

DEVELOPMENTS IN THE SWISS RADIOACTIVE WASTE DISPOSAL PROGRAMME

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ABSTRACT

Nagra is pursuing two repository programmes, one for HLW and spent fuel and one for LLW and short-lived ILW at the Wellenberg site. After an extensive site evaluation, the Wellenberg site was selected for the L/ILW repository and a special company responsible for construction and operation (GNW) was founded. The suitability of the site was confirmed by the Swiss Nuclear Safety Inspectorate (HSK) in 1996. In addition to a federal licence, for a repository a mining concession for use of underground space has to be granted by the Canton in a public referendum. The decisive cantonal vote in June 1995 was negative (48% in favour) and created a politically difficult situation. Wellenberg is geologically suitable, but politically blocked. Efforts made to overcome this situation subsequent to the political referendum are described. A more stepwise implementation of the repository was requested, postponing until a future time the decision regarding closure of the repository. Nagra evaluated such a modified closure concept, which involves leaving the caverns without backfill until a final decision is taken, allowing a period of up to 100 years for deliberation.

In the HLW repository programme, Nagra is considering two host rock options: the crystalline basement and the Opalinus Clay in Northern Switzerland. A recent 2D seismic survey marked the end of the extensive field work in the crystalline programme for the time being. For the Opalinus Clay, a programme consisting of a 3D seismic survey and a deep borehole in the region of the Zürcher Weinland has been carried out with promising results. This programme is complemented by investigations in the international Mont Terri Rock Laboratory, an important source of data for clay formations. The next milestone will be the finalisation of a project demonstrating the feasibility and safety of a repository in the Opalinus Clay and/or the crystalline basement (Project "Entsorgungsnachweis"). Besides investigations for a repository in Switzerland, the general option of disposing of high-level waste within the framework of an multinational project is being kept open.

INTRODUCTION

Swiss law requires the permanent safe disposal of radioactive wastes in geological repositories. In order to meet this requirement, Nagra is pursuing two repository programmes, one for LLW and short-lived ILW at the Wellenberg site in the Swiss Alps and one for HLW and spent fuel in Northern Switzerland. For the limited quantities of HLW, the option of disposal within the framework of a multinational project is being kept open. This paper summarises the status of, and developments in, the Swiss radioactive waste disposal programme.

LOW- AND INTERMEDIATE-LEVEL WASTE (L/ILW) DISPOSAL PROGRAMME

Widely accepted site selection process

Nagra's site evaluation procedure for a LLW/ILW repository began as long ago as 1978. The initial 100 siting options were gradually narrowed down to a total of four potential sites in three different host rocks (anhydrite, marl and gneiss). These four sites were included in a final evaluation. Site investigation programmes were designed and carried out at all four sites to produce comparable databases, taking into account the different levels of pre-existing information. Based on the results of these investigations, the

Wellenberg site in the community of Wolfenschiessen (Canton Nidwalden) was selected in 1993 for the L/ILW repository ([1], [2]).

The transparency and objectivity of the evaluation procedure leading to the selection of Wellenberg was attested by a political commission specially set up with representatives of all four siting cantons. The site selection procedure and the scientific and technical results were reviewed and accepted by the Federal Safety Authorities and the Federal Government took positive note of the findings of its experts in 1994. On a cantonal level, an independent Expert Group, established by the Government of Canton Nidwalden in the run-up to the decision on a concession (see below) in 1995, regarded the site selection procedure as transparent and acceptable.

Time-consuming, multi-level licensing procedure

The selection of a site is only the first step in the lengthy and time-consuming licensing procedure for a repository. Three political levels are involved i.e. the Federal Government, the Canton of Nidwalden and the siting community Wolfenschiessen. At the federal level, the major requirements are a licence for preparatory measures (site investigation and characterisation with boreholes and an exploratory drift), a general licence and licences for construction, operation and closure.

The Federal Government decides on the application for the general licence after extensive, two-phase hearings involving the siting community and the Canton, and also various experts and institutions. In the Canton of Nidwalden, the response of the Cantonal Government to the "hearing questions" of the Federal Government must be voted upon by the cantonal electorate; however this vote is only consultative in nature. The final decision of the Federal Government must be ratified by the Federal Parliament. The general licensing procedure is expected to take several years. The subsequent licences for construction, operation and closure will be granted by the Government alone without further need for ratification.

In addition to the federal licence, a special mining concession application for use of underground space must be submitted to the Canton. The repository and exploratory drift are considered to be facilities which may interfere with hypothetical future mining projects and, in Switzerland, mining issues are covered by cantonal law. The concession must be granted by the Cantonal Government and, in order to be valid, the decision of the Cantonal Government must be ratified by the public in a cantonal referendum.

At the siting community level, the necessary prerequisites (e.g. adjustment of the local zone planning) to proceed with the project are already met. The siting community is a member of the construction and operation company GNW (see below).

First federal licensing step and first cantonal referendum

In June 1994, a special company responsible for repository construction and operation (Genossenschaft für nukleare Entsorgung Wellenberg - GNW) was founded and the application for the general licence was submitted to the Federal Government. The application consisted of a comprehensive technical report [3] presenting the necessary details on the geological situation of the site, outlining the construction of the facility, specifying the waste categories foreseen for emplacement in the repository and summarising the safety and environmental impact reports. Special reports were devoted to long-term safety and to ecological considerations, such as the Preliminary Safety Assessment Report [4] and the Report on the Environmental Impact Assessment [5].

Parallel to the general licence application to the Federal Government, an application for a mining concession for the construction of an exploratory drift and also for the repository was submitted to the Canton in June 1994. Although the siting community accepted the project in two separate votes by majorities of 63% and 70%, the corresponding decisive cantonal vote on June 25th 1995 was negative by a very small margin (48% in favour). This created a politically difficult situation: Wellenberg was selected in a comprehensive evaluation procedure as the most suitable site and its geological suitability was confirmed repeatedly by the relevant safety authorities. Should the site be abandoned for purely political reasons?

Subsequent to the popular referendum, technical work continued and a synthesis of all geological investigations was completed in 1997. Within the framework of the ongoing federal general licensing procedure, the suitability of the site for further work towards implementation was confirmed by the Swiss Nuclear Safety Inspectorate (HSK) in a comprehensive technical review report in 1996 [6].

After the referendum, the Federal Government suspended the general licence procedure on the request of the Government of Canton Nidwalden in June 1997. It will only continue after the political decision on how to proceed at Wellenberg has been made and first results from an exploratory drift are available.

Two main reasons for the negative outcome of the referendum

A key reason for the negative decision was revealed by an opinion poll carried out after the vote – the fact that the concession applied for would cover both an exploratory drift and construction of the repository. According to the poll, a stepwise procedure, with granting of a part-concession for the exploratory drift only, would result in agreement of 65.5 per cent of the voters.

In addition to the very emotional anti-nuclear campaign heavily influenced by organisations such as Greenpeace, another main aspect contributing to the negative vote was the proposed repository emplacement concept. It was planned to backfill the voids between the emplaced disposal containers in the caverns successively, layer by layer. Retrieval of the waste after backfilling is possible in principle but would involve rather high expenditure and effort. In the interest of long-term safety, no specific provisions were made to minimise retrieval costs. In the perception of the public, the mere fact that, during emplacement of the waste, empty space in the caverns would be backfilled immediately evoked a feeling of "loss of control". It was regarded as taking an irreversible decision at a much too early stage. In many discussions, a more stepwise implementation was advocated, postponing until a future time the decision regarding closure of the repository, thus giving future generations an opportunity to carefully consider the proposed solution. When asked in the opinion poll "In a second vote would you grant a concession if the repository project were optimised in order to make the waste retrievable?", 61 per cent said yes and only 25 per cent no.

The voters did not therefore reject the Wellenberg site as such: they voted mainly against a combined concession for an exploration drift and a repository and against the lack of explicit provision for retrievability of the waste. As a conclusion, a more stepwise approach with regard to the concession licensing (1) and to the full implementation and final closure of the facility (2) may lead to the necessary public acceptance of a Wellenberg repository.

How to proceed in the L/ILW programme?

As the decision of the people to reject the first proposal has to be respected, GNW is prepared to adapt the proposed concept in response to public feeling. In Switzerland, as a direct democracy, many proposals are adapted after a first negative vote to move to a second one. To meet the first requirement

mentioned above, GNW has indicated its willingness to restrict a new concession application to an exploratory drift alone.

To take account of the second requirement on retrievability, GNW has also decided to adapt the repository concept. A careful analysis has been performed by Nagra of fundamental ethical aspects, the possibilities available given the legal requirements and framework in Switzerland, possible technical solutions and implications for passive long-term safety. The results were published in late 1998 in Nagra's Technical Report series [7].

The general licence specifies the site location and the basic characteristics of the project. The application requires to give information on the construction and operation of the facility, describing the "approximate layout of the underground and surface structures". Correspondingly, questions relating to the possibility of repository inspection and waste retrieval were only briefly dealt with in the application documentation. Monitoring and inspection are nevertheless planned, just as retrieval of the waste remains a (theoretical) possibility even after the repository has been closed. However, the long-term safety may neither depend upon such provisions nor be compromised by them [8]. The point in time at which the repository should be closed was not specifically discussed - there was a tacit agreement that the repository caverns and access tunnels would be closed and sealed stepwise according to operational requirements.

As a result of discussions both in public and within the Wellenberg technical working group (see below), it was decided to specify the corresponding repository project stipulations more precisely and to adapt them to meet the results of the discussions. As prescribed by the ethical and legal requirements, long-term safety remains the first priority and will be assured by a passive barrier system independent of any uncertain human factors. The procedure for closing the repository was changed and the time of closure defined. Before closure, there will be a phase in which the waste can be retrieved easily, facilitated by dispensing with the continuous backfilling of the caverns during emplacement of the waste (Table 1). During this phase, which can last up to 100 years (a period selected arbitrarily on the basis of technical experience with tunnels through the Swiss Alps), the waste containers will be securely stacked in the caverns and easily accessible. Consequently, the decision on closure need not be made before future generations have convinced themselves of the safety and appropriateness of the solution offered. This planned procedure provides an ideal solution that fulfils legal requirements (passive long-term safety), ethical requirements (the benefiting generation handling the waste disposal problem themselves) and political requirements (providing as much leeway as possible for our descendants). The modified repository concept fulfils all of these requirements equally (Figure 1).

A detailed analysis of the modified repository concept shows that, with an appropriate layout, stability throughout the planned time period of one hundred years can be guaranteed. In the modified concept all waste packages will be loaded in pre-fabricated containers before emplacement in the caverns. This ensures the easy retrieval of the waste and allows the caverns to be backfilled without difficulty at a later date. Examination of radiological operational safety has shown that safety targets for both normal operation and for any possible incidents can be met.

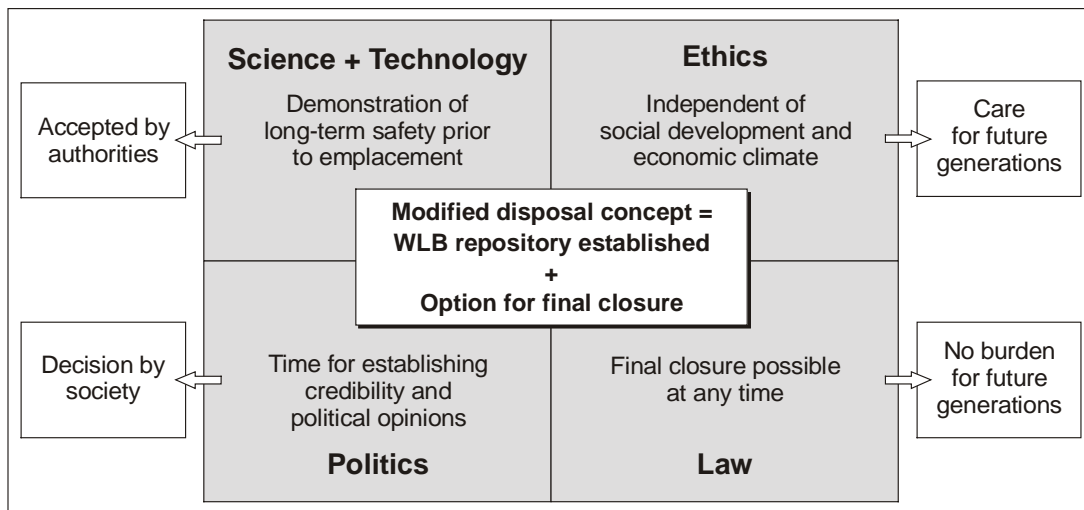
The introduction of a phase of easy retrieval results in no changes to the sealing barriers after closure. All the components in the original layout will be available. However, the phase of easy retrieval could have consequences for certain safety-relevant properties of selected repository components. In particular, the ventilation of the caverns which have been kept open will lead to partial carbonisation of the buffer material in the repository containers. The safety analysis has, however, shown that, even with the introduction of a phase of easy retrieval, safety is guaranteed and that, also for the modified repository

concept, the Wellenberg site can provide a safe repository for low- and intermediate-level radioactive waste.

Table 1: Stepwise approach towards a passively safe geological repository

Phases on the way to repository closure				
Phases	Federal gov.	Canton	Retrievability	Monitoring
1. Surface-based site investigation	Preparatory measures	—	—	Long-term geological monitoring
2. Site investigations underground	Preparatory measures	Concession	—	
3. Repository construction	General license, Construction license	Concession	—	
4. Waste emplacement	Operating license	—	easy	Radiological monitoring of nuclear facility
5. Post-emplacment phase with open caverns	—	—	easy	
6. Backfilling and sealing of caverns	Clearance by HSK?	?	normal	Long-term monitoring
7. Sealing of access tunnels	Decision Federal gov.?	?	normal	
8. Post-operational phase	Institutional controls?	—	difficult (Mining techn.)	

Figure 1: Four important components of the proposed adapted repository concept



Long ongoing political process

On the political level, the Federal Government decided to work towards a solution which would take account of both its fundamental energy policy and the democratic rights of the Canton. The Federal Department of Transport and Energy therefore invited the Canton to take part in a commission on decision-making for further actions. Two working groups were set up to report to the commission on technical and economical aspects, respectively. The Wellenberg technical working group reviewed the site selection procedure, monitoring and retrievability, the exploration strategy and other technical aspects. The other group examined the positive and negative economic impacts of the planned repository on the siting region.

The corresponding reports [9], [10] and [11] were presented to the public in September 1998. The technical group concluded that "from a technical point of view, work on the Wellenberg site has to proceed. In a next phase, more investigations with an exploratory drift should be carried out and questions which are still open should be answered". The main conclusion of the working group on economic aspects is that "the advantages of the construction and operation of the repository for the siting region outweigh the disadvantages considerably". The superior commission summarises the following points in its report:

- Based on present knowledge, technical as well as economic reasons argue in favour of Wellenberg.
- From the point of view of the representatives of the Canton of Nidwalden in the commission, it is a matter for the responsible ministry of the Federal Government to decide whether or not to proceed at Wellenberg.
- Before a decision on construction of a possible repository, further investigations with an exploratory drift have to be performed.
- Legal questions relating to closure of the repository and liabilities also have to be answered before a decision on construction.

The expected decision on Wellenberg was further delayed because, during the work of the commission for Wellenberg, the responsible Minister of the Federal Government initiated a dialogue and consensus group on nuclear waste disposal. The group, which was made up of representatives of the nuclear industry and Nagra, opponents (Greenpeace and a similar national group called the Swiss Energy Foundation), government representatives and their experts, had to provide input for preparation of a revision of the Swiss Atomic Law that is currently underway. The group's remit was to discuss the questions of further reprocessing of Swiss spent fuel and to compare the concepts of "final disposal in geological repositories" versus "indefinite monitored (provisional) retrievable storage". As expected, the dialogue came to an end in late 1998 without reaching a consensus on either question. The opponents tried to use the dialogue process to at least further delay any progress on Wellenberg by questioning the concept of final disposal, not only for HLW but also for L/ILW. This allowed them to argue that the relatively advanced Wellenberg project is based on a fundamentally wrong concept and therefore has to be reconsidered. This is in sharp contrast with the recommendations of the Swiss safety authorities. Nevertheless, with regard to Wellenberg, the president of the group recommended in his report that the next step should be the construction of an exploratory drift to provide results for decision-making irrespectively of any concept comparisons.

In the meantime, the Federal Government invited the nuclear utilities, the environmental organisations, the siting cantons and communities (of nuclear power plants and potential repositories) to search together for a solution to the nuclear waste disposal issue (together with other questions, such as setting limits to the lifetimes of existing reactors). There was no consensus reached, so it is now up to the Federal

Government to make a decision. In preparation, the Government set up a Group of Experts, to compare different disposal concepts (i.e. geological disposal versus long-term, retrievable storage) and based on the results will make a corresponding recommendation for the revision of the Swiss Atomic Law. The group will also address the question how to proceed with Wellenberg. The report is expected to be published in January 2000. This means that it will be early spring 2000 before there is any clarity as to how to proceed at Wellenberg. The expected outcome is to have a new referendum in the Canton, in a first step only on an exploratory drift, around late 2000 at earliest.

The further procedure for implementing a geological repository will be a stepwise, very open and transparent procedure. It will eventually provide future generations with a well-prepared solution, i.e. with a facility that can, at any stage, be transformed within a few years into a passive safe repository if societal consensus to do so is reached. This would avoid any undue burdens for future generations and give them maximum flexibility in using their resources in their own best interests.

HIGH-LEVEL WASTE (HLW) DISPOSAL PROGRAMME

In the HLW repository programme, Nagra is considering two host rock options: the crystalline basement and the Opalinus Clay in Northern Switzerland. Figure 2 gives a rough overview of the programme.

Crystalline basement option

The regional field work on the crystalline basement finished in 1989 and the corresponding synthesis reports were completed in 1994. The main reports include a comprehensive geological synthesis [12], a safety assessment study [13] and an overview and summary report [14]. The reports are currently still under review by the safety authorities and the corresponding report is expected by the middle of 1999.

At the end of 1994, Nagra applied for federal permits for two site investigation programmes, one for the Opalinus Clay and one for the crystalline basement. The programmes were reviewed by the federal authorities and their experts. For the crystalline basement programme, subsequent discussion in a working group with representatives from the federal authorities, their experts and Nagra led to a modified programme. It was recommended to focus on a different area west of Leuggern, namely the Mettau valley, for continuing exploration of the crystalline basement. Accordingly, a 2D seismic survey was carried out in the new area during winter 1996/97. The survey marks the end of the field work in the crystalline programme for the time being.

Opalinus Clay option

Investigations of the sedimentary layers in Northern Switzerland during the early nineties showed that the Opalinus Clay formation might be well-suited for hosting a high-level radioactive waste repository. After a systematic regional selection process, the region of the Zürcher Weinland (Canton of Zürich) was identified as being of first priority for further investigations [15]. In the region, the sediments are almost horizontally bedded and the Opalinus Clay has a suitable layer thickness of 100-120 metres at an appropriate depth of 400 to 900 metres below ground surface. Since the deposition of the sediments, the region has experienced almost no tectonic movements or disruption of the original sedimentary layers, making it an ideal candidate site.

The regional investigation programme consists of a 3D seismic survey over an area of about 50 km² and a deep borehole at the Benken site. An important source of information on the in situ properties of the Opalinus Clay is the work being carried out at the Mont Terri Rock Laboratory (Canton of Jura), which was constructed in a motorway reconnaissance tunnel traversing the same Opalinus Clay formation at a

depth of around 300 metres. The Mont Terri Rock Laboratory is considered to be of great value for Nagra not only for the Project "Entsorgungsnachweis" (see below) but also in the long term.

The extensive seismic survey was successfully completed during winter 1996/97. Recording was carried out with a 30-metre station spacing on a regular grid of in-lines and cross-lines laid out at intervals of 180 metres. Roughly 9,000 shotpoints were recorded in a densely populated agricultural area of 50 km². Before accessing the land for the operation, individual permits from all the landowners had to be requested on a voluntary basis. With an open and transparent permitting campaign, it proved possible to obtain permission to access 98 per cent of the land plots. This excellent coverage of the area resulted in a very good data quality of the survey.

The data were processed during 1997 and early 1998. The overall high data quality allowed a detailed structural characterisation of the Opalinus Clay layer and the entire sedimentary sequence. This was completed at the beginning of 1999. Faults and flexures with throws larger than about 10 metres can be resolved directly from the amplitude data. The result clearly demonstrates the absence of any fractures with a displacement of more than 10 m over a large area (more than 30 km²). The seismic results thus allow the results of the borehole to be extrapolated over an area much larger than would actually be needed for a repository.

The borehole was started in September 1998 and completed in spring 1999. The Opalinus Clay was found at a depth of 540 to 652 metres. The sedimentary layers 100 metres above and below, and the Opalinus Clay layer itself, show the expected very low hydraulic conductivity. Values for the Opalinus Clay tend to be around or below the detection limit of approximately 10⁻¹³ m/s. Results of rock mechanics measurements indicate that the construction of a repository should be possible without too much difficulty.

Together with other data currently being compiled from the Mont Terri Rock Laboratory and from other boreholes in Northern Switzerland, information from the exploratory borehole at Benken and the 3D seismic results will serve as input for regional hydrogeological modelling, engineering feasibility studies and performance assessment.

Next milestone in the Swiss HLW programme

Based on the broad knowledge of the crystalline basement resulting from investigations performed to date and the new ongoing exploration of the sediment option, the next stage in the HLW programme (Figure 2) will be the finalisation of the demonstration of feasibility of HLW disposal in Switzerland (Project "Entsorgungsnachweis"). This will include demonstration of the existence of a sufficiently extensive body of host rock with the required properties for making the safety case. Besides full acceptance of the safety case and the technical feasibility by the safety authorities, this was the question which was not answered to the complete satisfaction of the authorities in the Project "Gewähr" submitted in 1985 [16].

It is not required that all three components of the feasibility demonstration (siting, safety and technical feasibility) be answered for both host rock options, but for one option all three must be fully covered. It might well be that, because of the excellent explorability of the sediment option from the surface, this demonstration will be done only for the Opalinus Clay. Nevertheless, this does not mean that, for eventual construction of a Swiss HLW repository, the crystalline option will be abandoned. The documentation and reports for Project "Entsorgungsnachweis" will be submitted for evaluation by the safety authorities around 2001.

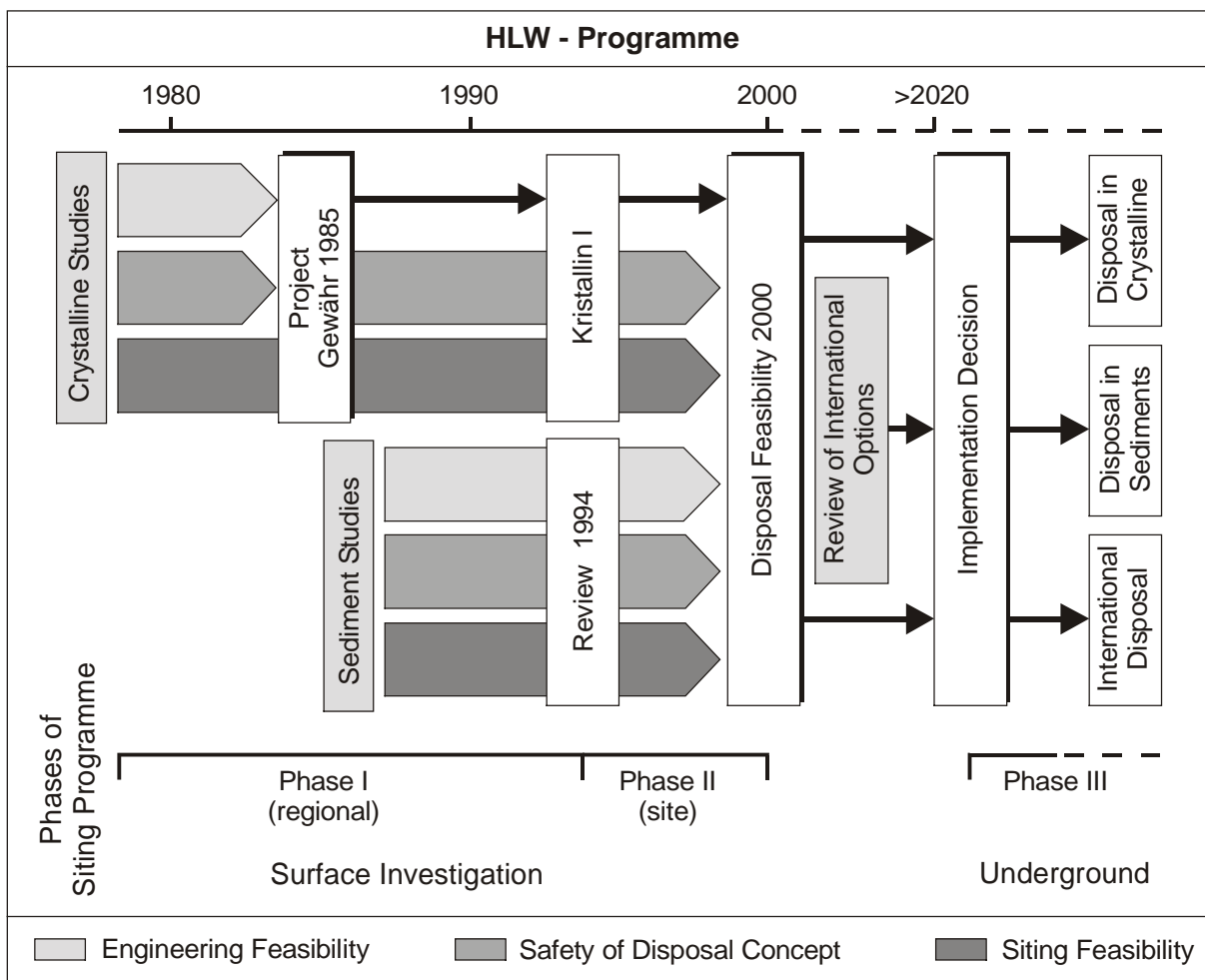


Figure 2: History and future of the Swiss HLW-Programme

Openness to multinational solutions

Besides investigations for a repository in Switzerland, the general option of disposing of high-level waste within the framework of a multinational cooperative project is being kept open. Since the eighties, this has been a publicly accepted part of the Swiss waste management strategy. The multinational option is also supported by the Swiss Government and several corresponding statements have been made by the responsible minister. Nagra's objective is to provide the necessary technical basis for a corresponding political decision. This decision can be deferred, but must allow sufficient time for further exploration of a suitable site and subsequent construction of the HLW repository, allowing operations to start when required, around the middle of the next century.

In Nagra's view, a multinational repository could be beneficial, especially for countries with small nuclear programmes like Switzerland. However, such a repository must fulfil the following requirements:

- it must comply with high, internationally accepted safety standards,
- it must be located in a democratic country with social and political stability that also has the necessary infrastructure and

- it must find political and public acceptance in the host country and in the customer countries and must also have the support of the relevant international bodies.

Nagra's main priority continues to be waste management projects in Switzerland, therefore work on disposal of HLW in Switzerland as described above is not affected at all by multinational options. Because LLW and short-lived ILW must be disposed of in Switzerland, the L/ILW programme is completely independent of any multinational repository project.

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