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TECHNICAL POSITION PAPER

LIBNA FAULT

RESPONSE TO IRSN/DIR/2013-00010

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Introduction

This Technical Position Paper discusses the current interpretation of the Libna Fault, and specifically addresses a letter issued by Institute for Radiological Protection and Nuclear Safety (IRSN) to Gen Energija (GEN), dated 9 January 2013. IRSN has expressed their view of the Libna Fault and its possible effect on the Krško I nuclear power plant (NPP) and the proposed site for Krško II. IRSN's view is based on information developed over the past two years through mid-2012 by a Consortium led by Bureau of Geological and Mining Research (BRGM) that includes IRSN as a member.

IRSN, using somewhat outdated information, states that the Libna fault lies within a "few hundred meters" of the Krško II NPP sites and is a capable fault based on the Consortium's Libna Hill trench studies. IRSN further opines that the Krško II NPP sites, therefore, cannot be determined suitable and a search for alternative sites should be considered. IRSN also states that the implications of the information available to IRSN on the safety of the Krško I NPP should be addressed in a timely manner.

In response to the views expressed by IRSN, GEN would like to call attention to ongoing field and analytical work that implements many of the recommendations made by the Consortium. Results of this work, while preliminary at this time, suggest that IRSN conclusions regarding the Libna Fault and site suitability are premature.

Statements and Responses

Using the most recent information available, we address the IRSN statements in a Statement-Response mode as follows. Please note that, because the field and analytical work is not complete as of this date, these responses are preliminary. They are based, however, on the best currently available information which was not available to IRSN as of the date of their letter to GEN on 9 January 2013,

IRSN Statement No. 1: The Libna Fault outcrops "a short distance from the Krško II sites" and is "located at only a few hundred meters from these sites."

Response No. 1: There is no professional consensus that the Libna fault "outcrops" on Libna Hill. Lacking further information from IRSN, it is assumed that IRSN is referring to the NE facing escarpment on Libna Hill (not an outcrop). From a gross geomorphic perspective, the "outcropping" of the Libna Fault is a reasonable, simplified, first-order interpretation; however, more careful investigation indicates that the landform in question is a response to multiple processes that are dominantly controlled by mass wasting-related processes.

Recent research based on an extremely high-resolution 1.0 meter (m) digital elevation model (DEM) derived from light detection and ranging (LiDAR) has indicated several complex processes that are responsible for shaping the current surfaces of Libna Hill. Please refer to ***Figure 1-1***.

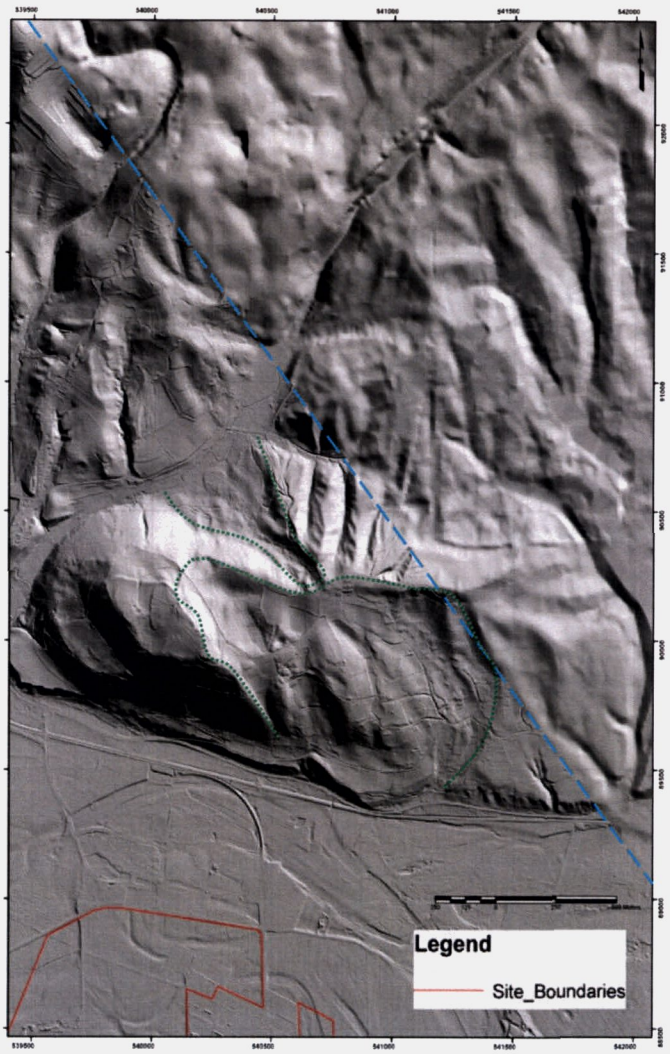

FIGURE 1-1
LIDAR IMAGE- LIBNA HILL

Prior landscape analysis by IRSN was conducted on a 12.5 m DEM; consequently, identifying the smaller-scale features that provide key information about these processes was not possible. The LiDAR DEM clearly shows that the dominant surface processes responsible for forming the escarpment are mass wasting movements that include karst collapse and both deep-seated (>3 m) and shallow landsliding (***Figure 1-2***). Field mapping and ground-truthing supports this finding. In the field, numerous landforms were observed that are indicative of the various types of mass wasting that are evident along the escarpment and the entire southern slope of Libna Hill.

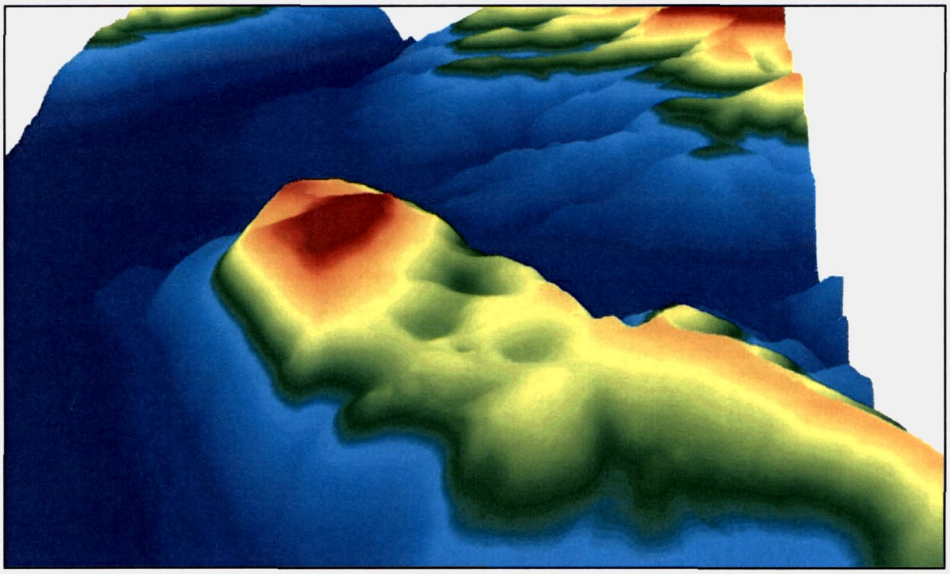

FIGURE 1-2
LIDAR IMAGE – DEM

Additional evidence supporting an interpretation of large-scale mass wasting resides at the southern base of Libna Hill. A limestone outcrop at that location was mapped previously as an erosional feature; however, structural geological evidence observed in the field indicates that the large limestone block is a slide block that was originally near the top of the upper Libna Hill.

The processes that form Libna Hill are not unique in the Krsko region. Mass wasting controls many of the slopes throughout much of the region. Approximately 9 kilometer (km) SE of Libna Hill, above the town of Čatež ob Savi, a very large deep seated slide is clearly shown on the LiDAR Imagery (shown on ***Figure 1-3)***. This feature was geologically mapped over several years prior to being recognized. The LiDAR was able to identify it immediately.

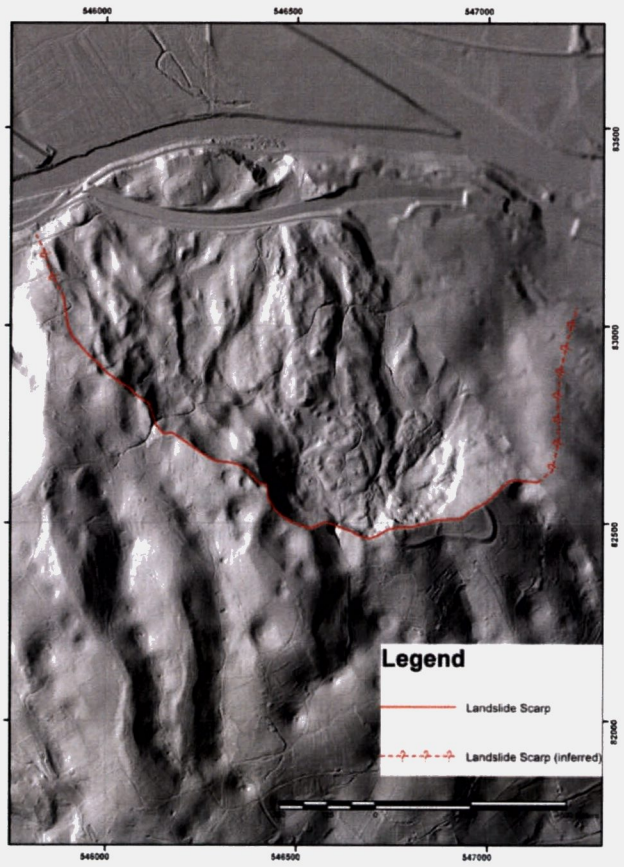

FIGURE 1-3
LANDSLIDE NEAR ČATEŽ OB SAVI

The geological similarities between the Čatež ob Savi landslide and the southern slope of Libna Hill are critical to understanding the geomorphological conditions in the Sava Valley. Both reside on the flanks of an anticline with steeply dipping stratigraphy comprised of Cretaceous clastic flysch sediments at the anticline's core, and carbonate rocks on their flanks. In addition, both regions have extensive karst development. This combination of geomorphic processes has led to regional slope instabilities, and has resulted in numerous deep-seated landslides in the region. The surface expression of the Libna fault is markedly enhanced by other processes as well.

In conclusion, new and much more detailed LiDAR Imagery interpretation and DEM analysis indicates that, what has been heretofore interpreted as a fault scarp, is dominated by mass

wasting including karst development. The geomorphological evidence on the south slope of Libna Hill indicates active slope failure.

IRSN Statement No 2: The finding that the Libna fault is capable "does not allow concluding in a favorable manner as regards the suitability of the Krško II sites."

Response No. 2: The IRSN Statement No. 2 is taken out of context of the overall findings of the BRGM Consortium Phase 1 Geology Report which states:

> *Libna fault is not an important structural element of the Krško basin. Moreover, from its geomorphic expression and its mapped length, it seems unlikely that it is a fault that is capable of generating earthquakes large enough to produce surface fault rupture. However, recent findings in the trench #2 at the Libna Hill indicate that the Libna fault may be described as capable if capability is defined in line with Safety guide SSG-9 (IAEA, 2010; where capability is not necessarily related to earthquakes on the fault of concern) and if the lower age-estimates of Pl,Q formation are taken as relevant.*

As described in Response No. 1, new data from LiDAR DEMs have revealed the surface expressions that have been previously interpreted as a fault scarp is actually dominated by mass wasting with limestone dissolution (i.e., karstic collapse features). This phenomenon is not unique to Libna Hill and is common on slopes within the Sava Valley around Krško.

The DEM clearly identifies four sinkholes along the trace of the Libna feature on Libna Hill, as well as the deep-seated landslide features. This new evidence indicates that the offset observed in the Libna Hill Trench is either completely or partially related to mass wasting and karst development.

It is important to note that the DEM has revealed that Trench 2 from the Libna Hill Trench Study was excavated immediately adjacent to one of these sinkholes, and most likely within an area that underwent landsliding in the past. Therefore, an interpretation of displacement of tectonic origin must take into account the clear impact of the non-tectonic geomorphic processes that have been identified. Displacement estimates based on tectonic origin are not supportable and without merit.

The age of the fault displacement is a key factor for assessing fault capability. The youngest estimates from optically stimulated luminescence (OSL) ages derived from samples taken by the BRGM Consortium from Trench 2 are considerably younger than anticipated. The OSL results as admitted by Consortium members are problematic as their luminescence signals were near saturation. This suggests that a reasonable age cannot be obtained using OSL because of the mineralogical properties of the local sediments and bedrock. This is a known problem in many regions of the Southern Alps.

Further to this point, the ages may have been pushed artificially younger due to bioturbation (e.g., animal burrowing and root penetration). GEN is currently supporting a large-scale geochronology campaign to determine the true age of the sediments that were used by the Consortium to assess the age of the samples obtained in the Libna Hill Trench. Multiple methods are being applied, including cosmogenic radionuclide (CRN) and OSL. There are also multiple independent laboratories being utilized for this work. With relatively limited geochronology and inconclusive results, it is not possible to declare the Libna Fault a capable fault.

Given the new information obtained, and the present lack of additional age dates that are forthcoming, suggests that it is premature to make a determination as to the significance of the Libna fault to the safety and performance of a planned Krško II NPP. These new data strengthen the position of BRGM that the Libna fault is tectonically insignificant.

IRSN Statement No. 3: The use of Probabilistic Fault Displacement Hazard Analysis (PFDHA) in establishing site suitability represents a challenge given the limited international experience and "lack of recognized methods and tools."

Response No. 3: The PFDHA was carried out as an additional tool to complement the findings of geologic and geophysical studies for establishing site suitability. The study provides additional information that is relevant to risk-informed decision making in a regulatory environment, both for existing nuclear power plants and new sites. It is important to emphasize that GEN proceeded with the PFDHA in order to provide additional information of the potential hazard of fault displacement at the Krško II proposed NPPs. It was not to provide an alternative means of evaluating site suitability. In fact, GEN is currently conducting a comprehensive field investigation to develop a greater understanding of the features on Libna Hill and a more robust

seismotectonic model for the region. This work includes high-resolution geophysics, paleoseismology, geochronology studies, and tectonic geomorphology studies.

PFDHA has been used in the United States of America (USA) on a number of nuclear projects and is recognized by the International Atomic Energy Agency (IAEA) in Specific Safety Guide SSG-9 for assessing fault displacement hazard at existing nuclear power plant sites. Results from PFDHA were included in a license application to the United States Nuclear Regulatory Commission (USNRC) for a high-level nuclear waste repository at Yucca Mountain, Nevada, USA. The fault displacement hazard results formed part of the safety case establishing that the repository met the performance goals of the regulatory requirements. The methodology and data to determine the on-fault and off-fault characteristics were developed from a worldwide dataset described in a major, international publication (Peterson et al. 2011); this same methodology and input data have been used for faults in the Krško region and a subsequent sensitivity of fault parameter values was performed to demonstrate the conservatism of the PFDHA.

The available results from the PFDHA indicate that fault displacement of engineering significance has a very low exceedance probability for a nuclear island footprint within the East and West Krško II NPP sites. The exceedance probabilities are well below regulatory levels of concern and are lower than the typical probabilities of a core melt or a large radioactive release.

The PFDHA for the Krško II sites underwent a recent peer review. The Peer Review Panel was made up international experts who have worked for the IAEA, USNRC, or both. The Peer Review Panel indicated that the input parameters for the PFDHA are in some cases too conservative and should be re-considered to develop a "best estimate" type of analysis. PFDHA sensitivity analyses, which are also being carried out, provide a more appropriate way of investigating the impact of conservative assumptions. The Peer Review Panel Report states the following on the issue of designing the NPP for fault displacement:

> "The Peer Review Panel agrees that the PFDHA study has shown that the resulting magnitude of offset displacements for the base-case parameters are small and insignificant and need not be considered for further study for the new facility."

The PFDHA and Sensitivity study results indicate that the hazard of fault displacement at both the east and west sites is extremely low. The Peer Review Panel is of the position that the application of the PFDHA for assessing fault displacement hazard for a new NPP is

acceptable. The ongoing field and analytical investigations of the Libna fault suggest that the hazard posed by the Libna fault is insignificant to the safety and operation of a new NPP at Krško.

IRSN Statement No. 4: "Thus, IRSN considers that the use of PFDHA is more appropriate in the process of upgrading safety demonstration of existing nuclear facilities than for supporting the licensing of new plants."

Response No. 4: We addressed this specific issue at the Peer Review Panel Meeting on 16 January 2013. It is noted that the author of that particular text in SSG-9 was Dr. Aybars Gurpinar, a member of the Panel. The Panel addressed this matter in their letter and we quote below from that document:

> "Although, the IAEA Safety Guide recommends the use of a probabilistic fault displacement hazard analysis for existing NPPs, the present study is valuable for the following reasons:
>
> > It constitutes a risk informed approach for the estimation of potential displacements and their engineering significance,
> >
> > It assists in understanding the importance of the various supposed faults in the site vicinity in order to prioritize additional field investigations."

It is important for regulatory decisions to be risk-informed and to take advantage of all information that is potentially relevant

Conclusion

GEN continues to carry out robust, multidiscipline investigations to assess whether any capable faults with the potential to affect the safety of nuclear installations exist at the East and West Krško II sites. The most recent phase of investigation that has been carried out over the past six months incorporates tectonic geomorphology, geochronology, and high-resolution seismic (HRS) geophysics, following the advice of the Consortium on this matter. The investigations are evaluating evidence as to whether the Libna fault and/or the Stara Vas feature are capable faults.

Multiple geochronology techniques are being used to constrain the age of the youngest fault offset. HRS is being used to determine the buried southern extent (total length) of the Libna feature and evaluate the existence of the postulated Stara Vas fault. The preliminary results of these investigations suggest that the IRSN conclusions regarding the Libna Fault and site suitability may be premature.

References

M. D. Petersen, Dawson, T. E., Chen, R., Cao, T., Willis, C. J., Schwartz, D. P., and Frankel, A. D., 2011, "Fault Displacement Hazard for Strike Slip Faults," BSSA, Vol. 101, No. 2, pp. 895-825.