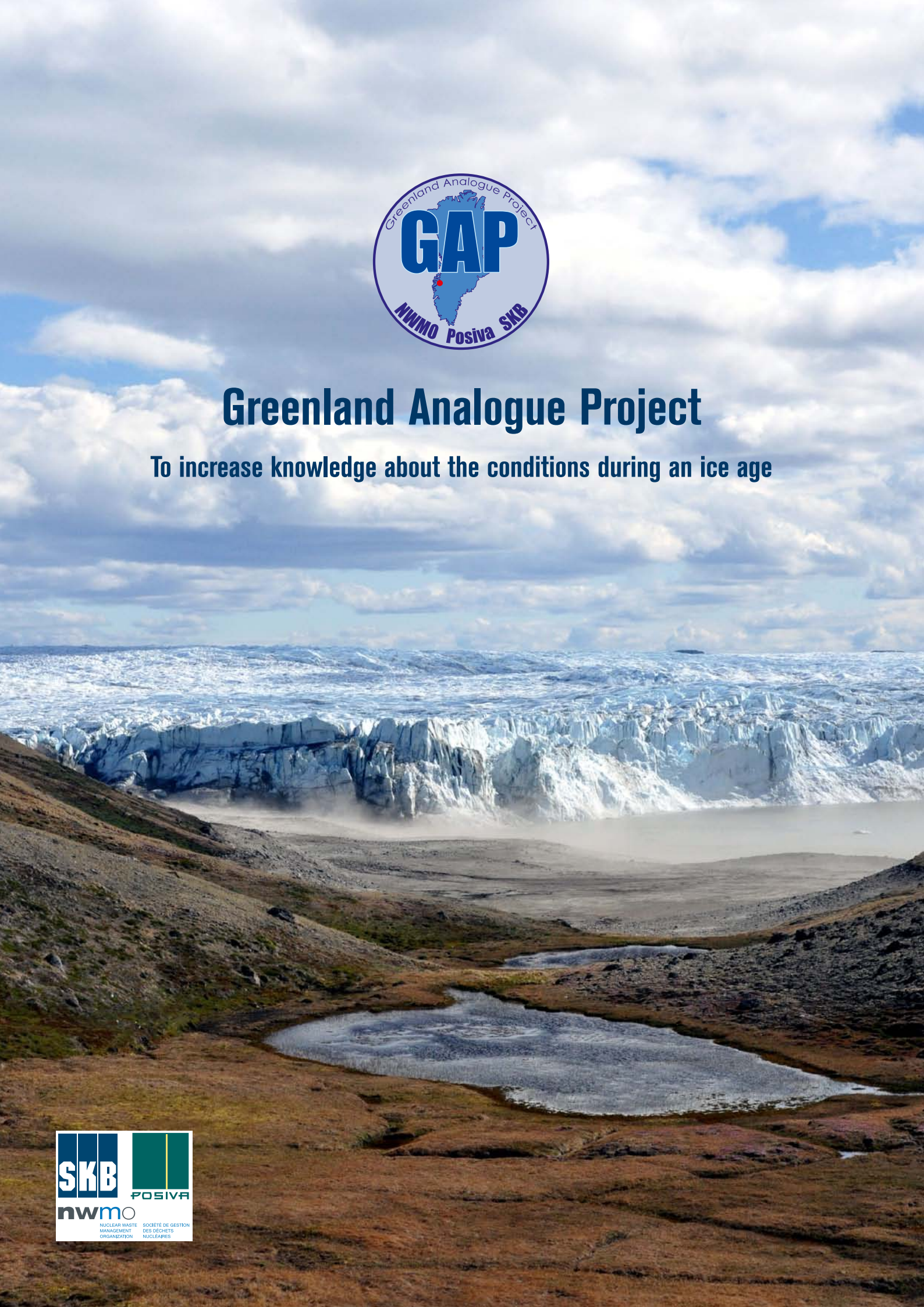

Greenland Analogue Project

To increase knowledge about the conditions during an ice age

SKB
POSIVA
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

SKB, Posiva and NWMO are carrying out a project on Greenland to increase knowledge about the conditions during an ice age.

In a project on Greenland's west coast, east of Søndre Strømfjord, the Swedish Nuclear Fuel and Waste Management Company (SKB), our Finnish equivalent Posiva, the Nuclear Waste Management Organization (NWMO) in Canada, and researchers from universities and geological surveys in the United States, Canada, United Kingdom, Denmark, Finland and Sweden are studying the ice sheet and are drilling in the bedrock at the ice edge. The main aim is to further our knowledge of the groundwater flow and the water chemistry adjacent to a continental ice sheet.

Must meet the requirements

As far as SKB is concerned the basic question is how an ice age would affect a final repository for spent nuclear fuel.

A final repository for spent nuclear fuel must meet the Swedish authorities' safety requirements during warm climates as well as during ice ages. The requirements apply for 100,000 years. This is such a long period of time that, despite the inferred current global warming, we need to analyse cases of glaciation for the investigated sites for a final spent fuel repository in Sweden. We are in other words approaching a new ice age, regardless of whether this will be in 5,000 years, 50,000 years or even further in the future.

The main issue for SKB, however, is not to investigate the most probable time for the start of the next ice age. In our safety analyses we must instead cover all the relevant possibilities, so as to ascertain the magnitude of the stresses for the final repository.

Which changes affect the barriers?

We are particularly keen to study the changes that affect the repository's protective barriers: the copper canister, the bentonite clay buffer and the rock. We are also investigating changes in the surface and what happens if, in spite of everything, radioactive substances spread, e.g. in an environment near to an ice sheet where there is permafrost.

An important question in our analyses is how the groundwater's flow and chemistry are affected during glaciations. For the final repository to be safe the groundwater should not be too saline, have too low a salinity or contain dissolved oxygen.

The ice sheet governs water exchange

During warm (interglacial) periods groundwater exchange in the rock is regulated by precipitation and topography. During glaciations, however, the ice sheet governs this water exchange. The weight of the ice depresses the bedrock, and the stress load in the rock changes. The shape and hydraulic properties of the ice simultaneously govern where the groundwater forms and how it moves. This leads to the water in part being able to find new routes, and to changes in the water fluxes. The meltwater from the ice also has a low salt content and contains dissolved oxygen, which could affect the functioning of the final repository in a negative way.

When the climate is cold and permafrost spreads, e.g. before an ice sheet developes, this also affects the way the groundwater moves. Permafrost can also lead to more saline groundwater. In order to study all these issues in more

SKB, Posiva, and NWMO investigate how the Greenland inland ice affects hydrology.

Photo: Lillemor Claesson Liljedahl

Hot water ice drilling through the ice sheet to study the basal pressure driving groundwater flow.

Photo: Joel Harper

detail we have turned our attention towards Greenland, where an ice sheet can be studied under the relevant conditions. The rock types in the selected area in western Greenland are highly reminiscent of those in the investigation sites in Sweden, Finland and Canada – a prerequisite for the study to be meaningful for SKB, Posiva and NWMO.

Focus on ice sheet hydrology

The Greenland Analogue Project is largely about investigating the hydrology of the ice sheet and in the bedrock adjacent to the ice. The hydraulic conditions at the bed of the ice sheet, at the boundary with till and rock, is of great significance to where and how the groundwater forms under the inland ice.

Certain areas of the ice sheet are frozen to the bed. There is no free water here, and consequently there is no groundwater formation. Other areas of the ice sheet are basal melting, and in these parts the meltwater forms groundwater. The distribution of basal melting and basal frozen conditions is governed by many factors, including the climate on the ice surface, the ice's dynamics and movement and heat flow in the bedrock.

Water from the ice surface can also get down to the bottom through crevasses and moulins, and can form groundwater. This happens in areas close to the front of the inland ice, where melting is taking place on the surface. One uninvestigated issue is the size of the area over which this water can reach the base.

The Greenland Analogue Project is a four year field and modelling project, according to current plans. Activities in the field started in summer 2008. A number of weather stations and GPS receivers were positioned on the ice in collaboration with Danish, Dutch and English researchers. Geological mapping of the bedrock in front of the inland ice was also performed in preparation for the forthcoming drilling into the bedrock.

Meltwater production calculated

Data from the weather stations are used to calculate how much meltwater is produced, and GPS receivers are measuring ice movement. There is a clear connection between these two parameters. How much the ice moves depends largely on how much meltwater is produced and the associated water pressure at the base of the ice. Through detailed study of how the ice's movements vary, we can thus draw indirect conclusions about the hydraulic conditions at the base of the ice.

Radar mapping of ice thickness

Radar measurements have been carried out to survey the ice and gather data to map the thickness of the ice, and find out where it is basal frozen or where it is basal melting.

For SKB, Posiva and NWMO the hydraulic pressure at the base of the ice is a parameter of great interest, as it affects the groundwater flow. This is studied by drilling several boreholes through the ice along a 40 kilometre long profile, which begins at the ice edge and ends at the ice sheet. Using the results from the radar studies we have selected drilling sites where we know that the ice is melting at the base.

The subglacial water pressure was

Borehole drilling to repository depth to study the water chemistry and pressure gradient.

Photo: Anne Lehtinen

measured in the boreholes to see how it varies locally, regionally and over time. Actual measurements of water pressure have never before been performed on this scale on an ice sheet. The results will be used to improve the assumptions in our reasoning and model simulations.

Bedrock drilling in front of the ice margin

On its way down through the rock the dissolved oxygen in the groundwater reacts with minerals in fissures and rocks. In summer 2011 we drilled a hole in the bedrock down to a depth of about 500 metres – the same as the planned depth of the final repository in Sweden and Finland. This borehole will help us study to which depth the glacial meltwater has penetrated and what the pressure gradients are.

The hole starts in an ice-free area near the ice margin and goes down obliquely under the ice sheet. The flow and chemical composition of the groundwater in the hole are studied, in order to see how the inland ice has affected the groundwater and the conditions in the bedrock at 500 m depth.

In our work of analysing the long-term safety of a final repository in Sweden we have used a large number of pessimistically selected scenarios in order to cover the prevailing uncertainties, e.g. for the hydraulic conditions in the event of glaciation. In SKB's latest safety analysis for a final repository for spent nuclear fuel, SR-Can, we noted that glacially formed groundwater could lead to erosion of the bentonite clay buffer under pessimistically selected conditions. This in turn means an increased risk of corrosive attack on the canisters.

Observations reduce uncertainties

To reduce the uncertainties in future safety analyses, both for the final repository for spent nuclear fuel and for the final repository for low- and medium-level waste, SKB needs to know more about the processes at work during an ice age. The observations from the Greenland ice sheet constitute an important contribution towards improving the conceptual and mathematical models we are using. The results from some of our investigations will also be used, by other researchers within the field of geosciences, to estimate how sensitive the Greenland ice sheet is to global warming.

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel and Waste Management Co
Box 250 SE-101 24 Stockholm, Sweden
Phone: +46 8 459 84 00 www.skb.se