



Brownfield decommissioning and Landfill  
soil remediation case studies  
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# REDEVELOPMENT OF A RAILWAY AREA WITH BURIED COAL SLAG

UGO BACCHIEGA (BBT SE BRENNER BASITUNNEL)

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Fazilität „Connecting Europe“  
Cofinanziato dall'Unione europea  
Meccanismo per collegare l'Europa



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# THE CONTEST



The **Brenner Base Tunnel (BBT)** is the heart of the **Scandinavia-Mediterranean TEN Corridor** from Helsinki (Finland) to La Valletta (Malta), constituting a main step target in the European transport policy.

## SCAN-MED CORRIDOR

**9.300 km Corridor length**

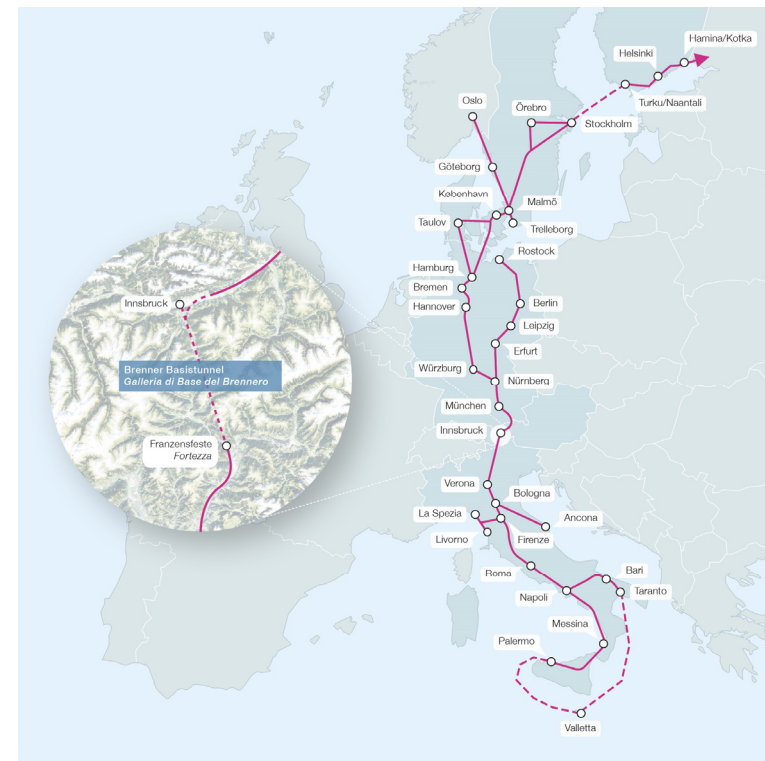
**7 States**

**110 Mio./mln people**

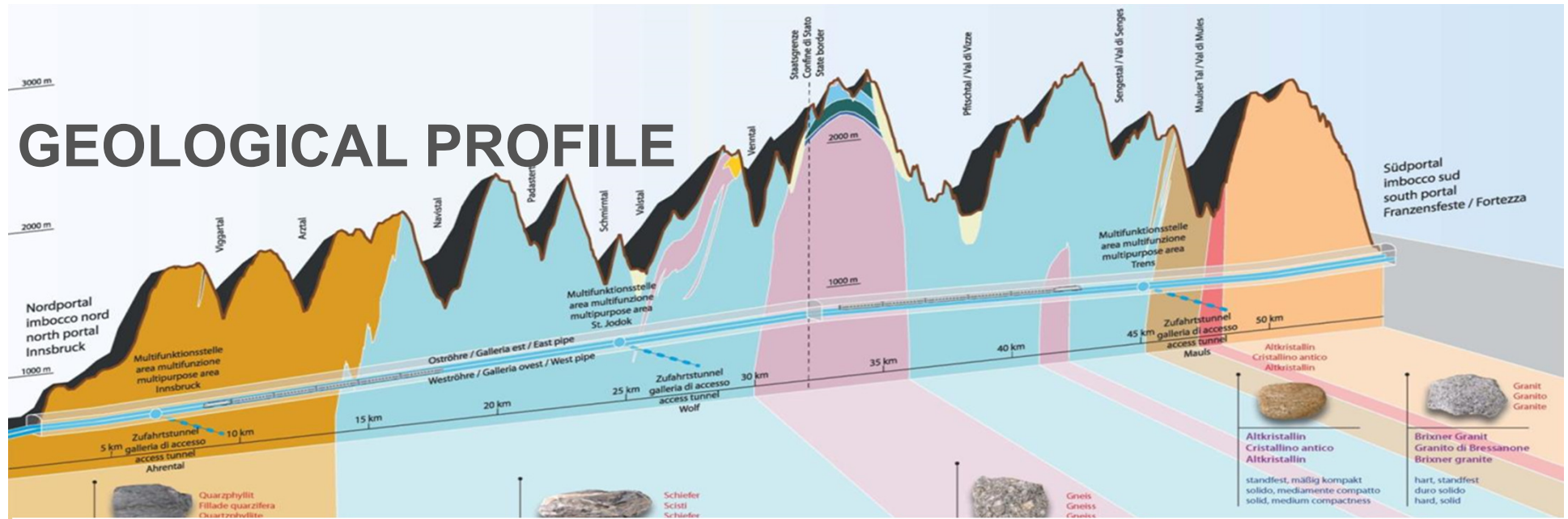
**BBT**

**64 km Tunnel length**

**2 States**

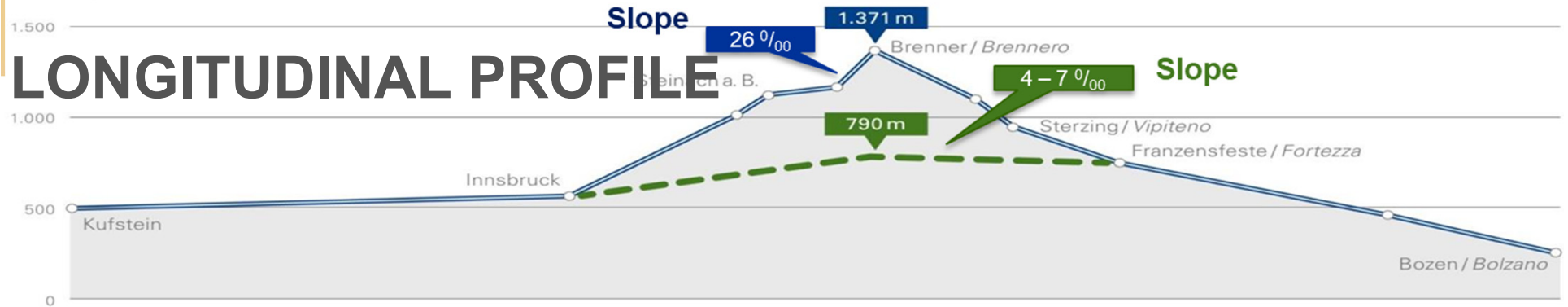


# GEOLOGICAL PROFILE



Höhe (m ü. d. M.)  
altitudine (m s.l.m.)

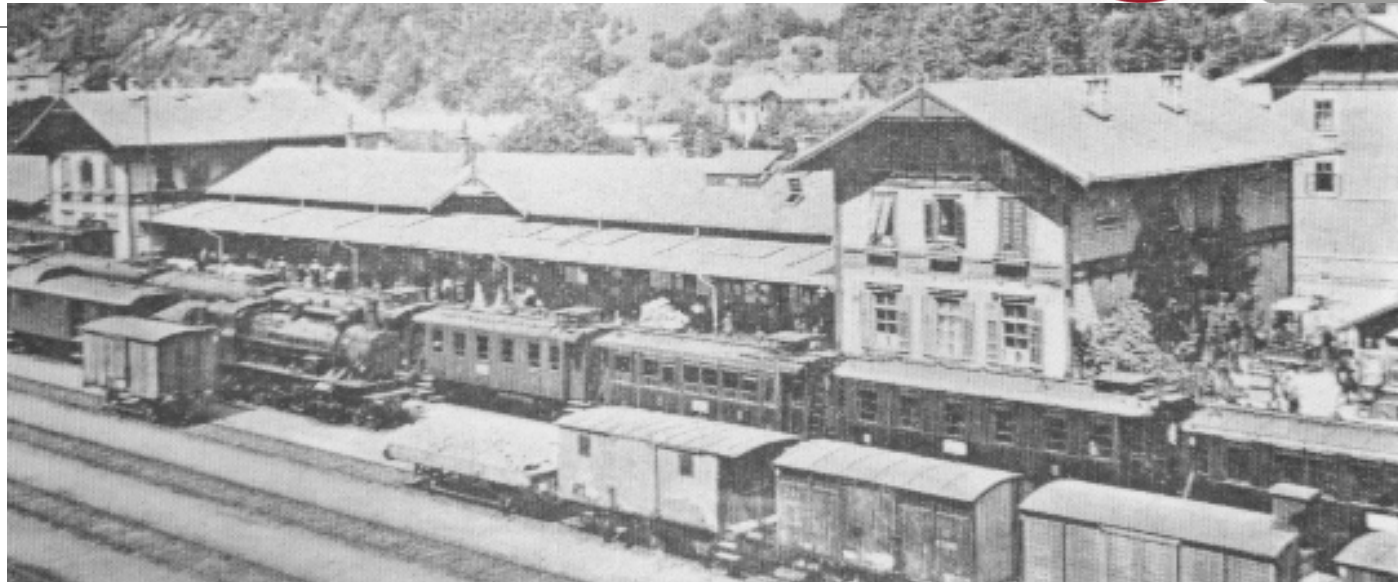
# LONGITUDINAL PROFILE



# SITE DESCRIPTION

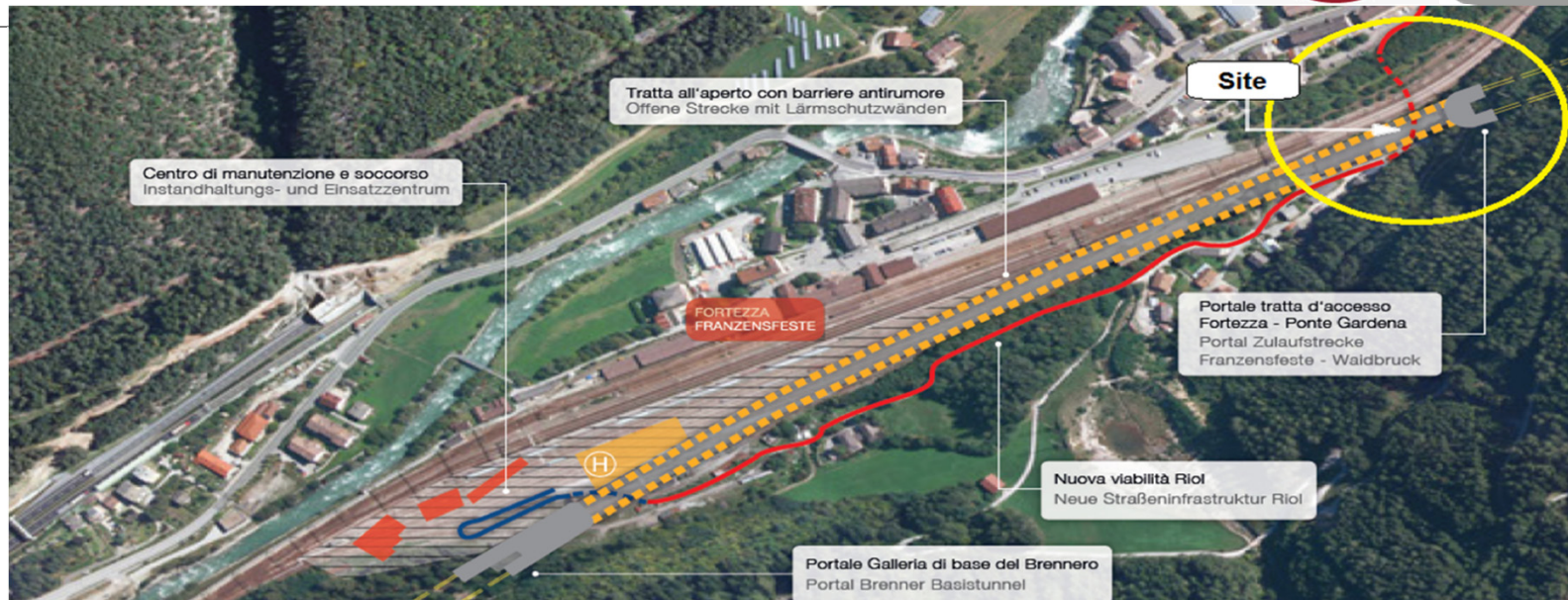


The case study considers the active railway area of **Fortezza** in the province of Bolzano, in Italy.



The **railway area** of Fortezza was built in the second half of the 1800s on the Brenner line. Over the years it was also intended to carry out maintenance activities on the steam locomotives that were operational until the 1970s. It underwent an intense bombing on April 20<sup>th</sup> 1945 and was a station of border controls until the Shenghen Agreement. Currently, only seven railway tracks are active.

# SITE DESCRIPTION



At the railway embankment, an underpass of the current carriageway is planned, due to the new viability required by the Brenner Base Tunnel (BBT) works. During construction works, debris flow terrains modelled with **large quantities of waste (coal residues mixed with partially vitrified slag)**, mainly due to the former maintenance activities of steam locomotives, have been found below demolished buildings.

# REGULATION

These waste (coal slag) are configured as historical carryovers prior to the Italian Decree 915/82, excluded from waste/landfill abandon.

Among the soil management, two hypotheses were considered:

1. **Soil remediation**<sup>1</sup> by transfer to landfill: par. p) art. 240 Decree 152/06;
2. **MISP**<sup>2</sup> by construction of a green barrier wall: par. o) art. 240 Decree 152/06.

In order to define the materials as inerts for backfilling, the absence of risk for environment contamination and for human health was verified through a **site-specific Risk Assessment** (185, c.1, letter b) and c) Decree 152/06).



1 par. p) «bonifica: l'insieme degli interventi atti ad eliminare le fonti di inquinamento e le sostanze inquinanti o a ridurre le concentrazioni delle stesse presenti nel suolo, nel sottosuolo e nelle acque sotterranee ad un livello uguale o inferiore ai valori delle concentrazioni soglia di rischio (CSR).



2 par. o) "Messa in Sicurezza Permanente: l'insieme degli interventi atti a isolare in modo definitivo le fonti inquinanti rispetto alle matrici ambientali circostanti e a garantire un elevato e definitivo livello di sicurezza per le persone e per l'ambiente. In tali casi devono essere previsti piani di monitoraggio e controllo e limitazioni d'uso rispetto alle previsioni degli strumenti urbanistici".

# GEOLOGICAL AND ENVIRONMENTAL SURVEYS



The underground of the area has been characterized by soil borings, monitoring wells, trench, geophysical surveys and chemical analysis for:

- **Soil** (Provincial Decree 1072/05, Decree 152/06 Annex 5, Part IV, Tab.1-B)

Composti inorganici: Antimonio, Arsenico, Berillio, Cadmio, Cobalto, Cromo totale, Cromo VI, Mercurio, Nichel, Piombo, Rame, Selenio, Stagno, Tallio, Vanadio, Zinco.

Composti aromatici: Benzene, Etilbenzene, Stirene, Toluene, (m+p) - xilene, o - Xilen, Xilene, Solventi organici aromatici, Composti policiclici aromatici, Benzo(A)Antracene, Benzo(A)Pirene, Benzo(B)Fluorantene, Benzo(K)Fluorantene, Benzo(G,H,I)Perilene, Crisene, Dibenzo(A,E)Pirene, Dibenzo(A,H)Pirene, Dibenzo(A,L)Pirene, Dibenzo(A,I)Pirene, Dibenzo(A,H)Antrace, Indeno(1,2,3 Cd)Pirene, Pirene, IPA totali

Nitrobenzeni: Nitrobenzene, 1,2 - Dinitrobenzene, 1,3 - Dinitrobenzen, Cloronitrobenzeni.

Composti alifatici clorurati: Clorometano, Diclorometano, Triclorometano (Cloroformio), Cloruro di vinile, 1,2-Dicloroetano, 1,1-Dicloroetilene, Tricloroetilene, Tetracloroetilene, cis+trans 1,2-dicloroetene, 1,1,1-Tricloroetano, 1,2-dicloropropano, 1,1,2-Tricloroetano, 1,2,3-Tricloropropano, 1,1,2,2 Tetracloroetano.

Idrocarburi: Idroc. L. 5>C<=C12, Idroc. P. C>12.

Amianto.

- **Groundwater** (Provincial Decree 1072/05, Decree 152/06 Annex 5, Parte IV, Tab.A)

Composti inorganici: Arsenico, Cadmio, Cromo totale, Cromo VI, Ferro, Mercurio, Nichel, Piombo, Rame, manganese, Zinco.

Composti aromatici: Benzene, Etilbenzene, Stirene, Toluene, p-xilene.

Composti policiclici aromatici: Benzo(A)Antracene, Benzo(A)Pirene, Benzo(B)Fluorantene, Benzo(K)Fluorantene, Benzo(G,H,I)Perilene, Crisene, Dibenzo(A,H)Antracene, Indeno(1,2,3 Cd)Pirene, Pirene, IPA totali.

Composti alifatici clorurati: Clorometano, Diclorometano, Triclorometano (Cloroformio), Cloruro di vinile, 1,2-Dicloroetano, 1,1-Dicloroetilene, Tricloroetilene, Tetracloroetilene, Esaclorobutadiene, 1,1-Dicloroetano, 1,2-dicloroetilene, 1,2-dicloropropano, 1,1,2-Tricloroetano, 1,2,3-Tricloropropano, 1,1,2,2 Tetracloroetano, sommatoria organoalogenati.

# GEOLOGICAL AND ENVIRONMENTAL SURVEYS



- **Waste** (Provincial Decree 1072/05, Decree 152/06 Annex 5, Part IV, Tab.2, Decree 27.09.10, Decree 5.02.98)

Composti inorganici: Antimonio, Arsenico, Berillio, Cadmio, Cobalto, Cromo totale, Cromo VI, Mercurio, Nichel, Piombo, Rame, Selenio, Stagno, Tallio, Vanadio, Zinco.

Composti aromatici: Bario, Benzene, Etilbenzene, Stirene, Toluene, (m+p) - xilene, o - Xilene, Xilene, Solventi organici aromatici.

Composti policiclici aromatici: Antracene, Benzo(A)Antracene, Benzo(A)Pirene, Benzo(B)Fluorantene, Benzo(K)Fluorantene, Benzo(G,H,I)Perilene, Crisene, Dibenzo(A,E)Pirene, Dibenzo(A,H)Pirene, Dibenzo(A,L)Pirene, Dibenzo(A,I)Pirene, Dibenzo(A,H)Antracene, Indeno(1,2,3 Cd)Pirene, Pirene, Perilene.

Nitrobenzeni: Nitrobenzene, 1,2 - Dinitrobenzene, 1,3 - Dinitrobenzene, Cloronitrobenzeni, idrocarburi: Idrocarburi Leggeri  $5 < C \leq C_{12}$ , Idrocarburi pesanti  $C > 12$  (come sommatoria da C13 a C40).

Amianto, Solidi totali (Residuo a 105°C), Solidi totali (Residuo da 40 °C a 105°C), Nitriti, Fluoruri, Solfati, Cloruri, Fenoli, Cianuri, COD, Idrocarburi totali.

- **Geotechnical parameters**

Physical, volumetric and mechanical strength parameters: Contenuto in acqua - UNI CEN ISO/TS 17892-1, Determinazione massa volumica - UNI CEN ISO/TS 17892-2, Analisi Granulometrica per vagliatura su terre - UNI CEN ISO/TS 17892-4, Determinazione Limite Liquido e Limite Plastico UNI CEN ISO/TS 17892-12, Peso specifico dei grani - UNI CEN ISO/TS 17892-3, Classificazione UNI 11531-1, Determinazione contenuto in solfati solubili in acido - UNI EN 1744-1, Prova di costipamento Proctor Modificata-UNI EN 13286-2.

- **Geophysical parameters**

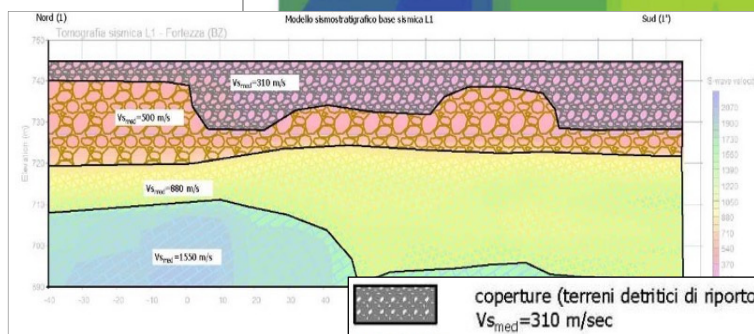
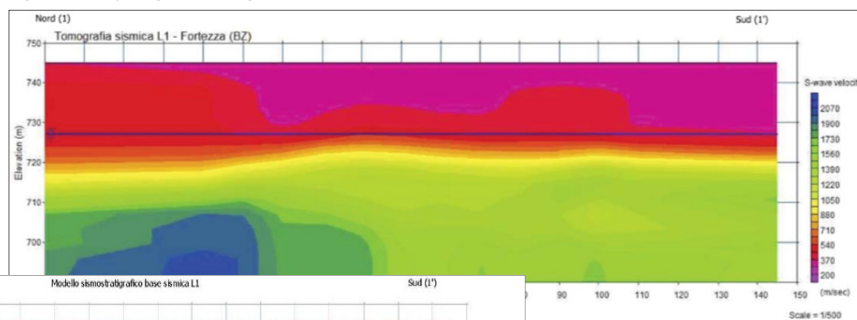
MASW, Seismic Tomography, frequency electromagnetic tomography, Georadar surveys and electromagnetometer surveys.







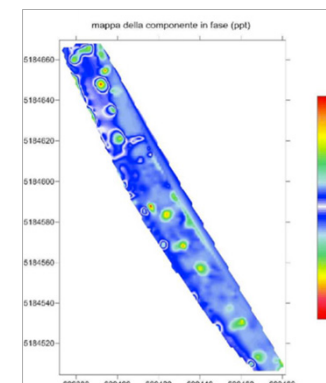
# GEOLOGICAL AND ENVIRONMENTAL SURVEYS



Seismic tomography, geological interpretation.



-  coperture (terreni detritici di riporto antropico) con  $V_{s\_med}=310$  m/sec
-  terreni detritici di riporto antropico con  $V_{s\_med}=500$  m/sec
-  rocce in posto (da detritiche ad alterate) con  $V_{s\_med}=880$  m/sec
-  bedrock sismico (roccia)  $V_{s\_med}=1550$  m/sec

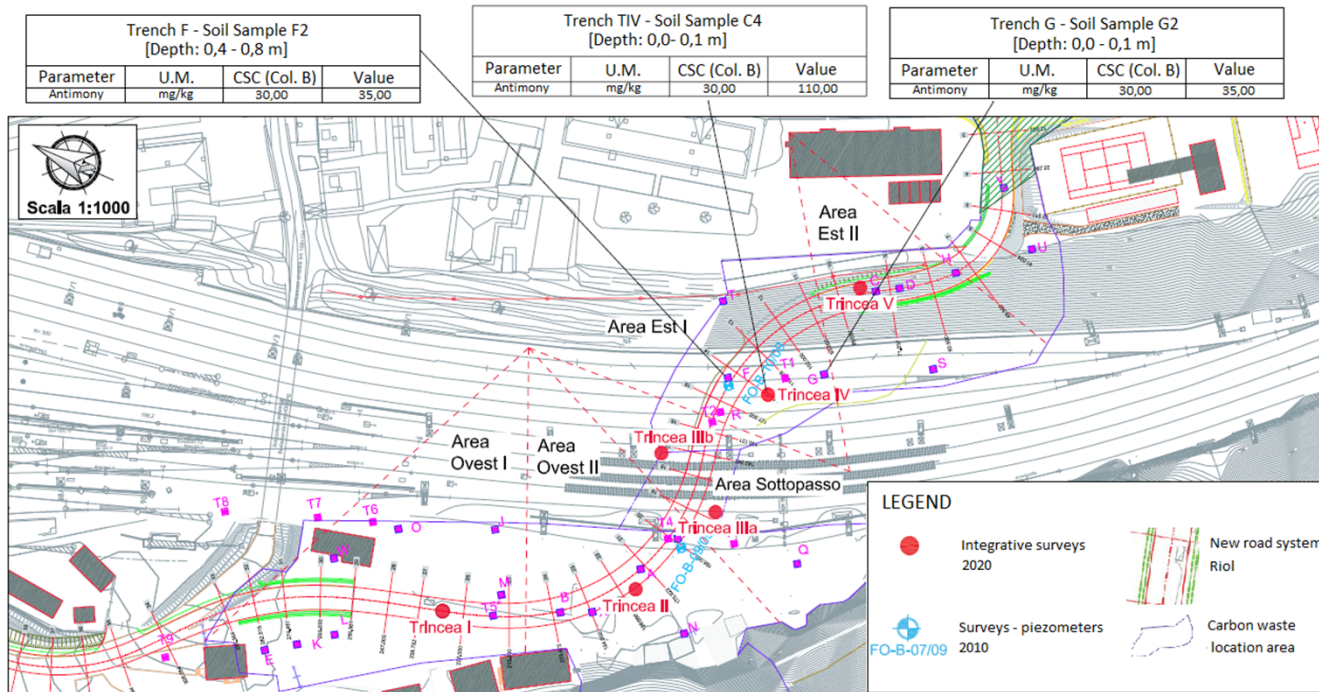


Geophysical survey with electromagnetometer (freq. 16 kHz) Electromagnetic anomalies from metal residues, soils with ferrous waste / dust within the first 2-3 m depth.

Geophysical surveys have been executed also to geotechnically characterize the railway area at the border with the residential area where the green barrier is planned (about 3.000 sqm).

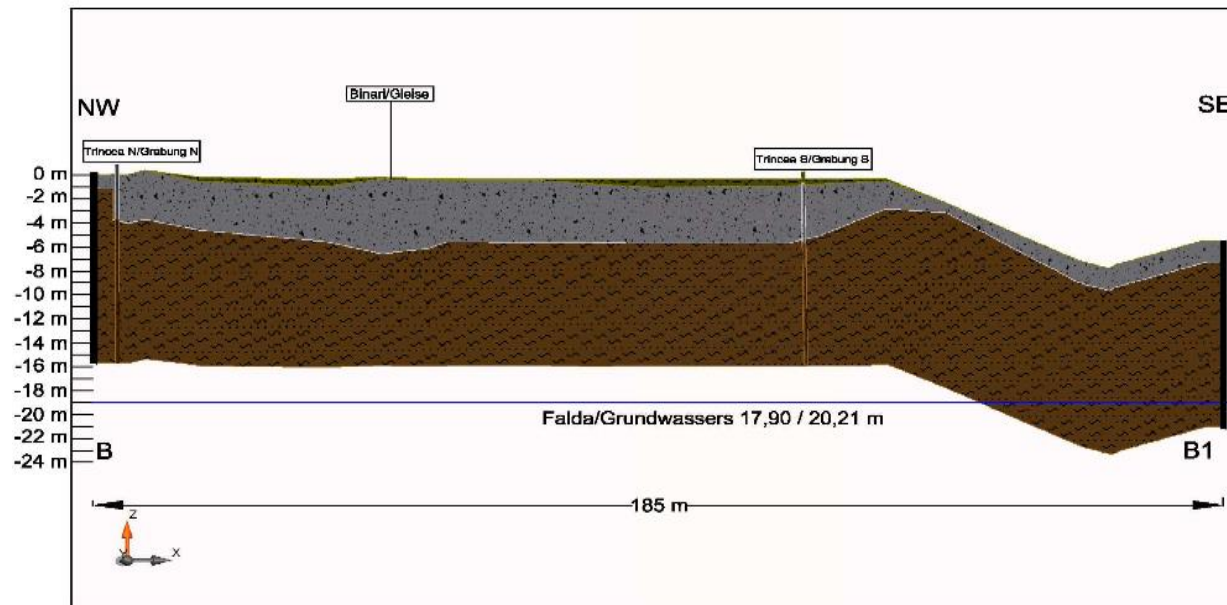


# GEOLOGICAL AND ENVIRONMENTAL SURVEYS



The environmental investigations highlighted the presence of metals, heavy hydrocarbons (C>12) and PAHs not exceeding the limits CSC for industrial site. The only parameter whose concentration was found exceeding the industrial limit was **Antimony** (110 mg/kg), detected in surface soil (0-1 m below ground level), in the East underpass area.

# GEOLOGICAL AND ENVIRONMENTAL SURVEYS



The exams on the subsoil of the area quantified a buried layer of soil with waste of coal slag with a thickness of about 5,2 meters.

The results of the analytical tests confirm that the samples can be classified with the European waste code CER 17 05 04 **“Waste from construction and demolition operations** (including soil from contaminated sites): soil and rocks, other than those referred to code 17 05 03”.

# RISK ASSESSMENT



According to the Decree 152/06 and the resolution of the Provincial Government of Bolzano, a **site-specific Risk Assessment** was performed by means of Risk-net v.3.0 software.

- The **human targets** identified are the workers in the railway area (on-site target) and the inhabitants in the residential area outside the railway (off-site target)
- **Six active migration routes** have been identified for the current scenario
- The size and extension of the contamination source was determined and the representative concentration of the source (CRS) was defined applying the "**worst case**" principle, by selecting the maximum value from the detected anomalies

Exposure path	Soil ingestion and dermal contact	Outdoor particulates inhalation	Indoor particulates inhalation	Outdoor vapor inhalation	Indoor vapor inhalation	Leaching to groundwater
On-site receptors	YES	YES	YES	NO	NO	YES
Off-site receptors	NO	YES	NO	NO	NO	YES

# RISK ASSESSMENT



Risk – Surface soil	On-site	Health Risk	Soil ingestion	R	-	
				HI	4,28e-2	acceptable
			Dermal contact	R	-	
				HI	5,65e-3	acceptable
			Outdoor particulates	R	-	
				HI	2,69e-7	acceptable
			Cumulative Outdoor Risk	R	-	
				HI	4,85e-2	acceptable
	Indoor particulates	R	-			
		HI	2,69e-7	acceptable		
	Cumulative Indoor Risk	R	-			
		HI	2,69e-7	acceptable		
		Environmental Risk	Leaching	Rgw	1,57e-1	acceptable
	Off-site	Health Risk	Outdoor particulates	R	-	
HI				1,13e-6	acceptable	
Cumulative Outdoor Risk			R	-		
			HI	1,13e-6	acceptable	
Environmental Risk		Leaching	Rgw	6,66e-02	acceptable	

The results of Risk Assessment in **direct mode** show that:

- there are **no risks for humans** (on-site workers and off-site residents);
- for the area of interest, there are **no environmental risks** due to leaching and groundwater transport (environmental risk is acceptable).

# RISK ASSESSMENT



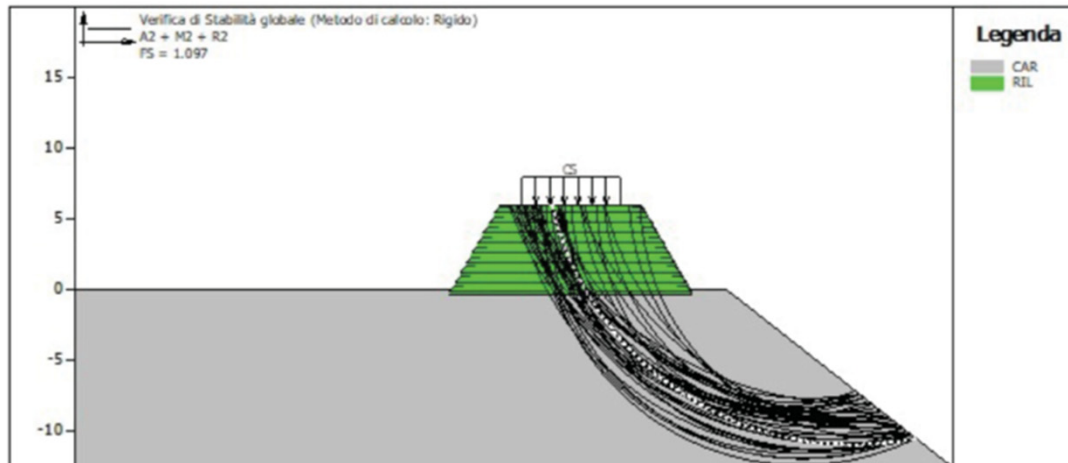
The results of the Risk Assessment in **inverse mode** to evaluate the risk threshold concentration (CSR), i.e. the concentration whose overcoming requires safety measures and remediation, show that:

- the calculated CSR are higher than the site's representative source concentration, confirming that **remediation of the site is not necessary**.

Contaminant	CSR (HH) (mg/kg) health risk	CSR (GW) (mg/kg) groundwater risk	final CSR (mg/kg) minor HH & GW
Antimony	722	223	223

Therefore, the **excavated materials can be managed as inert for backfilling with the reuse on site** [about 19.357 m<sup>3</sup>] for the construction of a green barrier wall and on site backfilling (MISP procedure) and the **not-excavated materials can remain on-site** [avoiding other remediation procedures].

# RISK ASSESSMENT FOR STABILITY



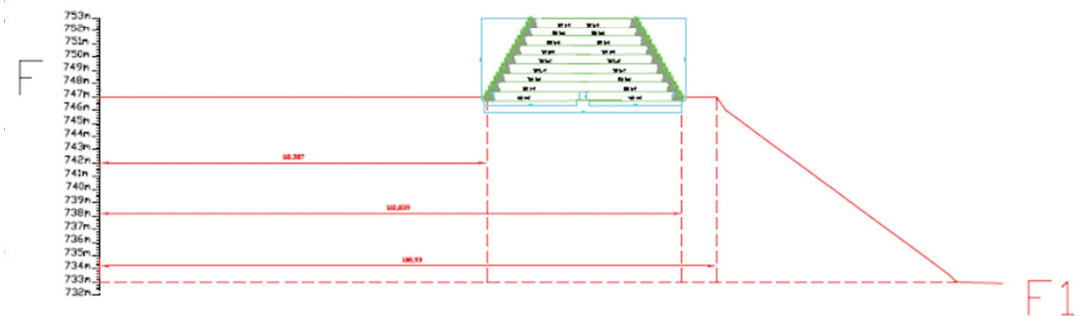
Evaluation of safety factors for stability with the software MacStars W, research of potential slipping surfaces with Bishop - Jabu method and with Mohr - Coulomb failure criterion:

$$\tau = c + (\sigma - u) * \tan(\phi')$$

( $\tau$  = maximum shear stress,  $c$  = cohesion,  $\sigma$  = total normal pressure,  $u$  = interstitial pressure,  $\phi'$  = angle of friction)

The **stability conditions** and the design of the structure were **verified** by seismic and geotechnical studies. Seismic study included the calculation of the seismic action of the project and the seismic limit states.

## PROFILO F - F1



# THE GREEN BARRIER



*Actual view of the railway area from the residential area*



*Green barrier rendering at the entrance to the underpas*

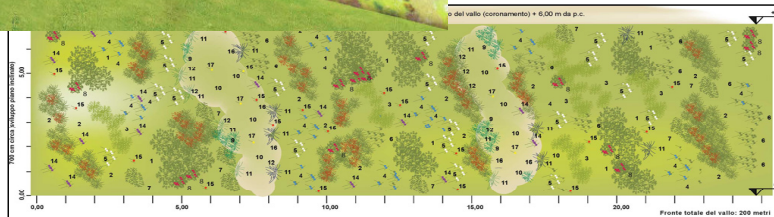
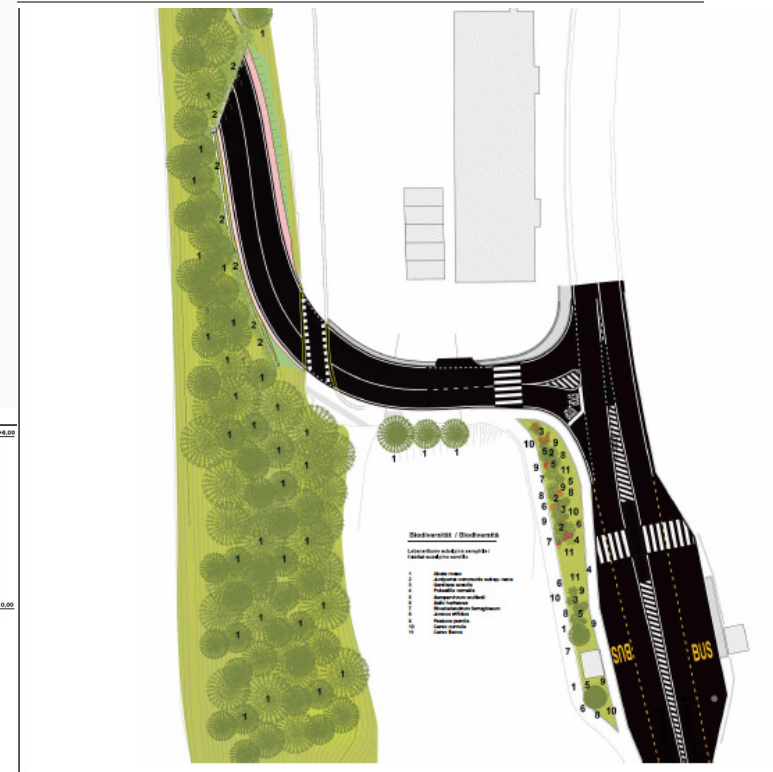
The **green barrier** consists of a reinforced embankments structure, about 200 meters long, 18 meters large and 6 meters high, built with pre-assembled units of double twisted wire mesh designed to resist the shear, compression and traction forces acting naturally or generated by the loads induced on the structure.



# THE GREEN BARRIER



Greening with attention to biodiversity and native species



Esplorare il vallo	Ecologia	Stimolazioni sensoriali
<p><b>Da lontano / i paesaggi</b>                      Gli accostamenti con una biodiversità continua uniforme</p> <p><b>Da vicino: la biodiversità</b>                      L'aggiunta di elementi vegetali con differenti tra loro, connessi e composti e insieme contribuiscono alla vita dell'ambiente.</p> <p>Il vallo contiene un'idea, una ricerca di ordine che esalta le differenze vegetali.</p>	<p>Landa subalpina verotta</p> <p>1 UVA ORSINA                      2 BIRICO                      3 GINEPRO COMUNE NANO                      4 GINEPRO DI FOCHI                      5 PULSATILLA PRIMAVERILE                      6 SEMPINOLO DI VOLFEN                      7 SALICE NANO                      8 ROSA DELLE ALPI</p> <p>con macchie di Landa nero-arbutiva e di Proteale</p> <p>9 GIUNCO DELLE CRESTE                      10 AVENA DELLE ALPI                      11 FESTUCA ANGINE                      12 CARICE BICURIA                      13 CARICE GLAUCO                      14 GIOCCA                      15 SALIZETELLA MAGGIORE                      16 ACHILLEA MILLEFOLIOLE                      17 CAGLIO</p> <p>Arctostaphylos uva-ursi                      Calluna vulgaris                      Juniperus communis subsp. nana                      Campanula azarita                      Pulsatilla vernalis                      Campanula trachelium                      Salix herbacea                      Rhododendrum ferrugineum</p> <p>Juncus trifidus                      Avena praecoxa                      Festuca ovina                      Carex curvata                      Carex flacca                      Carex flacca                      Sanguisorba officinalis                      Achillea Millefolium                      Galium verum</p>	<p>Alimentare i profumi nelle stagioni. Fanci, erbe aromatiche, attuali.</p> <p>Toccare le piante. Riconoscere le forme.</p> <p>Guardare - cercare i colori e le forme nella natura. Quanti versi sai riconoscere nel paesaggio?</p> <p>Sentire a piedi nudi camminare sui prati, alla scoperta dei valori tattili, della temperatura, dell'umidità delle superfici a stede.</p>



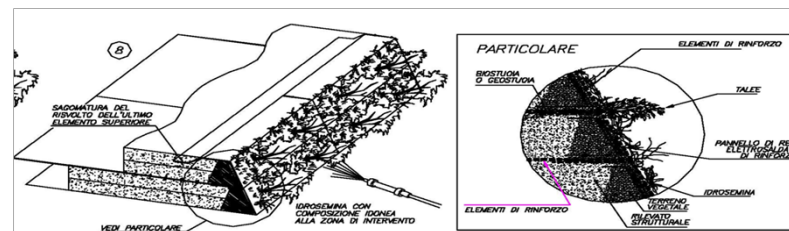
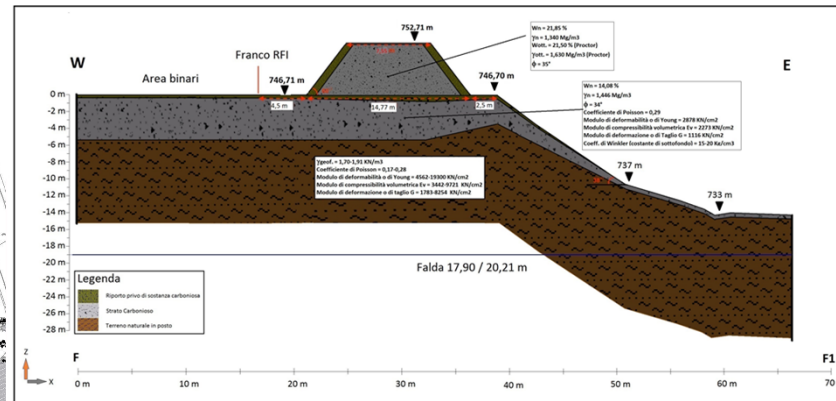
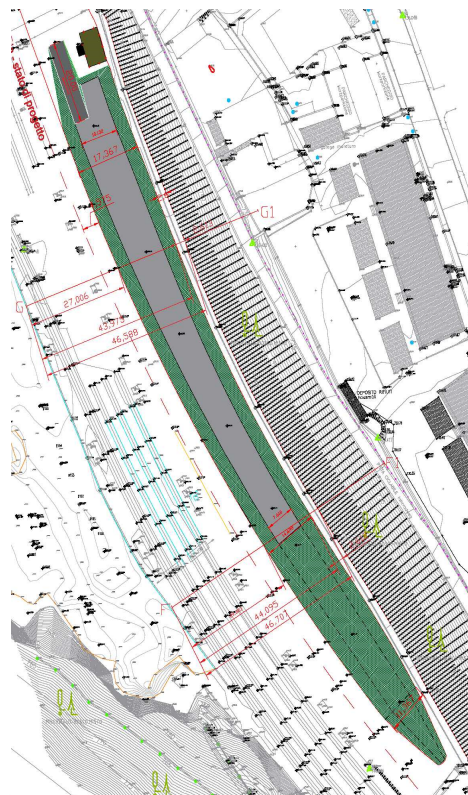
# SUSTAINABLE BENEFITS



If compared to the landfill disposal **MISP** by **green barrier** presents **benefits** for the **environment, society** and **economy**.

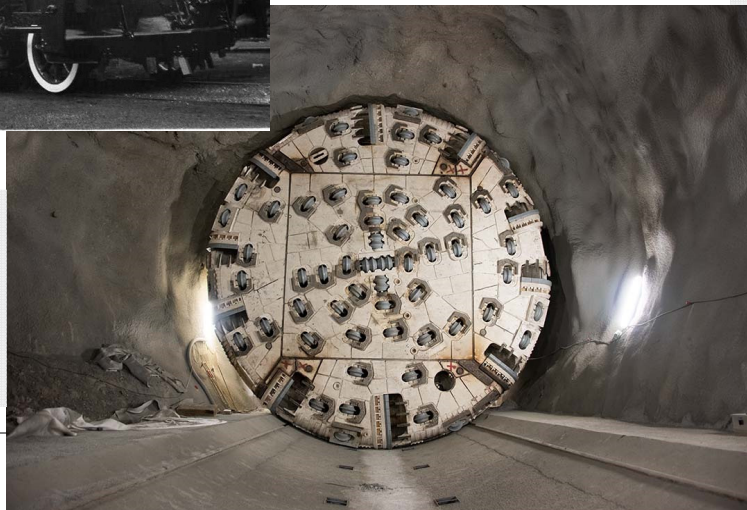
Benefits	Effects
Environment	Conversion of up to 90% of the excavated soil into a valuable resource
	Saving $1.44 \times 10^7$ liters in term of fuel
	Reduction of $4.67 \times 10^7$ t in term of CO <sub>2</sub> eq
Society	Creation of a new green area for the citizenship, with pedestrian paved walking area (about 2.000 sqm)
	Allow to safeguard public resources by using them more efficiently and rationally
	Reduction of the noise and of the visual impact caused by the existing railway
Economy	Reduction up to 91% of the costs, because of avoiding soil landfilling Savings of over 3 million euros in public resources

# CONCLUSIONS



The reuse on-site of the soil with coal slag is an opportunity for the redevelopment of the area. **The application of the Risk Assessment confirmed that the project would lead to no health and environmental risks.** The green barrier project was approved by the EIA Committee at the Autonomous Province of Bolzano and submitted to the EIA Commission of the Italian Ministry of the Environment and will be realized within 2021.

# GLÜCK AUF!



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Thanks for your attention!

Grazie per l'attenzione!

Danke für Ihre Aufmerksamkeit!

[https://www.youtube.com/watch?v=hn-K6rPUDB8&feature=emb\\_title](https://www.youtube.com/watch?v=hn-K6rPUDB8&feature=emb_title)

<https://www.ecosurvey.it/project/discarica-bonificata-bbt/>

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