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Pipeline System Routing Study

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|-------------|-------------|--------------------|-----------------|----------------|-----------------|
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1. INTRODUCTION

1.1 FOREWARD

In the context of negative emissions and decarbonizing industry, carbon capture and storage (CCS) is being discussed as an option for Switzerland. The search for domestic storage sites is ongoing, in the meantime, there could be a possibility of collecting Swiss CO₂ and sending it to storage sites under the North Sea, that are planned to open by end of 2024 (Northern Lights project by Equinor, Shell, Total).

In Switzerland, KVA Linth is currently performing a feasibility study for a capture plant with a potential provider, other emitters are also exploring cost and feasibility.

Saipem has been awarded for the feasibility and cost estimate of building a “collection network” (similar to a distribution grid for gas) to connect to Switzerland’s largest CO₂ emitters on the one hand and to transmission pipelines on the other hand by 2030.

The study should give a first indication of cost, according to a Class 5 estimate.

Switzerland has currently 32 large emitters, defined as point sources that emit over 100,000 tons/y of CO₂ (see Figure 1.1.1). Together, these 32 large emitters emit about 7 million tons of CO₂ per year.

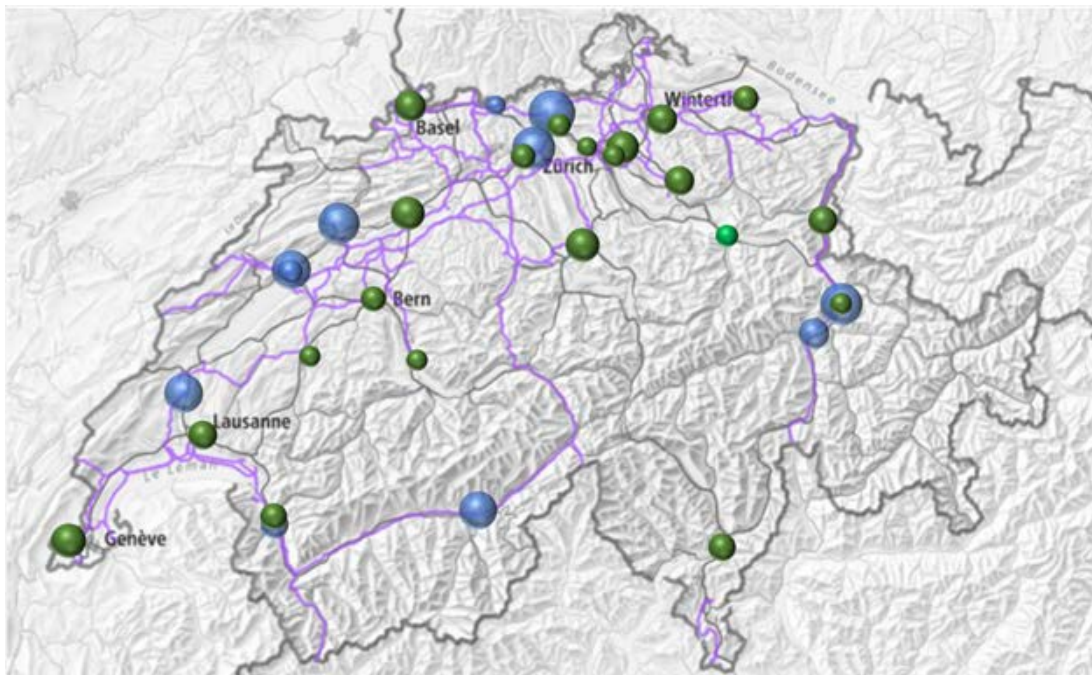




Figure 1.1.1: Large emitters and current natural gas pipeline network in Switzerland

Currently, none of these plants has a capture facility – it is expected that the current study should provide an indication of optimal conditioning parameters (water content and purity) for the CO₂.

The CO₂ collecting network subject of the present study will transport the captured CO₂ stream up to a delivery point, from where a long transmission pipeline will deliver the CO₂ to a selected location, for final sequestration.

Two options are possible:

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- Transmission towards the North could start in Basel
- Transmission towards South should be assumed to be in Collombey, where an existing oil pipeline leads to Genoa

The transmission pipeline is not part of the current SoW.

It is requested that the new pipeline network to follow the existing natural gas pipelines corridors as much as possible. Furthermore, the possibility to use decommissioned gas pipeline sections is to be considered. A specific effort shall be made to clarify possible configurations for the Kanton of Zurich, where different scenarios are possible to connect additional smaller point sources.

1.2 SCOPE

Scope of the present routing study is to find out and propose pipeline network transport configuration of the CO2 collection system, in line with the applicable code and with the criteria of safety and integrity to be requested to such a kind of work.

The assumptions of the study has been based on desktop assessment only, the input data has been taken from information freely available on local and international web sites, literature, national or European geographical institutes, Geoportals etc., the digital terrain model used will either be the SRTM database.

As part of the study were provided the criteria used for the development of the routes, therefore all their characteristics of interest at this level of design were identified.

In the scope of the work, emphasis was placed on identifying the main difficulties (especially crossing) and challenges that can be expected, to provide elements for the further evaluation technical and economical of the project.

The collection from the emitters is developed with flowlines system designed with the aim of:

- generate the minimum disturbance on the affected land and natural environment
- enable to guarantee its integrity avoiding the area with human risk

The aim of the work was also to represent in an overall map Drawing 000-LC-B-81000 all the pipeline network identified in the study; all the data used were collected in an ArcGIS Geodatabase.



1.3 DEFINITIONS

The abbreviations when used in this document will have the meanings described here in the following list:

| | |
|---------------|-----------------------------------------|
| COMPANY/OWNER | VB SA |
| CONTRACTOR | Saipem S.p.A. |
| PROJECT | CO2 COLLECTION NETWORK CONCEPTUAL STUDY |

1.4 ABBREVIATIONS

| | |
|-------|---------------------------------|
| ALARP | As Low as Reasonably Possible |
| API | American Petroleum Institute |
| ATCI | Actualized Transport Cost Index |
| CAPEX | Capital Investment Cost |
| CCS | Carbon Capture and Storage |
| CS | Compression Station |
| QRA | Quantitative Risk assessment |

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| | |
|-------|--------------------------------------------|
| ESIA | Environmental and Social Impact assessment |
| KP | Kilometre Post |
| MOP | Maximum Operating Pressure |
| MM | Million |
| NPS | Nominal Pipe Size |
| OD | Outside Diameter |
| OPEX | Operating Cost |
| SCADA | Supervisory Control and Data Acquisition |
| SMYS | Specified Minimum Yield Strength |
| WT | Wall Thickness |
| PE | Polyethylene |
| DPh | Dense Phase option |

1.5 APPLICABLE CODES & STANDARDS

- ISO 27913-2016, “Carbon dioxide capture, transportation and geological storage — Pipeline transportation systems (2016).
- ISO 13623, “Petroleum and natural gas industries — Pipeline transportation systems”
- DNVGL-RP-F104, “Design and operation of carbon dioxide pipelines” (2019)
- API SPECIFICATION 5L-2018, 46th Edition, “Line Pipe” (2018)

1.6 REFERENCES

- [1] 000-ZA-E-09001 Pipeline System Hydraulic & Optimization Study Report
- [2] 000-LC-B-81000 Overall map of pipeline Routes
- [3] M. Nyborga*, K. Arvidssona, J. Johanssonb, S, Liljemarka, L. Olsson - GHGT-10 - Risk analysis methodology for CO2 transport including quantified risk calculation.
- [4] M.M.J. Knoopea*, I.M.E. Rabenb, A. Ramíreza, M.P.N. Spruijtb, A.P.C. Faaij - The influence of risk mitigation measures on the risks, costs and routing of CO2 pipelines

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2. EXECUTIVE SUMMARY

The routing desktop study for the pipeline system has been carried out by determining its configuration in terms of pipeline routes, lengths, population density, difficulties, crossings.

Possible corridors have defined and proposed, on large scale basis as requested in the Scope of Work and have been managed by using ArcGIS tools.

The total length of the routes defined in the study is 1032 km include large pipeline diameter NPS 30" (and 14" / 16" for dense phase option) as follows:

- 229 km for western Trunkline, which 16 km are as offshore in Geneva Lake,
- 141 km for Eastern Trunkline.

The routing study carried out has defined a possible network route scenario, consisting of the two main trunklines southeast and southwest of the Basel delivery point. The western trunkline shall also have the capacity to feed with the entire CO₂ production, the delivery point south of Collombey.

The routing criteria has been supplied, however the method priority has been given to the parallelism with existing pipeline by forming possible "technical corridors"; this seems to be a generally more acceptable proposal, even by the territorial and national authorities, when it comes to occupying the land with a linear technological structure.

In section 4.3 is shown that the development of the CO₂ collection network has been optimized by using as much as possible the existing gas pipeline network.

On the other hand, it must also be considered that linear structures (roads, railways, power lines, canals and buried pipelines) meet different requirements from a technical and functional point of view, and above all from a safety point of view, so this approach is not always beneficial.

Special care has been paid to highlight the area with higher population density and it is recommended that those areas to be carefully investigated in next design in terms of mitigation measures to be taken.

Cartographic study has been performed using available geo-database and GIS tools to establish the criticalities along the thousand kilometers of routes developed.

The pipeline installation criteria and in particular the right of way and trench to be considered has been described. Main crossings either as rivers and main road and railway, for each line have been listed in summary tables and installation methodologies for these crossings have been supplied; this issues are deemed a key point for ensuring a safe and reliable route proposal.

In Section 6 the finding has been collected in summary tables and the main point of attention for the routing has been supplied as the areas of greatest predictable criticality at this stage.



2.1 RECOMMENDATIONS

The routes thus established in the area are to be considered feasible corridors of interest on which to carry out the Pipeline System Hydraulic & Optimization Study but at the same time they are the starting point for developing routes for final design, after having carried out all the design activities, geotechnical surveys, topographic surveys, environmental impact assessment (ESIA) and application to the authorities.

By carrying out these activities, optimizations will be possible, but also re-routings with local extensions and the adoption of different installation technologies.

The current study also reports a whole series of data that it was possible to deduce from the cartographic analysis and which, on a qualitative level, can support the estimates made.



Focus has to be made to the points of particular attention (section 6.3) and to all the further studies necessary to complete and consolidate the feasibility.

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In particular, the crossing of Geneva Lake was highlighted as a main challenge. This issue poses severe technological as well as environmental and economic impact problems, some design concept have been developed as guidelines which shall be a complement to the feasibility defined in this study.

Through this study are provided many elements and details to be investigated in the next development of the project.

Throughout all the section of the report, the QRA activity is mentioned several times as key point for the further design phase; the involvement of the local authorities, that is a focal step of ESIA, shall be for the whole project including the results of the QRA. It is recommended to share with local Authorities in advance and during the permit application process, the hazard mitigation measures resulting from QRA and freeze the routing before the detail design phase.

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3. BASIC DATA

The basic data used for the routing study for the CO2 pipeline collection network, as mainly drawn from Ref.[1] and are here below summarized.

3.1 DESIGN PARAMETERS

The following Table 3.1.1 reports the design data and the operating parameters for the CO2 Collection Network.

Table 3.1.1: CO2 Collection Network – Main Design Parameters

| Parameter | | Gaseous Phase Transport | Dense Phase Transport |
|--------------------------------|--------------|------------------------------------------------|------------------------------------------------|
| Fluid | - | CO2 | |
| Design Pressure ⁽¹⁾ | [barg] | 40 | 150 |
| Maximum Design Temperature | [°C] | 50 | 50 |
| Design Flowrate ⁽²⁾ | [ktons/year] | 5095 (East Trunkline) 3909 (West Trunkline) | 5095 (East Trunkline) 3909 (West Trunkline) |
| Design Life | [years] | 30 | 30 |
| Hydraulic Roughness | [µm] | 20 | 46 |
| Burial Depth | [m] | See section 5.2.3 | See section 5.2.3 |

Notes:

- 1) A maximum operating pressure of 175 barg has been selected for the offshore section of the Western Trunkline crossing Geneva Lake
- 2) For detailed information on single emitter rates, refer to Section 3.2.

The considered CO2 stream composition is reported in (Ref.[1]). The same composition is considered for all the emitters.

3.2 CO2 EMITTERS DATA

Following Table 3.2.1 reports a list of the considered CO2 emitters reported together with the respective location and emission rates, as per Ref.[1]. Each CO2 emitter is connected to the main trunkline by means of a dedicated flowline. Depending on the emitter geographical location, the emitter can be connected either to the East or West Trunkline, as indicated in the below table.

The coordinates system is the WGS 1984 geographic coordinates system, with the following parameters:

Name: GCS_WGS_1984
 WKID: 4326
 Authority: EPSG
 Angular Unit: Degree (0,0174532925199433)
 Prime Meridian: Greenwich (0,0)
 Datum: D_WGS_1984
 Spheroid: WGS_1984
 Semimajor Axis: 6378137,0
 Semiminor Axis: 6356752,314245179
 Inverse Flattening: 298,257223563



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Table 3.2.1: CO2 Collection Network – List of CO2 emitters



Flow conveyed to Eastern Trunkline

| Emitter | Longitude | Latitude | Elevation | CO2 Emission Rate |
|--------------------------------------------|-----------|----------|-----------|-------------------|
| | | | m | ktons/year |
| Axpo Tegra AG | 9.4246 | 46.8263 | 605 | 240.8 |
| Holcim (Schweiz) AG (1) | 9.5529 | 46.9155 | 540 | 454.5 |
| GEVAG Trimmis | 9.557 | 46.9161 | 539 | 122.0 |
| VfA Buchs | 9.4836 | 47.1756 | 448 | 206.5 |
| KVA Linth | 9.04 | 47.135 | 430 | 123.3 |
| KEZO Hinwil | 8.8206 | 47.3083 | 548 | 218.4 |
| KVA Thurgau | 9.1383 | 47.5575 | 432 | 166.1 |
| KVA Winterthur | 8.7526 | 47.4981 | 454 | 225.1 |
| KVA Limmattal | 8.403 | 47.4166 | 384 | 103.6 |
| ARA Werdholzli | 8.4814 | 47.4009 | 396 | 40.0 |
| ERZ KHKW Hagenholz | 8.5653 | 47.4142 | 430 | 400.0 |
| Renergia Zentralschweiz AG | 8.376 | 47.1135 | 412 | 286.6 |
| Jura Cement Fabriken | 8.1568 | 47.4147 | 353 | 470.4 |
| GEKAL Buchs | 8.1035 | 47.389 | 392 | 156.9 |
| KVA Turgi | 8.2678 | 47.4844 | 350 | 133.8 |
| Holcim (Schweiz) AG | 8.2391 | 47.5217 | 351 | 554.5 |
| DSM Nutritional Products AG - Werk Sisseln | 7.9786 | 47.5476 | 307 | 100.9 |
| IWB Basel | 7.5833 | 47.5467 | 263 | 242.5 |

Flow conveyed to western Trunkline

| | | | | |
|---------------------------------|--------|---------|-----|-------|
| Les Cheneviers | 6.0322 | 46.1942 | 368 | 302.1 |
| TRIDEL Lausanne | 6.6392 | 46.5277 | 610 | 211.2 |
| Holcim (Suisse) SA | 6.5464 | 46.6557 | 450 | 378.7 |
| LONZA AG | 7.8882 | 46.2967 | 648 | 366.0 |
| SATOM Monthey | 6.96 | 46.2781 | 396 | 175.9 |
| Cimo SA | 6.9653 | 46.2529 | 403 | 196.4 |
| SAIDEF Fribourg | 7.1218 | 46.7725 | 597 | 112.8 |
| Juracime SA | 7.0296 | 47.034 | 436 | 158.8 |
| Varo Refining Cressier SA | 7.0358 | 47.04 | 429 | 383.4 |
| Vigier Cement AG | 7.2493 | 47.1848 | 596 | 436.9 |
| Energiezentrale Forsthaus (KVA) | 7.4139 | 46.9515 | 578 | 160.1 |
| AVAG KVA AG | 7.6062 | 46.7621 | 562 | 113.3 |
| KEBAG AG | 7.5706 | 47.2153 | 432 | 284.2 |

Some of the above emitters are located very close to each other, therefore it is assumed that the following emitters can be considered as a unique emission source (i.e. it is assumed that the captured CO2 coming from the

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following plants couples will be available for compression at the same location (to be defined), in order to have a single compression station).

- Holcim (Schweiz) AG (1) and GEVAG Trimmis (total CO2 emission = 576.6 ktons/year): according to the above coordinates, the distance between the 2 emitters is below 400 meters.
- Juracime SA and Vigier Cement AG for the WT (total CO2 emission = 542.2 ktons/year) : according to the above coordinates, the distance between the 2 emitters is below 800 meters.

3.3 FLUID DELIVERY POINTS

The locations of the 2 proposed delivery points are reported in the below Table 3.3.1 and the destination area is shown in Figure 3.3.1: Delivery points areas. The proposed network configuration shall be capable to deliver the CO2 to both the delivery points.

It is foreseen to operate the western trunkline in both directions, i.e. to Basel and to Collombey, while the Eastern Trunkline will be designed considering all the Eastern emitters being routed only to Basel delivery point.

In case Basel delivery point is not available or not operative, it will be evaluated the possibility not to capture the CO2 at some Eastern emitter to reduce the trunkline flowrate and the system pressure drop up to Collombey area.

Table 3.3.1 CO2 Delivery Points

| CO2 Delivery Point | Longitude | Latitude |
|---------------------------|------------------|-----------------|
| Basel area | 7.8973 | 47.5827 |
| Collombey area | 6.9562 | 46.2967 |



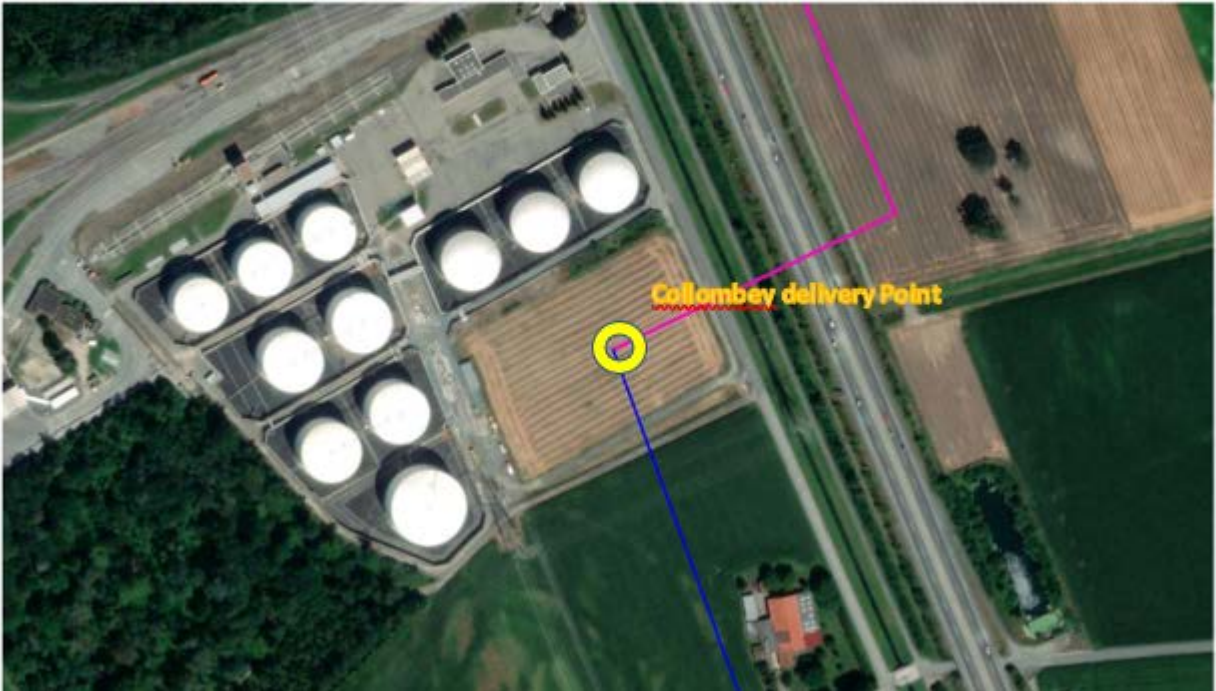


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Figure 3.3.1: Delivery points areas



| | | | |
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3.4 LINE PIPE

Table 3.4.1 reports the characteristics of the line pipes ref [1], assumed:

Table 3.4.1: Line pipe characteristics considered for this study

| | |
|----------------------------|---------------------------------------|
| Design Code | ISO 13623 |
| Design Pressure | as per Table 3.1.1 |
| Steel Grade | ISO L450MB (equivalent to API 5L X65) |
| Internal Coating | n/a |
| External Coating | 3 mm PE |
| Corrosion Allowance | 1 mm |

The line pipe wall thickness evaluation for hoop stress considerations is based upon the methodology outlined in Clause 6.4.1.1 of ISO 13623:2017.

The minimum required line pipe wall thickness for hoop stress considerations is then determined by the addition of any required corrosion allowance.

3.5 CLASS LOCATION DEFINITION

The applicable code ISO 13623 Annex B.2 (Table 3-2) specifies the location classes for onshore pipelines as below reported:



1. Locations subject to infrequent human activity with no permanent human habitation. Location class 1 is intended to reflect inaccessible areas such as deserts and tundra regions.
2. Locations with a population density of less than 50 persons per square kilometer. Location class 2 is intended to reflect such areas as wasteland, grazing land, farmland, and other sparsely populated areas.
3. Locations with a population density of 50 persons or more but less than 250 persons per square kilometer, with multiple dwelling units, with hotels or office buildings where no more than 50 persons may gather regularly and with occasional industrial buildings. Location class 3 is intended to reflect areas where the population density is intermediate between location class 2 and location class 4, such as fringe areas around cities and towns, and ranches and country estates.
4. Locations with a population density of 250 persons or more per square kilometer, except where a location class 5 prevails. A location class 4 is intended to reflect areas such as suburban housing developments, residential areas, industrial areas, and other populated areas not meeting location class 5.
5. Location with areas where multi-store buildings (four or more floors above ground level) are prevalent and where traffic is heavy or dense and where there may be numerous other utilities underground.

The distances used to determine the population densities should, until CO₂-specific distances are defined and stakeholder-accepted, be determined using dispersion modelling.

The location class that is used in specification of design factors. It is defined as number of people per square kilometer, (Population density), see - ISO 13623, and shall be determined by laying out zones along the pipeline route, with the pipeline in the centerline of this zone having a width not less than 400 m, and to be determined for category E fluid pipelines taking into account the possibility of very low temperature during a leakage of high pressure pipelines, giving high density gas that may float significant distance.

The length of the zones shall be 1.5 km and located at any location along the pipeline.



Focus shall be given to classification of the fluid to be considered, in case of the accidental release consequence due to the change in characteristics of the product. Hazardous distances for CO₂ may be considerably longer than

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for gas pipeline, particularly in valleys or low laying areas, due to the higher release inventory mass and the heavier than air density. According to ISO 13623 last edition CO2 is categorized by category E as shown in Table 3.5.1

Table 3.5.1: Classification of fluids with respect to potential hazard to public safety As per Table 1 — of ISO 13623 Code

| | |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Category A | Non-flammable, water-based fluids. |
| Category B | Flammable and/or toxic fluids that are liquids at ambient temperature and at atmospheric pressure conditions. Typical examples are oil and petroleum products. Methanol is an example of a flammable and toxic fluid. |
| Category C | Non-flammable fluids that are non-toxic gases at ambient temperature and atmospheric pressure conditions. Typical examples are nitrogen, argon and air. |
| Category D | Non-toxic, single-phase natural gas. |
| Category E | Flammable and/or toxic fluids that are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases and/or liquids, or supercritical fluids. Typical examples are hydrogen, <i>carbon dioxide</i> , natural gas (not otherwise covered in category D), ethane, ethylene, liquefied petroleum gas (such as propane and butane), natural gas liquids, ammonia and chlorine. |

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4. ROUTING CRITERIA

4.1 GENERAL

The general recommendation with respect to CO2 pipeline routing is to adopt the standard approach as for route selection for hydrocarbon pipelines (category E as per ref. ISO 13623)

The general criteria adopted in this activity are listed below; they represent general guideline principles to be followed in the routing process but tailored to the present Switzerland CO2 pipeline network:

- Pay attention to Human presence on the land affected especially in consideration that the emitters are inside industrial plant and facilities and sometime in urban areas.
- Keep safety clearance (in case of High Pressure or dense phase pipeline) from existing houses, buildings, existing private and public property.
- Follow in parallelism the existing linear structures present on the affected land. This criteria is considered necessary at a first approach in developing hundreds of kilometers of routes, as required by the present project, considering that the presence these existing corridors and easement of pipeline, roads, powerline could generally be favorable to a possible extension of a new right of way for the new CO2 pipeline. This particular aspect is then addressed in the following chapter 4.3.
- Environmental issues considerable at a desktop study level, (before the EIA activities to be performed in advanced phase)
- hydrogeological conditions (waterstreams and watertable) and geological condition that could be highlighted at this level of study
- morphological condition of the area, especially in the southern mountainous area that dictate the corridor by using the more suitable valleys.

Point of attention has been the presence of populated area in the route nearby. This issue is studied at desktop level but shall be focused on further design stage by direct site survey and shall be the basis for the QRA activity. The main crossing shall be foreseen in a trenchless method (i.e. HDD), this certainly applies to large river crossings, to the most important highways, main roads, and railways. In some morphologically complicated situations, it will have to be defined whether the aerial bridge crossing can be considered.

Since the route corridors were defined at little scale the interferences of the pipeline with the scattered rural urbanization were not generally taken in account.



At the present level of desktop routing study the lithology of geologic formations encountered along a pipelines are not considered as well as all the features related to geohazards (seismic issues, active faults landslides, erosion, low bearing capacity soils, etc ..) shall be investigated in future phase.

4.2 ROUTING ARCHITECTURE

The routing study drawn a possible network route scenario, consisting of the two main trunklines (eastern and western) both reaching the Basel delivery point. Moreover the western trunkline shall also have the capacity to feed the delivery point south of Collombey with the full flowrate.

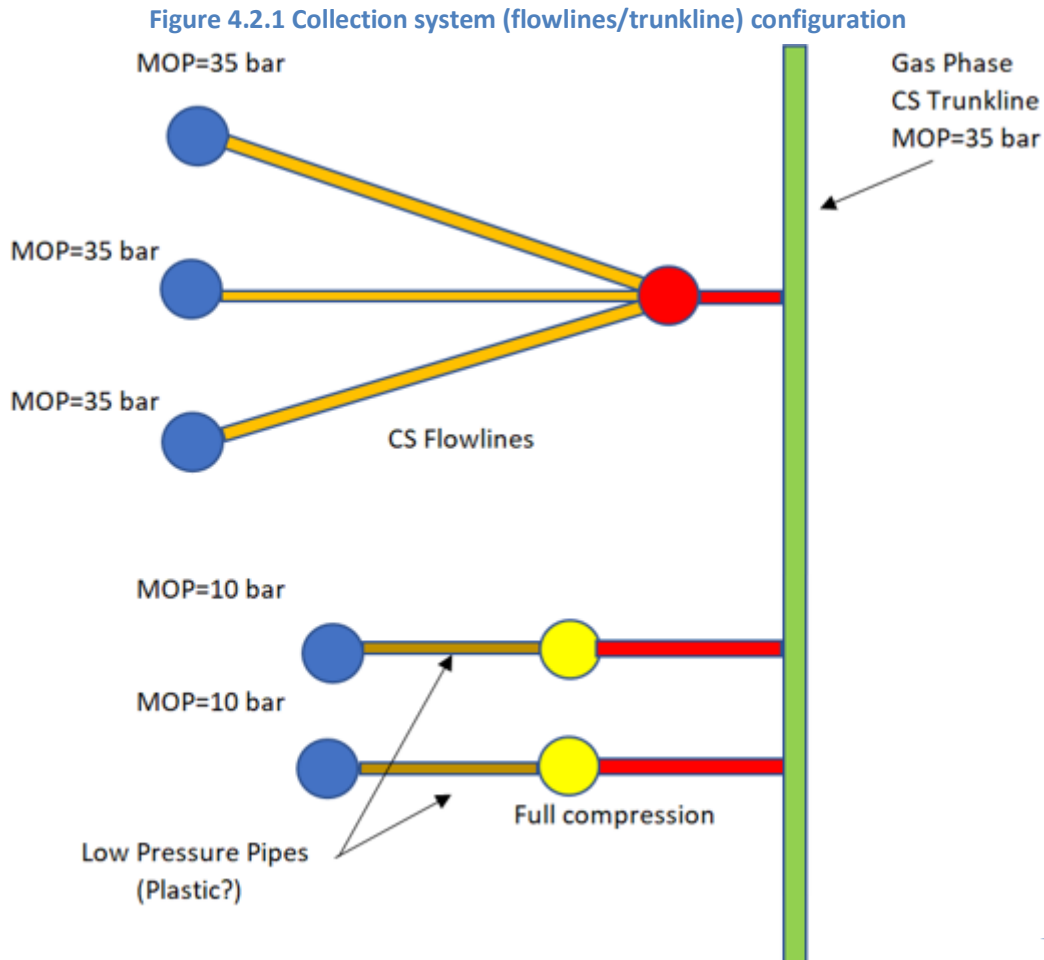
The flowlines shall be in most of cases as finger type connection to the trunkline, this configuration is particularly efficient in case of gaseous phase transport, as the compression station located at the emitter can provide the pressure required to enter the trunkline without the need for any additional compression.

The system taken as reference for the routing study is the Gaseous Phase Transport - Base Case (however generally the will not change for the dense phase option); the routing has been developed in consideration of gas phase and relevant category E of fluid. However the dense phase option is as a more hazardous fluid so that more stringent recommendation oriented on the proximity of human presence shall be expected as result of QRA, considering also that, according to ASME B31.4, dense phase CO2 is classified as a hazardous liquid. In view of this, additional care is deemed necessary as mitigation measures.

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The CO2 is transported in gaseous phase, with a MOP of 35 barg. Due to safety reasons, some flowlines crossing urban areas are considered with a MOP = 10 barg (i.e. low pressure flowlines). Ref. [1] 000-ZA-E-09001 Pipeline System Hydraulic & Optimization Study Report.

The selected configuration for routing study is the gathering of CO2 in gaseous phase transport with possibility of low pressure flowlines. Additional compression is required outside urban areas. Plastic pipes could be used for low pressure flowlines.





4.3 PARALLELISM WITH EXISTING LINEAR STRUCTURES

The design approach to the project of the CO2 pipeline collection network, in consideration of the affected land and related level of human presence, the criterion of following in parallel the existing linear structures is generally considered a good design practice in order not to have thoughtless land occupation. Furthermore, such a criterion is generally well considered by the authorities responsible for regulatory planning.

Moreover, to consider general regional planning issues, the route should be “bundled” with existing infrastructural facilities, such as other pipelines and sometimes with transport systems (mainly roads and tracks).

Whenever deemed appropriate, this criterion was applied in the present study.

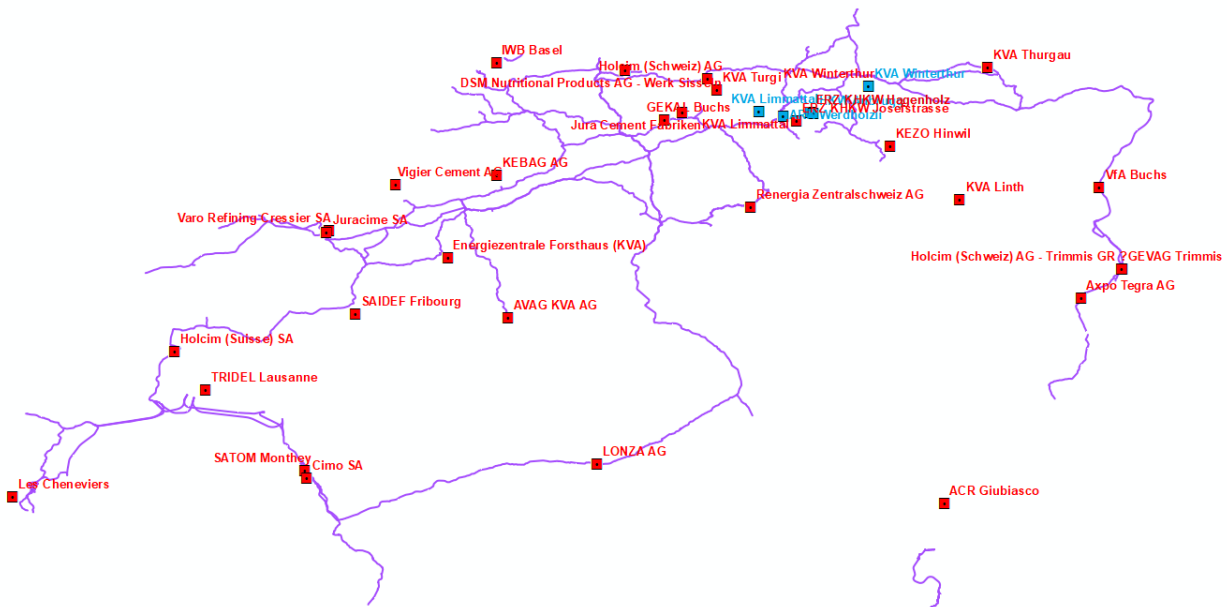
The linear structures considered are the roads, railways, canals and other well identifiable features in the present cartographic investigation phase made on available satellite images; but above all the existing buried pipelines were taken into consideration in particular the high pressure gas lines ones of national network.

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The latter data was made available by the client, as digital cartographic information was included in the GDB "geodatabase" developed for the project, this data layer allowed to draw the proposed routes for flowline and trunkline in parallel location where possible as a real common right of way.

As can be seen clearly In Figure 4.3.1, the existing gas pipeline network is very favorable for the development of the CO2 collection network.

Figure 4.3.1 Existing pipeline network



However, in view of previous pipeline design experiences, it is important to keep in mind that: in all situations, in which there is a complex morphology, together with the presence of constraints due to industrial buildings or road structures, such as in the land concerned, an existing gas pipeline probably occupies "the best position", this fact and can be more of an obstacle than an advantage for the location of the new line.



Powerlines have generally not been taken into consideration, having different requirements in their development. Indeed, in future phases they may constitute an aspect to be verified as interference, given that in many cases the power lines and their pylons occupy areas of hindrance to a new pipeline.

The parallelism with roads and railways in some cases can be beneficial in the development of routing, but two aspects must be considered:

- Very often these lines have no conflict with inhabited areas, sometimes they go directly in city center, as in the case of railway stations, therefore they are not in favor of a parallelism with the project flowlines
- The requirement of these line in terms of slope and crossing hindrance and curvature are completely different from the ones required for project lines.

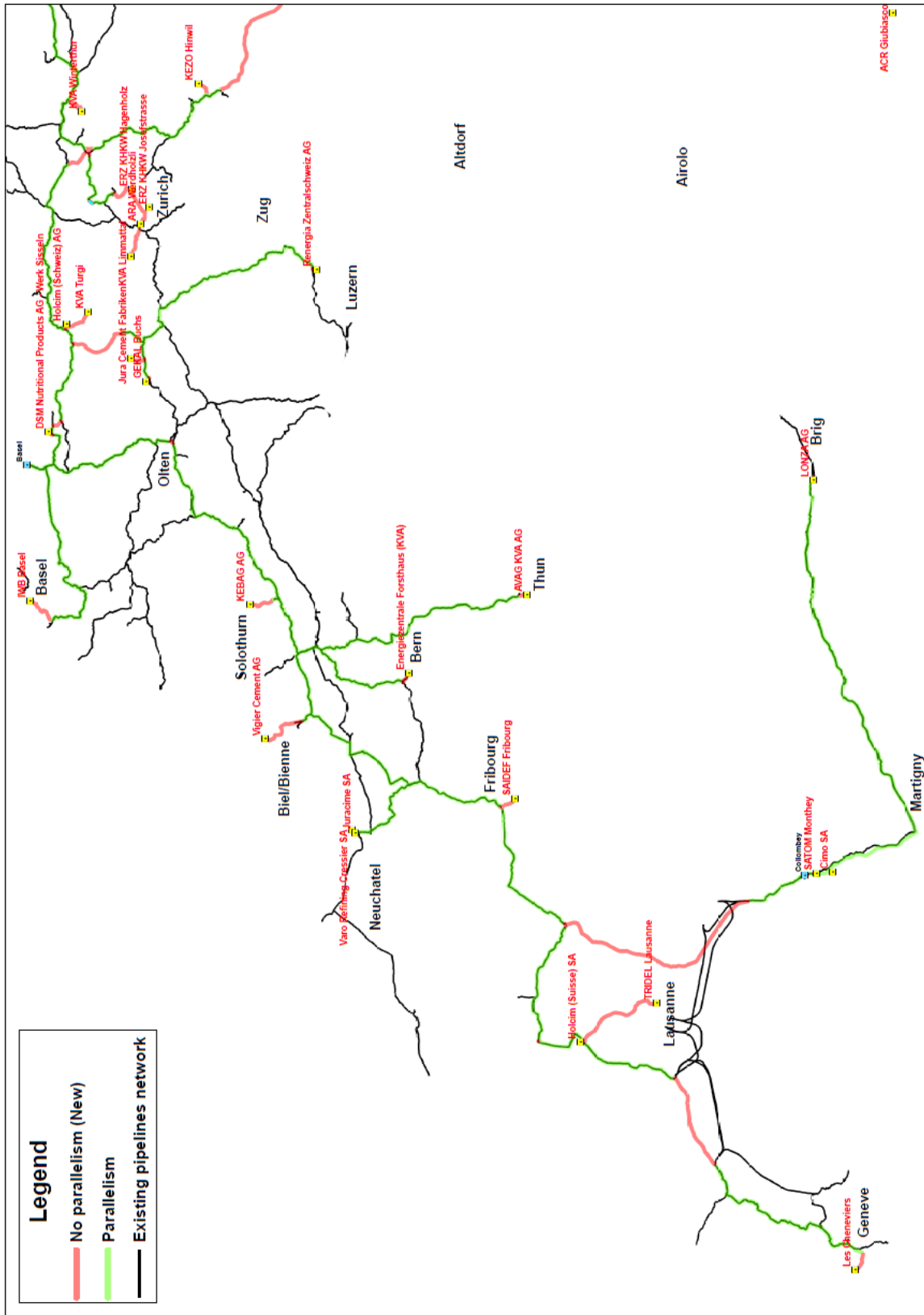
In conclusion the routing study followed the existing gas pipelines corridors where possible, for an amount of 775 km, with the aim to use their Right of Way (an adequate separation distance between the CO2 pipeline and third party owned pipeline have to be considered).

Other conventional routing criteria has been adopted for all the other sections where the parallelism was not present or possible (254 km), due to population density, environmental sensitive area morphology, geohazard, etc.

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Detail lengths of each parallelism is given in table Table 6.2.4 and Table 6.2.5 and represented in Figure 4.3.2 and Figure 4.3.3.

Figure 4.3.2 parallelism inside existing gas pipeline corridor - Western side





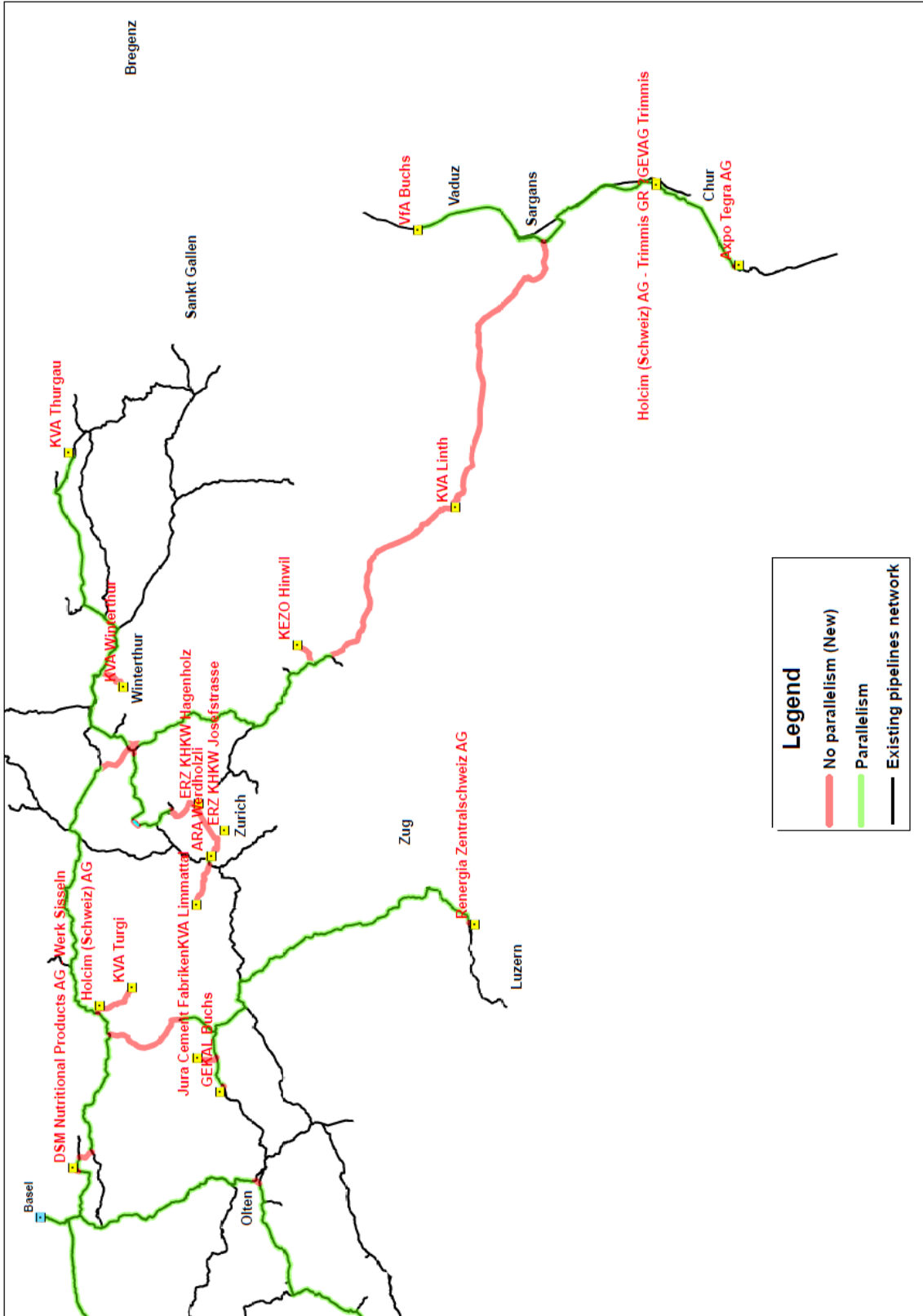


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Figure 4.3.3 parallelism inside existing gas pipeline corridor - Eastern side



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4.4 POPULATED AREAS

Based on the analysis of satellite images the sections with the highest concentration of buildings have been identified for the estimation at the level requested in the present desktop study.

The study considers and reports the percentage of potential conflicts with urban areas in Table 6.2.12 (as result of desktop analysis). Sometime the project pipeline running in parallelism with existing gas pipeline can conflict with some urban area.

In this case, considering the common practice to keep a safe separation between the new pipeline and the existing one (i.e. 10 m, depending on QRA consideration and owner requirements), the real clearance has to be verified at site case by case in next design phase.

4.4.1 Population Density assessment

The population density, has been preliminary assessed by cartographic analysis, using ArcGIS tool, laying out a buffer strip along the pipeline route centerline having a width not less than 200 m both side of the route under study, as requested by ISO code.

To evaluate the population density along the pipeline lines provided, an empirical methodology has been developed in the present study based on the available data and preliminary assessment was possible.

- A buffer was created around all the 400 m wide lines (200 + 200 m on both sides).
- All the buildings polygons present in the OPENSTREETMAP GIS dataset have been extracted from this buffer (downloadable from the link below).
<https://download.geofabrik.de/europe/switzerland.html>

The cartographic study performed are shown in abstract figures:

- Figure 4.4.1 Map study methodology
- Figure 4.4.2 Density of dwelling from Swiss Federal Geoportal
- Figure 4.4.3 Check method of dwelling with satellite images
- Figure 4.4.4 Typical Population density map



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Figure 4.4.1 Map study methodology

Download OpenStreetMap data for this region:

Switzerland

(one level up)

The OpenStreetMap data files provided on this server do not contain the user names, user IDs and changed IDs of the OSM objects because these fields are assumed to contain personal information about the OpenStreetMap contributors and are therefore subject to data protection regulations in the European Union. [Extracts with full metadata](#) are available to OpenStreetMap contributors only.

Commonly Used Formats

- [switzerland-latest-osm.pbf](#), suitable for Osmium, Osmosis, impoem, osm2pgsql, mkgmap, and others. This file was last modified 6 hours ago and contains all OSM data up to 2020-11-23T21:42:02Z. File size: 330 MB; MD5 sum: a59265ca55a8cd1287a4101433c55b8b.
- [switzerland-latest-free.shp.zip](#), yields a number of ESRI compatible shape files when unzipped. [\(format description PDF\)](#) This file was last modified 5 hours ago. File size: 586 MB; MD5 sum: 2dd132932c9fac97cd617787571f47.


Other Formats and Auxiliary Files

- [switzerland-latest-osm.bz2](#), yields OSM XML when decompressed; use for programs that cannot process the .pbf format. This file was last modified 1 day ago. File size: 548 MB; MD5 sum: ec9858777bb39a8851d8f8b840db466d.
- [switzerland-internet-osm.pbf](#) The history file contains personal data and is available on the [internal server](#) only. See notice above for further information.
- [.bbox](#) files that describes the extent of this region.
- [.osm.gz](#) files that contain all changes in this region, suitable e.g. for Osmosis updates
- [raw_directory_index](#) allowing you to see and download older files

Sub Regions

No sub regions are defined for this region.

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- crn_dre_bauzonen
- gis_osm_railways_free_1
- gis_osm_roads_free_1
- gis_osm_waterways_free_1
- gis_osm_buildings_a_free_1
- gis_osm_landuse_a_free_1
- gis_osm_water_a_free_1
- TOT_FLOW_LR
- Flowlines_1
- Buildings_400m
- Flowlines_buffer_400m
- WMS BGD1
- Batimetria_Lago_geo.img
- DTM_90m_Switzerland.img
- Basemap
- OpenStreetMap
- Basemap
- World Imagery
- Basemap





Table

Buildings_400m

| FID | Shape * | osm id | code | fclass | name | type | area |
|-------|---------|-----------|------|----------|------------------|---------------|---------|
| 3297 | Polygon | 281572879 | 1500 | building | | train_station | 673,078 |
| 14468 | Polygon | 102858493 | 1500 | building | | train_station | 569,014 |
| 21356 | Polygon | 456833908 | 1500 | building | | train_station | 495,414 |
| 15092 | Polygon | 118642294 | 1500 | building | Bahnhof Trübbach | train_station | 334,099 |
| 9827 | Polygon | 330844451 | 1500 | building | | train_station | 298,07 |

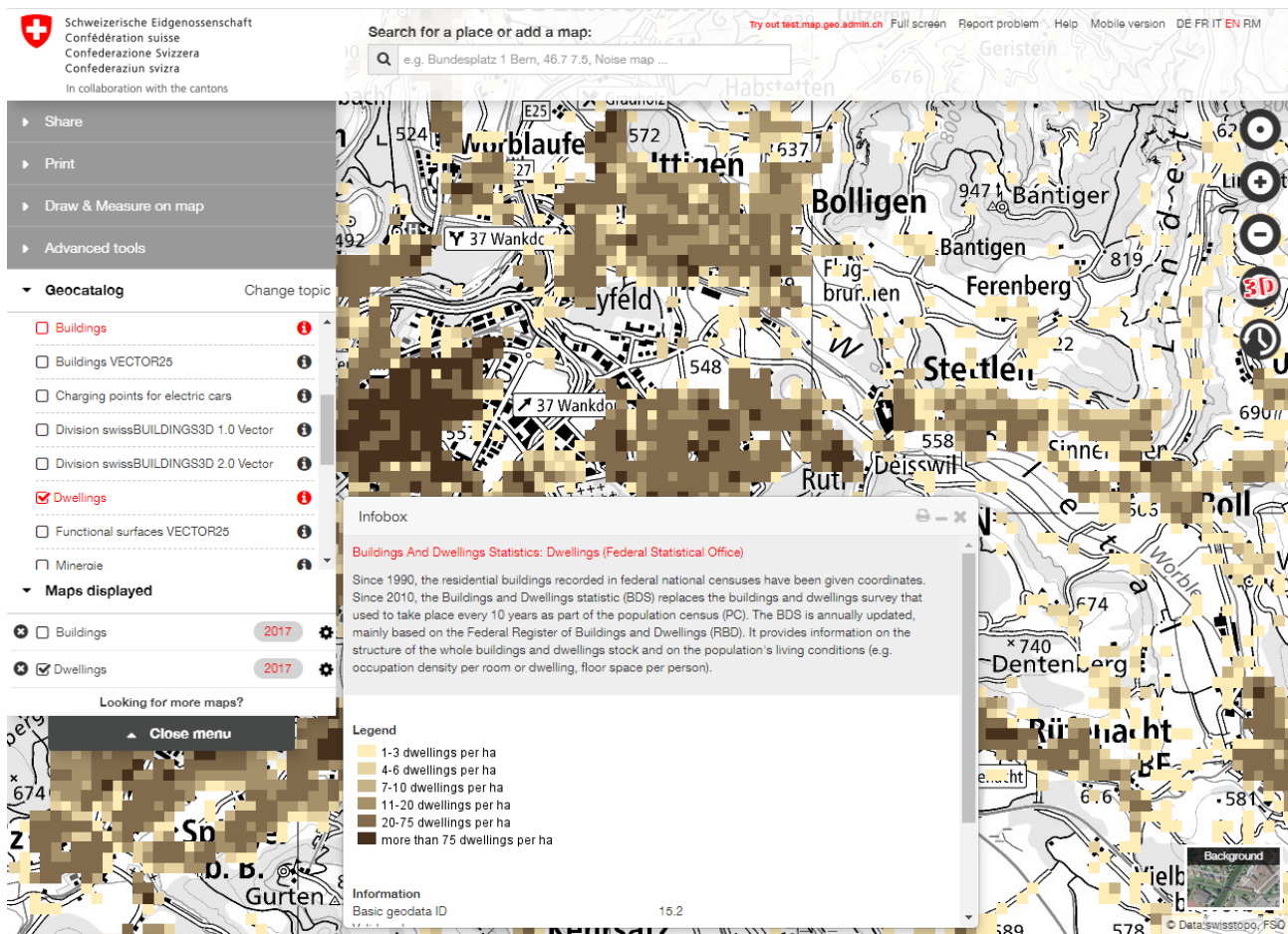
(0 out of 22368 Selected)

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In order to identify residential buildings (dwellings) as precisely as possible and exclude all the others not considerable with permanent human presence, it has been made reference to the information contained in the “geocatalog” then all buildings considered “non-residential type” have been eliminated, for example industries, shopping centers, etc. (see previous figure, information contained in the "name" and "type" fields). But since this information in the OPENSTREETMAP dataset is not complete, to proceed with a more precise filtering, we proceeded as follows:

In the Swiss Federal Geoportal, available at <https://www.geo.admin.ch/it/carte/carte.html> there is a digital map including of the density of dwellings which shows the “number of dwellings” present for each hectare of territory (see figure below).

Figure 4.4.2 Density of dwelling from Swiss Federal Geoportal



By displaying this map on a GIS, through the WMS service, it was possible to superimpose the polygons of the buildings extracted from the OPENSTREETMAP data and then proceed with further filtering, so that was possible to eliminate all the buildings that did not fall on the brown cells where the residential houses are present. A further check has been performed by viewing the satellite images available online using Esri's ArcGIS. Finally it has been possible to draw digital polygons of dwellings, rather reliable, based on original data taken from OPENSTREETMAP source and the satellite images used (see figure 4.4.3 below, in which the polygons of “non-residential buildings” have been selected (in blue color) and excluded from the final density definition.

Figure 4.4.3 Check method of dwelling with satellite images

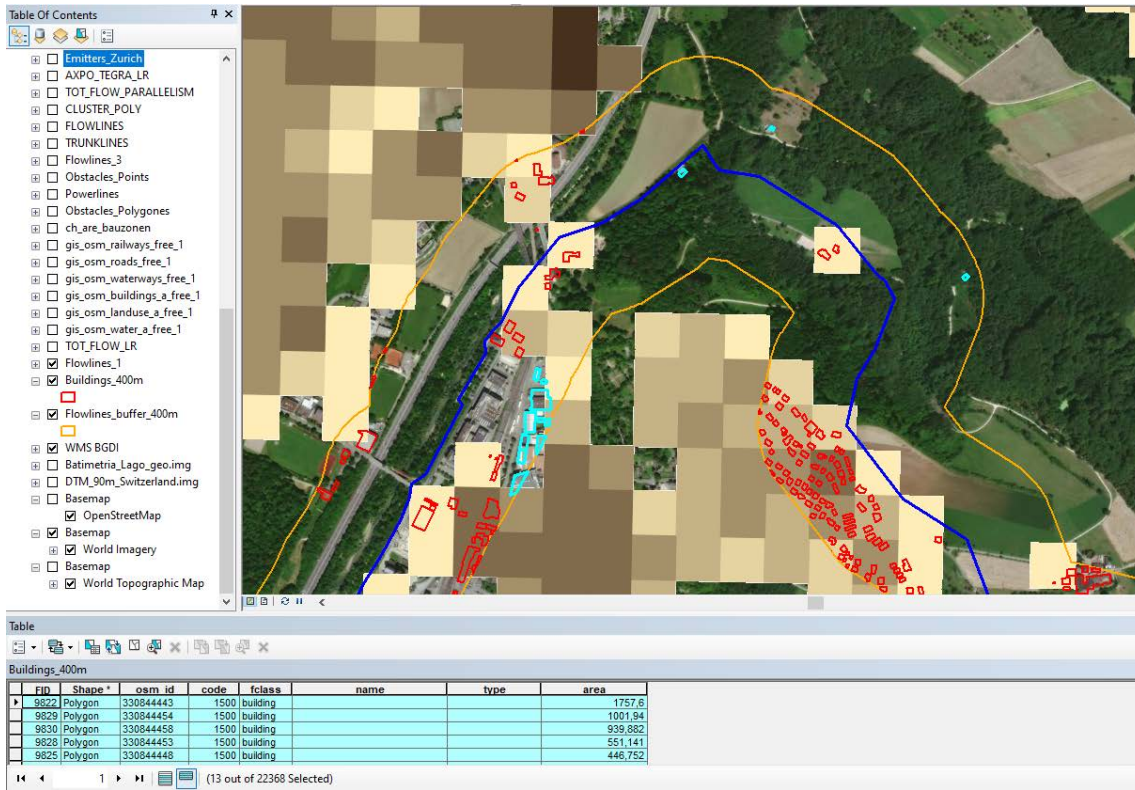
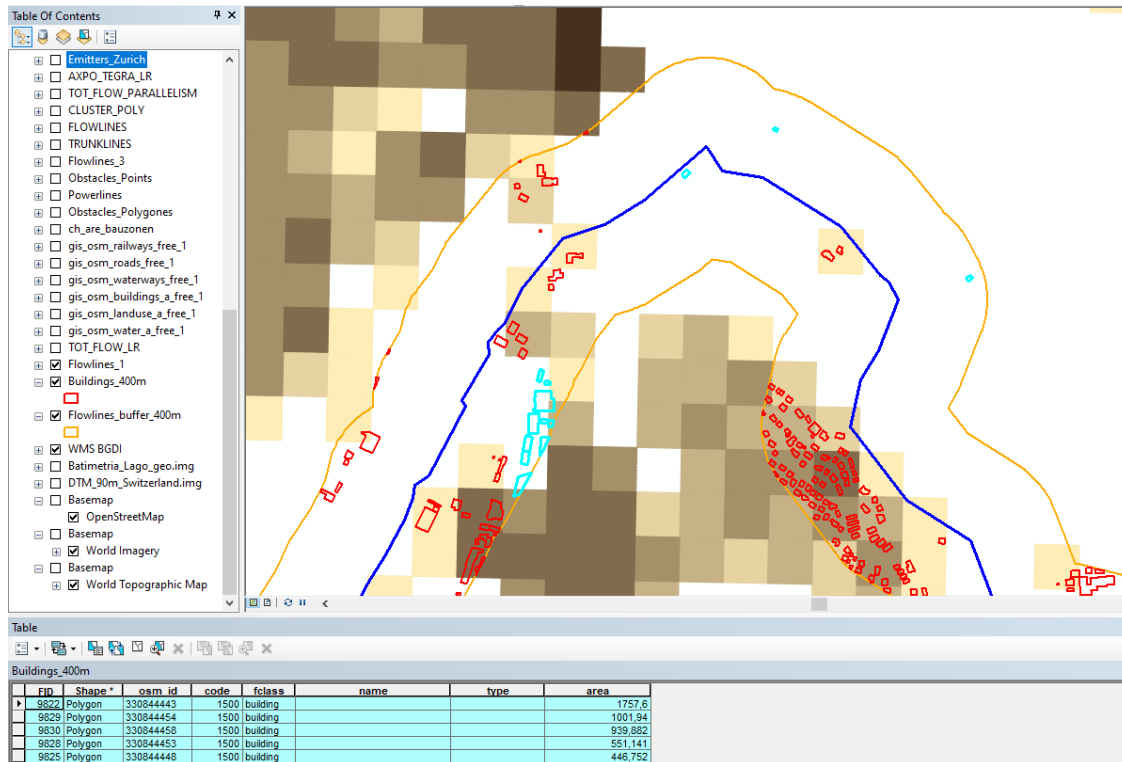




Figure 4.4.4 Typical Population density map



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The methodology for the assessment of population density along the pipeline route can be easily guide the route design for the definition of the design factor in compliance with the ISO code, so that the method used above can be profitably adopted in the further design phases.

Once the extension of each single critical area is defined the adoption of mitigation measures such as increasing of pipe cover, of concrete wall or culvert should be considered in next routing steps.

In appendix 1 some abstracts from satellite images of some critical section of populated area affected by pipeline route.

4.5 ENVIRONMENT-RELEVANT ROUTING PRINCIPLES

The present routing study has been performed at a desktop study level; however, effort has been made to consider the following environment-relevant principles to be observed in route selection:

- Consideration and bypassing of ecologically valuable areas. These include both European conservation areas and national nature reserves, natural monuments, and protected biotopes.
- Consideration and bypassing of forested areas, ecologically valuable matured forests where valuable as desktop study. If forested areas cannot be bypassed due to other constraints, existing forest aisles taken by tracks and / or overhead power lines visible on satellite images used for the present desktop study.
- Consideration of other known obstacles or usages, such as mining areas and areas earmarked for the protection and mining of raw material deposits that could be evaluated by observation of satellite images.

4.6 DETAIL ROUTE DEFINITION IN FUTURE DESIGN PHASE

Existing and planned constraints to route selection occurring within the area of interest should be identified to assist the selection of route options. The constraints identified shall be plotted on suitably scaled maps, considering the complexity of terrain and information gathered. Potential corridors of interest shall then be selected for routes development.

The preferred routes of the CO2 network should be selected, considering all the technical, environmental, and safety-related factors that can be significant during installation and operation of the pipeline system. It is evident that the shortest corridor only in minor cases results the most suitable.

A detailed route investigation within the selected route corridors of the present study preceded by a desk study, With consultation and visual appraisal making use of all information available within the public domain, shall be advisable.

Prior to the selection of the final route, land and environmental surveys shall be made and, in some cases, only after a geotechnical investigation the route can be confirmed.



These investigations should cover sufficient width and depth around the provisional route and have sufficient accuracy to identify all features that can adversely influence installation and operation of the pipeline system. This should be accompanied by further detailed consultation with all affected third parties' sites visit where appropriate.

Third-party activities along the pipeline route and related safety aspects should be investigated.

The involvement of the local authorities, that is a focal step of ESIA, shall be for the whole project including the results of the QRA. It is recommended to share with local Authorities in advance and during the permit application process, the hazard mitigation measures resulting from QRA and freeze the routing before the detail design phase.

A complete set of data relevant to design, construction and the safe and reliable operation of the pipeline system should be compiled from records, maps, and physical surveys.

In case QRA is requested in a future phase, assessment calculations generally should be done about the potential dispersion in the environment in relation with different buffer widths.

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In case of dense phase option, the fluid is more hazardous and requires more stringent safety criteria and in particular clearance from human presence and settlement. In view of this, it is recommended a review the proposed route using the methodology shown in section 4.4.1 jointly with topographic survey, considering the prescription of the future QRA and relevant mitigation measures (see section 5.6).

In detail phase, after the route narrowing and selection, the route shall be recorded on alignment sheets of an appropriate scale. The coordinates of all significant points, such as target points, crossing points, sharp bending shall be indicated. Contour lines should be recorded at intervals sufficient for design purposes, particularly about the installation and operational phases, and consideration should be given to the requirement for a vertical profile of the route.



Route and soil surveys shall be carried out to identify and locate with sufficient accuracy the relevant geographical, geological, geotechnical, corrosivity, topographical and environmental features, and other facilities such as other pipelines, cables and obstructions, that can impact the pipeline route selection.

In future design phase, the flexibility analysis (i.e. calculation of the pipeline structural behavior at bends and at unrestrained sections) relevant to the onshore pipeline under construction, hydrotest and operating loads shall be checked vs the internationally applicable Codes and Standards, and good engineering practice.

The Allowable Stress Design criteria is satisfied if the equivalent stress (Von Mises criteria) is lower than a percentage of the SMYS, depending on the applicable Design Factor.

The preliminary stress-analysis needs to be performed to evaluate the basis of the pipeline initial design. These structural checks have the following scope:

- Evaluate (from the structural point of view) the basic choices (the feasibility) of the on-shore pipeline preliminary design;
- Evaluate and suggest the anchoring and/or the flexibility at the pipeline terminal points, scarper trap and where required in special points.
- Specify the minimum requirements for the detailed stress-analysis.

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5. PIPELINE DESIGN

5.1 GENERAL

The pipeline shall be installed joining by welding line pipes, which have been properly prepared, laying them along a predefined right of way and buried in a trench.

The main typical activities to construct an onshore pipeline can be outlined as follows:

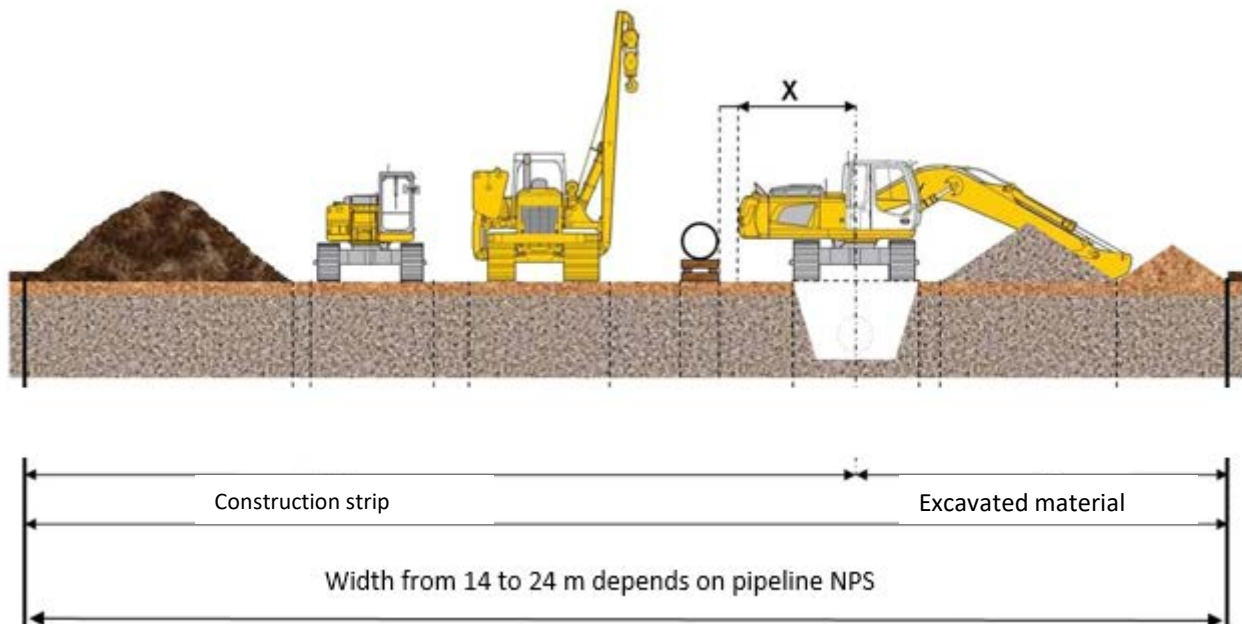
- logistics and work route (transportation, stacking out, yard preparation);
- right of way (clearing and grading, topsoil stripping);
- trenching (blasting, dewatering, backfilling);
- mechanical assembly (handling and stringing, bending, line up welding, NDT, field joint coating.
- lowering, tie-in of assembled section, and backfilling.
- crossing of particular points (Trenchless or open cut);
- sites restoration.
- hydrotest, and final tie-in.

5.2 RIGHT OF WAY AND TRENCH



5.2.1 working strip

Right of way is necessary for pipeline installation, the dimensions, and main features of the ROW expected for this project, is reported in Figure 5.2.1: Features of a standard Right of way.

Figure 5.2.1: Features of a standard Right of way



ROW is surveyed, designed and drawn on proper alignment sheets, then at work commencement ROW is signaled at field along the entire route all pipeline work (movement of lorries, cranes, excavator, side booms, etc) be allowed only inside this working strip. In Figure 5.2.2: Right of way main phases for pipeline construction are shown.

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In difficult situations, or to reduce the environmental impact, it is possible to restrict the width of the ROW; nevertheless, this fact increases the complexity of the assembly work.

After clearing the vegetation and removing the layer of topsoil (usually storing this for final reinstatement) from the area along the route, the ground is levelled to facilitate the excavation work and the lining the line pipe. Where present, the topsoil removed shall be placed outside the working area in dedicated storage areas that shall be agreed in advance with land Authorities.

In the presence of slopes, specific right of way preparation works is required, to grade the level to the configuration of pipeline laid.

The ROW shall be graded to eliminate sharp high points, minimizing bending to allow the laying always within the limits allowable elastic bending radius. In rocky sections, the first layers of outcrop shall be cut and levelled.

Connection from different slopes shall be done by elastic bend where possible, but where necessary and when the space is limited, pre-formed bends will be supplied.

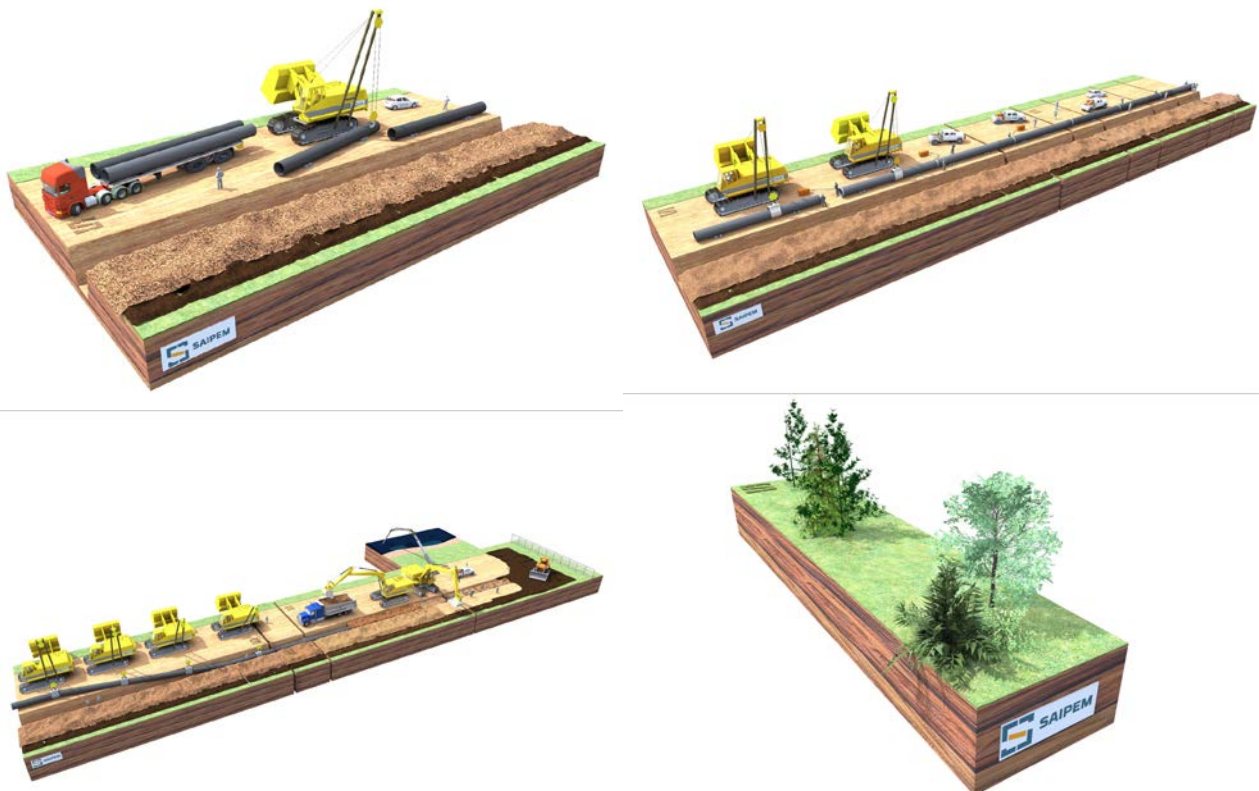
Pipes shall be collected from the stacking areas and shall be transported by conventional trucks along the pipeline route. Access will be foreseen with connection from road network to allow for the movement of equipment and manpower.



Along the ROW the line pipe will be laid in proximity of the trench on timber skids or sandbags, to protect the external coating.

Changes to the vertical and/or horizontal alignment during the construction shall be provided by cold bending of line pipe; cold bending of pipes will be performed at the temporary pipe stacking areas by bending machine.

For line pipe handling and laying in the trench cranes or side booms shall be used.

Figure 5.2.2: Right of way main phases for pipeline construction



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5.2.2 Clearances

In the section where CO2 pipeline laid parallel to existing gas pipeline, common practice is to maintain a minimum clearance of 10 m from the closest pipe. This distance is considered safe enough to avoid interferences in rocky areas but also in areas where loose soil is present (a separation study generally is requested for the purpose). Along the sections parallel to existing pipeline proper markers and excavated soil protection berm shall be located during construction phase. In case equipment must overpass these buried pipelines, suitable mechanical protections will be placed on the ground (i.e. steel plates, concrete slab, or soil embankment).

In the case where the pipeline route needs to be located closer of crossing existing structures, QRA study and hazard identification shall be carried out to define containment measures in case of pipe rupture and relevant hazards minimization.

5.2.3 Trench

As a reference, for onshore pipelines the minimum cover of depth should follow the specifications given in ISO 13623 Sec.6.8.2, however, due consideration needs to be taken about the influence a possible rupture, considering that crater size and geometry will be a function of pipeline depth of cover, this could influence the fluid release and dispersion in the surrounding.

For the trench, the referred applicable code provides different minimum coverages (1.2m depth in case of loose soil and 0.5m in case of sound rock sections), however, due to the nature of the transported fluid, it is considered appropriate to increase this minimum burial depth in rocky area to 0,9 m.

The trench in rocky soil shall be excavated to achieve at the bottom a minimum width so as to provide, on both sides of the installed pipeline, a minimum trench wall clearance of 200mm.

Bedding and padding material shall be placed under and around the pipe for a minimum of 200mm.

The pipeline housing in the trench foresees that suitable selected material (sandy grainsize material free from large and sharp stones), shall be used as bedding and padding around the pipeline. Where the trench will be completely excavated in sound rock the use of "rockshield" protection overcoating shall be considered.

Further requirements relevant to the effect of pipeline wall temperature inside the trench and to the freezing effect of the soil, and relevant undesired ground settlements, or cases of possible frost heave, shall be addressed in the future design phase.

Mechanical excavators will be used to excavate the trench, but all the unrippable sections may be requested to be drilled and blasted with explosives. In this case application for permitting and approval must be carried out. The hard rock must be drilled by rock drilling equipment and blasted to achieve the required depth and the required dimension of the trench bottom.

The trench features and requirement is shown in Figure 5.2.3: Typical trench



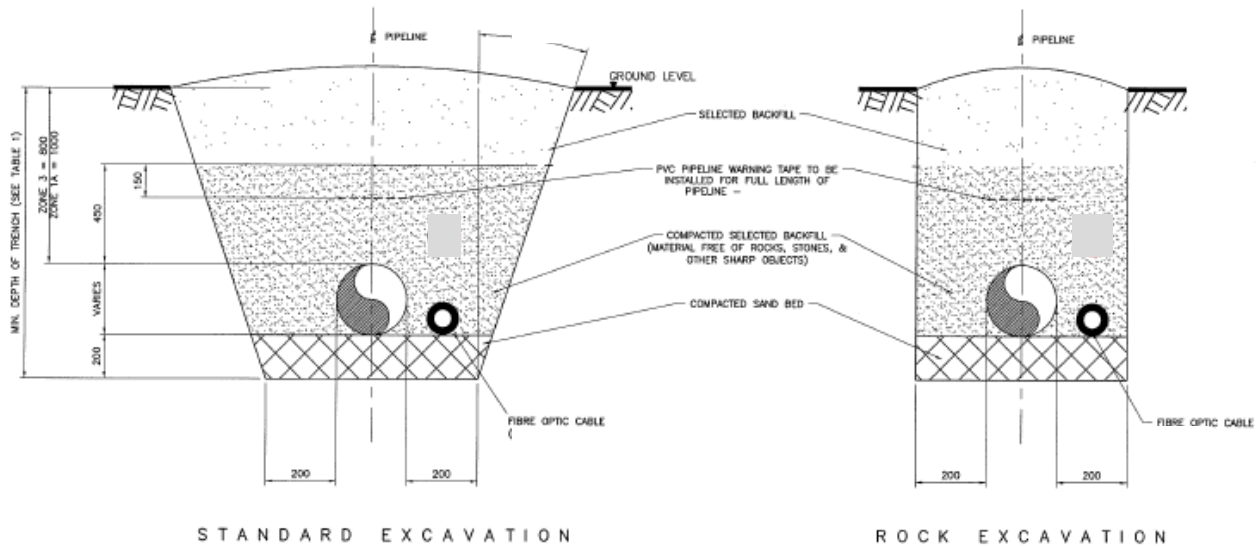
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Figure 5.2.3: Typical trench



5.3 PIPE WELDING

The main construction activity is the line pipe welding. Usually the most of the construction activities are planned according to welding schedule and relevant logistic requirements. Then, important activities are the application of anti-corrosive coating of the welded joints, non-destructive checks and repairing of the welds. All these operations are carried out in the field. These processes are also tested to ensure that the personnel, the equipment, and the materials used.

Non-destructive checks using automated ultrasonic systems shall be performed once the welding procedures have been qualified.

Welding the pipe joints can employ manual, semi-automatic and automatic techniques. For present pipelines semi-automatic techniques could be foreseen, but in some difficult section as steep slopes or tie-in for crossing installation completion, manual welding shall be more appropriate.



There are various technologies, but generally electric arc welding methods are used and they are differentiated by the type of shielding of the molten pool: submerged arc welding (with a continuous wire, of both automatic and semi-automatic types, often used on double joints), and gas protection welding (with a continuous wire, generally of the semiautomatic type, used on pipeline joints).

The completion of the welding is carried out through successive passes, also using different methods for individual passes.

The typical welding procedure requires the mechanical coupling of the joints to be welded using an appropriate clamping device which travels along the inside of the pipeline; in some cases an external coupling system is used, which has the task of holding the two edges securely. A check is then carried out to see if there is any misalignment, the edges to be joined are pre-heated and the welding work is carried out with intermediate temperature checks between the passes.

X-ray or manual ultrasonic are added to AU testing.

After successful NDT on welded pipes, the joint is protected from corrosion applying qualified materials-procedures. The pipes shall arrive on-site already coated, whereas coating of the welded joints is of necessity carried out on the line, hence the welded joint shall be prepared through cleaning, sanding and reheating, followed by the application of the protective material, which is generally of the same type as that used to protect the rest of the line pipes (layers of polyethylene or polypropylene on epoxy resin). The electrical insulation of the joint and of the rest of the pipeline is checked using high voltage instruments called leak-seekers.

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5.4 CATHODIC PROTECTION

The material selection for the CO2 pipeline network foreseen the carbon steel pipeline, this imply the design and adoption of typical corrosion protection by mean of external coating and impressed current system. As a pre-requisite for effective application of cathodic protection (CP) and in addition to adequate external coating, the onshore pipeline will be electrically isolated from other structures, such as Emitters compression station and CO2 Terminals, by suitable in-line isolation joints installed above ground or in inspection pits.

5.5 CROSSINGS

Wherever the pipeline route crosses roads, railways, waterways and underground or surface-laid third-party pipelines, special temporary work and structures are required, i.e. they are subject to special approval by the responsible authorities and owners and have to comply with the applicable statutory regulations, technical regulations and state-of-the-art pipeline construction practice.

In general, crossings of infrastructural facilities are to be as short as possible, i.e. more or less at right angles. Any variations due to higher-level constraints or within the context of route bundling are to be justified.

When determining crossing points, the additional land required for the working strip is to be considered depending on the crossing construction method involved.

CO2 network developed for the present project shall face a large amount of crossing such as roads, railways, rivers, waterways, powerlines, and several buried crossings.

The minor roads generally shall be open cut, so that at end of the installation work the trenched roads section has to be backfilled, compacted and then restored to its original condition, in order to reinstate as soon as possible, the traffic on the public roads. During construction period diversion road could be required.

When executing this type of crossing the work preparation will be carefully developed to reduce the road interruption as minimum as possible, during daily time.

In case of buried service crossing the pipeline is designed with sufficient burial depth and separation clearance considering the integrity of the pipeline and the stability of the crossed lines. In crossing such services all the necessary protecting precaution requested by the owner shall be taken. The existing pipeline and other crossings shall be executed by carrying-out the ditch excavation by using mechanical means or by hand excavation when necessary. The line pipe shall be installed under the existing facilities and then the backfilling shall be conducted in a manner not to disturb the existing facilities.

For other crossing consideration shall be given to providing a greater separation distance if there is a risk of damage to the third-party service during pipeline construction or damage to the pipeline during maintenance of the third-party service. The crossing needs to be performed according to agreement with the third-party.



At all places where pipeline intersects with a high voltage powerline, assessment on corrosion potential is required to ensure the pipeline CP system would not be affected especially in correspondence of the closest pylons.

In case of waterstream the scouring capacity and erosion condition are a very important feature to be investigated to prepare a safe crossing design for CO2 pipelines, hence a proper hydrological and hydraulic studies of the stream affected and relevant basin have to be conducted in further design phase.

5.5.1 Slopes

When crossing of areas with morphological features not favorable to execution of a conventional working strip, such as steep slopes special measures, such as side protection and erosion control, to be applied for safe construction and operation, must be considered.

Side slopes encountered along the pipeline route will be benched by cut and fill method to form a level running track and level working platform for welding and trenching operations.

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In these conditions, granular backfilling material should be resistant to erosion. In some cases, methods such as rip-rap (big rock pieces) placing, claying, asphalt application can be performed. Erosion risk should be taken into account while determining the backfill material and compaction level.

Before ditching operation in areas with very high slope, the working flat terrace shall be made every certain distance to allow the excavator working on it toward both up and down directions. The excavator shall be driven to the next flat terrace to ditch continually once it reaches its limit working scope on a flat.

5.5.2 Trenchless crossing

In all the cases where requested to cross services without open cut the trench to install the project trunklines and flowlines the crossing shall be performed by horizontal drilling or auger boring from a thrust pit excavated on one side of the road to the other side where a receiving pit shall be prepared in advance.

The methodology is shown in Figure 5.5.1 and an example is shown in Figure 5.5.2.

Based on the depth of the entry and exit points the thrust pit will be excavated, considering of the geometric features of the jacking equipment. The reception pit can be prepared and excavated prior to or upon reaching the required length with the bore.

The Thrust Boring equipment consists of a Thrust / Auger Boring Machine, base frame with rails, steel jacking shield, rotating cutting head, augers, jacking frame and hydraulic power pack.

The Cutting head is installed at the front of the pilot pipe and the boring operation proceeds by rotating the augers and cutting head, and simultaneously moving the boring machine forward via hydraulically operated jacks.

The boring operation will start pushing the first pilot pipe gently forward and once the first section of the steel pipe has been installed, the next section is lowered into the pit, using a crane or excavator with adequate lifting capacity, allocated inside the thrust machine, levelled, aligned with the first pipe and welded securely together.

The full string of the carrier pipe, already prepared (welding, NDT, and joint coating), outside of the receiving pit, will be welded together with the pilot pipe and pulled back into the unlined bore, using the same Thrust Block and hydraulic system of the Thrust Boring equipment.

The road / railway tracks will be closely monitored during thrust boring operations.

Inside the borehole the pipeline shall be inserted, the external coating of the pipeline string to be installed, shall be protected by adequate collar spacers.

At the completion of installation, the borehole shall be sealed with cement mortar.

In CO2 project the amount of the thrust auger boring to be performed for the trunkline and flowline crossings is summarized in section 6.2.1.



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Figure 5.5.1: Trenchless method for railway and road crossing

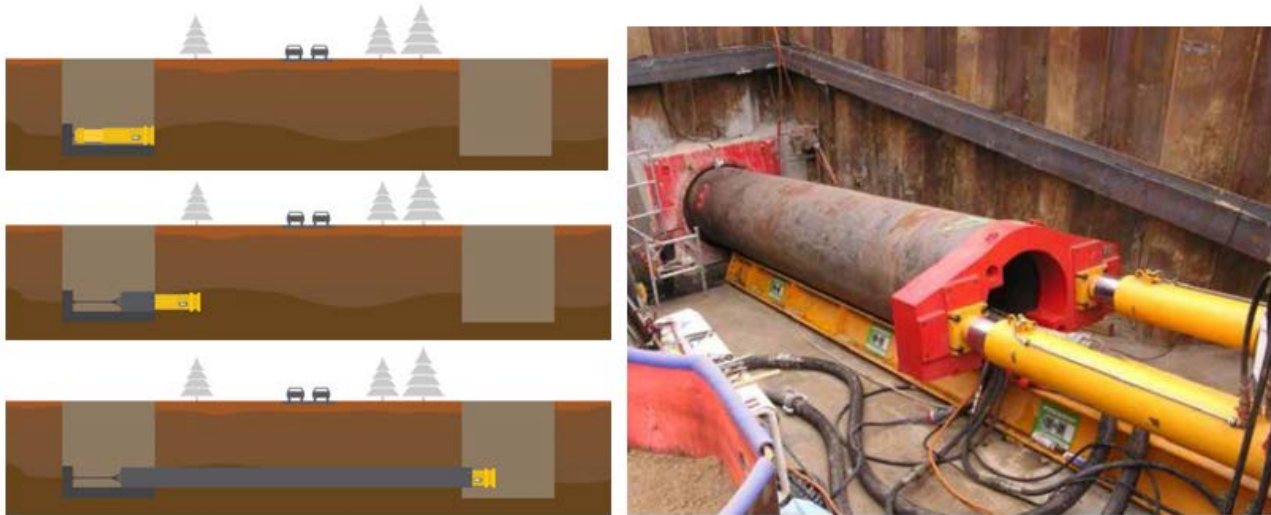




Figure 5.5.2: Trenchless installation for road crossing



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5.5.3 Horizontal Directional Drillings

Horizontal directional drilling (HDD) shall be as a preferred crossing method in many situations for the installation of CO2 flowlines and trunklines of the project to cross watercourses as well as large river and other obstacles. This technology, as shown in Figure 5.5.3, is considered a potentially low impact construction technique. In many cases, however, the suitability of the HDD method must be evaluated and compared to more traditional open-trench construction techniques in order to ensure that an appropriate technique is chosen for the conditions and concerns present at a particular crossing. Recognition of the advantages, limitations and potential risks of HDD is an important step in future design activity.

It is important to consider that an HDDs may represent a critical path on the overall project schedule therefore, all aspects of planning and design for an HDD need to be assigned a high priority or importance value due to their potential effect on the overall project.

The selection of the optimized crossing location based on an overland pipeline routing assessment shall also consider the detail of crossing, alignment, and access for the HDD construction.

The horizontal alignment shall be designed to provide sufficient space for the working area at the drilling rig site and the pipe site as well as for the pre-fabrication of the pull section.

The pipeline routing should allow for layout areas, entry/exit pads, access routes, and minimal points of inflection in the design drill path and the pipe string layout area.

Prior to commencement of HDD operations, the section of pipeline to be installed shall be fabricated, welded, non-destructively tested (X-ray & UT) and field coating applied.

After testing of the coating and completion of any repair work, the pipe section to be pulled back shall be placed on stable roller supports to reduce friction during pulling and to protect the pipe coating. The rollers shall be mounted to ensure that the penetrating downward bend follows the given penetration angle and that the calculated elastic radius of curvature is not exceeded.

Prior to installation of the pipe section by HDD the pipe string will be fabricated and tested on site and the HDD process is generally accomplished in three stages:

- **Pilot Drilling:** A small diameter pilot hole shall be drilled under directional control along a designed and pre-planned directional path to emerge at the exit location on the crossing.
- **Pre-reaming:** a borehole which is 30% to 50% greater than the outside diameter of the pipe to be inserted shall be realized.
- **Pull Back:** When pre-reaming is completed the pipe section shall be pulled back into the reamed borehole filled with drilling fluid to exit the tunnel at the original start location. Pull back shall immediately follow pre-reaming.

The pre-fabricated steel pipe section shall be completed and ready for insertion before pre-reaming and conditioning of the borehole is completed.

In CO2 project the amount of the HDD to be performed for the trunkline and flowline crossing is summarized in section 6.2.1.



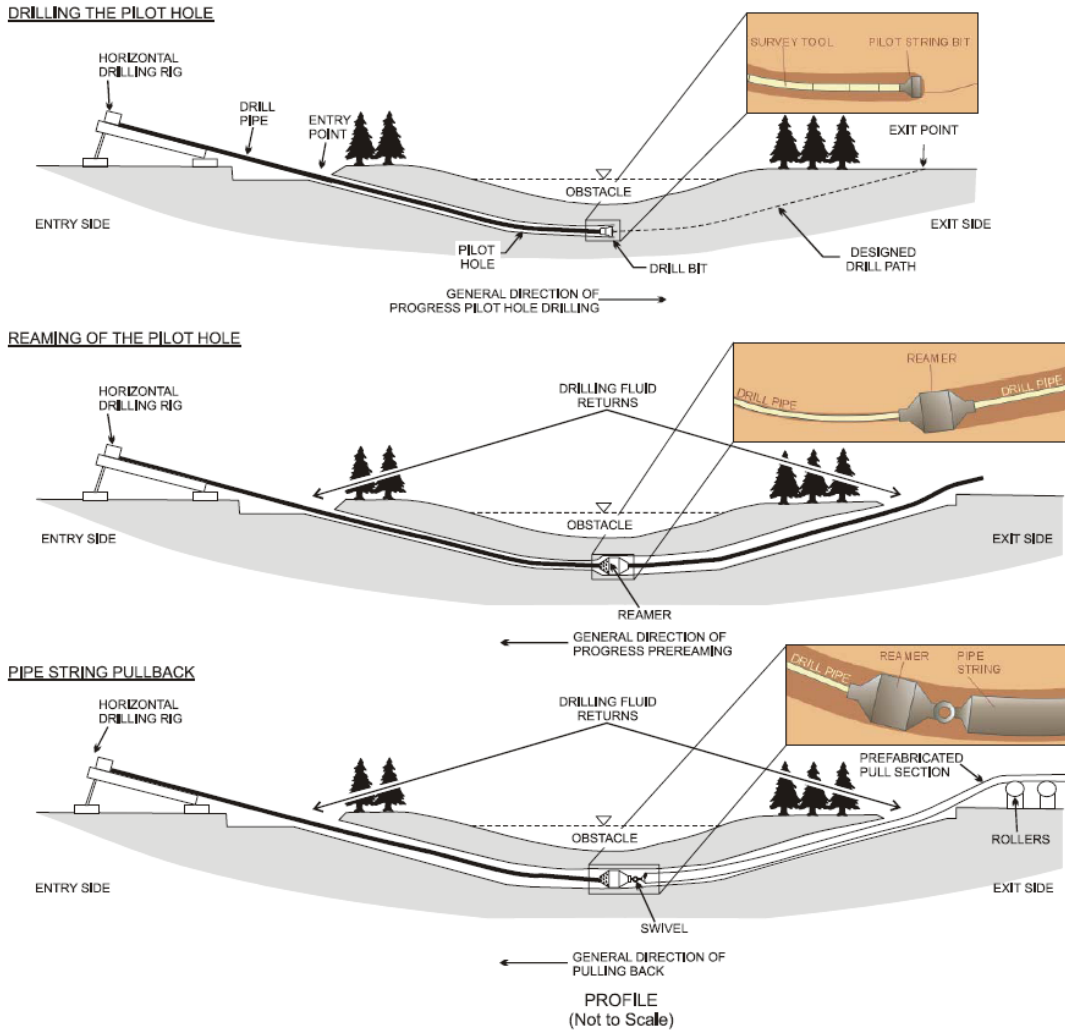


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Figure 5.5.3: HDD methodology

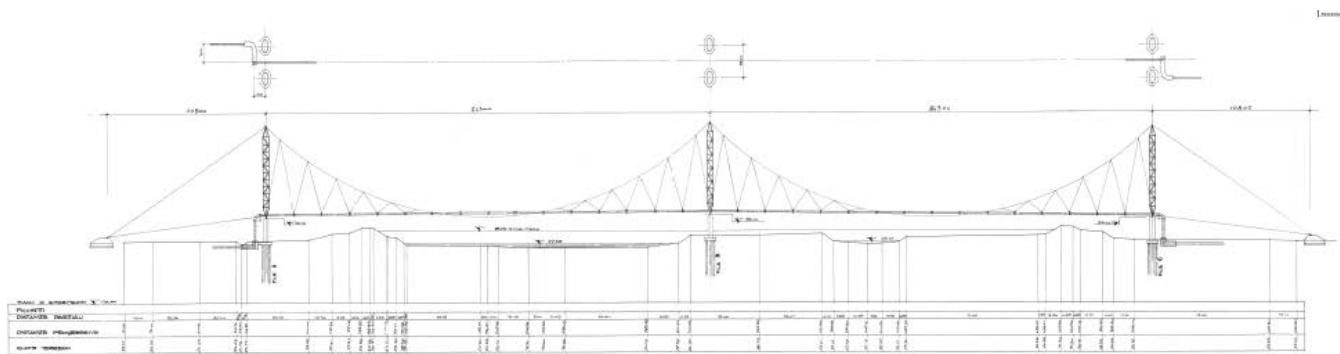


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5.5.4 Aerial Bridges

The crossing with Aerial bridges can be considered only in extreme cases and where it is not possible for technical and economic reasons to carry out trenchless underground crossings of the obstacles present; in any case, the use of this technology is excluded in the case option of dense phase CO2 transport pipeline.



Figure 5.5.4: Example of Aerial Bridge for a gas pipeline



Along the routes there are many cases of air crossing also of the gas pipelines often in parallel with the CO2 flowlines. See Figure 5.5.5

Figure 5.5.5: Aerial Bridge for an existing gas pipeline bridge parallel to CO2 pipelines routes west of Bienne



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5.6 MITIGATION AND SAFETY MEASURES

As for gas pipeline, the routing study comply the recommendation for avoiding (densely) populated areas, however this was not always possible for this reason it is recommended in next phase of the project the adoption of mitigation measures to reduce as low as reasonable possible (ALARP) the residual risk.

Examples of measures which reduce the failure frequency are increasing the wall thickness, marker tape above the pipeline, burying the pipeline deeper or covering the pipeline with protective concrete slabs. (see Ref. [4]).

Further measures that reduce the consequence of a CO2 pipe failure are installing block valves on the pipeline as mentioned in ref. 000-ZA-E-09001 Pipeline System Hydraulic & Optimization Study Report.

The mitigation measures shall be generally also in relation to the future ESIA Recommendation.

The following risk mitigation measures are to be considered:

- Designing the pipeline, in critical areas, with a lower design factor of 0.45 to lead to a higher wall thickness, which gives resistance to excavators and other construction equipment.
- Weekly surveillance frequency to detect unauthorized excavations along the pipeline route and action can be taken before the pipeline is damaged.
- Installation of additional automatic block valves, which spacing shall be defined by QRA study, shall be foreseen to isolate a pipeline section if a leakage occurs and thereby limit the amount of CO2 released. The last measure does not decrease the failure frequency of the pipeline but diminishes the consequence of a release.
- Bright-colored marker tape can warn an excavator driver that there is a pipeline under the ground.
- Moreover, In more critical situation:
 - Protective concrete slabs, or culvert, casing, to reduce the possibility of interference by external actions such as mechanical excavation works that could hit buried pipe.
 - Burying the pipeline deeper (at 2.0 m) reduces possibility of rupture of the pipeline by external action.

As concern CO2 dense phase option, more detailed QRA activities shall be required including investigation of areas with presence of settlement or human activity developed in areas with topographical depressions located in the route proximity.



5.7 PIG LAUNCHER/RECEIVER

The pipelines shall be designed with the installation of permanent pig traps to allow free passage of gauge, scraper and intelligent inspection pigs, ref. to project document [1] 000-ZA-E-09001 .

The pipeline pig trap system shall be designed to provide, in a safe manner and without flow interruption, the equipment to either insert and launch a pig into a pipeline and receive and retrieve a pig from a pipeline.

5.8 LINE BLOCK VALVE STATION

For Line BVS (Block Valve station) Ref. to project document [1] 000-ZA-E-09001 .

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6. ROUTE FINDINGS

6.1 SUMMARY OF THE LINES

A list with the length and sizes of all the flowlines and trunkline sections is reported in Table 6.1.1. and

Table 6.1.2.

Table 6.1.1: Pipeline Data eastern network

| NAME | LENGTH | BASE CASE | | | DENSE PHASE OPTIONAL CASE | |
|---------------------------------|-----------|-----------|--------|-------|---------------------------|-------|
| | | flow | ND (") | WT mm | ND (") | WT mm |
| LES CHENEVIERS | 82.748 m | HP | 12 " | 6,35 | 12 " | 6,35 |
| LONZA AG | 92.905 m | HP | 14 " | 6,35 | 14 " | 6,35 |
| CIMO SA | 913 m | HP | 6 " | 4,78 | 6 " | 4,78 |
| SATOM MONTHHEY | 158 m | HP | 6 " | 4,78 | - | - |
| HOLCIM (SUISSE) SA | 249 m | HP | 6 " | 4,78 | 6 " | 4,78 |
| TRIDEL LAUSANNE_LP | 10.960 m | LP | 10 " | 6,35 | 10 " | 6,35 |
| TRIDEL LAUSANNE_HP | 6.835 m | HP | 6 " | 4,78 | 6 " | 4,78 |
| W32 | 35.805 m | HP | 20 " | 7,92 | 10 " | 11,13 |
| W31 | 4.964 m | HP | 14 " | 6,35 | 16 " | 15,88 |
| ENERGIEZENTRALE FORSTHAUS (KVA) | 22.815 m | HP | 8 " | 6,35 | 6 " | 7,11 |
| AVAG KVA AG | 46.650 m | HP | 8 " | 6,35 | 6 " | 7,11 |
| SAIDEF FRIBOURG | 3.318 m | HP | 6 " | 4,78 | 6 " | 7,11 |
| VARO REFINING CRESSIER SA | 764 m | HP | 10 " | 6,35 | 8 " | 8,74 |
| JURACIME SA | 453 m | HP | - | - | - | - |
| VIGIER CEMENT AG | 11.730 m | LP | 12 " | 6,35 | 12 " | 6,35 |
| KEBAG AG | 5.998 m | LP | 10 " | 6,35 | 10 " | 6,35 |
| W6 | 17.752 m | HP | - | - | - | - |
| W9 | 5.086 m | HP | 8 " | 6,35 | 6 " | 7,11 |
| IWB BASEL_HP | 42.954 m | HP | 8 " | 6,35 | 8 " | 6,35 |
| IWB BASEL_LP | 6.077 m | LP | 10 " | 6,35 | 10 " | 6,35 |
| RENERGIA ZENTRALSCHWEITZ AG | 46.459 m | HP | 10 " | 6,35 | 6 " | 7,11 |
| TRUNKLINE WEST | 229.340 m | HP | 30 " | 9,53 | 16 " | 15,88 |





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Table 6.1.2: Pipeline Data Western network.

| NAME | LENGTH | BASE CASE | | | DENSE PHASE OPTIONAL CASE | |
|----------------------------------|-----------|-----------|--------|---------|---------------------------|---------|
| | | flow | ND (") | WT (mm) | ND (") | WT (mm) |
| TRUNKLINE EAST (Rhine Valley) | 56.980 m | HP | 20 " | 7,92 | 16 " | 6,35 |
| TRUNKLINE EAST (Linth to Basel) | 141.679 m | HP | 30 " | 9,53 | 14 " | 14,27 |
| E12 | 15.988 m | HP | 14 " | 6,35 | 8 " | 8,74 |
| KVA Turgi | 5.380 m | LP | 8 " | 6,35 | 8 " | 6,35 |
| Holcim (Schweiz) AG | 246 m | LP | 8 " | 6,35 | 6 " | 7,11 |
| Jura Cement Fabriken | 2.676 m | LP | 12 " | 6,35 | 12 " | 6,35 |
| GEKAL Buchs | 4.934 m | LP | 8 " | 6,35 | 8 " | 6,35 |
| E13 | 3.455 m | LP | 16 " | 6,35 | 16 " | 6,35 |
| E14 | 592 m | HP | 8 " | 6,35 | 6 " | 7,11 |
| KVA Winterthur | 3.881 m | LP | 10 " | 6,35 | 10 " | 6,35 |
| KVA Limmattal | 6.691 m | LP | 8 " | 6,35 | 8 " | 6,35 |
| KVA Thurgau | 32.523 m | HP | 10 " | 6,35 | 6 " | 7,11 |
| KEZO Hinwil | 2.998 m | HP | 6 " | 4,78 | 6 " | 7,11 |
| ARA Werdholzli | 150 m | LP | 6 " | 4,78 | 6 " | 4,78 |
| ERZ KHKW Hagenholz | 609 m | LP | 12 " | 6,35 | 12 " | 6,35 |
| E7_HP | 18.803 m | HP | 10 " | 6,35 | 6 " | 7,11 |
| E7_LP | 2.806 m | LP | 16 " | 6,35 | 16 " | 6,35 |
| E6 | 13.636 m | HP | 10 " | 6,35 | 6 " | 7,11 |
| E9 | 1.377 m | HP | 8 " | 6,35 | 8 " | 6,35 |
| E10 | 6.374 m | LP | 10 " | 6,35 | 10 " | 6,35 |
| E11 | 32 m | HP | - | - | - | - |
| Axpo Tegra AG | 15.471 m | HP | 8 " | 6,35 | 8 " | 6,35 |
| Holcim (Schweiz) AG - Trimmis GR | 139 m | HP | 8 " | 6,35 | 8 " | 6,35 |
| GEVAG Trimmis | 163 m | HP | - | - | - | - |
| VfA Buchs | 18.280 m | HP | 8 " | 6,35 | 8 " | 6,35 |
| KVA Linth | 247 m | HP | 6 " | 4,78 | 6 " | 7,11 |
| DSM Nutritional Products AG | 917 m | HP | 6 " | 4,78 | 6 " | 7,11 |

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Here below is shown the split of the trunkline, a different Wall thickness is selected for Geneva lake.

| Split of trunkline west | LENGTH | BASE CASE | | | DENSE PHASE OPTIONAL CASE | |
|--------------------------------------|------------------|-----------|--------|--------------|---------------------------|---------|
| | | FLOW | ND (") | WT (mm) | ND (") | WT (mm) |
| TRUNKLINE WEST 30" - 1 | 13.347 m | HP | 30 " | 9,53 | 16 " | 15,88 |
| TRUNKLINE WEST 30" - 2 (Geneva Lake) | 16.382 m | HP | 30 " | 33,20 | 16 " | 17,48 |
| TRUNKLINE WEST 30" - 3 | 199.611 m | HP | 30 " | 9,53 | 16 " | 15,88 |

In the below Figure 6.1.1 and Figure 6.1.2, the preliminary pipeline routings are reported for the East and West Trunkline Systems respectively. Basel is the delivery point for the East trunkline, whereas the West trunkline is bidirectional, with Basel and Collombey as possible delivery points.



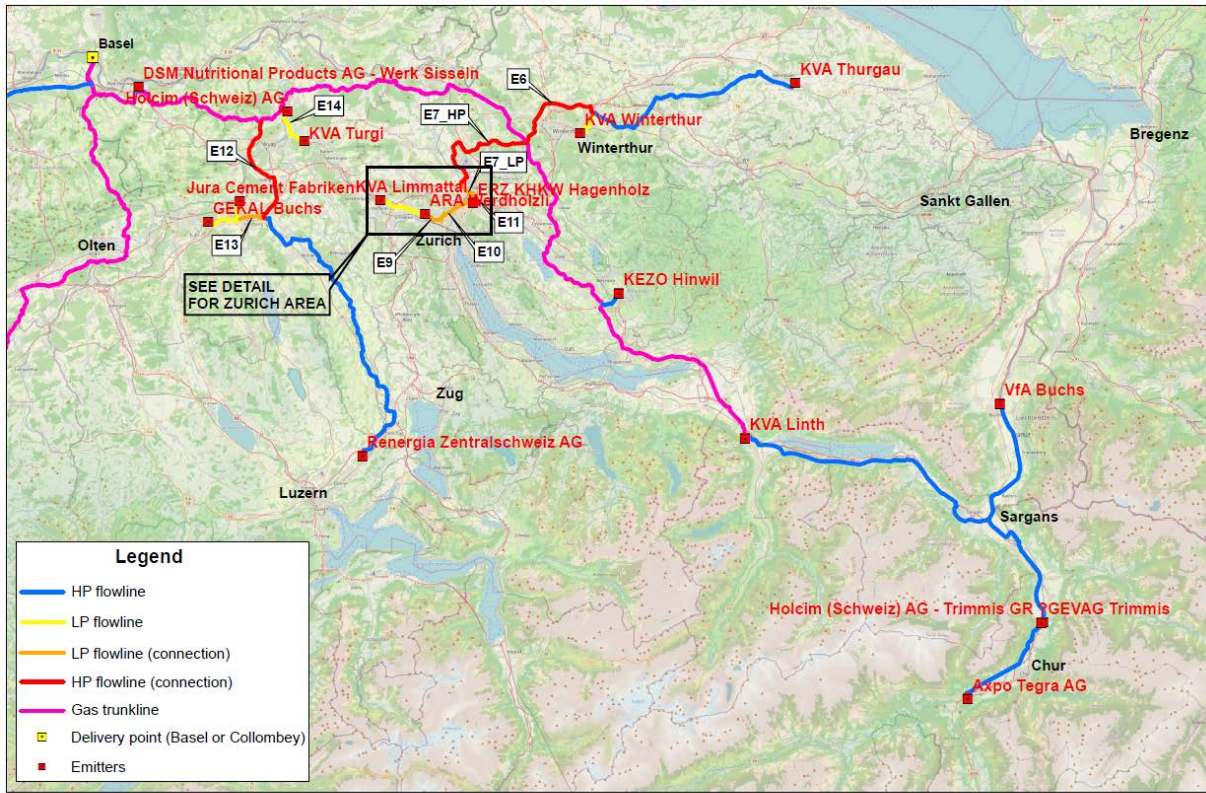
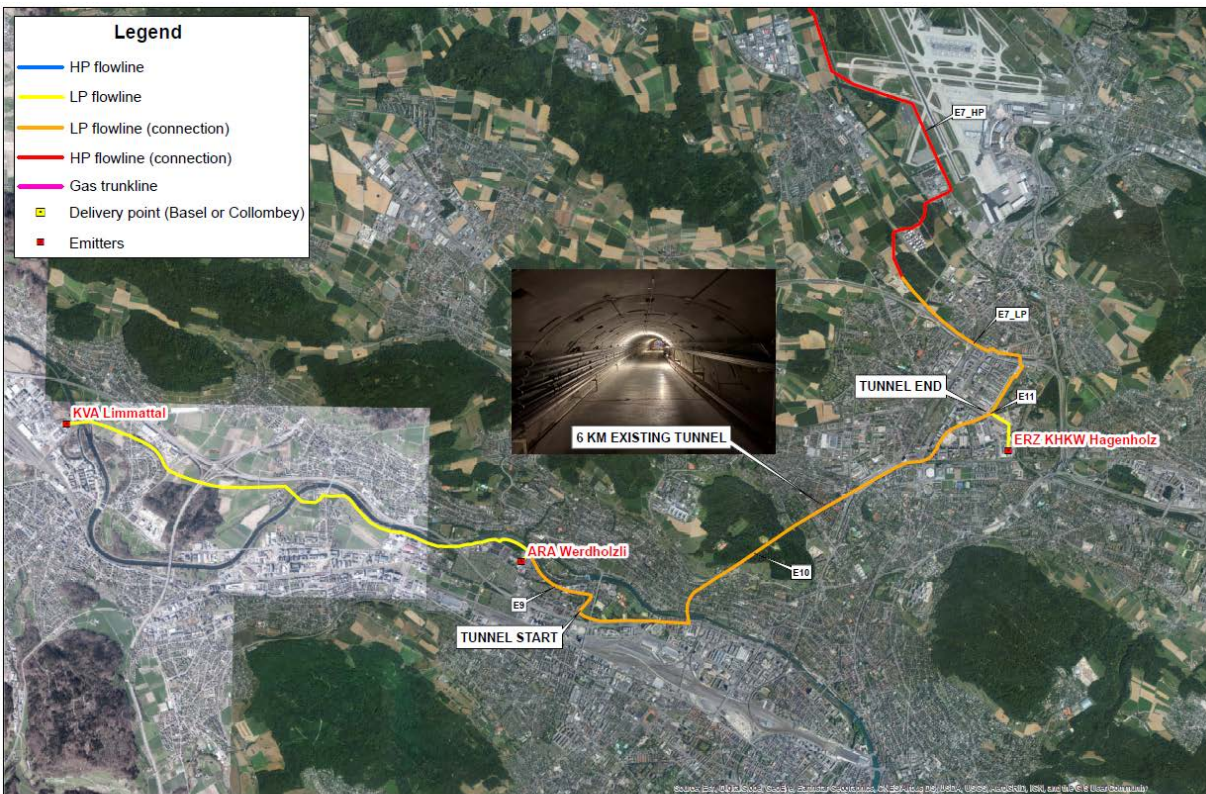
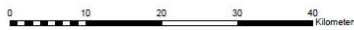
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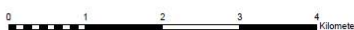
Figure 6.1.1: East Trunkline to Basel – Proposed Routing



SWITZERLAND - CO2 COLLECTION NETWORK
EASTERN TRUNKLINE
PRELIMINARY ROUTING



SWITZERLAND - CO2 COLLECTION NETWORK
ZURICH AREA
PRELIMINARY ROUTING





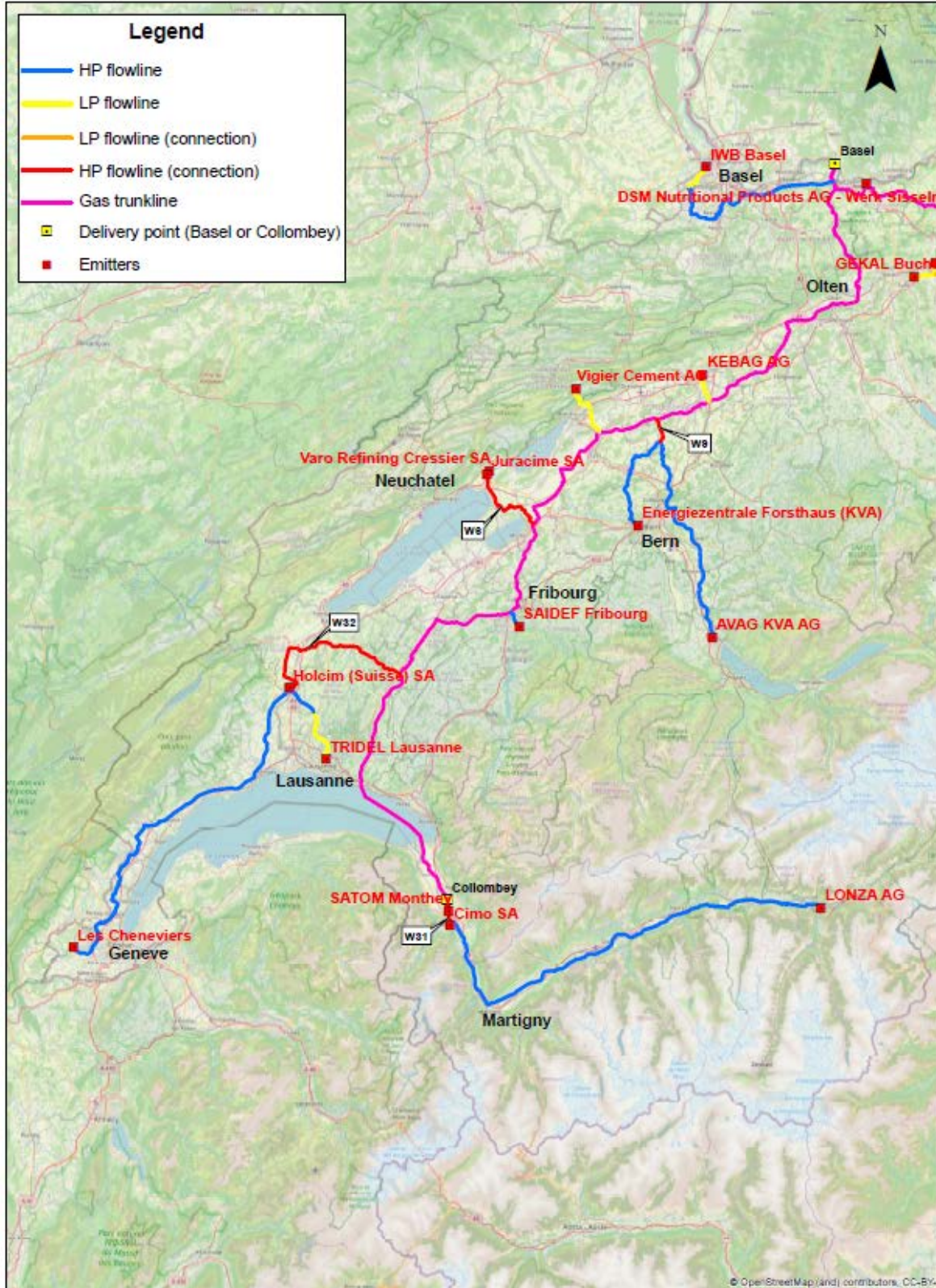


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Figure 6.1.2: West Trunkline to Basel – Proposed Routing



SWITZERLAND - CO2 COLLECTION NETWORK
WESTERN TRUNKLINE
PRELIMINARY ROUTING

0 10 20 30 40
kilometers

| | | | |
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In the following Figure 6.1.3 and Figure 6.1.4 the pipeline elevation profiles are reported for East Trunkline and West Trunkline respectively, assuming Basel as delivery point in both cases.

Figure 6.1.3: Eastern Trunkline to Basel – Elevation Profile

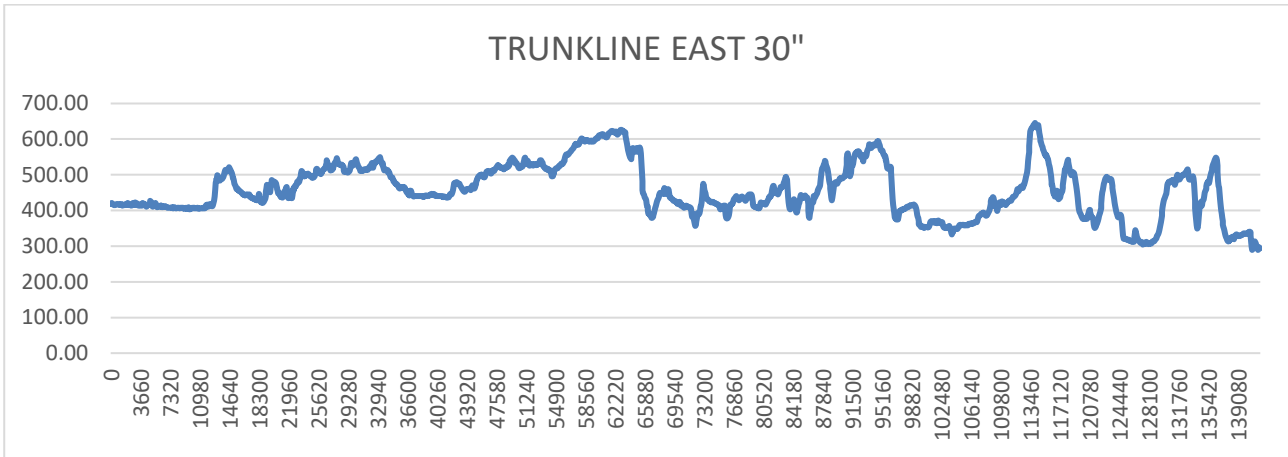
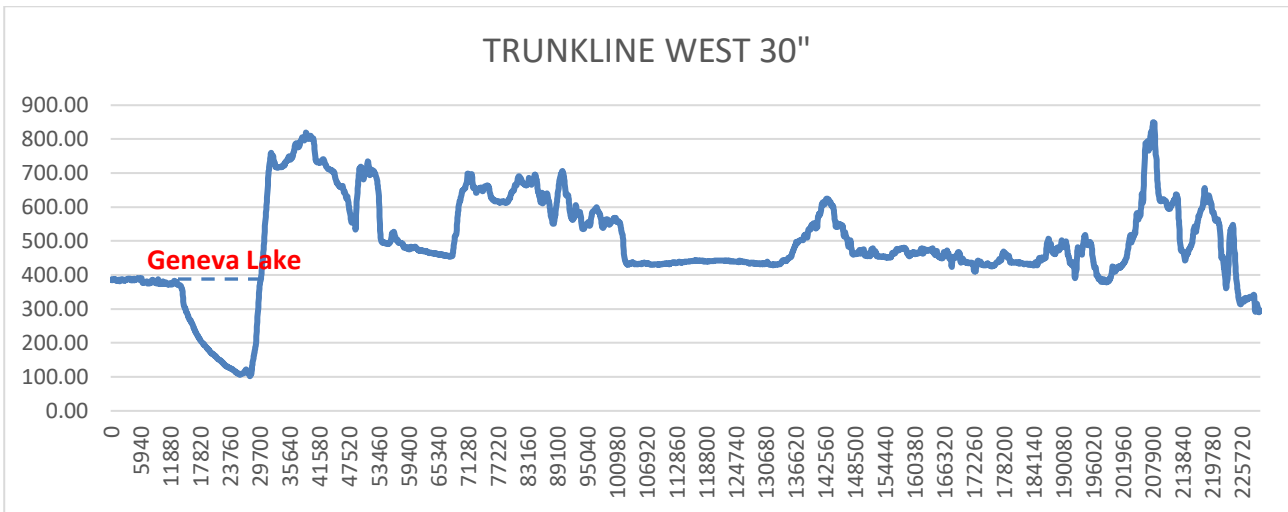




Figure 6.1.4: Western Trunkline to Basel – Elevation Profile





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6.2 NETWORK PIPELINE - LINE DESCRIPTIONS

The following Table 6.2.1 and contain brief descriptions of the single lines developed for the network completion and moreover in the analysis of the main crossings found in the cartographic survey carried out.

Table 6.2.1: Description notes summary for pipelines of Western Trunkline

| Name | Length | Notes |
|---------------------------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRUNKLINE WEST | 229.340 m | The trunkline starts in the flat area of Rhone river flowing into the Geneva Lake. The lake crossing reaches a deep of 275 m from the surface and rising with quite steep slope the north bank in the vicinity of Cully City. The route then climbs the gentle slopes until the highland east of Lousanne. congested area is found close to Friburg and south of Bienne. Many crossings of Aar River by HDD must be considered in the area north of Berna and Luzern. The last part of the route to Basel and Rhine basin is more hilly. |
| Les Cheneviers | 82.748 m | The flowline routing has several proximities to populated areas, at the beginning a route diversion from parallelism with gas pipeline has been considered necessary to reduce interference with populated area. |
| LONZA AG | 92.905 m | the route is along the Rhone Valley, 5 Rhone river crossing are needed, several populated areas is encountered, critical routing to be checked. Many crossing of road and infrastructures are present. Almost all the route is parallel to existing gas pipeline. |
| Cimo SA | 908 m | The emitter is within industrial area and the flowline can be directly connected to Lonza flowline. |
| SATOM Monthey | 158 m | The emitter is within industrial area and the flowline can be directly connected to Lonza flowline. |
| Holcim (Suisse) SA | 249 m | The emitter is within industrial area and the flowline can be directly connected to Les Cheneviers flowline. |
| TRIDEL Lausanne_LP | 10.960 m | The emitter is within the city and for 10 km close to residential area north of Losanna. Compression to HP at the end |
| TRIDEL Lausanne_HP | 6.835 m | After 10 km LP, compression at 35bar is required to connect connection line from Les Cheveniers |
| W32 | 35.805 m | to be checked minor route section to be located out of parallelism |
| W31 | 4.964 m | suitable also for Dense Phase option up to Connection to Trunkline West from SATOM Plant area. |
| EnergieZentrale Forsthaus (KVA) | 22.815 m | Large crossing of Aar River- minor adjustment for dense phase option. |
| AVAG KVA AG | 46.650 m | The flowline runs in proximity of several urban areas. The option of HP is concerned and has to be confirmed after site verification of routing. |
| SAIDEF Fribourg | 3.318 m | urban areas are present in the vicinity, in case of dense phase option some more check on routing is required, to verify the proper clearance from existing settlements. |
| Varo Refining Cressier SA | 764 m | A common treatment and compression of Varo and Juracime SA should be considered, the two emitters are 500 m far then convey to Flowline W6 |

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| Name | Length | Notes |
|-----------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Juracime SA | 453 m | see Varo SA flowline |
| Vigier Cement AG | 11.730 m | First part in a valley with presence of quarry - second part routed across industrial congested and sometime populated areas - Aar Kanal to be crossed by HDD. |
| KEBAG AG | 5.998 m | The flowline affects some urban area, and crosses a large water course, Emme Kanal. Additional compression is required at the trunkline node. |
| W6 | 17.752 m | Main Crossing of Zihil Kanal Berna - only minor section close to populated area |
| W9 | 5.057 m | Routed in an open country area |
| IWB Basel_HP | 42.954 m | the second part after the congested suburban area of Basel area after a CS is considered at present as HP condition, however the present route, parallel to existing gas pipeline seems affecting to much populated and congested areas, hence the entire routing could be reconsidered in a future design phase. |
| IWB Basel_LP | 6.077 m | The emitter and first part of LP flowline is within industrial area and in the residential areas of Basel Town. |
| Renergia Zentralschweitz AG | 46.459 m | Flowline generally along open country areas but several villages and populated area in the proximity, in case of dense phase the route must be reconsidered in some part bto increase the clearance from settlements - The route crosses 3 times the Reuss River |







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Table 6.2.2: Description notes summary for pipelines of Eastern Trunkline

| Name | Lengths | Notes |
|----------------------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRUNKLINE EAST (Rhine Valley) | 56.980 m | First section runs in Rhine valley (two crossing are foreseen), in some of this section some congested area to be passed and defined with detailed routing. In correspondence of the village of Mels the route leaves the Rhine valley overtaking the populated area climbing the left side of the valley. The route run in parallel to existing road up to the Walenstadt Lake. Here morphological challenge are found due to the steep sides of the valley. the selected route climbs the left side, however this route option result concerned, and the entire solution must be reviewed in a future phase especially in the case of Dense Phase Option. |
| TRUNKLINE EAST (Linth to Basel) | 141.679 m | Trunkline from Linth to Hinwil runs in almost flat area along Linth Kanal for the first section avoiding the most populated area in the surrounding. Then, before the Kezo emitter connection, starts the almost continuous parallelism with existing pipelines up to the northern delivery point. Populated area is present east of Zurich Area, and several infrastructures including highways and railways are to be crossed. More undulated area are found by the route in North west of Zurich area up to Basel. |
| E12 | 15.988 m | The route, in parallelism with existing pipeline, is snaking between villages and populated area in the proximity, a Crossing of Aar River by HDD (sensitive area) is required. The option of dense phase is considered but further routing investigation and topographical data gathering are requested. |
| KVA Turgi | 5.380 m | The emitter is in urban area. The flowline is 4 km long and large part is inside populated area. Tributary Aar river as large crossing to be faced. LP solution is required with Additional compression before connection to Holcim flowline, to be considered optimization of compressor station. |
| Holcim (Schweiz) AG | 246 m | The emitter is within industrial area and the flowline is a short pipe be directly connected with Flowline LP coming from KVA Turgi, then the compressor HP shall be before connection flowline E14 |
| Jura Cement Fabriken | 2.676 m | The flowline crosses a wood area, the environmental issues of the route proposed must be verified. LP is selected because as GEKAL flowline convey in E13 flowline that run in a populated area. |
| GEKAL Buchs | 4.934 m | The flowline is LP and connected with Jura cement Fabriken then convey into E13 |
| E13 | 3.455 m | The connection flowline runs in populated and congested area for many length |
| E14 | 592 m | Short connection to Trunkline (rerouting to avoid Double crossing of Aar River |
| KVA Winterthur | 3.881 m | The emitter is within Zurich city. The flowline is 4 km long. Additional compression is required to enter Thurgau flowline |
| KVA Limmattal | 6.691 m | The flowlines are within Zurich area. The 2nd compression up to 35/140 bar can be located close to airport area, outside the city |
| KVA Thurgau | 32.523 m | Flowline generally along open country areas but several villages and populated area in the proximity, The case of DPh can be considered suitable - HDD Crossing of Thur River is necessary. Murg river crossing requires further design consideration |

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|--------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| KEZO Hinwil | 2.998 m | The emitter is within industrial area and can be directly connected to the trunkline (also in case of dense phase transport) |
| ARA Werdholzli | 150 m | The emitter is within Zurich city. The flowline is short branch. To be Combined flowline E9 |
| ERZ KHKW Hagenholz | 609 m | The emitter is within Zurich city. The flowline is short branch. To be Combined flowline E7 |
| E7_HP | 18.803 m | E7 combined flowline collect the flow from Zurich emitters, the first section is LP case the second section close to the Zurich Airport, should be compressed to HP. |
| E7_LP | 2.806 m | see above |
| E6 | 13.636 m | Combined flowline collecting Winterhur and Thurgau emitters could be HP case but in case DPh route to be reconsidered in some section |
| E9 | 1.377 m | Connection flowline LP inside Zurich City |
| E10 | 6.374 m | Connection flowline LP inside Existing Tunnel below Zurich City |
| E11 | 32 m | Connection flowline LP inside Zurich City |
| Axpo Tegra AG | 15.471 m | Flowline inside the Rhine congested Valley, Parallelism with existing pipeline is concerned, especially for the section of existing tunnels for gas pipeline DN 22". - <i>We would like to point out that at present it can be imagined that it is possible to put the new 10 "pipe inside these tunnels, but this aspect will have to be investigated more thoroughly first of all with the owner and then as feasibility and risk analysis.</i> Large river crossing at starting point. Many routing morphological challenges to be defined, but at present is considerable suitable to HP; confirmation shall be done after the further design stage. |
| Holcim (Schweiz) AG - Trimmis GR ? | 139 m | The emitter is in left side of Rhine river, short branch to connect the flowline from Axpo Tegra AG |
| GEVAG Trimmis | 163 m | The emitter is in right side of Rhine river, short branch to connect the flowline from Axpo Tegra AG crossing Rhine River (by aerial Bridge?) |
| VfA Buchs | 18.280 m | The emitter is in left side of Rhine river parallel to the highway. |
| KVA Linth | 247 m | Short flowline branch connection to the starting point of eastern trunkline |
| DSM Nutritional Products AG - Werk Sisseln | 917 m | Short flowline branch connection to the eastern trunkline |

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6.2.1 Summary of the crossings and special points

To complete the routing study, a summary of the crossing points found for each of the lines of the 1038 km flowlines and trunklines system is provided in Table 6.2.4 and Table 6.2.5. In the same tables are reported the route sections where the single route encounters populated area, as defined in section 4.4, and areas where the project routes can be considered in parallelism with existing pipeline, see section 4.3.

A combination of both issues is provided in appendix 2.

Other area of proximity with industrial area (such as plants and warehouses storage building, airport easement, quarry and other structures) are highlighted in the tables.

The selected crossing locations must grant a safe, economical, and easily maintained condition with care to be paid to the nature of the service or waterbody affected and its environment. In some cases, a minor correction of the alignment may significantly improve the design and reduce the cost and impact of crossing. However, sometimes the alignment may be dictated by other significant constraints (e.g., severe slope instabilities, environmental concerns, steep grades).

Summary of the pipeline crossings and special area is reported in Table 6.2.3

Table 6.2.3: Main features of pipelines

| Length | Populated (urban) | | Manned (industrial areas) | | Parallelism with gas PL | | Main river Crossing | Highway Railway Crossing |
|-----------------------|-------------------|----|---------------------------|----|-------------------------|-----|---------------------|--------------------------|
| Eastern Routes | | | | | | | | |
| 403 km | 18 km | 4% | 26 km | 7% | 261 km | 65% | 32 nr | 96 nr |
| Western routes | | | | | | | | |
| 628 km | 39 km | 4% | 38 km | 6% | 514 km | 82% | 24 nr | 105 nr |

As referred in the routing criteria it is assumed that the use of parallelism with gas pipeline, in the actual desktop phase, is always considered feasible except in some minor cases where it could not be beneficial. However, only with a further investigation of the realistic site condition the issue can be confirmed.



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Table 6.2.4: Main features of pipelines of Western Trunkline

| Name | Populated (urban) | | Manned (industrial areas) | | Parallel existing PL | | Main rivers | Highway Railway |
|---------------------------------|-------------------|-----|---------------------------|------|----------------------|------|-------------|-----------------|
| TRUNKLINE WEST | 6.300 m | 3% | 4.700 m | 2% | 186.497 m | 81% | 8 | 34 |
| Les Cheneviers | 3.200 m | 4% | 1.000 m | 1% | 53.146 m | 64% | 1 | 4 |
| LONZA AG | 12.900 m | 14% | 11.600 m | 12% | 92.640 m | 100% | 6 | 17 |
| Cimo SA | 0 m | 0% | 700 m | 77% | 0 m | 0% | 0 | 0 |
| SATOM Monthey | 0 m | 0% | 158 m | 100% | 0 m | 0% | 0 | 0 |
| Holcim (Suisse) SA | 0 m | 0% | 100 m | 40% | 0 m | 0% | 0 | 0 |
| TRIDEL Lausanne_LP | 200 m | 2% | 100 m | 1% | 0 m | 0% | 0 | 2 |
| TRIDEL Lausanne_HP | 0 m | 0% | 800 m | 12% | 0 m | 0% | 0 | 2 |
| W32 | 200 m | 1% | 1.500 m | 4% | 34.786 m | 97% | 1 | 6 |
| W31 | 0 m | 0% | 1.000 m | 20% | 4.421 m | 89% | 1 | 1 |
| EnergieZentrale Forsthaus (KVA) | 0 m | 0% | 900 m | 4% | 20.570 m | 90% | 1 | 3 |
| AVAG KVA AG | 2.200 m | 5% | 3.400 m | 7% | 44.763 m | 96% | 1 | 11 |
| SAIDEF Fribourg | 0 m | 0% | 100 m | 3% | 0 m | 0% | 0 | 2 |
| Varo Refining Cressier SA | 0 m | 0% | 600 m | 79% | 639 m | 84% | 0 | 0 |
| Juracime SA | 0 m | 0% | 100 m | 22% | 0 m | 0% | 0 | 1 |
| Vigier Cement AG | 1.000 m | 9% | 3.000 m | 26% | 2.090 m | 18% | 1 | 4 |
| KEBAG AG | 1.300 m | 22% | 500 m | 8% | 1.000 m | 17% | 1 | 3 |
| W6 | 700 m | 4% | 700 m | 4% | 17.752 m | 100% | 1 | 3 |
| W9 | 0 m | 0% | 0 m | 0% | 5.057 m | 100% | 0 | 0 |
| IWB Basel_HP | 4.400 m | 10% | 5.100 m | 12% | 42.640 m | 99% | 2 | 12 |
| IWB Basel_LP | 4.200 m | 69% | 500 m | 8% | 0 m | 0% | 0 | 0 |
| Renergia Zentralschweitz AG | 400 m | 1% | 3.000 m | 6% | 45.644 m | 98% | 4 | 10 |





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Table 6.2.5: Main features of pipelines of Eastern Trunkline

| Name | Populated (urban) | | Manned (industrial areas) | | Parallel existing PL | | Main rivers | Highway railway |
|--------------------------------------------|-------------------|-----|---------------------------|------|----------------------|------|-------------|-----------------|
| TRUNKLINE EAST (Rhine Valley) | 700 m | 1% | 1.800 m | 3% | 18.340 m | 32% | 8 | 15 |
| TRUNKLINE EAST (Linth to Basel) | 1.100 m | 1% | 1.900 m | 1% | 91.550 m | 65% | 5 | 19 |
| <i>E12</i> | 900 m | 6% | 2.800 m | 18% | 5.160 m | 32% | 2 | 5 |
| KVA Turgi | 1.600 m | 30% | 700 m | 13% | 0 m | 0% | 1 | 5 |
| Holcim (Schweiz) AG | 0 m | 0% | 180 m | 73% | 0 m | 0% | 0 | 0 |
| Jura Cement Fabriken | 0 m | 0% | 250 m | 9% | 0 m | 0% | 0 | 2 |
| GEKAL Buchs | 0 m | 0% | 1.700 m | 34% | 4.017 m | 81% | 0 | 3 |
| <i>E13</i> | 500 m | 14% | 1.200 m | 35% | 3.455 m | 100% | 0 | 2 |
| <i>E14</i> | 0 m | 0% | 0 m | 0% | 0 m | 0% | 1 | 0 |
| KVA Winterthur | 1.000 m | 26% | 1.500 m | 39% | 0 m | 0% | 0 | 3 |
| KVA Limmattal | 1.600 m | 24% | 1.600 m | 24% | 870 m | 13% | 2 | 2 |
| KVA Thurgau | 0 m | 0% | 120 m | 0% | 31.749 m | 98% | 2 | 5 |
| KEZO Hinwil | 250 m | 8% | 80 m | 3% | 0 m | 0% | 0 | 2 |
| ARA Werdholzli | 0 m | 0% | 150 m | 100% | 0 m | 0% | 0 | 0 |
| ERZ KHKW Hagenholz | 0 m | 0% | 430 m | 71% | 0 m | 0% | 0 | 1 |
| <i>E7_HP</i> | 400 m | 2% | 3.600 m | 19% | 14.916 m | 79% | 3 | 2 |
| <i>E7_LP</i> | 1.800 m | 64% | 200 m | 7% | 0 m | 0% | 0 | 4 |
| <i>E6</i> | 1.000 m | 7% | 600 m | 4% | 12.216 m | 90% | 1 | 4 |
| <i>E9</i> | 800 m | 58% | 300 m | 22% | 0 m | 0% | 0 | 1 |
| <i>E10</i> | 4.774 m | 75% | 1.600 m | 25% | 0 m | 0% | 1 | 1 |
| <i>E11</i> | 32 m | 99% | 0 m | 0% | 0 m | 0% | 0 | 0 |
| Axpo Tegra AG | 250 m | 2% | 1.274 m | 8% | 14.947 m | 97% | 1 | 2 |
| Holcim (Schweiz) AG - Trimmis GR | 0 m | 0% | 139 m | 100% | 0 m | 0% | 0 | 0 |
| GEVAG Trimmis | 0 m | 0% | 60 m | 37% | 0 m | 0% | 1 | 0 |
| VfA Buchs | 400 m | 2% | 1.000 m | 5% | 18.085 m | 99% | 0 | 7 |
| KVA Linth | 0 m | 0% | 50 m | 20% | 0 m | 0% | 0 | 0 |
| DSM Nutritional Products AG - Werk Sisseln | 0 m | 0% | 200 m | 22% | 0 m | 0% | 0 | 1 |

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6.3 GENEVA LAKE

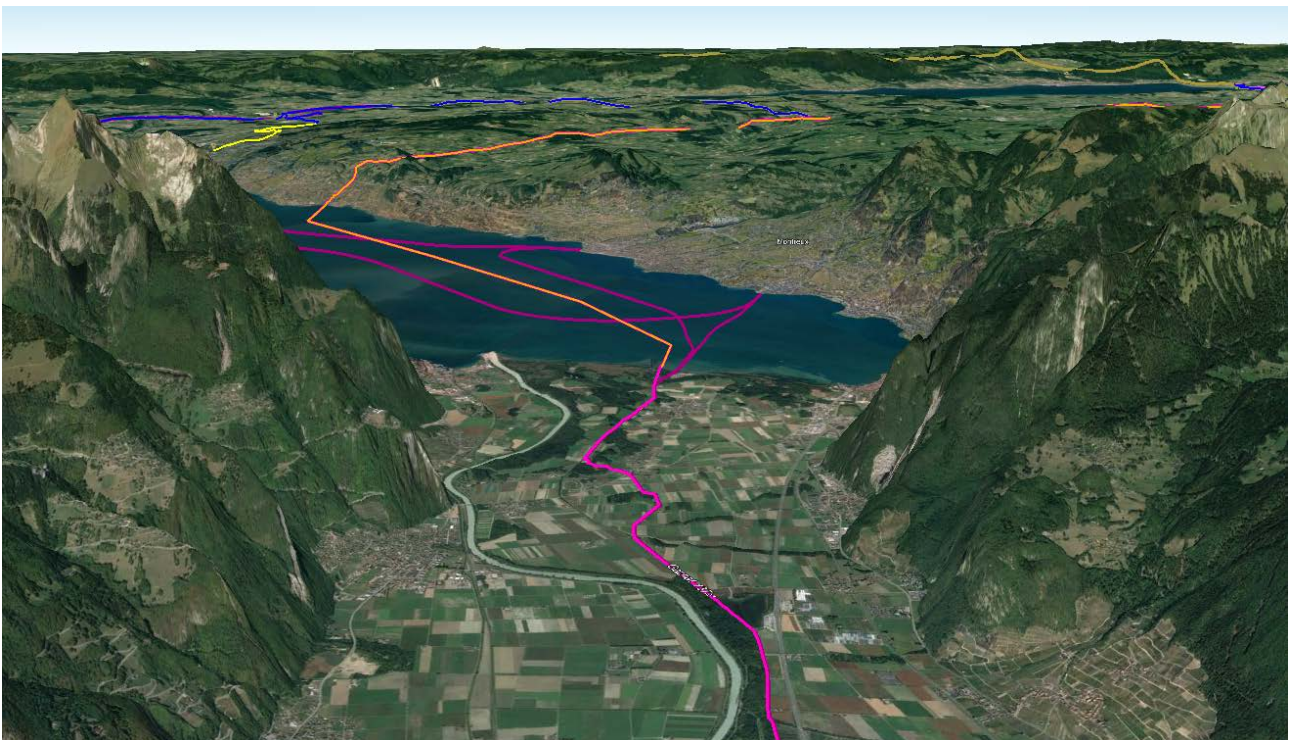
6.3.1 Routing Condition

For the completion of the study of the pipeline system it is necessary that the West trunkline reaches the delivery point foreseen in Collombey, which is located south of the Geneva lake; this for morphological and geographical reasons unavoidable and entails the need to cross the lake with an "offshore" route.

The realization of the crossing is also necessary for the collection of the flowlines of the three southern emitters of the system (Lonza AG, Satom Monthey and Cimo SA), which are located in the Rhone valley and can feed to the western trunkline in case of northern delivery.

The defined route section connects two points identified in the desktop study, the first on the northern bank east of Lausanne near the town of Bourg en Lavaux and the second on the southern bank, in the delta of the Rhone river a few kilometers west of the city of Villeneuve. The section defined is about 16 km long and the proposed route is shown in Figure 6.3.1 and Figure 6.3.2

Figure 6.3.1: Geneva Lake crossing view from south bank





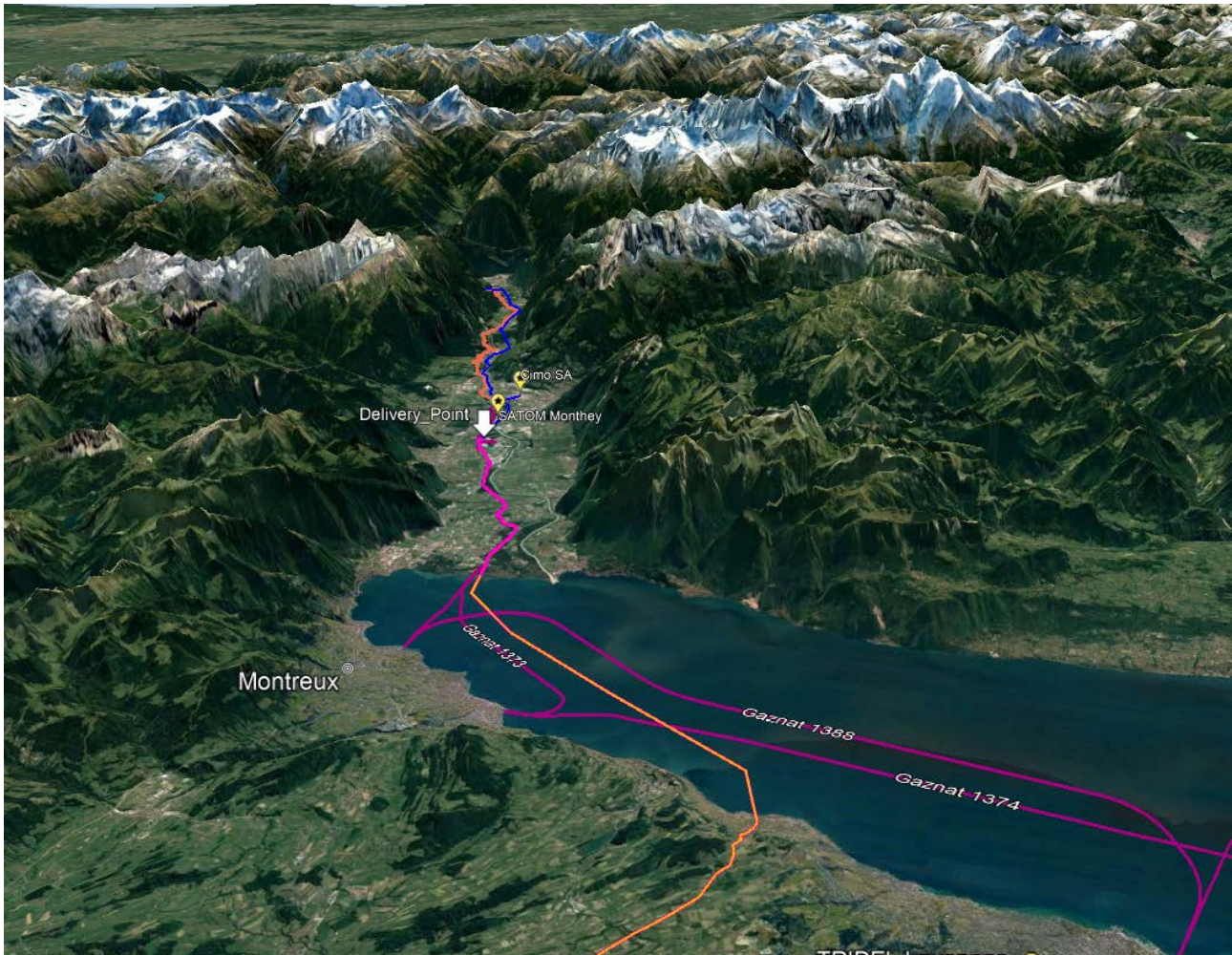
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Figure 6.3.2: Geneva Lake crossing view from north bank





The morphological conformation of Lake Geneva and the presence of urban agglomerations of the city of Montreux prevents the possibility of routing around the lake in the eastern area. The morphology of the lake is shown in Figure 6.3.3, where it is noted that the depths to be reached are about 280 m from the average surface of the lake, as shown the pipeline profile obtained.

A large diameter pipeline crossing of a wide and deep lake, like Geneva Lake is, from the engineering and installation point of view, results very similar to an offshore pipeline, but the closed and confined waters imply further challenges to be faced and issued to be solved, in particular the availability of high capability barge (marine type).

A summary of the main engineering activities to be performed and installation methods, means and tools to be examined, compared, and selected to proceed is reported hereinafter.

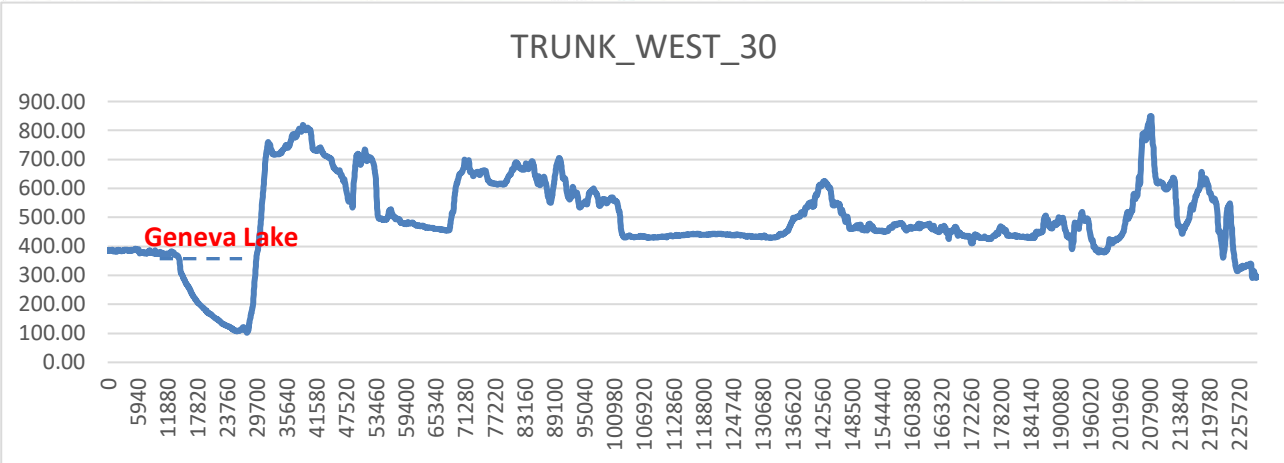
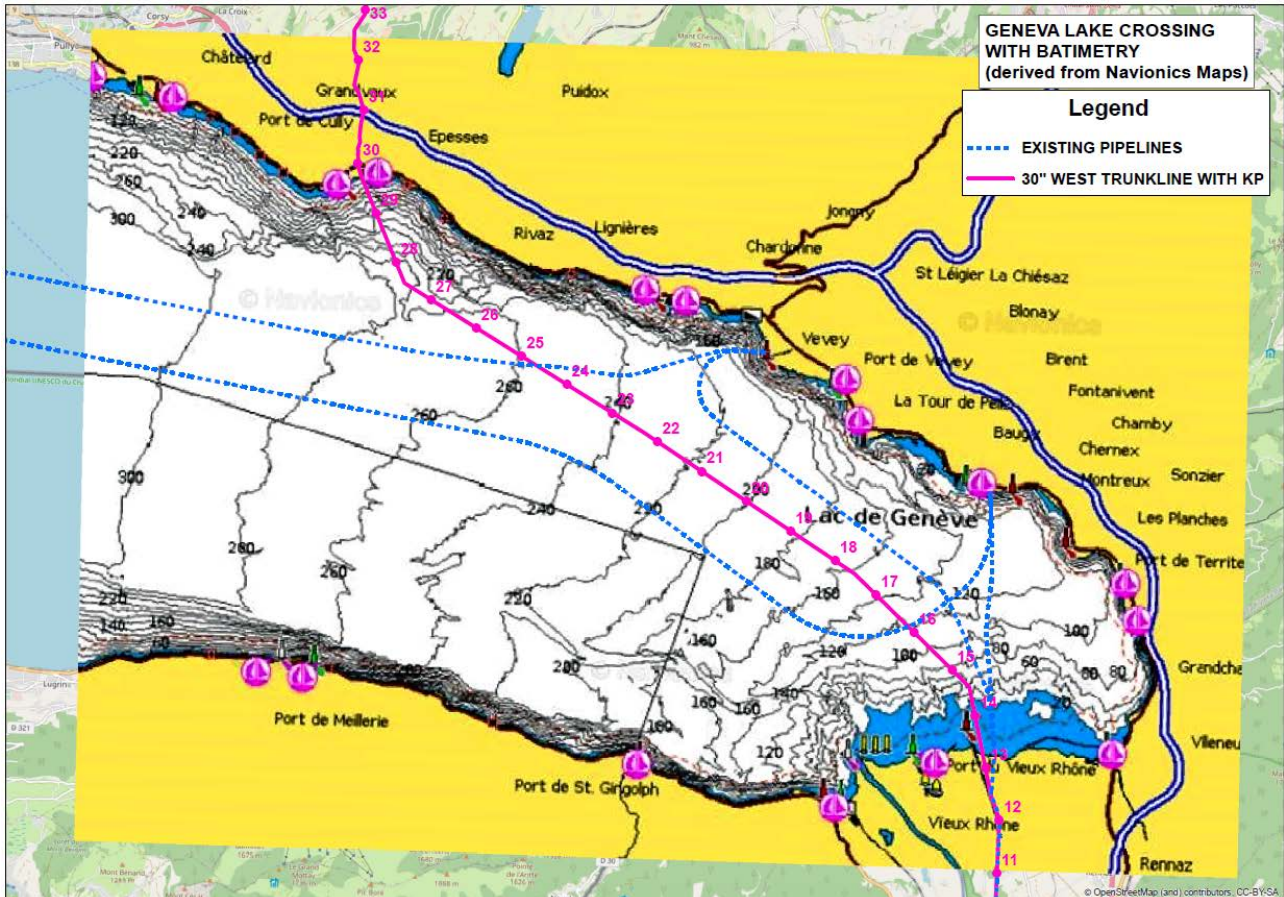
A preliminary market investigation shall be carried out in order to verify the availability of subcontractors and vessels on Geneva Lake to perform or be easily adapted to carry out the following activities:

- Collection of meteocean data.
- Collection of Geological, geophysical and geotechnical data.
- Morphologic survey of the bed of the lake and location of existing facilities and features.
- Pipeline laying and/or tow and supply during laying.
- Above water tie ins.
- Intervention works with trenching, dredging, gravel dumping, mattresses installation, etc.

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This is an important activity to be performed in advance to lead the engineering phase to easily affordable solutions, taking into account the confined body of water we are working in.

Figure 6.3.3: Geneva Lake bathymetry and profile



Considering all the process, fluid composition, flow data and pipe steel characteristics are already known, the most important design basis to be collected to proceed with engineering phase are:

- environmental data so called "Meteocean data"
- Morphology and soil features
- Presence of Existing facilities (e.g. pipeline, cables, etc..) to be crossed

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6.3.2 Shore Approaches

Different landfall morfologies are present at the North and South sides of the lake crossing route:

- The North side is rocky, very steep and densely anthropized onshore area with buildings, main roads, railway and motorway.
- The South side instead is more smooth and less steep with a probable soft soil and a flat and free enough onshore area without buildings and main roads between Villeneuve town and Rhone river mouth; moreover it is the same landfall point of other pipelines.



On the basis of the above characteristics different solutions/technologies are advisable at the two shore approaches.

Horizontal directional drilling HDD (as indicated in section 5.5.2) or Long microtunnel seems most advisable solution at the North side, in order to overtake the densely anthropized area with all the roads, including the motorway.

The trenchless method enable to install the pipeline without disturbance to environmental features and infrastructures generally present in the shore strip affected.

It is recommended an early involvement of relevant Land authorities must find out the opportune solutions timely, with proper design in these sensitive areas.

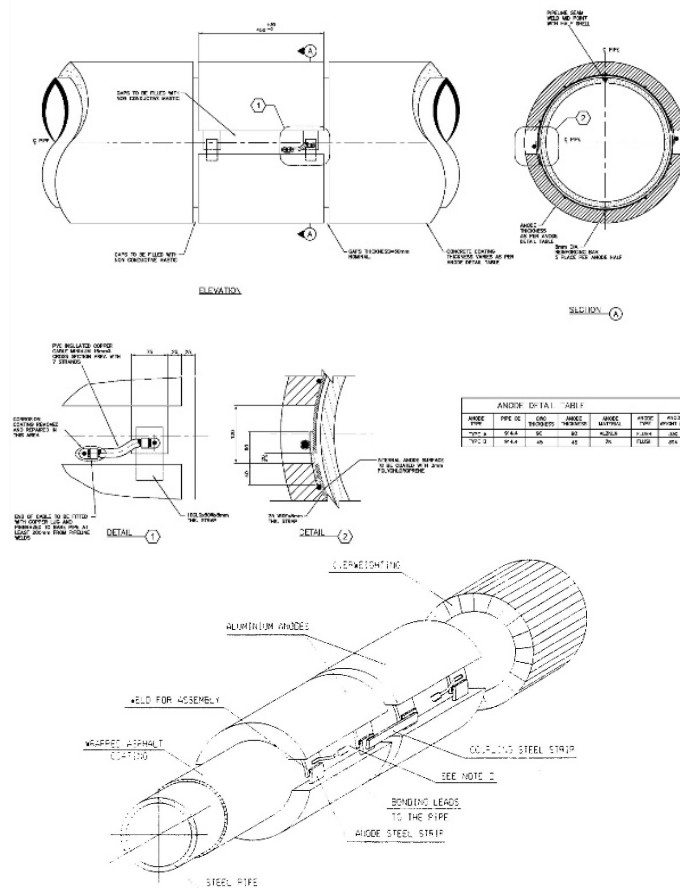
A traditional less expensive open trench solution may easily be applied at the South side considering the soil morphology as shown in Figure 6.3.4. Special attention shall be paid to the interferences with the existing pipelines in operating conditions.

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Moreover, some of the concrete coated pipes shall be provided with sacrificial anodes for under water cathodic protection. The distance between two consecutive anodes will be defined in the engineering phase.

The Figure 6.3.5 below shows a typical underwater pipe with concrete coating and anode installed.

Figure 6.3.5: Concrete coated pipes with anodes





6.3.4 Design principles

Being the landfalls already fixed, the best route to cross the lake shall be based on the results of the above described geo-morphological surveys of the bed of lake. The route shall be optimized taking in account:

- The need to reduce the free spans length.
- The minimum bend radius of the pipeline during installation. It should be forecast around 2500 – 3000 m based on pipes diameter and water depth.
- The presence of possible features/obstacles to the easy pipeline installation.
- The angle of incidence to the crossing of the existing lines that shall be as closer to 90° as possible; angles less than 30° should be avoided.

Once the route has been optimized, a few free spans will still be present due to the important unevenness of the bed of the lake, moreover existing lines shall be crossed avoiding direct contact with the new pipeline and route bend radius shorter than that allowed by soil friction and pipeline stiffness might be requested.

Stability problems might still be present mainly in the shallow waters or where the current is so strong that the thickness of concrete against it would be too much intervention works shall be designed as:

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- Pre-installation dredging and/or post installation trenching to bury the pipeline, reducing free spans length and height in soft soil, improving stabilization of pipeline.
- Pre-installation and/or post installation gravel dumping supports for: reducing free spans length in order not to exceed the allowable length in static (stress) and dynamic (vortex shedding induced by currents) conditions; creating a bridge crossing on existing pipelines.
- Concrete lateral counteracts to allow shorter bend radius along the route.
- Zero Radius Bends (ZRB) concrete sleeper to govern the triggering of ISB.
- Concrete mattresses to stabilize the pipeline on granite rocky soil and/or to protect existing cables (if any) when crossed by the new pipeline.
- Pre-installation concrete sleepers for creating a bridge crossing on existing pipelines.

Some examples of intervention works are shown in the Figure 6.3.6.



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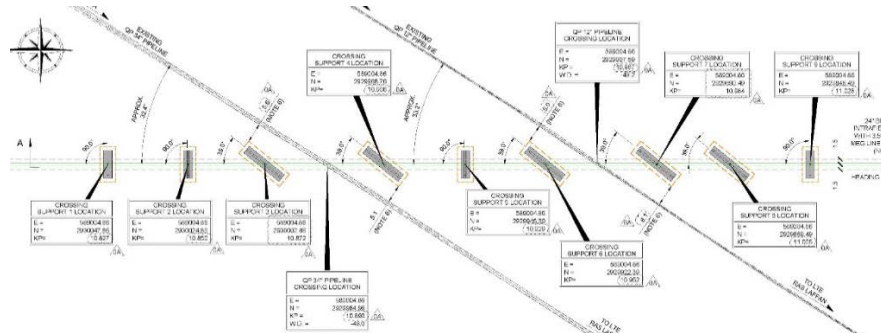
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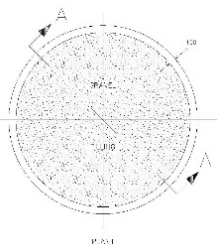
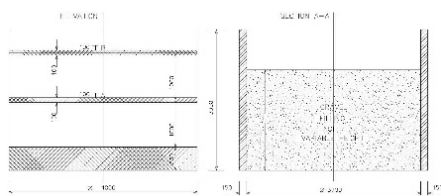
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Figure 6.3.6: Typical intervention works

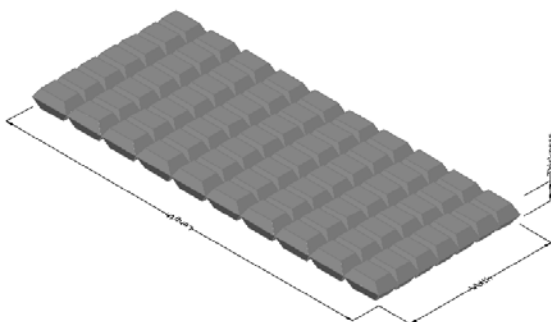


Crossing and concrete sleeper.

SIMPLE HOLLOW CYLINDER TYPE A





Lateral counteracts



Typical mattress support for cable crossings



Gravel dumping for stabilization of pipe

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6.3.5 Installation Methods

This activity might be the most challenging considering the availability of vessels in the lake and the size and weight of the pipeline.

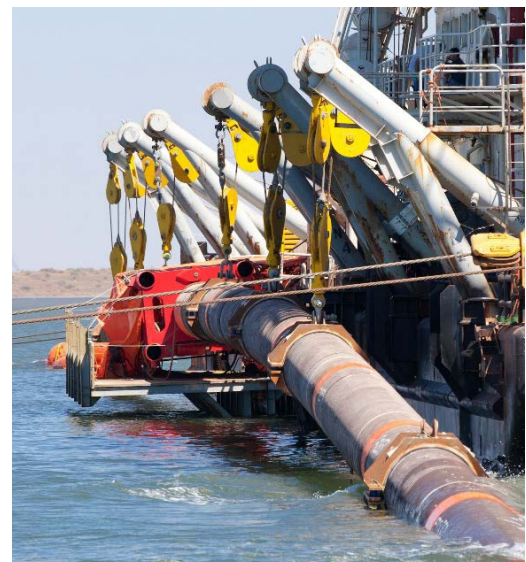
It is necessary to design the modification of the available barges in order to be able for the following main activities with all the ancillary works:



- Pipeline Laying along the straight and bent route with either shallow or deep water.
- Above water tie in with a sufficient number of side davits to lift the two sides of the laid pipeline, coupling and welding them together
- Gravel dumping for supports and stabilization works, if needed.
- Trenching activities at landfall.
- Lifting activities in order to install any prefabricated intervention work to be installed before laying.

Figure 6.3.7: Type of Barge suitable for laying the pipe in Geneva lake



Above Water Tie in



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An alternative solution to the use of available barges to adapt them for the above activities is the rest of a sufficient number of “Combifloat” prefabricated modular floating steel caissons, that can be easily assembled in different shapes and sizes to be equipped as lay (with rollers and tensioners), crane, dumping and or any use vessels (see the examples in the below Figure 6.3.8).



Figure 6.3.8: Combifloat barge



Combifloat modulus to be assembled



Laybarge and crane barge assembled with Combifloat moduli

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6.4 POINTS OF ATTENTION

The following section deal with the main criticalities found along the routes of the flowlines and trunklines.

6.4.1 Walensee lake – Trunkline East 20"

For the development of the projected network and connection of emitters located to the south-east, a route has been designed running through the valley of the Rhine river starting from the Axpo Tegra AG plant.

The trunkline then connects the emitters of Holcim Schweiz and Gevag and arrives in the locality of Mels where the flowline arriving from the Buchs KfA emitter also joins.

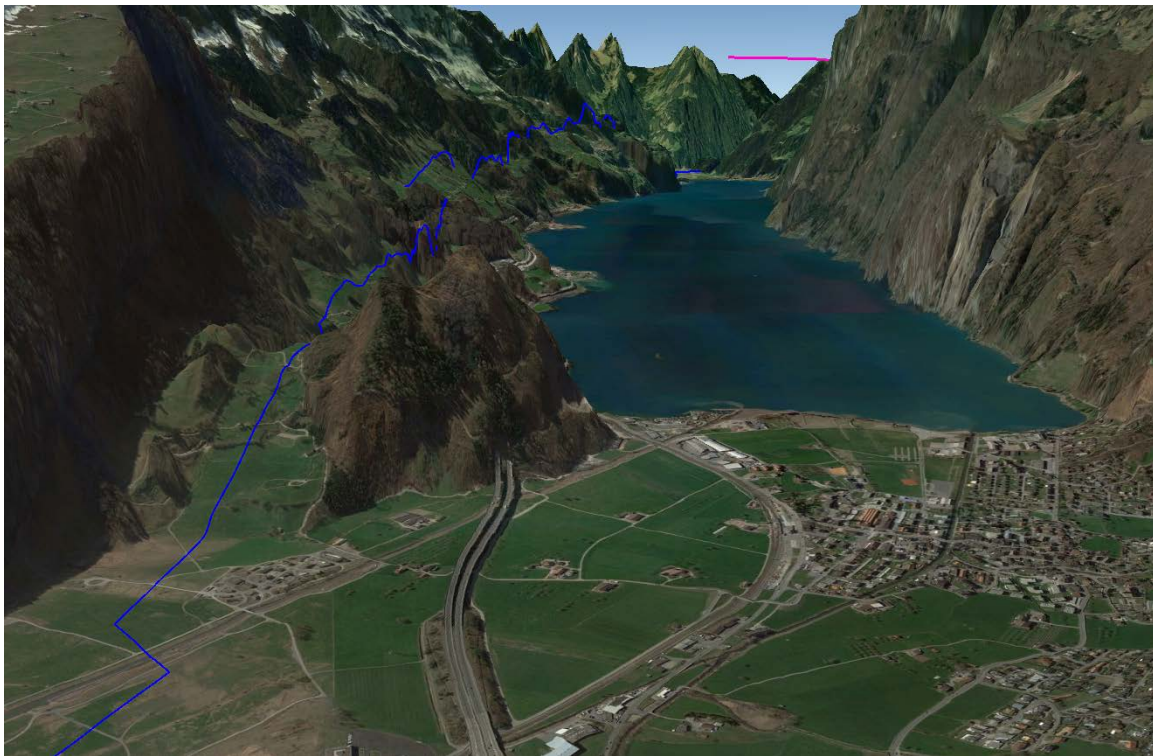
Up to this node the trunkline NPS 20 " is developed in parallel to the line of the existing Gas pipeline 22", but in order to connect the next emitter Linth KVA the natural direction to follow goes westwards, having to cross the narrow valley of Lake Walensee. Here the north shore of the lake presents an extremely steep mountainous slope, not suitable for routing the subject trunkline.

For this reason, a route is proposed in the study runs along the unduled and often morphologically uneven section south of the lake (see Figure 6.4.1); here it is highlighted that for the completion of the route feasibility definition of this particular point, only a further study can confirm the option proposed with details of adopted construction techniques and restoration works of the land crossed relevant cost impact.



It is noted that this part of the line reaches an elevation of over 800 m.

At present this solution is proposed as a base case, however in this same study an alternative solution is also proposed as shown in Figure 6.4.2

Figure 6.4.1: Trunkline East running in Walensee Lake valley



The alternative solution passes into the valley just north of the Chäserrugg ski resort, overcoming 1000 m of altitude and then descending into the valley of the Thur river Valley which is runned up and then turns southwest towards Lake Obersee.

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Both the alternative cases are shown in Figure 6.4.2: Trunkline East map of the alternative routes

Figure 6.4.2: Trunkline East map of the alternative routes



As reported in the study about the Geneva crossing, the possibility of “Combifloat” solution could be considered also in this case due to the fact that Walensee Lake bathimetries, shown in the below Figure 6.4.3, suggest possibility of laying as offshore method the pipeline inside the lake, the method could result cost effective and reducing environmental impact solution, since water depth and landfalls are far more affordable than for Geneva Lake crossing.

Figure 6.4.3: Trunkline East map possible alternative crossing the lake.

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6.4.2 Rhone river – Lonza flowline

The flowline that conveys the CO₂ produced by LONZA emitter runs for a long stretch along the valley of the Rhone river almost always planned in parallel with the existing gas pipeline. In many parts of the valley, the presence of infrastructures, roads, railways, power lines as well as working and manned areas, create situations of congestion and related potential risk, an example is given in the Figure 6.4.4 below.

Figure 6.4.4: Lonza Flowline along Rhone valley in congested situation with parallel gas pipeline



Along the route inside the valley there are also sections of high presence of dwellings e civil infrastructures; the actual proposal consider always to be parallel to the existing pipeline and its ROW, however there are situation to be checked in a more detailed design phase, due to real narrow passages to be overtaken.

An example is given in Figure 6.4.5, in this area the CO₂ flowline has to run at the bottom of the mountain slope to avoid populated areas and the existing gas pipeline sometime could constitute a hindrance to a proper routing.



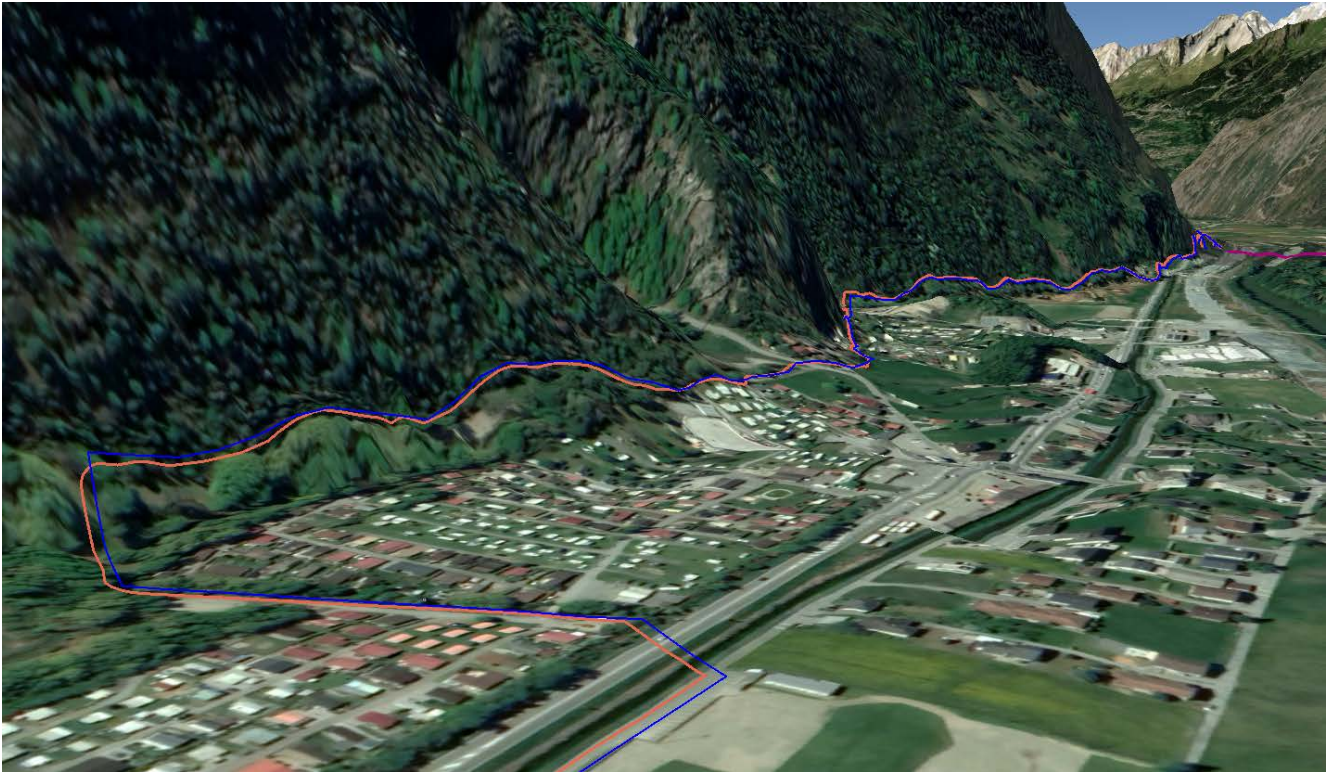


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Figure 6.4.5: Lonza Flowline along Rhone valley with proximity to populated areas.



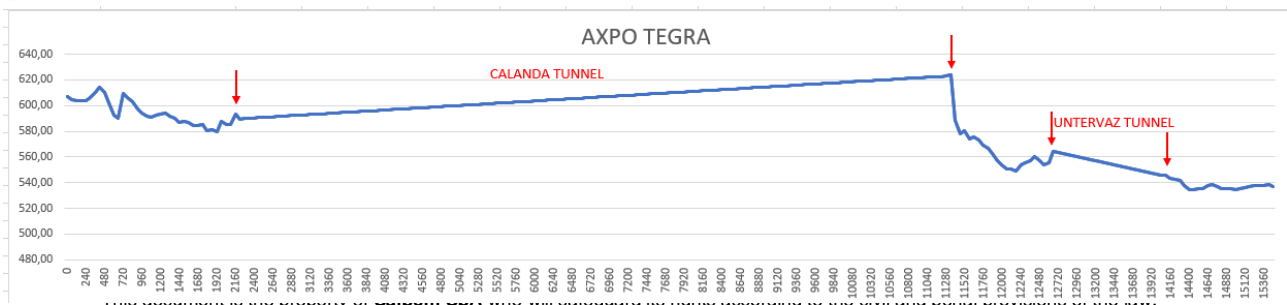
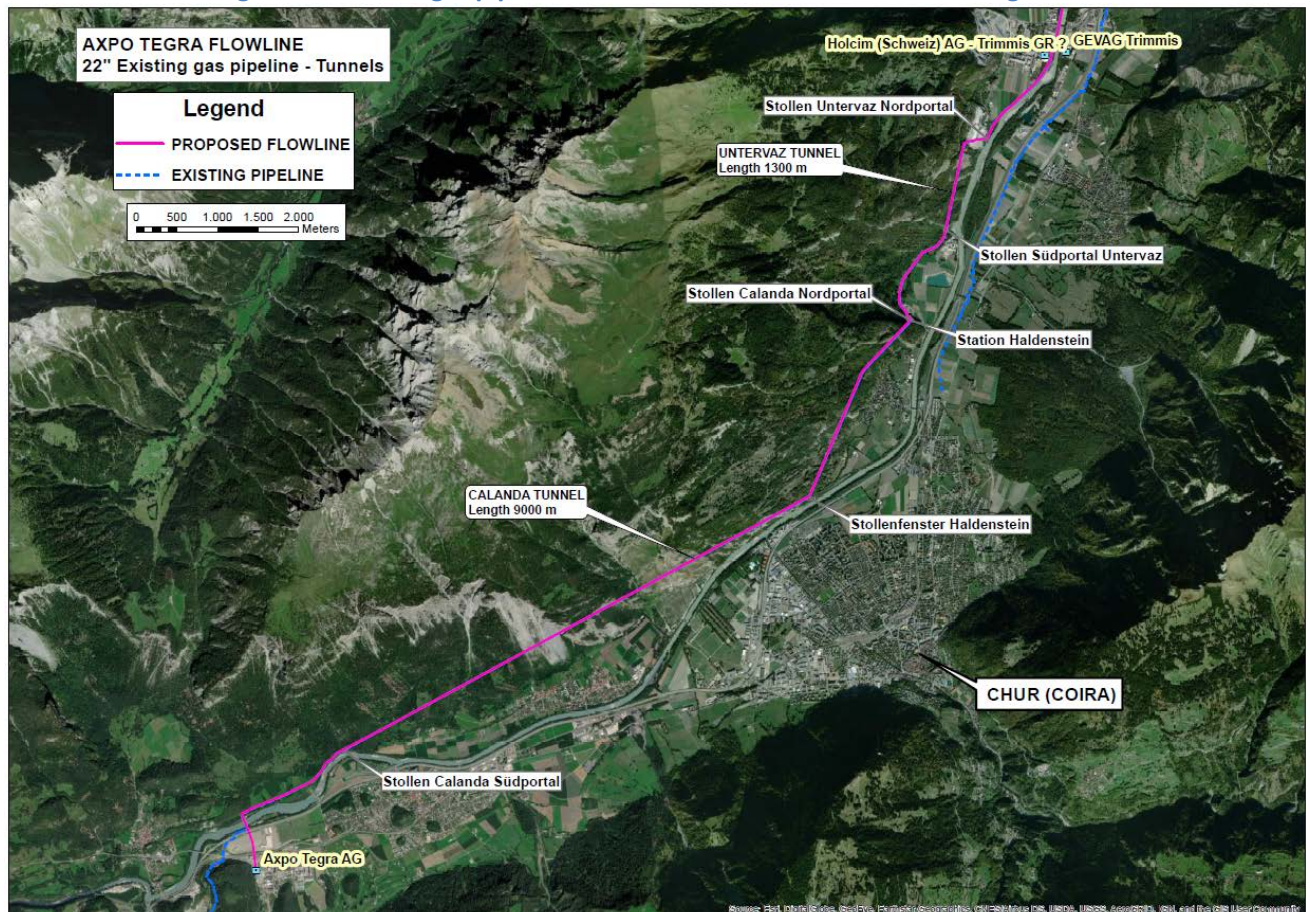
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6.4.3 Rhine river - Axpo Tegra flowline



The flowline for the gas collection from Axpo Tegra emitter runs northwards along the Rhine river valley, which is narrow and densely populated; in this area the urban agglomerations of Domat and Churs completely occupy the Rhine plain. For this reason, the solution chosen was to run parallel to the ROW of the existing EGO gas pipeline. From the information gathered, the existing gas pipeline is a NPS 22" with DP 45 barg in Carbon Steel API 5L X52. Due to the morphological and urban condition and in the section affected by the project flowline, the existing gas pipeline runs through two tunnels built for this purpose some years ago, the first 9 km long under Calanda mountain and the second 1.3 km long under Untervaz peak, whose planimetric characteristics are shown in Figure 6.4.6.

For the same morphological condition, at present it is assumed the installation of the CO2 flowline from Axpo Tegra be realized within the existing tunnel in parallelism with gas pipeline already laid. This assumption is done for preliminary design purpose and pre-feasibility completion but must be verified in next phase of the project. The cost impact of this solution has not been considered in the present study.

Figure 6.4.6: EGO gas pipeline inside tunnel in the area of Chur Village.



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It is expected a situation of the existing pipeline in the tunnel like the one shown in Figure 6.4.7.

Figure 6.4.7: Typical gas pipeline inside tunnel and possible configuration in the area of Chur Village.



In fact, to consolidate this proposal, it is necessary to define in early phase the following:

- possibility of agreement with the owner of the service to be able to install a second pipeline inside
- check that the spaces and requirements are adequate for laying a second pipe.
- check the operational safety conditions that can be reached
- feasibility definition for an installation method that guarantees the reliability of the work at the same time as the integrity of the existing service.

The installation of a second pipeline, will probably require works to adjust the layout of the existing tunnel and it will be necessary to verify:

- the space available for laying and verify the possibility of enlargement of the existing cross section,
- the possibility of relocation of existing utilities inside.

Enlargement works will be carried out after protecting with proper temporary works the existing pipelines for safety reason.

Enlargement work could be done by using mini excavators with demolition hammers and drills and pneumatic equipment manuals. Demolition operations shall be performed avoiding use of explosives.



Pipe string will be assembled inside the tunnel, starting from the end of tunnel to the entry point proceeding to hauling, stringing, line up and welding the pipes one by one.

The hauling and stringing phase will be carried out with special hauling equipment sized to perform the work inside the tunnel, and with gantry cranes; the pipe will be lowered on temporary supports (wooden skids) in order to facilitate the operations of line up and subsequent welding joint by joint. (see Figure 6.4.8: Sample of installation of new pipeline in existing tunnel.

There are cases where the tunnels have been used to install a second pipeline, for example Grimsel, Obergesteln and Griess long tunnels in Alps region between the Rihne river valley, in the Swiss Municipality of Obergesteln, and the Toce river valley, in the Italian Municipality of Formazza in the Piedmont region.

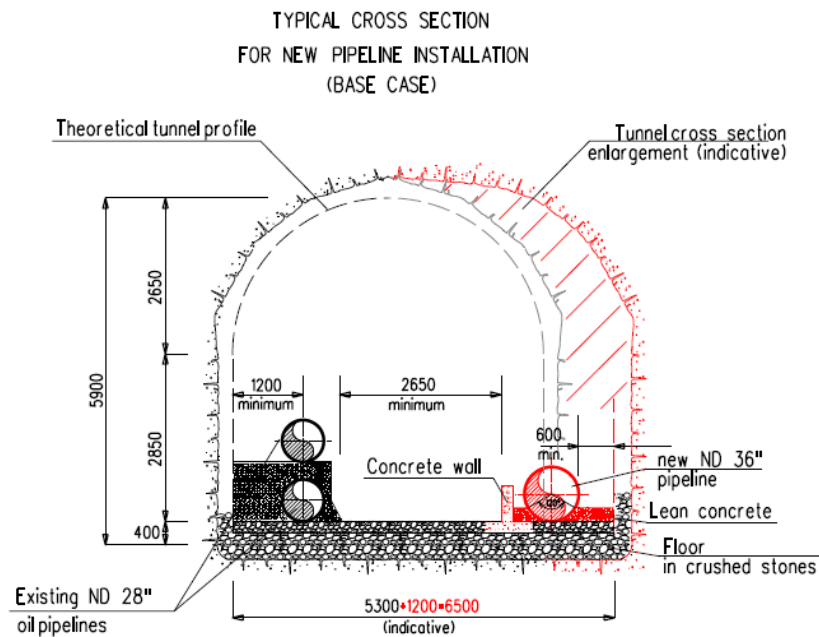
As alternative two option could be considered:

- Route study with microtunnelling or new tunnel sections to overtake the most critical section.

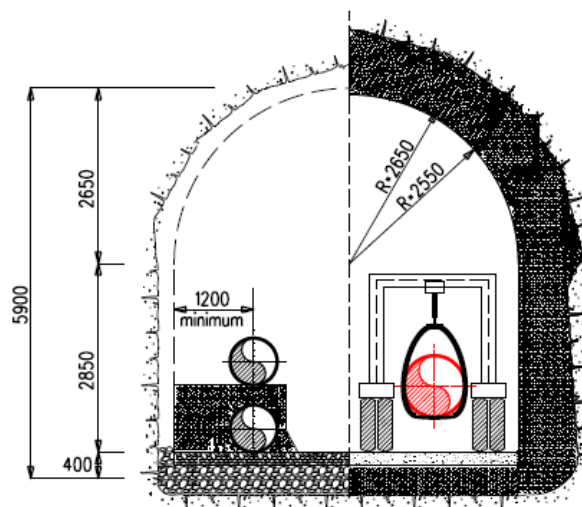
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- Achieve detailed topographic map and DTM to design a different route in the respect of the real found distance and with adoption of mitigation measures (increase WT, installation in culverts, separation wall, increase cover depth, etc,) to be tailored for the purpose.

Figure 6.4.8: Sample of installation of new pipeline in existing tunnel.



PIPE HAULING SPECIAL EQUIPMENT
(SECTIONAL VIEW)



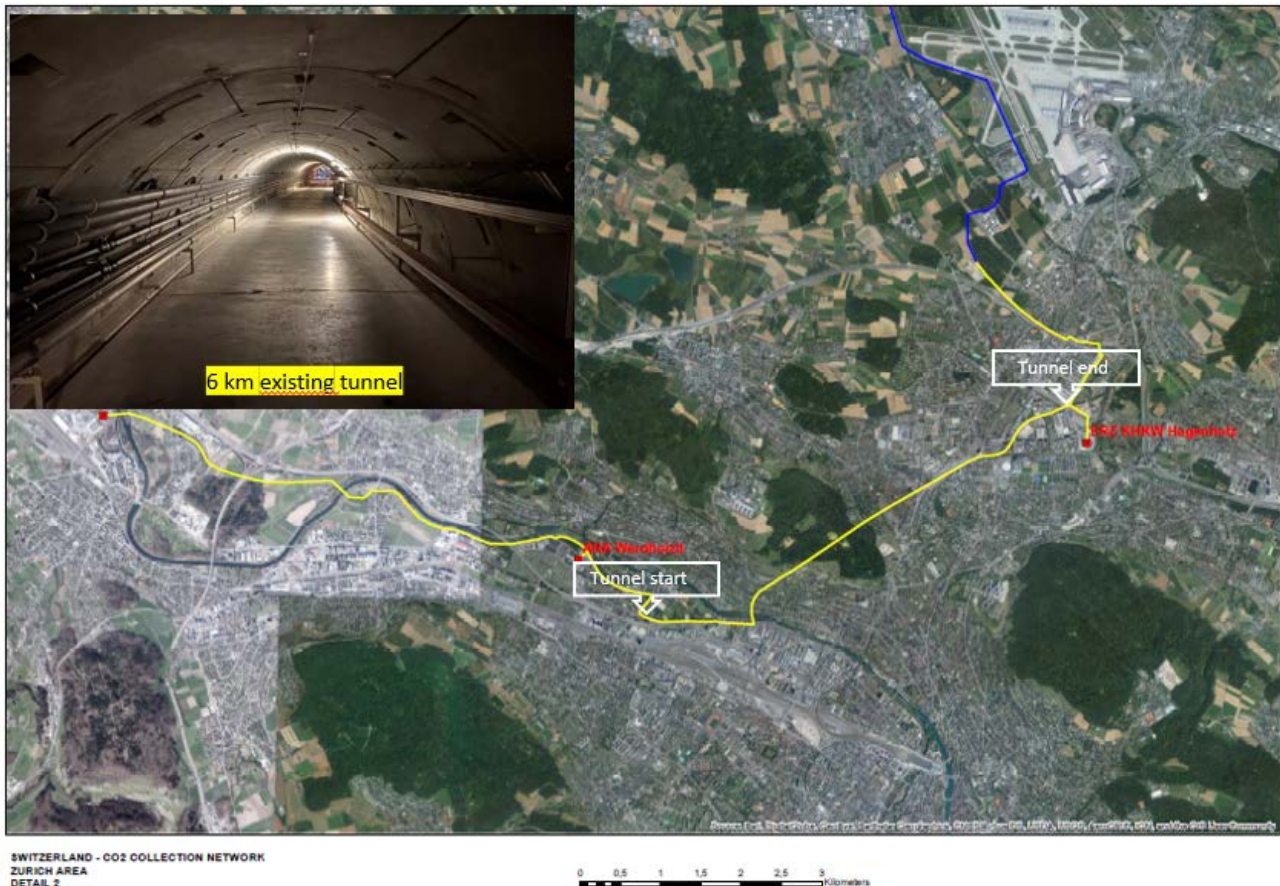
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6.4.4 Pipeline network in Zurich area

The routing study performed for the Kanton Zurich, foreseen the connection of 3 emitters (KVA Limmattal, ARA Wedholzli and KVA Hagenholz), by mean of low pressure flowlines.



In Zurich area, company advised about the opportunity to use the 6 km existing tunnel crossing the city center, that is considered available for CO2 transportation purposes (refer to Figure 6.4.9). The CO2 coming from the 3 Zurich emitters is collected in a flowline that will be routed inside the tunnel. The flowline size within the tunnel is 10" with a MOP = 10 barg, for the gaseous base case option.

Figure 6.4.9: Flowlines developed in the Zurich Kanton including the section inside existing Tunnel.



The NPS 10" Connection flowline to be installed inside the existing tunnel require a to prepare a design based on proper installation method statement, to finally confirm the feasibility of the solution chosen, this method can only be defined after the following steps to be performed:

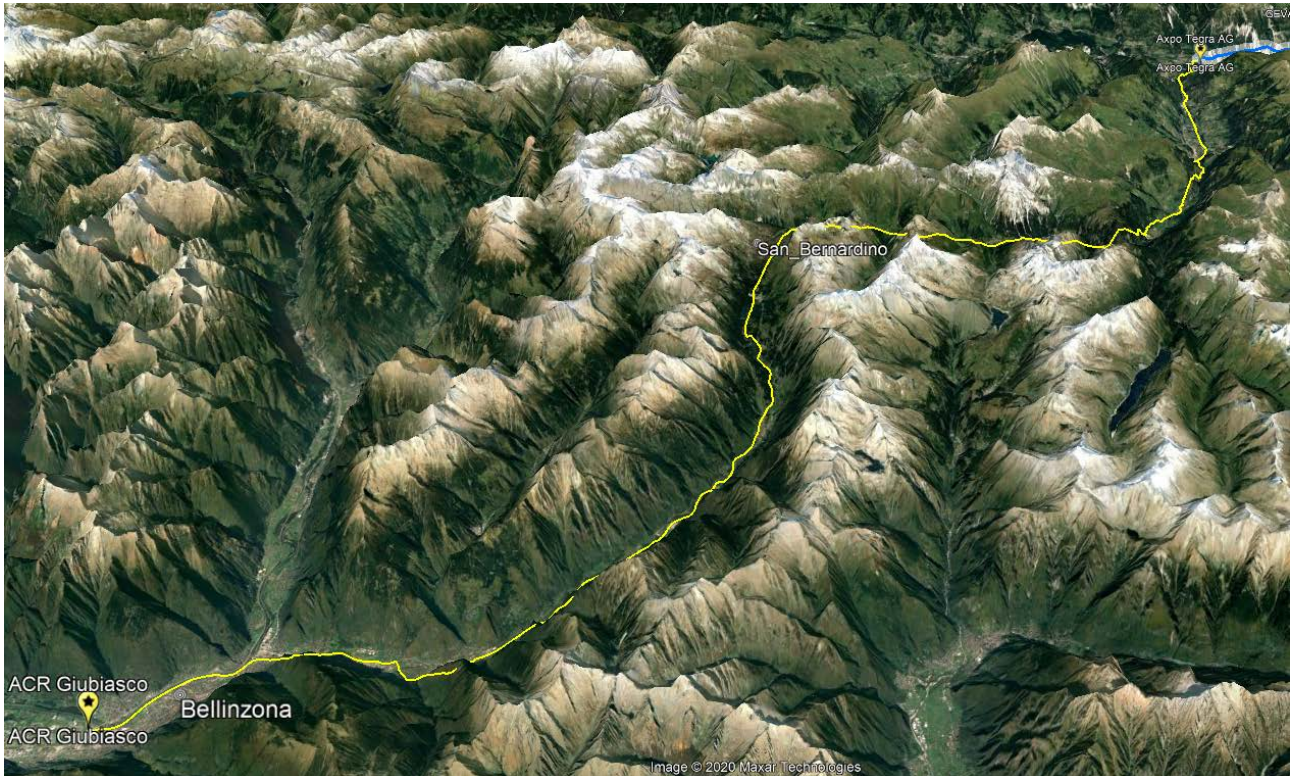
- Agreement with owners and definition of requirement to be complied for the permanent installation inside their asset (clearances, protection measures in operating phase),
- Hazard identification study for installation and operation phase and agreement for mitigation measures required.
- Achievement of "As built" detailed design of existing asset, including the layout and the data of the existing facilities.
- Definition of design at entry and exit point and highlight of possible conflict with other external structure present in the area.

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6.4.5 Giubiasco flowline exclusion

The emitter of Giubiasco is isolated and located far from the nearest emitter (Axpo Tegra). The routing development for this flowline is extremely challenging, crossing both mountain regions and a narrow densely populated valley. See Figure 6.4.10 Figure 6.4.11.

Figure 6.4.10: Giubiasco Flowline routing.



The length estimated is 105 km and the complications peculiar to this flowline, its cost has an impact on the East trunkline.

The estimated length is 105 km developed along the narrow valleys of the north side of the Alps, the flowline has to cross the San Bernardino Pass which exceeds an elevation of 2000 m, moreover in many places the morphology of the upper Rhine valley would require new tunnels to be drilled to run the route, finally many of the section have obstructions to the passage of the flowline due to the dense presence of settlements.

Due to the above it is recommended to exclude Giubiasco from the emitters to be connected to the CO2 collection network.



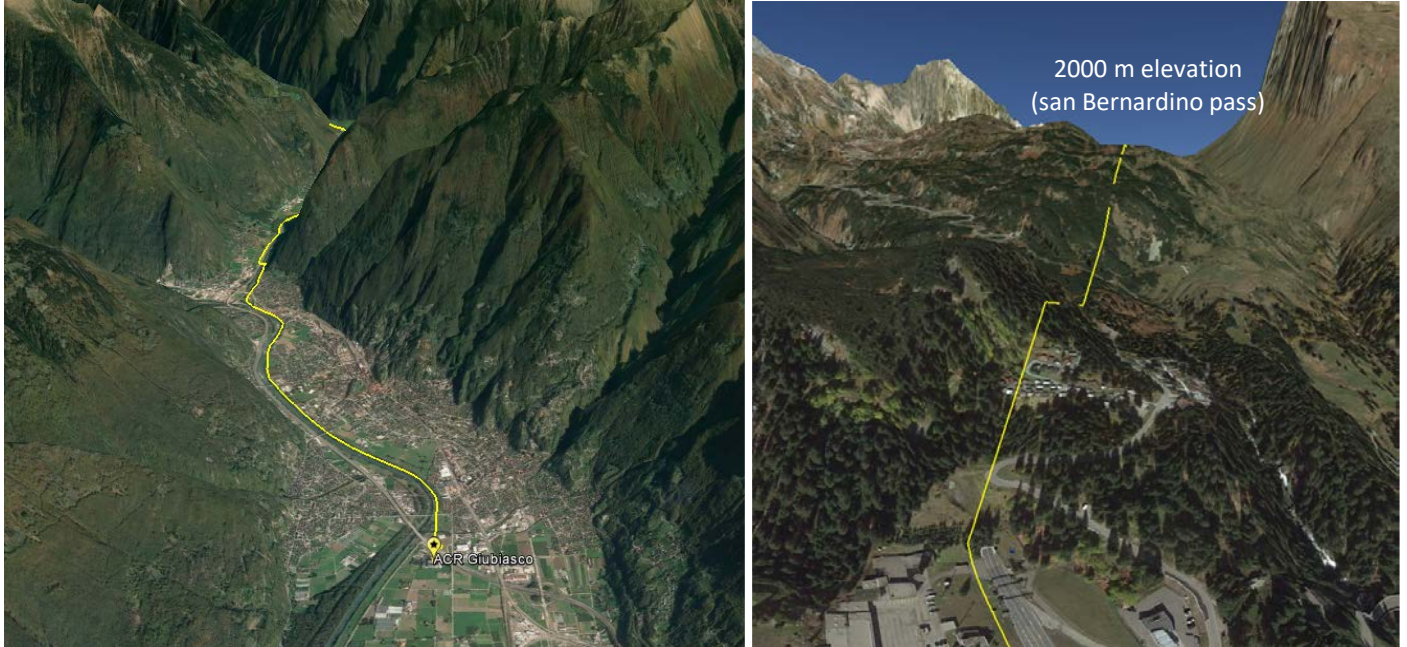


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Figure 6.4.11: Giubiasco Flowline route details.

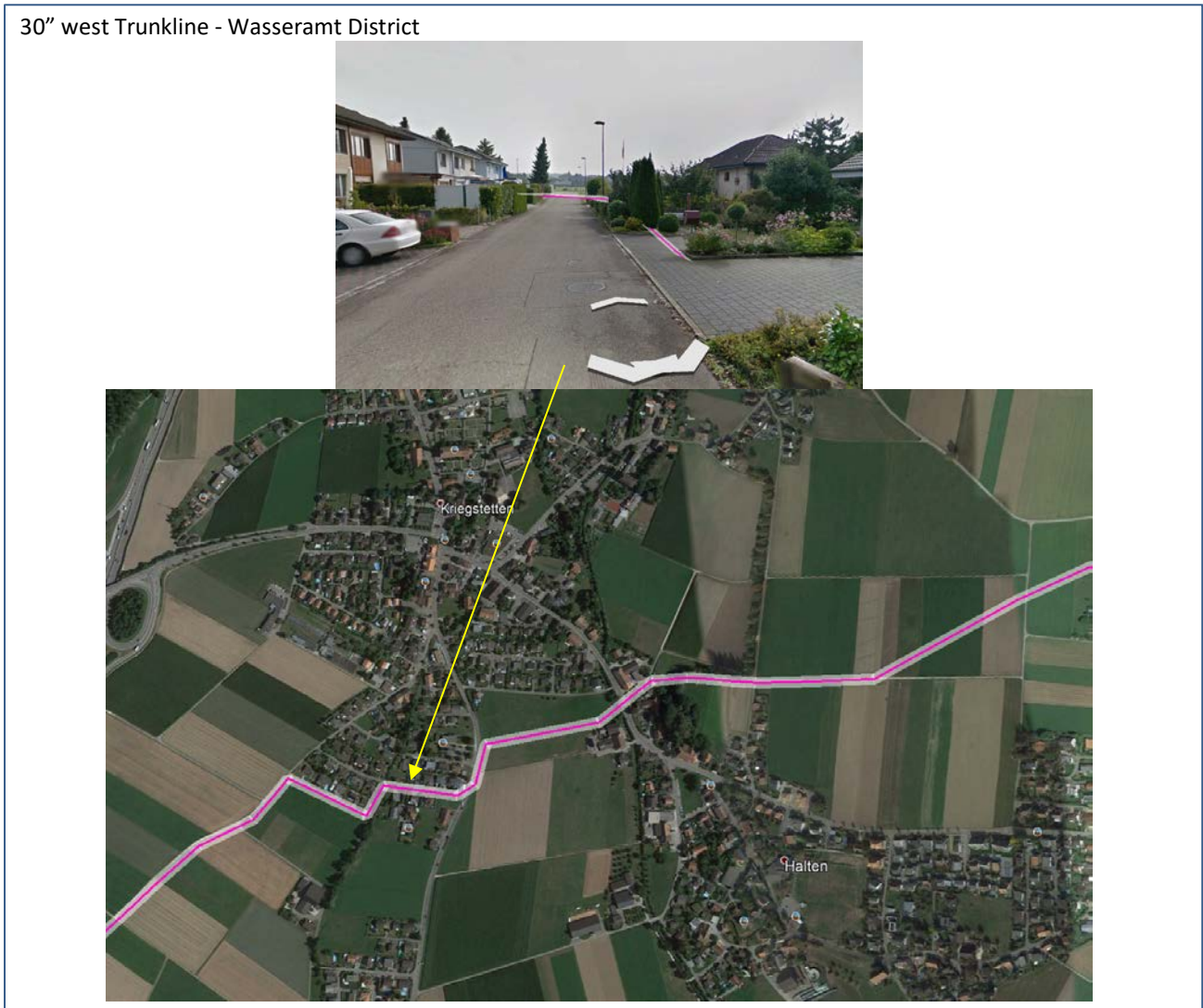


It is also considered that Giubiasco emitter contributes for only 2% of the total emissions (4% of the East Trunkline flowrate), hence for this reason in all the system configurations analysed in this routing study flowline have been disregarded.

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APPENDIX 1 – POPULATED AREA

In this appendix of the study report, some of the most critical route conflicts with populated area, are shown as sample.





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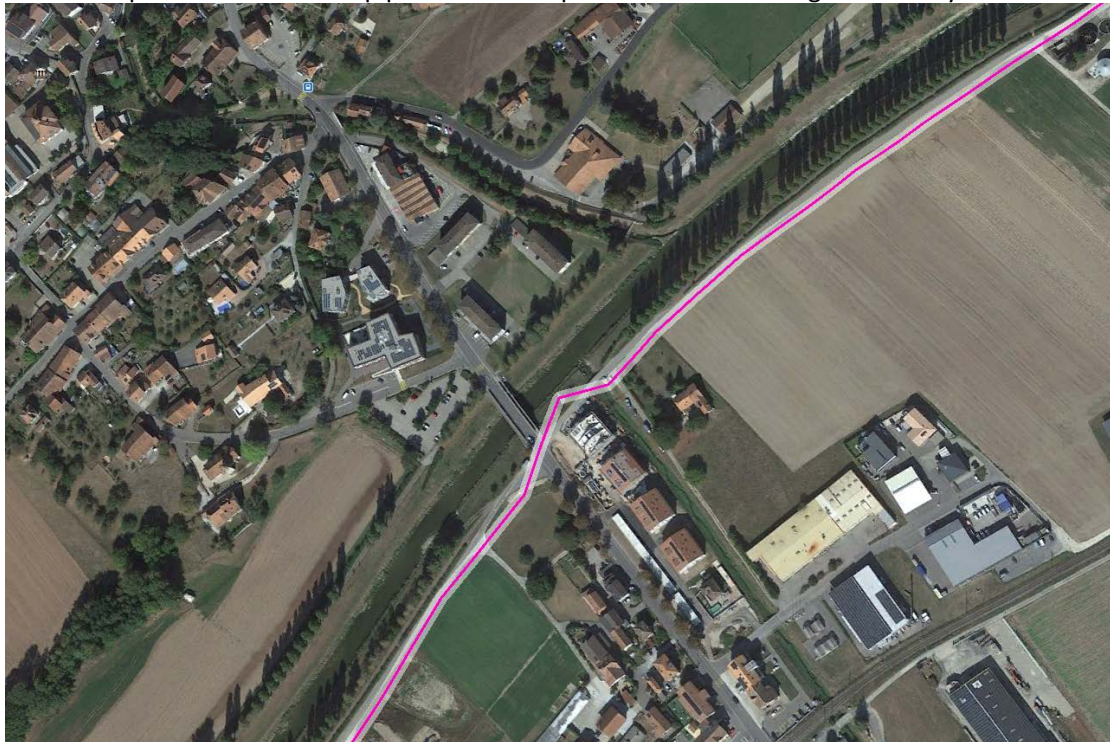
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Flowline from Les Cheneviers – yellow line is basis of study and Blu line is alternative with parallelism.



Trunkline NPS 30" parallelism with Gas pipeline in correspondence of the vottage of Valbroye. New building.





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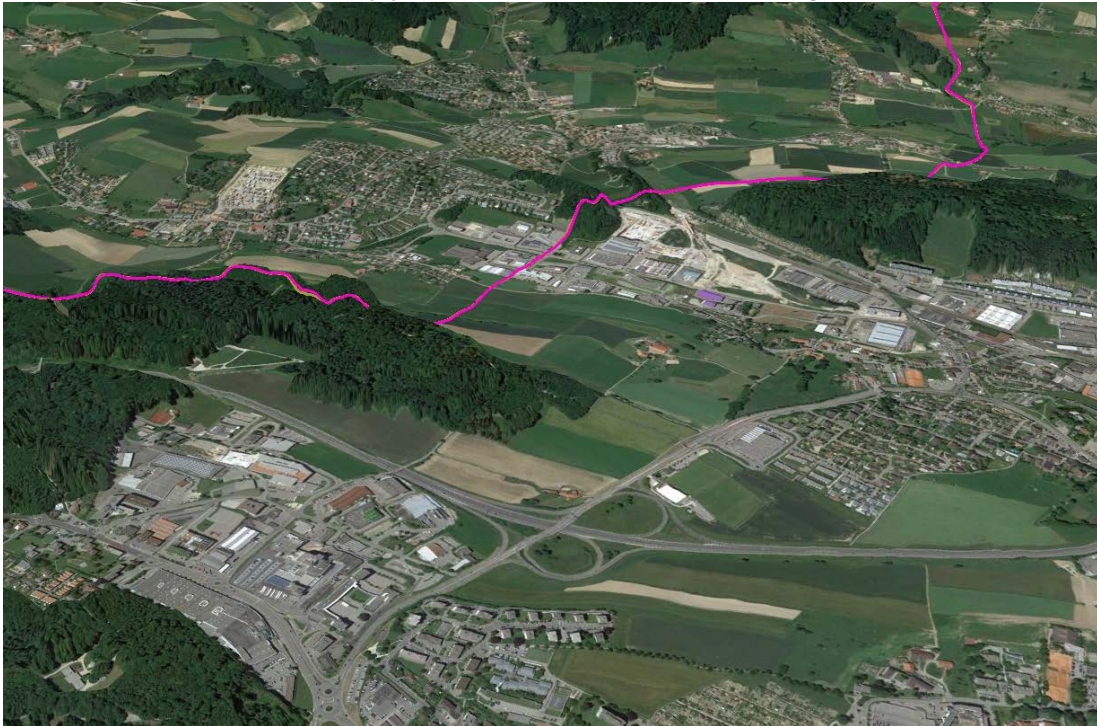
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Flowline Vigier Cement AG - - low pressure flow has been selected



Trunkline NPS 30" parallelism with Gas pipeline in the industrial area of Friburg.





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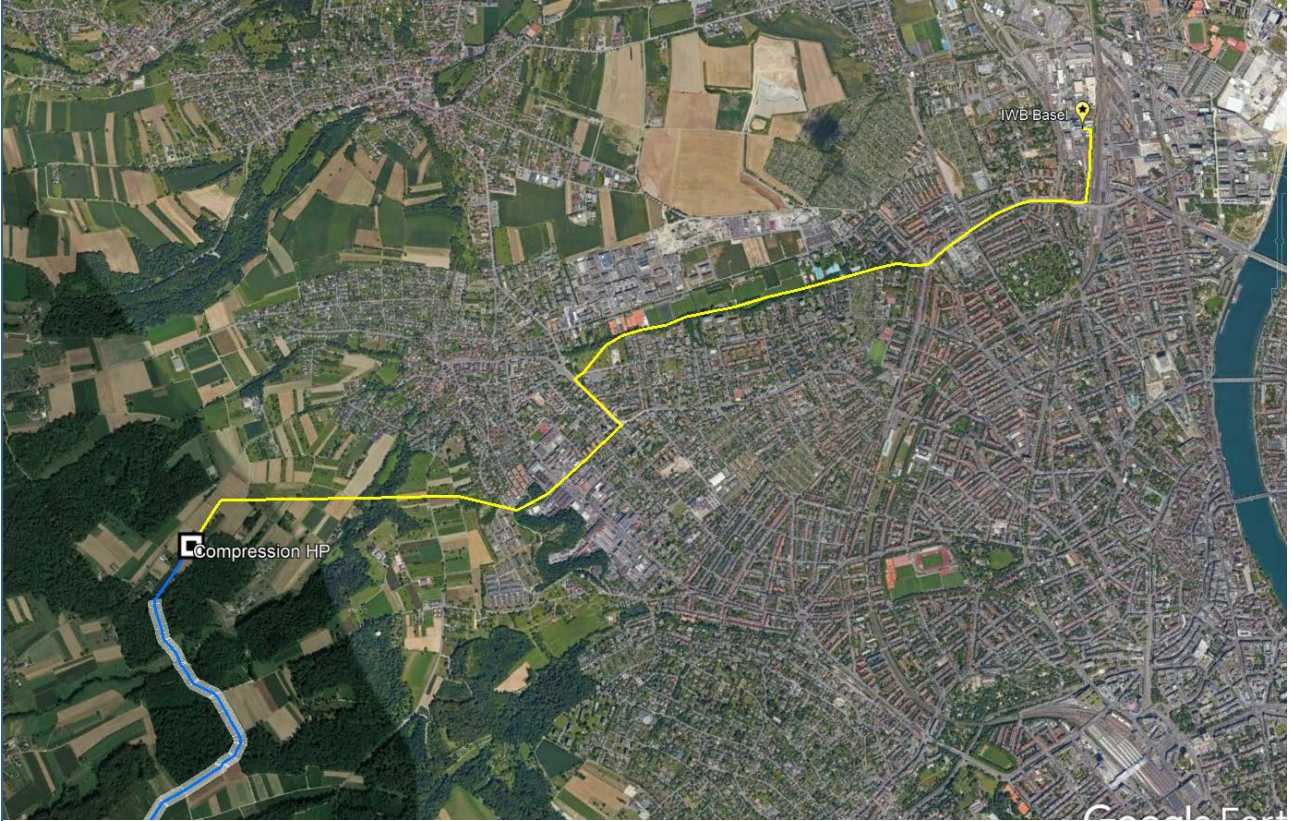
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IWB Basel Emitters and relevant LP Flowline crossing urban area

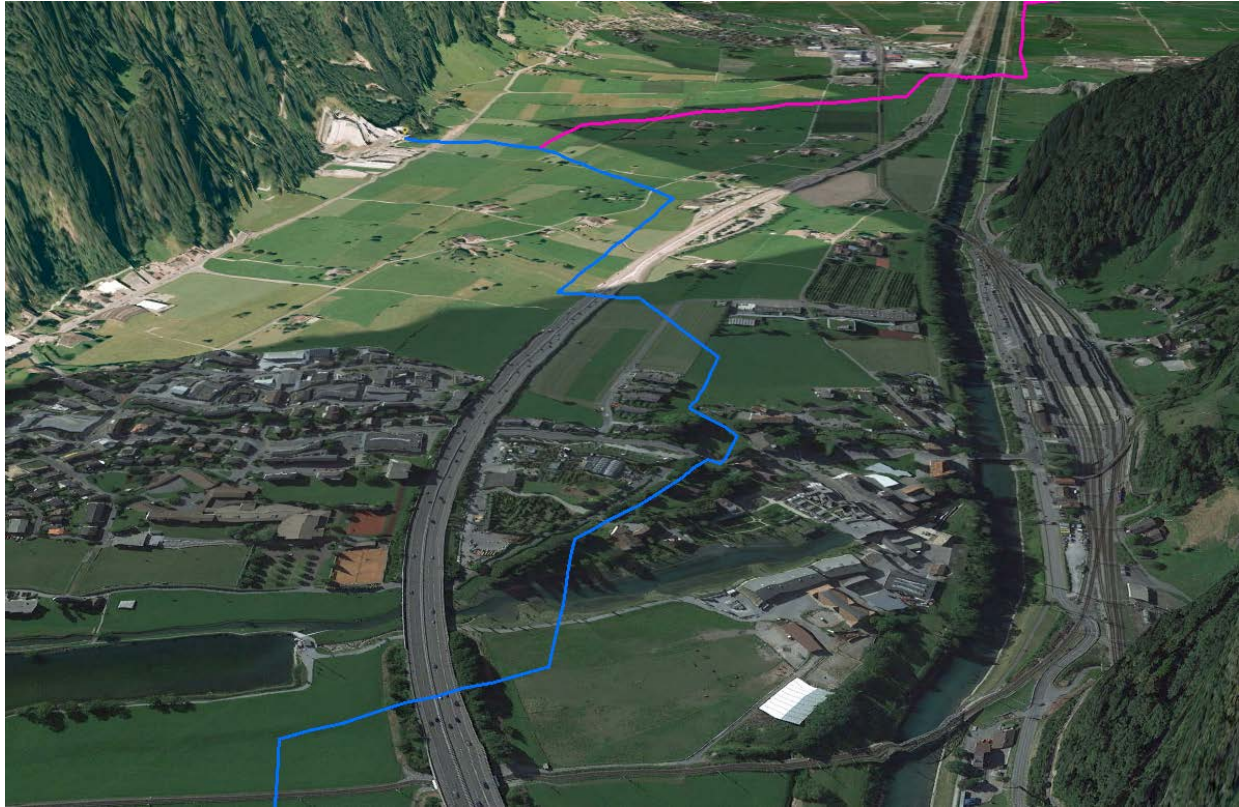


Combined flowline (E6) in Winthertur area with parallelism with Gas pipeline

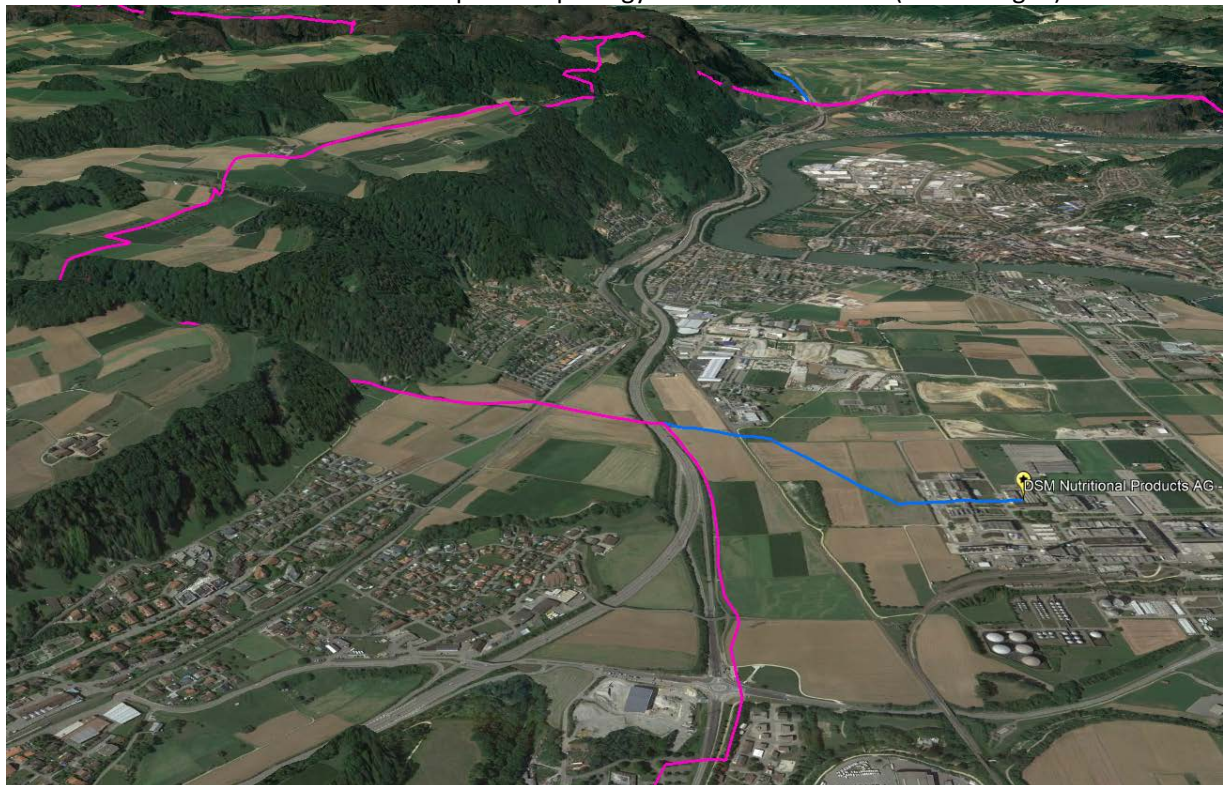




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South Eastern Trunkline NPS 20" crosses congested urban area just west of Walensee lake, in the narrow valley.



Eastern Trunkline NPS 30" routed in a complex morphology to avoid urban areas (Bad Sackingen)



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APPENDIX 2 – PARALLELISM WITH GAS PIPELINE IN POPULATED AREA

At the desktop study level, the areas with the presence of the following were assessed and categorized cartographically, along all the pipelines:

- residential areas
- commercial areas
- urban parks



and this category has been given primary importance as an area of attention.

All these cartographic assessments were cross checked with the presence also of the parallelism with the existing gas pipelines.

Moreover, were also identified the areas with proximity to



- industrial areas,
- quarry areas
- important road congestion infrastructures

The result is shown in the following tables.



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Parallelism with Gas Pipeline combined with proximity with populated area

| Name | From Kp | To Kp | Length (m) | Parallelism | Type |
|----------------|---------|-------|------------|-------------|-------------|
| Les Cheneviers | 28,3 | 28,45 | 150 | Y | residential |
| Les Cheneviers | 63,55 | 63,75 | 200 | Y | residential |
| Les Cheneviers | 76,45 | 76,72 | 270 | Y | residential |
| Les Cheneviers | 77 | 77,35 | 350 | Y | residential |
| LONZA AG | 7 | 8,5 | 1500 | Y | residential |
| LONZA AG | 15,8 | 16 | 200 | Y | residential |
| LONZA AG | 19,3 | 19,6 | 300 | Y | residential |
| LONZA AG | 21,35 | 21,55 | 200 | Y | residential |
| LONZA AG | 30,15 | 30,67 | 520 | Y | residential |
| LONZA AG | 36,9 | 37,35 | 450 | Y | residential |
| LONZA AG | 37,45 | 38,9 | 1450 | Y | residential |
| LONZA AG | 44,6 | 44,9 | 300 | Y | residential |
| LONZA AG | 45,2 | 46,35 | 1150 | Y | residential |
| LONZA AG | 51,2 | 51,85 | 650 | Y | residential |
| LONZA AG | 69,3 | 70 | 700 | Y | residential |
| LONZA AG | 82,3 | 82,6 | 300 | Y | residential |
| LONZA AG | 84,25 | 84,45 | 200 | Y | residential |
| LONZA AG | 86,24 | 87,14 | 900 | Y | residential |
| LONZA AG | 87,5 | 87,8 | 300 | Y | residential |
| LONZA AG | 90 | 91,1 | 1100 | Y | residential |
| W32 | 14,9 | 15,23 | 330 | Y | residential |
| W32 | 22,72 | 22,84 | 120 | Y | residential |
| W32 | 24,93 | 25,05 | 120 | Y | residential |
| AVAG KVA AG | 7,62 | 7,92 | 300 | Y | residential |
| AVAG KVA AG | 8,22 | 8,32 | 100 | Y | residential |
| AVAG KVA AG | 8,8 | 9 | 200 | Y | residential |
| AVAG KVA AG | 9,9 | 10,18 | 280 | Y | residential |
| AVAG KVA AG | 11,9 | 12 | 100 | Y | residential |
| AVAG KVA AG | 16,38 | 16,48 | 100 | Y | residential |
| AVAG KVA AG | 23,57 | 24,1 | 530 | Y | residential |
| AVAG KVA AG | 24,65 | 24,75 | 100 | Y | residential |
| AVAG KVA AG | 29,9 | 30,02 | 120 | Y | residential |
| AVAG KVA AG | 42 | 42,13 | 130 | Y | residential |
| AVAG KVA AG | 46,3 | 46,4 | 100 | Y | residential |
| KEBAG AG | 4,99 | 5,34 | 350 | Y | residential |
| W6 | 1,3 | 1,5 | 200 | Y | residential |
| W6 | 11,05 | 11,37 | 320 | Y | residential |

| | | | | |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|--|---------------------------------------|---------------|
|   | CUSTOMER: VB SA | | W.O. VB SA to Saipem Sept 2020 | |
| | LOCATION: SWITZERLAND | | JOB: 023115 | |
| | PROJECT: CO2 COLLECTION NETWORK CONCEPTUAL STUDY | | Doc. no. 000-LA-E-80001 | Rev. 0 |

| Name | From Kp | To Kp | Length (m) | Parallelism | Type |
|--------------------------|---------|--------|------------|-------------|-------------|
| Renergia Zentralschweitz | 41,8 | 41,87 | 70 | Y | residential |
| Renergia Zentralschweitz | 42 | 42,25 | 250 | Y | residential |
| E13 | 1 | 1,3 | 300 | Y | residential |
| KVA Thurgau | 1,98 | 2,18 | 200 | Y | residential |
| KVA Thurgau | 6,43 | 6,53 | 100 | Y | residential |
| E7_HP | 10,2 | 10,5 | 300 | Y | residential |
| E7_HP | 12,82 | 13 | 180 | Y | residential |
| E6 | 4 | 4,2 | 200 | Y | residential |
| E6 | 4,38 | 4,64 | 260 | Y | residential |
| E6 | 9,25 | 9,55 | 300 | Y | residential |
| IWB Basel_HP | 4,36 | 4,76 | 400 | Y | residential |
| IWB Basel_HP | 8,56 | 8,94 | 380 | Y | residential |
| IWB Basel_HP | 12,05 | 12,39 | 340 | Y | residential |
| IWB Basel_HP | 13,17 | 13,47 | 300 | Y | residential |
| IWB Basel_HP | 25,88 | 26,73 | 850 | Y | commercial |
| IWB Basel_HP | 26,73 | 27,27 | 540 | Y | residential |
| IWB Basel_HP | 27,95 | 28,21 | 260 | Y | commercial |
| IWB Basel_HP | 40,64 | 40,88 | 240 | Y | residential |
| IWB Basel_HP | 41 | 41,62 | 620 | Y | residential |
| TRUNKLINE EAST 30inch | 37,78 | 38,43 | 650 | Y | residential |
| TRUNKLINE EAST 30inch | 38,58 | 38,76 | 180 | Y | residential |
| TRUNKLINE EAST 30inch | 40,68 | 40,82 | 140 | Y | residential |
| TRUNKLINE EAST 30inch | 43,36 | 43,48 | 120 | Y | commercial |
| TRUNKLINE WEST 30inch | 2,88 | 3,16 | 280 | Y | commercial |
| TRUNKLINE WEST 30inch | 64,64 | 64,84 | 200 | Y | residential |
| TRUNKLINE WEST 30inch | 70,78 | 70,92 | 140 | Y | residential |
| TRUNKLINE WEST 30inch | 73,86 | 74 | 140 | Y | residential |
| TRUNKLINE WEST 30inch | 80,45 | 80,7 | 250 | Y | residential |
| TRUNKLINE WEST 30inch | 93,18 | 93,34 | 160 | Y | residential |
| TRUNKLINE WEST 30inch | 101,43 | 101,77 | 340 | Y | residential |
| TRUNKLINE WEST 30inch | 110,75 | 110,85 | 100 | Y | residential |
| TRUNKLINE WEST 30inch | 122,65 | 122,77 | 120 | Y | residential |
| TRUNKLINE WEST 30inch | 125,35 | 125,55 | 200 | Y | residential |
| TRUNKLINE WEST 30inch | 137,9 | 138,1 | 200 | Y | residential |
| TRUNKLINE WEST 30inch | 147,35 | 147,48 | 130 | Y | residential |
| TRUNKLINE WEST 30inch | 148,66 | 148,88 | 220 | Y | residential |
| TRUNKLINE WEST 30inch | 152,84 | 153,09 | 250 | Y | residential |
| TRUNKLINE WEST 30inch | 155,1 | 155,54 | 440 | Y | residential |
| TRUNKLINE WEST 30inch | 155,7 | 155,86 | 160 | Y | residential |
| TRUNKLINE WEST 30inch | 163,9 | 164 | 100 | Y | residential |

| | | | | |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|--------|--------------------------------------|--|
|   | CUSTOMER: VBSA | | W.O. VBSA to Saipem Sept 2020 | |
| | | | JOB: 023115 | |
| | LOCATION: SWITZERLAND | | Doc. no. 000-LA-E-80001 | |
| PROJECT: CO2 COLLECTION NETWORK CONCEPTUAL STUDY | | Rev. 0 | Page 78 of 78 | |

| Name | From Kp | To Kp | Length (m) | Parallelism | Type |
|-----------------------|---------|--------|------------|-------------|-------------|
| TRUNKLINE WEST 30inch | 168,82 | 168,97 | 150 | Y | residential |
| TRUNKLINE WEST 30inch | 180,03 | 180,2 | 170 | Y | residential |
| TRUNKLINE WEST 30inch | 180,85 | 181,05 | 200 | Y | urban park |
| TRUNKLINE WEST 30inch | 185 | 185,44 | 440 | Y | residential |
| TRUNKLINE WEST 30inch | 186,73 | 187,1 | 370 | Y | residential |
| TRUNKLINE WEST 30inch | 187,5 | 187,85 | 350 | Y | residential |
| TRUNKLINE WEST 30inch | 191,26 | 191,76 | 500 | Y | residential |
| TRUNKLINE WEST 30inch | 192,05 | 192,25 | 200 | Y | residential |
| TRUNKLINE WEST 30inch | 205,4 | 205,5 | 100 | Y | residential |

The evaluation is that there are 85 location with a total of 26 km.