

Hydrogeology of the Brenner Base Tunnel in the Italian section: observed inflows and forward monitoring procedures

P. Perello¹, S. Skuk², A. Spaziani² & A. Voza²

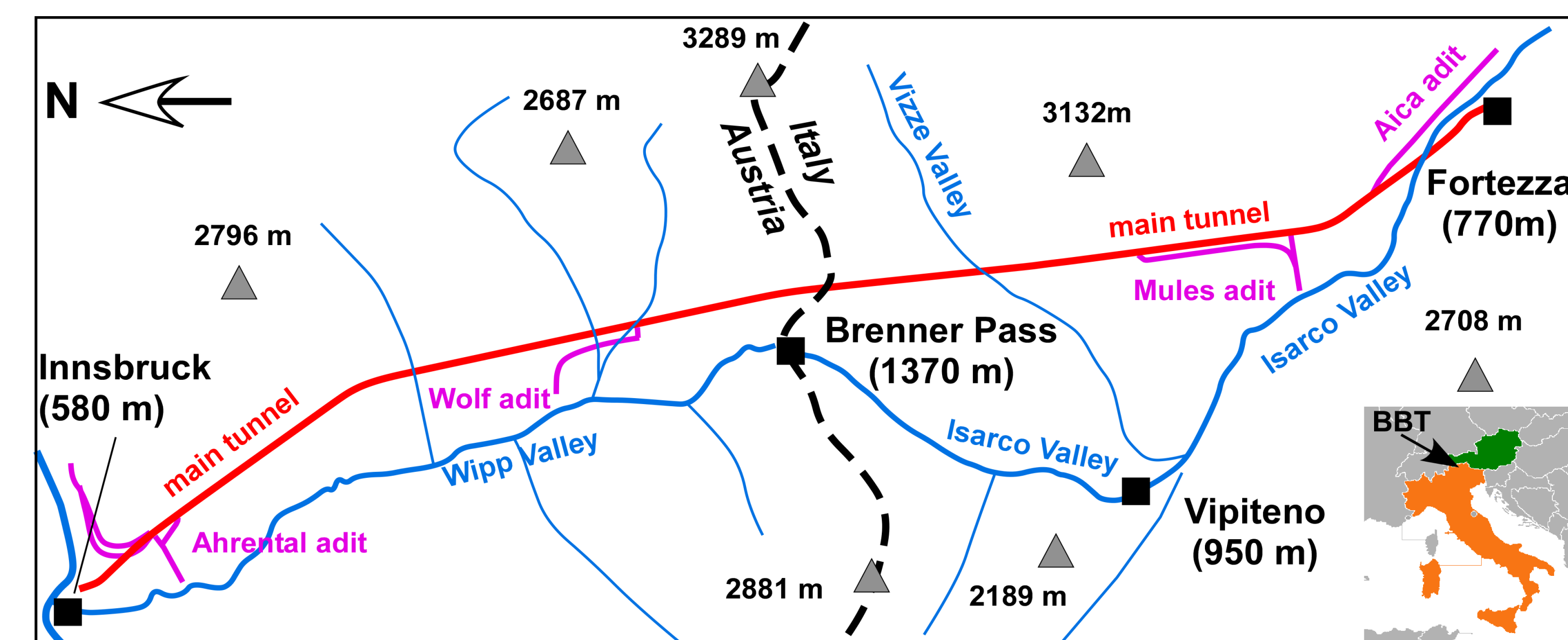
1 - GDP-GEOMIN s.r.l. - Via Vittorio Amedeo II 6, I-10121 Torino (Italy); 2 - Brenner Basis Tunnel, Tunnel di Base del Brennero BBT SE - Piazza Stazione 1, I-39100 Bolzano (Italy)



General Overview

The Brenner Base Tunnel (BBT), is a 55.6 km long railway tunnel. The tunnel is under construction since 2008 and completion is forecasted in 2032. Its main portals are located at Innsbruck (Austria) to north and at Fortezza (Italy) to south. Besides accessory structures, it is composed by two main tubes (MT hereon) of 10.7m diameter and 70m spaced.

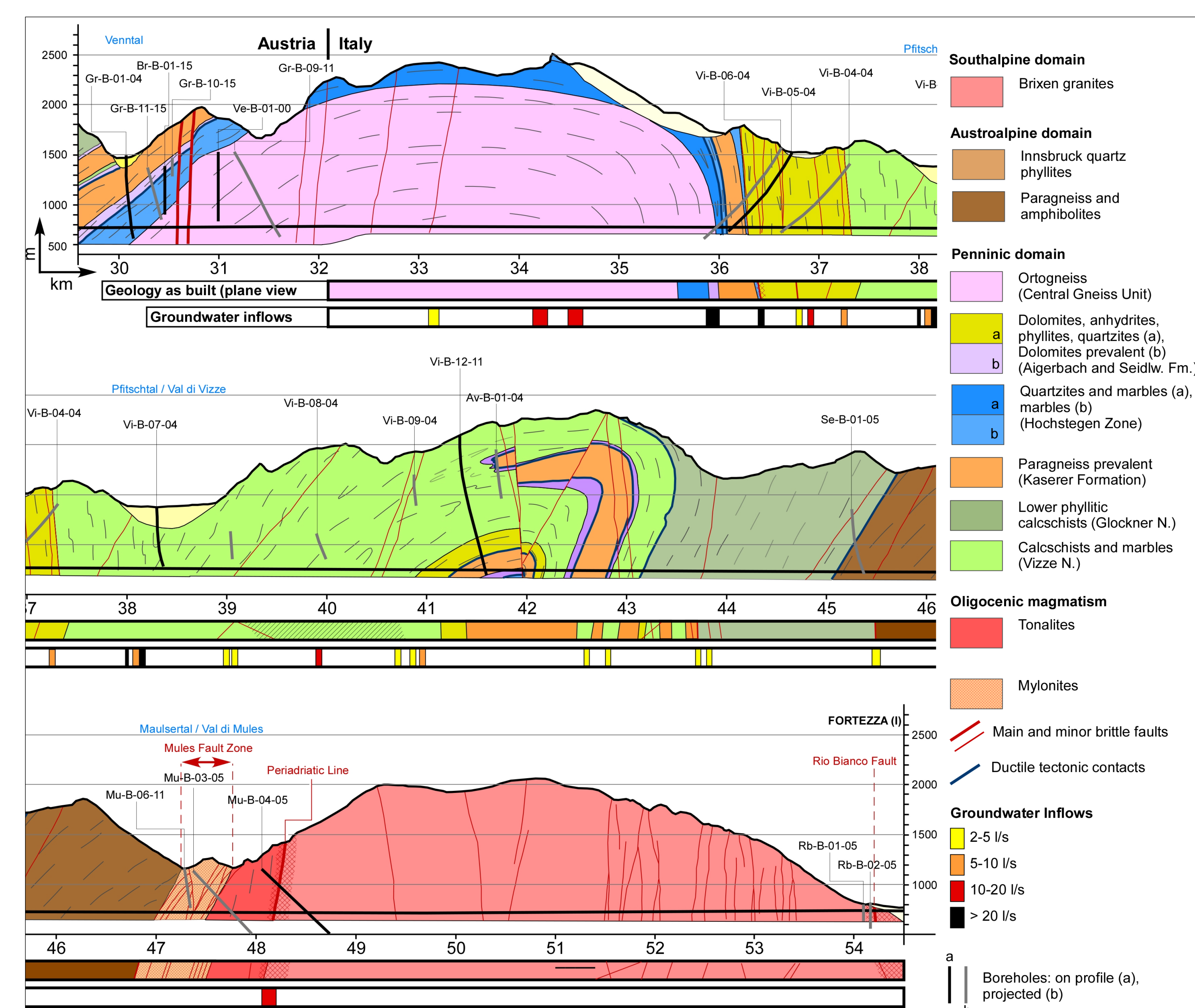
The Italian section develops underground for appx. 24 km. An exploration/drainage tunnel (EDT hereon) having appx. 6m diameter is mostly coaxial to MT. Its excavation always anticipates of several kilometers the excavation of the MT and it is the gallery that first activate the drainage of groundwater flow-systems. MT and EDT have been mostly excavated by double shield TBMs.



Geological Hydrogeological setting

The project is located in an Alpine context, with mountains ranges higher than 3,000 m. Maximum overburden overpasses 1,500 m.

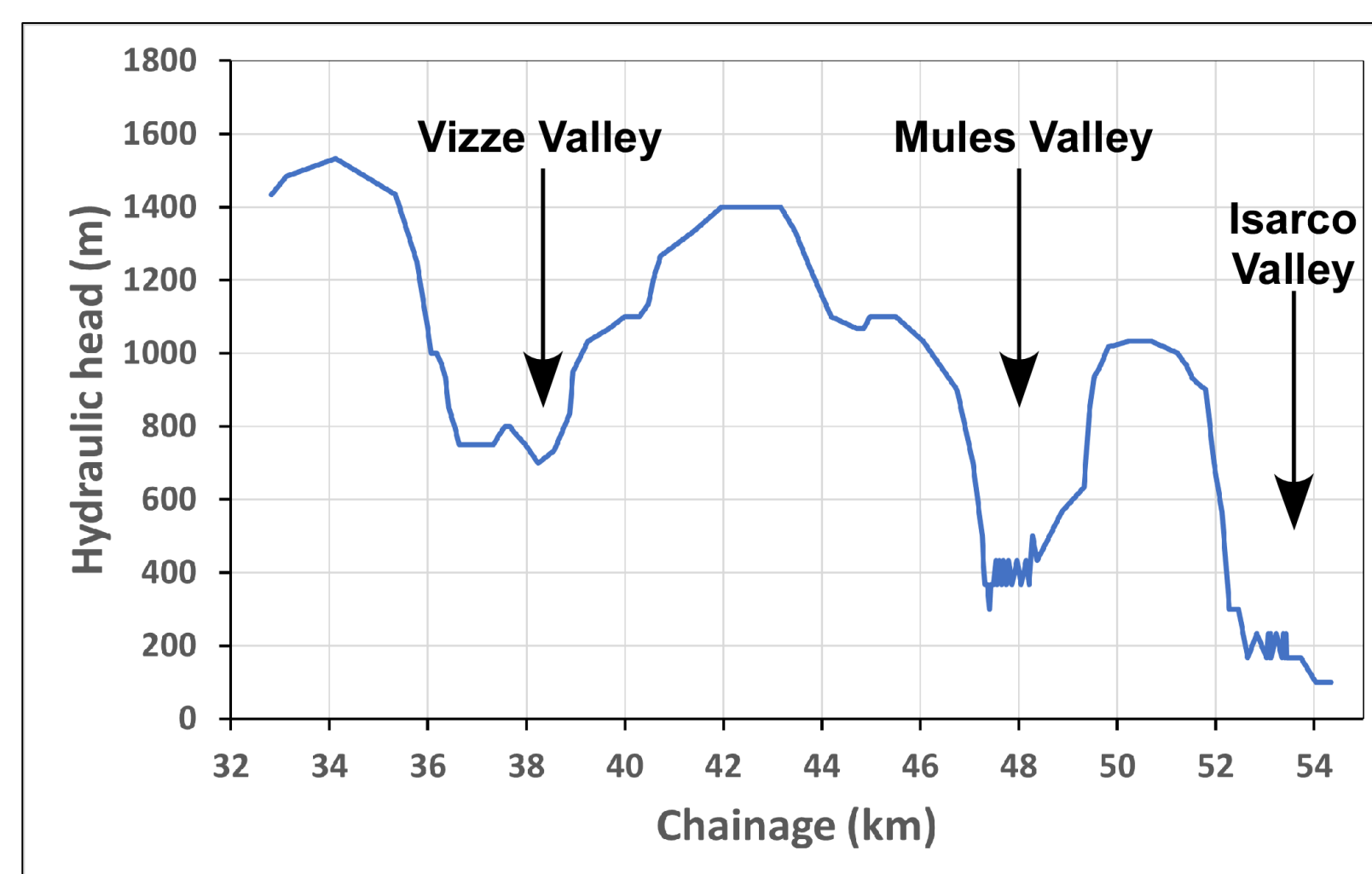
The geological setting along the alignment is totally characterized by crystalline rocks of magmatic or metamorphic nature (granites, gneiss, micaschists, marbles and evaporitic rocks).



Permeability is related to the fracture network, to faults and to chemical dissolution by water of carbonatic and evaporitic rocks. The latter are the most problematic for inflows occurrence.

Hydraulic conductivity (m/s)	1E-10	1E-09	1E-08	1E-07	1E-06	1E-05	1E-04	1E-03	1E-02
C1 Phyllites, Paragneiss, Tonallites, Mylonites									
C2 Metabasites									
C3 Phyllitic calcschists									
C4 Calcschists with marbles									
C5 Ortogneiss									
C6 Quartzites									
C7 Granites									
C8 Mixed marbles, dolomites, anhydrites and phyllites									

For hydrogeological purposes it is worth noting that the entire tunnel alignment is located at an elevation that, on average, is 200 m lower than the adjoining Isarco Valley. Galleries are therefore potentially able to intercept deep flow systems directed from the slope interior to the valley floor aquifer.

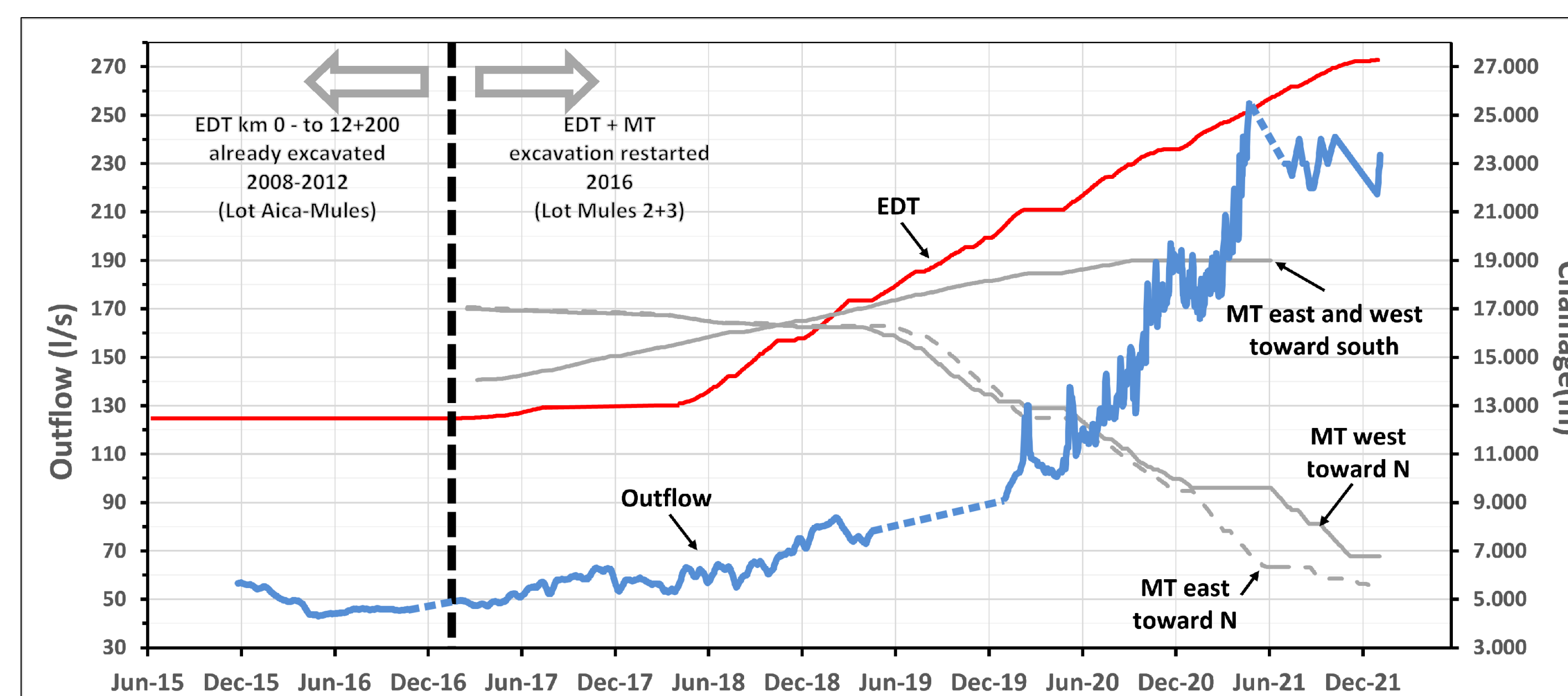


The tunnel is also located about 700m below the floor of another important valley, the Vize valley, confluent in the Isarco valley.

Unperturbed hydraulic head referred to the tunnel elevation is high to very high, as attested by the piezometric cells installed in several boreholes; a summary of the hydraulic heads along the MT is shown here to the left.

Groundwater inflows

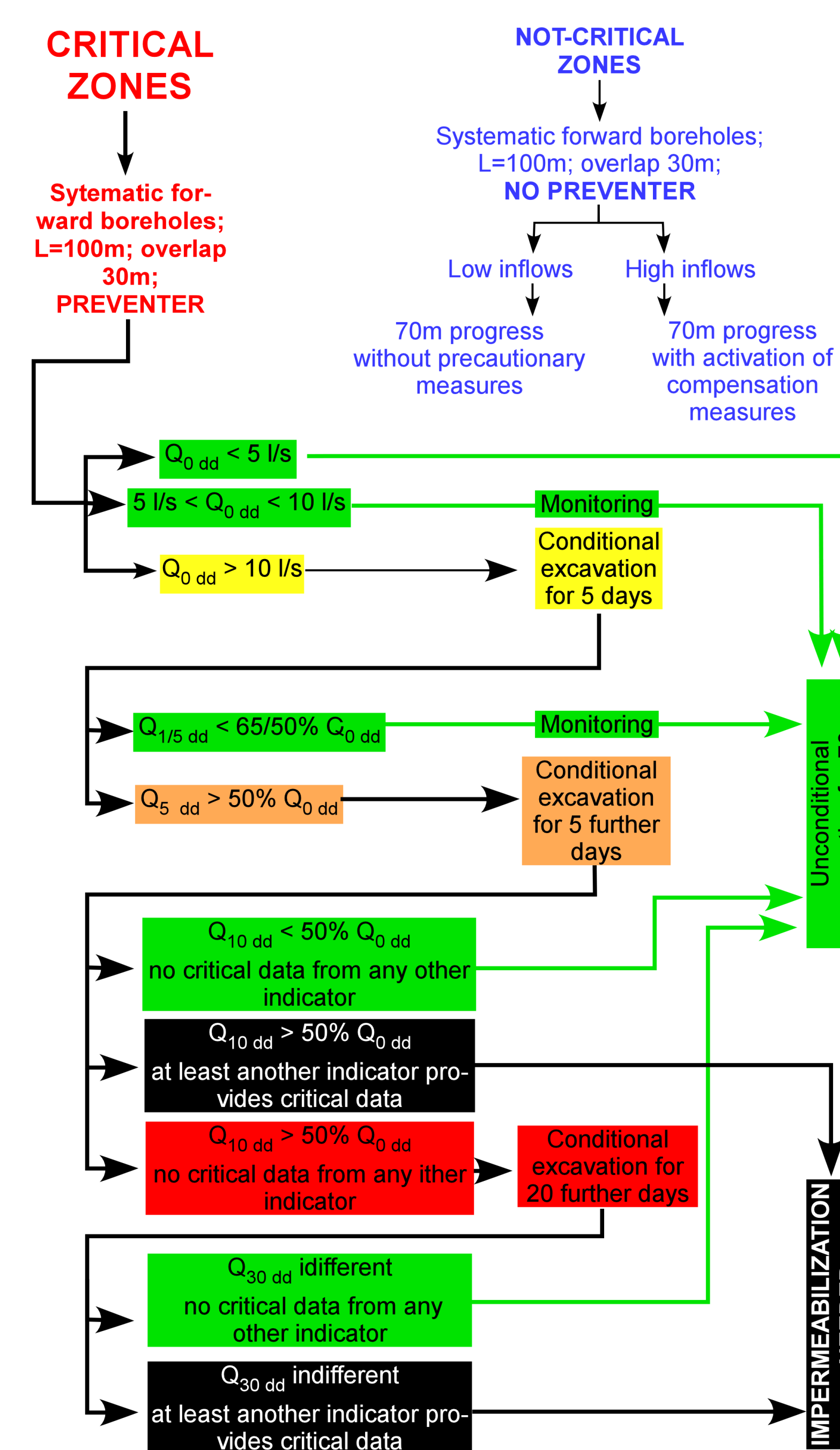
Following figure represents discharge recorded at the beginning of 2022, when 63% of the project was completed. Discharge reached a peak of about 250 l/s when the EDT, i.e. the tunnel whose excavation widely anticipated all others, cut the most permeable zone of the project, represented by the multilayer zone (complex C8) at km 36,0-37,5. After that moment the discharge tends to reduce, due to EDT excavation in progressively less permeable rocks and MT penetration in an already partially drained context.



Some of the hydrogeological singularities were characterized by the presence of abundant loosed material, resulting from marbles and anhydrites debonding caused by chemical dissolution. In MT west, at chainage 36+465 ca., the presence of large amounts of residual loosed rock, in association with high inflows, caused a long stop of the double shield TBM that was solved only after forward drainage and consolidation injections around the machine head.

Forward hydrogeological monitoring procedures

The principle that guided the design was to undertake all possible actions in order to avoid springs drying. Furthermore, in the tunnel area exists a thermal spring (Brennerbad) unique in all the region and with a relevant economic value. A dedicated forward monitoring procedure schematically summarized in the flow diagram below was activated during the excavation of the EDT in critical sections. It is based on the systematic realization of forward boreholes from the TBM by means of the drilling machine placed at the end of the shield. Flow from the forward boreholes is then the parameter evaluated in order to decide how to manage the situation, as shown in the figure. $Q_{0\ dd}$ = inflows at day 0, i.e. at the beginning of the groundwater discharge; $Q_{1/5\ dd}$ = inflow in the period between day 1 and day 5; $Q_{5\ dd}$ = inflow at day 5; $Q_{10\ dd}$ = inflow at day 10; $Q_{30\ dd}$ = inflow at day 30; field colors have the following significances: green=safety condition; yellow=attention condition; orange=alert condition; red=alarm condition; black=impact attested.



Boreholes have been mostly driven with the down the hole (DTH) hammer technique with length of 150m. In non-critical zones for the thermal aquifer, boreholes have been executed without any precaution, while in critical zones a blowout preventer apparatus was installed. This apparatus was applied both for safety reasons and to have the possibility of managing drainage in case of intersection with relevant flow systems. In order to place the preventer, a 20m long pre-drill was executed; a steel lining was then installed and cemented in order to tighten it against rock. The preventer was then screwed on this lining. Boreholes execution with preventer took generally one to two days. The monitoring procedure was structured as to decide, after each forward borehole, whether the excavation could proceed, or if adequate countermeasures had to be adopted before going forward. Figure below is a view of the TBM front zone with groundwater flowing from a borehole on the right

The procedure proved to be an effective aid to decision, since most of the time the flows from boreholes were below thresholds defined for entering in a situation of attention, therefore excavation continued almost without stops. Only in a couple of cases a situation of alert occurred but, by applying the criterium of the flow rate decrease in a few days, it was realized that excavation could go further.

