRP hazard results are robust and provide a defensible basis for use in safety-relevant applications for nuclear power plants in Switzerland.

References

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[2] US NRC, Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies", Report NUREG 2117 Rev.1, 2012.

[3] swissnuclear, "PEGASOS Refinement Project: Additional Comparisons of Recurrence for the Basel Earthquake Region", Technical Note PMT-TN-1294, 25 November 2014.

[4] swissnuclear, "PEGASOS Refinement Project: Addendum to: Additional Comparisons of Recurrence for the Basel Earthquake Region", Technical Note PMT-TN-1294 Addendum, 30 November 2014.

[5] US NRC, NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities", 2012.

[6] swissnuclear, "PEGASOS Refinement Project: Evaluation of key concerns of ENSI-RT in the late stage review, based on the RAIs", Technical Note TFI-TN-1292, 08 May 2014.

[7] swissnuclear, "PEGASOS Refinement Project: Reply on 'ENSI PRP Late-Stage Review - Initial List of Request for Additional information'", Administrative Note PMT-AN-1145, 4. April 2014.

[8] Youngs, R.R., "Backup b-value Assessment in PRP," TFI Team Consultant, 15 September 2014.

[9] Youngs, R.R., "Parameter Sensitivity for Seismic Source Characterization", TP1-RF-0388 presented during SP1 Workshop #4, 27.Feb. 2003.

[10] Youngs, R.R., "SP1 Seismic Source Characterization Earthquake Recurrence Relationships Computed From Seismic Source Parameters Developed in Hazard Sensitivity Model of EG1a to EG1d, TP1-TN-0334 to 0337, March 2003

Appendix 1: Overview of SP1 interactions related to ECOS02 and ECOS09 differences

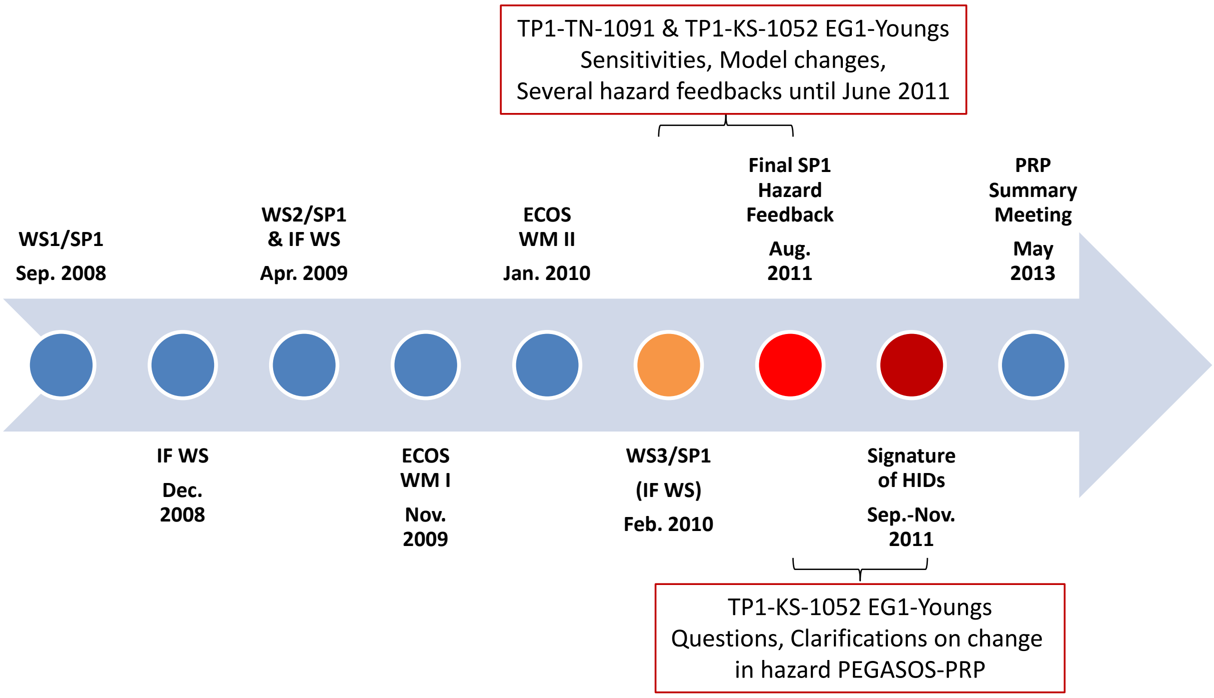

Figure 2 SP1 timeline.

Interaction	Date	Information Provided/Discussed	Implication
Workshop #1	2 Sept 2008	Possible differences in magnitudes for intensity-based magnitudes	Identified potential importance of catalog
Interface Workshop SP1/SP3	8 Dec 2008	Need for moment magnitude conversions for all events	Set importance in magnitude conversion issue
Workshop #2	28 Apr 2009	$M_L – M_W$ relationship is not linear for all magnitudes	Teams will need to address the impact of this issue for their use in recurrence calculations
		Bayesian and Kijko approaches incorporate recurrence in Mmax methodologies; Mmax has hazard significance	Mmax for sources will need to be reevaluated
		Depth distribution; Smoothing approaches; paleoseismic information	Teams conclude no need to modify their approaches
Working Meeting	1-2 Nov 2009	Non-linearity in M_L-M_W for magnitudes smaller than about 3 and influence on b-value in recurrence	Sensitivity analyses identified by each team to allow them to evaluate the importance of the issue and an approach to addressing it

ECOS/SP1 Working Meeting	26 Jan 2010	Comparison of the magnitudes, locations, and depths in ECOS02 and ECOS09	Identify possible shifts in location or magnitude that would need to be addressed in source boundaries or recurrence
		Summary of the five largest earthquakes within each for ECOS02 and ECOS09	Systematic changes in location or magnitude; or need to modify likelihood functions for Mmax assessments
		Updated earthquake focal depth distributions in Switzerland	Evaluation of need to modify assessed depth distributions for future earthquakes
		Impacts of new catalogue on estimates of catalogue completeness, as function of time and space; including M_L - M_w conversion, new intensity conversions, and adjacent countries	Completeness has impact on recurrence estimates for particular source zones
		Calculations of catalogue completeness ("Stepp plots"), recurrence rates, and Mmax for all SP1 seismic sources using ECOS02 and ECOS09	Evaluation of impact of new catalog on all recurrence parameters (a-, b-values, Mmax, exponentiality) for all seismic sources; identification of additional sensitivity analyses to see at next Working Meeting
ECOS/SP1 Working Meeting	22 Feb 2010	Comparative catalog completeness ("Stepp") plots for all teams using (1) their PEGAOS magnitude intervals for both catalogs and (2) adjusted magnitude intervals for the ECOS09 catalog based on the difference in the ECOS02 and ECOS09 ML-MW conversions.	Assessment of the effect of the updated catalog on regional recurrence rates
		Comparative recurrence calculations for large or regional source zones for each team based on ECOS02 and ECOS09 catalogs, using teams initial assessments for: • Adjustment to catalog completeness (time periods and magnitude intervals) • Truncated exponential and a modified truncated exponential model incorporating the curvature in the ECOS09 ML-MW conversion	Evaluation of the effect of various approaches to utilizing the updated ECOS09 catalog on regional earthquake recurrence rates, including b-values

		relationship	
		Comparative Mmax calculations for the Bayesian approach showing the effect of alternative approaches to using the updated ECOS09 catalog on the assessment of Mmax.	Evaluation of the effects on Mmax from the new catalog, including revised magnitudes from the larger observed earthquakes
Workshop #3	23 Feb 2010	Presentation of various assessments conducted for teams: completeness assessments that take into account the new non-linear relationship between ML and Mw, recurrence relationships using alternative magnitude distributions and minimum magnitudes, and recalculations of Mmax using the approaches specified by the experts.	Discussion across all teams of the impacts of changes to the catalog, approaches being taken to address uncertainties in all recurrence parameters including a-, b-values, Mmax, magnitude frequency distributions
		Team-by-team summary of assessments of key SP1 issues in light of new catalog, including source boundaries, depth distribution, smoothing, Mmax, and recurrence	Discussion across all teams of their assessments, uncertainties, and logic tree approaches for key SP1 issues; additional sensitivity analyses and calculations were identified that would be used to assist each team in the finalization of their models
EG1 - TFI Team interactions	24 Feb 2010 to Aug 2011 (Nov. 2011)	Numerous calculations and exploratory analyses conducted at requests of each team: comparisons of catalogs in historical vs. instrumental periods; b-values for various regions and time periods for use as prior distribution; recurrence calculations for various magnitude intervals, time periods, completeness regions; Mmax distributions for Bayesian and Kijko approaches for range of recurrence parameters	Provided insights needed by each team to finalize their SP1 assessments, uncertainties, and logic trees.

Appendix 2: Key parts of refinement compared to PEGASOS

Change (in SP1)	Improvements
Replacement of the ECOS02 by ECOS09	**Resolution of deficiencies in ECOS02**
New a- and b-values based on ECOS09	Based in more available data
Change (in SP2)	**Improvements**
New world-wide GMPEs	**Much better constrained** **>8 time increase in near-fault data** **Avoided need for Mag or Dist conversions**
New Swiss stochastic models	Generated a suite of alternative models consistent with the Swiss ground motion
GMPEs adjusted to be applicable at small magnitudes	Removed factor of 3 over-prediction of Swiss M3 ground motion data
New state-of-the-art kappa correction method developed and applied	**Makes the GMPEs applicable to the Swiss hard-rock**
New V/H models developed for hard rock sites	**Makes V/H models applicable to Swiss hard-rock**
Testing of GMPEs with intensity data	Provides a check that the global GMPEs are consistent with historical intensity data from Switzerland
Change (in SP3)	**Improvements**
New Site Amplification Factors Computed	**Collected New Site profile information, replacing the limited data from 1970s**
Updated Maximum Soil Ground Motion	Uses updated world-wide data on maximum ground motions on soil
Change (in SP2-SP3)	**Improvements**
Use single-station sigma for SP2 - Remove aleatory variability of site amplification from SP3	**Avoids double counting of the site response uncertainty and variability (SP2 and SP3)**
Use SP3 rock input motion spectra and shape consistent with the final SP2 models	Avoids inconsistencies in the spectral shapes, reducing uncertainty in the high frequency site amplification

Appendix 3: Post-PRP Comparison of SED Hazard 2015 with PRP 2013 results

The Post-PRP comparison of the SED hazard 2015 with the PRP 2013 results were performed by the PMT and are documented in PMT-TN-1295, submitted to Prof. S. Wiemer and ENSI on 18.8.2015.

The four figures below show exemplarily the comparison at all the NPP sites of the rock hazard UHS for PRP 2013 and SED 2015 in terms of mean, median, 5% and 95% fractiles. The SED rock UHS consists of 11 spectral acceleration amplitudes for 11 frequencies. The comparison at rock (when converted to the same rock reference) provides remarkable consistency between SED and PRP results at all sites in terms of mean, median and fractiles. It is worthy to mention that there are fundamental differences when developing site specific hazard (PRP model) and regional hazard results at the scale of country (SED model). Nevertheless, what can be seen in this specific comparison is that despite the different model assumptions used to compute the hazard the resulting hazard (here shown in terms of UHS at 1E-4) is consistent and comparable.

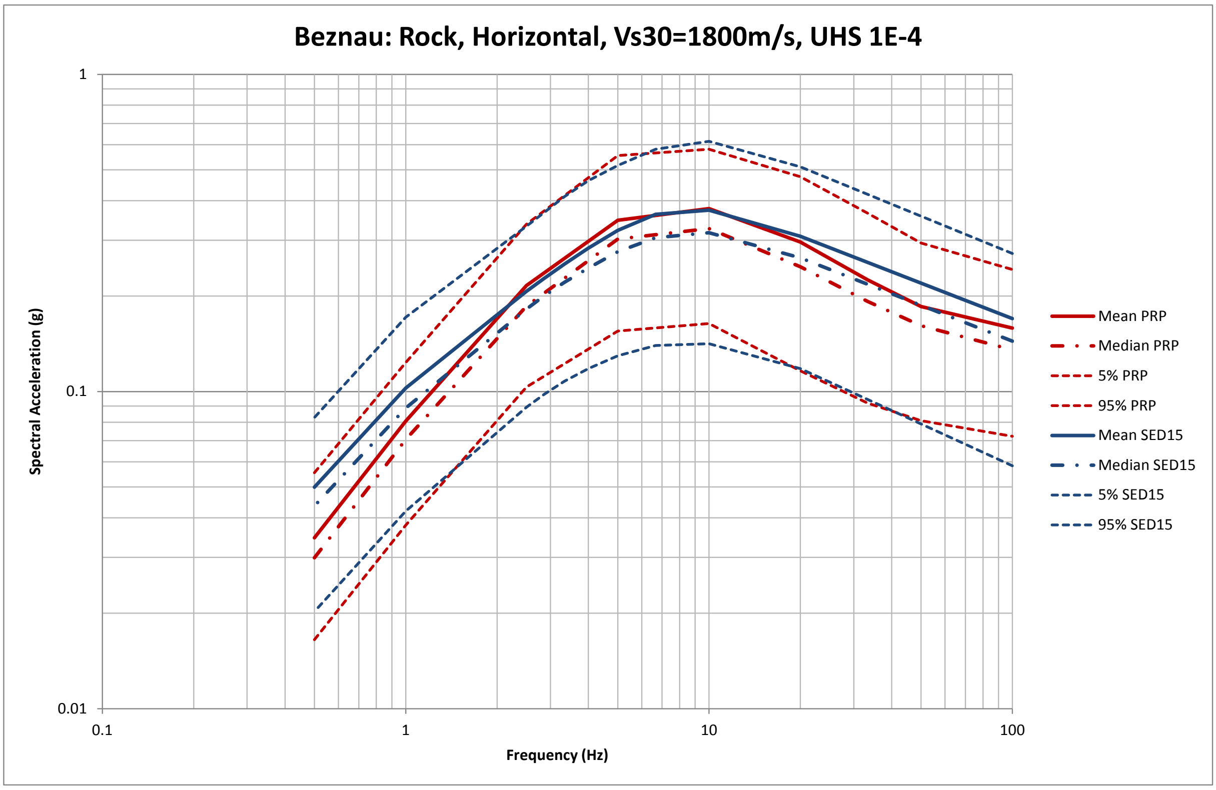

Figure 3 Rock hazard comparison for the site Beznau at an annual probability of exceedance of 1E-4 for PRP and SED 2015.

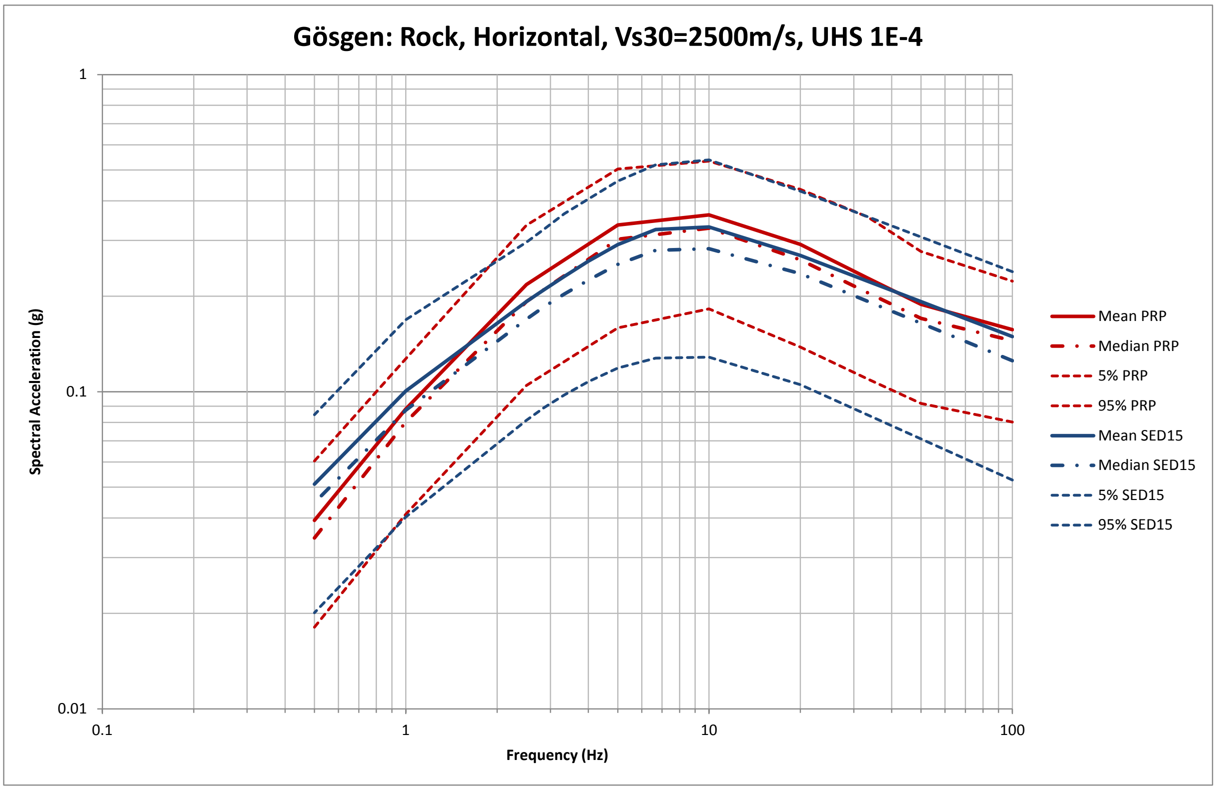

Figure 4 Rock hazard comparison for the site Gösgen at an annual probability of exceedance of 1E-4 for PRP and SED 2015.

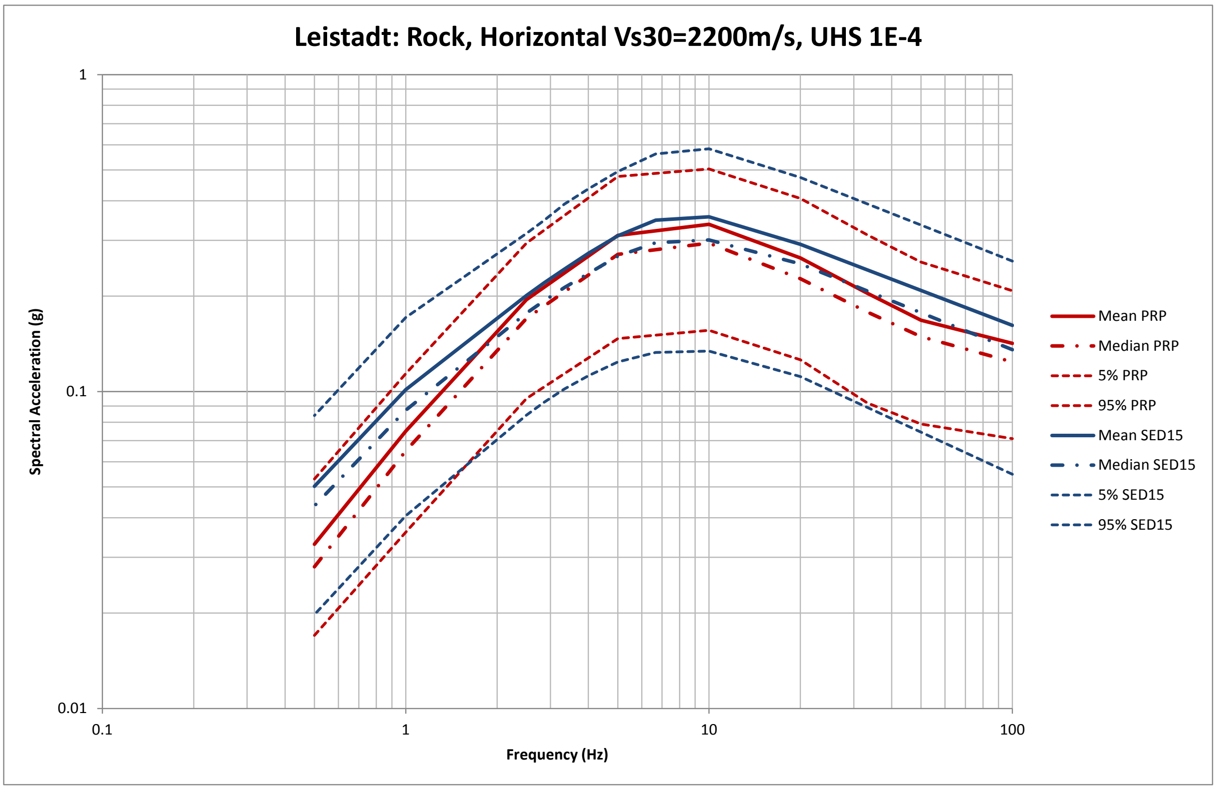

Figure 5 Rock hazard comparison for the site Leibstadt at an annual probability of exceedance of 1E-4 for PRP and SED 2015.

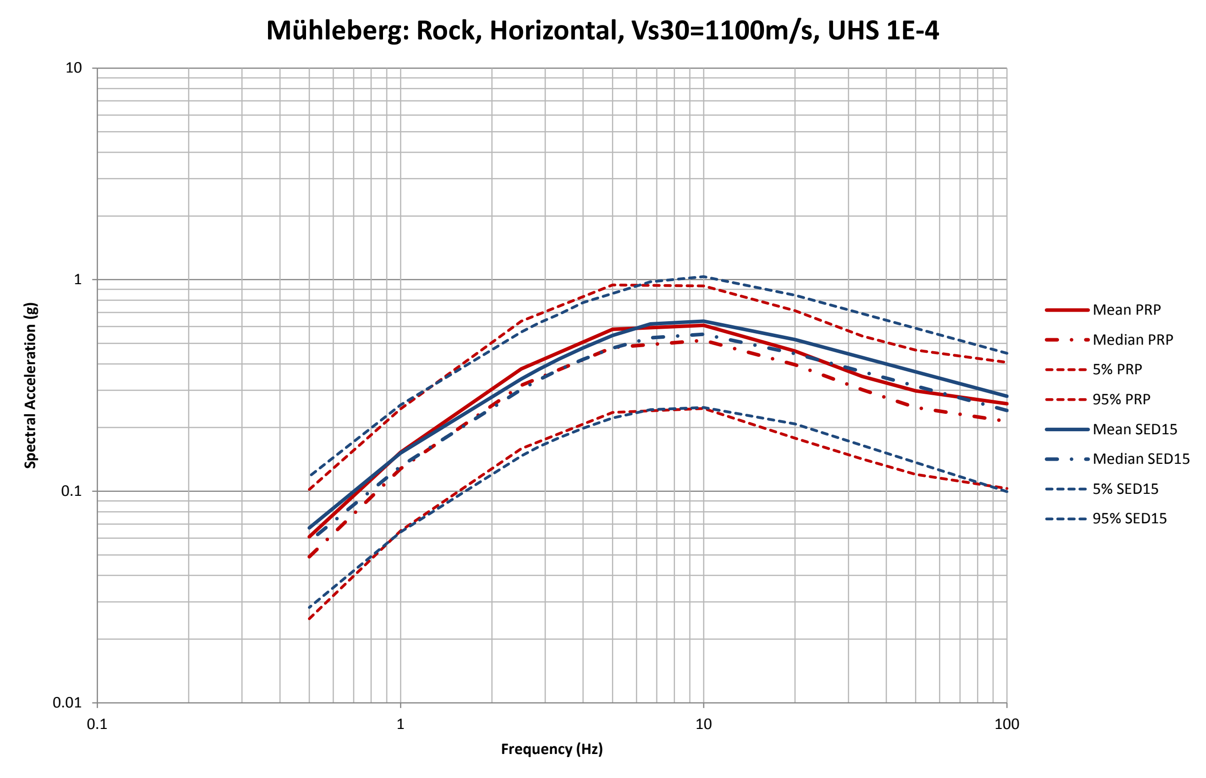

Figure 6 Rock hazard comparison for the site Mühleberg at an annual probability of exceedance of 1E-4 for PRP and SED 2015.

Appendix 4: Main criticism from the ENSI-RT and summary project position

Item/Page (ENSI review report)	**Title**	**Position ENSI**	**Position PRP**
4.1.1/21	Occurrence of SP1 workshops	2 WS and 1 IF	The Project Plan has 3 WS and 2 IF which were held. This wrong representation of facts should be corrected in review report.
4.1.2(a)/21,23 5.2.1/41 5.2.1/42	Scope of SP1 elicitation - SP1 process - SP1 models community view - Feedback on cumulative activity rate	Not appropriate - No significant change in hazard assumed - Interpretations date back 12-20 years - No opportunity for SP1 experts to make model changes	- SP1 elicitation was SSHAC L4 consistent. - Models are up-to date and reflect the experts' views. - Opportunity for changes was given; experts took 1 year before signing HID. Experts should not be result driven.
4.1.2(b)/23,24	SP1 elicitation of Mmax - Lower Mmax - Largest Mmax	Reflection of community view, significant inconsistencies among the teams - Mmax distribution covers different ranges - Insufficient feedback and interactions - Extreme limit parameters is special case - Proponents rather evaluators	- SP1 experts were not proponents. No consensus between the teams required in SSHAC L4. - Hazard results are similar between the 4 teams; range of uncertainty within the whole project is much larger. - PEGASOS had the same issue; thus, going back to PEGASOS wouldn't resolve ENSI's concerns.
4.1.2(c)/24,25 4.1.2(d)/26	SP1 elicitation of activity rates - Range of estimates - Ml-Mw relationship - Constant shift of 0.1	- Too late feedback for comparison of team results (across team differences) - Teams expressed difficulties with Ml-Mw	- No consensus between the teams required in SSHAC L4. - No "difficulties" were expressed by SP1; all teams dealt with the new form in one way or another. Positive acknowledgement of EG1b team is not valued. - Ml-Mw relationship is a built-in part of the new catalog and not a separate model of the SP1 experts (which cannot be changed without leading to implicit changes in the ECOS09) - Nonlinear Ml-Mw relationship is not unusual and has also been used e.g. for the CENEC catalog. Nonlinear form is also supported by the data.

			- Even the 0.1 shift still overestimates the data at larger M.
4.1.2(e)/27	SP1 derivation and use of hypocentral depths	- Minimum depth of rupture is not addressed. In contrast to geological and historical evidence of surface rupturing.	- Depth distribution has a negligible effect on the hazard. - No evidence in Switzerland for surface rupture. - Same model as in PEGASOS.
4.1.2(f)/27,28	SP1: Assessment of epistemic uncertainty	- ECOS02, ECOS11, SHARE and GEM catalog to be used as alternative models. - Lack of explicit epistemic uncertainty in Ml-Mw.	- Not state of current practice to use multiple catalogs. - Using multiple catalogs is beyond accepted project plan. - Epistemic uncertainty was indirectly translated in alternative b-values used by the teams in their logic tree.
4.1.2(g)/28	SP1: Impacts on final hazard results	- High variability in EG1 teams. - Reduction in hazard based on non-robust or insufficient elicitation.	- PEGASOS had the same issue of variability among teams and thus, going back to PEGASOS wouldn't resolve ENSI's concerns.
4.2.2/32	Presentation of epistemic variation in deaggregation results from SP2	Differences in deaggregation between PEGASOS and PRP are due to the changes in used GMPEs: - PRP report should discuss the variations. - SP2 experts not aware of magnitude sensitivity. - PRP results cannot be retained as stable for the future (due to use of new models) and revision of PS2 is required as more stable GMPEs become available	- Revised PRP report will include discussion of TFI-TN1287. - SP2 experts were well aware of behaviour of new models (low-magnitude cut, was included as adjustment for the 2008 GMPEs), but not necessarily of the resulting hazard deaggregation, as the experts shouldn't be result driven - The applied new GMPEs are based on a much larger dataset than in PRP and thus, by definition more stable. Swissnuclear strongly objects to the conclusion of ENSI-RT on this item that the overall PRP model cannot be retained as stable as the justification for this is not acceptable for a SL4 study (and the technical community)!

Appendix 5: Review items from the ENSI-RT not considered to be an issue by the project

Item/Page (ENSI review document	Title	Position ENSI	Position PRP
4.1.1/21; 4.1.2 (a)/21	Catalog update, ECOS'11	Replacement of catalog	No comment, as only generic observation of catalog exchange
4.2.1/28	SP2: New data and methods through research and development	Value of R&D effort: - Approach for selection of GMPEs - Inclusion of PSSM - Vs-Kappa correction - Harmonization of PSSM and GMPEs - Avoid double counting between SP2-SP3 through single-station sigma - V/H, Sigma_Vadd, Max GM - Expert centring, consideration of FFS	No comment, as everything positive for the PRP.
4.2.2/30	SP2 evaluation and integration phases	Compromise evaluation and integration phase due to R&D. Concerns: - Loss of 2 SP2 experts - Replacement by only 1 new expert, project fortunate to have found one - First 12-16 month appeared to not fulfil SSHAC L4 - Satisfactory evaluation phase realized, but considered as weak (compared to PEGASOS)	- Replacement was done in agreement with ENSI-RT. - At the beginning of the PRP the project was run according to the first approved project plan which didn't mention a SSHAC level for PRP. After feedback from ENSI-RT the PRP plan was updated and the project operated according to SL4. - After the new SP2 expert joined the team the evaluation and integration phase was explicitly implemented; this was fully SL4 consistent!
4.2.2/30	SP2: Scope in representing a community view	ENSI-RT concerns that approaches of SP2 not broad enough to capture the view of the "relevant" informed community. - Vs-Kappa correction acceptable for ENSI-RT - Q and stress drop not addressed	- Vs-Kappa correction was not properly addressed in PEGASOS. Q and stress drop were not explicitly addressed as GMPE correction parameters in PEGASOS. Thus, going back to PEGASOS wouldn't improve anything. - Stress drop variations are explicitly considered as part of the PRP model space of the PSSM.
4.3.1/32	PRP planning of a dedicated subproject	- Systematic evaluation of site response strength of PRP	No comments, as everything

	SP3 for addressing site response	- Elicitation according to SL4 - PRP site response at a level not yet reached by any other seismic hazard study	positive for the PRP.
4.3.1/32	SP3 PRP planning of site investigation and response analyses	Appendices on site investigations and site response calculations reviewed and approved by the SP3 experts and implemented according the project plan.	No comments, as everything positive for the PRP.
4.3.1/32	SP3: Expanded site-specific soils database	- New collected data represents significant improvement over PEGASOS. - Helped to reduce epistemic uncertainty.	No comments, as everything positive for the PRP. Going back to PEGASOS would mean ignoring all new site data and updated models.
4.3.1/33	SP3: Multiple approaches to site-response analysis	- Use of diverse appropriated methods and software - Input motions at rock interface coordinated between SP2 and SP3.	No comments, as positive for the PRP. Going back to PEGASOS would mean inclusion of the known double counting of uncertainties.
4.3.1/33	SP3: Plausibility of probabilistic site-amplification functions	Site amplification leads to consistent rock and soil hazard results.	No comments, as positive for the PRP.
4.3.1/33	SP3 workshops	6 WS, IF WS and WM	No comments, as statement of facts.
4.3.2/33	SP3: Reliance on 1D analyses	2D and 3D modelling of site response is considered an area of useful future refinement.	No comment, as no criticism on PRP SP3.
4.3.2/33	Open (partial) elicitation of one SP3 expert	Elicitation of J. Studer could not be concluded. Recommendation to eliminate Studer's model. Truncation model has only negligible impact on hazard. This aspect of Studer's model does not represent the community view on max GM.	Has a negligible effect on the hazard. Truncation model is only one piece of the full SP3 model of J. Studer. The model is questionable only for the site of Mühleberg at the soil surface. It is valid and reasonable for all other cases.
4.3.2/34	SP3: Reporting of rock motions	Missing information of the rock input motions in the PRP report for the site response analyses.	Revised PRP report will include discussion of input motions for SP3.

4.3.2/34	SP3: Strain-dependent model curves for KKG	Inconsistency of strain-dependent material properties with data.	Has a negligible effect on the hazard; range of uncertainty within the whole project is much larger. Item already resolved in the RAI-40.
4.3.2/34	SP3: Interpretations and reporting regarding liquefaction for KKM	Interpretation of liquefaction potential for KKM is misleading	Revised PRP report will include adequate representation of liquefaction potential for KKM, as already proposed in the response to RAI-39.
4.3.2/35	SP3: Sampling of gravel layers at KKM	No possibility to obtain soil samples for gravel layers.	The additional epistemic uncertainty allocated by SP3 for this lack of data has been presented as part of the answer to the RAIs. Revised PRP report will include a comparative figure as part of Volume 5.
4.3.2/35	SP3: Differences in site-investigations procedures for existing and planned plants at the locations of KKM and KKG	Treatment of site investigation results for the new NPP sites at KKM and KKG could have led to a lager variation of soil properties at KKM and KKG.	No comment. This means that site response at KKM and KKG could treated be "conservative".
4.4.1/35	SP4 presence at workshops	SP4 representative present at all relevant PRP workshops.	No comment, as generic observation.
4.4.1/35	Alertness to problems	PRP detected a problem in the computations before the PRP summary meeting and corrected it. QA worked.	No comment, as no criticism on PRP.
4.4.2/35	Formal procedures of software QA and maintenance	EPRI 2013 report on increased requirements for software development and testing. PSHA software employed in PRP is no longer maintained.	No comment, as statement of facts and no criticism on PRP.
4.4.2/36	Provision for independent checking of hazard results	Suggestion that PMT and TFI perform PSHA checks using independent software codes. New PEER study on software benchmark as option to perform such	Software benchmark and independent checking is not state of current practice within PSHA studies.

		checks.	
4.5.1/36	Dedicated SP1-SP2 interface workshops	2 dedicated IF WS	No comment, as only statement of facts.
4.5.2/36	Consistency in treatment of earthquake size		
4.5.2/37	Quality and level of SP1-SP2 interaction	Poor level of interaction at SP1-SP2 IF WS	Repetition of previous SP1 comments.
4.6.1/37	Dedicated SP2-SP3 interface workshops	Effective SP2-SP3 IF WS	No comment, as no criticism on PRP.
4.6.1/37	Common expert among SP2 and SP3	Common expert helped to ensure effective SP2-SP3 interface.	No comment, as no criticism on PRP. Improvement compared to PEGASOS.
4.6.1/37	SP2-SP3 integrated single-station sigma model	Avoidance of double counting of uncertainties between SP2 and SP3 due to use of single-station sigma approach.	No comment, as no criticism on PRP. Improvement compared to PEGASOS.
4.6.1/37	SP2-SP3 interface on Kappa and Kappa correction	Kappa scaling integrated treatment well-coordinated	No comment, as no criticism on PRP. Improvement compared to PEGASOS.
4.6.2/37	Schedule impact on SP2-SP3 interface	Final SP2 WS occurred too late for a final interaction of SP2-3.	SP2-SP3 interface was addressed through e-mail exchanges (2.-18. Dec. 2013) with SP3 after the last SP2 workshop (see TP3-KS-1121).
4.6.2/38	Representation of community view	Proponent views: no systematic representation of community view as requested by SSHAC	In aggregate, the results captured the center, body, and range of technically defensible interpretations.