Publishable Executive Summary 4

The Integrated Project known as ESDRED (Engineering Studies and Demonstrations of Repository Designs) is a joint research effort by major national radioactive waste management agencies (or subsidiaries of those agencies) and by research organisations, representing nine European countries. ESDRED is co-ordinated by the French National Radioactive Waste Management Agency (ANDRA) and is part of the European Union's 6th Euratom Framework Programme for Nuclear Research and Training. The five year Project has a total budget of EURO 18.7 million, of which 7.3 million is from the EU's Framework Programme.

The 13 partners (Contractors) from 9 countries in this project are:

Radioactive Waste Management agencies:
ANDRA, France
ENRESA, Spain
NAGRA, Switzerland
NDA, United Kingdom
ONDRAF/NIRAS, Belgium
POSIVA, Finland
SKB, Sweden

Technological R&D organisations:
AITEMIN, Spain
CSIC, Spain
DBE TECHNOLOGY, Germany
ESV EURIDICE EIG, Belgium
GRS, Germany
NRG, the Netherlands

ESDRED is focused on technology and has three main objectives. The first is to demonstrate, at an industrial scale, the technical feasibility of some very specific activities related to the construction, operation and closure of a deep geological repository for high level radioactive waste. The work is organised inside four (4) Technical Modules and essentially involves the conception, design, fabrication and demonstration of equipment or products for which relevant proven industrial counterparts (mainly in the nuclear and mining industry) do not exist today. At all times this work is meant to be carried out within the framework of compliance regarding the requirements for operational safety, long term safety, retrievability and monitoring.

Each of the four technical Modules involves from 3 to 7 Contractors and as many as 6 different national disposal concepts may be represented. The programmes within these Modules are provided below:

Module # 1: Buffer Construction Technologies for horizontal disposal concepts

Module # 2: Waste Canister Transfer and Emplacement Technology for horizontal and vertical disposal concepts

Module # 3: **Heavy Load Emplacement Technology** for horizontal disposal concepts

Module # 4: **Temporary Sealing (using low pH cement) Technology** for construction of sealing plugs and for rock support, using shotcrete techniques

A second and equally important objective is to promote a shared European vision in the field of radioactive waste disposal technology. This is accomplished through the INTEGRATION process, which is one of the key objectives that identify EURATOM's 6th Framework Programme. Among other things, Integration (Module #6) involves working together within Work Packages and/or Modules; sharing information; comparing one another's input data and functional requirements for consistency; ensuring that, where possible, fabricated components are compatible; and coordination of demonstration activities.

The third objective involving communication and training is deemed to be sufficiently important to merit a separate Module #5. Among other things it involves the dissemination of knowledge by way of press releases, pamphlets, technical articles and presentations, videos and eventually an international event. Training, with a focus on New Member States, is to be accomplished via conferences, workshops and courses.

A general project schedule is shown in **Figure 1** below:

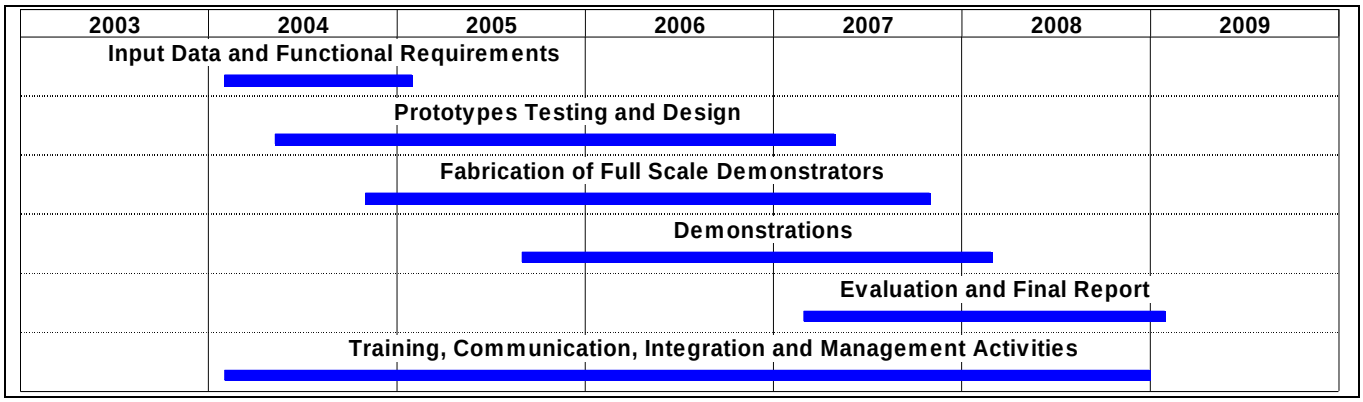

Figure 1: General Schedule of the ESDRED Project

As can be seen from the Figure 1 above, all of the design and testing of prototypes as well as the fabrication of most of the full scale demonstrators should have been completed during the year, and this was indeed the case. For various reasons which do not put the project in jeopardy work on 2 of the full scale demonstrators will carry over into 2008. Overall the fourth year of the Project, which terminated at the end of January 2008, can again be characterized as a success, given that the major objectives for the period were successfully achieved. These include:

- Additional testing of previously fabricated bentonite rings as well as testing of the entire related ring handling equipment.
- Preparations for a 30m long backfill test in a surface mock-up and for an underground sealing plug construction test both of which are to be carried out in 2008.
- Continuation of the saturation dynamics testing of a high gas permeability seal in a laboratory mock-up and the continuation of in-situ testing of 4 similar borehole seals at an underground laboratory.
- Continuation of a programme of non-intrusive seismic based monitoring experiments at the Mont Terri underground laboratory in Switzerland.
- Initiation of a similar monitoring test at the Grimsel site in Switzerland in parallel with other similar tests that are outside ESDRED (for comparison purposes).
- Completing the desk study regarding retrievability by doing a critical review of 2 national approaches.
- Award of a Contract for the design and construction of the last demonstrator to be built within the ESDRED programme i.e. for the transport shuttle, transport cask, gamma gates and related docking devices, pushing robot and mock-ups of the waste container and disposal drift.
- Completion of final modifications to SKB's heavy load deposition equipment and the start of equipment endurance testing which could potentially last through 2008.
- Transfer to, and reassembly of ANDRA's heavy load emplacement equipment at the temporary "demonstrator show room" in Limay near Paris.
- Underground construction and instrumentation of 4m long plug using low pH shotcrete.

- Continued improvements to the ESDRED web site (www.esdred.info) which had recorded over 14,000 visitors to the end of the year 2007.

- Running the third Low-pH workshop in Paris, France in June 2007.

- ESDRED partners presented papers and/or participated in conferences and workshops in at least 8 different countries on 3 continents.

- Fixing of the programme for the "International Technical Conference on the Practical Aspects of Deep Geological Disposal of Radioactive Waste" to be held in Prague, in the Czech Republic, June 16-18, 2008. This is being organised in cooperation with the Czech Technical University in Prague and RAWRA, the Czech national waste management agency.

THE TECHNICAL WORK ACCOMPLISHED DURING THE FOURTH YEAR INCLUDES:

Module 1: Buffer Construction Technology

The full-scale mock-up for the grout backfill experiment was constructed in the second half of 2007. The mock-up consists of a series of 13 segments of concrete pipes with a 3 m inside diameter. The inverted floor, constructed within these pipes, serves to support two 2 m diameter steel tubes, representing the disposed HLW Super Containers. **Figure 2** is a photograph taken during the construction when the steel tubes were being inserted. At the end of the 4th project year, the mock-up was in heating mode aimed at achieving the target internal temperature conditions. In October 2007, an on-site pre-test was performed, to identify the right mixing conditions for the grout during the injection test. **Figure 3** is a photograph taken during this pre-test, when the fluidity of the obtained mixture was being measured.

For the installation of the seal in the PRACLAY Plug test MX-80 bentonite was selected as the sealing material. The PRACLAY gallery was constructed in the Mol URL in September/October 2007.

Figure 2: Assembly of the full-scale mock-up

Figure 3: Grout preparation pre-test (check fluidity)

Concerning the complementary programme implemented on the bentonite rings, the **Figures 4 and 5** illustrate the additional work that was carried out.

Figure 4: Lifting Test by Ring Central Hole

Figure 5: Brazilian Shearing Test

Module 2: Waste Canister Transfer and Emplacement Technology

For the vertical concept the detailed design for all components was accomplished and the fabrication of the components and the test stand was launched in Year 4. Specialised companies were selected and contracts for the fabrication work were awarded. All the materials were ordered and the actual progress of the fabrication and the assembly of the components confirm the availability of the first components at the test site in March 2008. The construction work at the test site, to convert the turbine hall into a test stand, is scheduled to start beginning of February 2008. The **Figures 6 to 10** display the status of the component manufacturing whereas **Figure 11** provides a view of the steel construction work at the test site.

Following a one year delay with regard to the original planning (due to corporate strategy and not to ESDRED team inefficiency), ANDRA carried out a purchasing process, selected the appropriate Contractor to design, fabricate and test the full scale industrial demonstrator for the horizontal concept. In the course of a "Competitive Dialogue" the CEGELEC Company, based in Grenoble, acting as an industrial integrator, was chosen. The main components were designed and the most critical long lead items have been ordered. **Figure 12** displays the general layout of the industrial demonstrator for the horizontal emplacement concept.

After completing the second case study, i.e. investigating the possibilities of retrieving BSK3 canisters in the German vertical borehole concept, the final deliverable (Mod2-WP4-D4) for Work Package 4 "Retrievability Desk Study" was finalised and issued in May 2007.

Figure 6: Manufacturing of emplacement device

Figure 7: Manufacturing of transport cart

Figure 8: BSK 3 dummy

Figure 9: Fabrication of transfer cask

Figure 10: Fabrication of borehole lock

Figure 11: Construction work at test site

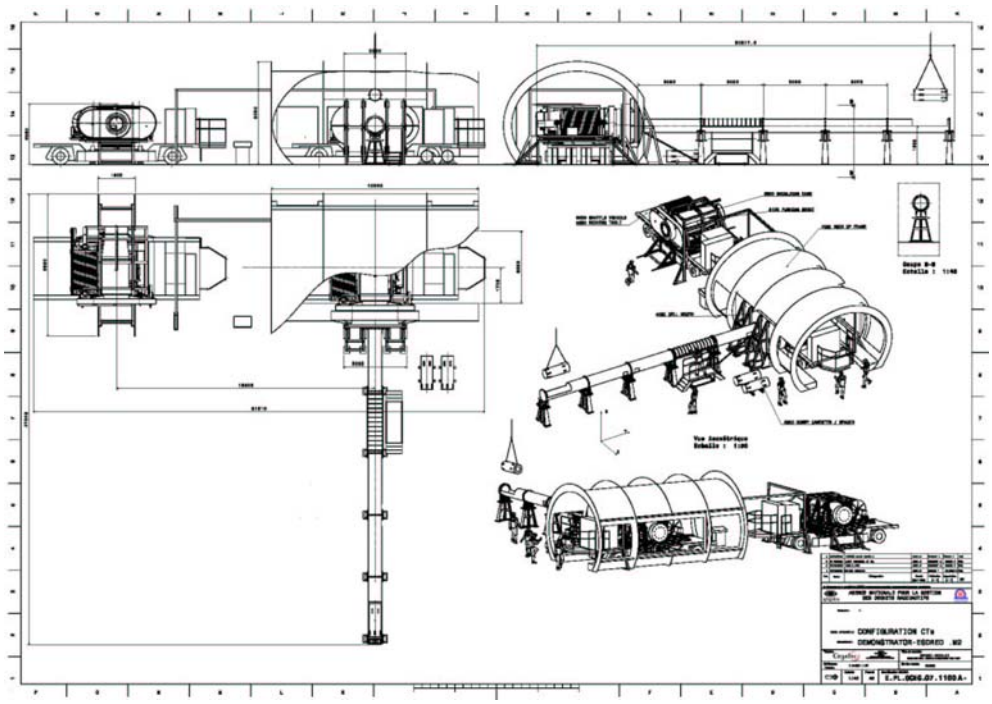

Figure 12: General layout of Demonstrator for Horizontal Emplacement

Module 3: **Heavy Load Emplacement Technology**

Concerning the KBS-3H deposition machine (Swedish concept developed by SKB, based on water cushion technology), the Site Acceptance Tests (SAT) was effectively performed on 16th February 2007. The official SAT, initially scheduled to commence on April 3rd 2006 had to be postponed after it was discovered that the deposition machine could not control the container whenever it was geometrically out of balance. An extensive trouble-shooting period took place with much back and forth activity between the factory and the test site. This led to various technical modifications, which have now been completed.

After the SAT, the deposition machine has been operated extensively and the total travel distance of the Super Container from February 2007 to the end of 2007 is about 12 km. The tests performed have shown that the emplacement equipment designed and fabricated within the scope of the ESDRED Project can operate effectively for the transport and deposition of Super Containers with a weight of 45t in horizontal drifts excavated in hard rock.

Further tests are however required to verify the availability and the reliability of this equipment over longer time periods. For example it has been observed that the water cushion technique used by

SKB/Posiva is sensitive to load variations. The system is also sensitive to the set-up alignment between the transport tube for the Super Container, the deposition drift and the start tube for the deposition machine. Some components have been replaced during this period e.g. water control valves and some reprogramming has also be necessary but generally the equipment has functioned well. Two types of Super Containers have been fabricated. The first container that was tested had a stainless steel shell and the seconded had a carbon steel shell. The Super Container with the stainless steel was dismantled late 2007 and only minor deformation of the shell could be observed. The tests with the seconded container are still ongoing.

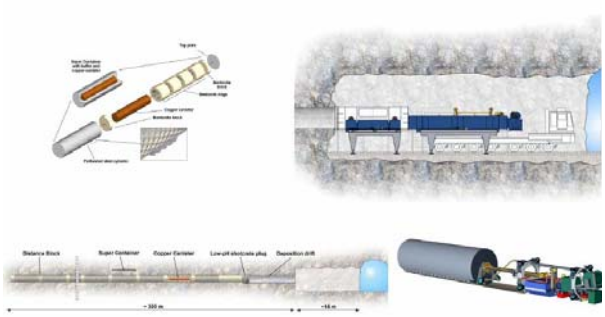

Figure 13: Main components in the KBS-3H concept

Figure 14: Installation of the KBS-3H deposition equipment at Äspö HRL, Sweden

ANDRA's deposition equipment is designed for emplacing sets of buffer rings and spent fuel canisters. Tests in mock-ups of horizontal disposal cells have shown that this emplacement equipment, designed and fabricated within the scope of the ESDRED Project, can be operated effectively for the transport and emplacement of the bentonite rings as well as the much heavier Spent Fuel Containers which weigh of 43t. . Further tests will need to be conducted in real underground conditions and over a longer period of time to assess the availability and the reliability of this equipment. It has also been observed that the air cushion technique used by ANDRA is sensitive to load variations. This means that the air cushions must be individually monitored and controlled. Finally, an efficient spooling system is considered necessary for a proper functioning of the air hose winch.

The test bench has since been dismantled, transported and re-erected in ANDRA's temporary show-room, at Limay (near Paris), where it is on display.

The results from the testing of the deposition equipment within Module 3 will be reported in the final report for the Module in May 2008.

Figure 15: ANDRA Deposition Equipment Test Bench

Module 4: (Temporary Sealing Technology)

A low-pH long shotcrete plug demonstrator was constructed in the Grimsel URL (Switzerland) between January 15 and March 29, 2007, with the aim of demonstrating its support capacity under realistic conditions.

The basic layout of the full-scale demonstration tests consists of a 4 m long parallel low-pH shotcrete plug constructed at the back-end of a 3.5 meter diameter horizontal gallery, excavated in granite with a TBM. One linear metre of highly compacted bentonite is sandwiched between the end of the gallery and shotcrete plug. The bentonite has been provided with an artificial hydration system to accelerate the saturation process and, if required, to impose a pore water pressure in the buffer. Besides several sensors and a data acquisition and control system were installed. The materials and equipment installed include: 38.5 m3 of concrete; 16 588 kg of bentonite; 22 humidity sensors, 2 total pressure cells and 2 piezometers in the bentonite; 5 total pressure cells and 4 piezometers between buffer front and the plug; and finally 4 extensometers and 25 geophones on the plug face.

The operational phase (testing) started on March 29, 2007 with the injection of water, at a pressure of 2 bars, at the back end of the bentonite buffer. A water leakage at the bottom of the plug delayed the artificial hydration of the bentonite buffer; some remedial actions were taken and, by the end of November the total pressure and humidity [of the buffer] started rising.

Therefore, the conclusion of the test, originally expected for end of January 2008, is now delayed for around 6-7 months.

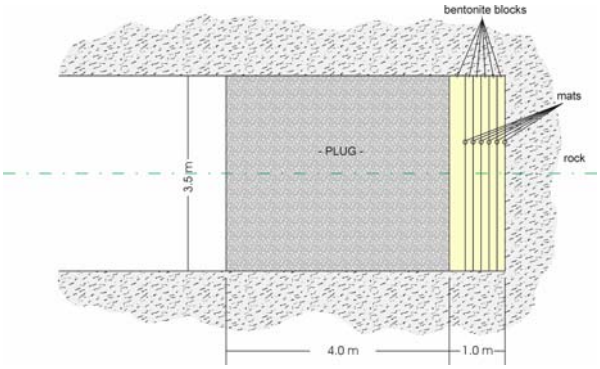

Figure 16: Long plug test. General layout.

Figure 17: Long plug test. Bentonite buffer construction

Figure 18: Long plug test - Data acquisition and control system

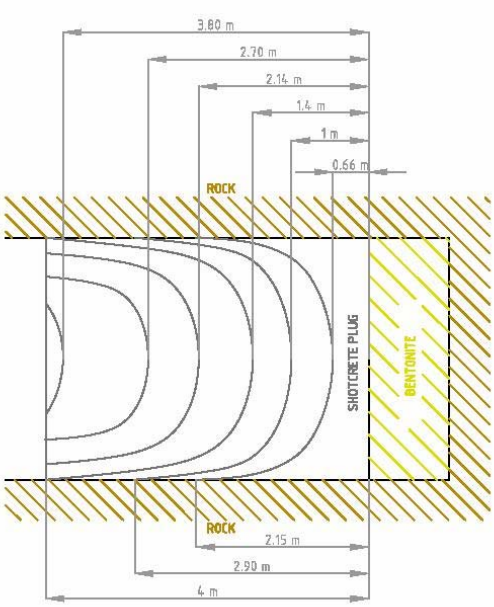

Figure 19: Long plug test showing curved layers of shotcreting

All laboratory tests of low-pH samples from the “low-pH shotcrete for Rock support demonstration test” at Hagerbach had been completed during 2007. The tests demonstrated that low-pH shotcrete is a feasible alternative for rock support in radioactive waste repositories from an engineering point of view (mechanical properties, constructability, etc).

Preparation of the final report of Module 4 has been started. The template was distributed by the end of November to the participants and it is planed to be released in summer 2008.

Figure 20: Field test with low-pH shotcrete for rock support at Äspö HRL, Sweden

Figure 21: Pilot tests with low-pH shotcrete at the Test Gallery Hagerbach Ltd, Switzerland

COMMUNICATION, TRAINING, AND INTEGRATION PROGRESS DURING YEAR 4:

The fourth year of the project included all of the usual events such as workshops, papers at conferences and articles in mostly in-house or sub-contractor publications. For the first time ESDRED activities also included an event organised specifically for the media. The most visible event of the year was the workshop on low pH cements organised by ESDRED and several of the partners. At the same time a lot of time and effort went into the planning for the "*International Event*" (Module 5 WP7) which will take place in the Czech Republic in June of 2008 (last contractual year).

Module 5: (Training & Communication)

Last year's "**Radioactive Waste Management**" training course at the University Politehnica in Bucharest Romania was the subject of a follow up presentation in Brussels, at an Information Meeting organised by the European Commission in relation to the 7th Euratom Framework Programme, Work Programme 2007. Otherwise the main training activity during the past year was the 3rd Low-pH Cement Workshop organised jointly by ANDRA and SKB. It was held in Paris, in June 2007. More than 30 highly specialized cement/concrete professionals from 10 different countries, including Canada and the USA, attended. This gave the audience an opportunity for a much wider outlook regarding the technical and scientific issues involved. The proceedings have been placed on the ESDRED web site at www.esdred.info.

ESDRED partners were equally active in the area of Communication. Various partners made presentations or provided papers to events in Canada, China, France, Germany, Sweden and the USA. This was also the first year that one of the partners held a special media event (SKB at Äspö) and also the first time that one of the partners produced a technical theme pamphlet (GRS regarding the results of the SB experiment).

Over the course of the year the IPC, with help from GRS and Ondraf/Niras, was able to finalise the programme for an International Conference in Prague, Czech Republic. The local co-sponsors are the Czech Technical University in Prague and RAWRA, the Czech waste management agency. A first Call for Papers and Circular was issued in April 2007 and the Second Circular was mailed on 31 January 2008. Details are available on the ESDRED web site at www.esdred.info.

Module 6: (Integration)

This challenging Module is the responsibility of the ESDRED Project Coordinator, also known as the IPC or Integrated Project Coordinator. Among other things the work in this Module involves managing a committee of independent Experts who are given certain technical documents to review or tasks to perform and who report directly to the Board of Governors, with copy to the Commission. During the course of the first three years of the Project these Experts reviewed and commented favourably on a number of Deliverables and witnessed 2 demonstrations, thereby completing all of their contractual assignments. This past year an additional demonstration was added to the Scope of the Experts' work. Consequently one of the Experts was invited to

witness an annular gap backfilling demonstration involving pure MX80 bentonite resulting in one additional Deliverable (D5.3).

In preparation for the coming (final) year of the project the IPC and the Module Leaders met twice to develop and agree on a common Table of Contents (and format) for all of the Final Technical Reports as well as for the Final Project Report.

Once again ANDRA & SKB demonstrated considerable cooperation/integration in preparing a common paper to be presented at the WM08 Conference being held this year in Phoenix, Arizona, USA (they will also do so for the Prague Conference to come).

Last year a number of ESDRED partners embarked (outside of ESDRED) on a related project called TEM or Test and Evaluation of Monitoring Techniques at the Grimsel Laboratory in Switzerland. The work is ongoing and one of the techniques being evaluated and compared is the ESDRED non-intrusive approach based on seismic tomography.

Finally it is worth noting that the ESDRED partners were unable to renew their cooperation and present a joint ESDRED-2, or similar proposal, in relation to the topics available within the EC's FP7 Programme. Nevertheless some of the partners, now used to working together for 4 years, have elected to continue cooperating together on various projects outside any EU framework.

CONCLUSIONS:

Whereas the third contractual year of the project was heavily dedicated to physical work, the fourth contractual year was mostly focused on monitoring (e.g. the long plug installed at Grimsel), planning and preparatory work (e.g. the long backfill test and the in-situ plug construction at MOL) and design work (e.g. the industrial scale "Waste Canister Transfer and Emplacement" systems for vertical and horizontal emplacement). These 2 demonstrators will be fabricated, erected and demonstrated towards the end of 2008.

Many of the ESDRED partners, if not directly involved with the organisation of the "*International Event*" in Prague will however contribute papers, provide session chairmen etc.

Project Coordination by

ANDRA, Agence nationale pour la gestion des déchets radioactifs
DP/TE Engineering Department – Project Division
1/7 rue Jean Monnet, Parc de la Croix Blanche
92298 CHATENAY-MALABRY Cedex
France
Phone: +33 1 46 11 80 46
Fax: +33 1 46 11 82 23
Contact: contact@esdred.info
Web Site: www.esdred.info