GEN energija Seismic Hazard Analysis Project for Krško 2

Presentation to

Slovenian Nuclear Safety Administration

27 January 2015

Project Goals

- Assess capability of faults within 5 km of the proposed East and West site for Krško NPP 2 (JEK 2)

- Determine Design Basis Earthquake (Safe Shutdown Earthquake, SL-2) on basis of PSHA results

Project Team

- Sponsor – GEN energija
- Team composed of RIZZO Associates (RIZZO) and the Geologic Survey of Slovenia (GeoZS) will execute the project

Key Guidance

- Slovenian Regulation: Zakon o varstvu pred ionizirajočimi sevanji in jedrski varnosti (ZVISJV)
- Primary Guidance
  - IAEA Safety Standards, Specific Safety Guide SSG-9
- Other Guidance
  - USNRC Regulatory Guide 1.208
  - SSHAC, NUREG/CR-6372
  - USNRC NUREG-2117

Quality Assurance

- Work will be carried out under the RIZZO Quality, Health, Safety, and Environmental (QHSE) program
- Implements requirements including:
  - ISO 9001:2008, ISO 14001:2004, ISO/IEC 17025:2005
  - US 10 CFR 50, Appendix B; 10 CFR 21
  - ASME NQA-1

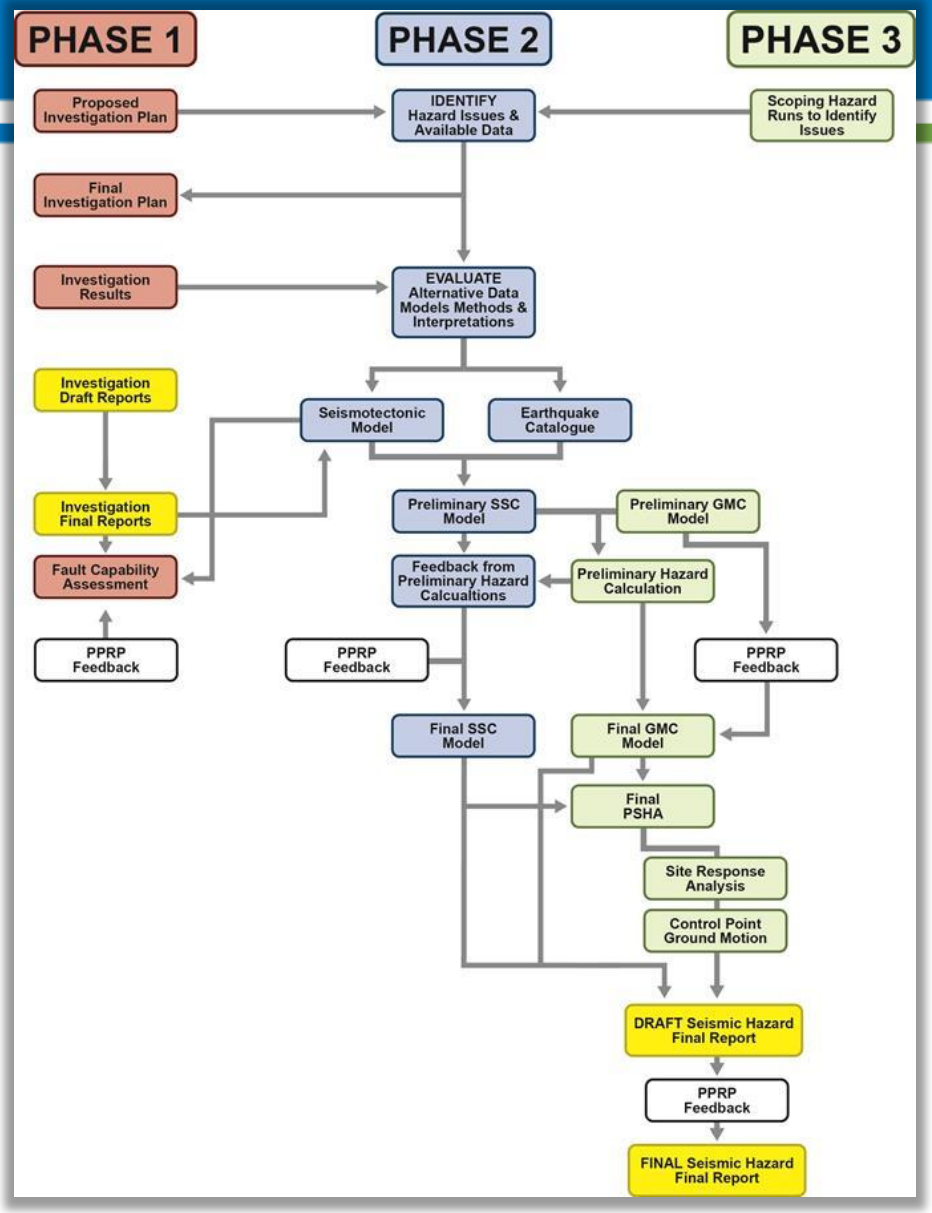
Framework for Technical Approach

- SSHAC Process for incorporation of uncertainty
  - Compile information
  - Evaluate information
  - Based on evaluations, develop an integrated representation of the center, body, and range of technically defensible interpretations
  - Peer review
  - Complete documentation of process

SSHAC Study Level

- Krško SHA Project will be carried out as a SSHAC Level 2 study
  - Interactions with resource and proponent experts carried out individually and often remotely
  - Participatory peer review panel (PPRP) will be used
    - Usually associated with SSHAC Level 3 and 4 studies

Framework for Technical Approach



PHASE 1

FIELD INVESTIGATIONS

Phase 1-Field Investigations

- Expand upon previous work
- Emphasis on Orlica fault zone (OFZ) and Artiče Structure (AS)
- Identify existence and characterize capable faults within 5 km of the East and West sites
- Support update of seismotectonic model and SSC models

Phase 1 – Field Investigations

- Integrated and iterative approach
  - Tectonic geomorphic characterization
  - Geophysical investigation
  - Drilling
  - Paleoseismological investigation
  - Age dating
- Level of effort will vary depending on what is encountered in these studies

Tectonic Geomorphic Characterization

- Investigate geomorphology of Krško region to identify evidence of most recent tectonic activity
  - Lineament analysis
  - Channel profile analysis
  - Drainage basin morphology
  - Basin-averaged denudation

Geophysical Investigation

- Shallow high-resolution seismic reflection profiles
- Target: top of Pontian, Plio-Quaternary, Quaternary sediments
- High number of active channels, high data fold
- Seismic source test prior to acquisition of every HRS profile
- Targets:
  - Zones with the projected possibility of paleoseismic trenching
  - Zones with open questions on fault presence/geometry

GeoZS

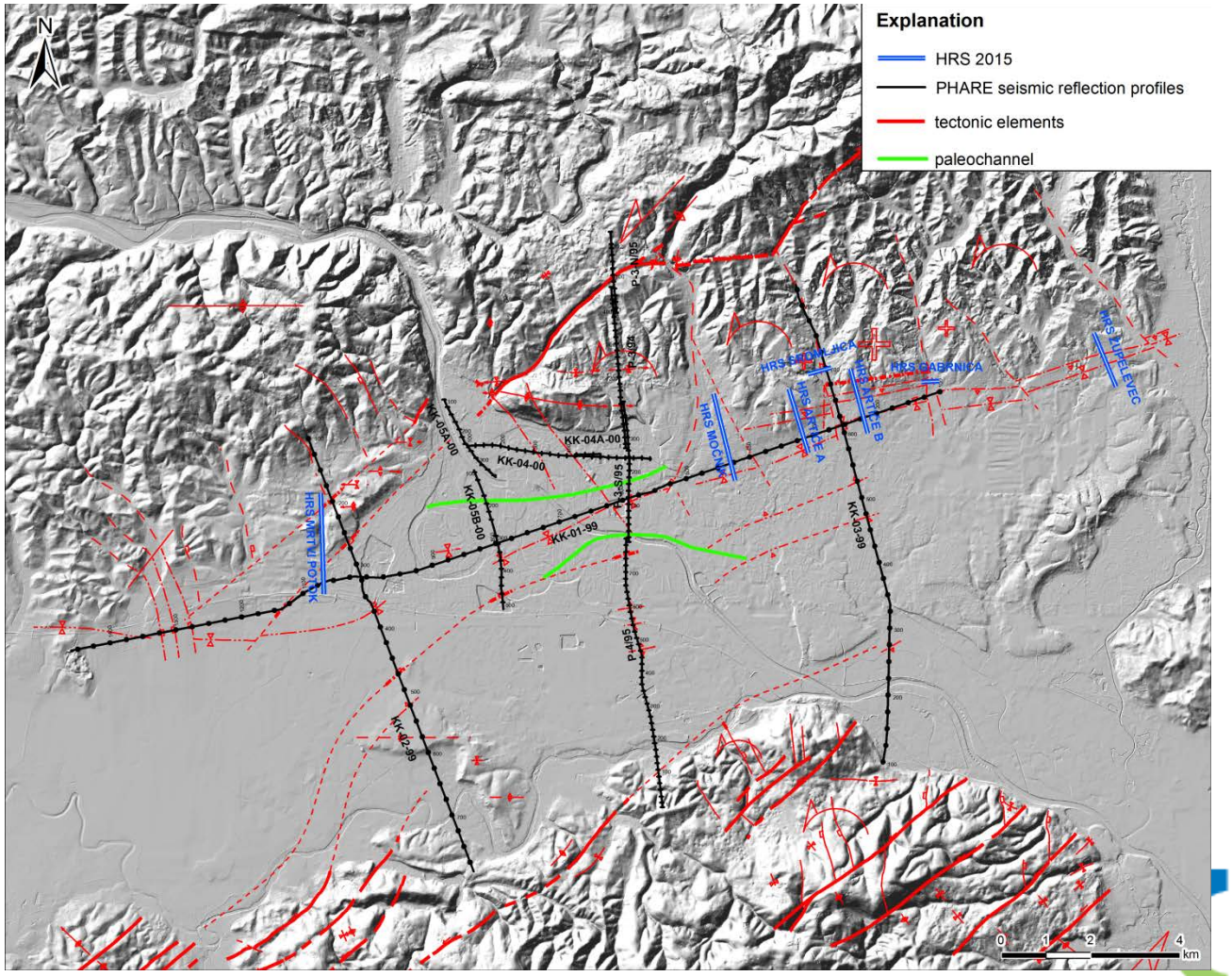
Geophysical Investigation

TABLE 2-1
Proposed Geophysical (High Resolution Seismic Reflection) Lines.

[Proposed] Geophysical Lines				
Line	**Length**	**Target Structure**	**Target Depth Range**	**Priority**
HRS Močnik 2015	2.0 km	Artiče structure	20 - 300 m	Necessary
HRS Sromljica 2015	0.6 km	Sromljica fault	20 - 150 m	Necessary
HRS Gabrnica 2015	0.4 km	Gabrnica fault	20 - 150 m	Necessary
HRS Župelevec 2015	1.3 km	Artiče structure	20 - 300 m	Necessary
HRS Mrtvi potok 2015	2.2 km	Orlica fault zone	40 - 500 m	Necessary
HRS Artiče A 2015	1.5 km	Artiče structure	20 - 300 m	Optional*
HRS Artiče B 2015	1.5 km	Artiče structure	20 - 300 m	Optional*

* Optional: either HRS Artiče A 2015 or B 2015 will be selected, based upon the results of HRS Sromljica 2015

Geophysical Investigation



Drilling

- To support interpretation of high resolution seismic (HRS) data.
- Seismic downhole, fully cored
- 2 boreholes necessary*:

BOREHOLE NAME	LOCATION	DEPTH	DOWNHOLE MEASUREMENTS	PURPOSE
ŽPL-1/2015	On the profile HRS Župelevec 2015, approx. at the center of Krško syncline	100 m	Seismic downhole optional (if detailed calibration of HRS required); recommended. Caliper probe for breakout analysis required);	Support to HRS Župelevec 2015 and to establish the existence of the Sava paleochannel towards the E
ART-01B/2015	Cross-section of HRS Artiče b 2015 and KK-01-99	250 m	Seismic downhole. Caliper probe for breakout analysis	Support to HRS Artiče B 2015

* Optional boreholes have also been identified that may be recommended if additional subsurface information is necessary to support the HRS profiles.

Paleoseismological Investigations

- Up to 8 provisional sites to be identified on the OFZ and AS based on other Phase 1 studies
- 5 of these sites will then be studied with geophysical methods to determine their appropriateness for trenching
- 3* sites will be trenched if appropriate conditions are encountered

* If it is determined that the three trenches are not adequate or if excavation problems arise on one of the trenches, a recommendation will be made for selection from the five locations identified for possible trench excavation.

GeoZS

Age Dating

- Goal is to obtain Plio-Quaternary geochronology for the 25-km site vicinity
- Targets for sampling will be determined from other field investigations
  - Deformed and undeformed sediments
  - Fault materials
  - Constraints on landscape evolution
- Multiple appropriate techniques

Age Dating

- Multiple appropriate techniques:
  - Cosmogenic radionucleides (CRN)
  - Optically stimulated luminescence (OSL)
  - Uranium-Thorium (U-Th)
  - Argon-Argon ($^{40}Ar/^{39}Ar$)
  - Radiocarbon (^{14}C)

Phase 1 Reporting

- For each field investigation technique, a report will be prepared
- Phase 1 Summary Report that integrates the results of the studies
- Fault Capability Report
  - Provide capability assessment per SSG-9
  - Peer Review

PHASE 2

FAULT CAPABILITY

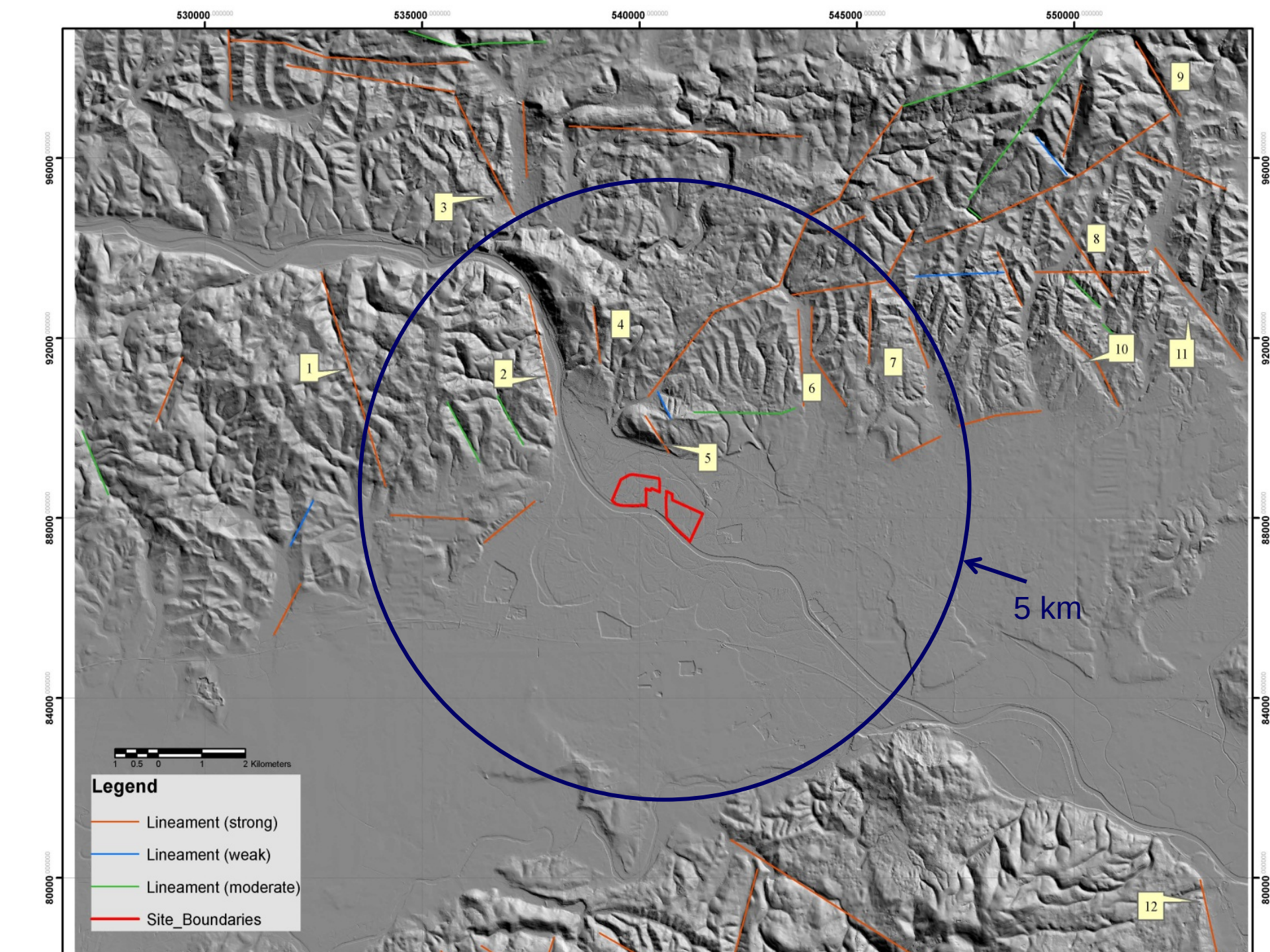
AND

SEISMIC SOURCE CHARACTERIZATION

Objectives for Assessing Fault Capability

- Assess tectonic deformation (fault displacement and surface deformation) within a minimum of 5 km from the proposed JEK 2 sites

- If determined capable assess fault displacement/surface deformation hazard following SSG-9 guidance with respect to the safe operation of the proposed JEK 2


530000
535000
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84000
80000
1
2
3
4
5
6
7
8
9
10
11
12
5 km
1 0.5 0 1 2 Kilometers
Legend
Lineament (strong)
Lineament (weak)
Lineament (moderate)
Site_Boundaries

Basis for Assessing Fault Capability

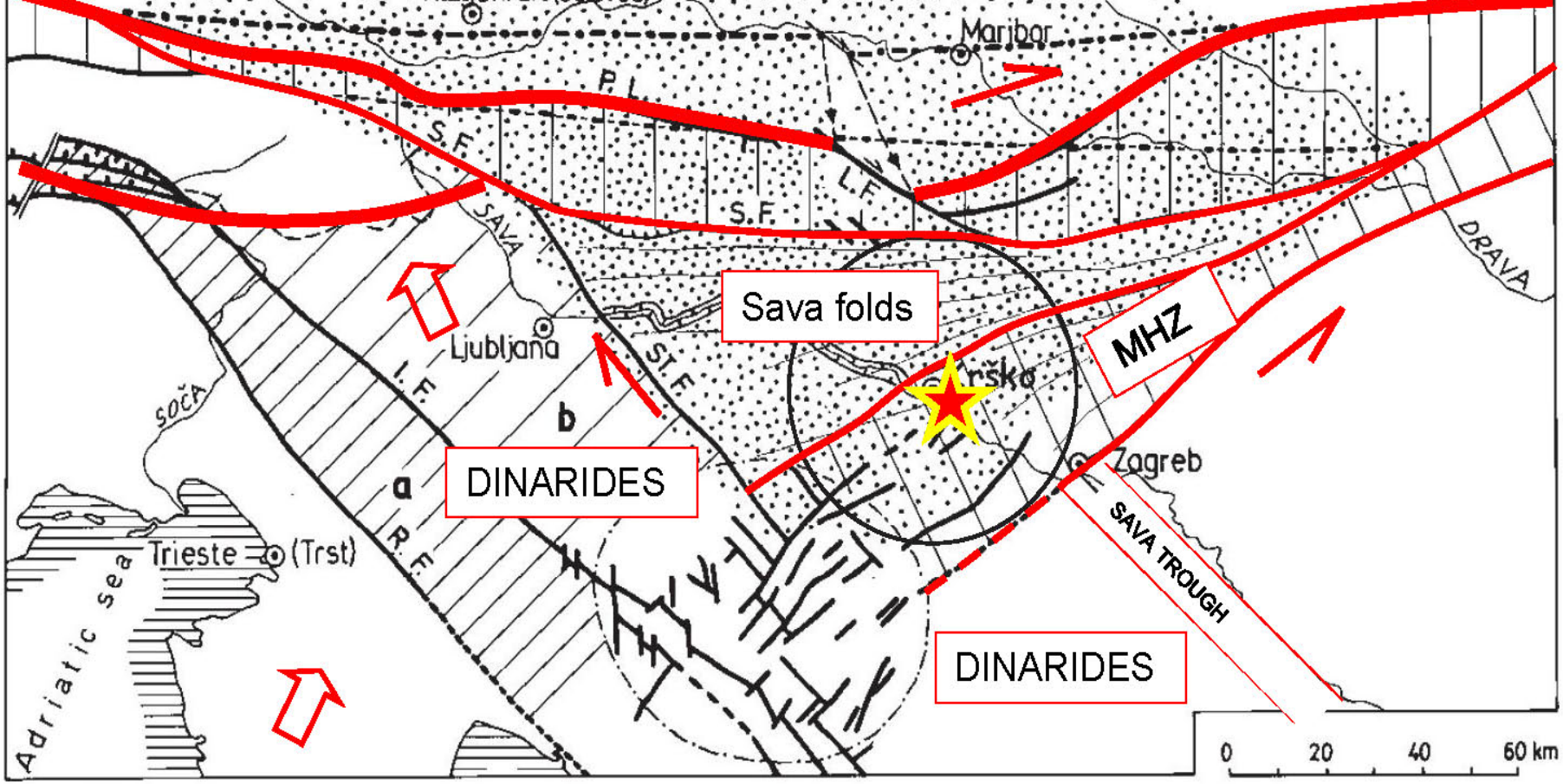
- Compile sufficient data on the behavior and geometry of faults within 5 km of the sites
  - Phase 1 investigations
- Develop a robust understanding of level of tectonic activity within the region
  - Updated and defensible seismotectonic model
- Develop a defensible technical basis for a reasonable time period to evaluate fault capability
- Participation of PPRP

Fault Capability Hazard

- Presence of a capable fault is not necessarily an exclusionary criteria; however, if, based on "*reliable evidence*" it has the potential to affect the safe operation of the plant, further evaluations may be considered
- A probabilistic fault displacement hazard analysis (PFDHA) may be appropriate
  - Currently not in scope of work

Seismic Source Characterization (SSC)

- Objective is to characterize seismic sources for input to the Probabilistic Seismic Hazard Analysis (PSHA)
  - Consider seismic sources (structures and zones) within the region that may be significant to the two sites
  - Develop seismic source model(s)



Periadriatic tectonic zone

Mid-Hungarian tectonic zone

Idrija tectonic zone, a- outer part, b- inner part

Idrija-Mid-Hungarian transsection zone

Sava compressive wedge

Primary position of the Periadriatic lineament

Primary position of the Sava fault

Sava gorge

Primary position of the Labot (Lavant) fault

Generalized direction of the folds

P.L. Periadriatic lineament

S.F. Sava fault

ST.F. Stična fault

I.F. Idrija fault

R.F. Raša fault

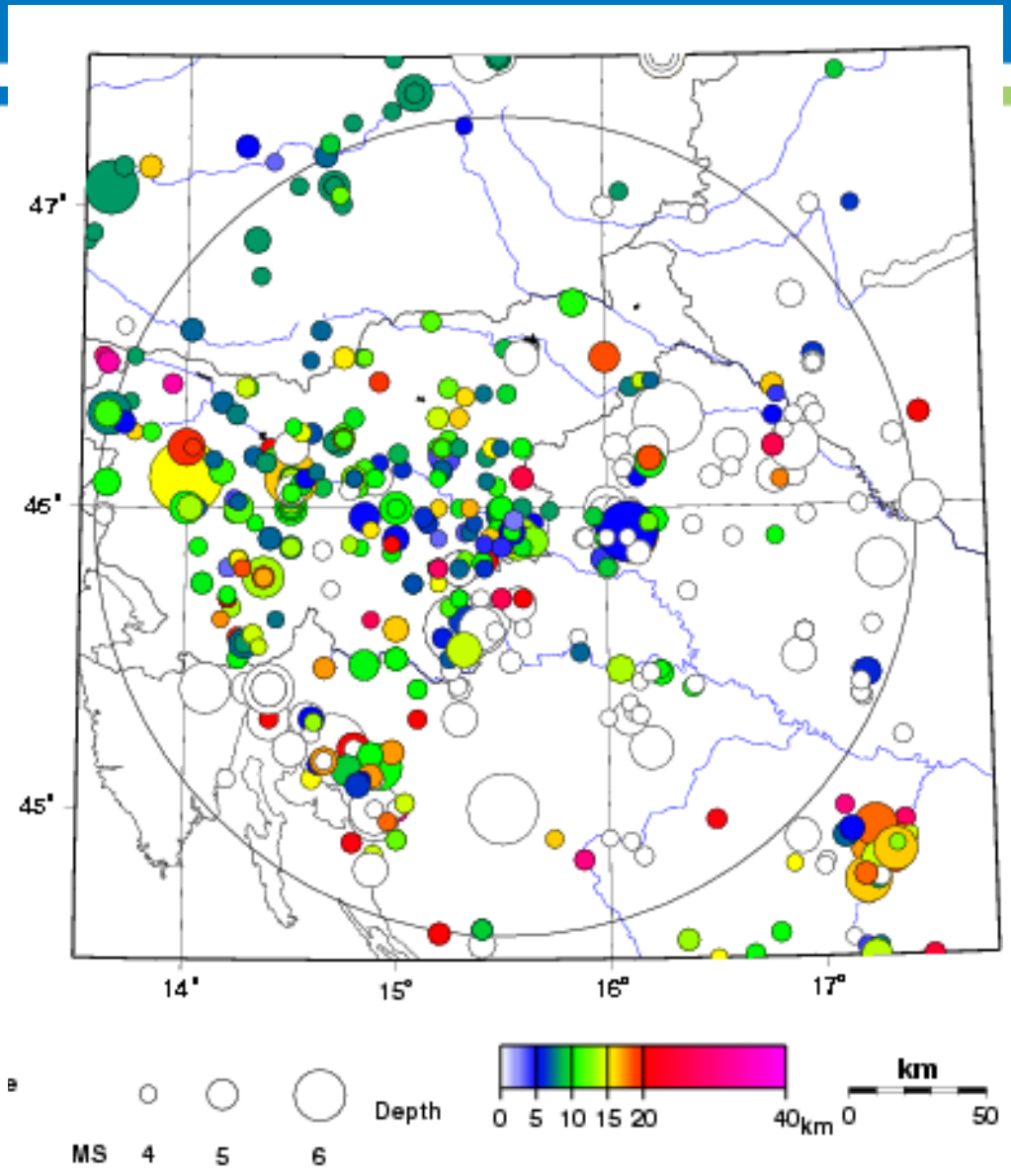
L.F. Labot (Lavant) fault

Earthquakes in Regional Area

Period:

567 – 2013

MS ≥ 4.0



GeoZS

Integration Team

- Establish SSC Technical Integration Team to:
  - Compile and evaluate available data on neotectonic activity
  - Update historical seismicity of the region and identify seismic sources
  - Update the existing seismotectonic model based on new data
  - Interview proponents of neotectonic models
- Develop SSC model(s)
- Inputs and model(s) reviewed by PPRP

SSC Model(s)

- SSC model(s) consist of:
  - Earthquake catalogue
  - Seismotectonic model
  - Identification of seismic sources
  - Maximum magnitude distribution
  - Recurrence models
  - Rupture characteristics

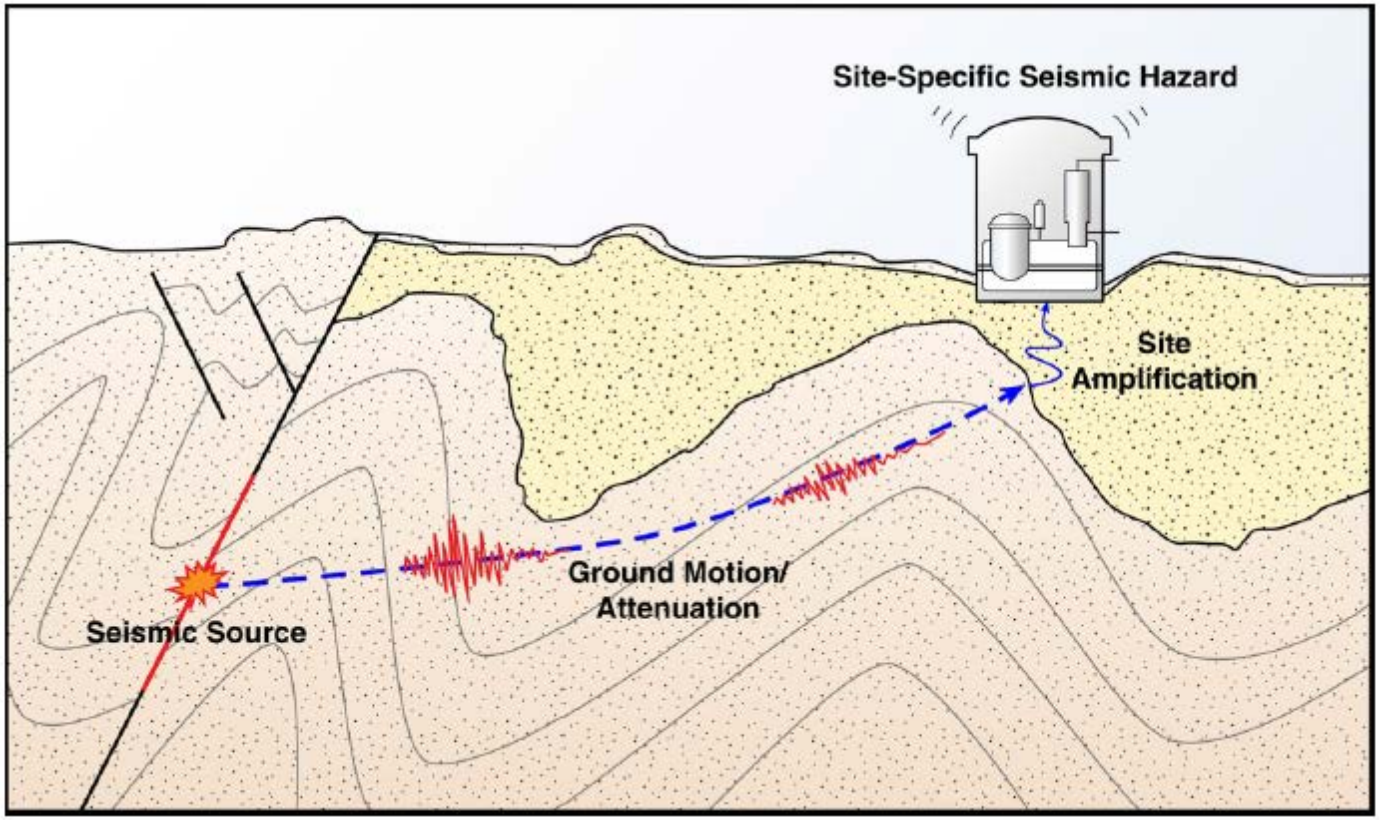
SSC Input to PSHA

- Identify and characterize seismic sources based on:
  - Recurrence
  - Magnitude frequency distribution
  - Source geometry (Length, width and depth)
  - Distance from sites and seismogenic depth
  - Maximum earthquake

PHASE 3

GROUND MOTION CHARACTERIZATION, PROBABILISTIC SEISMIC HAZARD ANALYSIS, AND CONTROL POINT GROUND MOTION

Ground Motion Characterization



Ground Motion Characterization

- Determine reference rock condition for PSHA (Shear-wave velocity, depth, attenuation characteristic)
- Model consists of:
  - Median ground motion and uncertainty
  - Ground motion variability (“sigma”)
- PPRP review prior to use in PSHA

Probabilistic Seismic Hazard Analysis

- Use SSC and GMC inputs to develop PSHA results for reference rock condition
  - Ground motion hazard curves
  - Uniform hazard response spectra

Probabilistic Seismic Hazard Analysis

- Deaggregation of results (dominant magnitudes and distances) contributing to hazard
- Sensitivity analyses

Site Response Analysis

- Assess information from JEK1 and other studies to develop approximate site response
- Use to adjust ground motion for the PSHA reference rock condition to corresponding ground motion for the control point

Control Point Ground Motion

- Control point at the top of consolidated material beneath the surficial gravels
- Basis for SL-2 ground motion is the uniform hazard response spectrum with a 1E-4 mean annual frequency of exceedance

Control Point Ground Motion

- Vertical control point response spectrum is determined from the horizontal control point response spectrum using an appropriate vertical-to-horizontal ratio function

SUMMARY

Summary

- GEN is implementing an integrated program to address seismological suitability issues and determine SL-2 ground motion response spectra
- Work will be carried out under the RIZZO QHSE program to ensure data are appropriate for nuclear site characterization