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Preservation of Records, Knowledge and Memory (RK&M) Across Generations

Reference Bibliography

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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

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Preservation of Records, Knowledge and Memory (RK&M) Across Generations

Reference Bibliography

This bibliography aims at providing an overview of the work performed in the field of preservation of records, knowledge and memory in relation to radioactive waste management, especially disposal. For each entry, an abstract outlining the relevance of the document to the topic of RK&M is provided. This bibliography is a living document that will be updated regularly during the lifetime of the RK&M project.

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Preservation of Records, Knowledge and Memory (RK&M) Across Generations

Reference Bibliography

[Last updated: 12-JAN-2018]

Introduction

This bibliography aims at providing an overview over the work performed in the field of the preservation of records, knowledge and memory (RK&M) in relation with radioactive waste management, especially disposal.

The following criteria have been used to select the references:

- The document (or at least part of it) addresses the preservation of RK&M in connection with the management of radioactive waste.
- The document is publicly available.
- One synthesis document (such as a report) is preferable to a list of papers with a similar content.
- Original documents (scientific reports and papers) are preferred to reviews or press coverage.

The bibliography has helped the participants in the RK&M Initiative to identify the topics of concern in the field of RK&M and, eventually, the issues that have not yet been addressed. It is not meant to be an all-encompassing list that includes any generic reference that might be useful in the study of those topics. Therefore it does **not** include:

- General studies outside radioactive waste management, e.g. on memory loss, communication, memory, or the history of institutions
- Studies belonging to the field of radioactive waste management but that are only indirectly related to RK&M preservation. As an example, this bibliography does not include studies of climatic changes at a specific site. Clearly, they would be relevant for the development of a marking system at that site, but they could be used for many other purposes as well.

The general bibliography starts on page 12. For each entry, an abstract outlines the relevance of the document to the topic of RK&M preservation. Starting in many cases from the abstracts supplied with the documents, remarks by the RK&M group have been added in the course of the project. Internet links (status: July 2017) are provided for ease of access.

The general bibliography is preceded by publications related to the RK&M project (p. 4) and conference papers presented at conference sessions dedicated to the topic of RK&M preservation (pp. 6–11). Entries in these two sections are not repeated in the general bibliography section.

The NEA would like to thank the many who contributed to the RK&M Initiative (2011–2018), by direct participation as a member, by participating in particular project meetings, workshops or conferences, by responding to project questionnaires, or by contributing to project documentation. With contributions from many, this bibliography was compiled and maintained by Anne Claudel (NAGRA).

Bibliography

1. Publications related to the RK&M project

Project documents

Available at http://www.oecd-nea.org/rwm/rkm/

- 2011 Collective Statement of the RWMC on Records, Knowledge and Memory Preservation across generations
- 2014 Collective Statement of the RWMC on Records, Knowledge and Memory Preservation across generations
- RK&M Workshop Proceedings – October 2011
- RK&M Workshop Proceedings – September 2012
- Planned for 2018:
    - Final Report
    - KIF Concept Report
    - SER Concept Report
    - Regulatory Catalogue

Studies and Supporting documents

Available at http://www.oecd-nea.org/rwm/rkm/

- Literature Survey on Markers and Memory Preservation for Deep Geological Repositories – December 2013
- Monitoring of Geological Disposal Facilities – Technical and Societal Aspects – February 2014
- Loss of Information, Records, Knowledge and Memory – Key Factors in the History of Conventional Waste Disposal – March 2014
- Markers – Reflections on Intergenerational Warnings in the Form of Japanese Tsunami Stones – May 2014
- International Mechanisms to Support Records, Knowledge and Memory Preservation Over the Short and Medium Term – July 2015

Conference

OECD Nuclear Energy Agency (2015): *Radioactive Waste Management and Constructing Memory for Future Generations: Proceedings of the International Conference and Debate 15–17 September 2014 Verdun, France*. OECD/NEA, Paris.
http://www.oecd-nea.org/rwm/pubs/2015/7259-constructing-memory-2015.pdf

Organised by the NEA with the support of Andra, the French Radioactive Waste Management Agency, "Constructing Memory – An International Conference and Debate on the Preservation of Records, Knowledge and Memory (RK&M) of Radioactive Waste across Generations" brought together nearly 200 attendees from 17 countries in Verdun, France in September 2014.
The scope of the international conference was to present and discuss experiences, projects and prospects related to the preservation of RK&M both in radioactive waste management and in other domains, such as archiving, cultural heritage, archaeology, communication, semiotics and the arts. The conference, consisting in equal parts of plenary sessions and group discussions, ensured that a wide range of perspectives were presented and provided the space for cross-fertilisation across the several domains and sensibilities that were represented.
The international conference was structured along three timescales used within the RK&M initiative of the NEA: short term (several decades and likely more than 100 years), medium term (several centuries after repository closure, extending up to 1 000 years) and long term

(potentially starting at around 1 000 years after closure). Opening and closing lectures provided useful context and summarised discussions, thus completing the programme of the event.

2. Waste Management Conference papers presented at RK&M sessions

2012: 38th Annual Waste Management Conference, WM2012, Phoenix (AZ), USA

Session 034: Panel/Papers: Geologic Repository Warning Messages to the Future - Ensuring Continuity of Memory and Messages to Future Generations

1 panel paper:

- Schröder J., Pescatore C. (2012): Preservation of Records, Knowledge and Memory Across Generations. An emerging Multidisciplinary Work Area and an NEA Project http://www.wmsym.org/archives/2012/papers/12218.pdf

2014: 40th Annual Waste Management Conference, WM2014, Phoenix (AZ), USA

Session 102: Records, Knowledge and Memory (RK&M) for Geologic Repositories of Nuclear Waste

8 papers:

- Bertrand J., Plumeri S., Beaumont O., Sollet P., Buschaert S. (2014): Contribution of Metrology to a Qualified Disposal Monitoring System Stable over Centennial Timescales http://www.wmsym.org/archives/2014/papers/14031.pdf
- Wagner S., Hart J. (2014): How to Increase Knowledge of the Existence of a Nuclear Disposal Facility to Future Generations: Knowledge Footprint - A Perspective From an Operational Facility http://www.wmsym.org/archives/2014/papers/14221.pdf
- Holtorf C., Högberg A. (2014): Nuclear Waste as Cultural Heritage of the Future http://www.wmsym.org/archives/2014/papers/14361.pdf
- Pescatore C. (2014): Preservation of Records, Knowledge and Memory (RK&M) across Generations. An Overview of the Eponymous OECD/NEA Project http://www.wmsym.org/archives/2014/papers/14425.pdf
- Hotzel S., Pescatore C., Raimbault P., Claudel A. (2014): When Dealing with the Long Term, Care as to How Terms are Used: Reflections from the OECD/NEA RK&M Project Glossary http://www.wmsym.org/archives/2014/papers/14437.pdf
- Dumont J. –N., Martin G. (2014): The First International Decennial Appraisal of the Detailed Memory of the Manche Disposal Facility http://www.wmsym.org/archives/2014/papers/14470.pdf
- Thakur P., Van Luik A. (2014): Reasons for Post-closure Monitoring of the Waste Isolation Pilot Plant Repository http://www.wmsym.org/archives/2014/papers/14531.pdf
- Clark A., Wisbey S. (2014): Application of Knowledge Management to the UK's Radioactive Waste Management Programme http://www.wmsym.org/archives/2014/papers/14651.pdf

Session 114: Panel/Papers: Records, Knowledge and Memory (RK&M) for Geologic Repositories of Nuclear Waste

2 panel papers:

- Setzman E. (2014): Preservation of Information and Communication With Future Generations http://www.wmsym.org/archives/2014/papers/14509.pdf

- Pescatore C., Schröder J. (2014): Markers and Deep Geological Repositories - Learning within the OECD/NEA Project on the Preservation of Records, Knowledge and Memory across Generations http://www.wmsym.org/archives/2014/papers/14589.pdf

2015: 41st Annual Waste Management Conference, WM2015, Phoenix (AZ), USA

Session 119: Records, Knowledge and Memory (RK&M) for Geologic Repositories of Nuclear Waste

8 papers:

- Toothman M , Patterson C., Patterson R. (2015): Communicating with Future Generations – Major Obstacles to Overcome
  http://www.wmsym.org/archives/2015/papers/15008.pdf
- Gueretta J, Montgomery J., McKinney R., Anglim C., Cameon P. (2015): Long-Term Surveillance and Maintenance Records: Challenges Inherent to Managing Electronic Records
  http://www.wmsym.org/archives/2015/papers/15165.pdf
- Wagner S. (2015): Risk Considerations for WIPP Passive Institutional Controls
  http://www.wmsym.org/archives/2015/papers/15173.pdf
- Dumont J. –N., Charton P., Boissier F. (2015): Andra's Strategy and Approach for Long-Term Memory Preservation of a Deep Geological Repository
  http://www.wmsym.org/archives /2015/papers/15174.pdf
- Van Luik A., Patterson R., Kirkes G.R. (2015): Influencing Future Exploratory Drilling Rates—A Potential Approach for the Waste Isolation Pilot Plant
  http://www.wmsym.org/archives/2015/papers/15307.pdf
- Kroitoru L., Kroitoru H., Thompson W., Bruner I. (2015): Evidence from the Ancient World on Long-Term Preservation of Artifacts
  http://www.wmsym.org/archives/2015/papers/15442.pdf
- Dumont J. –N., Charton P., Boissier F. (2015): Andra's Memory Program - Linguistics and Semiology
  http://www.wmsym.org/archives/2015/papers/15587.pdf
- Pescatore C. (2015): Second Phase of the OECD NEA International Initiative on the Preservation of Records, Knowledge and Memory across Generations
  http://www.wmsym.org/archives/2015/papers/15616.pdf

2016: 42nd Annual Waste Management Conference, WM2016, Phoenix (AZ), USA

Session 083: Global Experience of Records, Knowledge and Memory (RK&M) for Nuclear Waste Geologic Repositories

7 papers:

- Van Luik A., Klein T., Sahd G. (2016): Ethical Considerations for Developing Repository Warning Messages to the Future
  http://www.wmsym.org/archives/2016/pdfs/16152.pdf
- Dumont J. –N., Tunbrant S.,Wisbey S., De La Codre P. –H., Van Luik A. (2016): Key Information File for Radioactive Waste Repositories – Preliminary Tests
  http://www.wmsym.org/archives/2016/pdfs/16169.pdf
- Patterson R., Toothman M., Callicoat J., Klein T. (2016): A Conceptual World Information Library (WIL) and Land Use Information System (LUIS)
  http://www.wmsym.org/archives/2016/pdfs/16181.pdf
- Klein T., Van Luik A., Patterson R. (2016): As Permanent as Practicable: The reality of Permanent Markers
  http://www.wmsym.org/archives/2016/pdfs/16191.pdf
- Watson R., Callicoat J., Ward A.L. (2016): There is Nothing Here for You: Passive Institutional Controls and Preemptive Resource Exploitation
  http://www.wmsym.org/archives/2016/pdfs/16197.pdf
- Hotzel S., Wisbey S. (2016): Markers and Beyond: Categorizing Human Intrusion Situations to be Addressed in Sub-surface Marking Concepts
  http://www.wmsym.org/archives/2016/pdfs/16378.pdf
- Pescatore C., Van Luik A. (2016): Millennial Time Capsules as a Promising Means for Preserving Records for Future Generations
  http://www.wmsym.org/archives/2016/pdfs/16542.pdf

Session 113: Panel: Experience of Records, Knowledge and Memory (RK&M) for Nuclear Waste Geologic Repositories

No panel papers

2017: 43rd Annual Waste Management Conference, WM2017, Phoenix (AZ), USA

[Proceedings of the Waste Management Conferences series are offered online without charge one year after the conference. Thus, hyperlinks to the documents in the archived 2017 proceedings are likely to become activated in spring 2018.]

Session 023: Global Experience of Records, Knowledge and Memory (RK&M) for Nuclear Waste Geologic Repositories

3 papers:

- Wisbey S., Hotzel S., Dumont J.-N., Berckmans A., Claudel A., Tunbrant S., Van Luik A., De La Codre P.-H. (2017): Development of an Integrated System for the Long-term Preservation of Records, Knowledge and Memory relating to Radioactive Waste Disposal Facilities
  17099
- Anton F., Bandt G., Braun M. (2017): Knowledge Management in the Field of Nuclear Energy - How to Bridge the Gap between Retiring Workforce and Next Generations
  17101
- Dumont J.-N., Wisbey S., Hotzel S., Berckmans A., Claudel A. (2017): Analysis of the Needs for Long Term Memory and Knowledge Preservation Relating to Radioactive Waste Disposal Facilities
  17213

Session 024: Panel: Records, Knowledge and Memory (RK&M) for Nuclear Waste Geologic Repositories

No panel papers

Session 105: Global Experience of Records, Knowledge and Memory (RK&M)

4 papers:

- Parks E., Walker B. (2017). Launching a Research Archive for FUSRAP Site Records
  17057
- Van Luik A., Patterson R., Klein T., Watson R. (2017): Ethical Considerations in Determining the Societal Investment in Warning Future Generations about Latent Long-term Risks from Radioactive Waste Disposal Facilities
  17058
- Callicoat J., Watson R., Patterson R. (2017): Practical Considerations for the Implementation of a World Information Library (WIL)
  17112
- Patterson R., Klein T., Toothman M. (2017): Re-evaluation of Waste Isolation Pilot Plant's Passive Institutional Controls Program – Status
  17116

2018: 44th Annual Waste Management Conference, WM2018, Phoenix (AZ), USA

Proceedings are expected to be finalised in May 2018, therefore the current list of papers is still preliminary. The proceedings will be published in May/June 2018 (available by order) and made publicly available online without charge one year after the conference.

Session 086: Global Experience of Records, Knowledge and Memory (RK&M) for Nuclear Waste Geologic Repositories

Preliminary list of 6 papers:

- Blanquer F. (2018): Building Sustainable and Efficient Markers to Bridge Ten Millennia: The Understanding Issues
  18058
- Dumont J.-N., Brodu A., Clerc G., Dressayre C. (2018): Elaborating a First Version of a KIF for the Manche Surface Repository in France
  18060
- Hotzel S., Berckmans A., Claudel A., Dumont J.-N., Schröder J., Tunbrant S., Wisbey S. (2018): Results Of The OECD-NEA Initiative "Preservation of RK&M Across Generations" (2011–2018)
  18084
- Massart C. (2018): Constructing Memory Through Artistic Practices
  18197
- Graham N., Pietrzak A., Wilkinson J., Zook K. (2018): NUCLEAR, Landmarker for a Waste Isolation Site: International Architecture Competition
  18240
- Dumont J.-N., De Angelis R. (2018): Can we use Pictograms in a Long Term Communication System Related to a Radioactive Waste Repository?
  18301

3. General bibliography

- Adams M.R., Kaplan M.F. (1986): *Marker development for Hanford Waste Site disposal.* – Waste Management '86: Waste isolation in the U.S. technical programs and public education: proceedings of the symposium on Waste Management at Tucson, March 2-6, 1986; 1: General interest, p. 425-432.
  http://www.wmsym.org/archives/1986/V1/72.pdf
  Certain radioactive wastes, including stored wastes in single-shell tanks and pre-1970 solid waste burial grounds and contaminated soil sites, are currently located at the Hanford Site. The Hanford Defence Waste-Environmental Impact Statement is being prepared to assess options for the disposal of these wastes. In particular, barrier and marker systems are being designed and developed for placement over the wastes following site preparation. Archaeological analogues have been examined to provide guidance for the design of markers intended to communicate for up to 10,000 years. Materials, dimensions, and messages have been specified for both surface and sub-surface prototype markers. A prototype surface marker has been designed, and its procurement is pending. The integration of the barrier design and markers into a system has also been planned. Plans for placement of both surface and sub-surface markers have been completed.

- Advisory Committee on Nuclear Safety, Canada (2001): *Research in Support of Operational Safety at Nuclear Power Plants*. INFO-0724. ACNS, Ottawa.
  This document was prepared by an advisory committee to the Canadian regulator in order to assess the potential safety-related consequences of a significant reduction in funding for nuclear power research and development (R&D) in Canada. The committee was asked to make recommendations regarding major safety areas that required continued R&D, regarding actions that might be taken to ensure that trained persons would be available for recruitment within the industry, and regarding succession planning for staff both in the industry at large and within the regulatory body. The report recommends in particular an assessment of the retention of corporate memory in the nuclear industry, and contains a discussion of several types of knowledge that contribute to corporate memory, ranging from textbook scientific knowledge to information that is contained primarily in personal notes and recollections. The report also recommends the establishment of a cooperative training program involving the industry, the regulator, research institutions and universities, with “appropriate emphasis” on ageing, decommissioning and abandonment issues.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Raimbault P., Valentin-Ranc C. (1993): How to mark repositories in geological formation. - *SAFEWASTE 93: International Conference on Safe Management and Disposal of Nuclear Waste*, Avignon, 13-18 June 1993, vol. 3, p. 212-221.
  This paper presents a general reflection on how to reduce the probability of inadvertent human intrusion in the future, in particular with the use of markers.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Boursier F.O. (2000): Record and Archival System for the Monitoring Period of a Surface Disposal Facility. – American Nuclear Society: *WM '00: HLW, LLW, mixed wastes and environmental restoration - Working towards a cleaner environment*. Proceedings of Waste Management '00, February 27-March 2, 2000, Tucson, Arizona. American Nuclear Society, La Grange Park. Session 66, Paper 4.
  http://www.wmsym.org/archives/2000/pdf/66/66-4.pdf
  The French surface disposal facility *Centre de la Manche*, operated by ANDRA, remained in operation for 25 years. Shipments of waste packages stopped in 1994 and approval is pending for the facility’s transition into its monitoring period. ANDRA has set up a structure responsible for identifying all data and documents deemed useful for the knowledge and understanding of the site. This paper presents that structure, its objectives and associated means. It also provides a detailed

description of the constitution of the document collection, including sorting and identifying relevant items over the long term. The transfer of documents and data on a perennial support is also addressed, as well as details concerning archival storage. The maintenance of industrial "memory" is essential for safety purposes (in case of intervention during the monitoring period) and contributes to the improvement of public acceptance of the long-term waste management carried out at the disposal facility.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2006): *Disposal facilities: Preserving a collective memory for future generations.* ANDRA, Chatenay-Malabry. http://www.andra.fr/download/andra-international-en/document/editions/299.pdf

  This is one in a series of pamphlets published by Andra to explain its projects and operations to the general public. This particular pamphlet gives an overview of Andra's work, both past and ongoing, on preserving memory and knowledge of radioactive waste repositories. It notes that the purposes of this work include informing future generations of the presence of repositories to prevent inadvertent intrusion, describing the installation and potentially facilitating remedial action if required, and supporting future decisions. It gives a high-level description of what has been done to preserve information about existing facilities and studies being undertaken with respect to future geological repositories. It includes a short account of the characteristics of permanent paper. Illustrations are provided of record-keeping from the past, such as mediaeval manuscripts, the Académie Française, and long-lived monuments.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA) (2008): *Centre de stockage de déchets radioactifs de la Manche (50), situé sur la commune de Diguelleville. Mémoire de synthèse pour les générations futures (destinée à maintenir une connaissance minimale aux générations prochaines et à toutes celles qui se succéderont jusqu'en 2500 au moins)*. ["Centre de stockage de la *Manche" facility (radioactive waste disposal facility – acronym CSM), located within the municipality of Diguelleville in the Manche district. Memory synthesis report for future generations (intended to retain minimal knowledge for upcoming and successive generations, at least up to the year 2500)*.] CSM Record DD.NSY.ADSQ.07.0017.A. ANDRA, Chatenay-Malabry. http://www.andra.fr/download/site-principal/document/CSM_memoire_de_synthese_pour_les_generations_futures.pdf

  A synthesis report intended for future generations and presenting a history of radioactivity, a history of the *Centre de la Manche* and of its forecast impact on the environment, as well as the policy conducted by Andra in order to preserve a memory of the site. This synthesis report remains a draft one for now and it is expected that a final version will be completed at a later time.

- Agence nationale pour la gestion des déchets radioactifs (ANDRA), Charton P., Ouzounian G. (2008): A Challenge for Radioactive Waste Management: Memory Preservation. – *WM'08 Annual Waste Management Symposium: Proceedings*, February 24 -28, 2008, Phoenix, AZ. http://www.wmsym.org/archives/2008/pdfs/8014.pdf

  For short-lived waste for which disposal facilities have a life expectancy of a few centuries, ANDRA has set up a system for memory preservation. Based on the historical analysis on a comparable timescale and on an appraisal of information-conservation means, a series of regulatory as well as technical provisions were made in order to ensure that sound information can be transferred to future generations. Requirements associated to the provisions deal mostly with the legibility and formulation of the information that must be decrypted and understood – and therefore preserved – at least during the lifetime of the facilities. The paper describes the achievement at the *Centre de la Manche* Disposal Facility.

  In the case of deep geological repositories for long-lived radioactive waste, it is much more difficult to consider how to maintain the richness of the information over the long timescales. Based on the heritage of a much more ancient history, we must seek to find appropriate means in order to develop surface markers and even more to ensure their conservation over long timescales. It will

also be necessary, in the light of the experiments and efforts made in order to decrypt ancient messages, to find suitable expression aimed at populations in a distant future.

- Anderson K. (2005): Designing for deep time: how art history is used to mark nuclear waste. A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Theory, Criticism and History of Art, Design and Architecture within the joint degree M.S./M.F.A. program School of Art and Design Pratt Institute October 2005.
  This thesis presents a critical review of studies carried out in preparation for the design of a permanent marker system for the Waste Isolation Pilot Plant (WIPP) project. The focus is on non-linguistic visual aspects of the marker system. The primary subject of the dissertation is the work of the Markers panel documented in the Expert judgment on markers to deter inadvertent human intrusion into the Waste Isolation Pilot Plant report by Trauth et al (1993). A number of the studies that preceded and contributed to the Markers panel work are also reviewed in some detail, among them the report of the Futures panel (Hora et al 1991), as well as reports by Kaplan (1983), Sebeok (1984) and Tannenbaum (1984). Comparisons are also drawn with other studies and events, such as studies of symbols used to communicate information in public places, and the history of the Tilted Arc sculpture in New York City. The author concludes by suggesting that more thorough testing of designs should be carried out before the design is concluded and implemented.

- Aoki K., Fujii N., Kageyama H., Yoshimura K., Ohuchi J., Tsuboya T., RWMC (2008): Durable Media for Long-Term Preservation of Geological Repository Records. – *WM'08 Annual Waste Management Symposium: Proceedings*, Feb. 24 -28, 2008, Phoenix, AZ.
  http://www.wmsym.org/archives/2008/pdfs/8320.pdf
  The concept of a record preservation system should be the combination of several methods, the "Relay System" and the "Permanent System", in order to impart redundancy to the communication function. The former would maintain record preservation and communication functions in the framework of social systems whereas the latter would consist of durable storehouse facilities, recording media and markers/monuments and be independent of any social systems and human control.
  Several engraving experiments using laser technologies on durable artificial materials, such as silicon carbide, have been performed successfully. These technologies can be applied to not only documentary records – with a 500 page document reduced to a volume of 10 cm x 10 cm x 32 cm – but also to markers and monuments.

- L'art: vecteur puissant de la transmission de la mémoire. – *Revue générale nucléaire* 5, octobre 2015.
  This is a brief article on Cecile Massart's work. Cécile Massart is a Belgian artist whose work focuses on new means of conveying the memory of radioactive waste sites in the landscape (see below, Massart 2004)

- Bandolin G., Sörlin S. (2007): Laddade landskap – värdering och gestaltning av teknologiskt sublima platser. SKB R-07-14. Svensk Kärnbränslehantering AB, Stockholm (in Swedish)
  http://www.skb.com/publication/1404276/R-07-14.pdf
  This project (November 2004-January 2006) covered the design issues and questions about the values of place and landscape in which risk and danger are important elements. Another theme related to conservation issues, protection of monuments and memories, and in such "dangerous places". An important feature of the project was to visit and describe the locations characterised by high technological experimentation and the presence of risk and danger.
  Case studies included:
  - The power of the distance: Woomera, Australia.
  - The time breeds new questions: Yucca Mountain and Nevada Test Site, Nevada, USA.
  - Revaluations: Rocky mountain arsenal wildlife refuge in Denver, Colorado, USA.
  - A mansion in Eurajoki: Posiva, Finland.

  - Forsmark and Oskarshamn, Sweden.
  - "They will come back as an idea ...": About time, monuments and landscapes.

  In connection to site visits in the USA and Australia, interviews and visits were performed to museums and other institutions and complemented by extensive literature studies.

- Battelle (1978): Institutions in long-term nuclear waste management. – *Nontechnical issues in waste management: Ethical, institutional, and political concerns*, PNL-2400. Battelle, Columbus (Ohio), Chapter IV, 43-64.

  A number of concerns have been raised regarding the role that human institutions may have to play in the long-term management of nuclear wastes. Controversy exists concerning the need for any human institution to be involved in long-term management; there is also substantial uncertainty about whether human institutions could actually carry out any functions that might be required of them over the long term. Chapter IV provides a framework for thinking about institutional issues that may be involved in the long-term management of nuclear wastes. An attempt has been made to identify organisational functions that might be needed to insure the integrity of a waste repository over several centuries.

- Benford G. (2000): Deep Time: How Humanity Communicates Across Millennia. HarperCollins (new edition).

  The author first gives a summary of the different ways that humans have intentionally left evidence of their lives long after their death. He continues to chronicle recent and ongoing efforts to leave evidence of our civilisation to future humans and in outer space. The second half of the book is about how future generations will interpret the environmental state of the planet as a monument to our current society and how we can take action to change the state of the planet.

- Benford G., Kirkwood C.W., Otway H., Pasqualetti M.J. (1991): *Ten thousand years of solitude? On inadvertent intrusion into the Waste Isolation Pilot Project Repository*. LA-12048-MS. Los Alamos National Laboratory (also reproduced in SAND 90-3063: Expert judgment on inadvertent human intrusion into the Waste Isolation Pilot Plant, App. D).
  http://www.wipp.energy.gov/picsprog/documents/Ten%20Thousand%20years%20of%20Solitude.pdf

  This report documents the work of one of four interdisciplinary teams investigating modes of inadvertent intrusion into the WIPP repository over a period of 10000 years. After identifying a series of environmental and socioeconomic changes and factors with the potential for affecting the means and likelihood of inadvertent intrusion, the team developed a wide-ranging variety of illustrative scenarios. The authors argued that while the probability of any specific scenario may be very low, this does not mean that the probability of inadvertent intrusion is low. They concluded that given the wide range of foreseeable changes that could significantly affect the likelihood of intrusion, the overall probability of intrusion is appreciable (between 1% and 25%), and also that it is possible that the consequences of such an intrusion could well surpass the consequences of an intrusion carried out with present-day technology under present conditions. The authors recommended that markers to deter intrusion be investigated and deployed at the site as a means of reducing the likelihood of future intrusion.

- Berndes S. (2001): *Wissen für die Zukunft: Ethische Normen der Auswahl und Weitergabe naturwissenschaftlichen und technischen Wissens.* Diss. Univ. Cottbus. LIT, Münster.

  This dissertation addresses the issue of knowledge transfer in the general field of natural sciences and technology. A case study is devoted to information management systems for the management of high-level radioactive waste.

- Berndes S., Kornwachs K. (1996): Transferring knowledge about high-level waste repositories: an ethical consideration. – *High level radioactive waste management 1996: Proceedings of the seventh annual international conference*: Las Vegas, April 29-May 3, 1996, p. 494-498.

This paper is concerned with the ethical dimension of information management systems. It is frequently argued in Europe and North America that there is an ethical obligation to transfer knowledge about high level waste repositories. However, ethical obligations are closely linked to the difference existing between our civilisation and future generations. The study presents a list of ethical arguments, as well as a method involving various development scenarios.

- Berry W.E. (1983): *Durability of marker materials for Nuclear Waste Isolation Site*. BMI/ONWI-474. Batelle Columbus Laboratory.
  This report reviews the probable long-term performance of materials that might be used in markers for radioactive waste repositories. The performance assessed includes not only survival of the marker itself, but also continued legibility of markings inscribed on it, by limiting the permissible depth of deterioration to 1 mm. The materials reviewed include several metals, natural stone materials, artificial stone and ceramics, plastics. Most of the materials assessed were found to be unlikely to survive a period of 10000 years, but some metals (titanium, some nickel alloys) and ceramics (SYNROC, synthetic sapphire) were identified as having good prospects for survivability. Some library materials (paper, photographic film) were reviewed for protected indoor conditions, but none were assessed to be likely to survive without periodic re-copying.

- Bloomfield B.P., Vurdubakis T. (2005): The secret of Yucca Mountain: reflections on an object in extremis. – *Environment and Planning D: Society and Space* 23/5, 2005, p. 735-756.
  The processes through which boundaries are made and unmade conceptually, socially, and materially have been of enduring interest to a wide range of social scientific disciplines including sociology, anthropology, geography and science studies. These processes are studied using the example of the planned Yucca Mountain high-level nuclear waste repository in Nye County, Nevada.

- Bowen-Shrire M., Eckerhall D., Jander H., Waniewska K. (2008): Bevarande av information om slutförvar för använt kärnbränsle – förslag till handlingsplan. SKB P-08-76, Svensk Kärnbränslehantering AB, Stockholm (in Swedish).
  http://www.skb.com/publication/1764036/P-08-76.pdf
  This report is a proposal for an action plan with the ultimate aim of ensuring that information about the repository for spent nuclear fuel can be preserved and transferred for future generations. Its purpose is to present ideas on tangible measures and guidelines for information preservation and transfer, in the short and long term.
  The report deals with a number of aspects relating to information preservation as well as risks that can lead to the loss of important information. The main emphasis is on measures that need to be implemented in the near future to ensure that successive and direct information transfer is handled in a suitable manner.

- Bowen-Shrire M., Jander H., Waniewska K. (2007): Kunskapsbevarande för framtiden – Fas 1. SKB P-07-220, Svensk Kärnbränslehantering AB, Stockholm (in Swedish).
  http://www.skb.com/publication/1596997/P-07-220.pdf
  This report summarises the work done in the field of knowledge preservation regarding a repository for spent nuclear fuel in Sweden and in other selected countries. The purpose of the report is to provide a basis for a proposal for an action plan for knowledge preservation regarding a repository for spent nuclear fuel. It covers the basic principles and methods for information preservation and transfer, and describes their advantages and disadvantages. The report also covers topics such as the time perspective, target groups, context, and discusses the difference between the concepts information and knowledge. The conclusions of the report include a number of recommendations for further work.

- Brenk Systemplanung GmbH (BS) (2009): *Radioactive Waste and Spent Fuel Data Collection, Reporting, Record Keeping and Knowledge Transfer by EU Member States*. Final Report. European Commission, Brussels, Belgium.

This report was prepared for the EC to document the status of the implementation of national waste data collection systems in EU member states and candidate countries. The data contained in these systems comprise the primary records collected during pre-disposal waste management. In addition to compiling information about the structures and contents of waste data collection systems, the report also describes the legal bases, responsibilities and reporting requirements in each country. The scope includes low-level waste, high-level waste, and spent fuel if it is designated as waste. In addition to recording detailed information on the waste data collection systems in most member states and candidate countries, the report also identifies good practices and makes recommendations to the EC on possible actions for the Commission to consider in order to foster improvement in some areas where there is a lack of consistency.

- Bundesamt für Energie (2016): *Leitfaden zum Wissensmanagement in den Regionalkonferenzen: Wissensaufbau – Wissenstransfer – Wissenserhalt*. BFE, Bern, Switzerland.
  http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_582639228.pdf
  This document is a compact manual prepared by the Swiss Federal Office of Energy to help members of regional participation groups manage knowledge and information in the course of the site selection process, extending over 10-20 years.

- Bundesamt für Energie, Buser M. (2010): *Forschungsprogramm Radioaktive Abfälle: Literaturstudie zum Stand der Markierung von geologischen Tiefenlagern*. BFE, Bern, Switzerland.
  http://www.news.admin.ch/NSBSubscriber/message/attachments/19773.pdf
  A literature study on the current status of science and technology regarding markers and more generally knowledge preservation in the field of radioactive waste management.
  For an updated English version, see RK&M studies.

- Carpenter E. (ed.) (2016): *The Nuclear Culture Source Book*. Black Dog Publishing, London.
  The Nuclear Culture Source Book is a resource and introduction to nuclear culture, one of the most urgent themes within contemporary art and society, charting the ways in which art and philosophy contribute to a cultural understanding of the nuclear. The book brings together contemporary art and ideas investigating the nuclear Anthropocene, nuclear sites and materiality, along with important questions of radiological inheritance, nuclear modernity and the philosophical concept of radiation as a hyperobject.

- Chapman N., Dansie A., McCombie C. (2006): Preservation of archaeological materials in arid environments relevant to Yucca Mountain. – *Global progress toward safe disposal: Proceedings of the 11th international high-level radioactive waste management conference (IHLRWM)*: April 30 - May 4, 2006, Las Vegas, Nevada, p. 691-697.
  The objective of this study was to evaluate archaeological materials from underground openings or shallow burial in arid environments relevant to Yucca Mountain and to draw conclusions about how their state and their environment of preservation could be of relevance to design and operational aspects of the high-level waste repository. This type of study can be useful for the evaluation of long-lasting materials for record preservation.

- Chapman N., McCombie C. (2003): *Principles and standards for the disposal of long-lived radioactive wastes*. Waste Management Series, Vol.3. Pergamon, Amsterdam
  Of particular interest for RK&M preservation is Chapter 11: “Preserving records of the existence of the repository”. This book also includes chapters on Human intrusion and on Monitoring.

- Clegg R., Pinner A., Smith A., Quartermaine J., Thorne M.C. (1997): Consideration of post-closure controls for a near surface low level waste disposal site. – *Proceedings of an*

international symposium on Experience in the Planning and Operation of Low Level Waste Disposal Facilities: held in Vienna, 17-21 June 1996. Proceedings Series. IAEA, Vienna.

The paper discusses potential intrusion scenarios within the framework of the programme of disposal of low level radioactive wastes by British Nuclear Fuels plc (BNFL) at Drigg, Cumbria. Although control of the site is anticipated for a period of about 100 years post-closure, eventually restrictions on access will lapse. Potential modes of intrusion into the Drigg site – leading to exposure to, and/or exhumation of, the wastes – have been studied. Overall, it is concluded that provided that a variety of documentary records are established, ranging from local council archives to mass produced maps, then memory of the site can realistically be assumed whilst civilisation continues to exist. However, if this first line of defence fails, markers constitute a second warning system. Finally, assessment calculations can be used to demonstrate that, even if these two lines of defence fail, risks from intrusion and radiation doses contingent upon intrusive events having occurred would not be unacceptably large.

- Codée H. (2005): Safe is beautiful. - *CNS Waste Management '05*, Ottawa, Canada, May 8-11, 2005.

  This paper and the following describe how the HABOG storage facilities have been built into a work of art.

- Codée H. (2003): Give the public something, something more interesting than radioactive waste. - *Proceedings of Waste Management WM '03*, February 23-27, 2003, Tucson, AZ, American Nuclear Society, La Grange Park, Session 17, Paper 37.
  http://www.wmsym.org/archives/2003/pdfs/37.pdf

- Deyo Y.E., Pauling T. (2006): Community Involvement as an Effective Institutional Control at the Weldon Spring Site, a U.S. Department of Energy Office of Legacy Management Site. – *Proceedings of Waste Management Symposium WM '06, February 26 - March 2, 2006*: Global Accomplishments in Environmental and Radioactive Waste Management: Education and opportunity for the next generation of waste management professionals.
  http://www.wmsym.org/archives/2006/prof6377.html

  The U.S. Department of Energy (DOE) Weldon Spring Site Remedial Action Project (WSSRAP) was conducted for the purpose of remediating a portion of a former trinitrotoluene and dinitrotoluene production plant that was operational from 1941 to 1945 and a former uranium refinery that was operational from 1957 to 1966. Surface remediation activities concluded in 2001 with the completion of 18 km2 on-site engineered disposal facility. In order to deal with the long-term surveillance and maintenance issues at the site, a plan was established for development of a comprehensive public involvement and education program. In August 2002, the Weldon Spring Site Interpretive Center opened to the public with exhibits about the history of the area, the remediation work that was completed, and a site information repository that is available to visitors. In addition, the Hamburg Trail for hiking and biking was constructed, including a series of historical markers. A ramp and viewing platform with informational plaques were constructed on the disposal cell. Science-oriented educational programs that directly relate to past remediation activities and present long-term surveillance and maintenance issues are presented to St. Louis area school groups and other community-based organisations. Other innovative programs have been developed to address daily maintenance issues at the site and to promote beneficial community re-use of the property.

- Drottz-Sjöberg B.M. (2010): Perceptions of Nuclear Wastes across Extreme Time Perspectives. - *Risk, Hazards & Crisis in Public Policy* 1(4), 2010, Article 9.

  An empirical study, financed by the Swedish Radiation Authority (SSI), on perception of time, time periods, and responsibilities related to the final repository for spent nuclear fuel was conducted in 2002 in the municipalities of Oskarshamn and Östhammar. The overall results showed rather restricted time horizons among the respondents. Risk estimations relating to nuclear wastes were

not extremely high, and as usual the risk to others rated higher than the risk to oneself. People emphasized the importance of SSI reviews in the near future in contrast to the distant future, i.e., while under operation and up to 1,000 years, rather than for the longer time periods of relevance for the reviews. People also perceived the consequences to be much more severe in the shorter time perspectives than in the longer ones, given a leakage from the canisters in the repository. The importance of future generations' life situations was reported as high, and perceived to be of greater importance to oneself than to others. The construction of a safe final repository for spent nuclear fuel ranked the highest on a list of topics when respondents indicated the responsibilities of current generations.

- Eng T., Norberg E., Torbacke J. (et al.) (1996): *Information, conservation and retrieval*. SKB Technical Report 96-18. Svensk Kärnbränslehantering AB (SKB), Stockholm. http://www.skb.com/publication/13533/TR96-18webb.pdf

  This report was prepared following a seminar on information conservation and retrieval held in Sweden in 1996. It contains two papers presented at the seminar plus a reprint of the NSK KAN-1.3 report (Jensen 1993). The first paper is by Dr. Erik Norberg, Director General of the Swedish National Archives, which describes the role and history of the national and regional archives in Sweden, discusses problems that prevent large portions of the cultural heritage from being adequately preserved, and presents an action plan to address the situation. The issues raised include failure to document events, failure to set aside documents for preservation, use of unsuitable or inadequate storage media, inadequate search tools, and intentional removal of material in the interests of efficiency and savings in administration. The second paper, by Professor Jarl Torbacke from the Department of History at Stockholm University, describes the roles of archivists and historians in preserving and maintaining a nation's identity and culture, and notes the importance of open information in a democratic society. The third paper is a reprint of a report that is included separately in this bibliography, namely Jensen (1993) "*Conservation and retrieval of information".*

- Eng T. (1993): *The value and need for long term conservation of information regarding nuclear waste repositories*. - High level radioactive waste and spent fuel management: proceedings of the 1993 International Conference on Nuclear Waste Management and Environmental Remediation: Prague, September 5-11, 1993, vol. 2, p. 711-714.

  This paper discusses a system for best possible mitigation of human intrusion. With the present knowledge, this comprise the following parts: (a) development of planning procedures for long-term conservation of gathered information (present and future national and international archives, markers etc.); (b) continuous follow up of the state-of-the-art of information media; (c) preparations for national rules and regulations on nuclear waste information; (d) participation in international cooperation on issues concerning nuclear waste information keeping, transfer and retrieval.

- Engstroem-Laarouchi S. (2010): Means to reduce human activities at the site: markers, records... where do we stand? – *Workshop: Towards transparent, proportionate and deliverable regulation for geological disposal*, Tokyo, 20-22 January 2009. OECD Nuclear Energy Agency, Issy-les-Moulineaux, p. 175-178.

  The main activities of the Swedish Nuclear Fuel and Waste Management organisation (SKB) related to preservation of information about a geological disposal are discussed. The aim of information preservation is to avoid damage by accident and allow for our and future generations to make informed decisions. In the draft action plan, which should be presented in connection with the applications for the site selection process, suggestions on implementation of preservation of information are given. They cover the type of information of interest to be preserved, time horizons to consider as well as the potential incidents or events to envisage, their possible consequences and the measures to mitigate these consequences. Target groups are identified as well as strategies for preservation (from generation to generation, directly into a distant future). Different media for archives are envisaged. An international perspective, including international co-

operation, on information preservation is also discussed.

- Environmental-Social Advisory Services (ESAS), Atomic Energy Control Board (1997): *Comprehensive review of the literature on institutional controls to limit land use*. AECB, Ottawa.

  This report documents the results of a literature survey that was conducted in order to identify case studies that would provide a basis for estimating the duration of effectiveness of institutional controls to limit land use, and to identify attributes that contribute to the effectiveness of such controls. The literature survey was based primarily on a broad range of North American sources. The survey did not locate any case studies in North American literature of the long-term application and effectiveness of institutional controls on land use, but it did report a number of findings on the subject based on the survey. The report presents findings on a wide variety of types of institutional control over land use, both active and passive. The survey found no factual basis for believing that any form of active institutional control over land use would remain effective for longer than a few centuries at most. Passive controls such as markers and archives could survive for longer periods, but the literature suggests that their effectiveness would be problematic. The report includes an extensive bibliography of documents consulted.

- Fattah A. (1997): Requirements for records and reports related to safeguards for geological repositories. – *WM'97 : HLW, ILW, mixed wastes and environmental restoration - Working towards a cleaner environment*. Proceedings of Waste Management 97, Tucson, Arizona, March 2-6, 1997.
  http://www.wmsym.org/archives/1997/sess11/11-06.htm

  For effective and efficient application of safeguards, the IAEA requires vital information on facility design and operation. Part of the required information will also flow from the other obligations, e.g. safety, waste disposal, environmental protection, etc. An integrated approach to document all required information will be an advantage to all concerned. The basic safeguards approach for a geological repository will consist of continuous Design Information verification (DIV) and application of integrated safeguards verification system for inventory verification. DIV should confirm the integrity of the repository area and detect any/all undeclared activities, inter alia, the presence of sensitive equipment and tunnelling in the vicinity of the repository. As part of records keeping, the facility has to maintain records of the content and location of each spent fuel container. The IAEA and the State should retain all safeguards relevant documentation and information (i.e. records of the complete inventory of nuclear material and/or previous operations of the repository) deemed necessary. These records should be kept for at least as long as safeguards exist for the nuclear material in the repository.

- Flüeler T. (ed.) (2005): Long-term knowledge generation and transfer in environmental issues: A challenge to a knowledge bases-society: Invited session. – *PISTA 2005: The 3rd international conference on politics and information systems: Technologies and applications*, July 14-17, 2005, Orlando, Florida, USA. International Institute of Informatics and Systemics.

  The session was organised to explore the following issues: integration of a diverse range of knowledge and interests; prerequisites of sound sustained decision making for the long term; interplay between living (current) knowledge and preserved knowledge; and the role of governance. The following papers are included:
  - D. Metlay, “Obligation to Future Generations: The Interplay of Science and Policy”: describes the interplay of science and policy issues during the development of safety standards for disposal in the US
  - D. Easterling, “Incorporating the Interests of Future Generations into Nuclear Waste Policymaking: What Would They Say to Us?”: investigates ethical basis for decision making on radioactive waste and proposes a large-scale discovery process to investigate the potential for methods other than geological disposal.

  - G. McCarthy, I. Upshall, “Using Contextual Information Frameworks to Maintain Knowledge of Radioactive Waste”: describes the potential application of contextual information frameworks for preserving the contextual information necessary to make use of preserved data.
  - M. Bovy, V. Massaut, “Why an Open Common-Knowledge Process about Decommissioning Funds? How Transparency Supports Democracy”: explores ethical and philosophical issues and recommends a more broadly-based transparent decision making process for decision making on funding requirements for decommissioning.
  - C. Fricke, B. Faust, “Knowledge Transfer - Bifunctional Method for Knowledge Conservation”: describes a two-stage process for interviewing persons in order to pass on their knowledge, explicit and implicit, to successors.
  - T. Flüeler, “Long-Term Knowledge Generation and Transfer in Radioactive Waste Governance. A Framework in Response to the Future as an Enlarged Tragedy of the Commons”; discusses intragenerational and intergenerational equity and proposes that a working procedural approach to intragenerational equity issues could contribute to the success of a “rolling present” model for intergenerational knowledge transfer.

- Foote K.E. (1990): To Remember and Forget: Archives, Memory, and Culture. – *American Archivist* 53, Summer 1990, p. 378-392.
  http://courses.ischool.utexas.edu/Winget_Megan/2010/Fall/INF381/Readings/Foote_RememberForget.pdf
  The idea of archives as collective memory is sometimes employed as a metaphor for discussing the social and cultural role of archives. It is argued here that the idea is more than a metaphor and is supported by theories that would view collections of documents and material artefacts as means of extending the temporal and spatial range of communication. Two examples illustrate the interrelationship of archives and memory within this broadened view of communication and culture. The first arises from attempts to find ways to warn future generations of the location of radioactive waste repositories. The second revolves around pressure to efface from cultural landscapes evidence of tragic events that people wish to forget.

- Garfield S. (1994): «Atomic Priesthood» is Not Nuclear Guardianship, A Critique of Thomas Sebeok's Vision of the Future. - *Nuclear Guardianship Forum*, Issue 3, On the Responsible Care of Radioactive Waste Materials, Spring 1994.
  http://www.ratical.org/radiation/NGP/AtomPriesthd.html
  A review of Thomas A. Sebeok’s report to the Bechtel Group's Human Interference Task Force (Sebeok 1984, see below).

- Goldman N., Bertone P., Chen S.,Dessimoz C., Le Proust E.M., Sipos B., Birney E. (2013): Towards practical, high-capacity, low-maintenance information storage in synthesized DNA. – *Nature*; DOI: 10.1038/nature11875.
  Digital production, transmission and storage have revolutionized how we access and use information but have also made archiving an increasingly complex task that requires active, continuing maintenance of digital media. This challenge has focused some interest on DNA as an attractive target for information storagehttp://www.nature.com/nature/journal/vaop/ncurrent/full/nature11875.html - ref1 because of its capacity for high-density information encoding, longevity under easily achieved conditions and proven track record as an information bearer. The paper describes a scalable method that can reliably store more information than has been handled before: computer files totaling 739 kilobytes of hard-disk storage and with an estimated Shannon information of 5.2×10^6 bits were encoded into a DNA code. This DNA was synthesized and sequenced, and the original files could be reconstructed with 100% accuracy. Theoretical analysis indicates that this DNA-based storage scheme could be scaled far beyond current global information volumes and offers a realistic technology for large-scale, long-term and infrequently accessed digital archiving. In fact, current trends in technological advances are reducing DNA synthesis costs at a pace that should make this scheme cost-effective for sub-50-year archiving within a decade (Abstract: Nature online)

- Goodenough W.H. (1999): Communicating 10,000 Years into the Future. – *Human Organization* 58(3), p. 221-225.
  A personal record by an anthropologist who participated in the development of the WIPP markers.

- Haddal R.N., Finch R., Baldwin G. (2015): *Long-term information management (LTIM) of safeguards data at geological repositories*. Sandia Report SAND2015-8071. Sandia National Laboratories, Albuquerque.
  The studies published by Sandia National Laboratories in 2015 and 2016 (see Haddal 2016) examine what types of safeguards-related data should be included in a long-term information system for a deep geological repository. In addition to exploring current documentation and archiving needs in various countries that are considering repositories, the studies consider hypotheses about future needs and analyse the pros and cons of very long-term information management. They also include references to the RK&M project.

- Haddal R.N. (2016): *Long-Term Information Management (LTIM) of Safeguards Data at Repositories: Phase II*. Sandia Report SAND2016-10738. Sandia National Laboratories, Albuquerque.
  http://prod.sandia.gov/techlib/access-control.cgi/2016/1610738.pdf
  See above.

- Hart J. (John Hart and Associates, P.A.) (2000): *Permanent Markers Monument Survey: Contractor report*. Waste Isolation Pilot Plant, Carlsbad (New Mexico).
  http://www.wipp.energy.gov/picsprog/documents/monument%20survey.pdf
  This document describes a survey of prehistoric inscriptions in rocks in New Mexico and neighbouring Texas. The survey was carried out in order to determine how well various rock types within climatological zones similar to that of the WIPP site have performed as media for inscriptions in terms of both legibility and durability. Sites chosen were limited to rock types that have been proposed for use in permanent markers, in similar climatological conditions, and that have not undergone major restoration or artificial preservation. Rock properties, inscription characteristics, apparent ages of inscriptions and the effects of weathering and erosion were studied. Conclusions are presented on the durability of various rock types encountered, on the effects of aspect and rates of erosion, on the effects of the form of the inscriptions, and on the importance of contrast in colour and texture, and recommendations are made on rock type and form of inscriptions that might be used for permanent markers at WIPP. The report includes photographs and site reports from the sites studied.

- Hart J. (John Hart and Associates, P.A.) (2000): *Permanent Markers Material Analysis: Contractor report*. Waste Isolation Pilot Plant, Carlsbad (New Mexico).
  http://www.wipp.energy.gov/picsprog/documents/Materials%20Analysis.pdf
  This report presents the results of a literature review on materials proposed or suggested for use in a permanent marker system at the WIPP repository. The objectives of the review were to identify materials that could be suitable for each marker system, to evaluate these materials based on information available in the literature and from expert opinion, to recommend materials that appear to be best suited for specific marker applications, and to identify tests most appropriate for the screening phase of the testing program. The material design criteria adopted in the WIPP Permanent Markers Implementation Plan are described. Materials specified in the reference design as well as alternative materials identified both before and during the literature review are described and analysed vis-à-vis the design criteria. Comparisons are presented between candidate materials for each marker component. Conclusions and recommendations for the first level of material selection and testing in the screening phase of the permanent markers testing program are provided.

- Hart J. (John Hart and Associates, P.A.) (2000): *Ancient Cementitious Materials: Contractor Report.* Waste Isolation Pilot Plant, Carlsbad (New Mexico).
  http://www.wipp.energy.gov/picsprog/documents/Ancient%20Cementitious%20Materials.pdf
  This report describes a literature review of instances in which man-made cementitious materials have survived for very long time periods. Case studies of long-lived concrete structures are provided. The report documents attributes of the cementitious materials that promoted their survival. It demonstrates that there are examples of the use of man-made cementitious materials that have survived for as long as 8800 years. The report concludes that it should be possible to produce a concrete that will survive for a period of 10,000 years when used as a construction material for markers or monuments.

- Hart J. (John Hart and Associates, P.A.) (2004): *Passive Institutional Controls Implementation Plan*. Waste Isolation Pilot Plant, Carlsbad/New Mexico. DOE/WIPP 04-2301.
  http://www.wipp.energy.gov/library/PICsImplementationPlan.pdf
  This document presents an overview of the plan for implementation of the overall Passive Institutional Controls (PICs) program at WIPP. The program comprises three main elements: a records management program involving archiving of WIPP project-related documentation at a number of off-site locations; the permanent markers program at the site of the repository; and an "awareness triggers" program including dissemination of information to various agencies, post-closure control of the site by government and land use restrictions. A general description is given for each of these elements, and implementation schedules and timelines are presented. A public participation program is also outlined. The report includes attachments describing the regulatory requirements related to PICs, commitments made by the US Department of Energy (US DOE) in fulfilment of those requirements, and commitments related to PICs made by US DOE in the Hazardous Waste Facility Permit.

- Hart J. (John Hart and Associates, P.A.) (2004): *Permanent Markers Implementation Plan*. Waste Isolation Pilot Plant, Carlsbad/New Mexico. DOE/WIPP 04-3302.
  http://www.wipp.energy.gov/library/PermanentMarkersImplementationPlan.pdf
  This report is a supporting document to the WIPP Passive Institutional Controls Implementation Plan. It presents US Department of Energy (US DOE) plans for the design and implementation of the Permanent Markers Program including the establishment of performance specifications, determination of testing needs, and definition of a strategy for making design decisions. A brief overview of the regulatory requirements and commitments is given, followed by an outline of the markers design process, including performance and design criteria. There are six components of the permanent marker system: large surface markers, small subsurface markers, a berm, buried storage rooms, the hot cell (an existing structure to be left as a permanent monument), and an information centre. For each of these components, a conceptual design is presented, "open design considerations" (aspects of the design that have not yet been finalized) are listed, and alternative materials are listed. The development of messages to be inscribed on or contained in various marker system components is outlined. Program management activities and the quality assurance program are briefly described.

- Health and Safety Executive, United Kingdom (2015): *The management of higher activity radioactive waste on nuclear licensed sites: Section 7 Managing information and records relating to radioactive waste.* Joint guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees, p. 62–75.
  http://www.onr.org.uk/wastemanage/waste-management-joint-guidance.pdf
  This document is one component of regulatory guidance provided by the regulatory authorities in the United Kingdom to organisations responsible now and in the future for the management of high- and intermediate-level radioactive waste. It covers the topic of management of information and records for radioactive waste from its generation up to the end of regulatory control. This period is recognised to be in the hundreds of years. It contains general guidance on information

and records management policy, strategy, systems and procedures, including risk management and backup procedures. Transfer of records to other organisations in time is also addressed. It includes discussions on records media and on records storage facilities and archives. There is a general guidance on the nature of the information, records and metadata to be managed. Processes for periodic review of records holdings and for security and the protection of sensitive information are covered. The document also includes a list of references to national legislation, regulatory policies and guidance, and relevant national and international standards, e.g., in the field of archiving.

- Holtorf C., Högberg A. (2014): Communicating with future generations: what are the benefits of preserving cultural heritage? Nuclear power and beyond. - *European journal of Post - Classical Archaeologies* 4, 2014.
  Using the example of the legacy of the nuclear power station at Dounreay (UK), this paper discusses what it means to preserve information for the benefit of future generations.

- Hora S.C., von Winterfeldt D., Trauth K.M. (1991): *Expert judgment on inadvertent human intrusion into the Waste Isolation Pilot Plant*. SAND90-3063. Sandia National Laboratories, Albuquerque.
  http://www.wipp.energy.gov/picsprog/Test1/SAND90-3036%20Expert%20judgement,%20human%20intrusion.pdf
  This report describes the studies carried out by four multi-disciplinary expert teams (the "Futures Panel") to develop scenarios illustrating the possible development of future societies in the vicinity of the WIPP repository, and potential modes and likelihoods of human intrusion into the repository. Each of the four teams developed a methodology for delineating possible future societies and the possibilities for intrusion into the repository under those societies. The purpose of these scenario developments was to provide background information for later work to design markers, barriers and off-site information systems in order to deter future intrusion into the repository, or to mitigate its consequences. The intrusion scenarios identified by the four teams were highly varied, and served to alert subsequent design groups to the need to consider a very wide range of possibilities when designed markers and barriers. Each of the teams also developed quantitative estimates of the probability of various types of intrusion, as input to subsequent performance assessments.

- Hora S.C., von Winterfeldt D. (1997): Nuclear Waste and Future Societies: A Look into the Deep Future. - *Technological Forecasting and Social Change* 56(2), 1997, p. 155-170.
  Inadvertent human intrusion is thought to be a significant threat to nuclear waste repositories. At the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, four interdisciplinary teams of experts were brought together to provide insights into the modes and likelihoods of such intrusions as far as 10,000 years in the future. A formal expert elicitation process was used in obtaining their judgments. The teams provided scenarios that, although formed using different approaches, reflected several central themes including: the uncertainty about the need for resource exploration in the future, the rate at which technology develops or declines in future, the likely failure of government control of radioactive waste sites, and the preservation and potential loss of memory about nuclear waste.

- Human Interference Task Force, HITF (1984): *Reducing the likelihood of future human activities that could affect Geologic High-Level Waste Repositories*. BMI/ONWI-537. Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio
  http://www.osti.gov/bridge/servlets/purl/6799619-fpYg48/6799619.pdf
  The Human Interference Task Force was convened by the U.S. Department of Energy to determine whether means exist or could be developed to reduce the likelihood of future inadvertent intrusion into or interference with radioactive waste repositories. The report discusses siting, land use and institutional controls as one component of a multi-faceted approach to preventing intrusion. It describes and discusses various aspects that contribute to the reliability of communication of messages at varying levels of complexity, and recommends the use of permanent markers, both

surface and sub-surface, and of the collection and wide dissemination and storage of records about the repository and its contents. The report contains recommendations on the design of several types of markers and on the development, collection, distribution and archiving of records intended to inform future generations of the nature of the repository and hazards that would be posed by intrusion. The task force also recommended the establishment and use of a universal symbol to denote the presence of biohazardous waste. The task force concluded that significant reductions in the likelihood of human interference could be achieved that might be effective for as long as thousands of years after closure, by taking appropriate steps to communicate the existence of the repository to future generations. The report recommended further study on the effectiveness of various types of messages, on durability of messages and marker materials, and on mechanisms for transmission of messages.

- Husemann D. (2014): Das Archiv für die Ewigkeit. – *Bild der Wissenschaft* 4, 2014, p. 60-66. http://www.wissenschaft.de/archiv/-/journal_content/56/12054/3174917/Das-Archiv-f%C3%BCr-die-Ewigkeit/

  This paper describes the project „Memory of Mankind“ (see also https://www.memory-of-mankind.com/).

- Ialenti, V. F. (2014): Adjudicating Deep Time: Revisiting the United States' High-Level Nuclear Waste Repository Project at Yucca Mountain. – Science & Technology Studies 27(2), 2014, p. 27-48.

  This paper draws upon perspectives on legal personhood, expert knowledge-practices, and social relations to revisit the legal-procedural framing of the United States' planned high-level nuclear waste repository project at Yucca Mountain. Specifically, it examines how this project reinvented both (a) conventional figures of legal personhood as what is called a 'reasonably maximally exposed individual' and (b) legal adjudication's familiar 'rule-facts-judge' template as a frame for establishing the repository licensing regime's delegation of roles, responsibilities, and duties in response to its unique regulatory horizons that extended millennia into the future. Unpacking the implications of these familiar legal figures being brought to bear on historically unprecedented 'deep' timescales, this paper concludes by offering alternative lines of inquiry for interdisciplinary analysis of nuclear energy and its associated waste products that were revealed in developing this case study of the Yucca Mountain Project.

- [International Atomic Energy Agency (1995): *Establishing a national system for radioactive waste management*. IAEA Safety Series No. 111-S-1. IAEA, Vienna. Superseded by IAEA 2010, GSR Part 1, see below]

- International Atomic Energy Agency, Working Group on Principles and Criteria for Radioactive Waste Disposal (1996): *Issues in radioactive waste disposal: second report*. IAEA-TECDOC-909. IAEA, Vienna
  http://www-pub.iaea.org/MTCD/publications/PDF/te_909_web.pdf

  This is the second in a series of three reports on issues and concepts in the area of waste disposal by the IAEA's Working Group on Principles and Criteria for Radioactive Waste Disposal. Post-closure issues discussed in the document include the preservation of information and knowledge, public reassurance, and prevention of misuse of repository contents. The following chapter discusses a number of difficulties that arise in the application of the optimisation concept in radiation protection to waste disposal, particularly in light of the very long time scales involved and the inter-generational ethical considerations that arise in consequence. The final chapter deals with the potential for incompatibilities between safeguards concerns and safety considerations, both prior to and following closure of a repository. In general, the purpose of this document is to raise and present questions for further consideration, rather than to reach conclusions or propose potential solutions.

- International Atomic Energy Agency (1999): *Maintenance of records for radioactive waste disposal*. IAEA-TECDOC 1097. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1097_prn.pdf
  This document was prepared in order to advise national programmes on ensuring the retention and availability of information for future generations post-closure, and on a methodology for the compilation and long term management of records. The scope covers both near surface and geological disposal. The report describes the information needs of future generations and lists the essential elements of a records management system to meet those needs. It describes a hierarchical relationship between the high level information (HLI) needed by future generations, the intermediate level information required for licensing, and the primary level information generated during siting, design, construction and closure. It describes the types and content of records that should be collected in an HLI, and sets out the structure of a records management system, the organisation and responsibilities involved in its establishment and maintenance, and key issues to be addressed. The report includes an Appendix describing technical options for record media and retrievability.

- International Atomic Energy Agency (2001): *Waste Inventory Record Keeping Systems (WIRKS) for the management and disposal of radioactive waste*. IAEA-TECDOC-1222. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1222_prn.pdf
  This document is intended to provide technical guidance on the establishment of a waste inventory record keeping system (WIRKS), as well as presenting a methodology for the compilation and management of records in such a system. A WIRKS is considered to be a subset of the primary level information that would be gathered when waste is generated and during the pre-closure phases of the life cycle of a repository. While some of the information in a WIRKS may become part of the post-closure records, this document does not explicitly discuss the post-closure phase. The scope of the report includes both low-level and high-level waste. The document discusses the reasons why a WIRKS is needed during repository design, construction and operation, and provides technical guidance on the kinds of technical information that should be recorded for each waste package, as well as associated documentation (metadata). It also discusses responsibilities for and gives suggestions on the implementation and management of a WIRKS. The report contains several case studies on experience with WIRKS systems in a number of countries.

- International Atomic Energy Agency (2002): *Documentation for Use in Regulating Nuclear Facilities*. IAEA Safety Standards Series No. GS-G-1.4. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1132_scr.pdf
  This is the IAEA consensus safety standards Guidance document that provides recommendations on how to meet the safety requirements for documentation relating to the regulatory and authorisation process for nuclear facilities. The scope includes the life cycle of all kinds of nuclear facilities including waste repositories, but in the case of repositories it is limited to the stages up to and including closure, i.e. the end of direct regulatory control. The guide includes recommendations related to regulations and regulatory guides, to documents prepared by operators in fulfilment of regulatory requirements, and to documents produced for a specific facility by the regulator, including licences and licence conditions. The document also includes an Appendix describing the regulatory approval and authorization process in general.

- International Atomic Energy Agency (2002): *Issues relating to safety standards on the geological disposal of radioactive waste*: Proceedings of a specialists meeting held in Vienna, 18-22 June 2001. IAEA-TECDOC-1282. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1282_prn/t1282_part1.pdf
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1282_prn/t1282_part2.pdf
  This document contains the proceedings of a specialists meeting held in Vienna in June 2001. Sessions were devoted, among other topics, to “Human intrusion”, “Reversibility and retrievability” and “Monitoring and institutional control”. In the summary of the last session, it was noted that the

current generation has a limited ability to ensure that disposal will be implemented according to the current plan, and that each generation will make its own plans with respect to the use and closure of the repository. Each generation has the responsibility to pass down to the next generation the information, skills and knowledge needed to make informed decisions, and further consideration should be given to mechanisms for achieving the transfer or passing down of information between generations. In the final paper in that session, "Radiation protection activities after closure of geological repositories", M. Jensen and P. Wallberg pointed out that a large body of environmental monitoring information is already being built up, and this represents another source of information to be passed down to future generations. In relation to RK&M, see in particular Appendix A.6. Human intrusion, A.7. Reversibility and Retrievability, A.8. Monitoring and Institutional Control as well as the corresponding chapters 2.5, 2.6, 2.7, 4.2, 4.3 and 4.4.

- International Atomic Energy Agency (2003): *Predisposal management of high level radioactive waste: Safety guide*. IAEA Safety Standards Series WS-G-2.6. STI/PUB/1151. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1151_web.pdf
  This is the IAEA consensus safety standards Guidance document that provides recommendations on how to meet the safety requirements for the predisposal management of high level radioactive waste from nuclear fuel cycle facilities and large research and development installations. The guide includes in particular recommendations related to safety considerations for waste management and decommissioning, including preparation of documentation, as well as record keeping and reporting. The development of waste package specifications is addressed in an appendix.

- International Atomic Energy Agency (2003): *Record keeping for the decommissioning of nuclear facilities: Guidelines and experience*. Technical Reports Series 411. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/TRS411_scr.pdf
  This report provides information on how to identify, update as needed and maintain the necessary records to assist in the decommissioning of nuclear facilities. The records in question are generated and collected during the design, construction, operation, shutdown and post-shutdown phases of the facility prior to the completion of decommissioning. Advice is given on the selection of records to be retained from earlier life-cycle phases as well as from decommissioning activities themselves. Guidance is given on the establishment and maintenance of a records management system for decommissioning purposes, including periodic auditing. An appendix describes options for record storage media and retrievability. There are extensive annexes describing various national experiences with record keeping related to decommissioning.

- International Atomic Energy Agency (2003): *Predisposal management of low and intermediate level radioactive waste*. Safety guide. IAEA Safety Standards Series No. WS-G-2.5. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1150_web.pdf
  This is the IAEA consensus safety standards Guidance document that provides recommendations on how to meet the safety requirements for the predisposal management of low and intermediate level radioactive waste from nuclear fuel cycle facilities, large research and development installations and radioisotope production facilities. The guide includes in particular recommendations related to safety considerations for waste management and decommissioning, including preparation of documentation, as well as record keeping and reporting. The development of waste package specifications is addressed in an appendix.

- International Atomic Energy Agency (2004): *Records for radioactive waste management up to repository closure: Managing the primary level information (PLI) set*. IAEA-TECDOC-1398. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1398_web.pdf

The purpose of this report was to raise international awareness of the need to identify and manage pre-closure records in a manner that both serves the operational needs of a repository and the need to identify and transfer relevant information to future generations in a systematic manner. It provides an overview of the various records that could be generated up to repository closure and describes the need to identify the relevant records that are likely to be of value for future generations. It also describes the importance of the early establishment of a coordinated, integrated and well managed primary level information (PLI) set. Noting that waste often passes through a number of organisations between its generation and disposal, it points out the need for a single comprehensive records management system to ensure information is preserved through the transfers. It also describes information management considerations that need to be addressed by a records management system.

- International Atomic Energy Agency (2004): *Maintaining Knowledge, Training and Infrastructure for Research and Development in Nuclear Safety*. INSAG Series 16. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1179_web.pdf
  In 1999 INSAG (International Safety Advisory Group) stated the following principle: "Organizations concerned [should] ensure that operating experience and the results of research relevant to safety are exchanged, reviewed and analysed, and that lessons are learned and acted on." The purpose of this report is to emphasize the importance of maintaining capabilities for nuclear research and education, especially with regard to safety aspects, so that nuclear safety may be maintained in IAEA Member States, and to alert Member States to the potential for significant harm if the infrastructure for research, development and education is not maintained.

- International Atomic Energy Agency (2005): *Methods for maintaining a record of waste packages during waste processing and storage*. Technical Reports Series 434. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/TRS434_web.pdf
  This report is intended to provide guidance on current best practices for maintaining records of waste packages produced through various phases of the waste management process from waste generation through conditioning, storage and transport, until receipt of the waste packages at a disposal facility. The records in question include both records describing individual waste packages, and records describing the performance, operations and management systems of the organisations responsible for waste management. The report describes requirements, responsibilities and the main components of a records management system for waste packages. It includes appendices on available technologies for record storage, data transfer and waste package identification; suggested minimum contents of both package-oriented and process-oriented records; responsibilities for data generation and retention of various types during the waste package life cycle; and guidance for institutional waste generators such as hospitals and industrial radiographers.

- International Atomic Energy Agency (2005): *Standard Format and Content for Safety Related Decommissioning Documents*. Safety Reports Series No. 45. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1214_web.pdf
  This report provides practical information to the regulatory body and the operator on the safety related documents that need to be prepared to support the decommissioning process. These documents include the decommissioning plan and other supporting documents. Management of operational waste and spent fuel is outside the scope of this report. The document presents a typical table of contents for a decommissioning plan and gives detailed guidance on the contents of each section of the plan. In addition, a number of supporting documents, such as characterisation plans and reports, radiological survey plans and reports, policies and procedures, public relations plans, and the final decommissioning report, are also described.

- International Atomic Energy Agency (2006): *Risk management of knowledge loss in nuclear industry organisations*. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1248_web.pdf
  This publication addresses knowledge management tools and processes intended for use in nuclear power plants, in order to mitigate the risk of knowledge loss caused by the departure of experienced staff. These tools and processes could also, to a certain extent, be used in the area of waste disposal.

- International Atomic Energy Agency (2006): *Knowledge management for nuclear industry operating organizations*. IAEA-TECDOC-1510. IAEA, Vienna.
  http://www.iaea.org/inisnkm/nkm/documents/te_1510_web.pdf
  This report provides information on the application of knowledge management approaches and practices in nuclear industry organisations. Knowledge management is succinctly described as the process through which organisations generate value from their intellectual and knowledge-based assets. Thus it represents one facet or aspect of an organisation's overall management processes, systems and corporate culture. Knowledge management policies and strategies, practices, methods and techniques are described and explained in detail. Recommendations are made for further international initiatives aimed at providing support to nuclear organisations seeking to incorporate knowledge management methods within their management systems. A large number of appendices are included describing existing applications of knowledge management in nuclear organisations. These cover topics such as knowledge capture and transfer, knowledge dissemination, workforce and succession planning, and management techniques. A glossary of definitions of terms used in the knowledge management field is also included.

- International Atomic Energy Agency (2006): *Data Requirements and Maintenance of Records for Spent Fuel Management: A Review*. IAEA-TECDOC-1519. IAEA, Vienna.
  http://www-pub.iaea.org/mtcd/publications/pdf/te_1519_web.pdf
  This report is a review of requirements for data collection and management for spent nuclear fuel throughout its life cycle from fuel fabrication to reprocessing or disposal. Several different life cycle possibilities are considered, including direct disposal as well as various reprocessing or partitioning and transmutation options. Data requirements described include those related to operational needs, to safeguards obligations, to safety and licensing, and to meet international obligations such as reporting under the Joint Convention. Details are given on the kinds of data parameters that need to be recorded, including identification of the radioisotopes most important to post-closure safety of a repository. Information is provided on data management, including responsibilities and development and maintenance of databases. An appendix describes disposal-relevant data requirements for spent LWR fuel, and there are several annexes containing reports from a number of countries on current practices for spent fuel data management.

- International Atomic Energy Agency (2006): *The Management System for Facilities and Activities*. IAEA Safety Standards No. GS-R-3. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1252_web.pdf
  This is the IAEA consensus safety standards Requirements document that describes the requirements for establishing, implementing, assessing and continually improving a management system that integrates safety, health, environmental, security, quality and economic elements to ensure that safety is properly taken into account in all the activities of an organisation. It replaces previously published quality assurance requirements. Its scope covers the entire range of activities involving radioactive material, from major nuclear facilities to activities involving the use of radioactive sources, throughout their life cycles from initial siting and design up to decommissioning or closure. It does not define the specific requirements for safety applicable to these activities, but rather the requirements for managing the fulfilment of those safety requirements by both operating organisations and regulatory bodies. It describes the general requirements for a management system, management responsibility, management of resources, management of processes, and management of monitoring, assessment and improvement.

- International Atomic Energy Agency (2006): *Managing nuclear knowledge.* Proceedings of a workshop, Trieste, 22-26 August 2005. STI/PUB/1266. IAEA, Vienna. http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1266_web.pdf
  This is the proceedings of a workshop on nuclear knowledge management organised in response to recent trends, such as an ageing workforce, declining student enrolment and the risk of losing accumulated nuclear knowledge and experience. The challenges and solutions described in the papers apply to the nuclear industry generally and relate to the transfer of knowledge from current operating staff to their immediate successors, or to programmes organised in concert with educational institutions to address the training needs of the nuclear industry. The workshop included sessions on policies and strategies in nuclear science and technology, managing nuclear information resources, human resources and knowledge transfer in the nuclear sector, managing and preserving knowledge in the nuclear sector, networking for education, training and knowledge transfer. The papers presented at the workshop are included in the proceedings.

- International Atomic Energy Agency (2006): *Managing nuclear knowledge: Strategies and human resource development*, 7-10 September 2004, Saclay, France. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1235_web.pdf
  The objective of the conference was to reach a clear and common understanding of the issues related to nuclear knowledge management for sustaining knowledge and expertise in nuclear science and technology, in response to recent trends such as workforce ageing and declining student enrolment numbers, and the risk of losing accumulated knowledge and experience. The focus was on transfer of knowledge from staff at nuclear facilities to their immediate successors and on networking with educational institutions for capacity building.

- International Atomic Energy Agency (2007): *Retrieval, Restoration and Maintenance of Old Radioactive Waste Inventory Records*. IAEA-TECDOC-1548. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/te_1548_web.pdf
  This report was prepared by the IAEA to provide guidance to waste management organisations and regulators on developing a methodology for the retrieval, assessment, verification and restoration of waste inventory records for waste management facilities where the records are either lost or inadequate, and for the transfer of these records into a records management system that meets current internationally accepted standards. The report gives a number of examples of problems encountered in retrieval of records for repositories and other waste management sites, and describes a number of the needs for improvement of existing records, particularly in order to meet the requirements of the Joint Convention. It sets out a methodological framework for retrieval of waste inventory records, including establishment of a stepwise approach, prioritization of data retrieval steps, establishment of an approach for assessing the reliability of records, implementation of these steps, and data verification and validation. The methods are based on experience gained in a number of countries, and are illustrated with examples from that experience.

- International Atomic Energy Agency (2007): *International conference on knowledge management in nuclear facilities*, 18-21 June 2007. IAEA, Vienna http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/38/067/38067938.pdf?r=1 (Book of extended synopses)
  This reference is a collection of extended synopses of papers presented at the conference. The majority of the papers describe what is being done in various organisations to transfer knowledge, both explicit and implicit, from ageing and retiring staff at nuclear facilities to their successors. Two of the papers relate to information transfer about waste repositories and waste disposal: "Knowledge management in the Japanese high-level waste disposal programme" by T. Kawata et al, and "Transfer of radioactive waste disposal knowledge to future generations: A stiff challenge for universities", by B.B. Sabet and F.J. Elorza.

- International Atomic Energy Agency (2007): Drop it and run! New symbol warns of radiation dangers and aims to save lives. - *IAEA Bulletin* 48 / 2, p. 70-72. https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull48-2/48202087072.pdf
  This paper presents a new symbol developed by the IAEA to help warn populations about the dangers of radioactive sources.

- International Atomic Energy Agency (2008): *The management system for the disposal of radioactive waste*. IAEA Safety Guide GS-G-3.4. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1330_web.pdf
  Of particular interest to RK&M preservation are the provisions listed under the heading "Control of records", 5.47 – 5.54. Topics addresses include content and retention of records, recording media and record keeping, as well as transfer of information between organisations and to future generations.

- International Atomic Energy Agency (2008): *The Management System for the Processing, Handling and Storage of Radioactive Waste*. IAEA Safety Guide GS-G-3.3. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1329_web.pdf
  Of particular interest to RK&M preservation are provisions listed under the heading "Control of documents", 5.39 – 5.59. Topics addressed include content and retention of records, recording media and record keeping, as well as transfer of information between organisations.

- International Atomic Energy Agency (2008): *Long Term Preservation of Information for Decommissioning Projects.* Technical Reports Series No. 467. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/trs467_web.pdf
  This report is intended to provide guidance on the approaches and technologies that can be used for the organisation, maintenance, and later use of records that span a wide range of time and operating environments for the purposes of decommissioning nuclear. It includes a description of some records management tools, outlining the strengths and weaknesses of each of these types of records management application. It goes into some detail on issues of physical management of records, including such topics as long-term reliability and accessibility of media, storage facilities, maintenance, protection and security including disaster recovery, and criteria for destruction of records that are no longer needed. It also discusses human aspects of knowledge preservation and transfer, such as succession and recruitment planning and retention of nuclear knowledge necessary for a decommissioning project that could take many decades for its completion. It includes appendices describing national and international initiatives for nuclear knowledge management, on media and hardware considerations for long term preservation of records, and making recommendations for further research on long term preservation. There are extensive annexes describing national experiences with record keeping for decommissioning and examples of lessons learned from that experience.

- International Atomic Energy Agency (2008): *Planning and Execution of Knowledge Management Assist Missions for Nuclear Organisations*. IAEA-TECDOC-1586, IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/TE_1586_web.pdf
  The General Conference of the IAEA has adopted resolutions on Nuclear Knowledge that request the IAEA to develop corresponding activities. Current activities in knowledge management (KM) aim to further increase the level of attention and awareness given to activities for preserving and enhancing nuclear knowledge; to assist Member States to ensure the preservation of nuclear experience and competence needed for the effective and safe use of nuclear energy; to promote the networking of institutions for nuclear education and training; to evaluate the relevance of current programs and activities regarding nuclear knowledge, and to identify approaches aimed at how best to address the problems. The IAEA is implementing a special subprogram on Nuclear Knowledge Management with a focus on the development of guidance for knowledge management, on networking nuclear education and training and on the preservation of nuclear knowledge.

This document provides a common framework for KM missions and to provide general guidance for all mission participants.

- International Atomic Energy Agency (2009): *Predisposal Management of Radioactive Waste, General Safety Requirements Part 5*. IAEA General Safety Requirements GSR Part 5. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1368_web.pdf
  Of particular interest to RK&M preservation is provision 3.11, where maintenance of records and recording are listed among measures to ensure an adequate level of protection and safety.

- International Atomic Energy Agency (2010): *Technological implications of international safeguards for geological disposal of spent fuel and radioactive waste*. IAEA Nuclear Energy Series NW-T-1.21. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1414_web.pdf
  This report provides an overview of the technological implications of international safeguards at a generic geological repository containing spent fuel and radioactive waste during its design, construction, operation and post-operational phases. Prior to closure, these are in broad outline similar to those applicable to other nuclear facilities. The particular measures put in place would include measures specific to the design of the repository and its site, as well as measures common to other nuclear facilities in the country. These safeguards measures should be incorporated into repository design and planning from the outset. Following closure, while safe evolution of a geological repository must not be reliant on continuing, active, institutional control, the requirement to apply IAEA safeguards could necessitate a long term inspection regime which might continue post-closure. This inspection regime would be site-specific, and could involve remote surveillance and geophysical monitoring which would be dependent on the continued existence and accessibility of safeguards-relevant information about the repository.

- International Atomic Energy Agency (2010): *Governmental, legal and regulatory framework for safety.* General Safety Requirements. IAEA Safety Standards No. GSR Part 1. IAEA, Vienna. [supersedes IAEA 1995, 111-S-1]
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1465_web.pdf
  This publication covers the essential aspects of the governmental and legal framework for establishing a regulatory body and for taking other actions necessary to ensure the effective regulatory control of facilities and activities. It highlights in particular which records must be available and/or created in the framework of regulatory activities.

- International Atomic Energy Agency (2011): *Disposal of Radioactive Waste, Specific Safety Requirements*. IAEA Specific Safety Requirements SSR-5, IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1449_web.pdf
  Of particular interest to RK&M preservation are the provisions listed under Requirement 3 “Responsibilities of the operator”, Requirement 14 “Documentation of the safety case and safety assessment” and Requirement 22 “The period after closure and institutional controls”.

- International Atomic Energy Agency (2011): *Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation*. NG-T-6.7. IAEA, Vienna.
  http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1494_web.pdf
  This publication draws on the results of a coordinated research project on comparative analysis of methods and tools for knowledge preservation in nuclear organisations. The project was initiated by the IAEA in order to enhance the capacity of Member States to maintain and preserve the information and knowledge resources related to the peaceful uses of nuclear energy. The project participants explored methods and tools used to capture, interpret, analyse and disseminate data and information, as well as the knowledge ultimately derived from them. Furthermore, a survey tool on the current status of knowledge preservation in nuclear and supporting organisations was

developed. The analysis of the survey served as a basis for the recommendations and conclusions on good practices in knowledge preservation.

- International Atomic Energy Agency (2012): *Knowledge management for nuclear research and development organizations*. IAEA-TECDOC-1675. IAEA, Vienna. http://www-pub.iaea.org/MTCD/publications/PDF/TE_1675_web.pdf
  The IAEA nuclear knowledge management activities assist in transferring and preserving knowledge, exchanging information, establishing and supporting cooperative networks, and training the next generation of nuclear experts. This publication has been developed to address the specific needs of nuclear research and development and technical support organisations. Its declared purpose is to provide assistance to decision makers from nuclear research and development organisations on planning, implementing and sustaining knowledge management programmes to derive business benefit, i.e. in a short-term perspective. However, the tools described in the report can be used with a longer timeframe in mind.

- International Atomic Energy Agency (2016): *Knowledge Management and Its Implementation in Nuclear Organizations*. IAEA Nuclear Energy Series NG-T-6.10. IAEA, Vienna. http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1724_web.pdf
  The IAEA's nuclear knowledge management activities provide guidance in knowledge management and assist in transferring and preserving knowledge, exchanging information, establishing and supporting cooperative networks and in training the next generation of nuclear experts. This publication shares best practices and experiences based on the knowledge management assist visit programme undertaken by IAEA expert teams during the period 2005-2013. These visits have involved different types of organisations, including NPPs, nuclear R&D organisations and nuclear based educational establishments such as universities. Based on the records of these visits, a secondary aim of this publication is to provide feedback and recommendations for future development of the assessment tool(s) and participating organisations for improving future assist visits [INIS]

- International Atomic Energy Agency (2016): *Third International Conference on Nuclear Knowledge Management* [NKM-2016] – Challenges and Approaches, 7-11 November 2016, Vienna, programme and abstracts CN-241. IAEA, OECD/NEA. http://www-pub.iaea.org/iaeameetings/50805/Third-International-Conference-on-Nuclear-Knowledge-Management-Challenges-and-Approaches
  The purpose of the conference was to provide an opportunity to share experiences and lessons learned in the nuclear sector related to managing nuclear knowledge and to share practical approaches to knowledge management that could be used at the organisational, national, and international levels to develop and maintain a strong nuclear knowledge base. Various issues related to specific human competencies, methodological or process knowledge and technology-related knowledge that are needed to support the safe and sustainable application of nuclear technology were addressed.

- International Council on Archives, McCarthy G., Upshall I. (2006): *Radioactive Waste Information: Meeting our obligations to future generations with regard to the safety of waste disposal facilities*. ICA Study 18. ICA, Paris. http://www.ica.org/sites/default/files/ICA_Study-18-Radioactive-waste_EN.pdf
  - This report documents the results and conclusions of a study conducted under the auspices of the IAEA in 2002 to examine the critical importance of the preservation and transfer of information in ensuring the safety of radioactive waste disposal facilities for future generations. In this respect, preservation of the knowledge necessary to explain the context, structure and meaning of information is critical to prevent epistemic loss. Indeed, information is always created in a context delimited by both time and space: it therefore needs to be assessed in relation to a variety of parameters that will influence the meanings that can be derived. Such parameters – such as the administrative structures, the governance framework, the financial arrangements, the regulatory

environment, the status of scientific and technological knowledge, the evolution of the physical environment, the attitudes of special interests groups and the concerns of the community as a whole – should be systematically captured and preserved, and used to establish decentralised contextual information frameworks, starting at the local level.

- *International Journal of Nuclear Knowledge Management* 3(2), 2009. Special issue on Nuclear Knowledge Management: IAEA Perspective.
  Includes in particular: Gowin P., Kinker J., Kosilov A., Upshall I., Yanev Y. (2009): Knowledge management for radioactive waste management organisations, p. 157-169
  Knowledge management in radioactive waste management operations (and their regulation) is primarily concerned with ensuring that present and future generation of planners, decision makers and operators have access to appropriate sources of information and that the knowledge created can be efficiently and accurately disseminated and transferred. This must be done in such a way that key personnel are equipped with the necessary skills and competencies to understand and use the knowledge. The ultimate concern must be to support the long-term safe, efficient and cost effective management of the radioactive waste management facilities and their contents.
  Knowledge management will also make a major contribution to the retention and retrieval of information over the long periods of time peculiar to radioactive waste management. Retention of critical staff and knowledge transfer to new staff will clearly be necessary – this may be achieved through succession planning, training, mentoring, and other knowledge transfer processes.

- Jarvis W.E. (2003): *Time Capsules – A cultural History*. McFarland and Company.
  Time capsules have been used for thousands of years to store for posterity a selection of objects thought to be representative of life at a particular time. Such vessels have the dual purpose of causing participants to ponder their own cultural era and think about those to come.
  This work is a cultural history of five thousand years of time capsules and other related time-information transfer experiences. It examines both the formal and the popular culture aspects of the time capsule, from its roots in ancient Mesopotamian and Egyptian building foundation deposits to the present utilization of spacecraft probes and other extreme locations. The deposits of 3000 BC deliberately had no definite date and time to be opened; in 1876 AD came the idea of target-dated deposits. Also discussed are how "real" time capsules work, notional and archaeological time capsules, the height of the time capsule's popularity from 1935 to 1982, the preservation of writings in time capsules, keeping time in a perpetual futurescape, and turn of the century hype surrounding millennium time capsules.
  This book includes an extensive bibliography.

- Jensen M. (1994): Informing future societies about nuclear waste repositories. – *Radwaste Magazine* 1(2), 1994, p. 51-61.
  In 1990 a working group of the NKS (the Nordic nuclear safety program) was formed and given the task of established a basis for a common Nordic view of the need for information conservation for nuclear waste repositories. The Group investigated what type of information should be conserved, in what form the information should be kept, the quality of the information, and the problems of future retrieval of information, including retrieval after very long periods of time. Topics covered include the following: scientific aspects including social context of scientific solutions, information management, systems for conservation and retrieval of information including the problems of prediction, archives, markers, archives vs. markers, and continuing processes in society. Archive media considered included paper documents, microfilm and digital media, including media lifetimes.

- Jensen M. (1993): *Conservation and retrieval of information: elements of a strategy to inform future societies about nuclear waste repositories: final report of the Nordic Nuclear Safety Research project KAN-1.3.* Nordic Nuclear Safety Research, Stockholm.
  http://www.nks.org/scripts/getdocument.php?file=111010111119462

This is the final report of the Nordic Nuclear Safety Research Project KAN -1.3, whose purpose was to establish a basis for a common Nordic view of the need for information conservation for nuclear waste repositories, by investigating the types and forms of information and problems of future retrieval of the information in the long term. The scope covers all categories of radioactive waste from low-level waste to spent fuel, focusing on information needs in the post-closure phase. The stated motivations for preserving information include helping prevent inadvertent intrusion, enabling future generations to make decisions about safety and possibly remediation, and supporting future decision making on repositories generally. The report recommends a multi-faceted approach, including archives at regional, national and international locations complemented by markers at the site and possibly within the repository, and periodic reviews to determine whether some records no longer need to be kept. It recommends that guidelines be established on the kinds of records to be kept and their relative importance. It also makes suggestions for further research on potential threats to repositories and the role of information systems in responding to those threats, on types of information to be stored and procedures to extract and summarise information, and on cost effectiveness of information conservation measures.

- Johansson P, Lisberg Jensen E. (2006): *Identitet och trygghet i tid och rum – kulturteoretiska perspektiv på kärnavfallsfrågans existentiella dimensioner*. SKB R-06-119. Svensk Kärnbränslehantering AB, Stockholm (in Swedish).
  http://www.skb.com/publication/1233805/R-06-119.pdf
  Interviews and textual analysis investigate the underlying thoughts about structures related to time and space, discussed in connection with the planned final repository for spent nuclear waste in Östhammar and Oskarshamn. Through metaphor, argument and discourse analysis that characterised the debates and texts, as well as informants' own formulations, different conceptions have appeared. A somewhat surprising result was the great unity of the material with however clear dividing lines. With regard to the perception of time, the period up to the decision to build a repository as well as the actual construction period (”societal time”) can be apprehended, but the long-term “repository time” is incalculable. Depending on the type of time envisaged, opinions differ on the responsibilities towards future generations.

- Kaplan M.F. (1982): *Archaeological Data as a Basis for Repository Marker Desig*n. BMI/ONWI-354.
  This report presents a conceptual design for a marker system for a radioactive waste repository, based on a study of ancient man-made monuments. After a discussion of the reasoning behind marking the site, the report then describes a number of characteristics of messages to be conveyed, including message contents, location, survivability, detectability and comprehensibility. The report presents descriptions and assessments of a number of ancient man-mode monuments. Factors which contributed to the survival and understanding of these monuments are discussed, including the role of human actions in their destruction, and the importance of the existence of off-site written accounts of a monument in preserving understanding of its purpose. The report then presents a detailed description of a conceptual design for a system of markers to designate the site of a repository. The proposed system incorporates a series of monoliths to delineate the boundaries of the site, an earthwork in the form of a warning symbol, and a central structure to contain and preserve a copy of detailed written records, duplicating information that would also be archived at various off-site locations.

- Kaplan M.F. (1986): Mankind's future: Using the past to protect the future. Archaeology and the disposal of highly radioactive wastes. – *Interdisciplinary Science Reviews* 11(3), 1986, p. 257-268.
  See above.

- Kawata T., Umeki H., Osawa H., Seo T., Tsuboya T., Tanabe H., Yoshimura K., Asano H., Ohuchi J. (2007): Knowledge management in the Japanese high-level waste disposal

programme. IAEA-CN-153/1/O/01. – *International conference on knowledge management in nuclear facilities*, 18-21 June 2007. IAEA, Vienna.
http://www.iaea.org/inisnkm/nkm/documents/nkmCon2007/fulltext/FP/IAEA-CN-153-1-O-01fp.pdf
Planning and implementing disposal of high-level radioactive waste (HLW) is a multidisciplinary field. A wide range of relevant knowledge is needed to develop an associated safety case. Here, the term "knowledge" encompasses all of the science and technology (implicitly including social science, economics, etc.) which underpins a repository project. Knowledge management covers all aspects of the development, integration, quality assurance, communication and maintenance/archiving of such knowledge - including data, information, understanding and experience. In order to ensure that required knowledge is accessible to all stakeholders, including the implementer, the regulator, political decision-makers and the general public and that gaps can be identified and prioritised, it is important that knowledge bases are structured in a clear and logical manner. This paper describes the current status of knowledge management activities in the Japanese HLW disposal programme and provides a perspective on some of the developments in this field planned for the future.

- Kazutoshi S., Hajime T., Jin Ohuchi, Takao Tsuboya (2003): *Record preservation study on geological disposal: Significance and technical feasibility*. RWMC Technical Report RWMC-TRE-03001. Radioactive Waste Management Center RWMC, Tokyo.
http://www.rwmc.or.jp/library/pdf/RWMC-TRE-03001.pdf
This report summarises the results of a study carried out by the Radioactive Waste Management Funding and Research Center (RWMC) in Japan on record preservation as a component of institutional control measures for radioactive waste repositories. The study was intended to provide information to waste management and government organisations to help them formulate record preservation programs, with a primary underlying goal of improving public confidence in geological disposal. The objectives of record preservation were given as prevention of inadvertent intrusion and support for future decision making. In investigating possible methods for record preservation, five models for the development of future societies were postulated. In order to respond to this range of possibilities, the study recommended two parallel approaches: a "relay system", in which records are transmitted to future generations through institutions such as archives, and a "permanent system" based on durable markers and monuments. The report describes an experimental study into the durability of engraved messages on durable media and concluded that engraving on silicon carbide showed promise as a long-term recording medium. The report includes an appendix describing historical and archaeological examples of both record preservation and physical media and artefacts, and international studies related to preservation of information on radioactive waste repositories.

- Kliewer G. (1992): The 10,000-Year Warning. - *The Futurist* 26(5), 1992,17- (3 pages). Washington.
This paper describes the marker system developed for the Waste Isolation Pilots Plant (WIPP).

- Krupar J. (2007): Burying Atomic History: The Mound Builders of Fernald and Weldon Spring. - *The Public Historian* 29(1), 2007, p. 31-58.
The Fernald, Ohio and Weldon Spring, Missouri uranium refinery sites performed critical functions in the nation's nuclear weapons manufacturing complex during the Cold War. Two radioactive "tombs" have been created by the U.S. Department of Energy on the former grounds of these industrial centres. Radioactive contamination precludes the adaptive reuse of Fernald and Weldon Spring. Yet these two sites reside in counties that continue to experience steady population growth. The present and future generations need to be informed about the activities conducted at the sites for health, environmental, and educational reasons.

- LaPorte T., Keller A. (1996): Assuring Institutional Constancy: Requisite for Managing Long-Lived Hazards. - *Public Administration Review* 56(6), 1996, p. 535-544.

Institutional constancy of agencies and firms is discussed as a concept and an increasingly important political requirement for the operation of hazardous systems in the United States. Situations that increase demands for it are outlined and a basis for analysis and improving constancy is proposed.

- Lomberg J., Hora S. C. (1997): Very long term communication intelligence. The case of markers for nuclear waste sites. – *Technological Forecasting and Social Change* 56(2), 1997, p. 171-188.

  Two interdisciplinary teams have addressed the issues of physical durability and cognitive intelligibility of markers for a U.S. government site in New Mexico. Preliminary design criteria have determined which materials are best suited to constitute markers of different sizes and shapes. A variety of linguistic, symbolic, and pictographic approaches to content have been suggested. Additional study and testing of both materials and messages is required. The paper concludes that international standardisation of marker strategies is extremely desirable.

- Makino H., Hioki K., Osawa H., Semba T., Umeki H. (2012): A Challenge on Development of an Advanced Knowledge Management System (KMS) for Radioactive Waste Disposal: Moving from Theory to Practice. – In: *New Research on Knowledge Management Technology*, Huei Tse Hou (Ed.), InTech.
  http://cdn.intechopen.com/pdfs/29146/InTech-A_challenge_on_development_of_an_advanced_knowledge_management_system_kms_for_radioactive_waste_disposal_moving_from_theory_to_practice.pdf

  The exponential growth in the knowledge base for radioactive waste management is a cause for concern in many national programmes. In Japan, this problem is exacerbated by a volunteering approach to siting of a deep geological repository, which requires particular flexibility in the tailoring of site characterisation plans, repository concepts and associated Performance Assessments. Recognition of this situation led, in 2005, to initiation by Japan Atomic Energy Agency (JAEA) of an ambitious project to develop an advanced Knowledge Management System (KMS) aimed to facilitate its role as the supplier of background R&D support to both regulators and implementers of geological disposal. The paper reviews progress to date in this work, with emphasis on tailoring of existing Knowledge Engineering tools and methods to radioactive waste management requirements, and outline future developments and challenges.

- Marvy A., Lioure A., Heriard-Dubreuil G., Gadbois S., Schneider T., Schieber C. (2003): A look at new key performance criteria that could most affect the safety of long term storage of nuclear waste: A case study commissioned by CEA. Paper IAEA-CN-90/11. – *International conference on Issues and trends in radioactive waste management: Vienna, 9-13 December 2002*. IAEA, Vienna, p. 47-51.
  http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/34/016/34016251.pdf?r=1

  As part of the work scope set in the French law on high level long lived waste R&D passed in 1991, CEA conducted research work to establish the scientific basis and assess the feasibility of long term storage as an option for the safe management of nuclear waste for periods as long as a few centuries. The case study looks into several past and current human enterprises conducted over significant periods of time – one dating back to the end of the 18th century – outside of the nuclear field. As a result the study group obtained a set of performance criteria relating to issues like responsibility, securing funds, legal and legislative implications, economic sustainable development, all being areas which are not traditionally considered when technical studies are conducted.

- Massart C. (2004): How plural interests, values and knowledge could be translated into a concrete radwaste disposal project design: an artist's vision. – *Dealing with interests, values and knowledge in managing risk: Workshop proceedings*, Brussels, Belgium 18-21 November 2003. OECD/NEA, Paris, p. 117-121.

Professor and artist, C. Massart operates from the understanding that a proper role for art in radioactive waste management projects can help change the view of waste disposal by stakeholders and the broader public. She has investigated both the artistic aspects of waste management facilities themselves as well as artistic visions of themes associated with radioactive waste. For the past ten years, C. Massart has been working on a project entitled "An archived site for alpha, beta, gamma." She has explored three separate topics in which using art as a vehicle for communication offers an alternative and perhaps improved method for communicating over the more "traditional" verbal and written communications. The first was to portray radioactive decay not by measurements or comparisons to other risks, but to use the gradual lightening of colours to depict the gradual and natural decay of radioactivity with time in an artistic piece. Second, she demonstrated the possibilities for art to help maintain archives for the future, a key knowledge preservation activity for a programme that will span generations. Third, she showed the possibilities for art to influence markers that would ultimately be placed at waste management sites, preserving the continuity of knowledge regarding such sites.

- Merz E. (1985): Endlagerung: Übermittlung der Kunde vom Atommüll in ferne Zukunft. – *Atomwirtschaft, Atomtechnik*, May 1985, p. 234.
  This paper is a critical review of Sebeok (1984) and Tannenbaum (1984).

- Mey J. (1995): The last Canterbury Tale: Artificial intelligence in the fifth millennium. – *Prague Lingustic Circle* 1, 1995, p. 261-294.
  The paper discusses both Posner (1990) (see below) and the science fiction novel “Riddley Walker” by Russel Hoban. It includes in particular a reflection on the survivability of the language and on the concept of “atomic priesthood”.

- Moser C., Stauffacher M., Krütli P., Scholz R.W. (2012): The crucial role of nomothetic and idiographic conceptions of time: Interdisciplinary collaboration in nuclear waste management. – *Risk Analysis* 32(1), 2012, p. 138-154.
  This paper sums up the results of interviews with scientists from various disciplines, on the subject of the perception of time. Knowledge preservation is only marginally mentioned.

- Moser C. (2012): *On the understanding and processing of extensive timescales: the long-term dimension of nuclear waste*. Diss. ETH.No 20283. ETH, Zürich.
  This thesis approaches the issue of time and nuclear waste from different perspectives and by the use of different social scientific research methods.

- National Research Council, Committee on the Remediation of Buried and Tank Wastes, Board on Radioactive Waste Management (2000): *Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites*.
  Of particular interest for RK&M preservation is Chapter 5, Stewardship activities. This document deals in particular with the collection and dissemination of information related to the monitoring and remediation phase of residually contaminated sites. It also lists problems that can arise in conducting long-term stewardship activities.

- National Security Technologies ST (2007): *Passive Barriers to Inadvertent Human Intrusion for Use at the Nevada Test Site*. DOE/NV/25946-206. NST, Las Vegas. http://www.osti.gov/bridge/servlets/purl/917998-fysXWd/917998.pdf
  This report documents the results of a study conducted to identify types of engineered passive barriers that could deter future intrusion into buried low-level radioactive waste at the Nevada Test Site, in particular intrusion by drilling water wells. The study considered drilling technology, many natural and man-made materials, and both underground and above-ground barriers. Based on considerations of cost and effectiveness, the study recommended three types of barrier for use at

the Nevada Test Site: and underground layer of rubble, an underground layer of rubber tires, and an above-ground barrier mound.

- Nelson R.S. & Olin M. (eds.) (2003): *Monuments and memory, made and unmade*. University of Chicago Press. Chicago.
  This book collects essays about how monuments have functioned and been considered throughout the world, and how globalisation has challenged Western notions of the "monument." Examining how monuments preserve memory, these essays demonstrate how phenomena as diverse as ancient drum towers in China and ritual whale-killings in the Pacific Northwest serve to represent time.
  See in particular Bryan-Wilson J.: Building a Marker of Nuclear Warning, pp. 183-204.

- Nolin J. (1993): *Communicating with the future: implications for nuclear waste disposal*. – Futures 25(7), 1993, p. 778-791.
  This paper addresses both the possibility to transmit a message to be received thousands of years from now and the necessity for crucial information will be available and intelligible at a critical moment. Two perspectives are introduced: in one it is claimed that knowledge can survive through different contexts; in the other it is argued that the importance of context is such that time will render our messages incomprehensible. These perspectives are linked to two alternatives, both discussed within the context of US and Nordic nuclear waste management. One is the 'long-term concept' of a marker or an archive that conserves the information once and for all. The other is a 'short-term' concept that suggests a continuous recoding of the messages in new contexts in order to 'keep it alive'. Finally, a combination of these alternatives is discussed.

- OECD Nuclear Energy Agency (1995): *Future human actions at disposal sites: safety assessment of radioactive waste repositories = Les actions humaines futures sur les sites d'évacuation*. OECD/NEA, Paris.
  http://www.oecd-nea.org/rwm/reports/1995/nea6431-human-actions.pdf
  This document summarises the work of the NEA Working Group on Assessment of Future Actions in the 1989-1995 time frame. The Working Group reviewed work on the topic that had been done in member nations and internationally, identified issues deserving of further consideration, and made recommendations on generic approaches and further studies that could be undertaken. The scope of the work was limited to deep disposal of long-lived high-level wastes, and to potential inadvertent human actions post-closure with the potential to impact repository safety. The Working Group considered approaches to consequence analysis, measures to reduce the likelihood and/or consequences of intrusion, including preservation of records, knowledge and memory, and made recommendations on future international activities. Countermeasures to intrusion that were considered included in particular the conservation of information, physical markers, as well as physical barriers to intrusion. The group developed a set of scenario-building elements for development of future human action scenarios in safety assessment, and made recommendations for future international work, including development of an international archive of radioactive waste repositories and further work on markers.

- OECD Nuclear Energy Agency (2007): *Fostering a durable relationship between a waste management facility and its host community. Adding value through design and process*. OECD/NEA, Paris.
  http://www.oecd-nea.org/rwm/reports/2007/nea6176-fostering.pdf
  This report was prepared by the NEA's Forum on Stakeholder Confidence (FSC) in order to explore ways to achieve sustainability, i.e. societal durability, in planning and implementing radioactive waste management facilities. The target audience includes both potential host communities and national radioactive waste management programmes. The report focuses on the ways in which a facility might add value and improve the prospects for quality of life in the surrounding community in both the short and long term. It summarises arguments in favour of developing a sustainable relationship between a community and a radioactive waste management

facility through added cultural and amenity value. It identifies design considerations that may help facilities and sites fit into their community in an acceptable and sustainable manner. The design features considered include functional aspects such as multi-functionality, adaptability and flexibility; cultural aspects such as distinctiveness, aesthetic quality, understandability and memorialisation (heritage and markers); and physical aspects such as integration, amenity and accessibility. The report also addresses ways in which the planning, decision-making and implementation processes can provide added value for the community. The discussion is illustrated by examples gathered from several waste management programmes as well as direct input from stakeholders representing communities where facilities have been located or proposed.

- OECD Nuclear Energy Agency (2010): *More than just concrete realities: The symbolic dimension of radioactive waste management.* OECD/NEA, Paris.
  http://www.oecd-nea.org/rwm/reports/2010/nea6869-symbolic.pdf
  This report presents the results of a topical session held by the NEA's Forum on Stakeholder Confidence (FSC) in 2008 on the theme of the symbolic dimension in communicating about radioactive waste management facilities. It explores the symbolic dimension of radioactive waste as a whole, as well as of key waste management-related concepts such as safety and risk, land and landscape, and storage and disposal. It also addresses the role of framing of arguments and communications and the role this framing may play in how statements and communications are interpreted. The reports' conclusions emphasise the need for building awareness of the importance in shaping dialogue of symbols rooted in social convention and cultural tradition.

- OECD Nuclear Energy Agency (2010): R*adioactive waste repositories and host regions: Envisaging the future together*. Synthesis of the FSC national workshop and community visit Bar-le-Duc, France 7-9 April 2009. OECD/NEA, Paris.
  http://www.oecd-nea.org/rwm/reports/2010/nea6925-repositories-host-regions.pdf
  This report is a synthesis or proceedings of a workshop held at Bar-le-Duc, France by the NEA's Forum on Stakeholder Confidence (FSC) in 2009. The workshop focused on the implementation of France's high-level and long-lived intermediate-level waste management programme in the region near Bar-le-Duc. Workshop sessions addressed the French historical and legislative context, local public information, reversibility expectations and motivations, economic support and regional development, and environmental monitoring and the issue of memory, and also included a site visit to the underground laboratory at Bure. The discussion on memory noted that active memorialisation will depend on maintaining exchanges with the local public during and after implementation. The report also includes an international perspective on the workshop from the point of view of the NEA Secretariat. This perspective notes the importance of concerns raised over the long-term governance of the facility, including fears that a future national government might delegate responsibility for site monitoring and management to local governments that might not have the resources or capabilities to meet these requirements.

- Ohuchi J., Eng T., Tsuboya T. (2003): *International workshop on Record Management and Long-term Preservation and Retrieval of Information regarding Radioactive Waste, Rome, 27-28 January 2003*. RWMC Technical Report RWMC-TRE-03002. Radioactive Waste Management Funding and Research Center (RWMC), Tokyo.
  http://www.rwmc.or.jp/library/pdf/RWMC-TRE-03002.pdf
  This report compiles the presentation and discussions at the International Workshop on Record Management and Long-term Preservation and Retrieval of Information regarding Radioactive Waste held by RWMC and SKB in Rome on January 27-28, 2003.
  The main points discussed were as follows:
  - Regulations regarding "Knowledge Management" are not fully developed in most countries. Motives and key issues slightly differ between programs.
  - Systems for identifying important knowledge/records/documents are being developed
  - "Knowledge management" is an important field for all programs and needs further attention
  - The development on technical media continues (and will continue).

  - The question on the need for international archives has been raised
  - Early actions on knowledge management issues will improve the possibilities for future generations to make informed decisions regarding radioactive waste issues.

- Ohuchi J., Sugiyama K., Asano H., Tsuboya T. (2003): Conceptual system of robust record preservation on geological disposal. – *Process through cooperation: Proceedings of the 10th International high-level radioactive waste management conference*: March 30 - April 2, 2003, Las Vegas, Nevada, p. 1227-1234.
  See above, Ohuchi et al. (2003)

- Ohuchi J., Torata S., Tsuboya T. (2006): Robust record preservation system on geological repository. IAEA-CN-123/03/O/02. – *International conference: Managing nuclear knowledge: Strategies, information management and human resource development*, Saclay, 2004. IAEA, Vienna.
  http://www.iaea.org/km/cnkm/papers/ohuchi.pdf
  This papers considers the need for robust and redundant systems for record preservation that will be accessible, retrievable and understandable for future generations. The balance of active and passive system was addressed. It was also found that long-term record preservation may be useful to communicate with the current generation, as a “meta-signal”, in addition to aiming at warning and allowing decision-making. Finally, the laser-engraving technology on silicon carbide was presented as an alternative to paper and maybe to microfilm. Another case study concerned the future generations’ accessibility to the preserved records.

- Pasqualetti M.J. (1997): Landscape Permanence and Nuclear Warnings. *Geographical Review* 87(1), 1997, p. 73-91.
  https://www.researchgate.net/profile/Martin_Pasqualetti/publication/263154136_Landscape_Permanence_and_Nuclear_Warnings/links/02e7e53a06274d2b8c000000/Landscape-Permanence-and-Nuclear-Warnings.pdf
  From the perspective of a human lifetime, the hazards of some nuclear wastes are permanent, so the warnings we place at contaminated nuclear sites must be permanent too. This paper addresses questions of how best to provide one hundred centuries of public warning at the Waste Isolation Pilot Plant in New Mexico. Scenarios of intrusion developed to guide the design of warning markers predicted that most of the changes in the area will be social and cultural. Because blatant and permanent markers will increase, not reduce, the probability of inadvertent intrusion, the most appropriate warning is a "landscape of illusion." The author advocates the use of underground warning devices beneath a soft surface marker.

- Pastina B. (2004): Implementing long-term stewardship: a national challenge. - *IICER Workshop “Long-Term Performance Monitoring of Metals and Radionuclides in the Subsurface: Strategies, Tools and Case Studies”*, April 21, 2004.
  http://www.cistems.fsu.edu/PDF/pastina.pdf
  The purpose of this paper is to report on a National Academies workshop on long-term stewardship, held on March 16, 2004. The workshop was organised as a result of growing concerns among certain federal agencies and stakeholder communities over the environmental liabilities left behind at contaminated sites after clean-up ends. Views on clean-up end states differ significantly between the “remediator” and the “steward;” there appears to be significant challenges for periodic reviews of selected remedies, and there might be a need for policy changes in long-term stewardship regulations; also, different sites have different long-term stewardship needs but there are lessons to share. There appears to be a need for advice on the use of science and technology during clean-up and stewardship to reduce environmental liabilities.

- Paztor S.B., Hora S.C. (1994): Lessons from the Vatican archives for repository recordkeeping. – *Radwaste Magazine* 1(3), 1994, p. 39-47.

The Vatican Archives, one of the world's oldest document repositories, contains documents dating back to the ninth century and continuous documentation of the administration of the Roman Catholic Church from the twelfth century. By assessing the strengths (private collection in a politically neutral city-state) and weaknesses (inadequate protection from environmental threats, lack of adequate access system, rather haphazard policy regarding outside access to documents) of the Vatican Archives, valuable lessons can be learned for the design and management of an archival system for nuclear waste records.

- Pescatore C., Mays C. (2008): Geological disposal of radioactive waste: records, markers and people: An integration challenge to be met over millennia. – *NEA News*, 26, 2008, p. 26-30.
  http://www.oecd-nea.org/pub/newsletter/2008/Geological%20Disposal.pdf
  [See below, Pescatore & Mays 2009]

- Pescatore C., Mays C. (2009): Records, Markers and People: For the Safe Disposal of Radioactive Waste. – In: *VALDOR 2009: Values in Decisions on Risk, Stockholm (Sweden) 8-11 Jun 2009: Proceedings*.
  http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/41/021/41021980.pdf?r=1
  The timescales over which the hazard exists from radioactive waste (as well as from other wastes) are much longer than just a few thousands of years, and it must be accepted that the current generation's capacity to ensure continued integrity of the disposal facility cannot be projected indefinitely into the future, but rather diminishes with time. There is therefore the need to conceptualise a 'rolling future' in which each generation takes responsibility to ensure continuity and safety for the succeeding several generations, including a need for flexibility and adaptability to circumstances as they change. The issue of archives and markers that last as long as possible (the technological approach) continues to be a topical one. However, physical markers and archives may be complemented by - or integrated within - a cultural tradition that could be sustained over time starting with the planning of a repository and continuing through its implementation and beyond its closure. Because a radioactive waste management repository and site will be a permanent presence in a host community for a very long time, a fruitful, positive relationship must be established with those residing there, now and in the future. The challenge is to design and implement a facility (with its surroundings) that is not only accepted, but in fact becomes a part of the fabric of local life.

- Pescatore C. (2016): Long-term Records, Memory and Knowledge Preservation – Recent thinking and progress in the field of geological disposal of radioactive waste, and further avenues of research. – *Report published by the Swedish National Council for Nuclear Waste*.
  http://www.karnavfallsradet.se/sites/default/files/documents/report_pescatore_10_nov_2016_0.pdf
  This report is written on behalf of the Swedish National Council for Nuclear Waste and gives an introduction to the thinking and progress in the field of preservation of Records, Knowledge and Memory for geological disposal of radioactive waste and proposes avenues for raising awareness of this topic and investigating it further.

- Posner R., Sebeok T.A., Lem S., Bastide F., Fabbri P., Voigt V., Sonntag P., Rehder W., Tannenbaum P.H., Givens D.B., Blonsky M., Hauser S., Dreyer C. (1984): Und in alle Ewigkeit: Kommunikation über 10 000 Jahre: Wie sagen wir unsern Kindeskindern wo der Atommüll liegt? – *Zeitschrift für Semiotik* 6(3), 1984.
  Special issue of „Zeitschrift für Semiotik“, later revised and published as Posner 1990 (see below).

- Posner R. (ed.) (1990): *Warnung an die ferne Zukunft : Atommüll als Kommunikationsproblem* [Warnings to the far future: Radioactive wastes as a communications problem.]. Raben Streifzüge. Raben Verlag, München, 1990.

http://www.semiotik.tu-berlin.de/fileadmin/fg150/Posner_1990-Mitteilungen_an_die_ferne_Zukunft_ONLINE.pdf

Inquiries were launched in the USA, in Poland, France, Hungary, Brazil, and the Federal Republic of Germany to find semiotic solutions to problems arising from the communication of radioactive waste locations and dangers to posteriority over a period of 10000 years. It seems to be sure that neither natural nor artificial barriers nor remnants (e.g. skeletons) or sources (today's communication), but only explicit messages will keep intelligent creatures from intrusion into radioactive waste depositories. Among the subjects dealt with are: Pandora's box and how to prevent its opening; mathematical coding on living sign matter; living detectors and complementary signs: “ray cat”, “broken eye”, and nuclear sirens; the three-chamber system: a way to the democratic organisation of collective knowledge and conscience which can survive millennia. [Chapter summaries in English on pages 305–313]
Includes in particular:

- Roland Posner: Mitteilungen an die ferne Zukunft. Hintergrund, Anlass, Problemstellung und Resultate einer Umfrage
- Thomas A. Sebeok: Die Büchse der Pandora und ihre Sicherung: Ein Relaissystem in der Obhut einer Atompriesterschaft
- Stanislaw Lem: Mathematische Kodierung auf lebendem Trägermaterial
- Françoise Bastide / Paolo Fabbri: Lebende Detektoren und komplementäre Zeichen: Katzen, Augen und Sirenen
- Vilmos Voigt: Konzentrisch angeordnete Warntafeln in zunehmend neueren Sprachformen
- Philipp Sonntag: Künstlicher Mond am Himmel und Datenbank im Keller
- Wulf Rehder: Sicherung gegen Kodebrecher durch Randomisierung
- Percy H. Tannenbaum: Staffelung der Informationsquellen nach Inhalt und Entfernung von den Lagerstätten
- David B. Givens: Was wir aus der Menschheitsgeschichte lernen können
- Marshall Blonsky: Wes Geistes Kind ist die Atomsemiotik?
- Susanne Hauser: Problematisch sind nicht nur die Antworten, sondern bereits die Voraussetzungen

- Powell J., Griffiths G., Walpole S., Lutz M. (2009): The Fernald Preserve Visitors Center: The Fernald Experience - Revealing, Engaging, and Preserving. - *WM2009 Conference, March 1–5, 2009, Phoenix, Arizona*.
http://www.wmsym.org/archives/2009/pdfs/9426.pdf

The U.S. Department of Energy (DOE) Office of Legacy Management’s public involvement activities at the Fernald, Ohio, site include continued communication about groundwater remediation, the management of legacy waste, and the future of the Fernald site. The completion of the Fernald Preserve Visitors Center, in August 2008, ensures that information continues to be readily available and effectively communicated to the public. A primary goal of the Visitors Center is to function as an informational and educational centre within the surrounding community, with the information available at the Visitors Center serving as an institutional control. By offering information on a variety of topics, from the site’s history to its current condition, the Visitors Center increases public awareness and helps prevent unsafe disturbances to and uses of the site.

- Schiesswohl S., Bahrke C., Deyo Y., Uhlmeyer T. (2007): Long-Term Stewardship: Institutional Controls on Department of Energy Sites. – P*roceedings of Waste Management Symposium WM07, February 25 - March 1, 2007*: Global Accomplishments in Environmental and Radioactive Waste Management: Education and opportunity for the next generation of waste management professionals. American Nuclear Society, La Grange Park.
http://www.wmsym.org/archives/2007/pdfs/7462.pdf

The U.S. Department of Energy (DOE) has managed the Long Term Stewardship and Maintenance activities at DOE sites since 1988. DOE's Office of Legacy Management (LM) was established in December 2003, and its specific mission is to manage the DOE's post-closure

responsibilities and ensure the future protection of human health and the environment. LM has control and custody for legacy land, structures, and facilities and is responsible for maintaining them at levels suitable for their long-term use. LM uses a wide range of institutional controls (ICs) as part of efforts to appropriately limit access to, or uses of, land, facilities and other real and personal property assets; protect the environment; maintain the physical safety and security of DOE facilities; and prevent or limit inadvertent human and environmental exposure to residual contaminants and other hazards. DOE is using a "defence- in-depth" strategy which uses multiple mechanisms to provide 'layering' for additional durability and protectiveness: Proprietary controls, Governmental controls, Enforcement and permit tools with IC components, Informational devices. An additional practice that supports ICs at LM sites entails the use of engineered controls, such as fences, gates, access controls, etc.

- Schneider T., Schieber C., Lavelle S. (eds.) (2006): *Long term governance for radioactive waste management*, Final report of COWAM2, WP4. COWAM2-D4-12 CEPN - R – 301. December 2006.
  http://www.cowam.com/IMG/pdf_cowam2_WP4.pdf
  This is the final report of the COWAM2 Working Party 4 (WP4). COWAM2 (Community Waste Management) was a cooperative research programme supported by the European Community in 2004-2006 to investigate governance processes for radioactive waste management. The aim of WP4 was to propose guidelines in order to better address long term issues in decision-making processes and start long term governance. Investigating the topics of long term, future generations and governance, the report concludes that in order to bridge the gap between technically relevant and socially meaningful time scales, the most appropriate approach is one of continued transfers of knowledge, safety heritage and responsibility from each generation to the next. The working group investigated ethical issues and proposed ethical criteria in the areas of responsibility, justice and democracy. In order to best promote and achieve continuity and sustainability of surveillance, the group recommended the creation of centres of competence and integration of the radioactive waste management facility and its surveillance in a local/regional socio-economic development. Financing schemes were studied, and the importance of transparency was emphasised. The guidelines prepared by the group comprise a series of technical, institutional, financial, societal and ethical considerations to be taken into account in the establishment and continued development of long-term governance processes by stakeholders at local, national and international levels.

- Sebeok Th. A. (1984): *Communication measures to bridge ten millennia*. BMI/ONWI-532.
  http://www.osti.gov/scitech/servlets/purl/6705990/
  This report describes a semiotic analysis of the problem of devising a method of warning future generations of the presence of hazards at the site of a radioactive waste repository. It describes some basic principles of semiotics, or the study of messages conveyed by any means, whether linguistic or symbolic. It describes various types of messages and communications channels. Some problems with using images for communicating, as well as issues related to decipherment of written records, are described. The report recommends that a "relay system" of passing information from one generation to the next be initiated incorporating folkloristic or heritage elements and a built-in enforcement system intended to ensure that future generations continue the relay process ("atomic priesthood"). A high degree of redundancy and diversity of components, both linguistic and symbolic, is also recommended.

- Sheats D.G. (1992): Records Management in support of the licensing process for the high level radioactive waste facility. – *Proceedings of High Level Radioactive Waste Management*, Volume 1, La Grange Park, IL (United States). American Nuclear Society, p. 2083-2087.
  This paper addresses the Record Management Programme of the Yucca Mountain project.

- Sigurdson B.E., Snider R.C., Bilokury M.R. (2003): Issues and considerations on the development of an institutional control policy for uranium mines within Northern Saskatchewan. Paper IAEA-CN-90/60. – *International conference on Issues and trends in*

radioactive waste management: Vienna, 9-13 December 2002: Contributed papers. IAEA, Vienna, p. 308-313.

There is currently no clear provincial policy with respect to a proponent's application for release from a reclaimed and decommissioned site, and the resulting provincial responsibility for the long-term management and maintenance of the site once a release has been granted. Another policy issue has been identified with respect to the long-term institutional control of previously abandoned uranium mine sites.

- Sprenger F. (2007): *Atommüllendlager: Medien, Zeit und Raum eines Kommunikationsproblems*. Ruhr-Universität Bochum, Fakultät for Philologie.

  This book gives a general overview on communication issues over long timescales, focussing in particular on information theory, media and memory.

- Storm A. (2014): *Post-Industrial Landscape Scars.* Palgrave Macmillan.

  This book explores post-industrial landscape scars caused by nuclear power production, mining, and the iron and steel industry in Malmberget, Kiruna, Barsebäck, and Avesta in Sweden; Ignalina and Visaginas in Lithuania; and Duisburg in the Ruhr district of Germany.

- Svensk Kärnbränslehantering AB (2010): *Handling of future human actions in the safety assessment SR-Site*. Technical Report TR 10-53. SKB, Stockholm. http://www.skb.com/publication/2151438/TR-10-53.pdf

  This document is a supporting document to the safety assessment for a KBS-3 repository, and documents the scenarios and assumptions about future human actions that were used in that safety assessment. The report describes the strategy used by SKB to deal with future human actions. It then discusses a variety of prospective future actions with the potential to impact on the safety of the repository, i.e. on the health and safety of persons living in the vicinity. This is followed by a discussion of conceivable societal contexts for these future actions, with a view towards assessment of the plausibility of such actions. Knowledge, both at the general (hazards and management of radioactive waste) and specific (location and contents of the repository) levels, is recognised as a key issue. The discussion concludes that there can be no guarantee of preservation of knowledge, regardless of whether society evolves in a positive or negative way, and therefore future human action scenarios are credible events to be considered in the safety assessment. Several scenarios are selected and described and their potential safety consequences are evaluated.

- Swedish National Council for Nuclear Waste (2015): Nuclear Waste State-of-the-Art Report 2015. Safeguards, record-keeping and financing for increased safety. SOU 2015:11. Kärnavfallsradet, Stockholm. http://www.karnavfallsradet.se/sites/default/files/documents/report_2015_11.pdf

  This report includes a summary of the work of the RK&M project as well as remarks on records, knowledge and memory in the Swedish programme.

- TallBear K. (2001): *Tribal social & cultural institutions for long-term stewardship of hazardous sites*. Presented at the National Academy of Sciences National Research Council Board on Radioactive Waste Management, Washington, D.C., 3 April 2001 and at the Roundtable on tribal issues and opportunities related to the long term stewardship of contaminated federal facilities, Lakewood, Colorado, 14-15 March 2001. http://www.iiirm.org/publications/Articles%20Reports%20Papers/Environmental%20Protection/socialcul.pdf

  This paper argues that tribal social and cultural institutions should be integral to contemporary efforts in the "long-term stewardship" of persistent hazardous and nuclear wastes, in addition to standard institutional controls.

- Tannenbaum P.H. (1984): *Communication Across 300 Generations: Deterring Human Interference with Waste Deposit Sites*. BMI/ONWI-535. http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/16/010/16010245.pdf?r=1
  This report presents a social psychologist's review of issues related to the use of symbolic elements in markers intended to communicate the presence of a radioactive waste repository to future generations in order to deter inadvertent intrusion. It describes findings in a number of areas, including the role of message location, message content, and in particular various aspects affecting sensory reception, attention, perception and cognition, and memory. The trefoil and related symbols are investigated. The report makes suggestions on research that could/should be carried out to determine which kinds of symbols are most likely to be effective irrespective, to the extent feasible, of language and culture.

- Taylor B.C., Kinsella W.J., Depoe S.P. (eds) (2007): Nuclear Legacies: Communication, Controversy, and the U.S. Nuclear Weapons Complex. Lexington Books.
  In part 2 of this book, which emphasises organisational aspects of nuclear weapons production, Jason Krupar and Stephen Depoe compare historical preservation efforts at the Nevada test site near Las Vegas, the uranium refinery in Fernald, and the plutonium trigger factory at Rocky Flats near Denver. Laura A. McNamara's essay focuses on attempts to preserve knowledge about designing reliable nuclear weapons since the 1992 testing moratorium. On the basis of fieldwork at Los Alamos, she explores how nuclear weapons designers constitute, maintain, and modify their community of knowing.

- Theis S. (2002) : Die Dokumentation radioaktiver Abfälle im Lichte einer mehrere Jahrzehnte andauernden Zwischenlagerung = The documentation of radioactive waste in the view of several decades of interim storage. – *Praxis des Strahlenschutzes: Messen, Modellieren, Dokumentieren: 34. Jahrestagung des Fachverbandes für Strahlenschutz e.V., Kloster Seon, 21. –25. April 2002*. Fachverband für Strahlenschutz, Jülich.
  Except for the operational documentation of the waste producer and conditioner the properties of radioactive waste packages have been described from the very beginning of their production according to the acceptance criteria of the final repository which was available at the time being. In chronological order the respective repository projects were Asse, Konrad and Morsleben. Further requirements from interim storage had not been considered as necessary. After the German repository policy was modified in autumn 1998, a prolonged period of several decades without an operating national repository had to be considered. Hence the operators and supervising authorities of the existing interim storage facilities formulated additional requirements especially regarding qualification of the waste containers and additional details of several chapters of the waste documentation.

- Tolan T.L. (1993): *The use of protective barriers to deter inadvertent human intrusion into a mined geologic facility for the disposal of radioactive waste: a review of previous investigations and potential concepts*. Contractor Report. SAND91-7097. Sandia National Laboratories, Albuquerque.
  This report contains a background review of information on the use of protective barriers to thwart inadvertent intrusion into a radioactive waste repository, with particular reference to the WIPP repository. The physical and geological setting in which the WIPP repository is located are described, including the potential for resource exploration and extraction nearby. The regulatory requirements and guidance related to passive institutional controls are presented. Protective barriers would form one element of a defence-in-depth system of passive institutional controls. The report presents a review of previous investigations into the subject, including a description of surface mound barriers proposed for use at near-surface waste repositories at the Hanford Site. Observations are made on the potential location and nature of possible barriers for use at a geological repository, including the potential for barriers that would make drilling of boreholes difficult.

- Tonn B.E. (2004): Integrated 1000-year planning. - *Futures* 36(1), 2004, p. 91-108.
  This paper develops the concept of integrated 1000-year planning. The products of such planning, referred to as 1 000-year plans, are intended to deal with issues on a global scale and address the survival of humanity and the protection of the earth's environment. One thousand years is an appropriate global planning horizon because it is long enough to unmask big picture problems that appear to be invisible to today's societies. Furthermore, this time horizon encourages the perspective that over the long-term, many problems that seem unsolvable today, and therefore receive little attention and few resources, can indeed be overcome. Topics of 1000-year plans are numerous and include: energy, land use, carbon management, oceans, biodiversity, nuclear and hazardous waste, water, human Settlements, near-earth objects, and space exploration. The argument is made that responsibilities for action by current generations to benefit future generations be based on risk assessments and risk thresholds. In the near-term, 1000-year planning must be driven by an international grassroots coalition of scientists, policy analysts, environmentalists, planners, and concerned citizens.

- Tonn B.E. (2001): Institutional designs for long-term stewardship of nuclear and hazardous waste sites. - *Technological Forecasting and Social Change* 68, 2001, p. 255–273.
  This article evaluates several designs for an institution to act as the steward for legacy sites. To offer lessons learned about the characteristics of long-lasting human institutions, several that have existed for hundreds and thousands of years are reviewed, including the Dominican monastic order, the Sangha community of Buddhist monks, and universities such as those located in Oxford and Paris. Six alternative institutional designs are evaluated over a set of four evaluation criteria. It is recommended that the United States establish a new type of secular non-profit institution, entitled The Stewardship Institution, to act as steward for the sites. This option is judged most able to focus on the mission of stewardship, meet its technical challenges, survive inevitable periods of political and economic instabilities, and meet current generation cost and implementation concerns. Other institutions considered include a consolidated national stewardship organisation, a religious organisation, and a new state of the union called the Legacy State.

- Trauth K.M., Hora S.C., Guzowski R.V. (1993): *Expert judgment on markers to deter inadvertent human intrusion into the Waste Isolation Pilot Plant*. Sandia Report SAND92-1382. Sandia National Laboratories, Albuquerque.
  http://www.wipp.energy.gov/picsprog/Test1/SAND%2092-1382.pdf
  This report describes the studies carried out by two multi-disciplinary expert teams (the “Markers Panel”) to investigate the potential for markers to deter inadvertent human intrusion into the WIPP repository. Both teams agreed with the need to mark the site, and to provide accurate information at several levels of sophistication. The characteristics of a marker system were considered from several points of view, including architectural design, material properties, linguistics and message levels. Both teams recommended marker systems incorporating elements on a variety of scales ranging from large earthen berms to buried message disks or capsules, and bearing messages at a variety of levels ranging from rudimentary to detailed and technical. Both recommended the use of several languages in messages and the use of durable materials of little intrinsic value. Areas for further research and investigation were also identified, including physical properties of marker materials; culture-independent interpretation of graphic or pictorial messages; and culture-independent interpretation of written messages.

- Trauth K.M. (1994): WIPP marker development. - *Radwaste Magazine* 1(2), April 1994, p. 46-52.
  This paper describes the work carried out at Sandia National Laboratories to develop permanent, passive markers for the Waste Isolation Pilot Plant. [see also Hart 2004, Hart 2000, US DOE 2000, US DOE 1996, Trauth et al. 1993]

- Trautsch Chr. (2011): „Atomsemiotik – semiotische Probleme von Atommüll und Zeichen als Warnungen an die ferne Zukunft". Paper presented at the *Wiener Nuklearsymposium*, 4 October, 2011 and at the round-table *Arbeit an unlösbaren Problemen: Gott und Müll – Ewigkeitsstiftung durch Endlagerungsverpflichtung, Berlin,* 12 April, 2012. http://www.bazonbrock.de/werke/detail/?id=2625 (slides)

  This paper by a former student of R. Posner (see above Posner 1990) discusses potential contributions of semiotics to the issue of communication of warnings to future generations. It analyses the various components necessary to successful "significant communication" and describes three possible communication channels: physical ("traditional" markers with images, icons, etc.), biological (e.g. animals or plants acting as indicators to radiations), and cultural ("atomic priesthood" as described by Sebeok in Posner 1990). The author sees clear advantages in a "Council of the Future" in charge of transmitting complex warnings over generations.

- United Kingdom Nirex Ltd (2005): *Societal stability and implications for radioactive waste management*. UK Nirex Ltd Technical Note no. 483990. Nirex, Harwell (Didcot).

  The purpose of this study was to provide information on the longevity and stability of societies and institutions as a factor in decision making about options for long term management of radioactive wastes, in view of the fact that some proposed options (such as continued long-term storage) depend for their success on continued ongoing management. The method used was to identify and assess a number of historical analogues, including examples of civilisations, organisations and physical artefacts, with a view to identifying factors that may have contributed to their survival. The study found that survival of artefacts is unpredictable; actions or conditions that appeared in some cases to have contributed to preservation were found in other cases to have contributed to loss. Survival of organisations was generally dependent on the survival of the society in which they exist, and even in cases of survival, organisations often underwent substantial changes with time. The report concluded that methods for waste management that rely on continued active management (long-term storage) were unlikely to be successful in meeting safety requirements on the time scales required for management of long-lived radioactive wastes.

- United States Department of Energy / Waste Isolation Pilot Plant (1996): *Title 40 CFR Part 191: Compliance Certification Application for the Waste Isolation Pilot Plant: Appendix PIC: Passive Institutional Controls Conceptual Design Report.* Waste Isolation Pilot Plant, Carlsbad (New Mexico). http://www.wipp.energy.gov/picsprog/Test1/CCA_Appendix_PIC.PDF

  This report is part of the Department of Energy's application for certification for WIPP; specifically, it describes the principles, requirements and criteria established by DOE for the marker system at WIPP. A five-level hierarchy of on-site messages is described, including four levels to be incorporated into the marker system at the site and a fifth level of detailed documentation to be stored at various off-site locations. A proposed conceptual design for monuments and a message storage facility and information centre on the site are presented. A proposed design for surface earthworks (berms) is described, and a testing program for components of the marker system is outlined. Alternative conceptual designs and the reasons for choosing the proposed design over the alternatives are presented. Proposed sites for off-site archival storage for records are listed. Other passive controls such as inclusion of the site on maps and land ownership and land use controls are presented.

- United States Department of Energy / Waste Isolation Pilot Plant (2000): *Permanent Markers Testing Program Plan: Contractor report*. DOE/WIPP 00-3175. Waste Isolation Pilot Plant, Carlsbad (New Mexico). http://www.wipp.energy.gov/picsprog/Test1/PM%20Test%20Plan.pdf

  This report outlines a testing program for materials and design features and concepts that are proposed for use in the permanent marker system to be installed at the WIPP site at the time of repository closure. The proposed marker system includes large surface markers, small subsurface

markers, buried storage rooms, an information center, and large-scale earthworks (berms). A program of testing for each of these components, and the materials to be used in them, is outlined. The tests include both initial screening tests and extended tests intended to assess the long-term durability and viability of the marker system components. Program management, quality assurance and requirements applicable to the development and conduct of test and analysis plans are also described. A list of summary descriptions of proposed test methods is included in an appendix.

- United States Environmental Protection Radiation Agency (1996): *Compliance Application Guidance for 40 CFR Part 194*. EPA 402-R-95-014. US-EPA.
  http://www.epa.gov/rpdweb00/docs/wipp/cagfinal.pdf
  The Compliance Application Guidance (CAG) summarizes and explains the EPA final rule 40 CFR part 194, to assist the Department of Energy in the preparation and compilation of the WIPP Compliance Certification Application (CCA) and to assist in EPA's review of the CCA for completeness. In particular, the CAG includes provisions on the content of the compliance certification application, i.e. the kind of information and records that should be provided.

- United States Nuclear Waste Technical Review Board (2013): *Review of U.S. Department of Energy Activities to Preserve Records Created by the Yucca Mountain Repository: A Report to Congress and the Secretary of Energy*. U.S. NWRTB, August 2013.
  http://www.nwtrb.gov/reports/NWTRB%20Legacy%20Mgmt.pdf
  DOE's investigation of the Yucca Mountain site and its development of a license application generated over the 30-year lifetime of the Yucca Mountain project (YMP) massive amounts of technical and scientific information as well as extensive analyses of that information. Following the termination of YMP, responsibility for archiving and preserving Yucca Mountain scientific and engineering information was internally transferred from the unit in charge of the YMP, the Office of Civilian Radioactive Waste Management (OCRWM), to the Office of Legacy Management (LM). The U.S. Nuclear Waste Technical Review Board (NWTRB) was appointed to oversee LM's efforts to archive and preserve YMP documents and materials. Based on the results its review, the NWRTB found that a large part of Yucca Mountain documentation had been preserved and could be accessed and retrieved. Schedules approved by the National Archives and Records Administration (NARA) have been used to identify YMP records that should be preserved either permanently or temporarily (from 10 to 100 years). Some areas of concern have however been identified, including retrieving e-mails, loading and executing analytical software, as well as locating physical objects, such as videotapes, well logs, and maps, for which insufficient search aids exist.

- Upshall I., McCarthy G.J. (2007): The development of a contextual information framework model as a potential IAEA strategy to maintain radioactive waste knowledge . – *Proceedings of Waste Management Symposium WM07, February 25 - March 1, 2007*: Global Accomplishments in Environmental and Radioactive Waste Management: Education and opportunity for the next generation of waste management professionals. American Nuclear Society, La Grange Park.
  http://www.wmsym.org/archives/2007/pdfs/7374.pdf
  Effective inter-generational transfer of information on radioactive waste repositories using 'conventional' techniques will be highly dependent on societal stability. Our understanding of 'inter-generational transfer' should extend beyond the simple physical transfer of records into an archival repository towards the establishment of a working culture that places sufficient contemporary information into a form that ensures it remains accessible, and ultimately enhances, the knowledge of future generations. The IAEA has embraced the contextual information framework as a potentially viable approach to this particular challenge. A contextual framework comprises 'entities' that exhibit one or more definable relationships with a particular 'event'. People, organisations, concepts, ideas, places, natural phenomena, events themselves, cultural artefacts including records, books, works of art can all be conceptualised as entities. The draft IAEA Safety Report entitled 'Preservation and Transfer to Future Generations of Information Important to the Safety of Waste Disposal Facilities' was published as ICA Study 18 (see International Council of Archives

2006).

- Upshall I.R., Wisbey S.J. (2003): The long-term management of information on records on radioactive waste packages in the United Kingdom. Paper IAEA-CN-90/59. – *International conference on Issues and trends in radioactive waste management*: Vienna, 9-13 December 2002. IAEA, Vienna, p. 303-307.
  http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/34/016/34016299.pdf?r=1
  Careful consideration must be given to the type and form of the information associated with the creation, conditioning and packaging of radioactive waste and the threats to its continued integrity. United Kingdom Nirex Limited (Nirex), in association with experts in records media and management, has undertaken a programme of work to consider the range of media currently available, the threats to media integrity and the implications of a general move towards 'electronic' records. The results of this study are being used to develop an information management system strategy, capable of retaining data for all future phases of radioactive waste management.

- van Wyck Peter C. (2004): *Signs of Danger: Waste, Trauma, and Nuclear Threat*. University of Minnesota Press.
  This book retraces the history of WIPP to 1999.

- Wagner S., Beauheim R.L., Pfeifle T.W., Bethel B., Sosa-Yates G., Williams C.V., Milligan M., Fox M. (2002): *WIPP case study: Compliance Monitoring, Passive Institutional Controls, and Record Keeping*. SAND 2002-2010. Sandia National Laboratories, Albuquerque, New Mexico.
  http://www.osti.gov/bridge/servlets/purl/801375-2b1WnW/native/801375.pdf
  This document contains two separate reports: one on the compliance monitoring program at WIPP, and the other on passive institutional controls and record keeping. The compliance monitoring program report describes compliance monitoring parameters selected for both pre-closure and post-closure monitoring, including monitoring of radioactivity, hydrologic and geomechanical parameters, and human activities that could impact the performance of the repository. For pre-closure monitoring parameters, trigger values that, when exceeded, would result in further investigation have been established. Details of post-closure monitoring will be determined closer to the date of closure. With respect to passive institutional controls, the report describes the guiding principles, marker system design requirements and design criteria for on-site markers and messages, largely consistent with and building on the conclusions of the Markers Panel study (Trauth et al, 1993). The distribution of records of the knowledge of WIPP to off-site record centres and other regional and national institutions and organisations is also described. The pre-closure record keeping program for WIPP and a proposed records system at the Carlsbad Field Office are described.

- Warner P.J. (1996): International Atomic Energy Agency (IAEA) Initiatives: Records management for deep and near surface geologic repositories. – *NIRMA Symposium*, August 25-28 1996. SAND 96-2008C.
  http://www.osti.gov/bridge/servlets/purl/366468-5qdZON/webviewable/366468.pdf
  Presentation – aimed in particular at DOE and NARA (National Archives and Records Administration) – of IAEA activities related to the preparation of TECDOC 1097 (IAEA 1999).

- Warner P.J. (1997): *Traceability and retrievability: Documentation, the bridge from science to compliance.* – DOE Records Management Conference: Illuminating our legacy, focusing our future, Las Vegas, 23-26 June 1997. SAND 97-0485. DOE, Washington D.C.
  http://www.osti.gov/bridge/servlets/purl/510334-SkbrUN/webviewable/510334.pdf
  In this day of regulatory compliance, the fact that good science was practiced and documented is, in and of itself, not enough to assure a successful licensing or permitting result. A new level of documentation that clearly walks a non-project reviewer through the traceability of all activities and

decisions is required for successful acceptance of scientific results. Compliance reviewers (whether the Nuclear Regulatory Commission (NRC), Environmental Protection Agency (EPA), etc.) expect to verify the results of the scientific and program activities without the physical presence of the person or persons that conducted the activity. Traceability of activities and associated decisions through the retrieval of all associated records is a must. This presentation is based on lessons learned from the various quality assurance (QA) audits and program reviews of Sandia National Laboratories, Nuclear Waste Management Programs Center, scientific and programmatic documentation. The authors build a bridge from science to compliance from lessons learned.

- Warner P.J. (1997): United States of America activities relative to the International Atomic Energy Agency (IAEA) Initiatives: Records management for deep geologic repositories. – 1997 Waste Management Conference, March 2-7, 1997. Tucson, Arizona, 1-16. http://www.wmsym.org/archives/1997/sess35/35-01.htm
  Presentation of IAEA activities related to the preparation of TECDOC 1097 (IAEA 1999)

- Waste Isolation Pilot Plant WIPP (2007): How will future Generations be warned? http://www.wipp.energy.gov/fctshts/PICs.pdf.
  Factsheet describing the various Passive Institutional Controls (PICs) planned at WIPP.

- Weinberg A.M. (1972): Social institutions and nuclear energy. *Science* 177, 7 July 1972.
  This paper offers a historical perspective on societal issues in relation with radioactive waste disposal. The author begins with a review of the current (1972) status of nuclear energy development. Regarding the issue pf waste, the author notes that the option of permanent storage requires surveillance and active management in perpetuity and for this reason opts for sequestration from the biosphere (disposal) in preference. However, he notes that even geological disposal is vulnerable to human intrusion, thus requiring some degree of surveillance to prevent intrusion. In an often-quoted sentence, he states that "We nuclear people have made a Faustian bargain with society", meaning that while nuclear energy offers an almost inexhaustible source of energy, the price demanded is one of "both a vigilance and a longevity of our social institutions that we are quite unaccustomed to". He considers the vigilance aspect, protecting against nuclear and transportation accidents, to be the easier of the two demands to cope with; the requirement for longevity of institutions, in order to prevent human intrusion into and contact with waste, is in his view more problematic. Another often-quoted term used in this paper is that of a nuclear "priesthood"; he notes that permanent storage requires "keeping a priesthood that forever … guards the vaults", and also that we are already reliant on a "military priesthood" to guard against the inadvertent use of nuclear weapons. He expresses the hope that such a "priesthood" will not be necessary to protect wastes in geologic repositories, but does not go so far as to exclude such a need from consideration. This concept of a "nuclear priesthood" was later developed further by Th. Sebeok in the latter's report on Communication measures to bridge ten millennia (1984).

- Weinberg A.M. (1999): Scientific Millenarianism. *Proceedings of the American Philosophical Society* 143(4), 1999, p. 531-539.
  Science is increasingly requested to address concerns that span hundreds or even thousands of years into the future. This paper analyses our present-day responses to far-distant threats such as the issues posed by the long-term management of radioactive waste.

- Weitzberg A. (1982): *Building on existing institutions to perpetuate knowledge of waste repositories*. BMI/ONWI-379.
  This report discusses the potential roles of certain existing institutions and practices in preserving and transmitting information to future generations about the existence and location of radioactive waste repositories. The institutions or practices studied include widely distributed maps, focusing in particular on maps produced by the United States Geological Survey; the marker system of the National Geodetic Survey; the retention and archiving of documents in libraries and archives; and the incorporation of waste identification and location into a nationwide "one-call" system for

hazardous waste. Each of these approaches is discussed in turn, with a background description, a discussion of methods for applying it to waste repositories, and an assessment of its potential value. The purpose of the study was to supply information to be used in decision making about communication methods to be used for advising future generations about the locations and hazards of waste repositories.

- Wikander O. (2015): Don't Push this Button: Phoenician Sarcophagi, "Atomic Priesthoods" and Nuclear Waste. – In: *Vetenskapssocieteten i Lund. Årsbok 2015*, Rahm, H. (ed.), Vetenskapssocieteten i Lund, Lund.

  This article discusses the impact of historical sciences, classical philology and religious studies on the field of "Nuclear Semiotics", the scholarly discussion concerning communicating information about nuclear waste disposal into the far future. The author uses examples such as a Phoenician funerary inscription, the Antikythera Mechanism, ancient water power, and the reconstruction of mythology to shed light on problems inherent in such communication, especially in schemes such as Thomas Sebeok's idea of a pseudo-religious "Atomic Priesthood" that would perpetuate the tradition about stored nuclear waste. The article also aims at pointing out some ways in which the "nuclear waste question" can make historians view their own field in new ways.

- Wikander O. (2015): Language, Nuclear Waste and Society: The Preservation of Knowledge over Vast Periods of Time and its Relevance for Linguistics. *Lychnos: Annual of the Swedish History of Science Society*, 2015, pp. 7–25.
  https://lychnosblog.files.wordpress.com/2016/09/wikander-language-and-nuclear-waste.pdf

  This article discusses the impact of comparative/historical philology upon the question of Nuclear Semiotics, i.e. the field of how humanity is to communicate information about nuclear waste storage into the distant future and its (presumably human) inhabitants. It also turns this perspective on its head and discusses possible insights in the other direction – what Nuclear Semiotics can teach historical linguistics. It is argued that the "nuclear waste question" provides one of the clearest examples of the purely practical importance of human reflection upon the historical development of language and writing.

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  This report assesses the impact of extreme natural events on surface protective barriers designed for near-surface waste disposal sites at the Hanford Site. The events assessed include tornados, high-intensity precipitation, stream flooding, earthquakes, and volcanic ash deposition. A significant part of the report consists of descriptions of site-specific meteorology and climatology, hydrology, geology and seismology, and regional volcanic activity. Appendices document a seismic stability analysis that was performed for a prototype barrier, and laboratory shear tests performed on one of the materials used in the barrier (fluid applied asphalt).

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  The Nuclear Regulatory Commission (NRC) requires that the monuments or markers accurately identify the location of the repository, be designed to be as permanent as practicable and convey a warning against intrusion into the underground repository. This report discusses the following issues: (1) Post closure issues of underground repositories, e.g., record keeping and markers, public reassurance and prevention of misuse. (2) Optimization of radiation protection by optimizing radioactive waste management, siting analysis, repository design etc. (3) An interface between nuclear safeguards and radioactive waste management by safeguarding conditioning of spent fuel, during operational phase of repository and post-closure phase of the repository.