Civil Engineering (CE) Studies for the ≈80km Tunnel Project

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John Osborne (CERN GS-SE)

ARUP

GADZ
GÉOTECHNIQUE APPLIQUÉE
DERIAZ S.A.

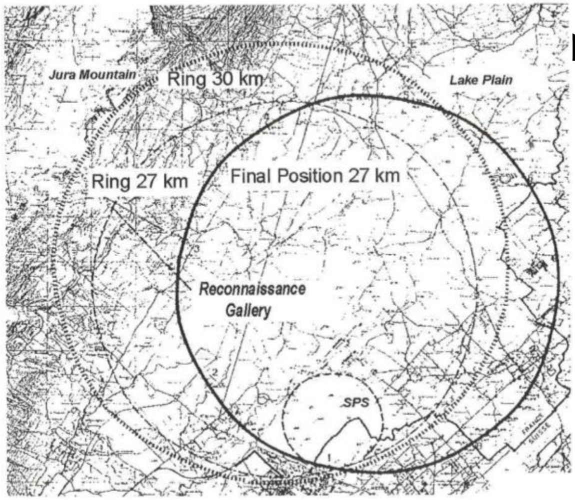
Outline

- Potential locations
- CE considerations
  - Geotechnical
  - Tunneling
  - Environmental
  - Optimization
- Cost estimate
- Feasibility / Risk issues
- Next steps

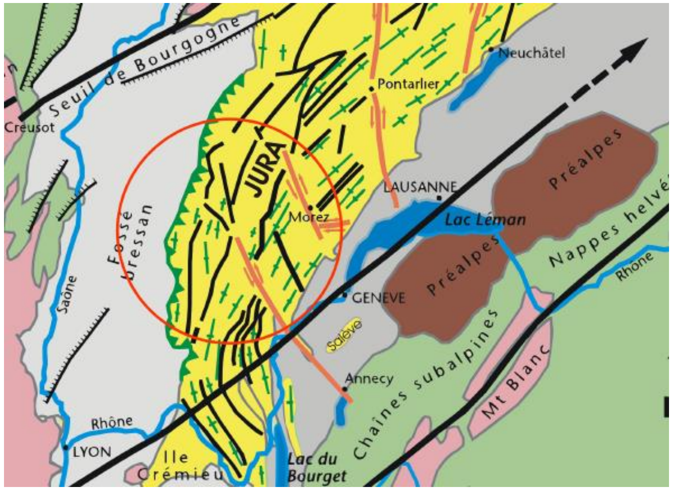
Potential locations

- Summer 2012 CERN GS-SE group were asked to study the pre-feasibility of an 80km ring tunnel in the CERN area.
  - Pre-feasibility study of an 80km tunnel project at CERN prepare for the European Strategy for Particle Physics 2012 : https://edms.cern.ch/document/1233485/1

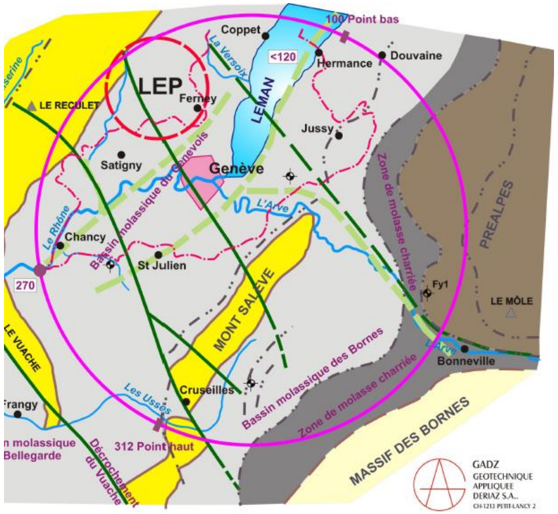
- Options for a ring tunnel have been proposed in the past
  - LEP: 30km prior to 27km



LEP 30km and 27km tunnel locations



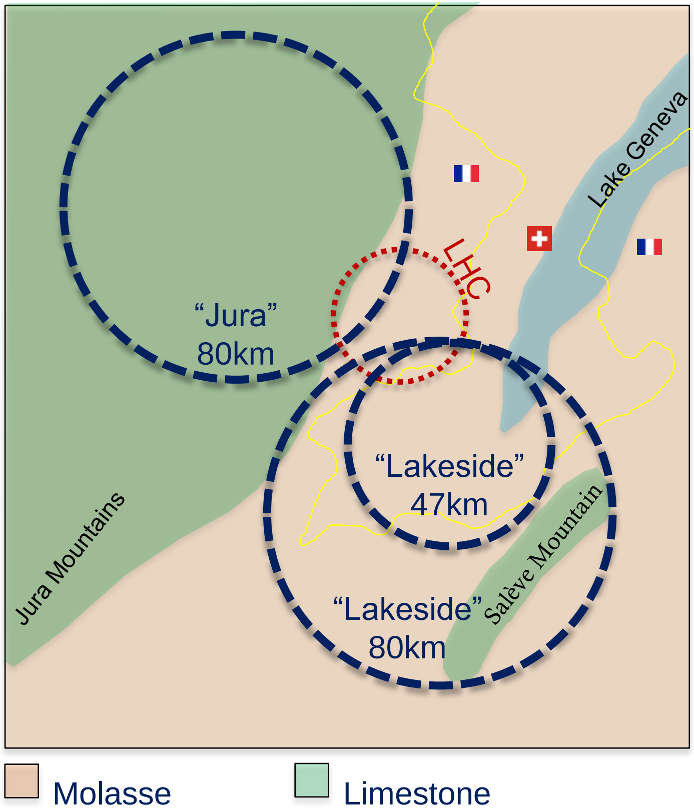
VLHC 240km tunnel location



VLHC 113km tunnel location

Potential locations

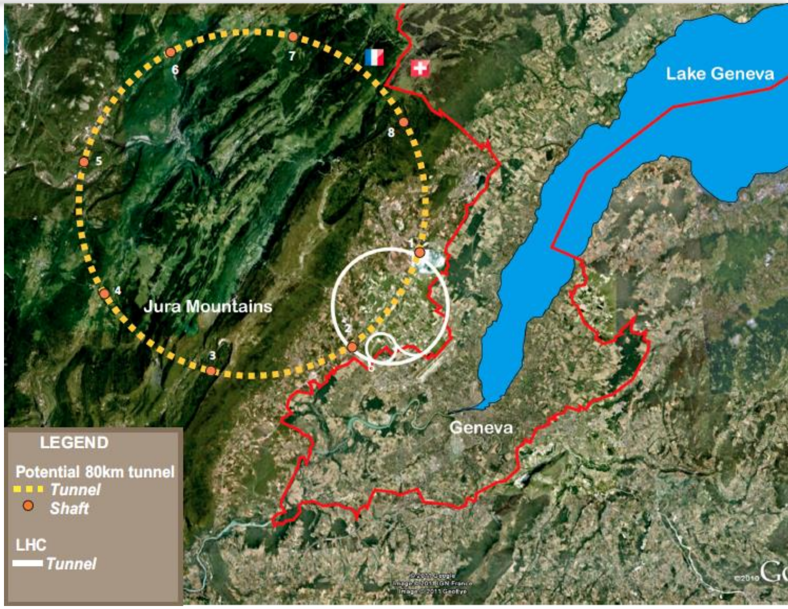
- Several locations have been studied for the possibility to construct an 80km ring tunnel in the CERN area.
  - Location constraints
    - CERN area
    - Connected to LHC/ SPS at one point
    - Depth (access shafts)



	Circumference	Average Depth	Max Depth below surface
LEP/LHC	27 km	100 m	170m
Jura	80 km	590 m	1270 m
Lakeside	80 km	280 m	690 m
Lakeside	47 km	220 m	320 m

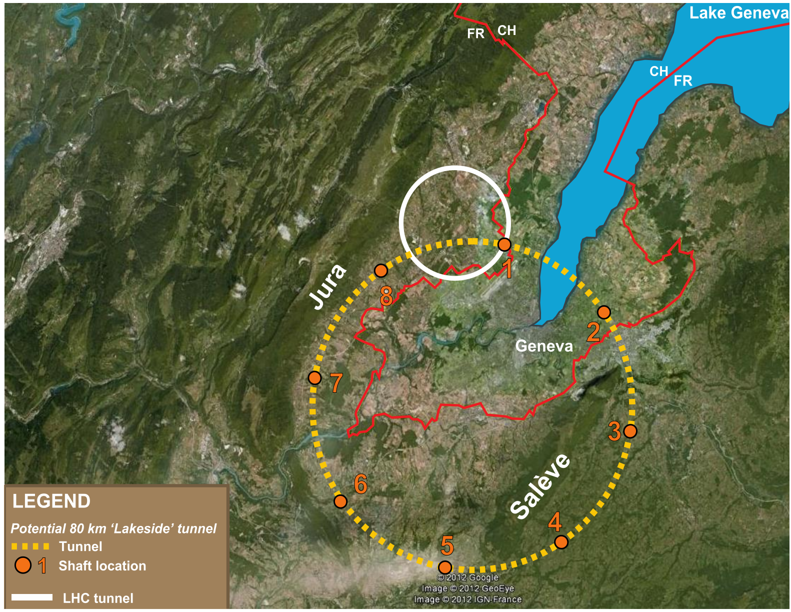
Potential locations

- Location 1:
  80km Jura option
  - Fully housed in France
  - 90% in Jura Limestones
  - 10% in Molasse
  - Connected to LHC
  - Shafts every 10km



Option 1: 80km Jura

- Location 2:
  80km Lakeside option
  - Housed in France and Switzerland
  - 10% in Limestones (Jura, Salève)
  - 90% in Molasse
  - Passes under Lake Geneva
  - Around the back of the Salève
  - Connected to LHC
  - Shafts every 10km



Option 2: 80km Lakeside

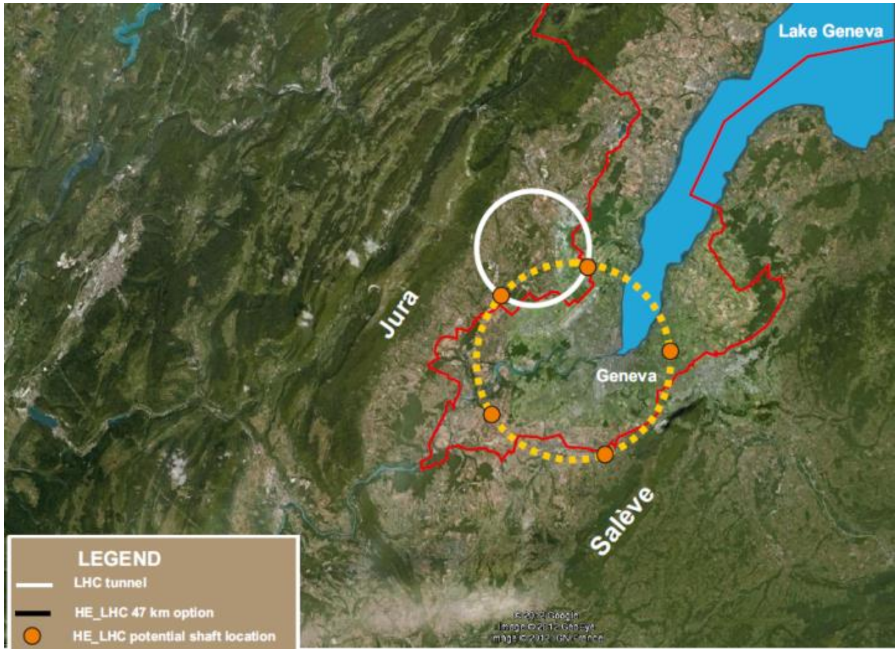
Potential locations

- Location 3:

  47km Lakeside option

  Studied from geotechnical viewpoint

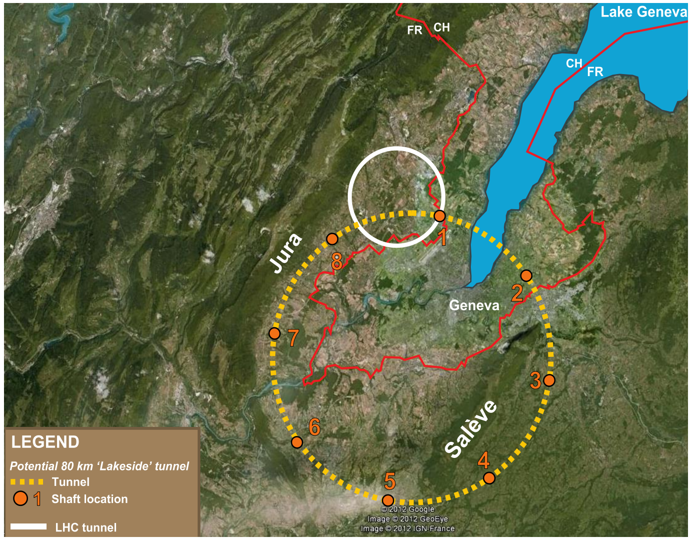
  – Fully housed in the Molasse rock (preferred excavation rock in the Geneva area)
  – Under Lake Geneva
  – In front of Salève and Jura
  – Housed in France and Switzerland
  – Connected to LHC
  – Shafts every 10km
    - Too short for physics goal?



Option 3: 47km Lakeside

Potential locations

- Pre-feasibility study performed by CERN and the specialized firm ARUP.
  - Focused on
    - geology & hydrogeology,
    - tunneling & construction,
    - environmental impacts



  - Result: for the 80km long tunnel location 2 ‘**80km Lakeside**’ is most feasible.

	Risk										
	water ingress	heaving ground	weak marls	hydro carbons	support & lining	ground response & convergence	hydrostatic pressure & drainage	Pollution of aquifers	effect of shafts on nature	effects of shafts on urban areas	**Total**
Jura 80	5	3	0	0	5	4	5	5	4	2	**33**
Lake 80	2	0	3	3	3	3	2	2	3	2	**23**
Lake 47	1	0	2	2	2	2	1	1	2	5	**18**

Feasibility
Low
High

Outline

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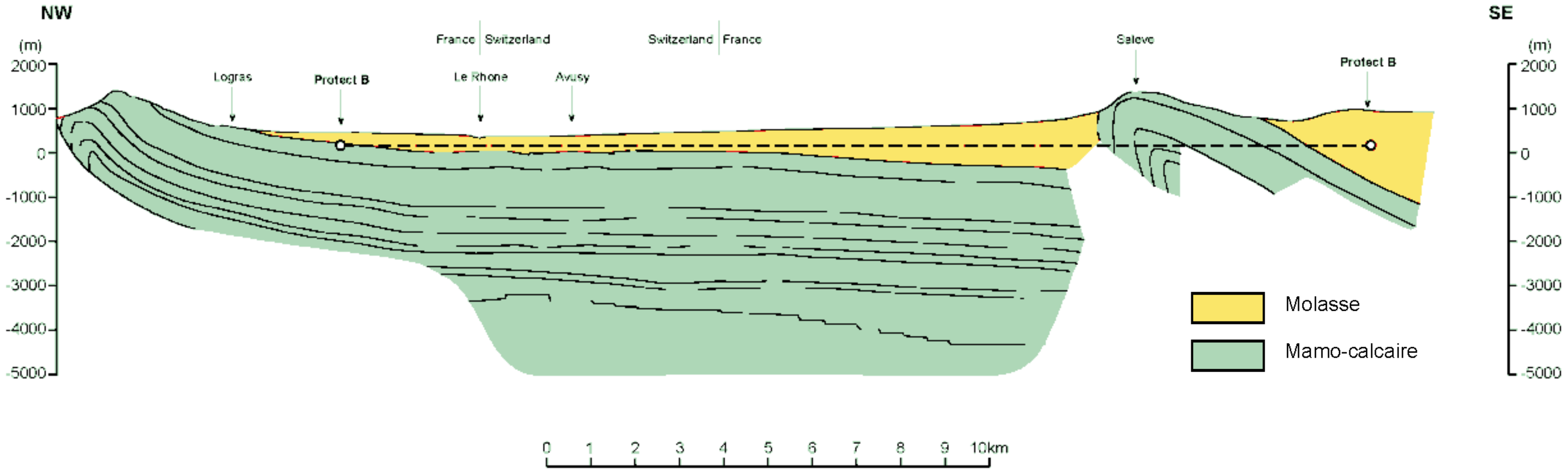
Tunnel passes through

- Moraines
- Molasse
- Limestones



Simplified geological profile

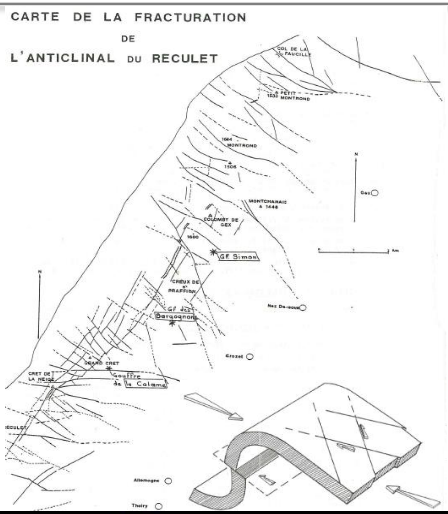
Rock properties

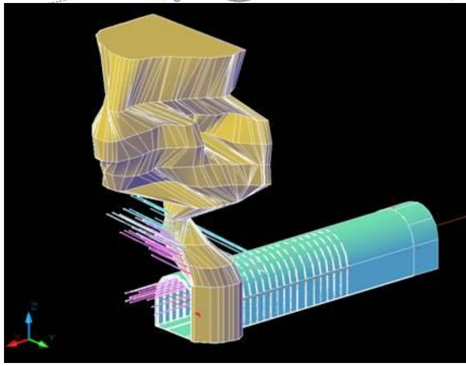
- Moraines
  - Glacial deposits comprising gravel, sands silt and clay
  - Water bearing units
- Molasse
  - Mixture of marls, sandstones and formations of intermediate composition
  - Considered good excavation rock:
    - » Relatively dry and stable
    - » Relatively soft rock
  - However, some risk involved
    - » Weak marl horizons between stronger layers are zones of weakness
    - » Faulting and fissures due to the redistribution of ground stresses
    - » Structural instability

Compression strengths

Rock type		Average σc (Mpa)
Sandstone	*weak*	10.6
	strong	22.8
	Very strong	48.4
Sandy marl		13.4
Marl		5.7

Above: fractures in Jura
Below: model of tunnel collapse due to karst





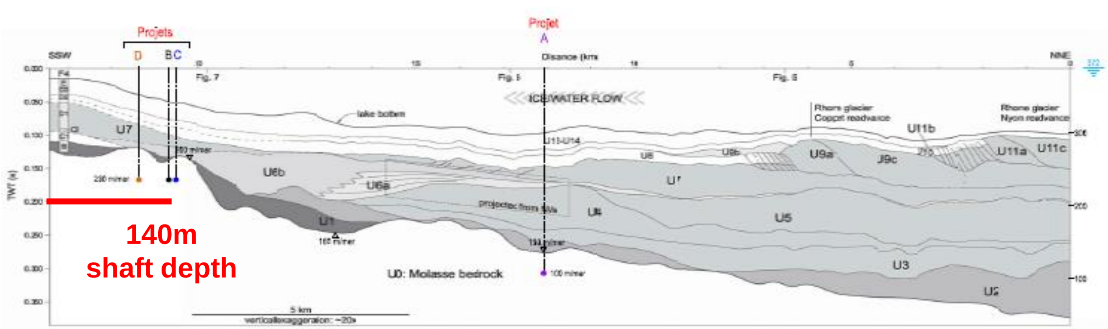
Rock properties

- Limestones
  - Hard rock
  - Normally considered as sound tunneling rock
  - In this region fractures and karsts encountered
    - » Risk of tunnel collapse
    - » High inflow rates measured during LEP construction (600L/ sec)
    - » Clay-silt sediments in water
    - » Rockmass instabilities
- Evaporates could be encountered
  - Known to exist in the 'deeper' parts of the Jura mountain
  - Unknown if these formations also exist at the foot of the Jura and Salève
  - Contain the mineral anhydrite, which reacts to water and pressure changes -> bad rock for tunneling
    - » Major structural instabilities

- **80km ring passes located :**
  - Geneva plain
  - Underneath Lake Geneva
  - Through Jura and Salève Mountains (~ 10%)

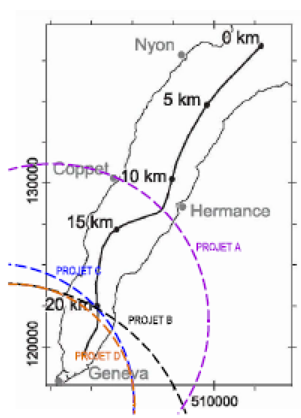
- **Geneva plain area**
  - Consists of Moraines and Molasses
    - Tunnel, tunnel enlargements and caverns located in Molasse
    - Shafts located in Moraines and Molasse
  - Near CERN the ground conditions are relatively well understood
  - More information and studies needed for the south and east areas (below Rhone River and east of Geneva)
  - During tunneling hydrocarbons could be encountered -> environmental issues and possible delays

- **Lake area** consists of Moraines and Molasse
  - Geology is not yet well understood
  - Depth Moraine-Molasse interface needs to be determined
  - Some seismic soundings performed for the possible construction of a road tunnel
    - Problems due to gas trapped in sediments -> more studies needed
  - We know that the depth of the Molasse increases rapidly towards NE
  - To ensure the positioning of the tunnel in the Molasse a minimal depth of ~ 140m is probably required



Profil synthétique longitudinal du Petit-lac

d'après Fiore-Giraclos et all. (2010)



CE considerations Tunneling

Geneva plain
Underneath Lake Geneva
Through Jura and Salève Mountains

– **Mountain area** consists of Limestones and evaporates
  - For 10% of tunnel
  - Difficult tunneling conditions
    – Local and unpredictable karst features
      » Water conduits
      » High flow rates (600L/ sec)
    – Water transports silt-clay sediments
      » Difficult to drawing off water through pressure relief holes
      » Increase of water inflow over time
      » Difficulties in removal of the water
      » Risk of aquifer pollution & depletion
    – Anhydrites -> 'badrock' causes swelling
      » Heaving of the tunnel invert
      » Structural instabilities
      » Probably low risk for 80km Lakeside option but high risk for 80km Jura option

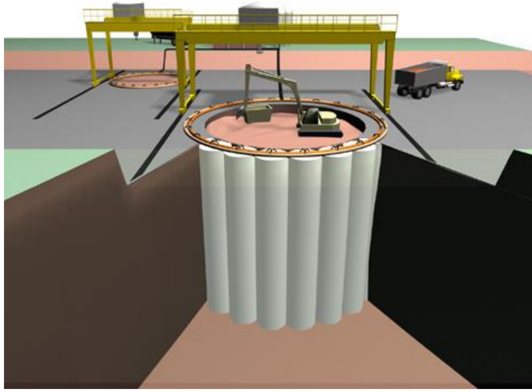
LEP tunnel collapse

Example of tunnel invert heave Chienberg tunnel, Switzerland

- Excavation methods
  - Tunnel in Molasse
    - TBM for main tunnel
      - » Tunnel advancement rate 150m/ week
    - Rockbreakers and roadheader for tunnel enlargements
      - » Tunnel advancement rate 30m/ week
  - Caverns in Molasse
    - Rockbreakers and roadheader
  - Shafts in Moraines – Molasse
    - Traditional excavation methods
    - Rockbreakers and roadheader
    - Special works faced withwater bearing units
      - » Ground freezing
      - » Diaphragm walling
    - Slipform technique for lining shaft

TBM

Roadheader



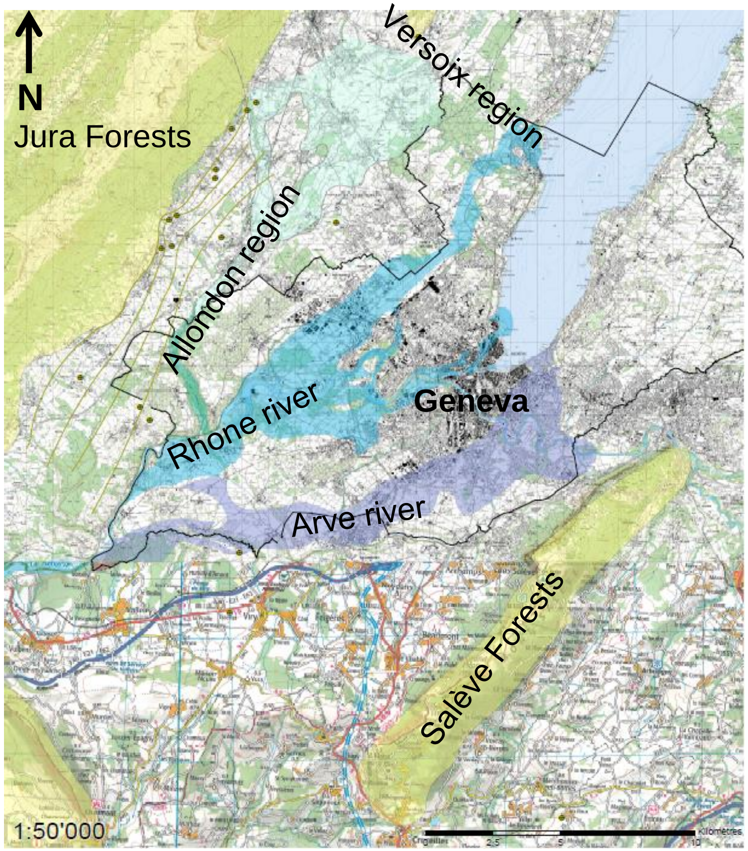
Ground freezing technique used at P5

– Excavation methods
  - Tunnel in Limestone
    – Choice between TBM and Drill & Blast (D&B)
      » Amount of tunneling through limestones is relatively short; D&B preferred
      » In areas with karstic features D&B allows free access to the face for grouting/ dewatering ahead of the face
      » Tunnel advancement rate 20m/ week

Drill & Blast

	TBM	Drill & Blast
Ground Type	Molasse	Jura Limestone
Water Pressures	up to 10bar	up to 30bar ?
Lining Options	• One pass undrained lining down to 100m • Two pass drained lining below 100m	Two pass drained lining

- For the 80km tunneling project, the environmental impacts should not be underestimated
  - project crosses many sensitive areas:
    - urban, agriculture, natural parks, protected groundwater areas etc.
  - Some main impacts issues to consider
    - Civil Engineering
    - Social acceptance
    - Landscape
    - Water protection
    - Natural areas
    - Radiation
    - Waste
    - Traffic

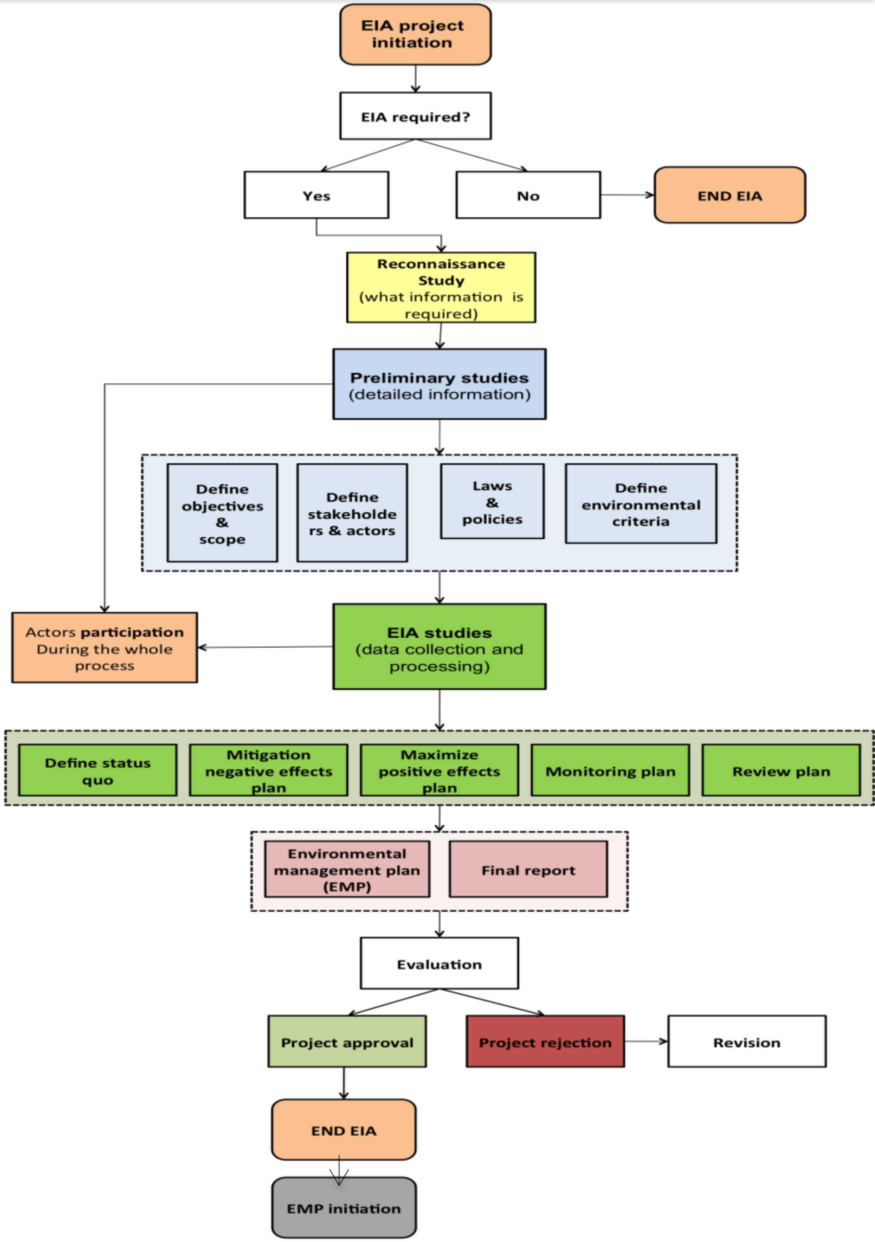


CE considerations *Environmental*

- Some examples of issues to consider
  - Civil Engineering
    - Spoil deposit
    - Risk of encountering hydrocarbons in the Geneva plain
    - Risk of polluting aquifers due to Civil Engineering works
    - Risk of depleting aquifers due to pumping water related to water inflow in the tunnel (karst related)
  - Social acceptance & landscape
    - Location of shafts in urban and natural areas
    - Excavated spoil has to be deposited somewhere
    - Electricity cables, roads etc
    - Radiation effects

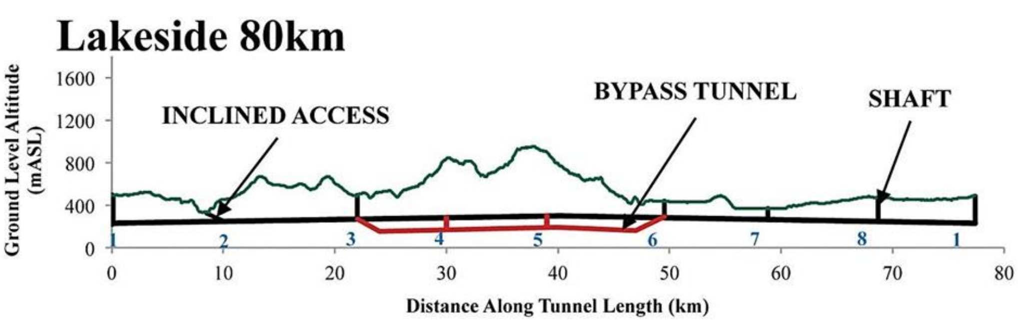
This is just the tip of the iceberg

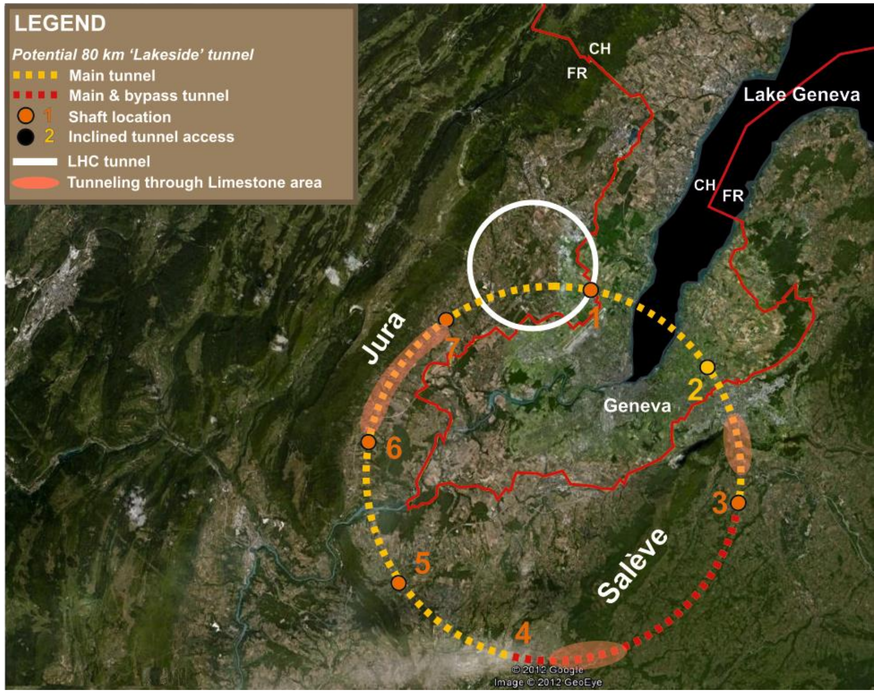
- Environmental Impact Assessment (EIA)
  - Long process, several stages, start early
  - Will have to be approved by <u>both</u> FR and CH
    - Approval difficulties may be encountered as with the “Annemasse Railway CEVA”, and the Geneva bypass tunnel “La traversee de la rade”



- Optimization studies for the project configuration have been started
  - Bypass tunnel in geological and environmental sensitive area
  - Inclined access tunnel in urban area

- More optimization studies needed
  - Incline tunnel?
  - More bypass tunnels?





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Cost Estimate

- Costing performed by the CERN GS-SE group
- Based on
  - Historical data (LEP, LHC, CLIC, ILC)
  - 2012 CHF unit costs from similar projects and contractors
  - Swiss standard catalogue used for cost breakdown structure
    - NO technical drawings available -> costing based on assumptions for project configuration
  - No optimization studies for the tunnel configuration have been performed yet.

Cost Estimate

- Assumptions
  - Tunnel
    - Internal diameter 5.6m
      - same as CLIC, standard size for European subway tunnels
    - 80km for machine tunnel
    - No tunnel enlargements
    - 33km for bypass tunnel and inclined access tunnel
  - Caverns
    - Two detector caverns
    - Six medium sized caverns at access points
  - Shafts
    - Two 18m internal diameter shafts connecting detector caverns with the surface
    - Five 9m internal diameter access shafts connecting the main tunnel with the surface

Cost Estimate

- Costs
  - Only the minimum civil requirements (tunnel, shafts and caverns) are included
  - 5.5% for external expert assistance (underground works only)
- Excluded from costing
  - Other services like cooling/ ventilation/ electricity etc
  - service caverns
  - beam dumps
  - radiological protection
  - Surface structures
  - Access roads
  - In-house engineering etc etc
- Cost uncertainty = 50%
- Next stage should include costing based on technical drawings

CE works	**Costs [kCHF]**
Underground	
Main tunnel (5.6m)	
Bypass tunnel & inclined tunnel access	
Dewatering tunnel	
Small caverns	
2 Detector caverns	
Shafts (9m)	
Shafts (18m)	
Consultancy (5.5%)	
TOTAL	

AMBERG ENGINEERING

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Feasibility / Risk Issues

Some examples of issues (that need further studies)

- Geotechnical
  - Unknown geology in lake area
  - Local ground stresses unknown
  - Risk of water ingress in limestone areas & moraines
- Tunneling
  - Risks related to karstic features and weak zones (faulting) in Jura
  - Degree of tunneling support
  - Heave of tunnel invert

	Risk										
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Feasibility

Low

High

Feasibility / Risk Issues

Some examples of issues (needs to be studied in more detail)

- Environment
  - Risk of environmental impacts such as civil engineering, social acceptance, pollution of aquifers etc
  - Risk of encountering hydrocarbons
  - Risk of EIA rejection
- Costs
  - Risk of cost increase due to all issues mentioned

	Risk										
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Feasibility

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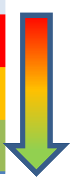

High

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Next Steps

- Project only in its very initial stage

- To continue further the following steps are required
  - Define project requirements
    - Detector cavern requirements, dump caverns, shielding requirements, other services defined, etc.etc.
  - Optimization studies for the tunnel configuration
    - E.g. tunnel inclination, shaft locations,possible increase tunnel circumference etc.
  - Create preliminary technical Civil Engineering designs
  - Continue feasibility studies
  - Continue environmental impact studies