

# THE SWISS HIGH-LEVEL WASTE PROGRAMME: STATUS AND FUTURE CHALLENGES

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## ABSTRACT

After about 25 years of studies and investigations covering both the crystalline basement as well as the overlying sediments in northern Switzerland, Nagra submitted at the end of 2002 comprehensive project documentation on the feasibility of safe disposal of SF / HLW and long-lived ILW in Opalinus Clay (Project *Entsorgungsnachweis*, or “demonstration of disposal feasibility” in English). The recently published reviews by the Swiss safety authorities all came to a positive conclusion about the project. The review phase was followed by a broad public consultation phase in 2005. Based on the results of the review and the public consultation phase, the Swiss Government (the Federal Council), in its meeting on 28 June 2006, decided to accept the demonstration of disposal feasibility. Furthermore, Nagra recently published a report on the siting possibilities for a SF / HLW / ILW repository from the geological point of view. All these documents show that a level of maturity has been reached that allows moving towards siting of such a repository. As a first step in the siting process the Swiss Government is currently preparing a site selection procedure that also defines the corresponding criteria; a first draft has been published in June 2006. Thus, the Swiss HLW programme is currently moving towards the important and challenging phase of deciding on the site for repository implementation, involving all relevant stakeholders.

## 1. Introduction

In Switzerland, nuclear power production by the current five plants contributes approximately 40% of the electricity consumed; the other 60% come from hydro power. The first commercial nuclear power plant went into operation in 1969, and since the late 70's investigations have been underway with respect to the safe disposal of high-level radioactive wastes in Switzerland (see the broad review of options reported in 1978 [1]). A first milestone was reached with submission of Project Gewähr in 1985, which looked at the feasibility of safe disposal of high-level waste in the crystalline basement of northern Switzerland ([2]). This study was based on a regional field programme (deep boreholes, 2D reflection seismics, investigation of regional geology, etc.), lab work and studies. In their review the Swiss authorities came to the conclusion that long-term safety and engineering feasibility were adequately demonstrated but that siting feasibility – the likelihood that a sufficiently large block of crystalline rock with the properties assumed in the study could be found and characterised with sufficient reliability – was not yet fully convincing due to the complex tectonic situation in northern Switzerland. The authorities also required that the investigations should be extended to sedimentary formations. Already in the field programme for the crystalline basement, Nagra had characterised the most promising sedimentary layers overlying the crystalline basement. From this data, together with data from other sources and taking into account the good general understanding of the geology of Switzerland, Nagra published a first interim report on the broad geological possibilities in sedimentary rocks in 1988 [3]. Based on this interim report and two other interim reports ([4], [5]), in 1994 an agreement with the relevant Swiss authorities was reached that field investigations for the HLW programme should focus on the Opalinus Clay (a Jurassic claystone formation) as a host rock and the Zürcher Weinland as a potential siting region for a comprehensive demonstration of disposal feasibility. After extensive investigations (including regional geological studies,

experiments at the Mont Terri rock laboratory, and using information from other sources), Nagra submitted at the end of 2002 comprehensive project documentation on the feasibility of safe disposal of SF / HLW and long-lived ILW in Opalinus Clay in the potential siting region of the Zürcher Weinland (Project *Entsorgungsnachweis*), see [6], [7], [8]. The recently published reviews of the Swiss safety authorities and their experts, as well as the review by an international review team under the auspices of the OECD / NEA, which was published in April 2004, all came to a positive conclusion about the project ([9], [10], [11], [12]). The review phase was followed by a broad, three-month public consultation phase in the fourth quarter of 2005. Based on the results of the review and the public consultation phase [13], the Swiss Government (the Federal Council) concluded on 28 June 2006 that disposal feasibility of SF / HLW / ILW in Switzerland had been successfully demonstrated [14].

However, besides the Opalinus Clay and the potential siting region of the Zürcher Weinland, other potential host rocks and siting alternatives also exist. Because of the public interest in the focussing on the Opalinus Clay and the Zürcher Weinland in 1994 ([5]), in 2002 a German – Swiss commission asked the AkEnd (a German working group that had the responsibility to develop a site selection process for Germany) for a review of the process that led to focussing the work on Opalinus Clay and the Zürcher Weinland. In their review the group came to the conclusion that the selection process had been conducted, by international standards, in a state-of-the-art manner. Furthermore, the group considered that the selection – based on safety criteria – of the Zürcher Weinland as the preferred option for the siting of a HLW repository was justified ([15]). Due to the continuing interest in alternatives, and in response to a request by the responsible Federal Minister, Nagra published in 2005 a report on the siting options for a HLW repository from the geological point of view ([16]), the results of which are summarized below in Section 2.

The information available and the documents produced show that a level of maturity has been reached that allows moving towards siting of a HLW repository. As a first step in the siting process the Federal Office of Energy is currently preparing a document defining a site selection procedure along with the corresponding criteria ([17]). It is expected that this site selection procedure will be approved by the Swiss Government in 2007 after a period of broad consultation with the cantons, the neighbouring countries and different interest groups. The siting process will allow extensive public participation.

## **2. Evaluation of siting options for a repository for HLW**

There is broad agreement that in the evaluation of siting options, safety has highest priority. Thus, in the first phase in the evaluation of siting, the main emphasis is placed upon those geological properties that are essential for safety and that ensure engineering feasibility; in the next phase, other issues like land use planning, environmental impact issues and socio-economic aspects also need to be considered.

In the recently published report on the siting possibilities for a HLW repository [16], Nagra applied a step-wise narrowing-down procedure to systematically evaluate the different geological options that Switzerland offers:

- In a first step, those parts of Switzerland that are less suitable with respect to long-term stability and / or are tectonically very complex were identified and were excluded from further considerations.
- In a second step, all the different rock types in the area not excluded in step one were assessed with respect to their potential for being a suitable host rock.
- In a third step, the spatial distribution of the potential host rocks in the geologically stable parts of Switzerland was derived (resulting in distribution maps). Taking into account larger scale (regional) geological features / elements, potential siting regions were identified.
- Finally, in a fourth step, the different resulting regions were assessed on a case-by-case basis.

The resulting siting options for HLW from the geological point of view are depicted in Figure 1 (from [16]) and can be summarised as follows: From the geologic stability point of view the Alps, the region south of the Rhinegraben as well as the Folded Jura are excluded from further considerations, the latter mainly due to its tectonic complexity. Within the remaining parts of Switzerland – the (eastern) Tabular Jura and the Plateau-Molasse – the analysis of stratigraphic profiles led to the conclusion that (from bottom to top) the crystalline basement, the Opalinus Clay (in some parts combined with other low

permeability strata below and above the Opalinus Clay) and the Lower Freshwater Molasse are potentially suitable host rocks. However, they differ markedly in their safety-relevant characteristics: The Opalinus Clay - a sedimentary rock deposited in a shallow marine environment - offers excellent radionuclide retention properties (very low permeability, good sorption properties, self-sealing of repository-induced fractures (e.g. EDZ)), due to its significant clay content and compaction, fine pore structure and homogeneity. The Lower Freshwater Molasse – a rather heterogeneous fluvio-terrestrial formation consisting of fine grained sediment layers (marly mudstones, etc.), which are intersected by more permeable sandstone channels – has less favourable transport properties. Also, the crystalline basement in northern Switzerland is intensely fractured due to its tectonic history and therefore also has less favourable transport properties than the Opalinus Clay. Due to their heterogeneity, both the Lower Freshwater Molasse and the crystalline basement are difficult to characterise and even after extensive characterisation, significant residual uncertainties with respect to transport properties are expected (the so-called undetected fast channels). This implies that for these two host rocks, it may be necessary to adopt a different safety concept: In contrast to the Opalinus Clay – where the host rock is the key barrier providing safety – in these rocks there may be the need to use very long-lived canisters (e.g. canisters with a copper shell as in Finland / Sweden) to achieve a convincing safety case.

In the Opalinus Clay of northern Switzerland several potential siting regions have been identified, including (from east to west): Zürcher Weinland, Nördlich Lägeren, Bözberg and Jurasüdfuss. There are again distinct differences between these potential siting regions, the differences being the properties of the under- and overlying rocks (in some regions these provide an additional strong transport barrier), the tectonic regime (the influence from Alpine orogeny ranges from being negligible to being clearly established), the lateral extent of non-disturbed rock, the depth of the repository horizon in the host rock, the boundary conditions for surface exploration (Quaternary cover, topography, housing density, etc.) with clear advantages for the Zürcher Weinland from the point of view of geology and safety.

However, this evaluation purely from the safety / geology point of view is considered not to be sufficient for final site selection; other factors need also to be taken into account. The site selection procedure currently under preparation by the Federal Office of Energy (already mentioned above) will also address land use planning, environmental issues and socio-economic aspects. This procedure will be based on the existing Land Use Planning Legislation (Sectoral plan or, in German, *Sachplan*, [17]). Interested parties (cantons, neighbouring countries, etc.) and the public will be involved in defining the site selection process.

### 3. Developing the future RD+D programme

After the positive review of project *Entsorgungsnachweis* by the Swiss authorities, the RD+D programme is currently being revised by Nagra. Already in the documentation of Project *Entsorgungsnachweis* key elements of the future RD+D programme were included. Currently, the reviews by the authorities are being analysed for further input and also experience abroad is being taken into account in defining the RD+D goals for next few years. The key elements of the RD+D programme will be included in the “Waste Management Programme” (in German: *Entsorgungsprogramm*) that is required by law. Nagra is currently developing this programme on behalf of the Swiss waste producers. Issues to be addressed in the RD+D programme include:

- the engineered barrier system (waste matrix stability, canister materials and design, properties of bentonite pellets used as buffer, etc.),
- the host rock (transport properties (including sorption), gas migration, geomechanics, etc.),
- repository design (encapsulation facility, different repository components, etc.),
- process models, systems analysis and safety analysis.

The RD+D programme will continue to rely on the underground rock laboratory at Mont Terri and also on the results from other URLs (e.g. Bure, Äspö, Grimsel). In addition, the Waste Management Laboratory at the Paul Scherrer Institute with its extensive infrastructure (hot laboratory, synchrotron light source, etc.)

and other competence centres (e.g. at the University of Berne) will continue to play an important role. Furthermore, international co-operation will continue to be a key element in the future RD+D programme. The results from RD+D together with site-specific information and the results from other projects will be used as technical input for the site selection process which eventually will lead to a general licence application for a HLW repository.

#### 4. Summary and conclusions

After about 25 years of studies and investigations (including regional and localised field investigations as well as extensive research, development and demonstration projects in the two underground rock laboratories at Grimsel and Mont Terri) covering both the crystalline basement and the overlying sediments, a significant level of maturity of the technical programme has been reached. Furthermore, the recently revised Nuclear Energy Law and the corresponding Ordinance provide a suitable basis for further developing the HLW programme. As a next step, a detailed site selection procedure is currently being developed by the Swiss authorities. Based on the good understanding of geology and the features that contribute to safety, it should be possible to move towards selecting a site for which a general licence will be submitted. This site selection process, however, will be very challenging and requires not only a high-level technical programme and the ability to plan and develop projects that consider the needs of the region (land use planning, environmental impact assessment, etc.), but also interaction skills for the dialogue with a broad spectrum of stakeholders involved in the process.

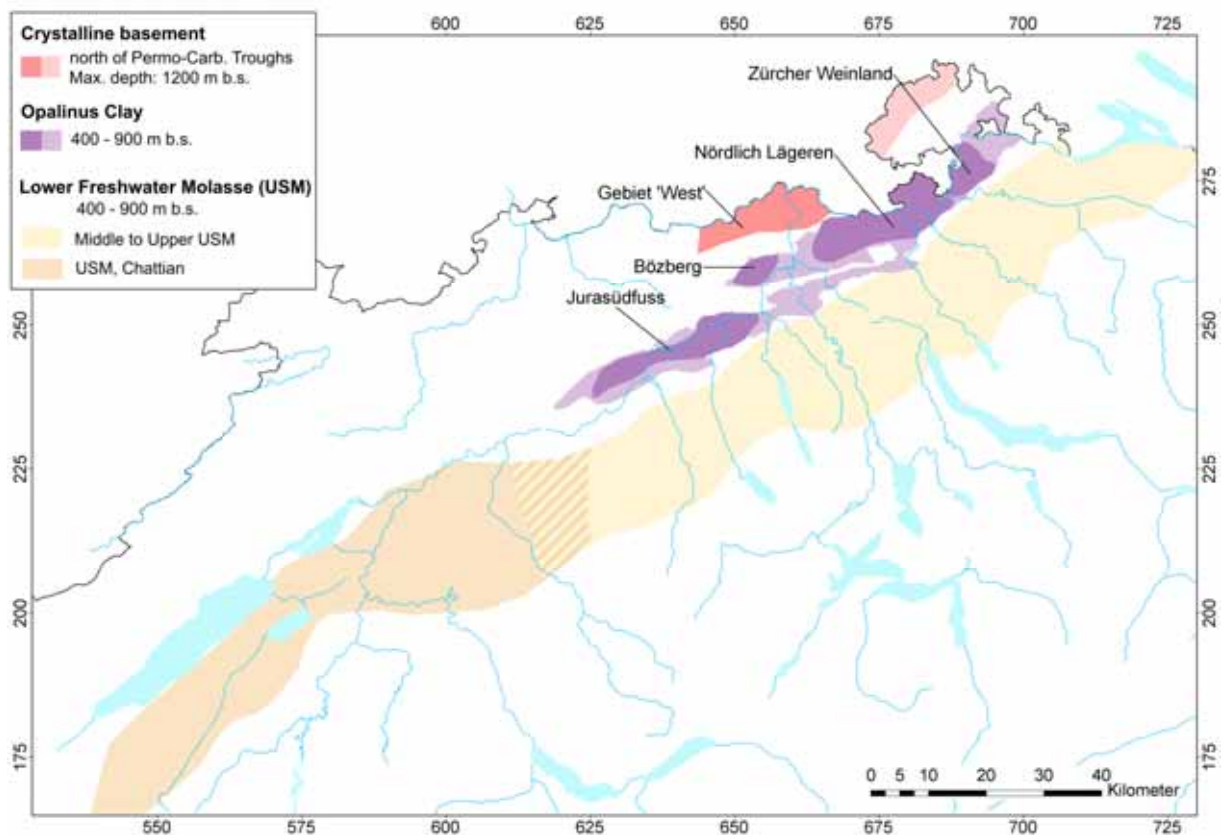


Fig. 1. Spatial distribution of potential host rocks at suitable depth and potential siting regions for a SF / HLW / ILW repository in Switzerland.

## 5. References

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