



What the HEC...

The Hydrogeological Excavation Code
Tools and data for planning tunnels
Reducing negative environmental impacts

Tunnels: What is it about?



Manifesto of L. Pinna – Underground Works conference Florence 1986

This Manifesto represents an artistic overview of the use of underground landscape, where mixing of transport modes is applied for a more sustainable use of underground space.

Today we will speak about Environmental Safeguards and Project Development.

Agenda

13:30 – 13:35	Welcome and introduction Massimo Marra, Principal Advisor, Capacity Building Coordinator, JASPERS
13:35 – 13:45	Opening remarks Inge Vermeersch, Head of Division, Regional Transport Division, JASPERS and Jeroen van Oel, DG REGIO
13:45 – 13:55	Tunnels and water – a short introduction Lorenzo Martelli, Senior Transport Engineer, JASPERS
13:55 – 14:20	Tunnels and the environment - Impact assessments (EU environmental legislation) Lise Praestegaard, Senior Environment Specialist, JASPERS
14:20 – 14:50	A water focus – the Water Framework Directive and River Basin Management Plans Lise Praestegaard, Senior Environment Specialist, JASPERS
14:50 – 15:00	Coffee Break
15:00 – 15:20	The HEC – introduction Lorenzo Martelli, Senior Transport Engineer, JASPERS
15:20 – 15:50	HEC methods - data collection, interpretation, presentation Lorenzo Martelli, Senior Transport Engineer, JASPERS
15:50 – 16:20	Using HEC – results, mitigation, compensation Lorenzo Martelli & Lise Praestegaard, Senior Transport Engineer, JASPERS / Senior Environment Specialist, JASPERS
16:20 – 17:20	Example(s) of implementation of HEC in tunnelling project(s) External speakers
	Final Q & A
17:20 – 17:30	Closing remarks Inge Vermeersch, HoD, RTAD

Note: all sessions include a 5 to 10 minutes Q/A session at the end of each session

YOUR Speakers Today

Jeroen van Oel,

European Commission - DG REGIO
Policy Analyst, Transport and Connectivity
issues – Unti G1 - Smart and Sustainable
Growth.



Lubos DURIC

Ministry of Transport in Slovakia –
Director of ERDF and CEF fund –
Roads Directorate



Massimo COLI

Senior tunnel expert
Member of the Scientific-Technical
Committee nominated by ASPI (Italian
Motorway Company) and Ministry of
Transport
HEC implementor



Massimo MARRA

Principal Advisor, Capacity Building
Coordinator – JASPERS Coordination
and Capacity Building Division
JASPERS/EIB



Lise PRAESTERGAARD

Regional Transport Advisory Division –
JASPERS/EIB
Senior Environmental specialist;
Lise has more than 25 years in
environmental assessment in
implementing infrastructures projects
worldwide



Lorenzo MARTELLI

Regional Transport Advisory Division
JASPERS/EIB
Senior Transport Engineer
Tunnel expert in several projects
Lorenzo has more than 25 years in
programming, designing and
implementing infrastructures projects

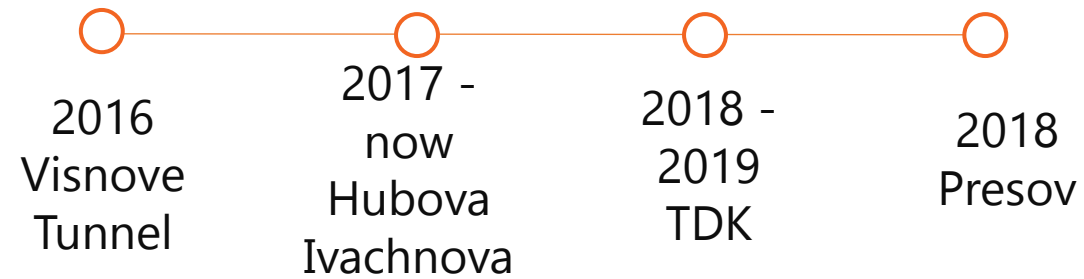


Inge VERMEERSCH

Head of Division
Regional Transport Advisory Division –
JASPERS/EIB

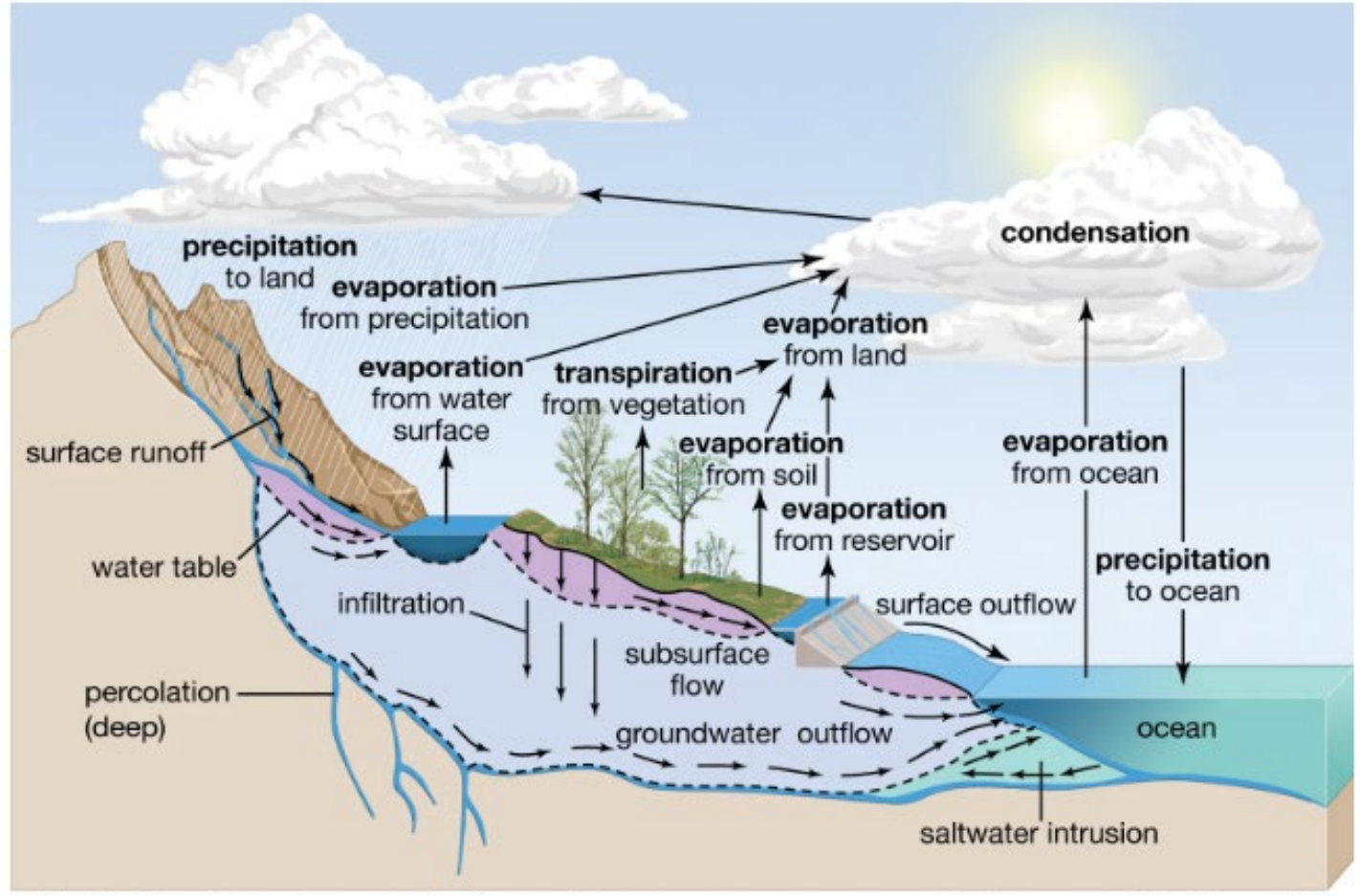


Key Assignments Milestones



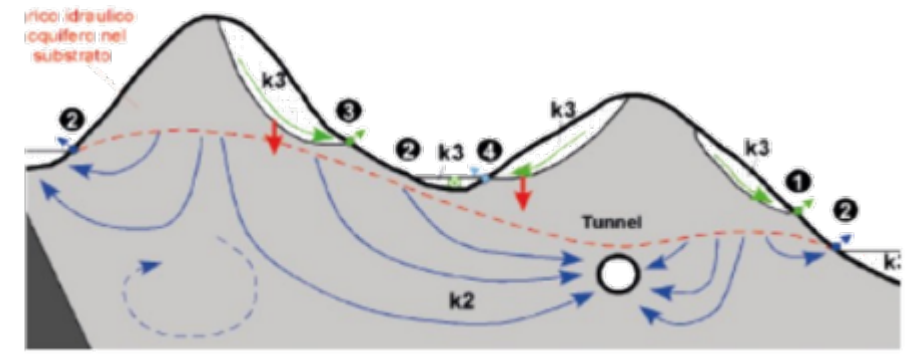
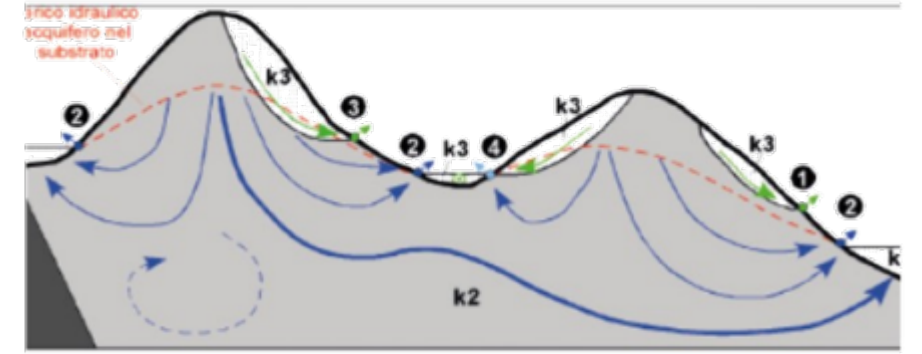
50 Km of Tunnels

The water cycle and the effects of tunnelling

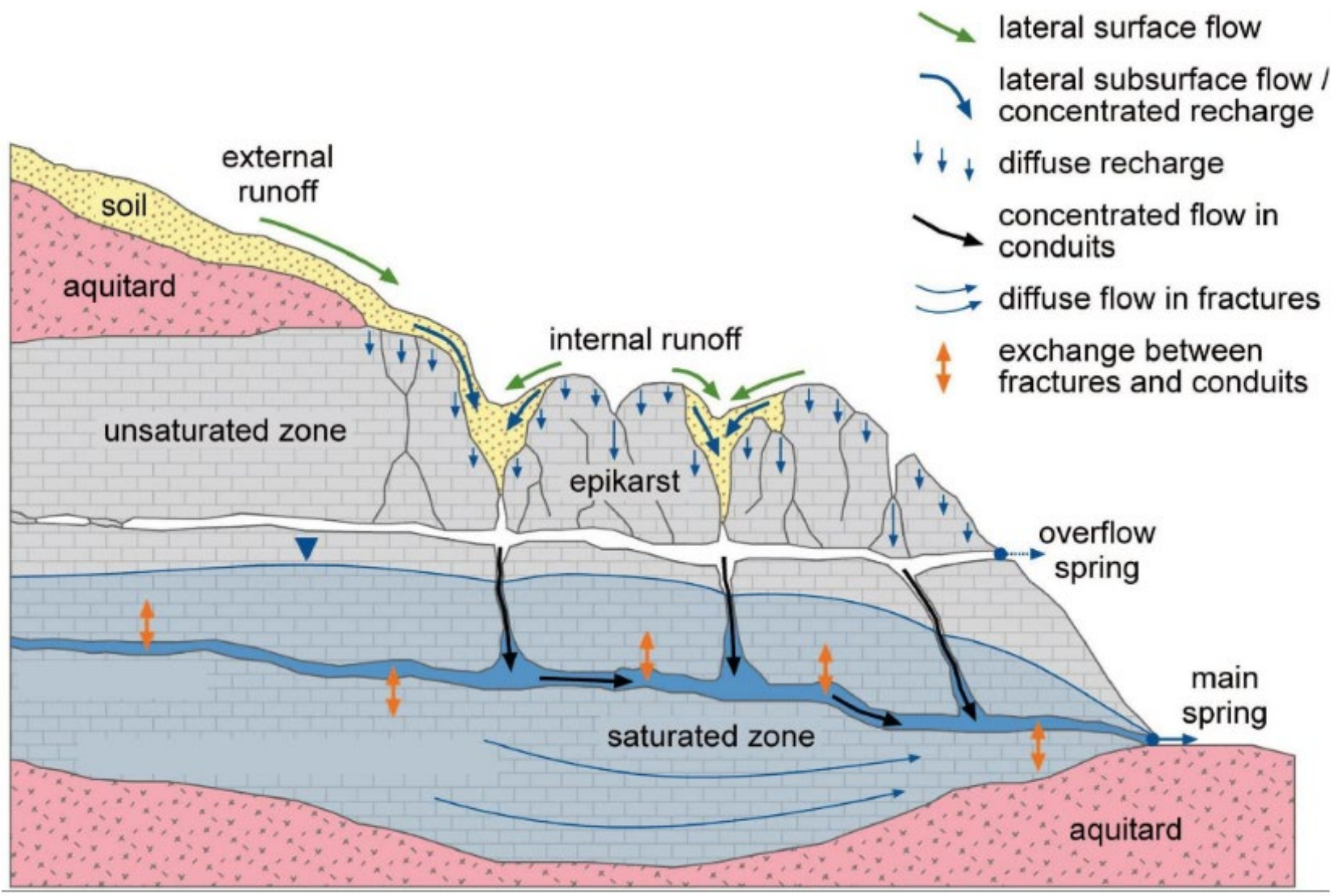


soil moisture groundwater
 © Encyclopædia Britannica, Inc.

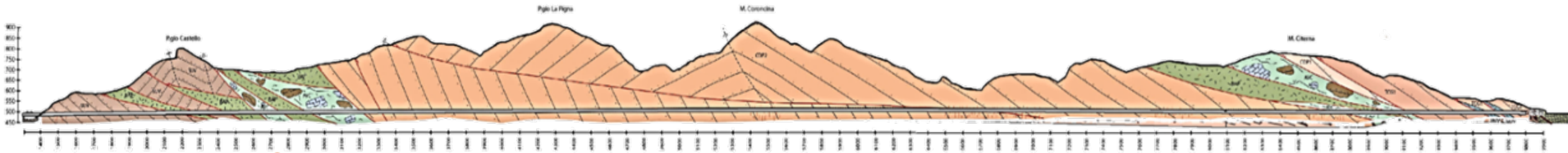
ocean covers 71 percent of Earth's surface
 196,950,000 sq mi (510,000,000 sq km)



Particular Case : Karst areas



Mutual interferences between tunnels/surrounding hydrology/hydrogeology framework



Areas of risks and impacts



Environment

- Impact on the hydrogeology
- Impact on the water table
- Unwanted diversion of water courses



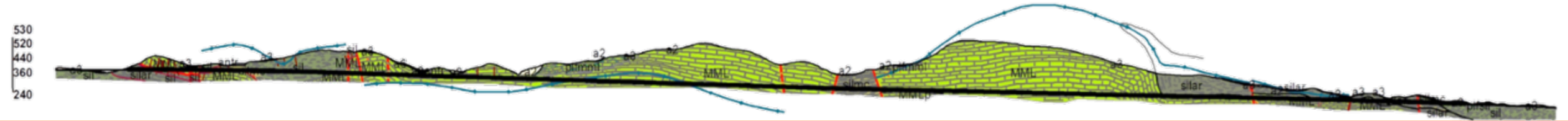
Tunnel

- Infringement with regulation
- Lack of environmental consent
- Delays in construction
- Flooding
- Erosion and corrosion
- Collapsing



Society - Economy

- Accidents and fatalities
- Disruptions of traffic and delays
- Public resistance for various reasons
- Cost and value for money issues



What Is Tunnelling & interference of Water 1/3



The estimated water inflows in these tunnels range from few litres to real underground rivers (more than 3000 l/s).

Water inflows during tunneling can put **safety at risk** and cause irreversible **damages to the natural water** resources.

Construction phases and the long-term operation of a tunnel can be disrupted, resulting in delays and cost overruns and investment reliability.

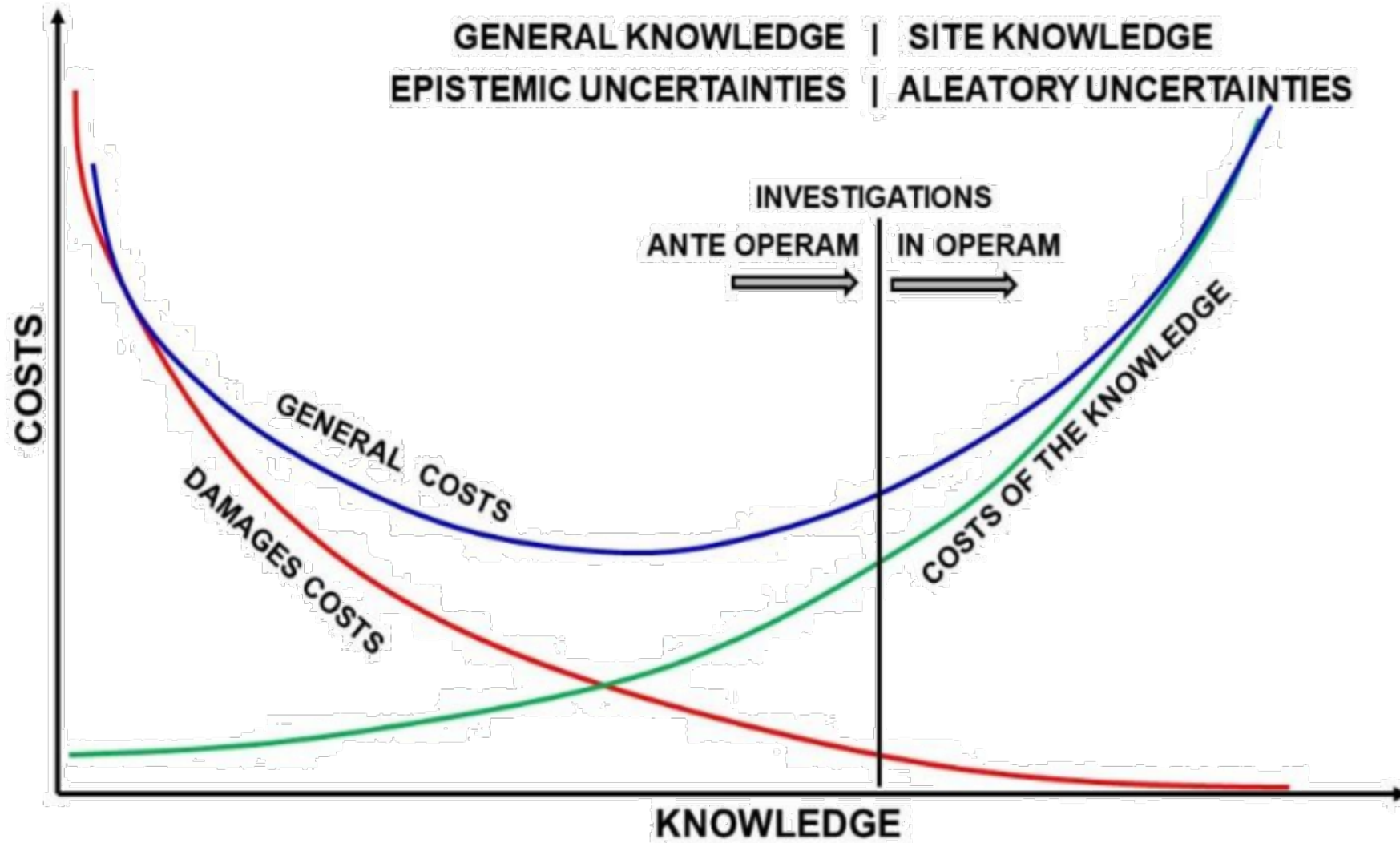
What Is Tunnelling & interference of Water 2/3

DIFFERENCES BETWEEN THE DESIGN OF SURFACE AND UNDERGROUND WORKS



Design	Surface Works	Tunnels and Underground Works
Medium	Predetermined	To be determined
Interaction with Environment	Predetermined	To be determined

What Is Tunnelling & interference of Water 3/3



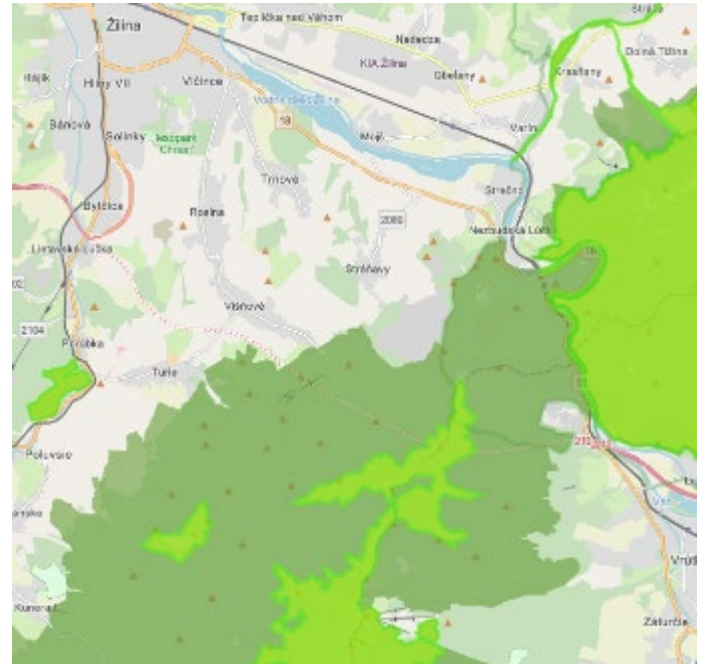
Assessing the hydrogeological status at a very early stage in the project cycle is crucial. With this in mind, JASPERS has adapted an existing methodology called Hydrogeological Excavation Code (HEC) to help Managing Authorities and Beneficiaries to identify and manage hydrogeological risks in tunnels.

The environmental perspective



The environmental directives

Environmental Directives:	Assessments
EIA Directive	Assessment of impacts of projects on the environment
Water Framework Directive (WFD)	Status and objectives for surface and ground- water bodies. River basin management plans (6 years) Assessment of impacts on waterbodies.
Habitats Directive (HD) Birds Directive (BD)	Natura 2000 management plans Site Specific Conservation Objectives (SSCOs) for species (incl. birds) and habitats (biodiversity) Universally, strictly protected biodiversity (Annex IV). Assessment of impacts on species and habitats



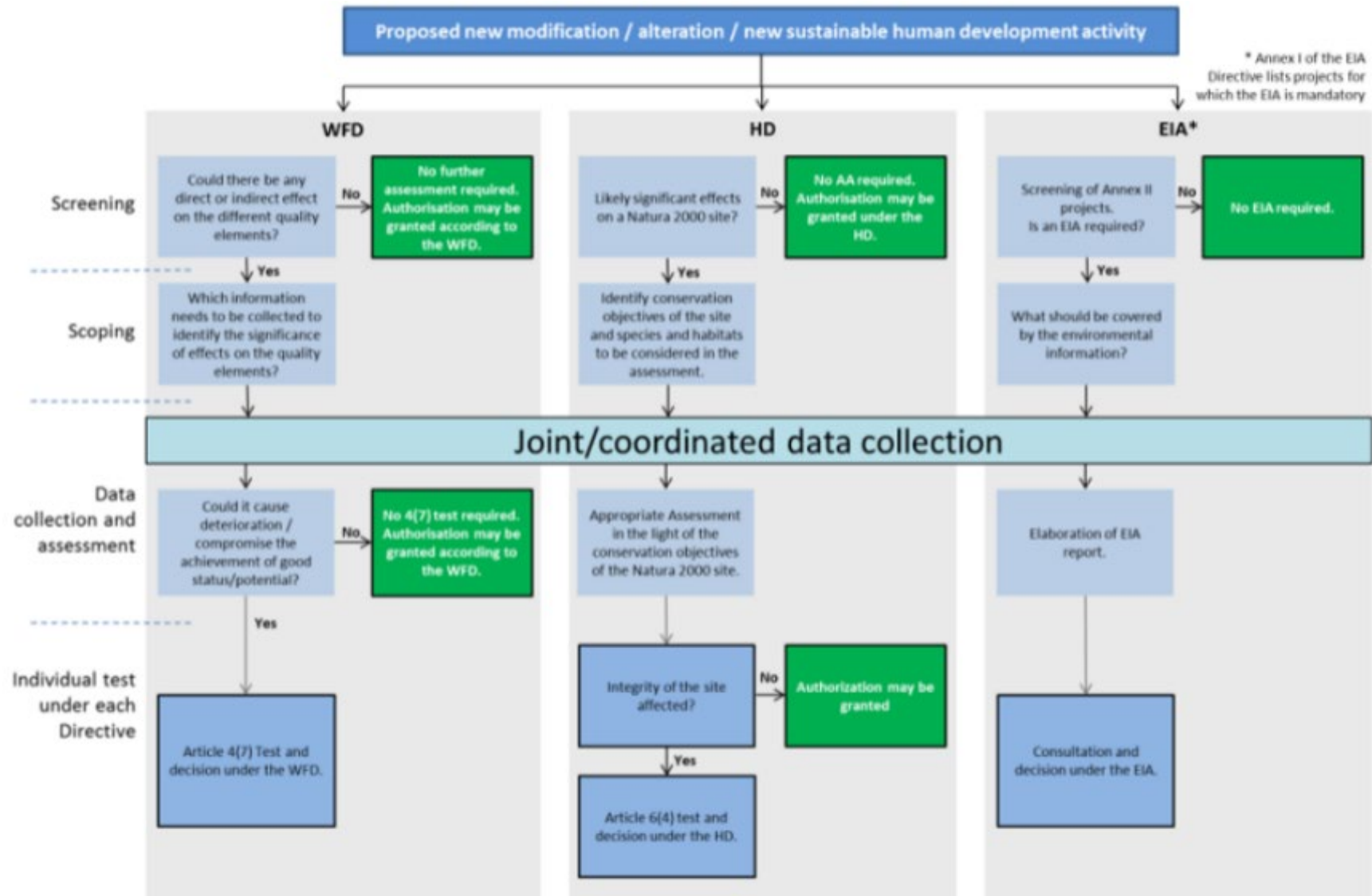
Environmental factors EIA Directive:

The environmental impact assessment shall identify, describe and assess in an appropriate manner, in the light of each individual case, the direct and indirect significant effects of a project on the following factors:

- (a) **population and human health**;
- (b) **biodiversity**, with particular attention to species and habitats protected under Directive 92/43/EEC (HD) and Directive 2009/147/EC (BD);
- (c) **land, soil, water, air and climate**;
- (d) **material assets, cultural heritage and the landscape**;
- (e) the interaction between the factors referred to in points (a) to (d).

2. The effects referred to in paragraph 1 on the factors set out therein shall include the expected effects deriving from the vulnerability of the project to risks of major accidents and/or disasters that are relevant to the project concerned.

Streamlining assessments



Tunnel projects - railways and roads



Tunnel projects (railways and roads)– EIAD

Annex I – Full EIA

7:

(a) Construction of lines for long-distance railway traffic

(b) Construction of motorways and express roads (3);

(c) Construction of a new road of four or more lanes, or realignment and/or widening of an existing road of two lanes or less so as to provide four or more lanes, where such new road or realigned and/or widened section of road would be 10 km or more in a continuous length.

Annex II – Screening for full EIA (Annex III criteria & the precautionary principle)

10:

(c) Construction of railways and intermodal transshipment facilities, and of intermodal terminals (projects not included in Annex I);

(e) Construction of roads, harbours and port installations, including fishing harbours (projects not included in Annex I)

(h) Tramways, elevated and underground railways, suspended lines or similar lines of a particular type, used exclusively or mainly for passenger transport

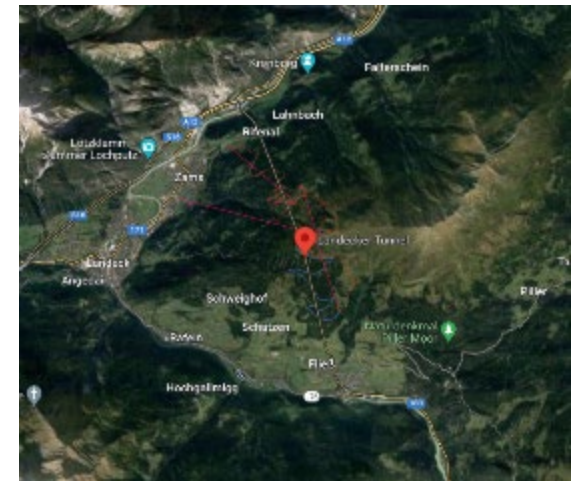
13:

Any change or extension of projects listed in Annex I or this Annex, already authorised, executed or in the process of being executed, which may have significant adverse effects on the environment (change or extension not included in Annex I);

Environmental impacts



- population and human health
- Biodiversity
- land, soil, water, air and climate
- material assets, cultural heritage and the landscape



Assessment flow



+



Environmental factors:

- Population and human health
- Biodiversity (incl. **HD/BD and annex IV species**)
- Land, soil, **water**, air, climate
- Material assets, cultural heritage, landscape
- Risks

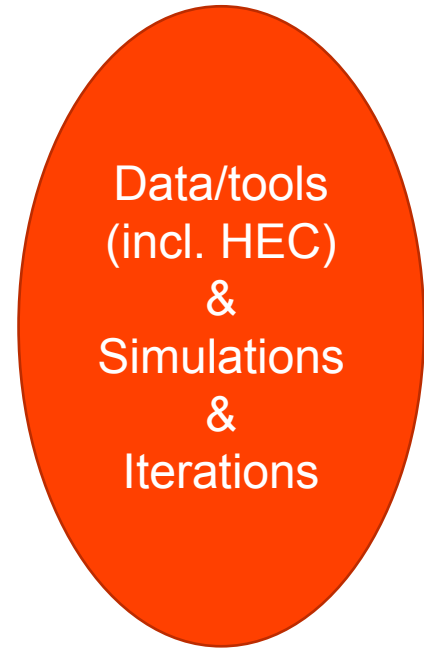
Impact assessments of tunnel projects

Environmental assessments

(Preparatory works + Construction + Operation phases)

- EIAD
- WFD
- HD/BD

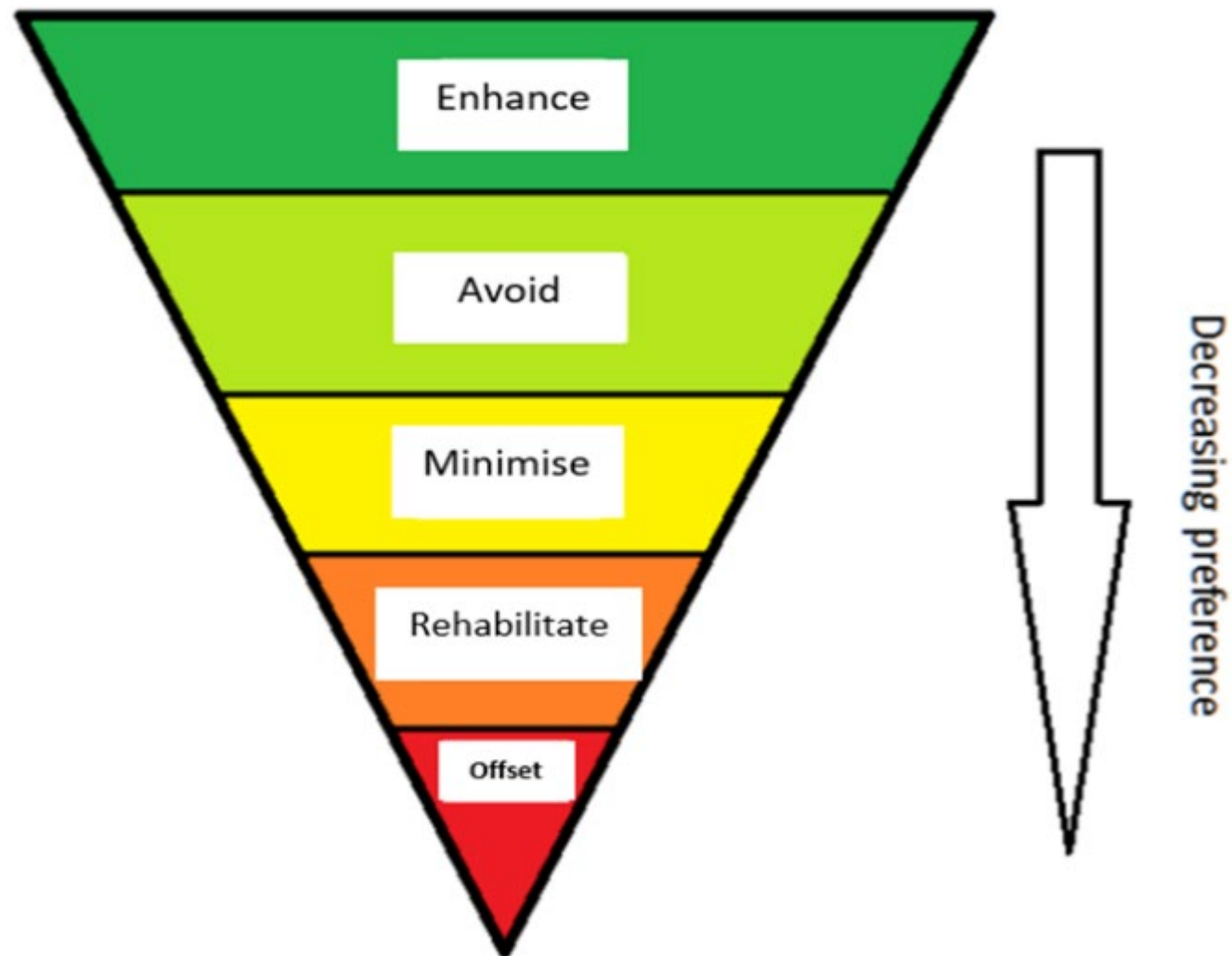
One-stop-shop



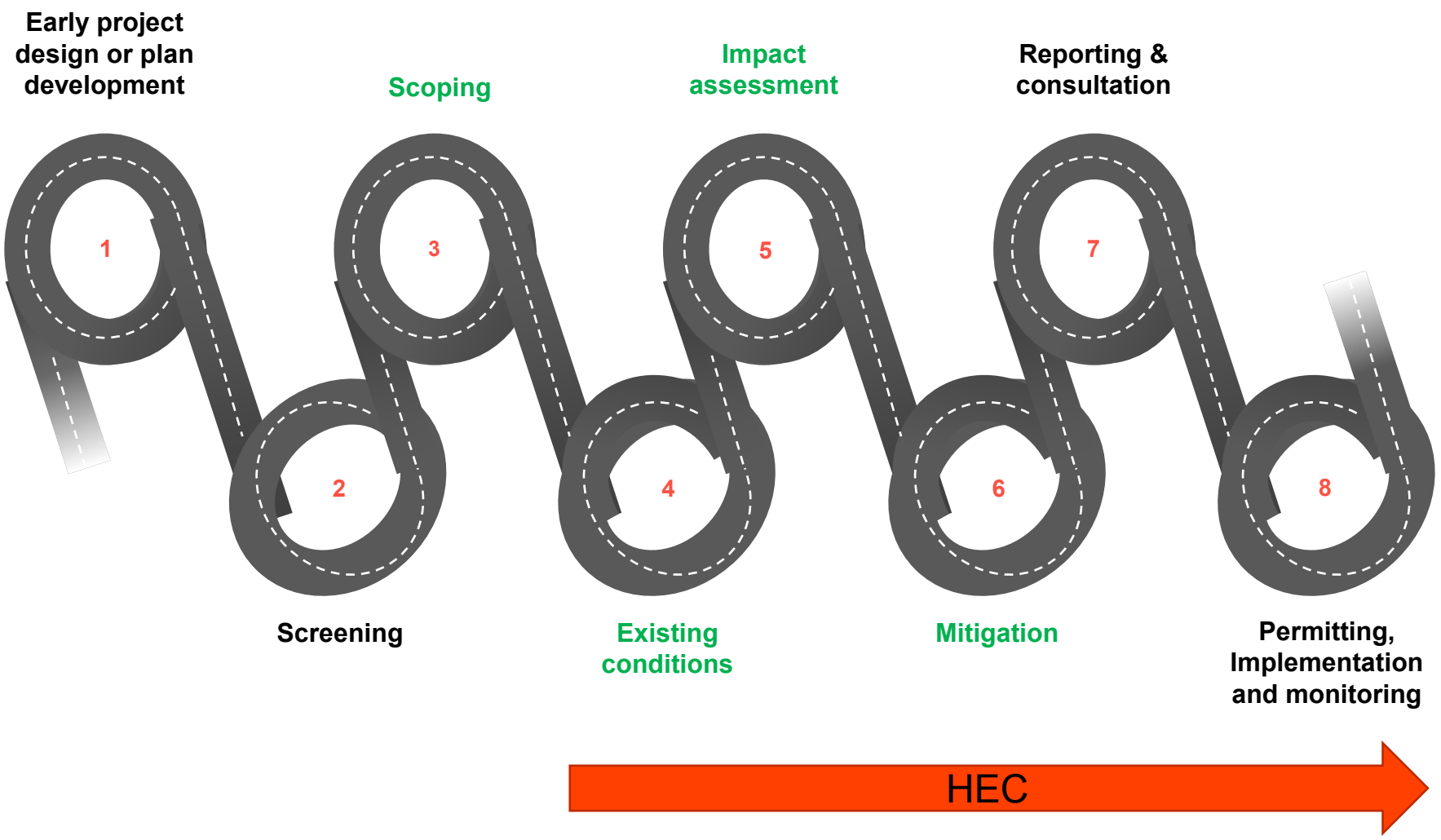
Technical project development

- Initial alternatives/variants
 - Preliminary Design
 - Detailed design
- Construction phase
- Operation phase

Mitigation hierarchy



EIA Process



Water in nature



The water framework directive

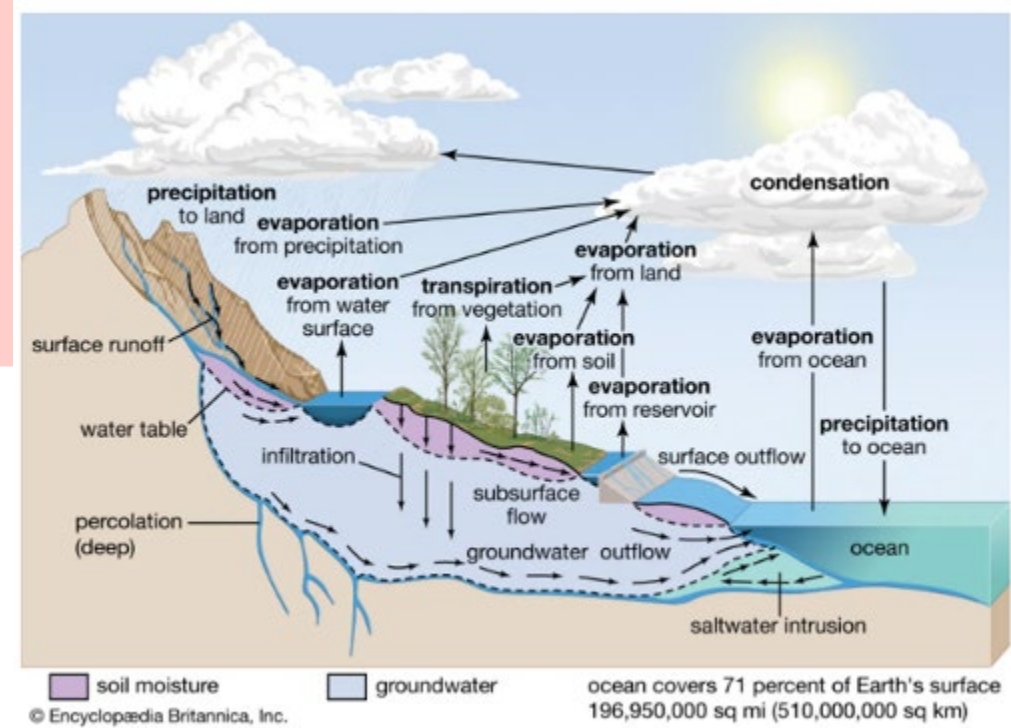
River Basin Management Plans (RBMPs) and Programmes of Measures (PoMs) to protect and restore water bodies (surface and ground) in order to:

- Maintain good status or
- Reach good status and
- Prevent deterioration of status



The water framework directive

Ground water bodies	Surface water bodies
<p>Quantity and quality status and objectives</p> <ul style="list-style-type: none"> • Protection against pollution • Prevent imbalance between use and recharge (quantity) • Maintain or achieve status <p>Awareness on connection to surface waterbodies</p> <p>Awareness on water dependent (protected) biodiversity</p>	<p>Ecological and chemical status and objectives</p> <ul style="list-style-type: none"> • Ecological status (5 classes) <ul style="list-style-type: none"> • Biological elements • Supporting elements • Chemical status <p>Awareness on connection to groundwater bodies</p>



Water Framework Directive in a nutshell

WFD (2000/60/EC): To protect and improve **ground waterbodies** and **surface waterbodies**

Surface waterbodies (SWBs): Rivers, streams, lakes, estuaries, coastal/marine..

SWB status: Biological, hydromorphological, physico-chemical, chemical status

Ground water bodies (GWB)

GWB status: Chemical and quantitative status

Surface water objectives – Ecological and Chemical: One-out-all-out principle

Good Ecological Status (bio., Hydro-morpho., physico-Chem. Spec. poll.)

Good Chemical Status

Good Ecological Potential (HMWB)

Classes: High, good, moderate, poor, bad

Chemical – Phase out Priority hazardous/Reduce priority substances

Status: Good or Bad.

River basin management plan (**RBMP**): Status and objectives, No deterioration or compromising.

Groundwater bodies: Quantity and quality (physical/chemical) objectives

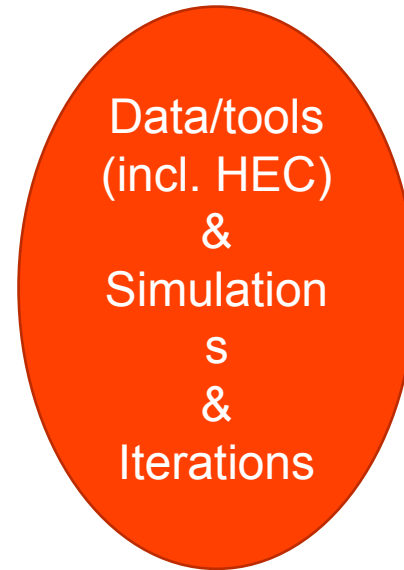
Groundwater example

<p>Starting point: Overall groundwater quantitative status is classified as "good" since each criterion meets the conditions for "good".</p> <p>Effect due to modification: Due to the modification one criterion is expected to deteriorate from "good" to "poor" (in this example due to the damage of a groundwater dependent terrestrial ecosystem), as well as the overall quantitative status, therefore triggering an Article 4(7) test.</p>					
	Criteria				Overall quantitative groundwater status
	1) Available groundwater resource is not exceeded by the long term annual average rate of abstraction	2) No significant diminution of surface water chemistry and/or ecology resulting from anthropogenic water level alteration or change in flow conditions that would lead to failure of relevant Article 4 objectives for any associated surface water bodies	3) No significant damage to groundwater dependent terrestrial ecosystems resulting from an anthropogenic water level alteration;	4) No saline or other intrusions resulting from anthropogenically induced sustained changes in flow direction.	
Starting point	G	G	G	G	G
Effect due to modification	G	G	P	G	P

WFD Assessment: Can the tunnel (construction and operation) affect waterbodies?

Collect information (D.T.S.)

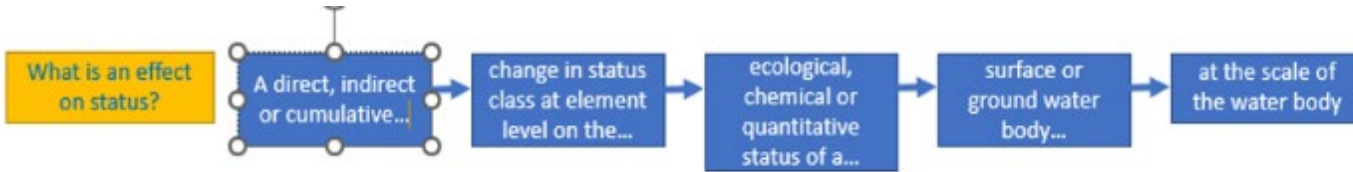
- Project info. incl. how WBs can be affected (GW: quantitatively + chemically; SWB: Surface water runoff, draining...)
- Potentially affected WBs – RBMP 3, 2021 – 2027 (objectives)
- Type, size and scale of WBs
- Natura 2000 & other biodiversity
- Baseline/status – incl. supporting elements
- Possible cumulative impacts



Data collection –studies and modelling (HEC)

- Identification of data need
- Identification of study need
- Planning and conduction of studies
- Assessment of project WB impact
 - Preparatory works
 - Construction works
 - Operation
- Mitigation (**No compensation in WFD**)
- Article 4.7 test requirement?

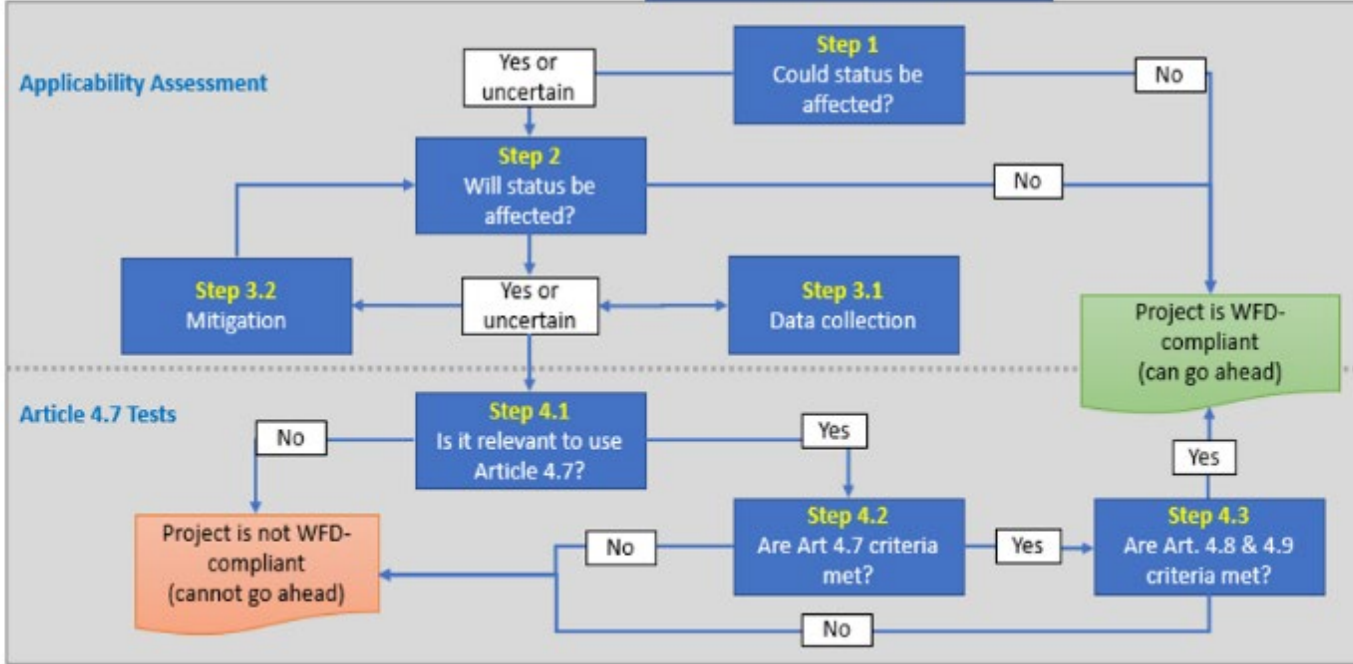
JASPERS WFD **Draft** Checklist tool: Flow chart



Steps to demonstrate WFD compliance

New project

Identify water body and its current status (= the baseline)



Using HEC + ref. to JASPERS checklist tool

Step 1: Without data – the question cannot be answered (precautionary principle) = uncertain

Step 2: HEC needed to answer question

Step 3.1 + 3.2: Iterations/mitigation – based on HEC findings

Step 4.1: If – with all mitigation – some significant negative impacts remain (= residual impact)

Article 4.7 (Derogation): Conditions to be fulfilled for tunnel project authorisation in case the tunnel may deteriorate water body status

All the following conditions must be met:

- (a) all practicable steps are taken to **mitigate** the adverse impact on the status of the body of water;
- (b) the reasons for those modifications or alterations are specifically set out and explained in the **river basin management plan** required under Article 13 and the objectives are reviewed every six years;
- (c) the reasons for those modifications or alterations are of **overriding public interest (IROPI)** and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development, and
- (d) **the beneficial objectives** served by those modifications or alterations of the water body **cannot** for reasons of technical feasibility or disproportionate cost **be achieved by other means**, which are a significantly better environmental option.

JASPERS Checklist tool

- [Water Framework Directive JASPERS Checklist tool.pdf \(eib.org\)](#)

Water Framework Directive Project assessment checklist tool

JASPERS' checklist tool¹

to use when a project² could affect
the **Water Framework Directive (WFD)** status
of a **surface water** body or a
groundwater body

Water Framework Directive JASPERS Checklist tool

July 2018

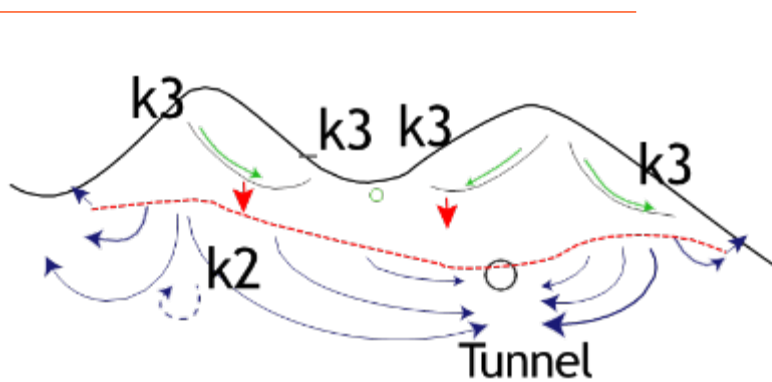


Questions?

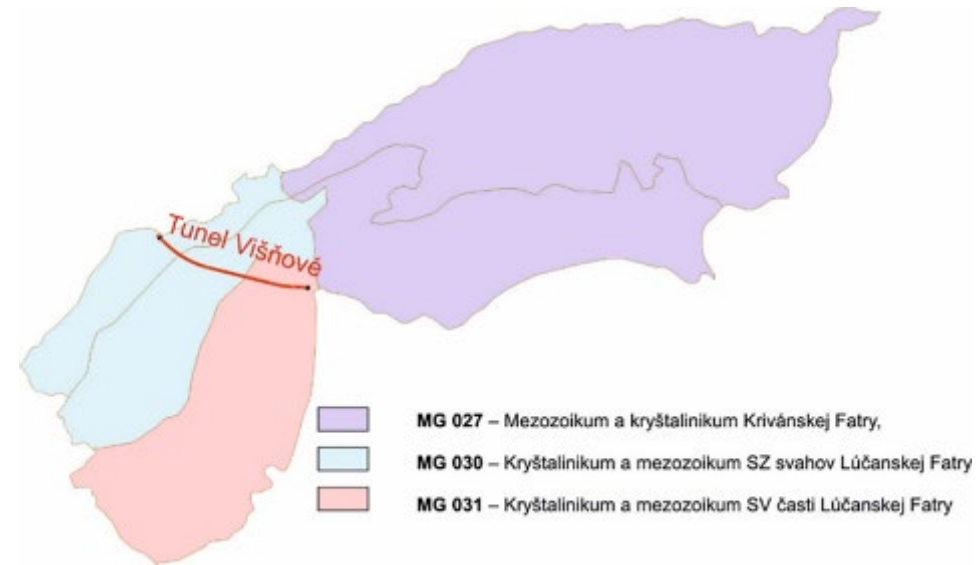
Coffee break!



What is The Hydrogeological Excavation Code (HEC) A 3-pillar protocol



Water table in dotted red:
Permeability $k_2 < k_3$



- MG 027 – Mezozoikum a kryštalinikum Krivánskej Fatry,
- MG 030 – Kryštalinikum a mezozoikum SZ svahov Lúčanskej Fatry
- MG 031 – Kryštalinikum a mezozoikum SV časti Lúčanskej Fatry

Step 1

- Hydrogeological and hydrological Model
- Assessment of the Area of Influence (rivers, springs and streams, water supply management)

Step 2

- Definition of Level of Acceptance, Temporary effects and Permanent effects, Value Engineering
- Assessment of preventive and mitigations measures

Step 3

- Monitoring on ground water levels
- Maintaining/validation of pre-grouting and others preventive measures

Environmental assessments

(Construction + Operation phases)

- WFD
- (EIAD)
- (HD/BD)

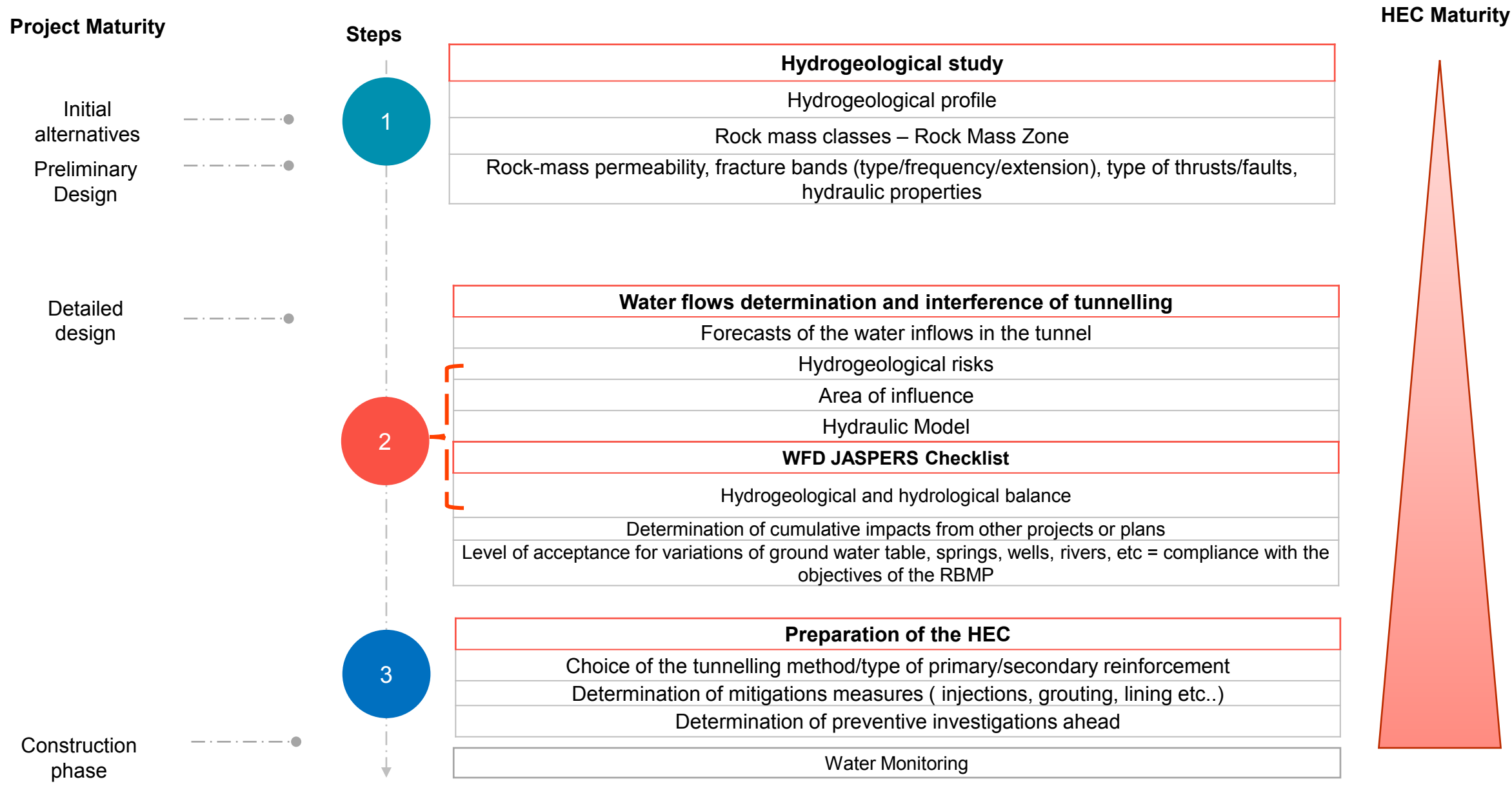
One-stop-shop



HEC

- Step 1- Hydrogeological and hydrological Model
- Step 2 -Definition of Level of Acceptance, Temporary effects and Permanent effects, Value Engineering
- Step 3 – Monitoring and Preventive Measures

HEC Process - Detailed activities – Project Maturity



Flow of the HEC – Objectives of each phases

Recommended Process of Detailed Objectives

01

Hydrogeological model

02

Level of acceptance Vs Value for Money

03

Assessment of Compliance with the WFD/RBMP

04

HEC – Mitigation Measures

05

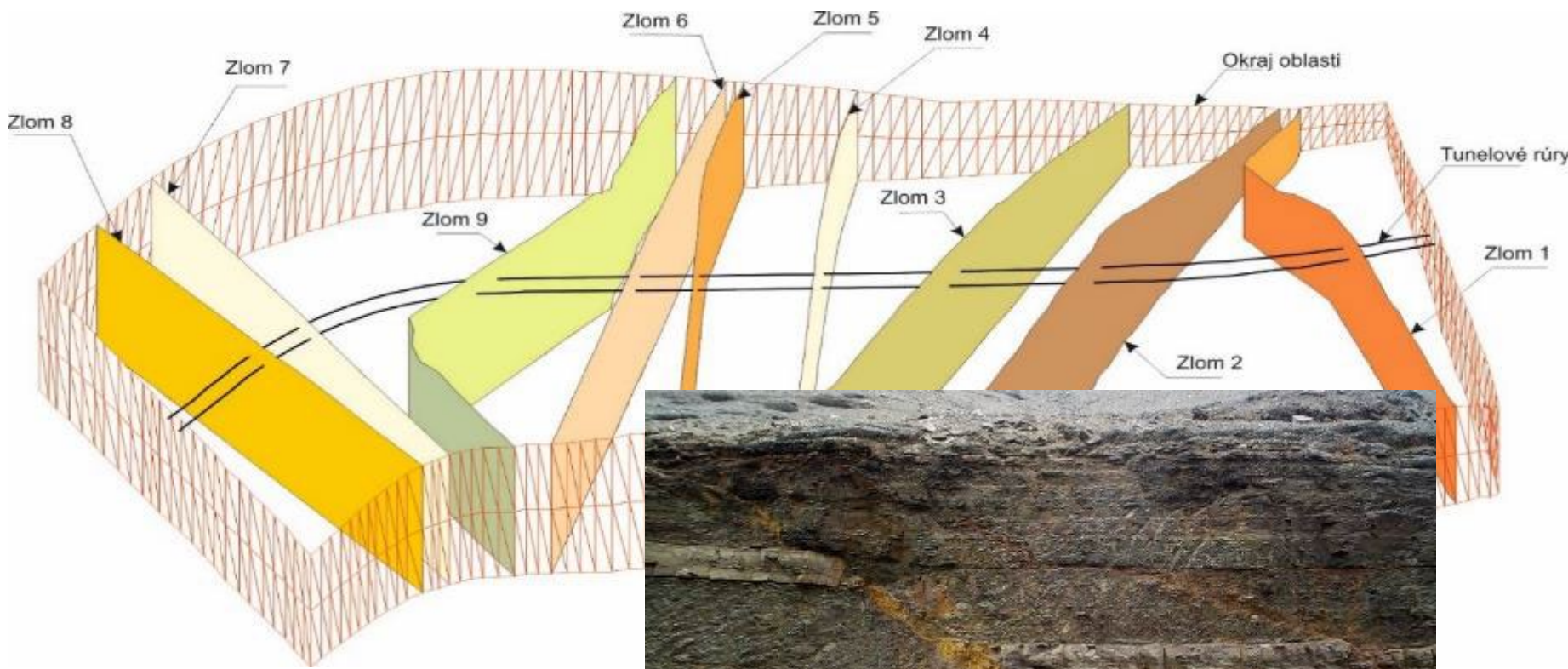
Water monitoring during works implementation

06

Validation of the HEC model

STEP 1 Hydrogeological Model

Assessment of Faulted zones & relationship at the Tunnel Axis

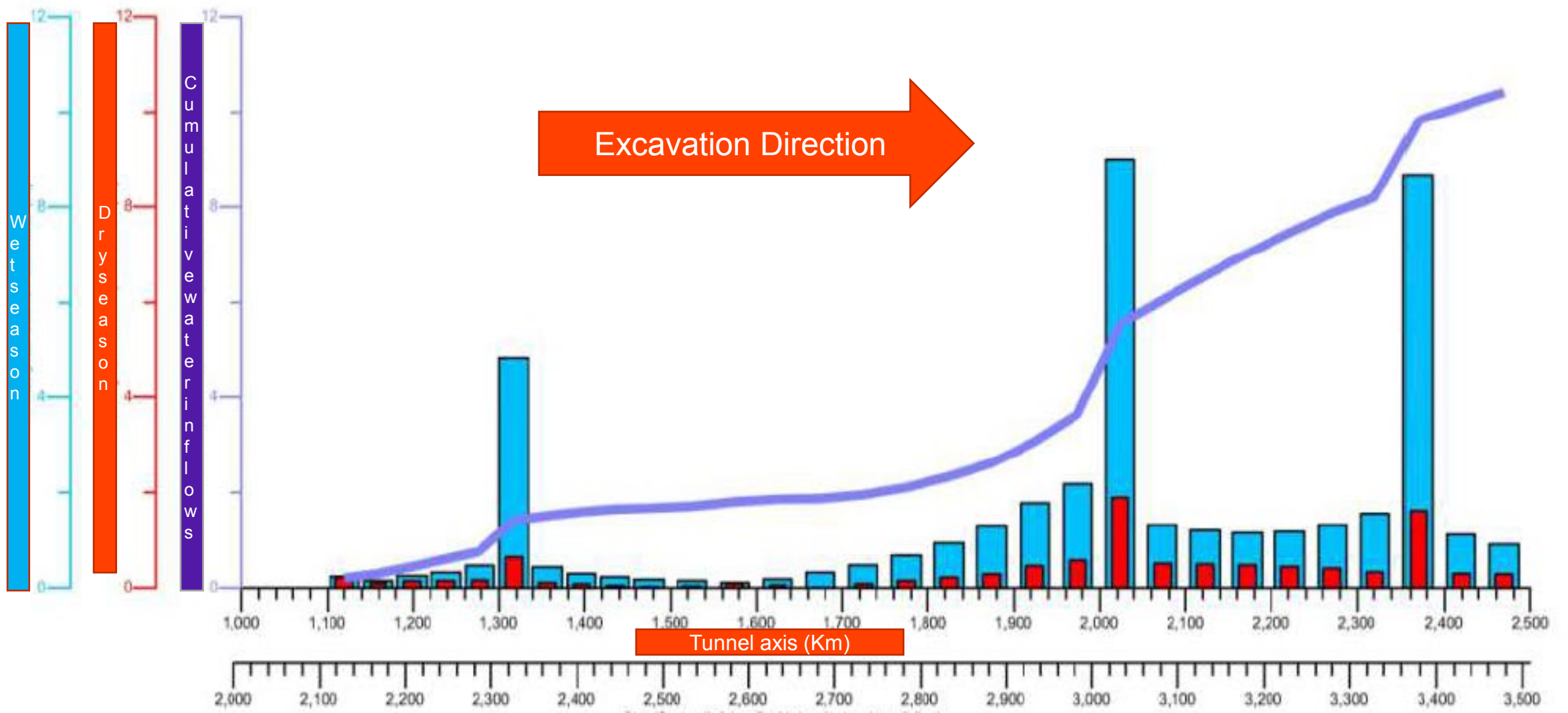


Tunnels axis



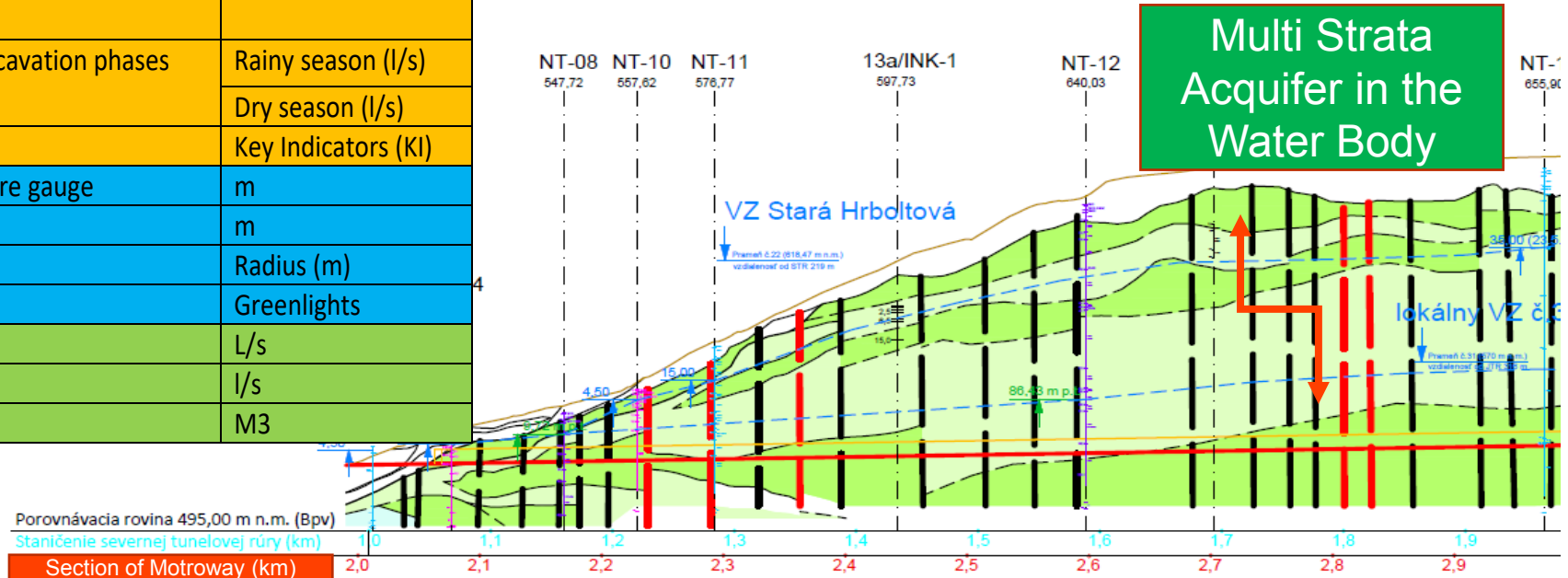
Thickness of the faults zones is around 5-15 m.

STEP 2: Assessment of water inflows

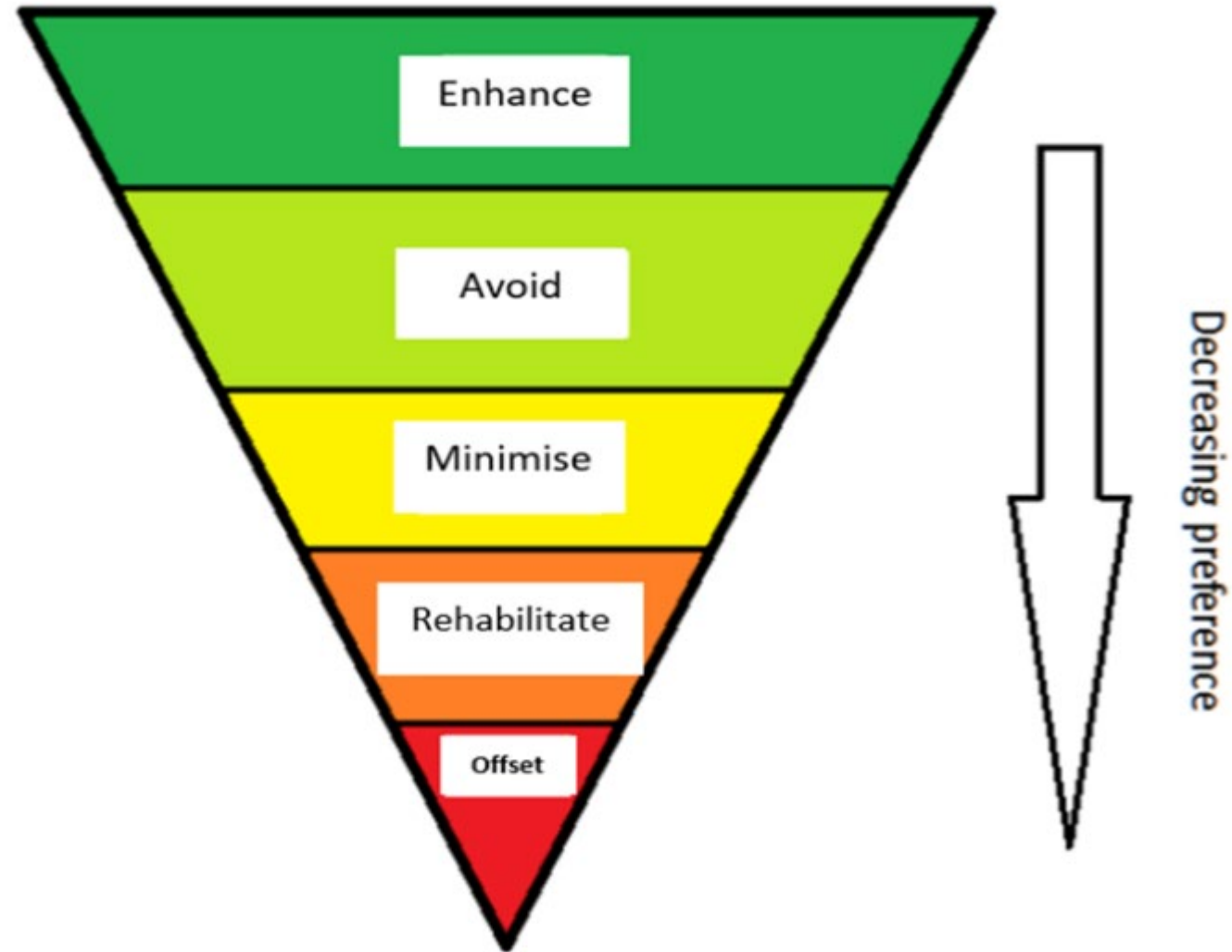


STEP 3 HEC – PROFILE

Chainage of the Tunnel		Km
Chainage of the Project		Km
DATA	Type of Permeability	Primary, Cracks...
	Hydrogeological Homogenous Units which can create significant damage to the groundwater available resources	Greenlight system
	Assumed Water Inflows during excavation phases	Rainy season (l/s)
		Dry season (l/s)
Probability of Karstic structures	Key Indicators (KI)	
Mitigation Measures	Execution of Pre-drills with pressure gauge	m
	Implementation of Georadar	m
	forecasted injections @ radial	Radius (m)
	Risk of high hydrostatic Pressure	Greenlights
Monitoring	Water inflows	L/s
	Streams, Springs	l/s
	Basins	M3

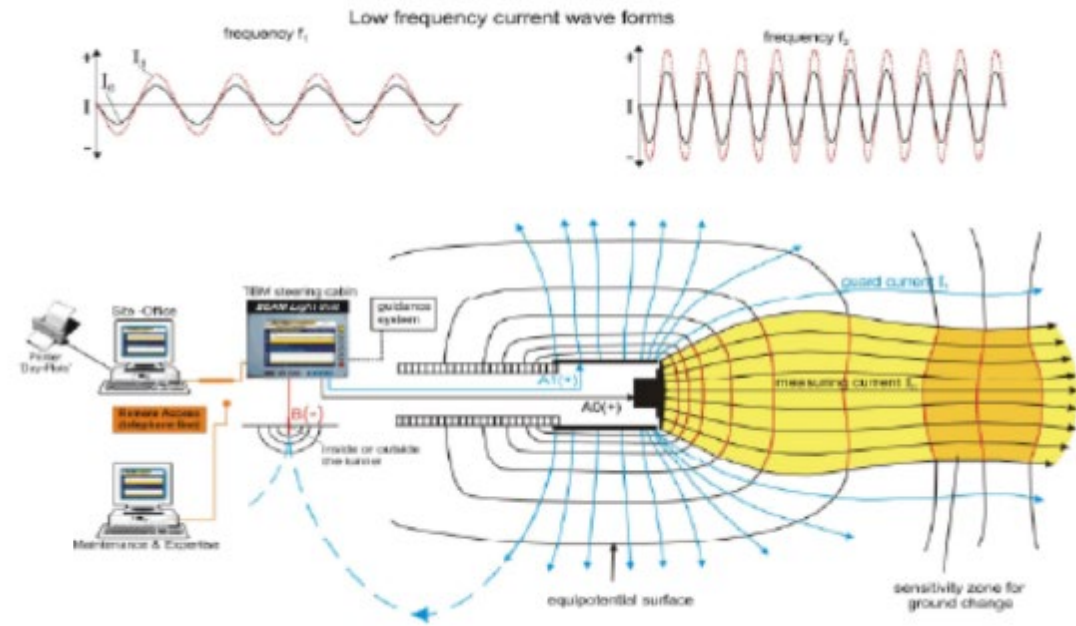
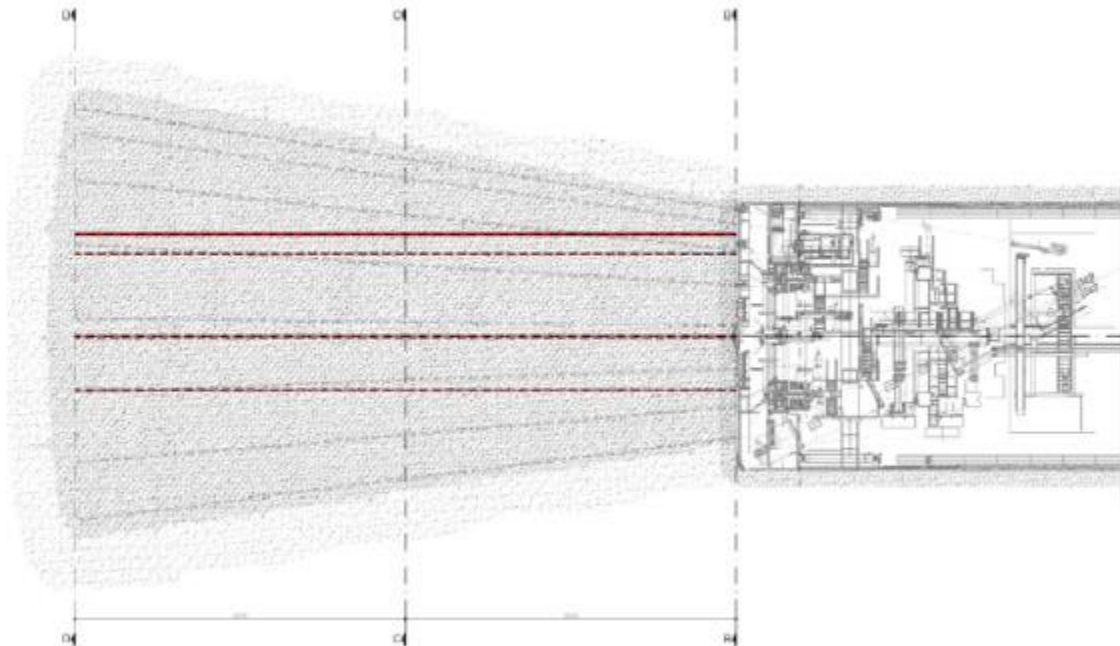


Mitigation hierarchy

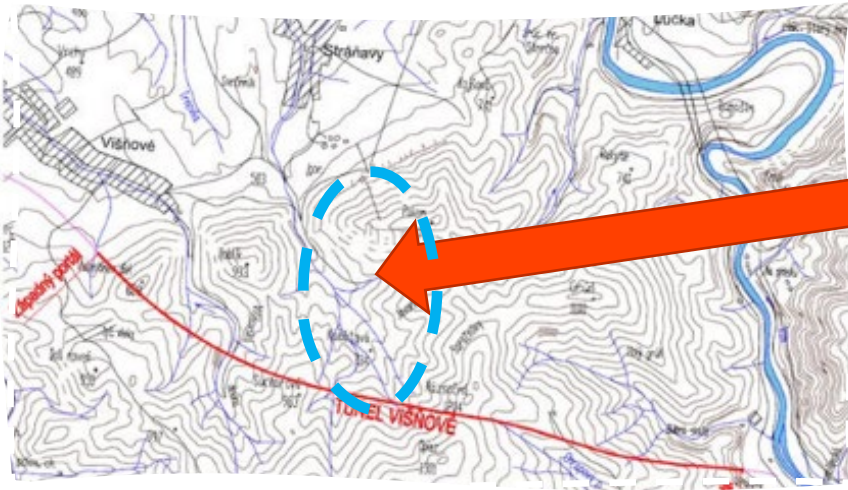


Mitigation measures – ex. by-pass Genoa

GALLERIE NATURALI		
CODICE DI SCAVO AI FINI IDROGEOLOGICI		
GALLERIE A OVEST DEL TORRENTE POLCEVERA REALIZZATE CON SCAVO MECCANIZZATO		
<p>I. RESPONSABILE PROGETTAZIONE SPECIALE SCAVA</p> <p>Ing. Andrea Tenzel Ord. Ingg. Parma N. 11154 RESPONSABILE UNICO TUN</p>	<p>II. RESPONSABILE INTEGRAZIONE PRESTAZIONI SPECIALISTICHE</p> <p>Ing. Orlando Motta Ord. Ingg. Pavia N. 1495 RESPONSABILE AREA DI PROGETTO GENOVA</p>	<p>III. DIRETTORE TECNICO</p> <p>Ing. Maurizio Torrali Ord. Ingg. Milano N. 16492 RESPONSABILE DIREZIONE DTP</p>

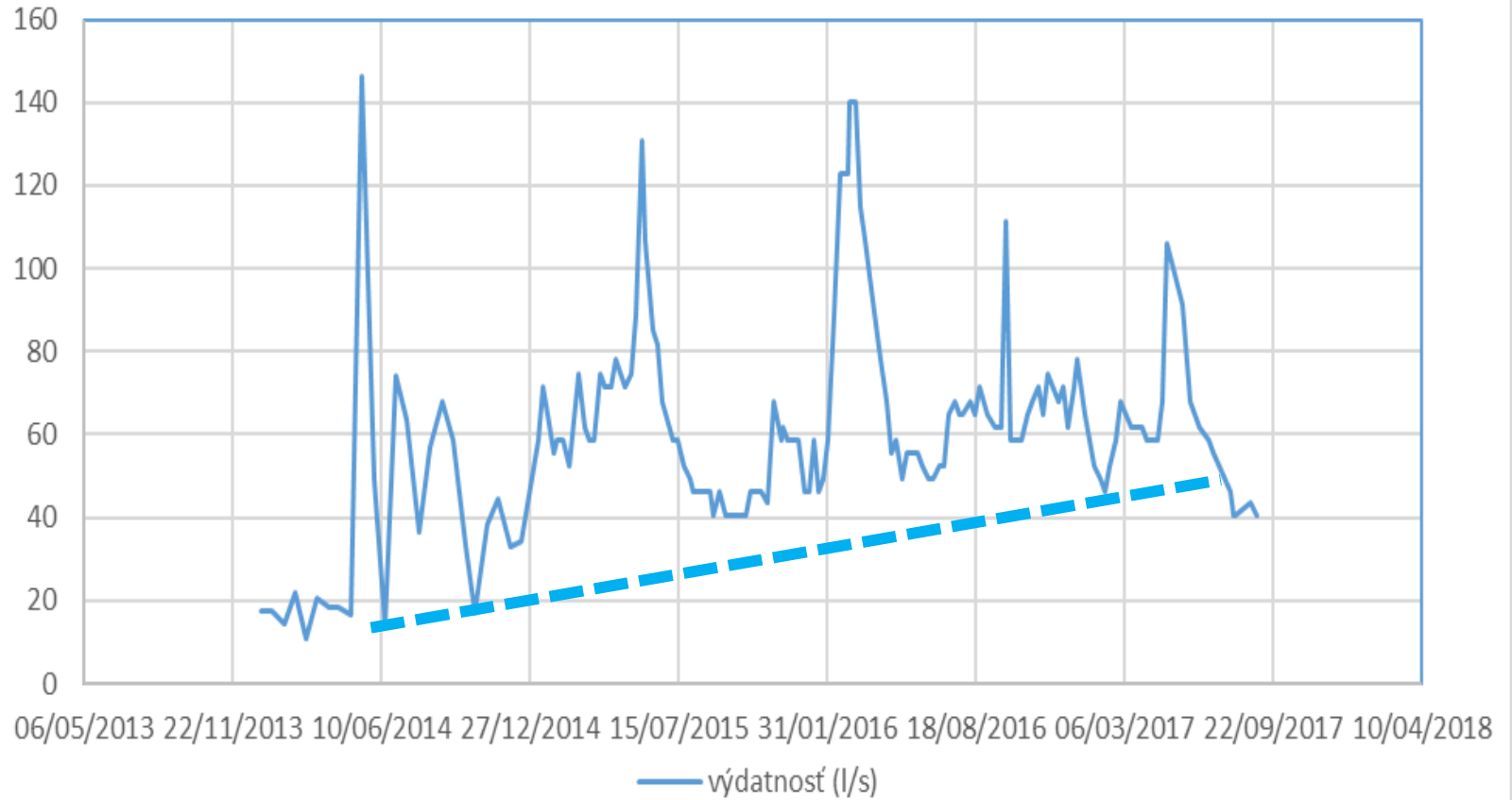


Examples of Water Monitoring



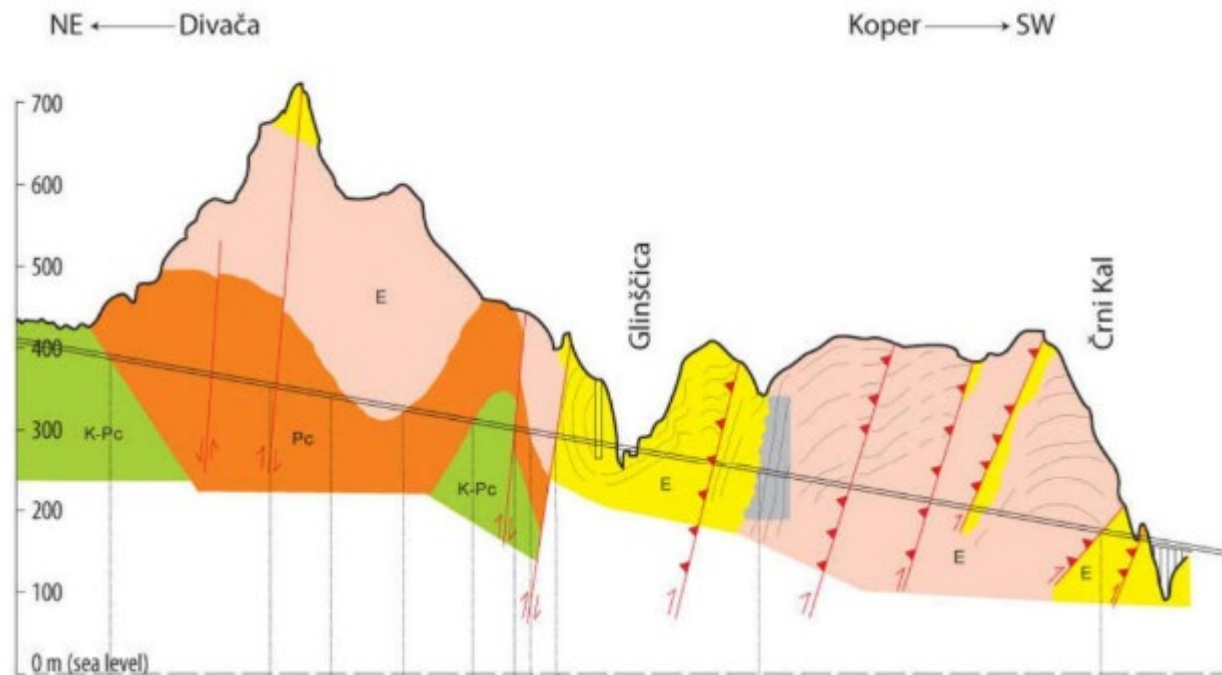
What if the quantity drop?
 What could it mean?
 What to do?

Capacity in l/s of the Stranavsky stream



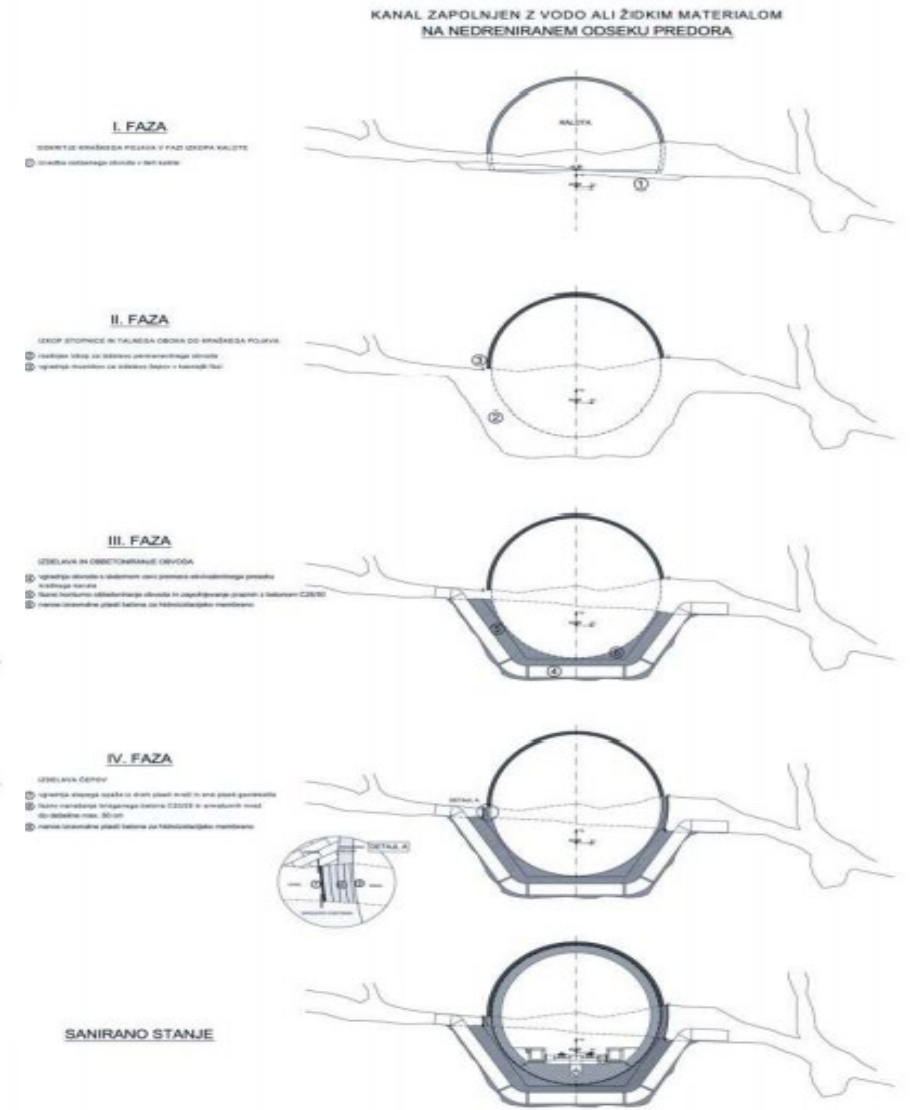
Karst Management Excavation Code – Scenarios Approach - Introduction

In difficult circumstances such as Karst geology.

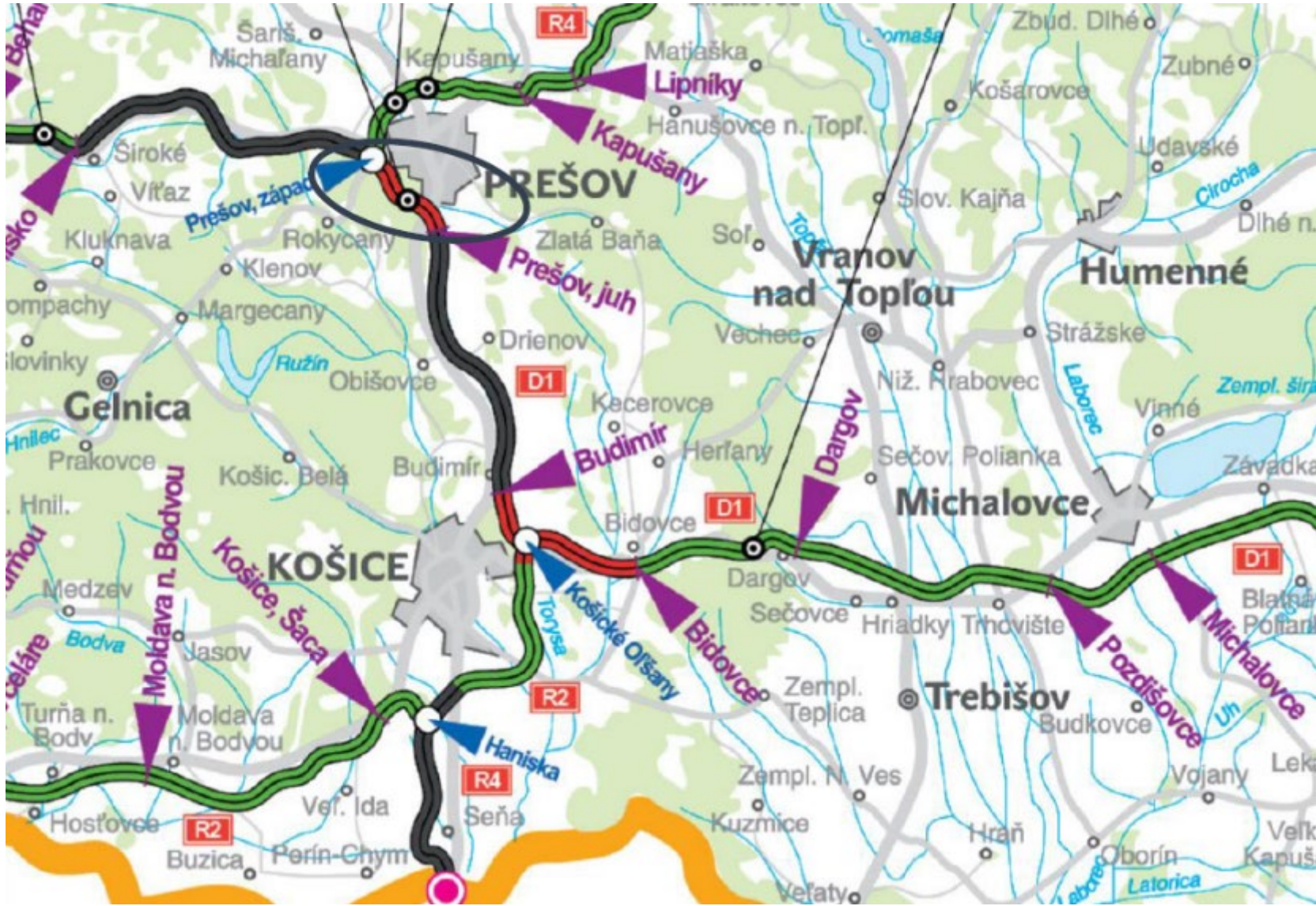


	A	B	C	D	E	F	G	H	I	J	K	
1	5-10	<5	<5	<10	<5	<10	<5	<10	<1	5-10	<5	
2	>10	<5	<5	<5	<5	<10	<5	<5	<1	<10	<1	
3												

Section 1
 Density of expected parts of the caves (on km) 2
 Diameter of expected parts of the caves (m) 3



Case: Tunnel on D1 west of Presov

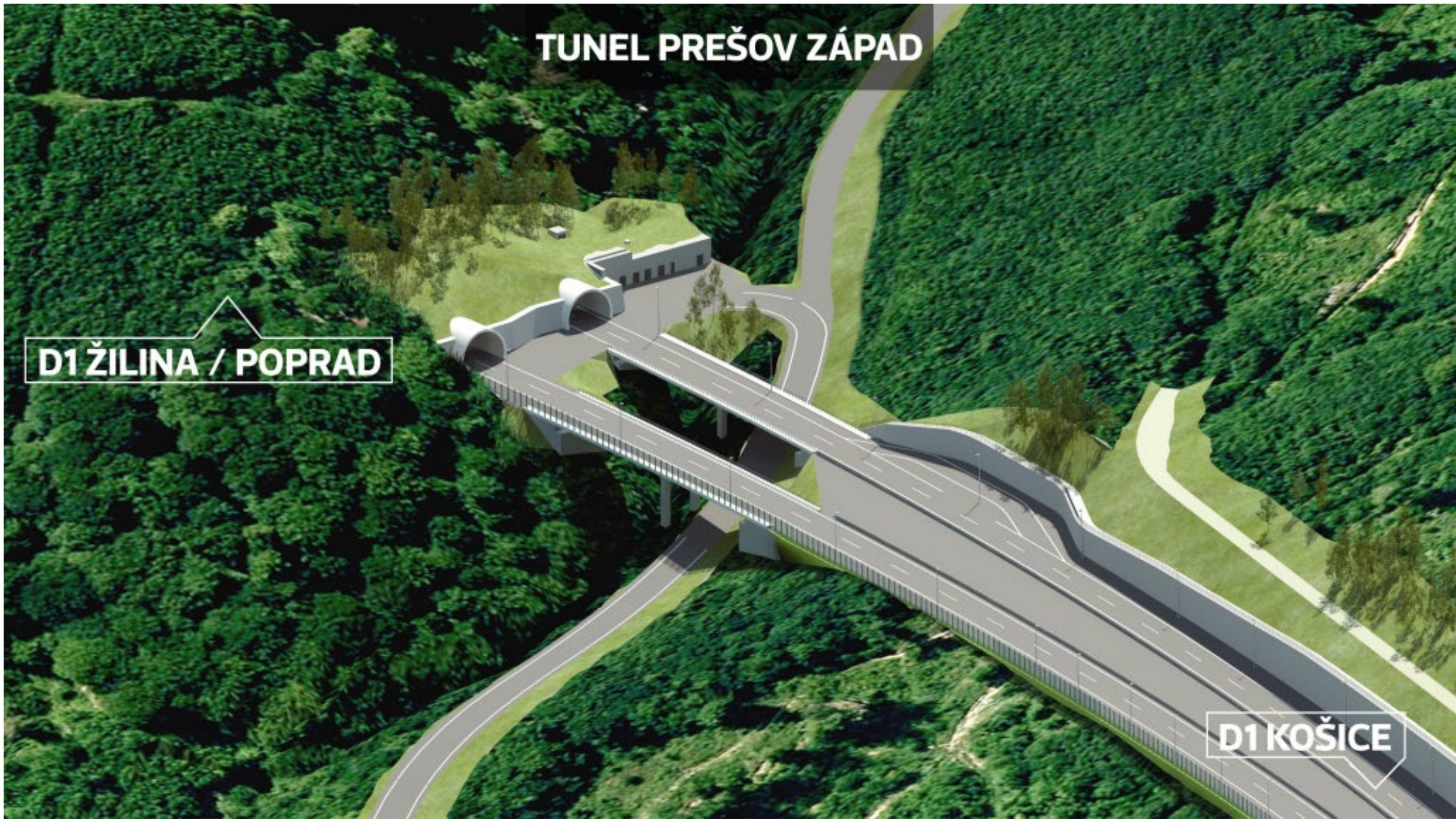


- 7.8 km motorway
- 2.2 km twin tube tunnel

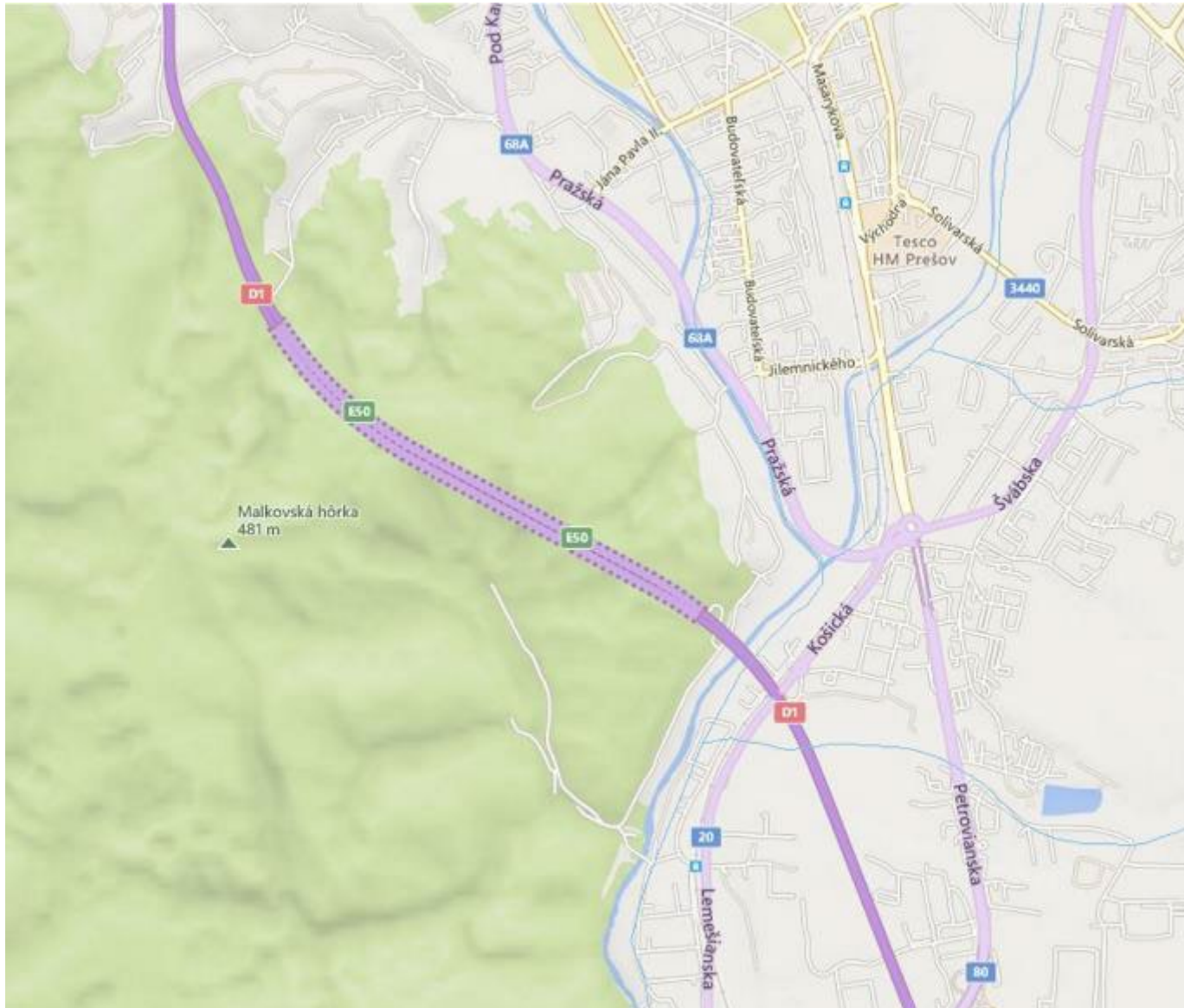
TUNEL PREŠOV ZÁPAD

D1 ŽILINA / POPRAD

D1 KOŠICE



Presov tunnel (assuming sign. impacts for ill.)



Tunnel characteristics:

- 2244 m long
- 2 twin tubes
- Construction methodology: D&B - NATM

Potentially impacted waterbodies:

3 Surface water bodies

- SKH0016 Torysa,
- SKH0017 Torysa,
- SKH0046 Delňa

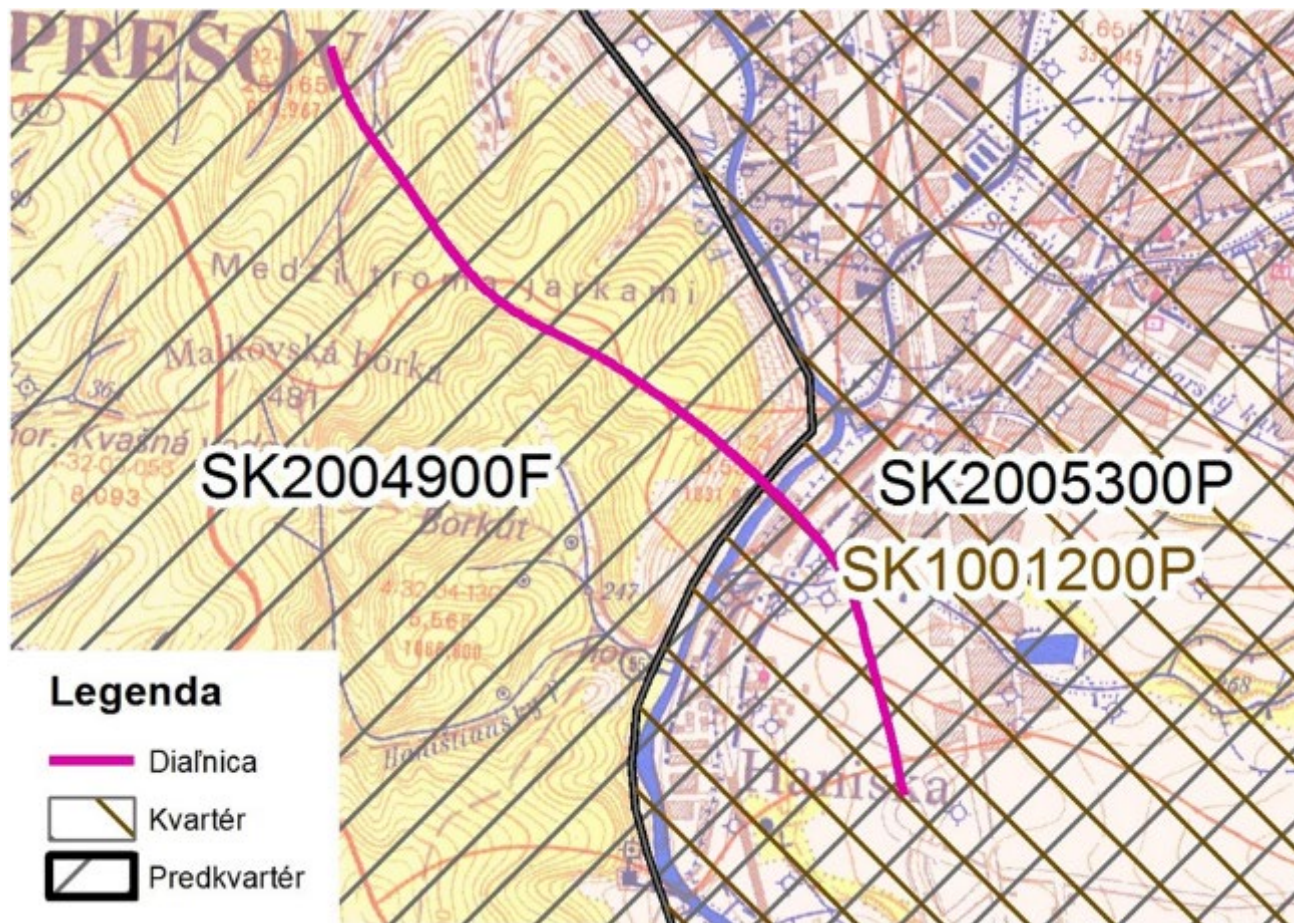
1 Groundwater body

- SK2004900F

Potentially impacted elements (EIA)

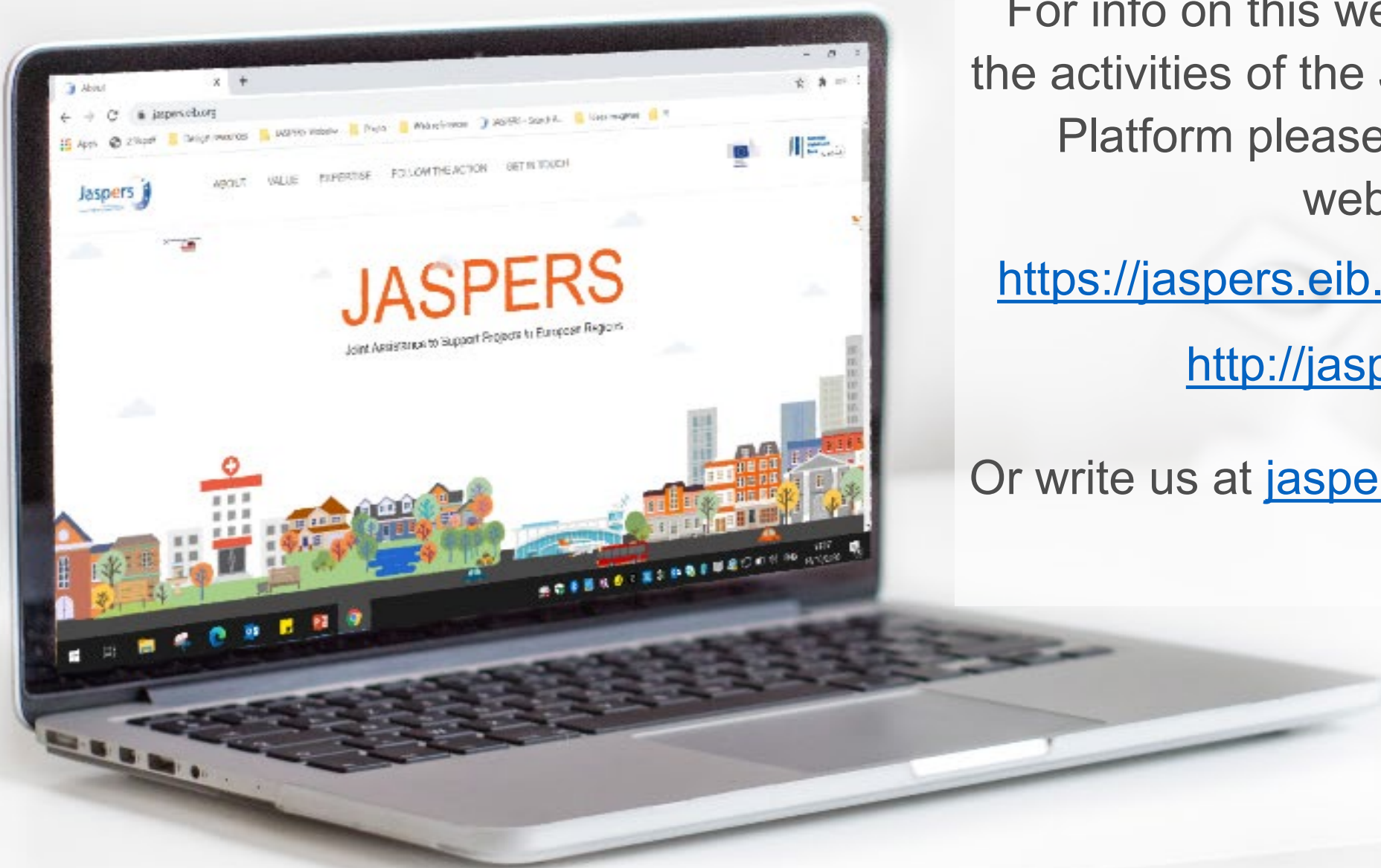
- Natura 2000
- Nationally protected elements a.o.
- Annex IV species

Waterbodies – Baseline/status



Slovak RBMP 3 (May 2022) – sub plan Hornád:

- **Baseline/status:**
 - **Surface WB: Chemical + ecological** (incl. supporting elements - hydromorphological and physico-chemical)
 - SKH0016Torysa (Moderate ecological + good) Chemical condition
 - SKH0017Torysa (Bad ecological + good chemical condition)
 - **Ground waterbody: Chemical + quantity**
 - SK2004900F: Good quantitative and Good chemical status
- **Objectives:**
 - Surface WBs: Good ecological + Good chemical
 - Ground waterbody
- **Programme of Measures (PoM)**



For info on this webinar and details on the activities of the JASPERS Networking Platform please visit the following websites::

<https://jaspers.eib.org/knowledge/index>

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