Cleuson-Dixence Galery

Site Location and Characteristics

The Cleuson-Dixence hydroelectric scheme is in the canton of Valais. It connects the Grande Dixence dam to the Cleuson dam via an underground headrace tunnel crossing the massif beneath the Dent-de-Nendaz.

The tunnel is exploited by Alpiq and thus represents an equipment for which not all detailed are publicly available. Therefore, all the information on which we based our work cannot be included in this report. We include elements that are already public, or certain others whose details do not compromise the operator's interests.

The Galery

The Cleuson-Dixence headrace tunnel is a 15.8 km-long underground structure operated by Alpiq. It conveys water collected at the intake bored through the wall of the Grande Dixence dam to a surge chamber located beneath the Dent-de-Nendaz. From there, water is directed down an armoured shaft to the underground powerhouse of Bieudron, where electricity is generated. The tunnel crosses the Dent-de-Nendaz Member.

The digging of the tunnel occurred in the 1990's and has been heavily monitored before, during and after the tunnelling works. In addition to the gallery, several boreholes have been drilled along the gallery path, mainly to better characterized the rocks properties before the actual drilling.

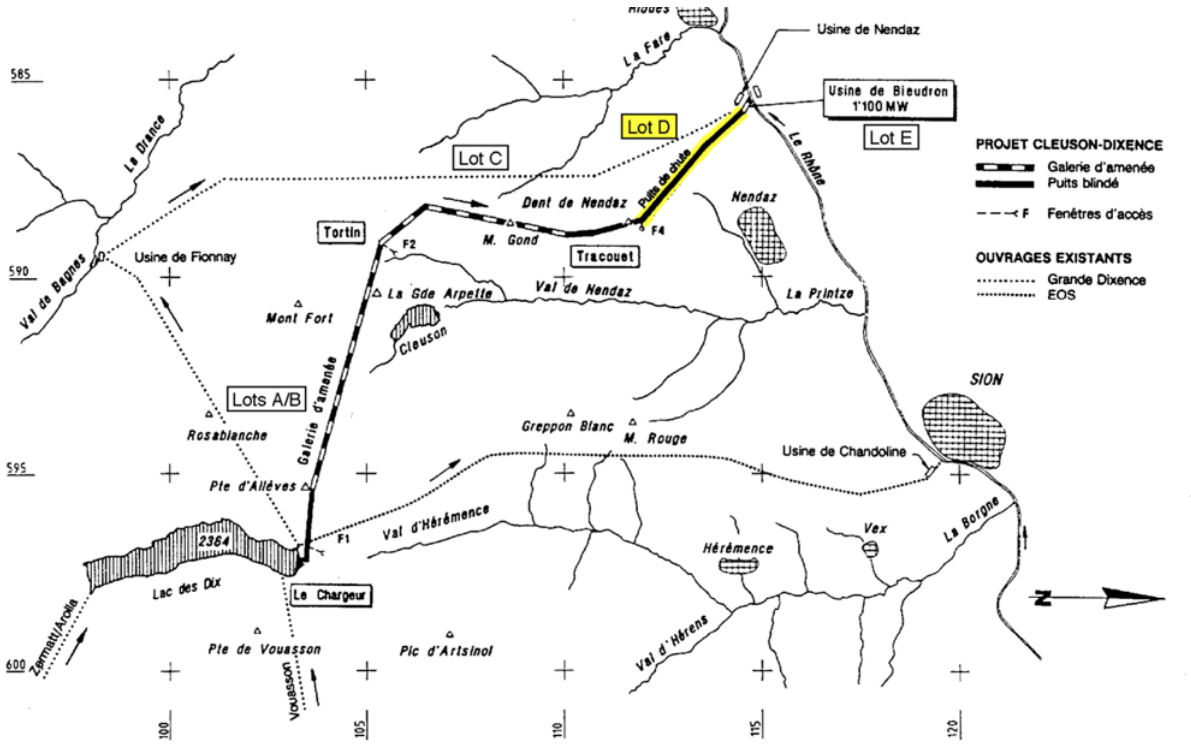


Figure 1 : Schematic map of the Cleuxon-Dixence Gallery (Norbert, 1998)

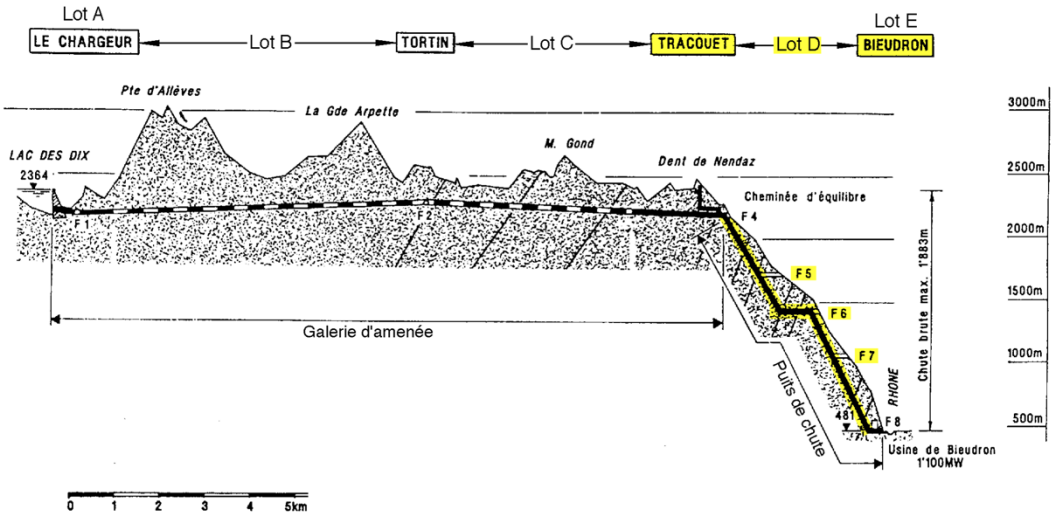


Figure 2 : Gallery cross-section, details on the different stages for tunneling works ('Lot')

Geological and Hydrogeological Settings

The Cleuson-Dixence galerie is located in the Souwthern Est part of the Wallis canton, south of the Rhône. This area belongs to the Penninic Domain (tectonic unit derived from Mesozoic basins, formed between the European and Adriatic continents). The Penninic domain is subdivided into Lower, Middle and Upper Penninic subdomains that are bounded by major thrust faults. [Gouffon, 2024]. The Rhône-Simplon Fault – SW-NE of orientation (RS on the map) marks the boundary Helvetic domain (to the North and to the West). All units within th e Penninc Domain contain far-traveled sedimentary cover rocks and basement rocks transported over considerable distances, and thus highly fractured.

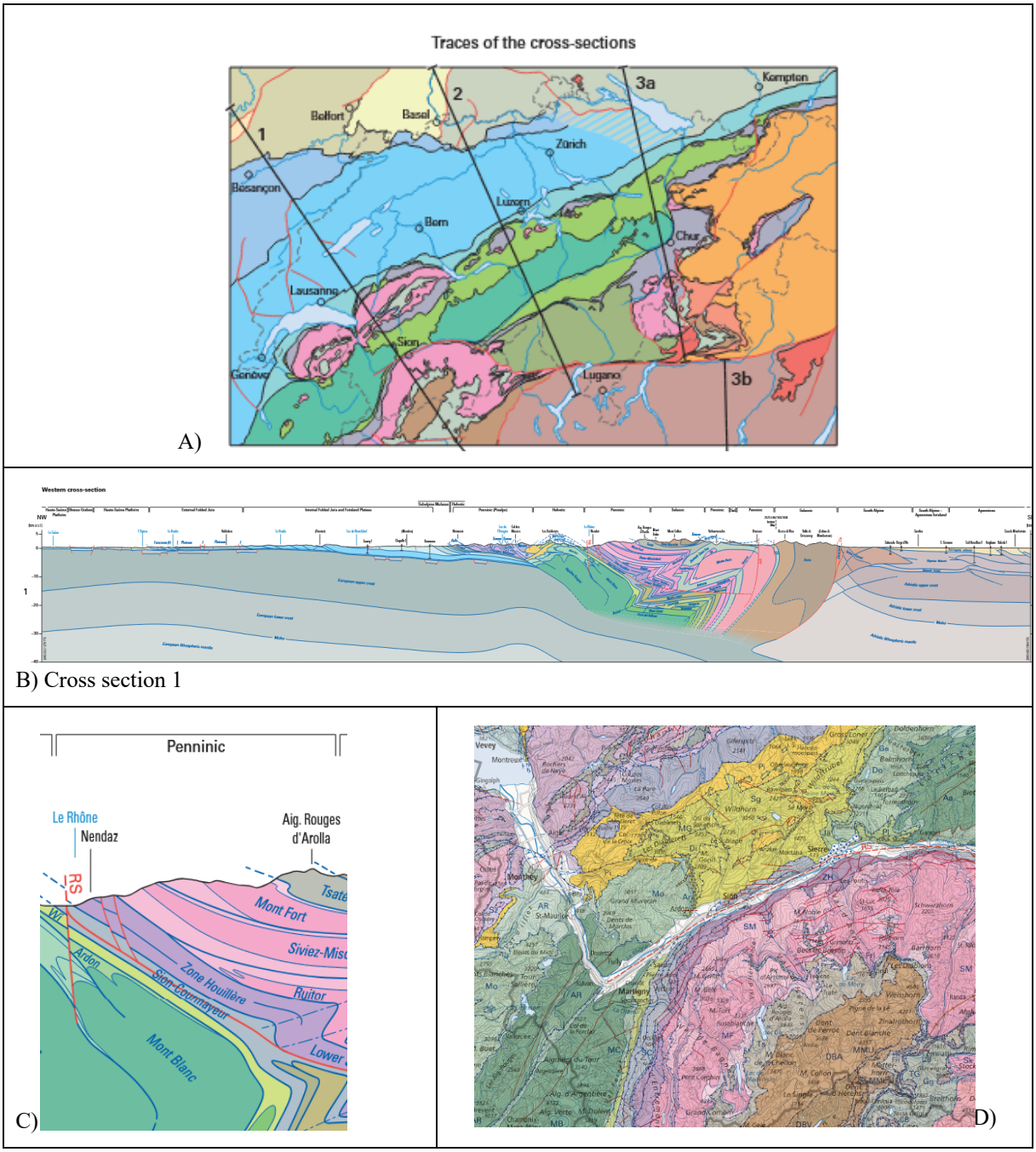


Figure 3 : Geological and Tectonic context (A-location of the cross-section, B) cross section 1, C) detail from cross-section 1 on the Nendaz region, D) Tectonic 500) from Gouffon, 2024.

For the purpose of FracSYS project, focus was kept on the Northen part of The Cleuson-Dixence Galerie. In this area, Lower and Middle Penninic Subdomains where in intersected.

Table 1: Tectonic units in Main tectonic units – Gouffon, 2024; Loprieno et. al. 2010 ; Pantet et. al., 2020 ; Swisstopo, 2024).

Domain	Subdomains	Units	Ages and dominant lithologies
Penninic	Middle	Mont Fort Nappe	Paleozoic basement, overlain by a thin, discontinuous cover of Triassic-Jurassic metasediments, mainly breccias. Tectonic contact with the Siviez-Mischabel nappe
		Siviez-Mischabel nappe	Crystalline basement (sedimentary and magmatic origin of Proterozoic to Ordovician age) and typical Briançonnais sedimentary cover
		Zone Houillère	Late Carboniferous to Permian metasediments, locally rich in coal, Early and Middle Triassic sediments
	Lower	Sion-Courmayeur Nappe ("Roignais-Versoyen" slice, and "Pierre Avoi" slice)	flysch-type rocks (Cretaceous) highly metamorphized

Detailed geological context and local terminology

Among the gallery digging reports and hydrogeological local studies, ways to describe geological units varies (in time and depending on authors), and differ from the tectonic units describes before. Terminologies differ also from more recent studies (Sartori et.al., 2006), but harmonization of terminologies what out of the scope for this study. Thus, only terminologies as described in the publicly available description of the galerie (Alpiq, 2015) were kept. Those names are also the ones found in Norbert, 1998. From Norbert, the local terminologies are given as in the table x.

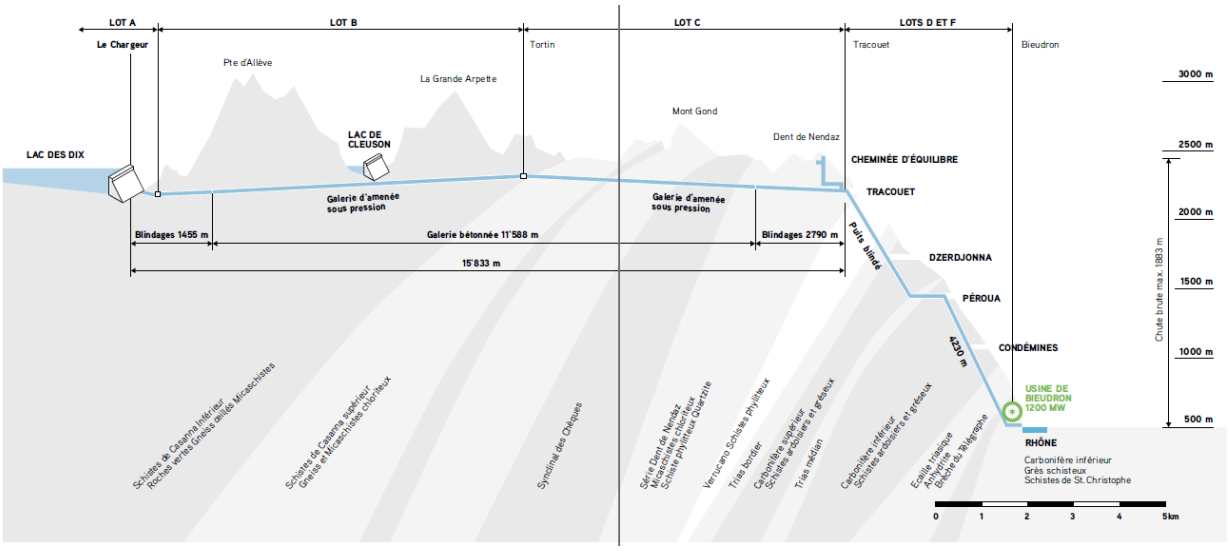


Table 2: Schematic cross section with geological units (Alpiq, 2015).

Terminology	Lithologies
Série de la Dent de Nendaz	metaconglomerates, coarse meta-arkoses, and light green quartzites with dispersed quartz pebbles, alternance with grey metagreywacke, quartz-sericite schists, and metapelites. All is highly folded with a superimposed schistositie
Verrucano	Sericitic sandstones and schists, Sericitic quartzites
Trias bordier	Quartzites, mylonitisées
Carbonifère supérieur	Schistes ardoisiers et gréseux, fortement tectonisés
Trias Médian	Anhydrite, niveau quartzo-phyllitiques
Carbonifère inférieur	Grès schisteux et schistes gréseux, schistes conglomératiques, interlits charbonneux,
Brèche du télégraphes	Calcaires gréseux et dolomitiques plus pou moins bréchifiés, niveaux de schistes séricito-phylliteux
Ecailles triasiques	Anhydrite et dolomie bréchique à ciment anhydritique
Grès et schistes de Saint Christophe	Grès et schistes, lentille triasique, peu fracturé

Figure 4 : Geological units intersected by the Cleuson-Dixence galery – Norbert, 1998

Fracturing and Groundwater Flow

Monitoring during drilling and monitoring after was extensively documented. Records of lithology, fracturing intensity, and water inflows were compiled. Precise positions of these various elements were provided and served as the basis for establishing this case study.

From the geological records, it was observed that all geological units encountered were metamorphosed, and that numerous indications of fissuring/fracturing were identified. The properties of these materials (anisotropy, porosity, mineralogy) must also be considered in relation to this metamorphism.

Groundwater circulations have been monitored during the tunnelling works and after within dedicated devices (pressure gauges in the fractured network, flowrate gauges at drainage facilities outlet, piezometers and springs).

Observations related to the gallery digging shows the alternance of completely dry sections of rock, and water inflows located in the fractured and mylonitized zones. Flow rates were reported within the range of 10 to 50 l/s at best during the tunnelling works, but most of the producing fractures yields about 5 l/s. It is stressed that this initial flow rate shows a rapid decrease.

Flowrates at outlet of drainage gallery (F6, F5 ‘windows’ in Norbert, 1998) varies between 0.2 and 1 l/s approximately.

Pressure gauges measuring pressure at the outside of the armoured shaft, i.e. in the fractured medium, registers annual high and low pressures, in good accordance to snowpack melt (high pressure) and dry season.

These various observations demonstrate that the Cleuson Dixence sector exhibits the characteristics of a fractured system, in which water circulates through discontinuities related to fracturing. The aquifer systems remain of modest extent with respect to the relative low flow rates (few litres per seconds). Annual variations in flow rates or in piezometric heads demonstrate that these systems benefit from annual recharge and are drained toward natural outlets (surface springs) or anthropogenic ones (Cleuson-Dixence gallery). Thus, despite not being located in crystalline rock context, the Cleuson-Dixence case study seems to exhibit suitable properties to study fractured aquifers.

Baseline data and Geological Modelling

To build the conceptual model, and implement into the FracSYS prototype, following data where used :

From Norbert, 1998

- Gallery alignment, in plan and in depth
- Longitudinal Cross-section – LOT D, 1/50 000
- Boreholes location and geological logs

From public sources

- Borehole
- Extract of the GeoCover of the Geological Atlas of Switzerland 1:25 000 (rasterised version)
- Traces profiles from Geological Atlas of Switzerland 1:25000

Other datasets remain to be imported / digitalised such as detailed fractures derived from DEM, etc.

The results of the geological modelling can be access through visual KARSYS page https://www.visualkarsys.com/vk/project/2453