

**nagra** ● we care

**annual report  
2017**

## **Foreword**

Corina Eichenberger, President of the Board of Directors	2
Thomas Ernst, Chief Executive Officer	3

## **Highlights of the year**

6

## **Our mandate**

9

## **Work developments**

Inventory of radioactive materials	11
Sectoral Plan process	13
	16

## **Scientific-technical background**

25

## **Rock laboratories**

31

## **International Services and Projects**

International collaboration	39
	40

## **Public outreach**

45

## **Organisational structure 2017**

Members of the Cooperative, Board of Directors, Commissions and Statutory Auditor	48
Organigram of the head office 2017	52
	53

## **Annual financial statements 2017**

Comments on the annual financial statements 2017	55
Balance sheet	56
Profit and loss account	57
Cash flow statement	58
Notes to the annual financial statements	59
Accumulated accounts	60
Notes to the accumulated accounts	65
Report of the Statutory Auditor	67
	69

## **Appendices**

Waste inventories and volumes	71
Publications in 2017	72
Glossary / Abbreviations	74
	75

# Foreword



## **Corina Eichenberger, President of the Board of Directors**

Managing radioactive waste is a task of national importance. This is underlined by the complex and time-consuming process adopted for selecting sites for deep geological repositories. In recent years, Nagra's employees have shown great endurance and diligence in preparing countless documents as part of this process. The demanding and technically challenging work involved implementing the criteria and requirements specified by the Federal Government based on a sound scientific background and always with safety as the paramount goal. This challenge could only be met by working together.

2017 saw important progress being made towards applying for the general licences for the repositories and this is particularly gratifying for me. I would like to mention one key milestone: the start of the open consultation procedure for Stage 2 initiated by the Federal Council at the end of November 2017. The Federal Council's proposal is that the three siting regions Jura Ost, Nördlich Lägern and Zürich Nordost should undergo further investigation in the final Stage 3 of the site selection process. Our extensive documentation, the expert opinions of the regulatory authorities and the responses from the consultation procedure will provide the Federal Council with a sound basis for making its decision, which is expected for the end of 2018. The decision on Stage 2 is also the green light for initiating Stage 3.

Nagra is now preparing for the upcoming field investigations. The search for a site that is most suitable in terms of safety will be supported by the results of further geological investigations: Quaternary boreholes are planned for 2018 and, from 2019, exploratory boreholes will be drilled in all the siting regions. The challenges will thus continue for Nagra and its employees.

My warmest thanks go to the members of the Board of Directors for their helpful and constructive cooperation, as well as to the Executive Board and all Nagra employees for their sense of responsibility, commitment and competence in working towards safe waste disposal.

A handwritten signature in black ink, appearing to read 'C. Eichenberger'.

Corina Eichenberger

### Thomas Ernst, Chief Executive Officer



The focal points of 2017 were the review of Nagra's siting proposals for Stage 2 of the Sectoral Plan process and planning the investigations for Stage 3. The Swiss Federal Nuclear Safety Inspectorate (ENSI) published its assessment of the siting proposals in April, finding that Nagra had taken adequate account of the prescribed criteria. It supported the proposal that the regions Jura-Südfuss, Südranden and Wellenberg should be placed in reserve, as well as the further investigation of Jura Ost and Zürich Nordost and focusing on the Opalinus Clay as the preferred host rock. In contrast to Nagra, ENSI considered that the decision to place Nördlich Lägern in reserve was not sufficiently justified and called for investigations to be continued in this region in Stage 3. In its expert opinion published in June, the Federal Nuclear Safety Commission (NSC) supported all the key conclusions of ENSI. The Federal Council initiated the open consultation period for Stage 2 in November. The draft of the results report that forms part of the consultation process follows the recommendations of ENSI and the NSC.

Nagra completed its seismic investigations in Nördlich Lägern and submitted applications for exploratory boreholes in the region. By the end of 2017, the applications for the boreholes in all three siting regions had been opened for public consultation and hundreds of objections had been processed. Before the end of the year, the Federal Department for the Environment, Traffic, Energy and Communications approved one borehole (in the Quaternary) in line with the Nuclear Energy Act. Both the permits for the exploratory boreholes and the decision of the Federal Council on Stage 2 are expected in 2018. Overall, the progress made in the Sectoral Plan process has been very satisfying.

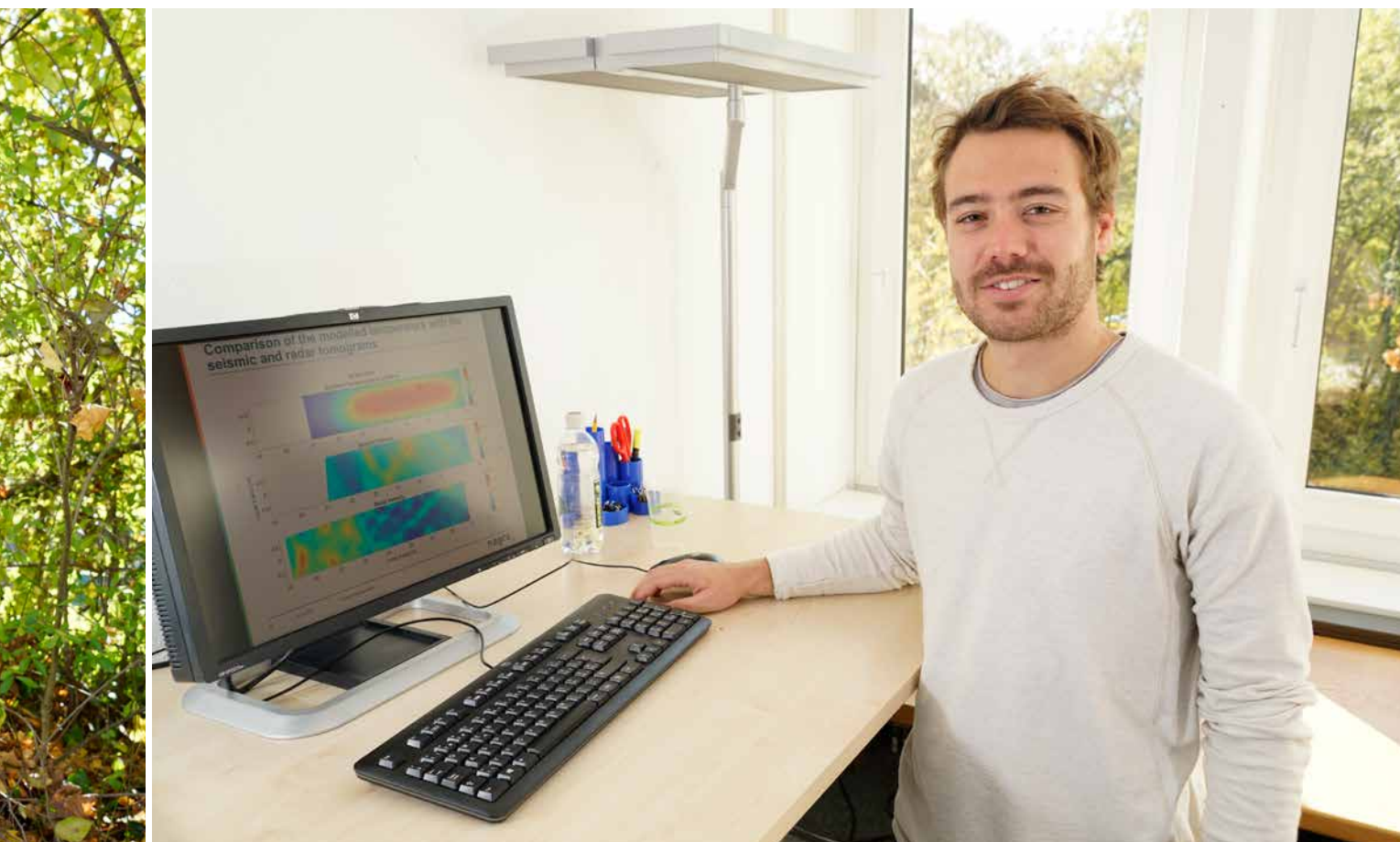
This also applies to the new organisational structure of Nagra. The new posts created by this have been filled with competent personnel; the unique nature of its task makes Nagra an attractive employer for well-trained, capable people. My special thanks go to all the Nagra employees for showing great commitment in shaping and implementing this exceptional cross-generational project.

Dr. Thomas Ernst









#### EXCHANGING KNOW-HOW AND EXPERIENCE

Whether as experienced freelancers, consultants, flexible temporary staff or trainees – an external workforce supports Nagra throughout the year. “An exciting experience”, “informative and multifaceted”, “unique projects” and a “cool working environment” – these are the responses we received, for example, from the trainees who worked for Nagra in 2017. 14 young men and women worked alongside Nagra staff for around half a year in the rock laboratories, on hydrogeological investigations, international projects, inventorying radioactive waste and in many other areas. Some portraits (text-boxes) in this annual report provide an insight into the work of these trainees and freelancers.

# Highlights of the year



**3<sup>rd</sup> February:** The largest Swiss 3D seismic campaign to date is completed.



**27<sup>th</sup> February:** The public inspection period for the applications for exploration permits begins in the Jura Ost siting region.



**18<sup>th</sup> April:** ENSI publishes its evaluation of Nagra's siting proposals.

**FEBRUARY** Nagra's 3D seismic campaign was completed on 3<sup>rd</sup> February. Beginning in October 2015, 3D seismics were used to investigate an area of around 200 km<sup>2</sup> covering 53 communities in the three siting regions Jura Ost, Nördlich Lägern and Zürich Nordost. With over 51 000 measurement points, this was the most extensive 3D seismic campaign ever carried out in Switzerland.

**FEBRUARY** The 30-day public inspection period for the applications for exploratory borehole permits began on 27<sup>th</sup> February in the Jura Ost siting region. Nagra staff were available to answer questions at information sessions offered in the communities of Bözberg, Effingen, Remigen, Riniken and Zeihen. Exploratory boreholes require a permit from the Federal Department of the Environment, Transport, Energy and Communications (DETEC). The permits are expected to be granted by the end of 2018.

**MARCH** On 13<sup>th</sup> March, the public inspection period for the applications for exploratory borehole permits began in the communities of Dachsen, Laufen-Uhwiesen, Marthalen, Rheinau and Trüllikon in the Zürich Nordost siting region.

**MARCH** Nagra published a series of reports on the production, consumption and transport of gases in deep geological repositories: a synthesis report and several further reports summarise the current state of knowledge on this topic.

**APRIL** On 18<sup>th</sup> April, ENSI published its safety-based evaluation of Nagra's siting proposals. It agreed that Jura Ost and Zürich Nordost should be further investigated in Stage 3 of the Sectoral Plan process as siting regions for repositories for low- and intermediate-level waste (L/ILW) as well as for high-level waste (HLW). Contrary to Nagra, ENSI concluded that, taking existing uncertainties into account, the reasons for placing Nördlich Lägern in reserve were not sufficiently robust. ENSI therefore proposed that this region be included for further investigation in Stage 3. In its assessment published in June, the Federal Nuclear Safety Commission (NSC) came to the same conclusion.





**June 2017:** In the Isenbuck/Berg area, several measurement stations investigate groundwater flow.

**JUNE** Several groundwater measurement stations were set up in the area of Isenbuck/Berg in the Zürich Nordost siting region. These measurements aim to determine how and where the groundwater flows in this area. The results were summarised in a technical report.

**AUGUST** On 24<sup>th</sup> August, Nagra submitted six applications to the Swiss Federal Office for Energy (SFOE) for exploratory boreholes in the Nördlich Lägern siting region. The affected communities are Weiach, Eglisau, Bülach, Stadel (two applications) and Glattfelden.



**26<sup>th</sup> September:** The 7th International Clay Conference opens at the Congress Centre in Davos.

**SEPTEMBER** From 26<sup>th</sup> to 28<sup>th</sup> September, more than 400 scientists from 23 countries gathered in Davos to share knowledge about the role of clays and clay materials in the disposal of radioactive waste. For the first time, the Clay Conference took place in Switzerland and was hosted by Nagra with the support of other organisations.

**NOVEMBER** The public inspection period for the applications for exploration permits in five communities in Nördlich Lägern began on 1<sup>st</sup> November.

**NOVEMBER** The Federal Council opened its consultation process for Stage 2 of the site selection process for deep geological repositories. In its findings, the Federal Council proposed that the three siting regions Jura Ost, Nördlich Lägern and Zürich Nordost be further investigated in the final Stage 3. The consultation process continued until 9<sup>th</sup> March 2018.



**22<sup>nd</sup> December:** The Swiss Federal Office of Energy (SFOE) approves the first Quaternary borehole in the community of Riniken in Canton Aargau.

**DECEMBER** On 22<sup>nd</sup> December, DETEC approved the first Quaternary borehole in the community of Riniken in Canton Aargau. Prior to the approval, the application for the borehole permit was reviewed by the SFOE, ENSI and other authorities. It was also opened for public inspection for a period of 30 days, during which no objections were raised.



Swiss Parliament building in Bern



# Our mandate

Deep geological disposal of radioactive waste is a technically and societally challenging task. Nagra approaches this with the necessary respect and a sense of responsibility for the cross-generational protection of humans and the environment.

According to the Nuclear Energy Act, the polluter pays principle applies to the management of radioactive waste. The Cantons are the main shareholders in the electricity utilities that operate the nuclear power plants; this means that the responsibility for waste management lies not only with the power plants, Nagra and the Federal Government but also with the Cantons.

Radioactive waste arises from the operation and later decommissioning of the nuclear power plants and from a range of applications in the fields of medicine, industry and research (MIR waste).

Nagra was set up in 1972 by the Swiss waste producers and given the mandate of developing and implementing safe, sustainable solutions for the disposal of the waste. The members of the Nagra Cooperative are the nuclear power plant operators, the Zwiilag interim storage facility and the Swiss Confederation (responsible for MIR waste).

Within the defined legal framework, Nagra is responsible for planning, constructing and operating deep geological repositories. This work of national significance includes selecting suitable sites in line with the "Sectoral Plan for Deep Geological Repositories", which is under the lead of the SFOE. Nagra prepares siting proposals that are then reviewed by the responsible authorities and commissions. This is followed by a broad public consultation phase before the Federal Council makes a decision. Nagra also submits the licence applications for the planned repositories: one for low- and intermediate-level waste (L/ILW) and one for spent fuel and high-level waste (SF/HLW), or for a combined repository for both waste categories.

Nagra maintains inventories of radioactive materials and advises the waste producers on conditioning of the waste into a form suitable for disposal. A wide-ranging research and development

programme has also been underway since the 1970s. In this context, Nagra works closely with the Paul Scherrer Institute (PSI, Villigen) and various universities and technical institutes both in Switzerland and abroad.

## OUR ACTIVITIES

- Working together with the authorities and the siting regions within the framework set by the Sectoral Plan process
- Characterisation and inventorying of radioactive materials as the basis for planning repository projects, checking waste specifications as part of official waste clearance procedures and as a service to the members of the Nagra Cooperative
- Acquisition and evaluation of the field data required for safety analyses and repository projects
- Designing the repository facilities and engineered barrier systems and planning operating procedures
- Ongoing analysis of results and data as part of safety assessment studies and evaluation of the knowledge base with a view to upcoming repository licensing procedures
- Development of databases and refining, verifying and validating the data and models used in safety analysis
- International collaboration with the aim of optimising planning and development activities
- Informing the public
- Providing expert services to third parties





Silvio Giger, geomechanics project manager, visually inspecting a borehole. His experiment involves investigating rock properties using samples in the laboratory and with in-situ tests in boreholes.

# Work developments

## Legislation

On 21<sup>st</sup> May 2017, 58.2% of the Swiss electorate voted in favour of the first package of measures of the so-called Energy Strategy 2050, which comprises a total revision of the Energy Act. Switzerland will no longer grant general licences for the construction of new nuclear power plants; existing nuclear power plants may be operated as long as their safety is assured. The revised law also foresees a ban on reprocessing of spent fuel assemblies. The existing moratorium will be extended until June 2020. The legal revisions entered into effect on 1<sup>st</sup> January 2018.

## Authorities

The Swiss Federal Office of Energy leads and coordinates the Sectoral Plan process. ENSI is the national regulatory authority for nuclear safety and for the security of Swiss nuclear installations. In this capacity, it monitors Nagra's siting investigations for deep geological repositories and their subsequent construction and operation. The Expert Group on Nuclear Waste Disposal (EGT) was set up by ENSI to provide support on geological and engineering aspects of deep geological disposal. The EGT is also responsible for certain tasks within the Sectoral Plan process. The Federal Nuclear Safety Commission (NSC) advises the Federal Council, the Federal Department for the Environment, Transport, Energy and Communications (DETEC) and ENSI on questions relating to the safety of nuclear installations. The Nuclear Waste Management Advisory Board was set up by DETEC to advise it on the implementation of the repository site selection process within the framework of the Sectoral Plan. It offers an outside perspective thanks to its independent status and its position as a national advisory board.

## Waste Disposal and Decommissioning Funds

The Waste Disposal Fund secures the financing of the disposal of operational waste and spent fuel following the shutdown of the nuclear power plants, as well as of reprocessing waste. The Decommissioning Fund covers the financing of the decommissioning and dismantling of nuclear facilities at the end of their operational lifetime as well as the disposal of the resulting waste. The

owners of the nuclear facilities contribute to the Decommissioning and Waste Disposal Funds, which are both supervised by the Federal Government. At the end of 2017, the accumulated capital in the Waste Disposal Fund amounted to around CHF 5.2 billion and in the Decommissioning Fund to around CHF 2.5 billion. More information can be found on the website of the Funds ([www.stenfo.ch](http://www.stenfo.ch)). On behalf of the owners of the nuclear installations, swissnuclear presented an updated Cost Study in 2016. The cost estimates form the basis for determining the contributions to be paid by the owners into the two Funds. The responsible authorities reviewed the documents. At the end of 2017, the Administrative Commission of the Funds

## LEGAL FRAMEWORK

The legal provisions applying to radioactive waste management are contained in the Nuclear Energy Act and the associated Nuclear Energy Ordinance.

### The following principles apply:

- Radioactive materials should be handled in such a way as to minimise waste production.
- Radioactive waste must be disposed of in a way that ensures the permanent protection of humans and the environment.
- All radioactive waste produced in Switzerland must, as a general rule, be managed and disposed of in Switzerland.
- The duty of disposal lies with the waste producers, in line with the polluter pays principle.
- The management strategy specified for all waste types is monitored deep geological disposal.
- The waste producers are required to prepare a Waste Management Programme which has to be reviewed and approved by the Federal Government.
- The licensing procedures are focused at the federal level. The general licence for a nuclear installation is subject to an optional national referendum. Participation of the siting Cantons, neighbouring Cantons and neighbouring countries in the process is required by law.
- The Federal Government defines the objectives and requirements applying to the site selection process in a Sectoral Plan.
- The costs of decommissioning and waste disposal are covered by funds into which the operators of the nuclear facilities pay annual contributions; the funds are supervised by the Federal Government.



provided information about the review and the payment of contributions into the Funds as proposed to DETEC.

### Waste Management Programme being reviewed

The Nuclear Energy Act and Ordinance require the waste producers to provide the responsible authorities with a Waste Management Programme for all types of radioactive waste arising in Switzerland and to update this every five years. The Programme sets out the procedure for realising safe repositories up to the time of their closure. In line with a requirement of the Federal Council, the updated Waste Management Programme (see text-box below) was submitted at the end of 2016 together with a Research, Development and Demonstration Plan; both are currently being reviewed by the authorities.

### Sectoral Plan for Deep Geological Repositories

Article 5 of the Nuclear Energy Ordinance requires the Federal Government to specify the objectives and criteria for the deep geological disposal of

radioactive waste in a Sectoral Plan. The Federal Council approved the conceptual part of the Sectoral Plan for Deep Geological Repositories, which regulates the site selection process, on 2<sup>nd</sup> April 2008. The technical feasibility and safety of geological disposal in Switzerland had already been confirmed with the approval by the Federal Council of the high-level waste “Entsorgungsnachweis” feasibility study in June 2006 (the feasibility of safe disposal of low- and intermediate-level waste was recognised in 1988). The Sectoral Plan process (see figure below) attaches great importance to the requirement for transparent information and participation of the affected parties. The authorities and the public in the siting regions and in neighbouring foreign countries, as well as interested and foreign organisations, may participate in the process, which ends with a decision of the Federal Council and Parliament on the general licences for the repositories. Their decision is then subject to an optional national referendum.

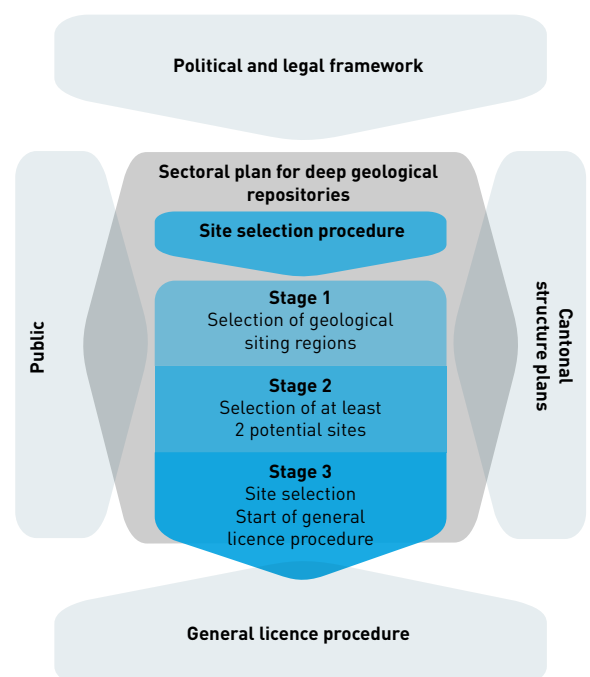
#### WASTE MANAGEMENT PROGRAMME

The 2016 Waste Management Programme was prepared by Nagra on behalf of the waste producers and updates the first programme from 2008. It is reviewed by the SFOE, ENSI and the NSC. Following an open consultation process (around mid-2018), the Federal Council is expected to decide on the Programme around the beginning of 2019. The Federal Council regularly reports to the Federal Assembly on the status of the Programme.

The 2016 Programme provides the framework for the long-term planning of deep geological repositories. It contains information on the origin, types and volumes of radioactive waste and its allocation to the repositories, as well as on the design and layout of the facilities. It also contains an implementation plan and details on financial planning, as well as information on the duration and capacity of interim storage. Nagra also outlines its information strategy in the document.

Nagra updated its Research, Development & Demonstration (RD&D) Plan at the same time as preparing the Waste Management Programme and submitted the two reports to the SFOE.

#### Stages, responsibilities and interactions in the Sectoral Plan for Deep Geological Repositories (figure from the SFOE)



# Inventory of radioactive materials

The centralised inventory of existing radioactive waste maintained by Nagra was updated to include packages with conditioned waste produced in 2017. The nuclear power plant operators and Zwiilag use the inventory as a tool for managing their interim storage facilities. Together with predictions of waste expected to arise in the future, the centralised inventory also forms the basis for the “Model Inventory of Radioactive Materials” (MIRAM). MIRAM was also developed further, for example with updated figures for existing waste and data from calculations of expected gas production rates in a backfilled repository. With the development of the model waste volume frameworks and radiological inventories, MIRAM was also used for work that formed the basis for the 2016 Cost Study. Information on waste inventories and volumes of radioactive waste can be found on pages 72 and 73 under “Appendices”.

The study on demonstrating the criticality safety of spent fuel assemblies in disposal canisters carried out in 2016 was extended in 2017 to include additional variants of the disposal canisters. Investigations also continued on the behaviour and properties of fuel assemblies after longer periods of dry storage in interim storage facilities and subsequent transport to the repository. This project will extend over several years with international participation and includes both theoretical and experimental investigations. Transport concepts for the entire spectrum of waste were also developed and optimised.

In the run-up to its decommissioning starting from 2019, support was provided to the Mühleberg nuclear power plant in characterising and inventorying the expected decommissioning waste. This waste will consist primarily of the internals of the reactor pressure vessel and the vessel itself. Studies were also carried out on optimising decontamination technologies and on the concept for a waste treatment plant.

Nagra also worked together with the NPP operators and Zwiilag on containers for interim storage and deep geological disposal of decommissioning waste. Following initial tests with two prototypes,

the containers will go into series production by the time the Mühleberg NPP is decommissioned.

As part of the procedures for certifying the suitability of wastes for disposal, Nagra checked new processes for conditioning waste from the nuclear power plants and PSI in terms of suitability for later emplacement in a repository. The requirements of Nagra and ENSI that underpin the assessment of the waste were observed throughout and led to clearance of the procedures by ENSI.

## MOVING INTO COMPLETELY NEW AREAS

Birgit Baumgartner, environmental engineer

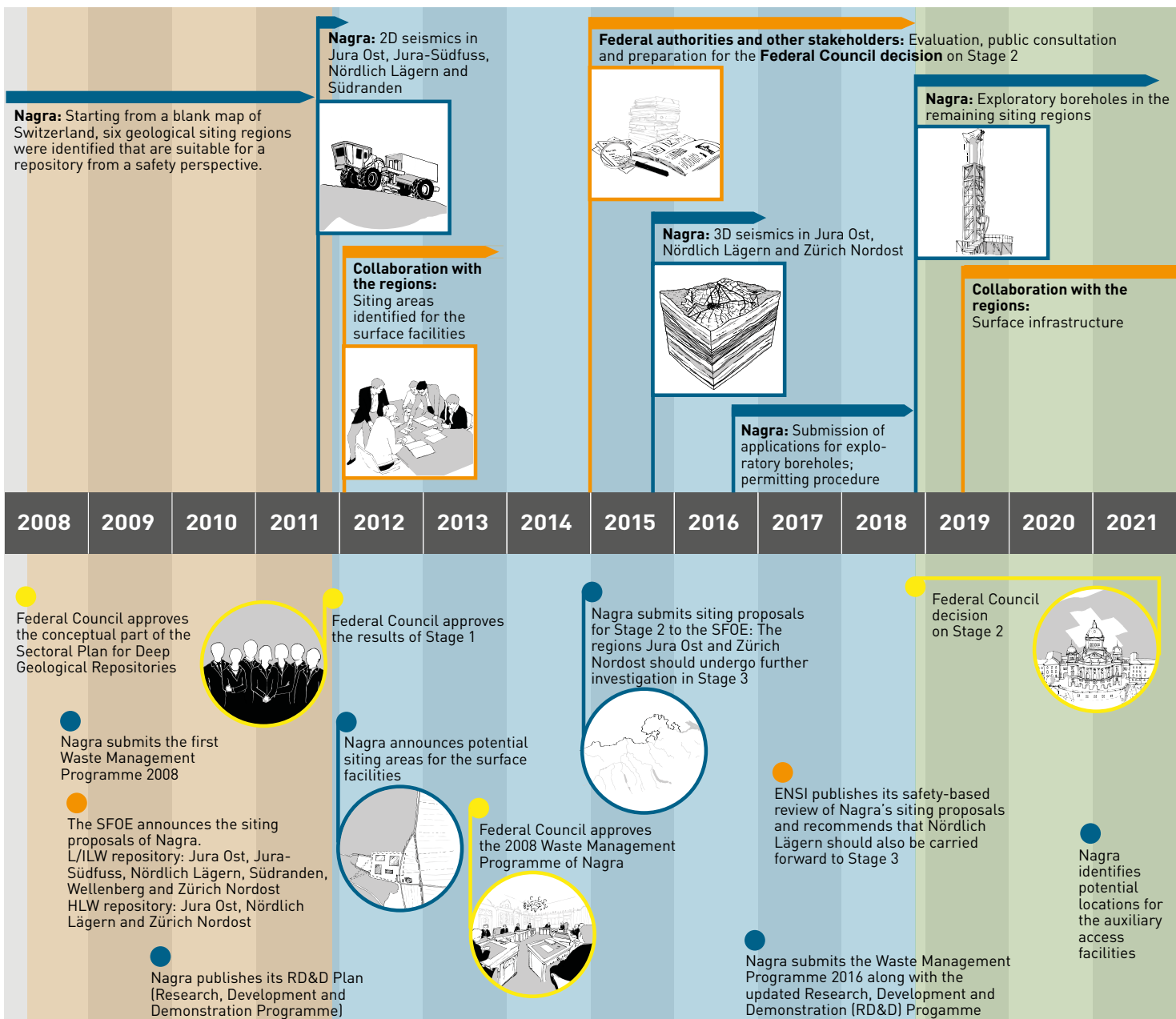


Birgit Baumgartner completed a several-month internship with Nagra ending in March 2017. “Even during my studies in environmental technology, I had already heard about Nagra’s work”, she says. Management of radioactive waste was not part of her course material, but she did learn something about seismics. “My internship at Nagra was something different”, she adds smiling. “I came into contact with areas that were completely new for me. Step by step I was able to gain an insight into the activities and areas covered by Nagra”, she continues. She found the work very interesting and instructive.

In the first months she worked in the area of data management, checking drilling profiles to establish where the Quaternary – the uppermost layer of unconsolidated rock – ends. She also helped with the documentation required for the applications for exploration permits. Her next move was to the Inventories & Logistics Section. In the waste inventory, existing and predicted radioactive wastes are recorded in a database, separated according to waste type; logistics deals with the planning and optimisation of future waste transports from the nuclear power plants and interim storage facilities to the repositories.

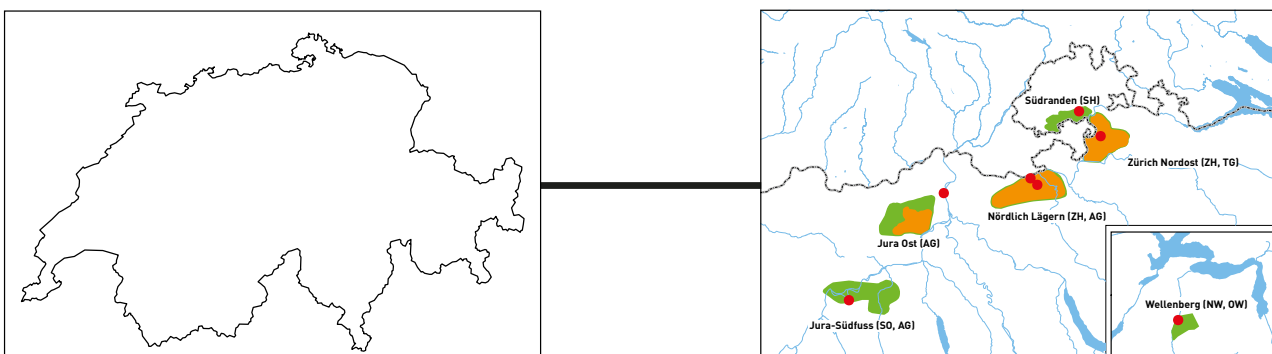
“For me, waste treatment, which also plays a role in the inventory, was something completely new”, explains Birgit Baumgartner. “But because I was working with it every day, I soon became familiar with all the terminology and abbreviations.” Besides testing the database for the so-called preliminary acceptance of individual waste packages, her main task was to research existing documentation. She reworked the implementation provisions for preliminary acceptance of radioactive materials and prepared a report on the history of preliminary acceptance. An individual waste package is a single container with radioactive waste that is destined for deep disposal. Individual packages go through a stepwise procedure before they are cleared for disposal with a preliminary acceptance. This is an important step in preparing for final acceptance. “Of course, final acceptance does not exist yet as there is no repository”, she explains. Birgit Baumgartner’s conclusion on radioactive waste management: “We all have a responsibility. It is important that the waste should be disposed of safely for a long time.”

# With the three-stage Sectoral Plan to deep geologi



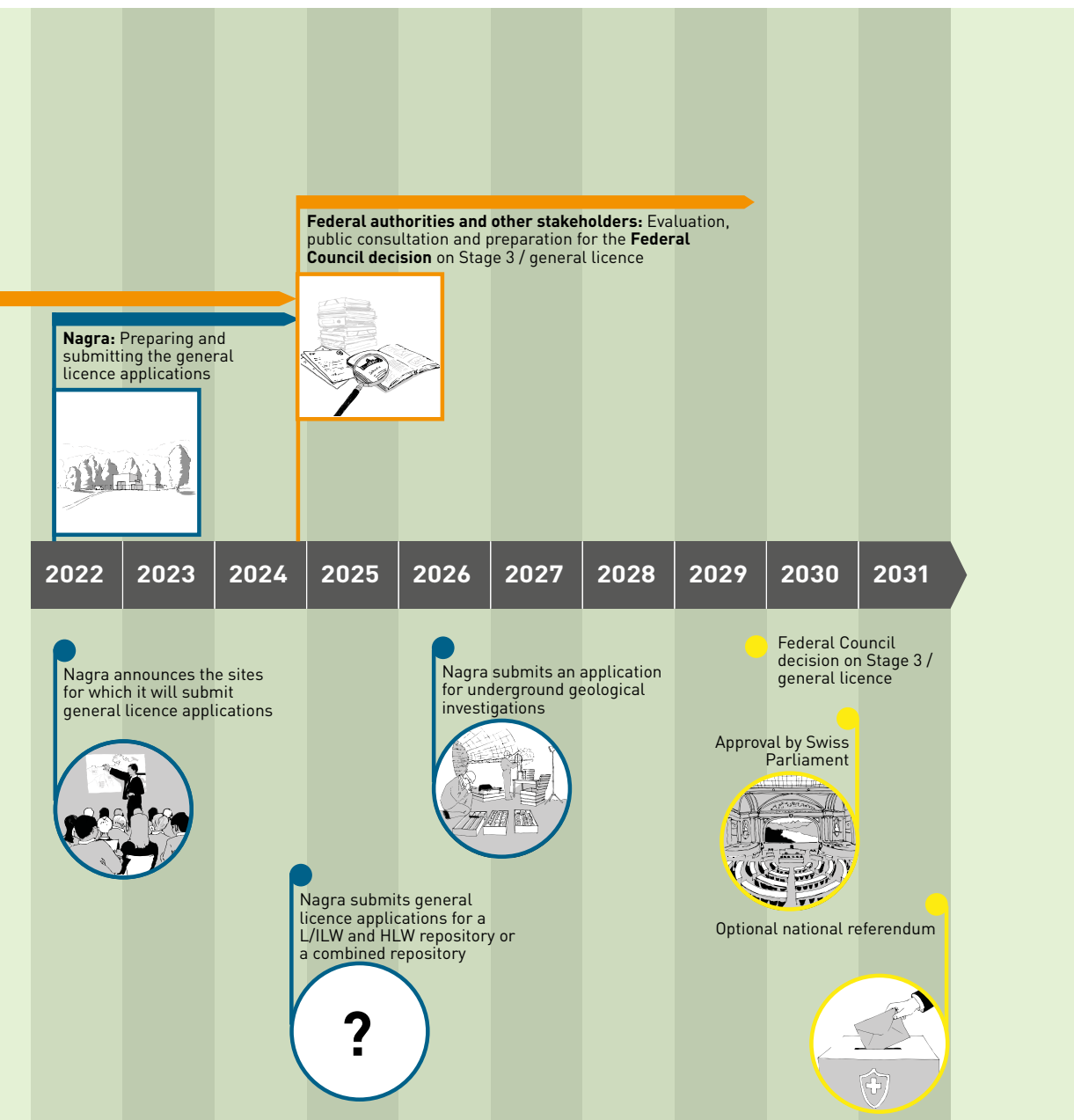
## Starting-point: Blank map of Switzerland / selection criteria: safety and engineering fe

### Federal Council decision on Stage 1



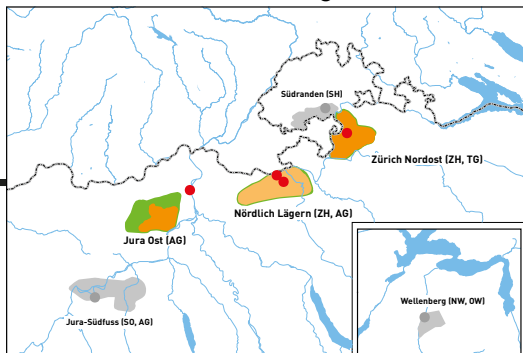
At the end of 2014, Nagra proposed the siting regions Jura Ost and Zürich Nordost for further investigation in Stage 3; the regions Jura-Südfuss, Nördlich Lägern, Südranden of all the siting regions. ENSI recommends that Nördlich Lägern should also be investigated further. The decision of the Federal Council on the siting proposals is expected

# cal repositories: retrospective and outlook

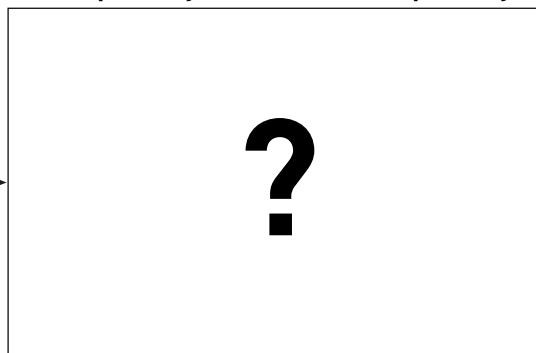


## asability

### Nagra proposals and safety-based evaluation of ENSI for Stage 2



### General licence applications for a L/ILW and HLW repository or a combined repository



and Wellenberg were to be placed in reserve. The decision was based on safety analyses conducted for each region and a safety-based comparison for the end of 2018.

(as of April 2018)

# Sectoral Plan process

## FEDERAL GOVERNMENT LEAD – PROPOSALS BY NAGRA – INDEPENDENT SUPERVISION

The Sectoral Plan process consists of three stages. The process is led by the SFOE and numerous bodies are involved, including Cantons, communities and neighbouring countries, interested organisations, associations, parties and the public (see figure below). Nagra prepares the scientific and technical background, proposes siting regions and sites and submits general licence applications for the repositories in Stage 3. ENSI reviews Nagra's proposals from the viewpoint of safety and engineering feasibility; for this, it draws on the support of external experts. Following open consultation and participatory procedures, the authorities and the Federal Council make an overall evaluation at the end of each stage.

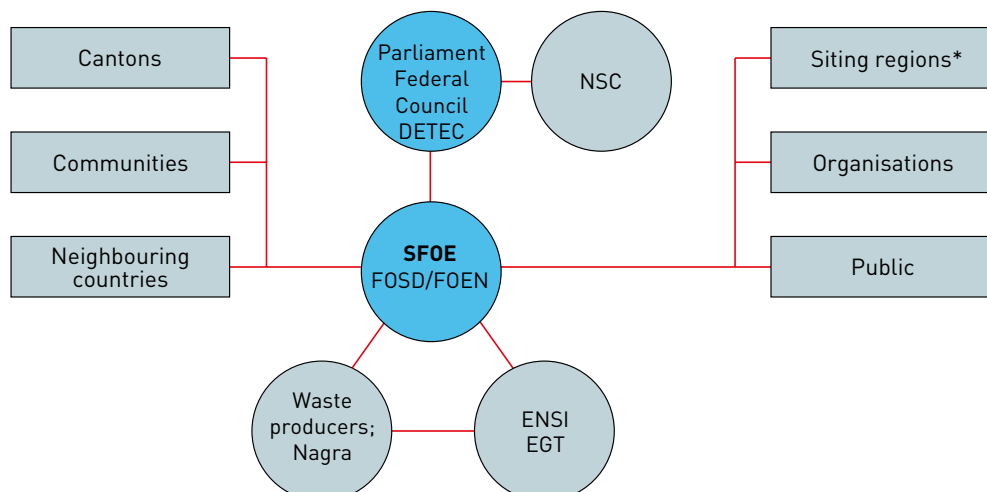
The fundamental question of how to safely dispose of all types of radioactive waste arising in Switzerland has already been answered: the Federal Council approved the feasibility demonstration for low- and intermediate-level waste (L/ILW) in 1988 and for high-level waste (HLW) in 2006. The question of where the two repositories can be constructed is being clarified within the framework of the Sectoral Plan for Deep Geological Repositories. Safety is always paramount in the search for sites. Because of its transparent, systematic approach and the extensive rights of participation

granted to a wide range of stakeholders, the Swiss site selection process is considered to be exemplary by other countries with nuclear programmes.

The infographic on pages 14 and 15 provides a retrospective and outlook on the site selection process for the repositories that was adopted by the Federal Government in 2008. The first stage lasted from 2008 to 2011. Starting with the whole of Switzerland, Nagra applied a systematic site selection process that resulted in three potential geological siting regions for the HLW repository and six (overlap with three of the HLW regions) for the L/ILW repository. Nagra's proposals were subjected to a rigorous safety-based review by various authorities and technical bodies and a wide stakeholder consultation. The Federal Council decided at the end of 2011 that all six potential siting regions should be carried forward for further investigation and that Stage 2 of the process should be initiated.

## Surface facilities - intensive participation in the siting regions

Collaboration with the siting regions led, in Stage 2, to submission by Nagra of proposals for at least one siting area for the surface facility of a potential repository in each of the six siting regions. In contrast with the underground facilities, the safety of a surface facility depends mainly on the design and not primarily on the site. This allows a certain



\*The regional conferences represent the siting regions

flexibility in selecting the siting area, with regional needs being taken into consideration. The intensive collaboration was aided by the commitment shown by the regional conferences – the regional participation bodies – and the siting Cantons in the process.

All the regional conferences responded to the proposals for the siting areas and, based on these responses, Nagra designated the areas to be followed up further and documented these in planning studies by 2014. They form an integral part of Nagra's proposals in Stage 2. They provide input for the socio-economic-ecological impact studies and for the preliminary investigations for the Environmental Impact Assessment (including specifications). The latter was submitted as part of the documentation for Stage 2. All these reports have now been reviewed by the federal authorities and the results included in the documentation for the open consultation phase.

### Nagra's proposals for Stage 3

Deciding which geological siting regions are to be proposed for Stage 3 is a scientific/technical issue. The long-term safety of a repository will be determined by the geology of the selected site. Together with the NSC and cantonal experts, ENSI specified the method to be followed by Nagra for comparing the siting regions. According to this, a siting region can be placed in reserve only if it shows clear disadvantages in terms of safety compared with the other regions. If this is not the case, the region will undergo further investigation in Stage 3.

The safety-based comparison led Nagra to conclude that all six geological siting regions fulfil the strict safety requirements set by the Federal Government and are thus suitable for the construction of the repositories. However, Nagra's view is that, compared to Jura Ost and Zürich Nordost, the other regions have clear disadvantages in terms of safety, even if they are suitable in principle. Nagra therefore proposed in December 2014 that the siting regions Jura Ost and Zürich Nordost should undergo further investigation in Stage 3 and that the regions Jura-Südfuss, Nördlich Lägern, Südanden and Wellenberg be placed in reserve.

### Detailed review of the siting proposals

Nagra's proposals were reviewed by ENSI (with its experts), the NSC, the Expert Group on Nuclear Waste Disposal (EGT) and other federal and cantonal offices. In September 2015, ENSI called for Nagra to submit additional technical documentation on the indicator 'Depth with a view to engi-

#### AN APPROACHABLE COMMUNICATOR WITH GREAT IMPACT

Petra Blaser, geologist



Petra Blaser came to Switzerland after completing her geology degree in Tübingen. She has worked on a self-employed basis on various projects for Nagra since 1988. Together with other experts, she worked in the early days on the hydrochemical analyses for the Nagra boreholes in Siblingen, Kaisen and Schafisheim. "Such investigation reports were novel at that time", she points out. "I was always interested in applied research such as hydrogeology or hydrochemistry". This led her to later complete a doctorate in the age structure of groundwater.

Her tasks and the focus of her work may have changed over the years, but her motivation remains the same. Petra Blaser enjoys discussing the disposal of radioactive waste with other people. She can often be found manning the Nagra stand at exhibitions and trade fairs and is an enthusiastic tour guide for visitors to the rock laboratories. She has also been involved in the production of numerous print products such as the first edition of the highly popular "Stone" book. "It is really satisfying to work on something from scratch", she underlines. Petra Blaser is a geologist with many interests and a wealth of experience who deals with her work responsibilities efficiently and flexibly. She has been responsible for editing many of Nagra's scientific reports and seeing them through to publication. She is always ready to assist when her wide expertise and open and friendly nature are an advantage. For example, she was often to be found at Wellenberg in the nineties, discussing repository projects with the local people. She was also involved during the so-called permitting process for the seismic campaigns and other field investigations from 2015 to 2017. During the permitting process, the affected landowners and tenants are informed personally about the work. For weeks on end, Petra Blaser went from door to door to discuss the field activities. "It was always really important to me to talk to people face-to-face when there were questions, uncertainties and even criticism." And: "The experience I gained during this work was in some ways like attending the school of life."

Petra Blaser has had many offers of employment. "I prefer to work on a self-employed basis", she adds. This allows her to choose how to allocate her time. "I work well under pressure", she says with a smile. "Working in a team, for example when preparing the exploration permit applications in the last two years, is a lot of fun." With all the different areas she works in, she has a good insight into Nagra's various activities. "The work is incredibly exciting and challenges my technical abilities", she concludes.



neering feasibility'; this is particularly relevant for the Nördlich Lägern siting region. The required documentation was submitted to the SFOE in August 2016. Nagra still stands by its original conclusion: a repository can be constructed safely in Nördlich Lägern, but this is very challenging at greater depth in the Opalinus Clay. For Nagra, this represents a disadvantage in terms of safety.

#### **ENSI and the NSC agree to six of Nagra's seven proposals**

ENSI presented the results of its review of Nagra's siting proposals at the end of 2016 and published the associated safety-based review on 18<sup>th</sup> April 2017. ENSI agrees that the siting regions Jura-Südfuss, Südanden and Wellenberg, proposed for a low- and intermediate-level waste repository, should be placed in reserve. It also agreed that the focus should be on the Opalinus Clay as the host rock. Jura Ost and Zürich Nordost should undergo further investigation in Stage 3; both are suitable for a HLW and a L/ILW repository or a combined repository. However, ENSI is of the opinion that the Nördlich Lägern siting region should also be carried forward to Stage 3 as the reasons for placing it in reserve are not sufficiently robust. The NSC aligned itself with this conclusion. The Cantonal Working Group on Safety and the Cantonal Expert Group on Safety (AG SiKa/KES) had already come to the same conclusion in a technical report published in January 2016, agreeing that Nördlich Lägern should not be placed in reserve.

In its opinion on the completion of Stage 2 published in September 2017, the Cantonal Commission also came to the same conclusion as ENSI and the NSC. It found that the Sectoral Plan process has fundamentally proved to be effective, fair and transparent and assured the Federal Government of its continued support in the process. It also recommended several improvements.

#### **Before the decision of the Federal Council on Stage 2 – further wide consultation of all interested parties**

The SFOE carried out an overall evaluation of Nagra's proposals based on the review by the authorities and the opinions of the Cantonal Commission and the regional conferences and followed the lead of its technical authorities: the three siting regions Jura Ost, Nördlich Lägern and Zürich Nordost should be investigated further in Stage 3. The three-month open consultation phase with all reports, reviews and expert opinions began on 22<sup>nd</sup> November 2017. All interested parties have the opportunity to express their views on the results of Stage 2 and on the upcoming process. The central document is a results report (on Stage 2) with the relevant findings and the so-called object sheets for the siting regions.

Based on all the relevant facts, the Federal Council is expected to decide on Nagra's proposals and on the completion of Stage 2 at the end of 2018.

#### **Work for Stage 3 already underway**

Nagra's task now is to carry out geological investigations in the siting regions remaining in the process, followed by a further safety-based comparison in Stage 3. Building on this, the selection of the sites for which general licence applications will be prepared will be made by 2022. The projects will be further concretised together with the regions and the Cantons before the licence applications are submitted around 2024.

#### **3D seismic measurements complete**

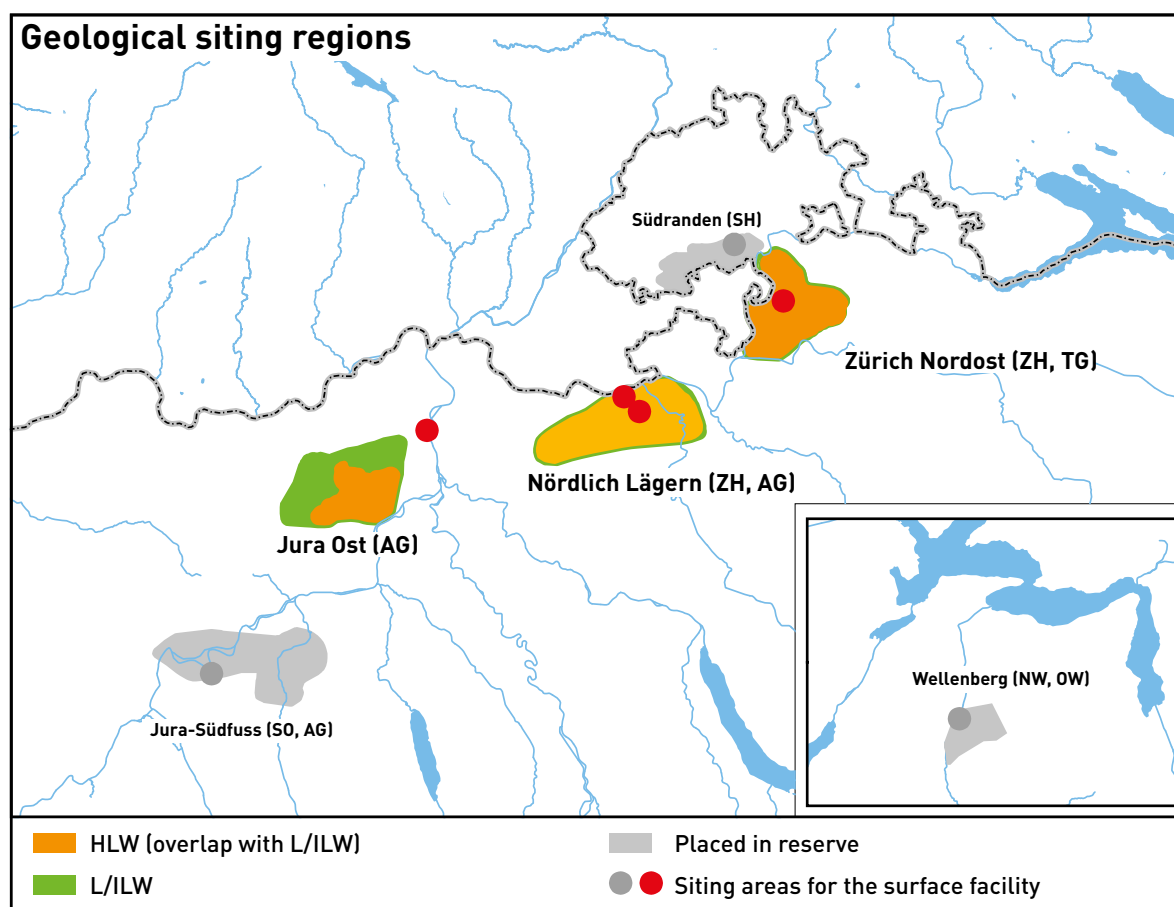
In the siting regions Jura Ost, Nördlich Lägern and Zürich Nordost, a total area of 200 square kilometres was investigated with seismic surveys between October 2015 and February 2017. Around 98% of the affected landowners and land managers who were contacted personally agreed to allow access to their land. Irrespective of their personal views on deep geological disposal, in this way they indicated their understanding that the work was necessary in the interest of safety. Due to this cooperation, it was possible to acquire a comprehensive database for all three regions. Data processing, analysis and interpretation are

already underway and should be completed by the end of 2018, initially without the detailed depth calibration provided by the exploratory boreholes.

### Applications for exploratory boreholes for all three regions under review

The planned exploratory boreholes (deep boreholes) represent a further important investigation tool in the three regions. These boreholes require a permit from DETEC. Nagra conducted discussions with the Cantons, local communities and landowners with a view to deciding on the locations of the drillsites; these have to comply with geological and spatial/environmental planning boundary conditions. Nagra submitted eight appli-

cations to the SFOE for each of the siting regions Jura Ost and Zürich Nordost at the end of September 2016; six applications for Nördlich Lägern were submitted in August 2017. The 30-day period of open inspection for the applications was initiated in spring for Jura Ost and Zürich Nordost and in November and December for Nördlich Lägern (for Glattfelden up to 16<sup>th</sup> January 2018). The number of objections lodged ranged from one to 140 for the individual applications. Nagra has already responded to the objections for Jura Ost and Zürich Nordost and the objectors were able to consider these responses at the beginning of 2018. Responses for Nördlich Lägern were in preparation at the beginning of 2018 and the first permits



Based on an extensive investigation programme and the results of the safety-based comparison, in January 2015 Nagra proposed the siting regions Jura Ost and Zürich Nordost for further investigation in Stage 3. In December 2016, ENSI recommended investigating the Nördlich Lägern region further in Stage 3 of the Sectoral Plan process. The Federal Council opened the period of open consultation at the end of November 2017. The decision of the Federal Council is expected at the end of 2018.



from DETEC are expected from the middle of 2018. Preparations such as setting up the drillsites will be followed by actual drilling work, planned for the beginning of 2019.

### **Quaternary investigations and other work**

The evolution of the land surface over the last two million years or so is investigated by studying layers of unconsolidated sediments. The aim is to be able to predict future long-term evolution, particularly of surface erosion, over several 100 000 years. Valleys that were overdeepened by glaciers and then refilled are investigated using 2D seismic cross-profiles and Quaternary boreholes.

2D seismics is specially designed for depths up to 400 metres and is aimed at locating the deepest point in profile sections in areas of overdeepening. At these locations, the unconsolidated rock filling the valleys is characterised using Quaternary boreholes. The seismic measurements in all the siting regions were completed in February 2017 and the evaluation of the data used for deciding on the locations of the Quaternary boreholes was completed in autumn 2017.

The first applications for Quaternary boreholes that did not require to be investigated in advance with 2D seismics were submitted to the SFOE in spring 2017 and the first permit was granted by DETEC on 22<sup>nd</sup> December 2017 in accordance with the Nuclear Energy Act. The Quaternary boreholes can be compared with boreholes for heat exchangers and will be drilled from 2018. They are usually around 100 metres deep, and in some cases several hundred metres. Drilling work will generally be carried out during the day, and at night for deeper boreholes.

Further geological investigations and studies will complete the databases for the documentation for site selection and the general licence applications.

### **Concretising the projects – discussion of the auxiliary access facilities**

Various facilities at the surface and underground are required for the operation of a deep geological repository. Additional accesses are required be-

## **REGIONAL CONFERENCES**

The regional conferences represent the interests of the siting regions in the participation process. They are made up of between 85 and 110 members, including representatives of local communities, regional organisations (e.g. associations or political parties) and individual members of the population.

Each regional conference has set up technical working groups that are responsible for considering specific topics in more depth and delivering informed opinions on these. All the regions have working groups on the surface facility, the socio-economic-ecological impact study and repository safety. The SFOE guides and supports the work of the conferences.

### **Information on the regional conferences (websites in German):**

Jura Ost:  
[www.jura-ost.ch](http://www.jura-ost.ch)

Jura-Südfuss:  
[www.jura-suedfuss.ch](http://www.jura-suedfuss.ch)

Nördlich Lägern:  
[www.regionalkonferenz-laegern.ch](http://www.regionalkonferenz-laegern.ch)

Südranden\*:  
[www.plattform-suedranden.ch](http://www.plattform-suedranden.ch)

Wellenberg:  
[www.plattform-wellenberg.ch](http://www.plattform-wellenberg.ch)

Zürich Nordost:  
[www.zuerichnordost.ch](http://www.zuerichnordost.ch)

\* Work suspended in autumn 2015

sides the surface facility and the main access for the transport of the radioactive waste from the surface to the underground facilities. In the case of shafts, these are the shaft head facilities; in the case of tunnels (ramps) they are termed portals. In November 2016, Nagra published a technical report providing a generic description of these auxiliary accesses and their infrastructure at the surface. The report was presented to the regional conferences and their surface facility working groups in 2017 and the first discussions were held with the cantonal departments under the lead of the federal authorities on criteria for the spatial configuration of these facilities. In contrast with

the areas for the surface facilities, the freedom in laying out these facilities is more restricted as their location is tied more strongly to the underground facilities. Proposals for auxiliary access facilities for all three siting regions will be prepared in 2018 and will be discussed in the regional conferences from the start of Stage 3 in 2019.

### **The final step: expected decision via the ballot box**

Based on the results of the investigations in Stage 3, Nagra will select the final repository sites (one each for a HLW and a L/ILW repository or a combined repository) and prepare the associated general licence applications. The applications are reviewed by the safety authorities and opened for public consultation; the Federal Council and Parliament then decide on the applications. The decision by Parliament is subject to an optional national referendum. If such a referendum is called for, the final say in the Sectoral Plan process would thus lie with the Swiss voters.

### **PRACTICAL EXPERIENCE IN THE TRUEST SENSE OF THE WORD**

Jennifer Anspach, geologist



"After my Masters in palaeo-climatology, my internship at Nagra was really applied research and not 'just' basic research", explains Jennifer Anspach, who studied geological sciences in Geneva and Zürich. For her university qualification, she studied sediment samples from rivers in Greenland and compared the resulting data with core samples from ocean floors that were believed to contain sediments from Greenland. "This allowed me to draw conclusions about the former size of the Greenland icesheet", she says.

At Nagra, Jennifer Anspach looked at karst deposits in Northern Switzerland, more specifically at the karstification of the Upper Malm limestones during the Lower Tertiary, a geological period covering 66 to 23 million years ago. Karst is produced by the chemical dissolution of limestones. The term also applies to a type of landscape found, for example, in the Jura. In hydrogeological terms, karst forms an underground drainage system consisting of channels and cavities. Jennifer Anspach studied the technical literature in detail, including reports on the construction of different tunnels, and investigated drillcores. This allowed her to obtain a better picture of the karst situation in Northern Switzerland. "The karstification of limestones gives geologists indications of where new water flowpaths could form", she explains. "The karst in the limestones of the Malm is of particular interest as it could be encountered during the construction of a ramp, an access tunnel to a repository, and also during the construction of shafts", she continues. These access structures have to be sealed against penetration of water. "In the siting regions proposed by Nagra, boreholes to date have encountered karst filled with sediments", she adds. Large cavities were not found.

Jennifer Anspach's work will provide the basis for further investigations and future planning. "I really enjoyed the work", she says. "I find it fantastic that my scientific investigations had such practical significance."

## COLLABORATION WITH THE REGIONS

The regional conferences provide information to their members and the opportunity to discuss topics relating to the site selection process for deep geological repositories (photos right and below the text-box).

In 2017, Nagra provided information on the planned exploratory boreholes in the Nördlich Lägern region (photos bottom left and centre).

Hanspeter Lienhart, president of the Nördlich Lägern regional conference, visited Nagra in June 2017. In his presentation, he spoke about how Nagra is perceived in the region (photo bottom right).











Compared to 3D seismics, smaller vibrator vehicles are used for 2D seismics. Around 53 kilometres of measuring lines with 15 000 geophones and 8000 shotpoints were laid out in all three siting regions.



# Scientific-technical background

The aim of the research and development work in 2017 was to expand the existing knowledge base for evaluating the safety of the deep geological repositories. Barrier concepts were optimised and alternatives developed further. Nagra's medium-term focus is on preparing the background for the general licence applications in Stage 3 of the Sectoral Plan process. The nature and scope of the work is defined based on the results of a review of the current status of science and technology and the resulting planning as outlined in Nagra's updated RD&D Plan (see text-box below right). The RD&D Plan was published in December 2016 and reviewed by the authorities in 2017. The report describes the activities planned for the next five to ten years. The resulting projects and work will be undertaken by Nagra according to a priority plan that ensures the continued focus of studies, modelling and the experiments in research laboratories and in the Mont Terri and Grimsel rock laboratories on the general licence applications.

## Geological field investigations

Preparations for the field investigations required in Stage 3 continued according to plan. The 2D seismic measurements for investigating the Quaternary (ice-age) deposits were completed successfully in the three siting regions. At the beginning of March 2017, the first application for a Quaternary borehole was submitted to the responsible authorities. The planned drilling depth is several tens to several hundreds of metres. The application was approved at the end of 2017 with conditions but without any objections. The Quaternary borehole programme will begin in spring 2018.

The 3D seismic measurements in the Nördlich Lägern region were also completed successfully at the beginning of 2017. With more than 17 000 excitation points and around 20 000 measuring points, the survey covered a total of 92 square kilometres in 17 communities – also including Germany – and extended over 77 days. The time-consuming data processing and analysis for the campaigns in Jura Ost and Zürich Nordost are

running according to plan. It is already clear that the data quality is very good and the measurements for the containment-providing rock zone are highly informative. The checking and calibration of the 3D seismics results will require exploratory boreholes to be drilled several hundred metres into the consolidated rock.

Six potential drillsites were evaluated in the Nördlich Lägern region and applications for permits were submitted to the authorities in August 2017. These were checked for completeness and then opened for public inspection in the relevant communities. The period of open inspection began in spring 2017 for the 16 applications submitted in 2016 for Jura Ost and Zürich Nordost. In parallel with this, work continued on the planning of drilling activities and measurements for the borehole campaign.

Numerous information events and distribution of fact-sheets in the communities were used to inform the public on the planned drilling campaigns. Objections and opinions were collected and are currently being addressed.

## RESEARCH AND DEVELOPMENT PROGRAMME (RD&D PLAN)

The R&D Programme forms the planning framework for the ongoing optimisation of the existing repository concepts, with remaining uncertainties being reduced and scientific advances being taken into consideration. The research activities cover a wide spectrum of topics: from gas transport and consumption in a repository through the behaviour of the engineered barriers to monitoring of a repository. Nagra will also carry out further geological investigations to characterise the underground environment in the siting regions and refine the knowledge of safety-relevant processes in the host rock. Investigations will also continue on long-term geological evolution such as erosion and climate developments.

In the Zürich Nordost region, field investigations are looking at the local groundwater situation in the Isenbuck/Berg area. This was requested by the regional conference. Measuring stations have been installed at this potential location for a surface facility and hydrogeological mapping and measurements carried out (see text-box below).

### Long-term safety analysis

In the area of long-term safety analysis, the focus was on carrying out extensive probabilistic sensitivity analyses on radionuclide release for both the L/ILW and HLW repositories. The aim was to have an objective review of the indicators used to date in the Sectoral Plan process and of the associated requirements and evaluation scales relating to the retention function of the geological barrier.

Using the current knowledge base for the geological siting regions Jura Ost, Nördlich Lägern and Zürich Nordost and the spectrum of potential repository layouts, around 10 000 release and dose calculations were carried out for each repository type. These were analysed using special probabilistic sensitivity analysis methods according to the current status of science and technology.

The results confirm the current system understanding and also provide new information on the connections between the properties of the preferential release pathways for radionuclides (faults and so-called “hard beds”) and their location relative to the disposal rooms. Knowledge of these connections is important for selecting the sites for the general licence applications.

### Geochemical retention processes and transport mechanisms

The retention (sorption) of radionuclides on clay surfaces is a key process in repository host rocks and confining units that are rich in clay minerals, and the process therefore has to be considered in safety analysis. The existing sorption model is being developed further to provide an integrated approach: from a sorption database for pure clay minerals and site-specific rock and porewater compositions, a flexible approach can be used to develop reliable datasets for safety analysis.

In 2017, important groundwork was laid for the further development of the sorption model with two reports documenting the thermodynamic sorption database for the two key clay minerals illite and montmorillonite. Data were also obtained on the mutual influence of sorption of radionuclides, so-called competitive sorption. This is an important process that is also considered by Nagra in its integrated approach. Important elements for parameterisation of sorption in the safety analyses are thus available. The fundamental understanding of the processes also provides additional sound arguments for the safety case.

#### “I HAVE NO REGRETS ABOUT MY CHANGE OF PERSPECTIVE”

Sacha Reinhardt, hydrogeologist focusing on in-situ borehole investigations



With more than 14 years of professional experience, Sacha Reinhardt is one of Switzerland’s most experienced specialists in hydrogeological investigations directly in the borehole. As part of the characterisation of regional groundwater aquifers and the host rock and confining units, he already carried out tests in exploratory boreholes for Nagra years ago as an employee of an external company.

Reinhardt then gave up his job. “Our family caught the travel bug”, he explains, “and we fulfilled a long-held dream – a journey by train and bus from the Caucasus to Iran.” On his return, he was offered the opportunity of a temporary position with Nagra. “I did some research on the latest developments and new technologies and equipment for optimising hydrogeological investigations in exploratory boreholes”, explains Reinhardt. He was thus able to make a valuable contribution to the groundwork for the boreholes.

He was then involved in Nagra’s groundwater investigations in the Isenbuck/Berg area, the planned siting area for a surface facility in the Zürich Nordost siting region. “We were able to perform a hydrogeological characterisation of the shallow ice-age deposits and investigate the locations of aquicludes and aquifers.” The flow direction and rate of the groundwater was also determined. “For this we installed numerous groundwater measuring stations at depths between 6 and 30 metres”, explains Reinhardt. Fluctuations in the groundwater table can be measured and water samples collected. He does not regret the change of perspective: “For once I was working not in the role of a contractor, but with Nagra, in the role of the client. I really enjoyed the work – the people were cool and the projects were exciting!”

### Repository-induced effects

The long-term safety of a deep geological repository can be adversely affected by different repository-induced effects. These include the spatial and temporal evolution of an excavation damaged zone in the host rock during the construction of the underground facilities, and gas formation and accumulation due to corrosion and degradation processes after repository closure. Thermo-hydro-mechanical interactions due to the heat production of high-level waste and hydrochemical interactions between the engineered and geological barriers also have to be considered.

During the year, the focus of the work on repository-induced effects was on identifying and characterising the indicators used for evaluating the barrier integrity and the analysis of transport pathways for gas and radionuclide release. A so-called storyboard was also prepared that describes the sequence of safety-relevant processes and phenomena over the entire time period of construction, operation and closure.

### Models of the repository environment

Other important activities involved model-based analyses. Thermo-hydro-mechanical modelling can be used to estimate the relevance for safety of repository-induced influences. Site-related repository environment models were developed for the siting regions Jura Ost, Nördlich Lägern and Zürich Nordost for a L/ILW and HLW repository. A model-supported indicator method was developed that allows a quantitative comparison of potential repository configurations in the three siting regions using suitability indexes which flow into the safety evaluation. The method was tested and documented in a dry run for the safety-based comparison.

### Alternative canister designs and materials

Collaboration continued with Nagra's Canadian sister organisation NWMO on the development of a copper-coated SF/HLW canister. The innovative programme is being followed with great interest by other sister organisations, and the Japanese waste management organisation NUMO joined as a partner in 2017. Both the 'cold spray' method

used in the vicinity of the welding seam and electrolytic deposition of the copper layer for the rest of the canister surface were developed further. In the case of the cold spray technique, progress was made particularly with respect to process automation and optimisation of costs. For electroplating, more homogeneous layers can now be applied. The production line was optimised and scaled by making modifications to the design of the electrolyte bath.

To improve process understanding in the near-field of the HLW repository, a modelling study was carried out on the migration of sulphide. Sulphide could have a significant influence on copper corrosion. The results of the study will provide input for determining the required thickness of the copper coating of the canisters in the context of this specific disposal concept.

The variant of a disposal canister made of cast iron with a steel lid was also pursued further. Experiments were initiated on welding the lid together with the canister. Work was also carried out with Empa on the feasibility of alternative coating methods with materials such as nickel, titanium or ceramics.



### THE FOCUS ON FIELD WORK CONTINUED IN 2017

The 3D seismic campaign and the 2D seismic measurements were completed successfully in February and Nagra also carried out shallow boreholes and measurements in the siting regions.

Potential glacial deposits were investigated in the Feusi gravel pit near Oberweningen (see photos right). These could provide evidence of an old glacial advance. Past glaciations deliver information on the possible extent of future glaciers, which is important for modelling erosion scenarios.











Michael Treuthardt, a member of the technical services team at the Grimsel Test Site, supports scientists in performing their experiments.



# Rock laboratories

## Grimsel Test Site (GTS)

Nagra has been conducting research at the Grimsel Test Site (GTS) for almost 35 years and more than 20 partner organisations from around the world are currently involved in the projects. The laboratory is located at a depth of 450 metres in the crystalline formations of the Aar Massif in the Bernese Alps and hosts different experiments aimed at testing and further developing concepts for safe disposal of radioactive waste in deep geological repositories. The GTS is now recognised worldwide as an important research platform in the general field of geosciences.

### Ideal boundary conditions

The favourable geological conditions at the site, the enormous wealth of experience and excellent infrastructure offer ideal working conditions for researchers from a wide range of disciplines. This is reflected in the interest shown by national and international research institutes who are involved in partner projects or are performing their own experiments. An important contribution to knowledge transfer is made by the "Grimsel Training Centre" (GTC) that organises summer schools and training courses.

### Involving the partners is important

The GTS partners come together every year in June in the Grimsel region for the International Steering Committee Meeting (ISCO). They discuss current research results and financial aspects. ISCO also considers the initiation of new projects and decides on the future strategic direction of the rock laboratory.

### Well anchored in the local region and visible beyond national borders

The Grimsel Test Site is well established in the local communities of Guttannen, Innertkirchen and Meiringen and continues to work closely with local companies. Regular information exchanges were held as part of the highly successful partnership with the local hydropower company Kraftwerke Oberhasli (KWO), from which both sides benefited during the year. There is excellent collaboration with the operating personnel of the

power plants Grimsel I and II, the KWO visitors' service and the Grimsel hotels.

In 2017 the doors of the rock laboratory were opened again to numerous visitor groups from Switzerland and abroad, with 1214 people visiting the facility. Several journalist groups were also welcomed to Grimsel, including KBNe – the Korean Broadcasting Network of South Korea. High-level representatives from the fields of politics and economy also paid a visit, for example the Vice-President of the China National Nuclear Corporation.

#### "I NEVER IMAGINED MYSELF WORKING IN AN OFFICE"

Andrea Wettstein-De Marco, assistant, Grimsel Test Site



"Direct contact with people has always been important to me", says Andrea Wettstein. "This was behind my decision to train as an assistant with the post office. Working at the counter gave me plenty of customer interaction." In her current position with Nagra, she also has contact with people within and outside Nagra. Andrea Wettstein has worked for Nagra since 1999 as assistant to the Head of the Grimsel Test Site. However, her workplace is not in the rock laboratory itself but in the offices of Nagra in Wettingen. "I never imagined before that I would work in an office", she says smiling. Her responsibilities include administrative work such as preparing contracts and invoices, finalising protocols and, of course, supporting her boss. Andrea also organises project meetings and workshops, which she particularly enjoys. This includes the teaching offered by the "Grimsel Training Centre", which provides scientists from all over the world with further training on subjects such as the behaviour of the engineered barriers or hydraulic investigations in the rock.

A regular highlight for Andrea Wettstein is the ISCO meeting, during which partner organisations meet for two days every year in the Grimsel region to exchange information on their projects. "I am responsible for organising everything from A to Z", she explains. She is then "on site" with the project managers and scientists and is always happy to see well-known faces. She also helps to organise tours for foreign visitor groups wishing to experience the rock laboratory. The transport to Grimsel and the visit to the "tunnel" require careful organisation. "I find it exciting that the rock laboratory is active in an international context", she adds. "This allows me to put my language skills to use and to learn something about the customs and traditions of other countries."

Finally, she adds: "I am proud that my work with Nagra and the Grimsel Test Site allows me to make a contribution to the safe disposal of radioactive waste in Switzerland. We are responsible for taking care of our waste."

## MAIN PROJECTS AT THE GRIMSEL TEST SITE

### **CFM (Colloid Formation and Migration) Fundamentals of radionuclide migration in crystalline rock**

Formation and transport of colloids and their influence on radionuclide mobility

### **EBS Lab (Engineered Barrier Laboratory)**

Small- to medium-scale experiment with the components of the engineered barriers and measurement of parameters

### **FEDEX (Full-scale HLW Engineered Barriers Experiment)**

1:1 demonstration of the emplacement concept for high-level waste (experiment complete, final reporting underway)

### **FORGE<sup>1</sup> (Fate of Repository Gases)**

Experiments on gas migration in engineered barriers (bentonite/sand)

### **GAST (Gas-Permeable Seal Test)**

Gas sealing experiment: controlled gas transport through the engineered barriers (gas-permeable tunnel seals for the L/ILW repository under realistic conditions and on a realistic scale)

### **ISC (In-situ Stimulation and Circulation Test)**

Controlled hydraulic stimulation of existing fault zones  
Sub-project of the ETHZ-DUG-Lab project  
(SCCER-SoE, Swiss Competence Center for Energy Research – Supply of Electricity)

### **LASMO (Large-Scale Monitoring)**

Monitoring and characterisation of the geosphere

### **LCS (Long-term Cement Studies)**

Long-term interactions between cement solutions, porewaters and rock; cement injection experiment (experiment complete, final reporting underway)

### **LTD (Long-term Diffusion)**

Long-term diffusion of radionuclides

### **MaCoTe (Material Corrosion Test)**

Corrosion experiments (engineered barrier system components)

### **Plug Experiment (Engineering Studies and Demonstration of Repository Designs, previously an ESDRED sub-project)**

<sup>1</sup> Sub-project of an EU project

New projects running or in planning:

### **HotBENT (High-Temperature Bentonite Project)**

Investigations of the safety function of bentonite barriers under increased temperatures

### **CIM (C-14/I-129 Migration Through Aged Cement)**

Testing the transport properties of C-14 and I-129 through cement barriers

## High safety standards

The annual inspection of the radiation-controlled zone at the GTS by the responsible supervisory authority, the Federal Office of Public Health (FOPH), confirmed the high standard of the work with radioactive elements. Concepts for future experiments using radioactive tracers were also discussed with the FOPH and open questions addressed. The rock laboratory was also inspected from the viewpoint of worker safety and electrical safety and again high working and safety standards were confirmed.

## Current experiments at the Grimsel Test Site

The deep geothermal project ISC is led by the ETH Zürich and runs under the auspices of the Swiss Competence Center for Energy Research – Supply of Electricity (see box left). It provides baseline data for developing concepts for the use of deep geothermal energy and minimising the seismic impacts. A total of 15 boreholes were drilled and geophysical and hydrogeological investigations performed. The boreholes were equipped with the most-up-to-date technology for measuring deformation behaviour, pressure and temperature changes. In 2017, various rock formations (intact or fractured) were stimulated to improve the flow conditions and thermal circulation experiments were then performed.

The in-situ radionuclide experiments of the CFM and LTD projects in the radiation-controlled zone are still in the long-term phase of monitoring and sampling. As part of the CFM experiment, further characterisation and design work was carried out for the planned i-BET experiment. The field experiment should start at the beginning of 2018 and will examine the erosion of bentonite material under realistic in-situ conditions. In the LTD project, three boreholes were drilled for the in-situ experiment “Monopole-2”. Sample material was sent to Finnish, Czech and Japanese project partners (including SÚRAO, NUMO/JAEA) for analysis to determine the distribution of the radionuclides HTO (tritium) and Cl-36.

As part of the GAST gas sealing experiment, preparations were made for the first gas test, which is planned for the beginning of 2018. The measurement of gas-relevant parameters requires the pore pressures in the sealing section to be as homogeneous as possible, which is achieved by targeted control of the water injections. The injection system was developed using simulation calculations and installed in situ.

In the MaCoTe corrosion experiment, additional sample analyses were carried out and a further heated module of the project partner SÚRAO/UJV constructed. The non-heated modules of the partner NUMO were prepared for installation (beginning of 2018).

### Preparing for new projects

As part of the CIM migration experiment, the experiment design was further refined using modelling results and based on discussions with the project partners. The aim is to circulate a tracer cocktail with C-14 and iodine in a borehole filled with mortar that has been in contact with granite and groundwater for twelve years. This will allow the transport behaviour of radionuclides to be studied. The start of the field and laboratory work is planned for the first half of 2018.

The focus of work for the HotBENT project was on performing a pre-design study and preparing for a detailed design study. The calibration experiments for determining the dry density and the water content of the granular bentonite using heatable fibre-glass cables continued.

### "HOPEFULLY NOT ONLY MY CHILDREN AND CHILDREN'S CHILDREN WILL BENEFIT FROM MY WORK"

Berrak Firat Lüthi, engineering geologist



Berrak Firat Lüthi comes from Ankara in Turkey. "I came to Switzerland to do my Masters degree at the ETH in Zürich." And she continues with a smile: "The other reason was my Swiss husband." For her Masters, she measured the hydraulic conductivity in a groundwater aquifer, an important parameter for water transport in the ground. "Since August 2016 I have been working as an intern with Nagra on the EU Modern2020\* project", adds the engineering geologist, and explains that meaningful work is important to her. "I feel I can contribute to the safety of deep geological repositories and hopefully not only my children and my children's children will benefit from this."

The working location at Grimsel was something new for the young researcher. She was based in the Nagra rock laboratory for six months, carrying out experiments 450 metres below the surface. "In the evening I enjoyed the fresh air so much more", she says. She lived in friendly surroundings in a hotel – as she stresses herself – in the mountain village of Guttannen. She was involved in an EU project with a research community of 30 organisations and 12 countries, all with a common goal: "The aim of Modern2020 is to test, develop and apply measurement techniques for monitoring a future repository", she explains. "At the Grimsel Test Site, I carried out detailed tests on a new measurement technique for temperature using a fibre-optic cable", says Firat Lüthi. "A conventional temperature sensor can only be used to measure at one location." However, a whole temperature profile can be obtained as simultaneous measurements can be made along the cable. "To familiarise myself with the method, I started by experimenting in bentonite with a short cable", she continues. Water content, density and thermal conductivity of the clay-rich bentonite have an influence on temperature measurements. "With a measured temperature profile and comparative measurements, I can draw conclusions on these properties of the bentonite", she explains.

The aim is to use this method in future tests in rock laboratories and then in the pilot facility of a deep repository to monitor the waste that gives off heat to the surrounding rock. Bentonite is used to backfill and seal tunnels. The experimental phase in the rock laboratory is complete: "I am now evaluating the results and writing project reports." She enjoyed both project phases – both were also necessary to allow the other project partners to benefit from her experience. "I am given great support at Nagra", she summarises, "which allows me to implement my own ideas and learn a huge amount." She really enjoys living in Switzerland and working with Nagra. "My next project is to work on my German."

\*Modern2020 stands for "Development and Demonstration of Monitoring Strategies and Technologies for Geological Disposal".

## Nagra participation in experiments at the Mont Terri Rock Laboratory (FMT)

Experiments on characterisation of the Opalinus Clay have been underway in the international Mont Terri Rock Laboratory in Canton Jura since 1996. The rock laboratory gives Nagra the opportunity to investigate the properties of the Opalinus Clay that are relevant for disposal of radioactive waste. 16 partner organisations from 8 countries are cur-

rently involved in the research projects. The investigation programme is drawn up by a committee on which each partner is represented. The Mont Terri project is led by the Swiss Federal Office of Topography (swisstopo) and is supported by a "Commission stratégique". The interests of Canton Jura are represented by the "Commission de suivi".

### Expansion of the laboratory

In 2017, the financing for the expansion of the laboratory was secured. Tendering for the construction work under public procurement law led to a contract being awarded for the excavation and lining work. The work is expected to start in the first quarter of 2018 and will last till the end of 2019. The expansion will almost double the available space. Visitors will still be welcome during the construction phase.

### Focus of the work

Based on Nagra's multi-year research plan and recommendations made by the authorities, the focus of the work is on closer investigation of the properties of the Opalinus Clay host rock (FS-A, GC, HA-A, LT-A experiments), diffusion of radionuclides in the Opalinus Clay (DR-B experiment), generation of gas (FE-G), the corrosion of construction and container materials (IC-A) and the continuation of the long-term experiment on the interaction between Opalinus Clay and cement (CI experiment). The emplacement and heater experiment (FE-M) continues to deliver a large volume of high-quality data on the evolution of the near-field of a deep geological repository. Various tunnel structures (TS experiment) and their influence on the formation of the excavation damaged zone will be investigated in connection with the expansion of the laboratory.

### Quantifying rock properties

Rock properties and behaviour are being investigated in detail in the GC experiment. Core samples are collected in the rock laboratory and used in an external laboratory for novel deformation tests. These are appropriate for the high specific requirements of the Opalinus Clay. Geomechanical investigations can be carried out directly in a bore-

### "MANY OF NAGRA'S PROJECTS ARE UNIQUE"

Fabian Ammann, geophysicist



Fabian Ammann has worked for Nagra three times. "You could call me a repeat offender", he says laughing, "but this opportunity provided me with an insight into a range of projects." He worked on the Full-scale emplacement experiment (FE experiment) at Mont Terri, where Nagra is gathering practical experience with the waste emplacement process in a later repository for heat-producing high-level waste. Numerous sensors are being used to measure the effects of heat on the tunnel backfill and the surrounding rock – the Opalinus Clay. The sensors measure temperature,

humidity, pressure and deformation. "During my first internship, I wrote software scripts for graphic presentation of the sensor data", explains Ammann.

"Later, I compared the highly accurate measured values from the temperature and humidity sensors with data from geophysical measurement methods such as ground radar and seismics", continues Ammann. "My aim was to find out whether temperature and humidity could also be measured sufficiently accurately using these techniques."

"I also worked on the DR-B long-term diffusion experiment", says Ammann. In this experiment, Nagra is using a non-radioactive form of iodine to expand its understanding of the migration of radionuclides in the Opalinus Clay. Ammann was involved in the preparations for the experiment, in which iodine is released in a central borehole, migrates slowly through the Opalinus Clay and can be detected after years in three surrounding observation boreholes. "The measuring tool used to detect elements such as iodine, caesium and uranium directly in the Opalinus Clay works with X-rays", he explains. "At the beginning we used the tool to characterise all three observation boreholes", he continues: "This allows us to obtain a geological image of the minerals and fractures with the exact position in the boreholes." In the subsequent measurements with iodine, it is therefore clear what and how much was already in the rock.

"All my internships were very varied and involved applied research", says Fabian Ammann. "I appreciate the pioneering role adopted by Nagra in such experiments." There are not so many researchers in this area worldwide. "Many of Nagra's projects are unique", concludes Ammann.

hole (using dilatometers and petrophysical measurements); this provides information on rock behaviour and properties.

The measured values for rock samples obtained in an external laboratory under controlled conditions have to be transferable to in-situ investigations. This consistency is particularly important for data interpretation for upcoming exploration work in Northern Switzerland, where the Opalinus Clay will be investigated in deep boreholes under difficult conditions (drilling fluid, large depths).

#### KEY EXPERIMENTS IN THE MONT TERRI ROCK LABORATORY

##### CI (Cement-clay interaction)

Mineralogical interaction between claystone and cement

##### CI-D (Diffusion across concrete/claystone interface)

Diffusion across the concrete/claystone interface

##### DB (Deep inclined borehole through OPA)

Cored borehole through the Opalinus Clay

##### DR-A (Diffusion and retention)

Diffusion and retention of radionuclides

##### DR-B (Long-term diffusion experiment)

Long-term diffusion experiment

##### FE (Full-scale emplacement experiment)

1:1 emplacement experiment for investigating the near-tunnel environment, with sub-projects:

FE-G (Gas evolution in the FE experiment)

FE-M (Monitoring of the FE experiment)

##### FS-A (Friction properties of Opalinus Clay)

Laboratory investigations of hydromechanical properties of tectonically reactivated Opalinus Clay

##### FS-B (Imaging the long-term loss of faulted host rock integrity)

Imaging the long-term integrity loss of disturbed host rock zones

##### GC (Geomechanical in-situ characterisation)

Investigation and conceptualisation of tectonic fracture patterns

##### GD (Geochemical data)

Analyses of geochemical data

##### HA-A (Hydraulic & geophysical parameter variability)

Variability of the hydraulic and geophysical properties of the Opalinus Clay

##### HE-E (Heater experiment)

Behaviour of the engineered barriers under the influence of heat

##### IC-A (Corrosion in bentonite)

Corrosion behaviour of various types of metal in bentonite

##### LP-A (Long-term monitoring of pore pressures)

Investigation of flow processes along water-conducting systems

##### LT-A (Properties analyses labtesting)

Laboratory investigations of the properties of Opalinus Clay

##### MA (Microbial analyses)

Investigation of microbial reactions

##### MA-A (Modular platform for microbial studies)

Microbial processes in the bentonite barrier

##### SO-C (Facies analysis of the upper Opalinus Clay and the transition to the Passwang formation)

Facies analysis of the upper Opalinus Clay and the transition to the Passwang formation

##### TS (Testing different tunnelling support in sandy facies)

Testing possibilities for tunnel support in sandy facies

##### WS-I (Investigation of wet spots)

Understanding the self-sealing of the EDZ (Excavation Damaged Zone) and tectonic faults









### RESEARCH IN THE ROCK LABORATORIES

In the Swiss rock laboratories, Nagra and its partners are investigating the geological, chemical and physical processes that will occur under similar boundary conditions in a deep geological repository. Of particular importance are the effectiveness and long-term behaviour of the engineered and geological barriers under a range of influences: corrosion of the disposal containers, migration of radionuclides in the rock, the removal of gas and heat, etc.

The experiments help to improve process understanding, develop models for making predictions and deliver data for model calculations. Drilling technologies are also optimised and sensors developed and tested.







The annual ISCO meeting took place again in 2017, giving representatives of the Grimsel partner organisations an opportunity to exchange information about their projects. Around twenty partner organisations currently participate in the scientific studies being conducted at the Grimsel Test Site.





# International Services and Projects

With its continually increasing know-how, growing number of scientific staff and strengthening of its pool of experts, Nagra is in a strong position to effectively support its partners as well as other organisations.

## **Continuation of projects in Japan and South Korea**

In Japan, the focus of the collaboration with Nagra's sister organisation NUMO was on the methodologies and key quality management tools for the first two phases of the site selection process. The collaboration included hands-on know-how transfer through staff attachment. The exchange of information with RWMC in 2017 focused on the reviews of Nagra's proposals for Stage 2 of the Sectoral Plan process.

Studies continued in the rock laboratories and on neotectonics with the Japan Atomic Energy Agency (JAEA). Instrumentation and data analysis technologies were further developed with Obayashi Corporation. In South Korea, the collaboration with KORAD covered various aspects of site exploration and selection, as well as planning of the rock laboratory.

## **Expansion of European collaboration**

Several projects and consulting assignments were carried out for RWM (UK). Phase two of the project on the sealing of exploratory boreholes culminated in a field demonstration of the developed engineering methods. This next phase of the project began in June 2017. With SÚRAO (Czech Republic), Nagra collaborated on the planning of the experimental work in their Underground Research Laboratory, and with ONDRAF/NIRAS (Belgium) on the management strategy and system for the safety case. Finally, in Germany Nagra successfully applied its state-of-the-art approach on radiological assessment of reactor components, providing the basis for the optimisation of decommissioning waste packaging.

## **Training courses, a new project and advisory functions**

In Switzerland, Nagra conducted three tailor-made training courses on hydraulic testing and on the characterisation of excavation damaged zones and, in November, started a new project for the geoscientific characterisation of a landslide-prone construction site.

Nagra's experts were also involved in several high-level advisory groups and steering committees in Canada (NWMO/Geoscience Review Group), Finland (Posiva/safety case for the operating licence) and Japan (NUMO/Technical Advisory Committee).

## **INTERNATIONAL SERVICES AND PROJECTS (ISP)**

Nagra's ISP Division is responsible for projects with funding sources outside the Swiss national programme, as well as for the Grimsel Test Site. The activities cover a wide spectrum of projects in the radioactive waste management field – strategic programme planning, specification of waste inventories, site selection, characterisation and evaluation, repository design, safety case development, safety analyses, public communication, focused training and know-how build-up, as well as projects in other scientific and technical fields such as geothermal exploration.



# International collaboration

A regular exchange of information between Nagra and around 15 foreign partner organisations takes place within the framework of the various formal bilateral agreements. Joint projects are also carried out with several partners, either on a multi-lateral basis (e.g. rock laboratory projects in Swit-

zerland and abroad) or together with international organisations. Joint projects are also run in the laboratories of various research institutes as well as on the development of models and the evaluation of databases. Besides the formal collaboration structure, international contacts have also generated a close network of personal relationships, which provide Nagra scientists with opportunities to informally discuss technical issues with their peers.

Nagra's participation in the EU Framework Research Programmes represents an important component of its research and development activities. Collaboration with EU partners has been strengthened by Nagra's involvement in the "Implementing Geological Disposal of Radioactive Waste Technology Platform" (IGD-TP). Technical-scientific projects have started on several topics or are being discussed in working groups.

Nagra scientists also continue to be represented in numerous advisory bodies and working groups of sister organisations as well as of the OECD/NEA.

## Clay Conference 2017 in Davos

The 7<sup>th</sup> international conference on "Clays in Natural and Engineered Barriers for Radioactive Waste Confinement" was held from 24<sup>th</sup> to 27<sup>th</sup> September 2017. Nagra was among the conference organisers, welcoming 426 scientists from 23 countries to Davos to exchange expertise on the use of clays and clay materials in waste disposal. Nagra staff presented or co-authored 25 of the total 130 scientific publications. Numerous informal meetings with other waste disposal organisations and research institutions took place throughout the Conference.

## Framework Research Programmes of the EU

The Framework Research Programmes of the EU are specifically aimed at promoting a European research environment and are an important instrument for promoting collaboration on research projects within Europe. The challenges faced by industry and society today should be solved together and not at an individual state level.

### "I HAVE THE MOST EXCITING JOB IN NAGRA"

Cornelia Wigger, geographer



Cornelia Wigger wrote her doctoral thesis at the Paul Scherrer Institute. "On behalf of the Canadian waste disposal organisation NWMO, I examined the migration of anions through clay. Nagra was one of the organisations that provided me with rock samples", she explains. Like Switzerland, Canada is conducting research on clays for the disposal of radioactive waste. Her doctoral thesis provided Wigger with an insight into Nagra's work, and she was impressed with its concentration of expertise. "More than one hundred staff

members work together at Nagra to solve an important task of national and societal relevance". That was reason enough for Cornelia Wigger to begin a four-month internship at Nagra before she completed her doctoral thesis.

During this internship, she joined the EU project "Beacon" (Bentonite Mechanical Evolution) for Nagra. "For once I could leave the laboratory but still carry out applied research", Wigger says. She collected research data from waste disposal organisations regarding the mechanical behaviour of bentonite. "I enjoy gathering wide-ranging pieces of information and placing them into a larger context to see the bigger picture", Wigger comments and explains: "There are various ways in which bentonite is used to seal deep repository tunnels". Bentonite is used in granular form in Switzerland, as balls the size of golf balls in France and as blocks in Sweden. "Bentonite should be as homogeneous as possible to optimise the sealing properties", Wigger clarifies, and these safety aspects are the focus of the Beacon project. "Thanks to the EU project, I gained an insight into geomechanics and was able to expand my horizons", she summarises. She greatly appreciates the interdisciplinary cooperation between different nations as opposed to conducting research in isolation.

With her degree in geography, including a minor in geology, and the Nagra expertise she had already acquired, the young natural scientist was a perfect fit for the job of a spatial and environmental planner Nagra was looking for in late 2017. "I applied the moment I saw the job offer", Wigger states. She was given the job before she had completed her internship. Now she is responsible for the spatial and environmental aspects of planning the surface infrastructure of a deep geological repository. This puts her in touch with government agencies and external contractors. "I like diverse interface functions such as these", Wigger says and adds, "I think have the most exciting job in Nagra".

“Horizon 2020”, the 8<sup>th</sup> Framework Research Programme on research and innovation, was launched in January 2014. Based on a research agreement between Switzerland and the EU, Swiss scientists can fully participate in the EU Programmes. In return, Switzerland makes a direct contribution to the total research budget.

The research projects in the area of the deep geological disposal of radioactive waste allow Nagra to expand its technical knowledge base continuously and efficiently and to be instrumental in shaping important developments in Europe. In 2017, Nagra participated in various projects (see text-box to the right).

Within the framework of the “Horizon 2020” programme, Nagra is participating in the projects “Modern2020”, “CAST” and “Beacon”. It also benefits from the projects “MIND” (microbial processes in deep geological repositories), “DISCO” (investigating the dissolution behaviour of spent mixed-oxide fuel assemblies or of doped fuel assemblies in a geological repository environment), “THERAMIN” (using thermal treatment to minimise the volume of radioactive waste and to reduce its disposal risk) and “Cebama” (cement interactions).

#### **“CAST” project to be completed soon**

The corrosion of activated steel and Zircaloy as well as the leaching of ion-exchange resins and irradiated graphite release C-14 from radioactive waste, which is relevant for safety analysis. In the EU project CAST (see text-box right), the release of C-14 was investigated to determine the physical-chemical form in which it is then present. In experiments with steels and Zircaloy, various organic and inorganic chemical compounds containing C-14 were identified. There is evidence that, after initially releasing compounds containing water-soluble C-14, steels eventually release gaseous compounds instead. There is some indication that, with Zircaloy, the percentage of volatile C-14 compounds that are released immediately once a container breaches has been conservatively overestimated. For its safety analyses, Nagra was able to benefit from its participation in the CAST

project by reducing uncertainties regarding the release of C-14. It also strengthened the impetus to continue the development of models describing the migration of slightly volatile radionuclides.

#### **Framework Research Programme of the EU**

##### **Beacon (Mechanical Evolution of Bentonite Barriers)**

Bentonite is a natural, swelling clay-mineral mixture that is very suitable as an engineered barrier used for backfilling emplacement rooms and sealing zones. In the Beacon project, methods are being developed and tested to investigate the properties of bentonite barriers and their long-term development

Coordination: SKB (Sweden)

Participation: 25 organisations from 10 countries

Duration: 2017 – 2021

##### **CAST (CArbon-14 Source Term)**

Investigation of the release rate and speciation of C-14 due to the corrosion of activated steels and Zircaloy and by the leaching of exchange resins and graphite under repository-relevant conditions

Coordination: NDA (UK)

Participation: 33 organisations from 15 countries

Duration: 2013 – 2018

##### **Modern2020 (Development and Demonstration of Monitoring Strategies and Technologies for Geological Disposal)**

Preparing the basis for developing and implementing an efficient monitoring programme for deep geological repositories, taking into consideration the safety demonstration and the specific requirements of national programmes and local stakeholders

Coordination: Andra (France)

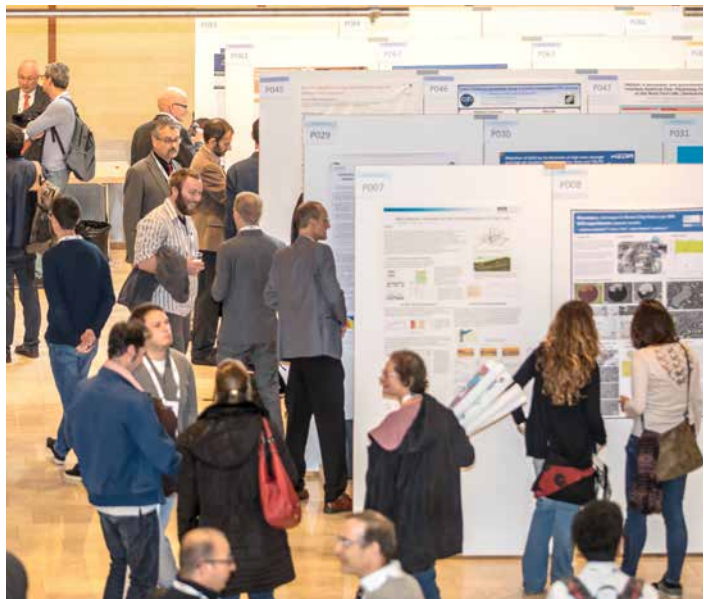
Participation: 30 organisations from 13 countries

Duration: 2015 – 2019

## INTERNATIONAL CLAY CONFERENCE

From 24<sup>th</sup> to 27<sup>th</sup> September, over 400 scientists from around the world gathered in Davos to attend the International Clay Conference. They exchanged their latest insights into the role of clays and clay materials in the disposal of radioactive waste.

Such international exchange enjoys a long tradition in the field of nuclear waste management. Scientific research collaboration extends beyond national and continental boundaries, as demonstrated by the arrival in Davos of scientists from 23 countries such as Japan, China, Canada, Mexico and the USA. Various videos taken at the Clay Conference are available on Nagra's YouTube channel.











2017 was another eventful year for Nagra, as recorded in pictures by the illustrator and cartoonist Julia Buschbeck from Zürich.



# Public outreach

## Transparency builds trust

Providing information that is factually correct and up-to-date and conducting open dialogue on a level suitable for the audience in question form the basis for building trust. Nagra's public relations group cultivates close contact with the public and provides them with information that is as comprehensive and transparent as possible and tailored to the different stakeholders. A wide range of communication tools and contact opportunities is used for this, including guided tours of the rock laboratories, presentations, Nagra's website and blogs, Facebook, brochures, films, media releases, presence at regional trade fairs and information events.

## Nagra exhibit emerges as a major public attraction

More than two years after its launch, the virtual reality exhibit "Journey through time to a deep repository" continues to draw many interested visitors and is one of the main attractions at trade fairs. Seated in a time-travel chair and equipped with virtual reality glasses, visitors experience how a future repository is constructed in the Opalinus Clay and filled with waste, and how it is integrated into a region. At the end of the ten-minute animation, the time-travellers land 60 000 years in the future. The modular exhibit can be operated flexibly in the regions, at times consisting of a single chair, at others of four chairs set up on a mobile trailer and up to seven chairs at a trade fair stand.

## Time travel in numerous communities

Nagra was present at 21 trade exhibitions, industrial fairs and other events that took place in Switzerland and Germany. To accompany the seismic measurement campaign in Nördlich Lägern, Nagra set up an information container in Glattfelden. These events provided an opportunity for a direct exchange of views with the public.

## Visitors service

A total of 5235 visitors toured the Grimsel and Mont Terri rock laboratories. The Grimsel Test Site attracted 1214 visitors, while the Mont Terri Rock Laboratory had 4021 visitors. Nagra organised four visitors' days at the Mont Terri Rock Laboratory for the public living in the potential

siting regions Jura Ost, Nördlich Lägern and Zürich Nordost. It also organised a further four days at the Grimsel Test Site; people who had entered a contest arranged by Nagra while visiting an exhibition were among those invited.

Nagra also organised three information trips for around 70 decision-makers from the areas of economics, politics and the authorities. The visits were to waste management facilities in Germany and Sweden and gave the participants from the full political spectrum the opportunity to find out about disposal concepts in other countries and to experience facilities that are planned or already in operation.

## NATURAL SCIENCES AND PUBLIC RELATIONS: A PERFECT MATCH

Marisa Brauchli, scientific-technical editor



Asked about her vocational training, Marisa Brauchli responds with a smile. "I am an environmental scientist", she says. "But my university studies also included a few years of geography and geology". Marisa Brauchli wrote her master's thesis in the field of geomicrobiology, investigating how microbes can form minerals in the ground. "Natural sciences have fascinated me since early childhood", Marisa Brauchli elaborates. "For me, understanding the processes occurring in our environment is a personal enrichment". Upon gradu-

ating from university, she completed an internship at the Cantonal Department for Environmental Protection in Zug and later took a job as a project manager for soil protection and neobiota. These are plants or animals that were introduced invasively into Switzerland.

However, Marisa's interests are not restricted to natural sciences. They also include journalism and public relations. As a student, she already had a part-time job as an online producer for the Swiss news journal "Blick". At her news desk, she posted the latest media releases and news online. Speed and precision were important. "And all of this took place during evening or night shifts, and we often worked until two in the morning", she recounts. But it was an exciting job and she enjoyed it a lot.

Marisa Brauchli appreciates the combination of natural science and public relations that she has found with Nagra. She is the contact person for the media and answers questions from journalists. Her duties also include drafting media releases and news as well as organising media events. She is also in charge of the sector School and Youth which includes a diverse offer such as the web portal, school visits, school lectures or tours of the rock laboratories. "As a natural scientist, I can easily identify with the topic", she emphasises. This holds true even when the duration of the entire process can appear difficult when seen from a communicative aspect. "I am really pleased to participate in this important and, particularly here in Switzerland, unique project", Marisa Brauchli adds.



### **Dialogue with schools and adolescents**

Nagra sent three newsletters to teachers and participated in an advanced teacher training course organised by the Leibstadt nuclear power plant. It also participated in the so-called “TecDays” held at various cantonal and secondary schools, and presented its school programme at a conference of cantonal middle schools in Zürich. Nagra held a keynote speech before the European Youth Parliament and welcomed a class to the Clay Conference in Davos. A class from the cantonal school in Wettingen visited Nagra, with the students gaining an insight into various areas of work. Within the framework of the educational training programme “Meeting Point Science City”, Nagra set up its exhibit “Journey through time to a deep repository” at the Swiss Federal Institute of Technology Zürich (ETH Zürich) as well as at the Irchel Campus of the University of Zürich. On Switzerland’s national “Future Day”, interested children were invited to visit Nagra; the activities were documented in a short video and a blog post.

### **Comprehensive information for the media**

Nagra held its annual media conference in April. A further media conference in August held on the submission of the applications for exploration permits was attended by twelve media specialists from print, TV and radio. To accompany the completion of the 3D seismic campaign in Nördlich Lägern, Nagra published a media release, a fact-sheet on the entire measurement campaign and a short video. In

June, Nagra published media releases on the diffusion experiment (including a short video) and the annual general meeting. An extensive media dossier was prepared for the Clay Conference. This contained five media releases on the Clay Conference, clays, the FE full-scale experiment and the Research, Development and Demonstration Programme (RD&D), as well as a portrait of Nagra geologist Andreas Gautschi.

Swiss Television visited Nagra and the interim storage facility Zwiilag to produce an episode for its “Reporter” programme. Bavarian Television filmed an episode of its programme “Faszination Wissen” (Fascination with Knowledge) at the Grimsel Test Site and at the Mont Terri Rock Laboratory.

### **Versatile and modern internet presence**

The Nagra website was updated with information on the field investigations such as the Quaternary boreholes and the start of the public inspection period for the applications for the exploratory boreholes. The section on “Earth sciences” now offers more facts about Switzerland’s geology. Nagra’s homepage regularly features new films linked from its YouTube channel, including the conclusion of the 3D seismic campaign, the diffusion experiment, the Clay Conference and “Future Day.”

On [www.nagra-blog.ch](http://www.nagra-blog.ch), staff members offer an insight into Nagra’s activities. Numerous articles were posted on field investigations, research, exhi-





An abundance of questions: on "Future Day", children could ask staff what qualifications were needed to work for Nagra and what working for Nagra was actually like.

bitions and projects involving schools and adolescents. Nagra used texts and images to share background information about the seismic measurements and exploratory boreholes, and the staff members responsible for the respective projects were introduced. A new feature on Nagra's blog is its interactive "Journey through depth and time", which belongs to the five most frequently visited sites on the blog. It is suitable for mobile devices and invites interested users into the underground of Northern Switzerland where they learn interesting facts about geology, for example what the landscape looked like 145–200 million years ago, what secrets drillcores reveal and which rocks are rich in fossils. To reach a larger audience, individual blog posts were linked to Nagra's Facebook account "Earth sciences".

#### Interesting videos covering the Clay Conference

Nagra reported extensively on the International Clay Conference in Davos with numerous text articles, and also created videos featuring leading scientists in the area of clay research. The main video and the individual videos, along with many statements, can also be viewed on Nagra's YouTube channel.

#### Using print products to explain current events

Nagra published an updated brochure about exploratory boreholes to accompany the public inspection period for the applications for exploration permits in Nördlich Lägern. A flyer with relevant

information was produced for each drillsite, and illustrative information boards were set up on site – this was also done previously in Jura Ost and Zürich Nordost. A special flyer was produced on the boreholes for Quaternary investigations.

The latest research findings on gas in deep geological repositories and on underground resources were publicised in the form of brochures. A special issue on erosion explains how the past reveals much about the future, and how erosion is a significant factor in the long-term evolution of deep geological repositories.

Many publications were updated: the brochures for the two rock laboratories Mont Terri and Grimsel, the booklet on radioactive waste and the leaflet on volumes and origin of radioactive waste. In 2017, Nagra again published two issues of "nagra info" and sent them to subscribers. Two electronic "e-info" newsletters were also issued.

#### Visit Nagra online:

- [www.nagra.ch](http://www.nagra.ch)  
Comprehensive information for the public
- [www.nagra-blog.ch](http://www.nagra-blog.ch)  
Learn about Nagra's work
- [www.erdwissen.ch](http://www.erdwissen.ch)  
Geology blog coupled with social media

# Organisational structure 2017



**Corina Eichenberger**  
**President of the Board of Directors**

"The safety of humans and the environment is the main priority in the management of radioactive waste. Waste disposal should have no negative impacts on the human environment and also has to be compatible with the needs of the host region. It is of great importance to me that we should strive to meet this challenge in the future and approach it with the greatest sense of responsibility."

## **Executive Board of Nagra**

Top row, left to right: Dr. Tim Vietor, Division Head Safety, Geology & Radioactive Materials; Maurus Alig, Coordinator Major Project Sectoral Plan Stage 3 / General Licences; Reto Beutler, Division Head Finance, Controlling & Human Resources; Patrick Senn, Division Head Planning & Construction of Deep Geological Repositories

Bottom row, left to right: Dr. Markus Fritschi, Deputy CEO & Division Head Collaboration Sectoral Plan & Public Outreach; Dr. Thomas Ernst, Chief Executive Officer; Dr. Piet Zuidema, Overall Project Manager Sectoral Plan Stage 2



### Head office

At the end of 2017, 113 people (excluding interns) were employed at Nagra's head office in Wettingen (110 permanent employees and 3 part-time staff/temporary employees), corresponding to 101.8 full-time positions (without interns and temporary posts).

### Board of Directors and annual general meeting

The Board of Directors held four meetings to handle ongoing business, with the focus on the Sectoral Plan process. The Board took note of the planned research and development work for 2018 and approved the required outline credit. The Technical Committee met four times and the Commission for Communication and Information held two meetings. The Finance Commission also met twice to consider the closing of the annual accounts for 2017, the budget for 2018 and the accumulated accounts. The annual general meeting of the members of the Nagra Cooperative took place on 20<sup>th</sup> June 2017 in Bern. The members approved the annual report and accounts for 2016. On 18<sup>th</sup> September, an extraordinary general meeting was held to decide on the cost distribution key between the members of the Cooperative and the modification to the regulation on awarding of contracts.

### Further members of the Nagra management team

From left to right: Dr. Andreas Gautschi, Chief Geoscientific Advisor; Dr. André M. Scheidegger, Deputy Coordinator Major Project Sectoral Plan Stage 3; Armin Murer, Deputy Division Head Collaboration Sectoral Plan & Public Outreach; Dr. Irina Gaus, Head of Research & Development; Dr. Stratis Vomvoris, Division Head International Services and Projects; Dr. Harald Maxeiner, Deputy Division Head Safety, Geology & Radioactive Materials





## DR. PIET ZUIDEMA

Dr. Piet Zuidema, a member of the Executive Board, took early retirement at the end of 2017 and set up as an independent consultant. Of his 34 years with Nagra, around 20 saw him as responsible for the scientific-technical field. His responsibilities included waste disposal, the RD&D programme, radioactive waste, geological investigations, repository design and safety assessment. As overall project manager, he helped to shape the site selection work in Stages 1 and 2 of the Sectoral Plan process. He worked with numerous international organisations such as the OECD/NEA and the IAEA and served as an adviser on many expert committees of foreign waste management organisations. Piet Zuidema will continue to act as an adviser to Nagra in the future.

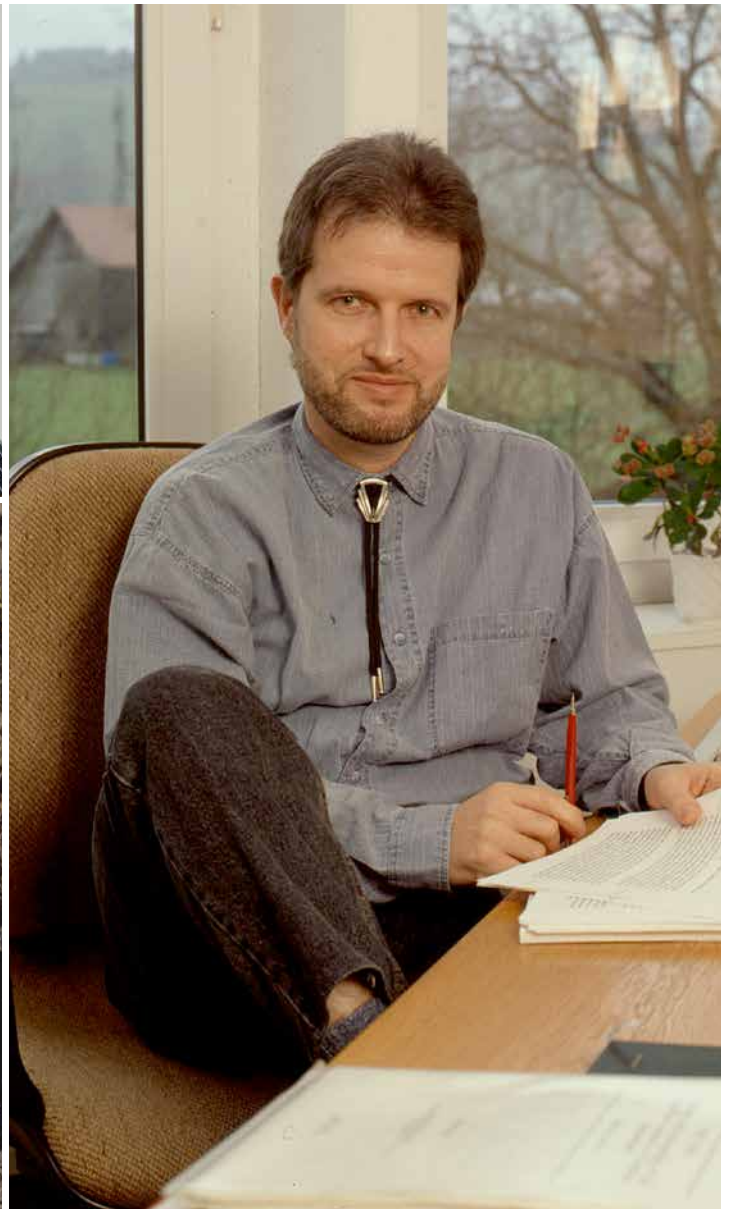






#### DR. ANDREAS GAUTSCHI

Dr. Andreas Gautschi, a member of Nagra's management team, retired at the end of August 2017. Over a period of 30 years, the geologist made a significant contribution to knowledge surrounding the deep geological disposal of radioactive waste. He was widely involved in different geological investigations, for example the various deep boreholes, the 2002 "Entsorgungsnachweis" and research projects at the Mont Terri Rock Laboratory. His work also included geochemical investigations such as the analysis of deep groundwaters. At the end of September, he acted as Scientific Chairman of the International Clay Conference in Davos. His extensive international network and links with waste management organisations worldwide were of great importance for the Swiss waste management programme. Andreas Gautschi will continue to advise Nagra in the area of geosciences.



# Members of the Cooperative, Board of Directors, Commissions and Statutory Auditor

## Members of the Cooperative

Swiss Confederation  
Bern

Alpiq AG  
Olten

Axpo Power AG  
Baden

BKW Energie AG  
Bern

Kernkraftwerk Gösgen-  
Däniken AG  
Däniken

Kernkraftwerk Leibstadt AG  
Leibstadt

Zwilag Zwischenlager  
Würenlingen AG

## Board of Directors

Corina Eichenberger  
Kölliken (AG)  
President of Nagra

Dr. Stephan W. Döhler  
Vice-President  
Axpo Power AG

Dr. Philipp Hänggi  
BKW Energie AG

Dr. Thomas Kohler  
Alpiq AG

Dr. Andreas Pfeiffer  
Kernkraftwerk Leibstadt AG

Dr. Michael Plaschy  
Kernkraftwerk Gösgen-  
Däniken AG

Ronald Rieck  
Zwilag Zwischenlager  
Würenlingen AG

Dr. Thierry Strässle  
Swiss Confederation

Peter Zbinden  
Erlenbach (ZH)  
Former CEO of AlpTransit  
Gotthard AG

## Technical Committee

Dr. Thomas Kohler  
Chairman  
Alpiq AG

## Finance Commission

Urs Helfer  
Chairman  
Axpo Power AG

## Commission for Communication and Information

Dr. Philipp Hänggi  
Chairman  
BKW Energie AG

## Commission for Legal Issues

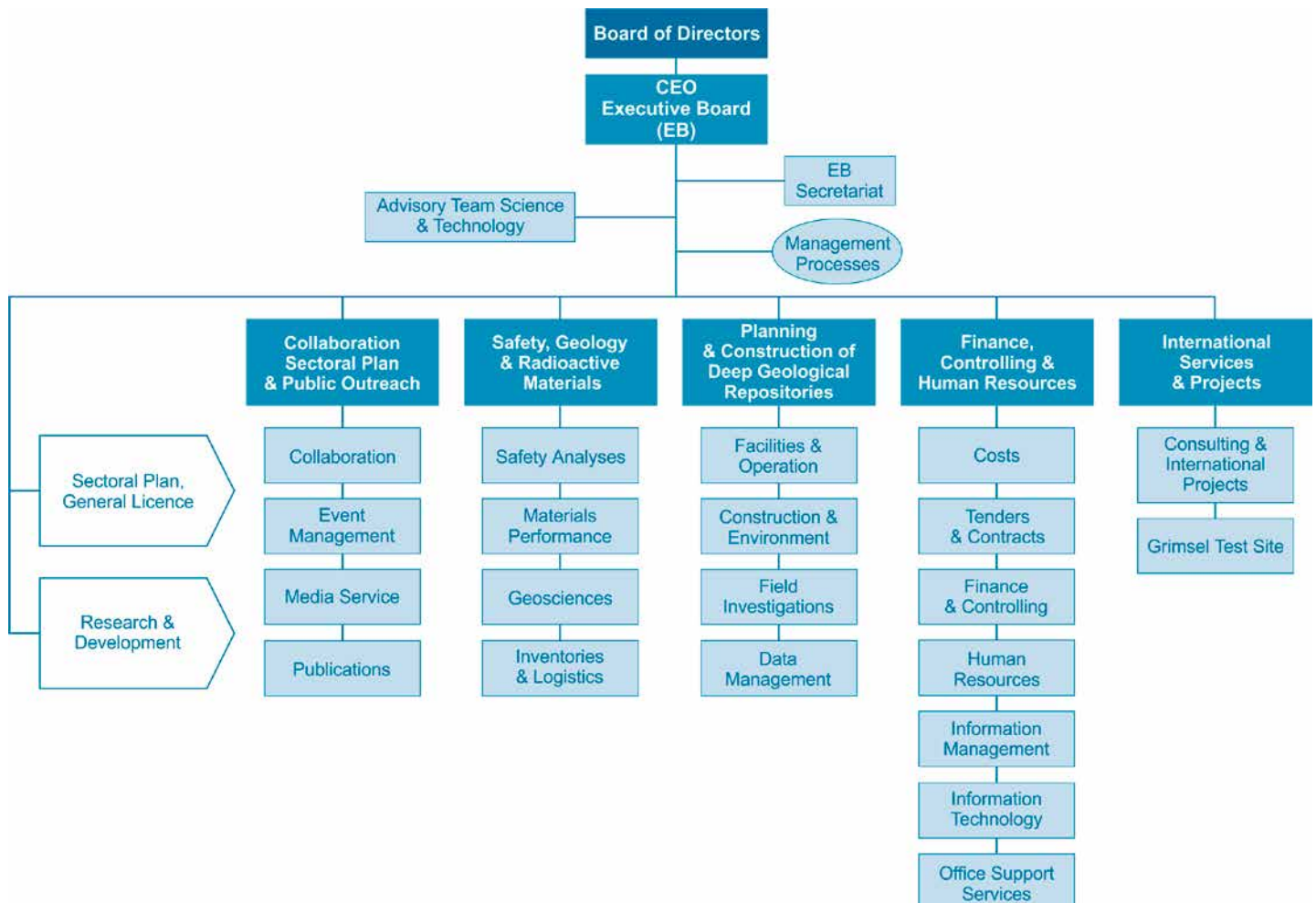
Hansueli Sallenbach  
Chairman  
Axpo Holding AG

## Statutory Auditor

PricewaterhouseCoopers AG  
Zürich



## Organigram of the head office 2017







# Annual financial statements 2017

# Comments on the annual financial statements 2017

The current financial statements for 2017 were prepared in line with the provisions of the relevant Swiss legislation, in particular the articles on commercial accounting and financial reporting of the Code of Obligations for individual financial statements (Art. 957 to 962).

Total expenditure minus proceeds from sales of goods and services and other income is borne by the members of the Cooperative, which results in a balanced year-end result.

Total income decreased by CHF 9.8 million compared to the previous year, mainly due to lower project expenditure (CHF -9.2 million) following the completion of the seismic measurements in the Nördlich Lägern siting region. Net income from sales of goods and services remained stable.

Staff costs, other operational costs and depreciation decreased by CHF 0.6 million.

Further information can be found in the notes to the annual financial statements.

Wettingen, 19<sup>th</sup> March 2018

A handwritten signature in black ink, appearing to read 'T. Ernst', written in a cursive style.

Dr. Thomas Ernst, Chief Executive Officer



# Balance sheet

Note	Assets	31.12.2017 CHF	31.12.2016 CHF
	<b>Current assets</b>		
	Cash and cash equivalents	17 168 125	15 639 717
C1	Trade receivables	323 533	268 573
	Due from third parties	323 533	216 305
	Due from members of the Cooperative	–	52 268
C2	Other current receivables	162 647	102 978
	Due from third parties	162 647	102 978
C3	Non-invoiced services	1 755 988	1 671 265
C4	Accrued income and prepaid expenses	558 593	1 138 921
	<b>Total current assets</b>	<b>19 968 886</b>	<b>18 821 454</b>
	<b>Capital assets</b>		
C5	Tangible fixed assets	1 729 962	1 610 261
	<b>Total capital assets</b>	<b>1 729 962</b>	<b>1 610 261</b>
	<b>Total assets</b>	<b>21 698 848</b>	<b>20 431 715</b>
	<b>Equity and liabilities</b>		
	<b>Current borrowed capital</b>		
C6	Trade payables	5 466 273	12 776 947
	Due to third parties	5 438 809	12 688 930
	Due to members of the Cooperative	27 464	88 017
	Other current liabilities	1 021 432	1 575 010
	Due to third parties	1 017 837	1 566 683
	Due to members of the Cooperative	3 595	8 327
C7	Advance payments received	1 631 483	1 521 686
C8	Deferred income and accrued expenses	13 439 660	4 418 072
	<b>Total current borrowed capital</b>	<b>21 558 848</b>	<b>20 291 715</b>
	<b>Total liabilities</b>	<b>21 558 848</b>	<b>20 291 715</b>
C9	<b>Equity</b>		
	Cooperative capital	140 000	140 000
	Annual profit (annual loss)	–	–
	<b>Total equity</b>	<b>140 000</b>	<b>140 000</b>
	<b>Total equity and liabilities</b>	<b>21 698 848</b>	<b>20 431 715</b>

# Profit and loss account

Note	1.1. – 31.12.2017		1.1. – 31.12.2016	
	CHF		CHF	
<b>C10</b>	<b>Net proceeds from sales of goods and services</b>			
	Net proceeds from services for third parties		2 547 296	2 704 634
	Research contributions from third parties		23 668	159 743
	Net proceeds from services for Cooperative members		785 148	549 259
	<b>Total net proceeds from sales of goods and services</b>		<b>3 356 112</b>	<b>3 413 636</b>
<b>C11</b>	<b>Contributions of members of the Cooperative</b>			
	Contributions to administration costs		700 000	700 000
	Contributions to project expenditure		51 602 784	61 390 262
	<b>Total contributions of members of the Cooperative</b>		<b>52 302 784</b>	<b>62 090 262</b>
	<b>Other operating income</b>		<b>139 272</b>	<b>56 555</b>
	<b>Operating income (total output)</b>		<b>55 798 168</b>	<b>65 560 453</b>
<b>C12</b>	Cost of materials (project expenditure)		34 602 520	43 796 381
<b>C13</b>	Staff costs		17 956 652	18 190 207
<b>C14</b>	Other operational costs		2 819 854	3 304 377
<b>C5</b>	Depreciation and value adjustments on fixed assets		221 855	137 825
	<b>Operating result</b>		<b>197 287</b>	<b>131 663</b>
	Financial income		-59 878	-153 498
	Financial costs		148 173	157 706
	<b>Annual profit before taxes</b>		<b>108 992</b>	<b>127 455</b>
	Direct taxes		108 992	127 455
	<b>Annual profit (annual loss)</b>		<b>-</b>	<b>-</b>

# Cash flow statement

		1.1. – 31.12.2017	1.1. – 31.12.2016
Note		CHF	CHF
	Annual profit [+] / annual loss [-]	–	–
C5	Depreciation and value adjustments on fixed asset items	221 855	137 825
	<b>Change in net current assets</b>		
C1	Decrease [+] / increase [-] trade receivables	–54 960	1 208 844
C2	Decrease [+] / increase [-] other current receivables	–59 669	–21 976
C3	Decrease [+] / increase [-] non-invoiced services	–84 723	–271 540
C4	Decrease [+] / increase [-] prepaid expenses	580 329	926 554
C6	Decrease [-] / increase [+] trade payables	–7 310 675	–551 945
	Decrease [-] / increase [+] other current liabilities	–553 578	723 903
C7	Decrease [-] / increase [+] advance payments received	109 797	–494 107
C8	Decrease [-] / increase [+] deferred income and accrued expenses	9 021 588	1 078 400
	<b>Cash flow from operating activities</b>	<b>1 869 964</b>	<b>2 735 958</b>
C5	Investments in fixed assets	–341 556	–232 551
	<b>Cash flow from investment activities</b>	<b>–341 556</b>	<b>–232 551</b>
	<b>Cash flow from financing activities</b>	<b>–</b>	<b>–</b>
	<b>Change in cash and cash equivalents</b>	<b>1 528 408</b>	<b>2 503 407</b>
<b>Change in cash and cash equivalents</b>		<b>2017</b>	<b>2016</b>
Cash and cash equivalents as at 1 <sup>st</sup> January		15 639 717	13 136 310
Cash and cash equivalents as at 31 <sup>st</sup> December		17 168 125	15 639 717
<b>Net increase/decrease in cash and cash equivalents</b>		<b>1 528 408</b>	<b>2 503 407</b>



# Notes to the annual financial statements

## A) General information

### Accounting legislation

The current financial statements were prepared in accordance with the provisions of Swiss law, in particular the articles on commercial accounting and financial reporting of the Code of Obligations for individual financial statements (Art. 957 to 962).

### Company, name, legal form and registered office

Nagra, National Cooperative for the Disposal of Radioactive Waste  
Hardstrasse 73, Postfach 280, 5430 Wettingen

### Type of audit

According to legal requirements (Art. 727, par. 2 of the Code of Obligations), the annual financial statements of Nagra are subject to an ordinary audit.

### Currency used for the accounting

The accounting is in the national currency (Swiss Francs; CHF).

### Cash flow statement

The cash and cash equivalents form the basis for the presentation of the cash flow statement. Cash flow from operating activities is calculated using the indirect method.

### Approval of the annual financial statements

The Board of Directors approved the annual financial statements on 19<sup>th</sup> March 2018 on behalf of the annual general meeting.

## B) Information on the principles applied in the annual financial statements

The main positions in the annual financial statements are assessed as follows:

### Cash and cash equivalents

Cash and cash equivalents comprise petty cash and credit balances on bank accounts. They are carried at nominal value. Foreign currency positions are carried at the exchange rate on the reporting date.

### Trade receivables

Trade receivables are reported at the invoiced amount minus the allowances made for the bad debts provision. The allowance is formed based on the maturity structure and recognisable credit risks.

### Receivables and payables towards involved parties

These positions are exclusively receivables and payables towards involved parties (i.e. the members of the Cooperative).

### Non-invoiced services

The capitalised work in progress and the advance payments received result exclusively from contracts for third parties. For the ongoing projects, all expenditure is capitalised in work in progress and all advance payments received are booked as a liability.

**Fixed assets**

Fixed assets are reported at acquisition cost minus the accumulated depreciation over the estimated useful lifetime of each asset category. Investments in hardware below CHF 20k (one-off) and software below CHF 100k (one-off) are debited directly to the income statement.

The lifetimes for depreciation fall within the following bandwidths for the individual categories that are relevant for Nagra:

Land	Depreciation only in the case of value impairment
Buildings	20 to 50 years
Operating and business equipment	5 to 10 years
IT hard- and software	2 to 3 years

Tenant fixtures are written off over the duration of the tenancy or, if shorter, over the useful lifetime of the asset, or are debited directly to the income statement.

Expenditure on repairs and maintenance that does not add value is debited directly to the income statement. Renewals that change the useful lifetime of assets are capitalised.

Assets removed from operation or sold are written off on the assets account at their acquisition values and the accumulated depreciation. The resulting profits or losses are entered in the income statement.

**Payables**

All payables are carried at nominal value. Services received and incurred liabilities are deferred according to the period.

**Provisions**

Provisions are formed when, based on events that have occurred in the past, the company has a legal or factual obligation, the extent and due date of which are unknown but can be estimated.

**C) Information, breakdowns and notes on the annual financial statements****C1) Trade receivables**

The increase compared to the previous year (CHF 55k) is due mainly to new international projects.

The implementation of the modified distribution key for the financing of Nagra according to the decision of the extraordinary general meeting of 18<sup>th</sup> September 2017 led to compensation payments among the parties involved in the amount of CHF 37.2 million. As the balance for Nagra is neutral, the individual positions are not carried under debtors or creditors.

As there were no identifiable credit risks as per the end of 2017, no value adjustment was made.

**C2) Other current receivables**

Other current receivables include cash contributions for securing the centralised billing procedure of the Swiss Federal Customs Administration (CHF 50k) and for securing the fulfilment of a customer contract (EUR 20k). From the salary accrual of December 2017, there are receivables towards employees of CHF 33k. Foreign VAT credit balances amount to CHF 58k.

**C3) Non-invoiced services**

Non-invoiced services consist of accrued internal services and third-party services for various projects. Project-specific verification is available.

**C4) Accrued income and prepaid expenses**

Accrued income and prepaid expenses comprise the open reimbursement of PSI (CHF 325k), the pre-payments for Suva 2018 (CHF 137k) and for rent for January 2018 (CHF 92k), as well as other small positions.

**C5) Tangible fixed assets**

	Land and buildings	Office and workshop	Vehicles	Total
	CHFk	CHFk	CHFk	CHFk
<b>Acquisition value per 01.01.2016</b>	<b>1 825</b>	<b>620</b>	<b>653</b>	<b>3 098</b>
Additions		152	80	232
Disposals			-87	-87
Reclassifications				0
<b>Acquisition value per 31.12.2016</b>	<b>1 825</b>	<b>772</b>	<b>646</b>	<b>3 243</b>
Additions		183	159	342
Disposals			-113	-113
Reclassifications				0
<b>Acquisition value per 31.12.2017</b>	<b>1 825</b>	<b>955</b>	<b>692</b>	<b>3 472</b>
<b>Accumulated depreciations per 01.01.2016</b>	<b>405</b>	<b>582</b>	<b>595</b>	<b>1 582</b>
Additions	30	69	39	138
Disposals			-87	-87
Reclassifications				0
<b>Accumulated depreciations per 31.12.2016</b>	<b>435</b>	<b>651</b>	<b>547</b>	<b>1 633</b>
Additions	30	126	66	222
Disposals			-113	-113
Reclassifications				0
<b>Accumulated depreciations per 31.12.2017</b>	<b>465</b>	<b>777</b>	<b>500</b>	<b>1 742</b>
<b>Carrying value per 01.01.2016</b>	<b>1 420</b>	<b>38</b>	<b>58</b>	<b>1 516</b>
<b>Carrying value per 31.12.2016</b>	<b>1 390</b>	<b>121</b>	<b>99</b>	<b>1 610</b>
<b>Carrying value per 31.12.2017</b>	<b>1 360</b>	<b>178</b>	<b>192</b>	<b>1 730</b>

**C6) Trade payables**

Compared to the previous year, trade payables decreased from CHF 7 311k to CHF 5 466k. This is due mainly to the high level in the previous year as a result of the 3D seismic campaign in Nördlich Lägern.



**C7) Advance payments received**

Advance payments received are for accrued internal services and third-party services for various projects. Project-specific verification is available. Because of the slightly higher volume of third-party contracts, the advance payments received per 31.12.2017 (CHF 1 631k) are CHF 109k higher than in the previous year (CHF 1 522k).

**C8) Deferred income and accrued expenses**

Deferred income consists mainly of the balancing of the annual financial statements that will be reimbursed to the members of the Cooperative (CHF 8 780k). There are also outstanding amounts for services in the amount of CHF 2 900k, that are due mainly to outstanding settlements (SFOE CHF 1 191k). The deferral for outstanding vacation time and overtime was reduced by CHF 38k to CHF 1 760k.

**C9) Equity**

The Cooperative capital is unchanged with CHF 140k and is divided into 140 share certificates of 1000 CHF each, with 7 certificates of 20 shares each being distributed.

**C10) Net proceeds from sales of goods and services**

Net proceeds showed decreases in both the proceeds from third parties and from research projects. The proceeds from the NPP operators increased slightly.

**C11) Contributions of the members of the Cooperative**

The contributions of the members of the Cooperative are invoiced on a quarterly basis according to the budget approved by the Board of Directors. A deviation from the budget leads to an additional charge or a credit that is booked in the year of accounting as prepaid expenses or deferred income. This has an annual result of CHF 0.

The implementation of the modified distribution key for the financing of Nagra according to the decision of the extraordinary general meeting of 18<sup>th</sup> September 2017 led to compensation payments between the parties involved in the amount of CHF 37.2 million. As the balance for Nagra is neutral, the individual positions are not carried under debtors or creditors (see C1).

**C12) Cost of materials (project expenditure)**

The project expenditure is made up as follows:

External services for:	2017	2016
	CHFk	CHFk
Projects	22 593	30 774
Communication	1 776	2 124
Fees (ENSI, SFOE)	9 558	10 265
Other	676	633
<b>Total</b>	<b>34 603</b>	<b>43 796</b>

**C13) Staff costs**

Staff costs, including social contributions, decreased compared to the previous year by 1.3 % to CHF 17 957k as part of the resource planning approved by the Board of Directors. The main reason was the reduction in the extraordinary contributions to the pension fund (CHF 590k). The ordinary contributions showed an increase of CHF 72k, while the settlement for outstanding vacation time and overtime was reduced by CHF 38k. The average staffing level in 2017 of 100.1 full-time positions (without temporary positions and internships) increased compared to the previous year by 3.8 full-time positions.

**C14) Other operational costs**

Other operational costs include rents and expenditure on property of CHF 1 163k, expenditure on informatics of CHF 519k and further operational costs of CHF 1 138k.

**D) Further information****Liabilities towards pension schemes**

As of 31.12 there were the following liabilities towards pension schemes	<b>31.12.2017</b>	<b>31.12.2016</b>
	CHF	CHF
Contribution statement December	196 093	188 838

In summer 2017, both employer and employees voted for a change from defined benefits to defined contributions for the PKE pension scheme as per 1<sup>st</sup> April 2018. This involves a buy-in to the higher level of cover ratio of the defined contributions scheme in the amount of around CHF 4.8 million (estimate as of July 2017) and individual contributions of around CHF 0.3 million. The Board of Directors approved the change under these conditions on 6<sup>th</sup> September 2017. Cash flow will take place in 2018.

**Contingent liabilities**

Nagra is not involved in any legal actions, legal disputes, regulatory or tax investigations, inquiries or other legal procedures that could have financial consequences for the annual financial statements for 2017.

As of 31<sup>st</sup> December 2017 there were no guarantee obligations.

## Accumulated accounts including adjustments

Note	Total income	Increase 2016 CHFk	Status 31.12.2016 CHFk	Increase 2017 CHFk	Compensation payment 2017 CHFk	Status 31.12.2017 CHFk
	Swiss Confederation	1 773 135	39 044 108	1 490 443	-	40 534 551
	Axpo Power AG	13 528 940	295 218 130	11 640 327	-17 574 148	289 284 309
	BKW Energie AG	6 566 917	137 738 024	6 194 474	-2 407 166	141 525 332
	Kernkraftwerk Gösgen-Däniken AG	17 970 771	384 530 558	13 738 077	-12 510 366	385 758 269
	Kernkraftwerk Leibstadt AG	21 550 499	435 847 889	18 539 463	32 491 680	486 879 032
	<b>Contributions for project expenditure</b>	<b>61 390 262</b>	<b>1 292 378 709</b>	<b>51 602 784</b>	<b>-</b>	<b>1 343 981 493</b>
	Contributions to administration costs	700 000	89 570 000	700 000	-	90 270 000
	<b>Contributions of Cooperative members to Nagra</b>	<b>62 090 262</b>	<b>1 381 948 709</b>	<b>52 302 784</b>	<b>-</b>	<b>1 434 251 493</b>
	<b>Contributions GNW</b>	<b>-</b>	<b>65 265 331</b>	<b>-</b>	<b>-</b>	<b>65 265 331</b>
E1	<b>Total contributions</b>	<b>62 090 262</b>	<b>1 447 214 040</b>	<b>52 302 784</b>	<b>-</b>	<b>1 499 516 824</b>



Note	Total expenditure	Increase 2016 CHF	Status 31.12.2016 CHF	Increase 2017 CHF	Status 31.12.2017 CHF
	Geoscientific studies	9 554 794	204 134 736	6 562 700	210 697 436
	Nuclear technology and safety	1 357 903	51 234 990	1 600 747	52 835 737
	Radioactive materials	1 970 314	45 597 618	1 468 066	47 065 684
	Facility planning	525 224	31 944 805	1 003 932	32 948 737
	Generic (non-site-specific) work	3 223 571	108 971 023	3 535 448	112 506 471
	General programme costs	6 348 904	94 128 419	4 205 100	98 333 519
	Fees and compensation	5 137 486	65 200 899	4 810 303	70 011 202
	<b>L/ILW programme</b>	<b>28 118 196</b>	<b>601 212 490</b>	<b>23 186 296</b>	<b>624 398 786</b>
	Geoscientific studies	13 553 919	355 316 550	10 702 930	366 019 480
	Nuclear technology and safety	2 138 820	74 355 985	2 390 299	76 746 284
	Radioactive materials	845 708	27 155 157	944 846	28 100 003
	Facility planning	561 741	26 764 570	1 005 201	27 769 771
	Generic (non-site-specific) work	4 706 332	126 601 711	4 792 179	131 393 890
	General programme costs	6 338 239	79 266 303	3 820 282	83 086 585
	Fees and compensation	5 127 307	66 971 274	4 760 751	71 732 025
	<b>HLW programme</b>	<b>33 272 066</b>	<b>756 431 550</b>	<b>28 416 488</b>	<b>784 848 038</b>
E2	<b>Project expenditure for repository programmes</b>	<b>61 390 262</b>	<b>1 357 644 040</b>	<b>51 602 784</b>	<b>1 409 246 824</b>
	<b>Administration and general project expenditure</b>	<b>700 000</b>	<b>89 570 000</b>	<b>700 000</b>	<b>90 270 000</b>
	<b>Total expenditure for L/ILW and HLW programmes, administration and general project expenditure</b>	<b>62 090 262</b>	<b>1 447 214 040</b>	<b>52 302 784</b>	<b>1 499 516 824</b>

# Notes to the accumulated accounts

The accumulated treatment of the contributions of the members of the Cooperative and the application of these contributions forms the basis, at the time of waste disposal, for any adjustments of payments among the members. It also indicates which work has resulted in project-related expenditure.

The structure of the total income is oriented primarily to the operating accounts.

## **E1) Contributions of the members of the Cooperative**

The contributions of the members of the Cooperative towards covering project costs are calculated based on the thermal output, the service lifetime-weighted output and the expected waste volumes of the individual nuclear power plants of the members.

The contributions of the members in the total amount of CHF 52.3 million (CHF 62.1 million in the previous year) correspond to those in the income statement. A contribution to administration costs is included.

The implementation of the modified distribution key for the financing of Nagra according to the decision of the extraordinary general meeting of 18<sup>th</sup> September 2017 led to compensation payments in the amount of a total of CHF 37.2 million, including VAT. These positions are considered in the accumulated accounts as net contributions per Cooperative member excluding VAT in the amount of CHF 32.5 million and the details are shown there.

The GNW contributions include payments by GNW for contract work on the Wellenberg project. This project is terminated.

## **E2) Project-specific expenditure for the repository programmes**

The two repository programmes (HLW and L/ILW) basically have the same structure in the presentation of the accumulated accounts and are oriented towards the most important technical tasks to be performed up to the completion of waste disposal activities. If there is no explicit reference to a specific programme, the following explanations of the individual positions apply to both projects.

### **a) Geoscientific investigations**

Geological investigations for identifying potential siting regions comprise geological studies in the investigation area of Northern Switzerland for deep geological disposal of high-level waste, as well as the processing of geological information for the low- and intermediate-level waste repository.

### **b) Nuclear technology and safety**

The work comprises the safety-based evaluation of potential siting regions, laboratory studies on the near-field and on the different backfill materials.

### **c) Radioactive materials**

This includes expenditure on assessing the disposability of waste packages and on ongoing documentation and inventorying of radioactive waste.

### **d) Facility planning**

This position includes expenditure on developing the concepts for the surface and underground facilities for the repositories for HLW and L/ILW.

**e) Generic (site-independent) investigations**

This includes work on developing methodologies, modelling and validation of the models used in safety analyses, laboratory studies, participation in the work in the rock laboratories (Grimsel and Mont Terri) and the research programmes of the EU.

**f) General programme costs**

This expenditure results from programme management, expenditure on cost studies and public relations activities.

**g) Fees and compensation**

This includes the fees passed on to Nagra from the regulatory and safety authorities.



# Report of the Statutory Auditor

## **Report of the Statutory Auditor on the annual financial statements for 2017**

As statutory auditor, we have audited the accompanying financial statements of Nagra, National Cooperative for the Disposal of Radioactive Waste, which comprise the balance sheet, income statement, cash flow statement and notes, for the year ended December 31, 2017.

### Management's responsibility

Management is responsible for the preparation of the financial statements in accordance with the requirements of Swiss law and the Cooperative's articles of incorporation. This responsibility includes designing, implementing and maintaining an internal control system relevant to the preparation of financial statements that are free from material misstatement, whether due to fraud or error. Management is further responsible for selecting and applying appropriate accounting policies and making accounting estimates that are reasonable in the circumstances.

### Auditor's responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with Swiss law and Swiss Auditing Standards. Those standards require that we plan and perform the audit to obtain reasonable assurance whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers the internal control system relevant to the entity's preparation of the financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the entity's internal control system. An audit also includes evaluating the appropriateness of the accounting policies used and the reasonableness of accounting estimates made, as well as evaluating the overall presentation of the financial statements. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

### Opinion

In our opinion, the financial statements for the year ended December 31, 2017 comply with Swiss law and the Cooperative's articles of incorporation.

**Report on other legal requirements**

We confirm that we meet the legal requirements on licensing according to the Auditor Oversight Act (AOA) and independence (article 906 CO in connection with article 728 CO) and that there are no circumstances incompatible with our independence.

In accordance with article 906 CO in connection with article 728a paragraph 1 item 3 CO and Swiss Auditing Standard 890, we confirm that an internal control system exists which has been designed for the preparation of financial statements according to the instructions of Management.

We recommend that the financial statements submitted to you be approved.

**PricewaterhouseCoopers AG**

Thomas Wallmer  
Audit expert  
Auditor in charge



Jonas Schwegler  
Audit expert

Zürich, 19<sup>th</sup> March 2018

# Appendices



# Waste inventories and volumes

Radioactive waste arises mainly from electricity production in the five Swiss nuclear power plants. It is also produced from the use of radioactive materials in the areas of medicine, industry and research (MIR waste).

## Waste volumes at the end of 2017

Nagra maintains a centralised database of all waste packages as a service to the waste producers. The following table shows the volumes and activities of waste prepared for geological disposal as of the end of 2017. The table does not contain pre-conditioned raw wastes and waste packages that were prepared, for example, for treatment in the Zwiilag plasma furnace.

<b>Conditioned waste (31<sup>st</sup> December 2017, figures rounded)</b>	<b>Volume (m<sup>3</sup>)</b>	<b>Activity (Bq)</b>
<b>Nuclear power plants</b>	3 620	$2.7 \cdot 10^{15}$
<b>Zwiilag</b>	2 182	$7.7 \cdot 10^{18}$
<b>Federal Govt. interim storage facility</b> (waste from medicine, industry and research)	1 578	$1.3 \cdot 10^{16}$ <sup>(1)</sup>

The “Zwiilag waste” consists of waste packages delivered to the interim storage facility from the power plants, waste packages from the plasma furnace and flasks with vitrified high-level waste from reprocessing.

<sup>1</sup> The increase in the activity for the Federal Government’s interim storage facility compared to last year results from around 100 additional small cylinders that marginally increase the volume.

### Predicted waste volumes and inventories for deep geological disposal

Planning the geological repositories requires input in the form of information on expected waste volumes. The total volume of waste for disposal will be around 92,000 cubic metres packages in disposal containers (see table for details). The volume of waste from the NPPs and Zwiilag results from the given operating lifetimes; the volume of waste from medicine, industry and research is based on the end of operation of the L/ILW repository.

Predicted waste volumes (47/60 year NPP operation) <sup>1</sup>	L/ILW (m <sup>3</sup> )		ATW (m <sup>3</sup> )		HLW/SF (m <sup>3</sup> )	
	conditioned	packaged	conditioned	packaged	conditioned	packaged
<b>BA-KKW</b> Operational waste from the NPPs (from cleaning systems and mixed waste), incl. post-operational phase	8 320	31 249				
<b>RA-KKW</b> NPP reactor waste (activated components)	478	1 811				
<b>SA-KKW</b> NPP decommissioning waste	18 378	26 803				
<b>WA-KKW</b> NPP reprocessing waste			99	414	114	398
<b>BA-ZWI</b> Zwiilag operational waste	6	22				
<b>SA-ZWI</b> Zwiilag decommissioning waste	461	563	24	24		
<b>BA-MIF</b> MIR waste collected from the FOPH and operational waste from PSI	3 645	8 432	168	634		
<b>SA-MIF</b> Decommissioning waste from PSI and CERN	10 578	10 578				
<b>BEVA/OFA</b> Waste from the future encapsulation/surface facilities for the L/ILW & HLW repositories	651	2 302				
<b>SF</b> Spent fuel assemblies					1 365	9 004
<b>Total volumes</b>	<b>42 517</b>	<b>81 760</b>	<b>291</b>	<b>1 072</b>	<b>1 479</b>	<b>9 402</b>
<b>Percentage</b> (rounded)	96.0 %	88.6 %	0.7 %	1.2 %	3.3 %	10.2 %
<b>Activity (Bq) <sup>2</sup></b>	7.9 · 10 <sup>16</sup> Bq		2.2 · 10 <sup>16</sup> Bq		1.9 · 10 <sup>19</sup> Bq	
<b>Percentage</b>	0.4 %		0.1 %		99.5 %	

<sup>1</sup> Basis: Waste Management Programme and Cost Study 2016  
Operating lifetime: NPP Mühleberg 47 years (till 2019), other NPPs 60 years  
Takes into account the planned revision of the Radiological Protection Ordinance and decay storage of radioactive materials for a maximum of 30 years with subsequent conventional disposal  
For explanations on the current waste volumes compared to previous modelling assumptions (MIRAM), see Nagra NTB 16-01

<sup>2</sup> Activity inventory for reference year 2075

# Publications in 2017

## **Nagra Technical Reports (NTB) / Nagra Work Reports (NAB)**

All NTBs can be downloaded from the Nagra website or are available in printed form at cost price. The NABs for Stage 2 of the Sectoral Plan process are also available as downloads.

The following reports were published in 2017:

Chemistry of selected dose-relevant radionuclides  
NTB 17-05, March 2017

Sachplan geologische Tiefenlager, Etappe 2:  
Fragen des ENSI und seiner Experten und  
zugehörige Antworten der Nagra NAB 17-01,  
April 2017

FEBEX-DP Post-mortem THM/THG Analysis  
Report  
NAB 16-17, August 2017

Grundwasseruntersuchungen am möglichen  
Standortareal ZNO-6b für eine Oberflächenan-  
lage NAB 17-28, December 2017

The list of the Technical and Work Reports can be found on the website ([www.nagra.ch](http://www.nagra.ch) > Infocorner > Publications / Downloads > Technical Reports > Full lists).

A series of print products for the general public were also published in 2017. They are generally not available in English. All brochures, fact sheets and annual reports can be downloaded from the Nagra website as PDFs.

### **Learn more about the disposal of radioactive waste**

Subscribe to Nagra's special issues or the "nagra info" brochures (available only in German or French) or to the Nagra blog under: [www.nagra.ch](http://www.nagra.ch)



# Glossary / Abbreviations

## **AG SiKa**

Cantonal Working Group on Safety

## **Alpiq AG**

[www.alpiq.ch](http://www.alpiq.ch)

## **ATW**

Alpha-toxic waste

## **Axpo**

[www.axpo.com](http://www.axpo.com)

## **BKW Energie AG**

Formerly Bernische Kraftwerke AG  
[www.bkw.ch](http://www.bkw.ch)

## **DETEC**

Swiss Federal Department for the Environment, Transport, Energy and Communications  
[www.uvek.admin.ch](http://www.uvek.admin.ch)

## **EGT**

Expert Group on Nuclear Waste Disposal  
[www.egt-schweiz.ch](http://www.egt-schweiz.ch)

## **Empa**

Swiss Federal Laboratories for Materials Science and Technology  
[www.empa.ch](http://www.empa.ch)

## **ENSI**

Swiss Federal Nuclear Safety Inspectorate  
[www.ensi.ch](http://www.ensi.ch)

## **FMT**

Mont Terri Rock Laboratory – rock laboratory in Opalinus Clay located near St-Ursanne, Canton Jura  
[www.mont-terri.ch](http://www.mont-terri.ch)

## **FOEN**

Federal Office for the Environment

## **FOSD**

Federal Office for Spatial Development

## **GTS**

Grimsel Test Site – Nagra's underground laboratory in crystalline rock on the Grimsel Pass, Canton Bern  
[www.grimsel.com](http://www.grimsel.com)

## **HLW**

Vitrified high-level waste from reprocessing

## **Horizon 2020**

Framework Programme for Research and Innovation  
<https://ec.europa.eu/programmes/horizon2020/>

## **IAEA**

International Atomic Energy Agency, Vienna  
[www.iaea.org](http://www.iaea.org)

## **IGD-TP**

Implementing Geological Disposal of Radioactive Waste Technology Platform (European Commission, Research & Innovation)  
[www.igdtp.eu](http://www.igdtp.eu)

## **ISCO**

International Steering Committee, Grimsel Test Site

## **JAEA**

Japan Atomic Energy Agency  
[www.jaea.go.jp](http://www.jaea.go.jp)

## **KES**

Cantonal Expert Group on Safety

## **KORAD**

Korea Radioactive Waste Agency  
[www.korad.or.kr](http://www.korad.or.kr)

## **KWO**

Kraftwerke Oberhasli AG  
[www.grimselstrom.ch](http://www.grimselstrom.ch)

## **L/ILW**

Low- and intermediate-level waste

## **MIR**

Radioactive waste from medicine, industry and research

## **MIRAM**

Model Inventory of Radioactive Materials

## **NAB**

Nagra Work Report

## **NDA**

Nuclear Decommissioning Authority  
[www.nda.gov.uk](http://www.nda.gov.uk)

## **NEA**

Nuclear Energy Agency, Paris  
[www.oecd-neo.org](http://www.oecd-neo.org)

## **NSC**

Swiss Federal Nuclear Safety Commission  
[www.bfe.admin.ch/kns/](http://www.bfe.admin.ch/kns/)

## **NTB**

Nagra Technical Report; scientific publication series

## **NUMO**

Nuclear Waste Management Organization of Japan  
[www.numo.or.jp](http://www.numo.or.jp)

## **NWMO**

Nuclear Waste Management Organization, Canada  
[www.nwmo.ca](http://www.nwmo.ca)

## **Obayashi**

Obayashi Corporation  
[www.obayashi.co.jp](http://www.obayashi.co.jp)

## **OECD**

Organisation for Economic Co-operation and Development, Paris  
[www.oecd.org](http://www.oecd.org)

**ONDRAF/NIRAS**

Organisme national des déchets  
radioactifs et des matières fissiles  
enrichies / Nationale instelling voor  
radioactief afval en verrijkte  
splijstoffen  
[www.ondraf.be](http://www.ondraf.be) / [www.niras.be](http://www.niras.be)

**Posiva**

Posiva Oy  
[www.posiva.fi](http://www.posiva.fi)

**PSI**

Paul Scherrer Institute, Villigen  
[www.psi.ch](http://www.psi.ch)

**RD&D**

Research, Development &  
Demonstration

**RWM**

Radioactive Waste Management  
[www.nda.gov.uk/rwm/organisation/rmb](http://www.nda.gov.uk/rwm/organisation/rmb)

**RWMC**

Radioactive Waste Management  
Funding and Research Center  
[www.rwmc.or.jp](http://www.rwmc.or.jp)

**SF**

Spent fuel assemblies

**SFOE**

Swiss Federal Office of Energy  
[www.bfe.admin.ch](http://www.bfe.admin.ch)

**SKB**

Svensk Kärnbränslehantering AB  
[www.skb.se](http://www.skb.se)

**STENFO**

Decommissioning and Waste Disposal  
Funds  
[www.stenfo.ch](http://www.stenfo.ch)

**SÚRAO**

Radioactive Waste Repository Authority  
[www.surao.cz](http://www.surao.cz)

**Swissnuclear**

Nuclear energy section of Swisselectric  
[www.swissnuclear.ch](http://www.swissnuclear.ch)

**Swisstopo**

Swiss Federal Office for Topography;  
project manager of the Mont Terri Rock  
Laboratory  
[www.swisstopo.admin.ch](http://www.swisstopo.admin.ch)

**Zwilag**

Centralised interim storage facility of the  
Swiss nuclear power plants for all  
categories of radioactive waste  
(Würenlingen, Canton of Aargau)  
[www.zwilag.ch](http://www.zwilag.ch)

Explanations of the abbreviations for the  
experiments at the Grimsel Test Site and  
the Mont Terri Rock Laboratory can be  
found in the text boxes on pages 32  
and 35.

**FURTHER INFORMATION:**

**Internet portal on nuclear energy**  
[www.kernenergie.ch](http://www.kernenergie.ch)

**Nuclear Forum Switzerland**  
[www.nuklearforum.ch](http://www.nuklearforum.ch)

**Radioactive waste (SFOE)**  
<http://www.bfe.admin.ch/themen/00511/01432/index.html?lang=en>

**Technical Forum on Safety**  
[www.ensi.ch/en/technical-safety-forum/](http://www.ensi.ch/en/technical-safety-forum/)

**Forum VERA**  
[www.forumvera.ch](http://www.forumvera.ch)

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