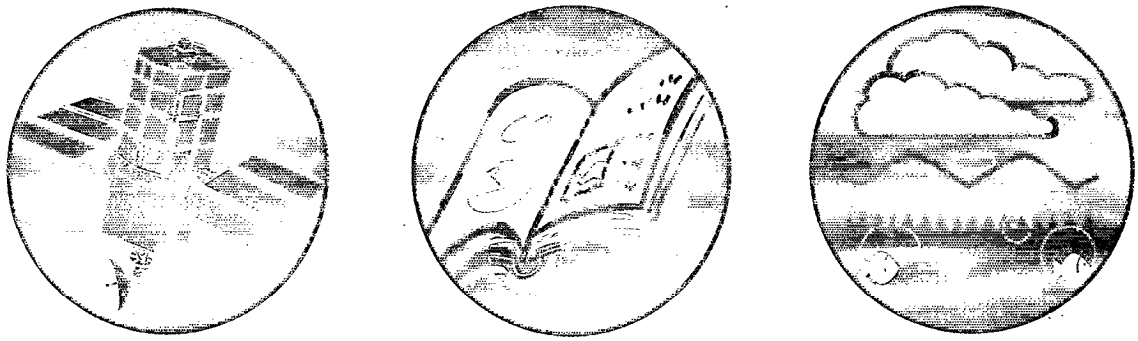
The NEA International FEP Database and its Use in Support of Regulatory Review



Research and Development

Technical Report
P280

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The NEA International FEP Database and its Use in Support of Regulatory Review

R&D Technical Report P280

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Statement of use
This report described the NEA/FEP database as developed to meet the Agency's needs and the procedures for its use in assessing safety cases for solid radioactive waste disposal.

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The NEA International FEP Database
and its Use in Support of Regulatory Review

CONTENTS

EXECUTIVE SUMMARY

A working group of the Nuclear Energy Agency has developed a database of features, events and processes (FEPs) relevant to the assessment of the long-term safety of radioactive waste disposal facilities. The Environment Agency participated in this work as described in a previous report, R&D Technical Report P97.

This report describes work done in order to

- provide an electronic version of the NEA International FEP Database in a convenient form suited to the Agency's needs.
- determine procedures for use of the Database in support of the Agency's review of an applicant's safety case for solid radioactive disposal, and in other appropriate Agency activities.

Section 1 of the report outlines the objectives and work done. Section 2 gives an overview of the current status, development and international use of the NEA FEP Database. Alternative uses of the Database by the Agency, and procedures for use, are discussed in Section 3. Two alternative procedures for use of the Database in scientific and technical review of an applicant's safety case are outlined and compared; these provide a framework for orderly identification and discussion of technical issues within the review.

It is concluded that the way in which the Database is used will depend on the circumstances and also the aims and preferences of the Agency. Detailed procedures for the use of the Database are best defined for the specific circumstances, taking account of the level of information available from the applicant, and the time and resources which the Agency may wish to devote to a given phase of review.

The NEA FEP Database has been developed as a tool to assist in performing or reviewing safety assessments of radioactive waste disposal facilities. The principle of the Database, and also the software framework, may be equally applicable to other technical or scientific assessments, e.g. of landfill facilities or river catchment pollution studies. Since the Database is now available to the Agency in an easily useable software implementation it will be possible for Agency staff to examine the database and assess its potential in these other areas.

KEYWORDS

Database, disposal options, legislation, radioactive wastes, radiological safety assessment, safety case assessment, scenario development, near-surface radioactive waste disposal, deep disposal of radioactive waste, methods and tools for safety assessment

1. INTRODUCTION

This report is prepared by Safety Assessment Management Ltd. for the Environment Agency under the terms of contract titled: "Implementation of the NEA International FEP Database by the Environment Agency".

The objectives of the project are:

- to provide the International FEP Database in a convenient form suited to the Agency's needs;
- to determine and define procedures for use of the FEP Database in support of the Agency's review of an applicant's safety case for solid radioactive waste disposal and in other appropriate Agency activities.

The following work has been carried out.

- Version 1.0 of the Database, as developed for the NEA Working Group, was demonstrated to Agency staff and at an Environment Agency open day.
- Various options for provision of an electronic version of the database to the Agency have been considered and an option selected, whereby the Agency are presented with a royalty free "runtime" solution for their exclusive use.
- Moderate developments have been made to the database, in parallel with developments made for the future use of the database by an NEA User Group. In particular:
  - an additional project database has been added, demonstrating that the International FEP List framework can also encompass descriptions of near-surface disposal facilities;
  - improvements have been made to user screens and supporting on-screen electronic information so that no knowledge of the database software implementation is required in order to use the database;
  - a version of the electronic database, Version 1.1(ea), has been prepared for exclusive use by the Agency.
- Procedures for the use of the FEP Database in support of the Agency's review of an applicant's safety case have been outlined.

This is the final report of the project. An overview of the current status, development and international use of the NEA FEP Database is given in Section 2. Alternative uses of the Database by the Agency, and procedures for use, are discussed in Section 3. Final remarks are given in Section 4. Version 1.0 of the NEA International FEP List is reproduced in Appendix 1. User documentation for electronic Version 1.1(ea) of the Database is given in Appendix 2; the software license is reproduced in Appendix 3.

2. THE NEA INTERNATIONAL FEP DATABASE

2.1 Background

The NEA International FEP Database is a tool to assist in the review, intercomparison and development of safety assessments for solid radioactive waste facilities. It was developed, between 1993 and 1997, by a Working Group of the OECD Nuclear Energy Agency (NEA) Performance Assessment Advisory Group (PAAG) [Sumerling 1996]. Her Majesty's Inspectorate of Pollution (HMIP) were one of seven partners that contributed to the funding of the development as described in Environment Agency R&D Technical Report P97, July 1997.

The NEA International FEP Database has two main components:

(1) **The International FEP List** – a list of factors or FEPs relevant to the assessment of long-term safety of solid radioactive waste repositories, that is comprehensive at a given level of detail and within defined bounds. The list forms a master list and classification scheme by which to examine the project-specific database entries. A 'glossary' style definition is attached to each FEP; this defines the scope and indicates the range of project-specific FEPs that might be mapped to each International FEP.

(2) **Project databases** – a collection of FEP lists, FEP descriptions and references, compiled during repository safety assessments and scenario development studies. Every FEP of each project database is mapped to one or more of the International FEPs. The information given within each project varies but, typically, includes descriptions of each FEP in the context of the disposal system considered and comments on the importance and representation of FEPs in assessment models.

Both parts exist as files in an electronic database with simple screening and selection tools, and various screen display formats. The basic mode in which the database has been designed to operate, illustrated in Figure 1, is as follows:

- Select an international FEP that most closely matches an enquirer's interest, a FEP can be selected by a search on FEP names and glossary definitions, or by examination of the International FEP List.

- Look up project-specific FEPs that have been mapped to that International FEP, and the associated literature references.

Alternative modes of use are possible and are facilitated by the simple database structure. For example, a user may examine, or perform word searches on, the project-specific FEP records or references directly, without using the International FEP List. The current database

is a starting point. It is expected that, in the future, project databases will be added and improvements made to the function of the database.

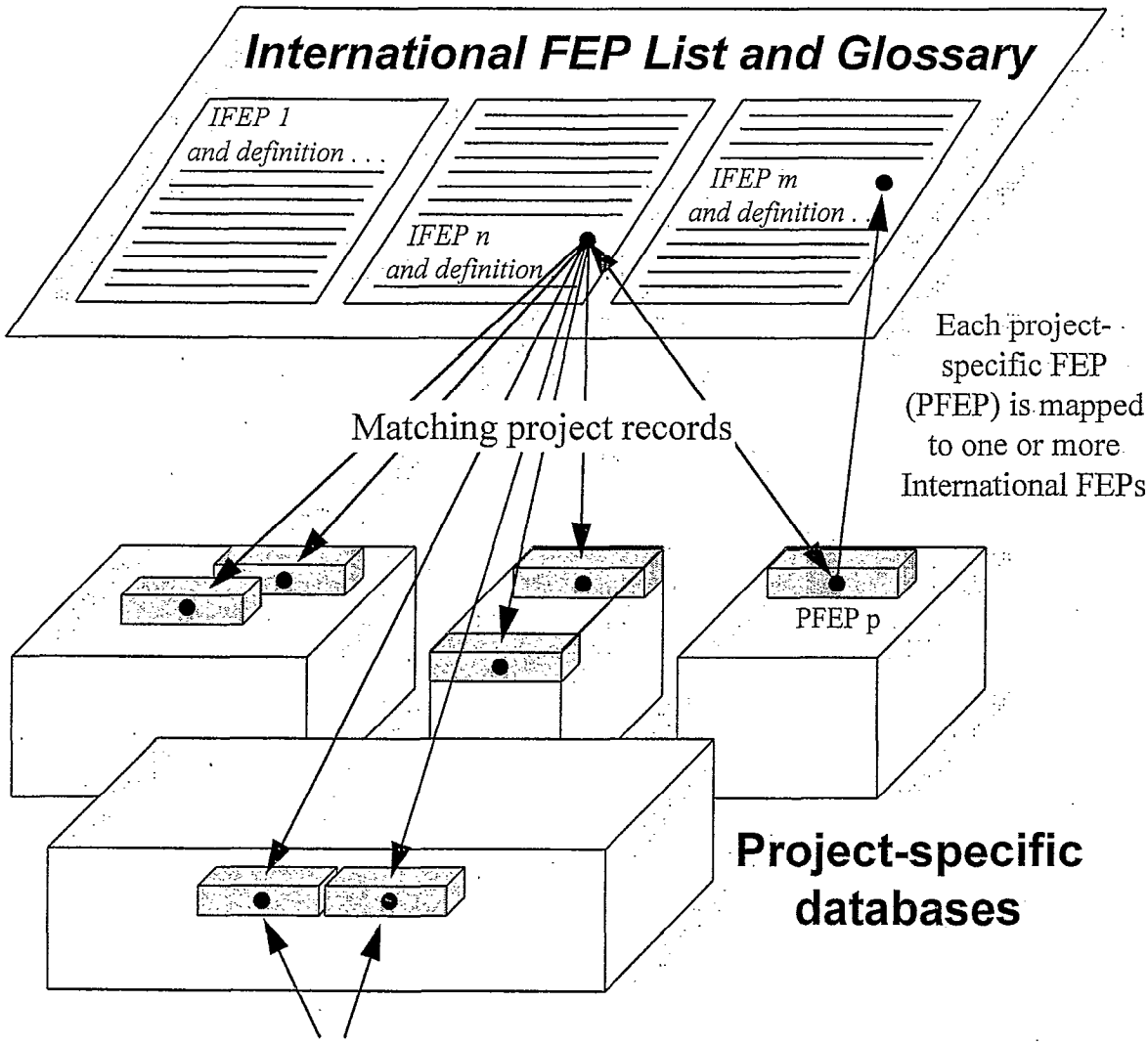


Figure 1: The International FEP List as a key to FEP descriptions and references held in project databases.

2.2 Current Status and Development

Version 1.0 of the Database was the final product of work by the NEA FEP Database Working Group. This was implemented on Claris FileMaker Pro, Version 2.1, a commercial database software which was selected because of its ease of use and also because its files are compatible (and interchangeable) between IBM PC and Macintosh computers. Version 1.0 of the database, containing seven project databases and over 1200 project FEPs, was distributed to members of the Working Group for review and private use. It has also, subsequently, been distributed on request by the NEA to other PAAG members. The development of the Database is documented in an OECD/NEA report [NEA, in press].

In September 1997, PAAG agreed to the need to maintain and develop the database by the establishment of a User Group, whose members would contribute to a fund for maintenance and development work to be carried out by a contractor. A read-only "runtime" version of the Database, Version 1.1, was also planned for distribution on CD-ROM with the OECD/NEA report, then in final draft.

Administrative difficulties at the NEA have delayed the setting up of a User Group so that a first meeting of an *ad hoc* group did not occur until October 1998. At this meeting a Work Programme was developed and administrative arrangements confirmed, so that it is expected that work under the project may resume during 1999. The following organisations have made a commitment to join the Core User Group and attended the 2nd Core Group Meeting in Madrid, May 1999:

SCK-CEN, Belgium	Ontario Hydro, Canada
VTT, Finland	GRS, Germany
BGR, Germany	JNC, Japan
ENRESA, Spain (also represented by CIEMAT)	
SKI, Sweden	SKB, Sweden
USDOE, USA (represented by Sandia)	Nagra, Switzerland

A few other organisations, notably ANDRA, France, have expressed an interest.

Meanwhile, the Environment Agency, because of their interest in the possible use of the International FEP database, placed a contract as described in this report to provide a version of the Database and outline its possible use in support of their regulatory role.

Under this contract the following work has been done.

1. An electronic version of a FEP database related to a near-surface radioactive waste disposal facility has been obtained. This is the issues database for the AECL preliminary safety analysis of the "Intrusion Resistant Underground Structure" (IRUS) at the Chalk River site [Stephens et al. 1997]. The database has been "mapped" to the

International FEP List and incorporated into the electronic FEP Database. This is of value to the Agency because of their ongoing interest in review of the safety case for the near-surface facility at Drigg. All other project databases within the NEA FEP Database are from safety assessments of deep disposal facilities; the incorporation of the IRUS project database demonstrates that the NEA International FEP List structure and database is also suited to safety assessment of near-surface facilities.

2. Developments have been made to the electronic database screens to make the database easier to use. In additional, more general work has been done to prepare the database for compilation as a runtime solution including extensive data checking and developing certain features. This work has not been charged to the Agency, however, as it is required as part of the NEA User Group Programme of Work, and should be covered from the User Group funds.

3. As a result a Database Version 1.1(ea) has been prepared for immediate use by the Agency. This has the same data and is very similar in function to a Version 1.1 which will eventually be made available via the NEA. The use and function of Version 1.1(ea) is outlined in Appendix 1.

2.3 International Use

The author is aware of at least two studies in which the NEA FEP Database has been used in support of repository safety assessment studies. These two studies illustrate the two main classes of use for the Database that were anticipated by the Working Group [NEA in press]:

- auditing of an existing project FEP List or safety assessment;
- assistance in developing project-specific FEP Lists or safety assessment.

2.3.1 Application to a spent fuel repository, Finland

Posiva Oy have reported the use of the Database to audit the TVO-92 and TILA-96 safety assessments of a repository for spent fuel in Finnish bedrock [Vieno and Nordman 1997]. The audit is performed with the assistance of a classification table illustrated in Table 1. Each of the 1261 Project FEPs in Version 1.0 of the Database is considered in turn and assigned to a class as given in the table. Analysis of this process shows that 806 of the FEPs were included in the previous assessments, 398 can be excluded, and 57 FEPs are identified that were "not considered". Of these

- several could be conservatively omitted,
- several were related to human actions which were not included in the TVO-92 and TILA-86 assessments,
- and several were related to more complex processes that considered in TVO-92 and TILA-96, e.g. desaturation/resaturation and chemical kinetics.

Overall, the report concludes that the International FEP Database is a good first step towards an international FEP encyclopaedia and serves as a handbook, especially for more exotic FEPs. The exercise did not reveal anything substantially new from TVO-92 and TILA-96 (although this in itself contributes to the process of confidence building in safety assessment).

Considered FEPs	
Scenario Model	Modelled in release and transport analyses.
Covered by conceptual model	Covered by the conservative conceptual models (for example, the U-tube flow through the repository) user in TVO-92 and TILA-96.
Primary data	Parameter in release and transport analyses.
Data selection	Taken into consideration when selecting parameter values for release and transport analyses.
Design	Taken into consideration in the design of the disposal system.
Discussed	Discussed (with reference to the chapter / page in concern).
Mentioned	Discussed briefly / mentioned (with reference to the chapter / page in concern).
TVO-85	Considered / discussed / mentioned in TVO-85.
FEPs which can be excluded	*Note: These are posterior judgements, no formal exclusion criteria were applied.*
Assessment basis	FEP in not relevant in post-closure safety assessment of disposal of spent fuel in copper-iron canisters in the Finnish crystalline bedrock.
Biosphere	FEP is related to transport or dose pathways of radionuclides in the biosphere. A stylised drinking water well scenario was used for indicative dose assessment in TILA-96. TVO-92 dose conversion factors were based on more detailed biosphere analysis.
Generic	The FEP name and the definition given in the project database have a broad scope and are covered by other more specific FEPs.
Very low probability	
Very low consequences	
Not considered FEPs	
Not considered	

Table 1: Classification of FEPs used in the auditing of the TVO-92 and TILA-96 safety assessments.

2.3.2 Application near-surface radioactive waste disposal facilities

The NEA International FEP Database is also in use in the IAEA "Programme on Improvement of Safety Assessment Methodologies for Near-Surface Waste Disposal Facilities" (ISAM), e.g. see [IAEA 1998]. This study is concerned specifically with developing and testing methods for safety assessment of near-surface facilities.

As the first stage of the development of a scenario methodology the NEA International FEP List was reviewed by an *ad hoc* working group. This group concluded that the International FEP list was, indeed, broadly applicable to near-surface disposal facilities, although noting that a few of the FEPs (from the section of "Geological Processes and Events") would not, in general, be relevant. In order to "tune" the list for use in ISAM three FEPs were added to the list:

1.3.19 Other geomorphological changes

2.1.15 Extraneous materials (in the waste and engineered features)

2.3.14 Animal/plant intrusion/disruption of the facility

and one FEP was subdivided thus:

1.4.06 Surface environment, human activities

1.4.06.1 Surface excavation

1.4.06.2 Pollution

1.4.06.3 Site use/development

With these modifications the database was accepted as a building block within the ISAM scenario method. Some work has since been done to review and amend the glossary definitions for each FEP to make them applicable to near-surface facilities.

The amended FEP List and Glossary have been used by one of the safety case working groups in ISAM. This group found that they re-visited the List several times in developing scenarios and models to be used in a safety assessment of an engineered vault facility. They screened out from the list processes that would not be relevant to the facility (mainly from the geological section), used the list to assist in defining the conditions of a base or "design" scenario, and to assist in the development of alternative scenarios.

The eventual outcome of work by IAEA ISAM should be the development of a FEP database for near-surface disposal facilities. This may then be included within the NEA International FEP Database as a project-specific database.

3. USE IN SUPPORT OF REGULATORY REVIEW

3.1 Alternative Uses

The expected general uses of the International FEP List and associated project databases are as:

- an aid to achieving and demonstrating comprehensivencss within an assessment;
- a tool to interrogate individual assessments as well as to assist in comparing assessments.

More detailed suggestions for use are given in Section 3.7 of the Working Group report [NEA in press]. In particular, it is suggested that the International FEP List may be used by reviewers to audit the scope of a completed assessment, or may be used as a starting point for discussion of assessment scope and completeness between a proponent and regulator.

Within a preliminary discussion of the possible use of the NEA Database by the Agency [Sumerling 1997], three broad possibilities were identified and discussed:

(A) use in scientific and technical review of an applicant's safety submissions;

(B) use in support of the independent analysis by the Agency;

(C) use of the Database, or developments thereof, as a tool to facilitate technical dialogue between the Agency and a potential applicant.

Use (C) would be possible if an applicant was prepared to put effort into the development of a dialogue tool, was willing to supply the tool to the Agency and, also, if the Agency considered that use of a tool developed by the applicant did not unduly constrain or bias its review. This path would imply a degree of commitment to a long-term review process and co-operation with the proponent that has not been achieved in Agency's exchanges with industry to date, nor is it clear it would be desirable from a policy perspective. This option is, therefore, not considered further.

The author's understanding is that the Agency is unlikely to commission large-scale independent analysis exercises in support of regulatory review in the foreseeable future. Thus, use (B) is not of immediate interest, although if the Agency decides to review its independent analysis capability in future, then the Database might be used as a starting point for a generic review of capability.

The following section therefore focuses on use (A).

3.2 Use in Scientific and Technical Review.

At least two basic methods can be envisioned by which the NEA FEP Database could be used as a framework for scientific and technical review of an applicant's safety submission.

Method A1: direct audit

The FEP Database could be used as a direct audit tool of the applicant's safety case, wherein either the International FEP List itself (method A1.1) or the list of Project FEPs (method A1.2) is used as the audit list. In either case, reviewers answer a set of predetermined questions for each FEP based on their examination of the applicant's submissions such as:

- is it necessary to treat the FEP for the specific disposal system?
- has, or how has, the applicant treated the FEP?
- is this treatment judged adequate?
- are any other sub-issues identified that should be considered/reviewed in more detail?

The audit of TVO-92 and TILA-96 reported by Vieno and Nordman (see Section 2.3) is a variant of method A1.2, i.e. audit against the project FEP List. In general, however, it is likely that method A1.1, i.e. audit against the International FEP List, may prove a more satisfactory and tractable method in support of a regulatory review. In this use, the project FEP information is used as ancillary information; it acts as a prompt and also indicates how given international FEPs have been treated in other safety assessments.

Method A2: independent system model elicitation

An alternative, or perhaps parallel, approach is to use the International FEP List, together with waste, repository and site information supplied by the applicant, to carry out an independent system model elicitation. That is, to form an independent judgement on the scope of modelling and calculations that will lead to an adequate assessment performance. Such exercises have been carried out as part of both the HMIP Dry Run 3 [Thorne 1992] and the independent assessment of Nirex proposals for the Sellafield site [Miller and Chapman 1993]. The added formalism proposed here is that:

- the International FEP List is used as a starting point for the system model elicitation,
- the independent system model is elicited with the specific purpose of using it as a template against which to review the applicant's analysis.
- judgements can then be made on the adequacy of the applicant's analysis and possible bias due to omission of important processes.

The last two stages were not carried out as part of the assessment of Nirex proposals, although in Dry Run 3, the independently derived system model was used to informally audit the HMIP system model, see [Sumerling 1992].

Comparison of the methods

Both of the methods proposed above are flexible to a large degree in that either could be performed:

- at different stages of the development of proposals,
- with different levels of information from the applicant,
- with different levels of Agency resource and support from scientific and technical experts,
- with different levels of formality.

Some broad characteristics can be identified, however, which should be considered when deciding which method is most suitable in given circumstances, as summarised in Table 2.

Method A1.1 : Audit against the International FEP List

- would lend itself to more formal application
- requires a complete safety analysis from the applicant in order to be thoroughly applied
- focuses on individual FEPs and their treatment by the applicant
- lends itself to breakdown and distribution of the work between several supporting experts
- or could be performed by Agency staff alone
- the applicant could be required to carry out part of the work by providing answers to specific questions

Method A2 : Independent system model elicitation and review

- independent model elicitation stage could be carried out in advance of detailed analyses from the applicant
- focuses on the total system and interactions, and identifies important processes and interactions independently
- would require meeting(s) of a group of experts to derive the independent model
- these same experts or different experts could be involved in the review stage
- likely to require more resources to apply thoroughly

Table 2: Characteristics of two alternative methods of using the FEP Database as a framework for scientific and technical review.

Overall, method A1.1 might be preferred if a more formal procedure was required or if time or resources were very limited; method A2 might be preferred if a full safety case is not available from the applicant, or if a greater degree of independence is required. In both cases, the method should be used to facilitate and structure technical discussion between the applicant and regulator, and this would be a very important part of its function, i.e. it provides a framework for orderly identification and discussion of the technical issues.

4. CONCLUDING REMARKS

This report has outlined the current status, development and use of the NEA International FEP database, and also discussed possible uses, and procedures for use, in support of the Agency's review of an applicant's safety case for radioactive waste disposal. The report is intended to inform the Agency of the current status of related work internationally and also to outline options for use of the Database by the Agency.

The way in which the database is applied will depend on circumstances and also the aims and preferences of the Agency. Detailed procedures for the use of the Database are best defined for the specific circumstances, taking account of the level of information available from an applicant, and the time and resources which the Agency may wish to devote to a given phase of review.

The NEA FEP Database has been developed as a tool to assist in performing or reviewing safety assessments of radioactive waste disposal facilities. The principle of the database, and also the software framework, may be equally applicable to other technical or scientific assessments, e.g. of landfill facilities or river catchment pollution studies. Since the Database is now available to the Agency in an easily useable software implementation it will be possible for Agency staff to examine the database and assess its potential in these other areas.

5. REFERENCES

IAEA 1998. ISAM Newsletter, Number 3, November 1998.

Miller W.M. and Chapman N.A. (editors) 1993. HMIP Assessment of Nirex Proposals: Performance Assessment Project (Phase 1) : Identification of Relevant Processes. Contractor report to Her Majesty's Inspectorate of Pollution, TR-Z1-11, available from the Environment Agency, London.

NEA in press. Safety Assessment of Radioactive Waste Repositories: An International Database of Features, Events and Processes. OECD Nuclear Energy Agency Paris (Draft January 1998) in press.

Stephens M.E. et al. 1997. Analysis of Safety Issues for the Preliminary Safety Analysis Report on the Intrusion Resistant Underground Structure. AECL-MISC-386, AECL Chalk River Laboratories, Ontario.

Sumerling T.J. (editor) 1992. Dry Run 3: A Trial Assessment of Underground Disposal of Radioactive Wastes Based on Probabilistic Risk Analysis: Overview. HMIP report DoE/HMIP/RR/92.039.

Sumerling T.J. (on behalf of the NEA Working Group) 1996. The NEA International FEP Database: Outcome of the Working Group. In Proceedings of the 7th International High Level Radioactive Waste management Conference, Las Vegas, Nevada.

Sumerling T.J. 1997. The Nuclear Energy Agency Database of Features, Events and Processes: Application by the Environment Agency. R&D Technical Report P97, Environment Agency, Bristol.

Thorne M.C. 1992. Dry Run 3 : A Trial Assessment of Underground Disposal of Radioactive Wastes Based on Probabilistic Risk Analysis; Volume 8: Uncertainty and Bias Audit. HMIP report DoE/HMIP/RR/92.040 (2 volumes).

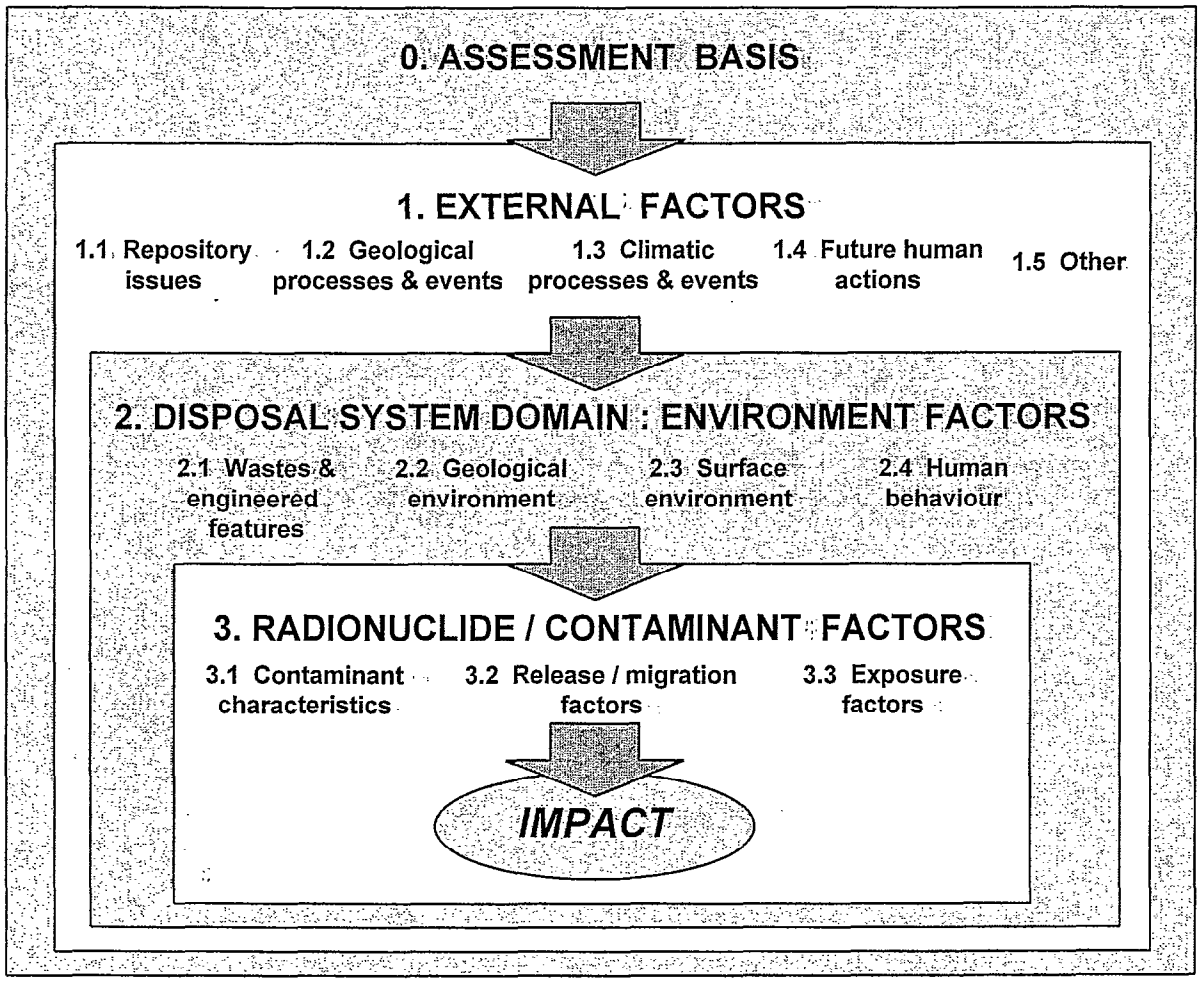
Vieno T. and Nordman H. 1997. FEPs and Scenarios: Auditing of TVO-92 and TILA-96 Against International FEP Database. Posiva Oy report 97-11, Helsinki, Finland.

APPENDIX 1:

THE NEA INTERNATIONAL FEP LIST

Classification and FEP Listing

The NEA International FEP List was derived with the assistance of a classification scheme illustrated below.



The next two pages give the definition of layers and categories within the classification scheme. The following four pages shows the International FEP List (Version 1.0) ordered according to the classification scheme under which it was derived.

Each FEP has been assigned an identifying number:

Layer . category . number.

This information may be useful when examining the International FEP List arranged in alphabetical (or any other) order. For example,

Accidents and unplanned events 1.1.12,

indicates that this FEP is considered to be an "External Factor" and a "Repository Issue".

LAYERS AND CATEGORIES OF THE CLASSIFICATION SCHEME (p 1 of 2)

LAYER 0. ASSESSMENT BASIS

Assessment basis factors are factors that the analyst will consider in determining the scope of the analysis; these may include factors related to regulatory requirements, definition of desired calculation end-points and requirements in a particular phase of assessment. Decisions at this point will affect the phenomenological scope of a particular phase of assessment, i.e. what "physical FEPs" will be included. For example, some classes of future human actions or extreme future events unrelated to the repository may be excluded.

Layers 1, 2 and 3 are defined relative to a definition of the "Disposal System Domain".

The disposal system domain consists of the wastes, engineered and natural barriers which are expected to contain the wastes, together with the potentially contaminated geology and surface environment, plus the further geology, surface environment and human behaviour that are generally considered together in order to estimate the movement of radionuclides, and exposure to man, following repository closure. The domain thus has both spatial and temporal extent.

LAYER 1. EXTERNAL FACTORS

External Factors are FEPs with causes or origins outside the disposal system domain, i.e. natural or human factors of a more global nature and their immediate effects. Included in this layer are decisions related to repository design, operation and closure since these are outside the temporal bound of the disposal system domain.

In general, external factors are not influenced, or only weakly influenced, by processes within the disposal system domain. In developing models of the disposal system domain, external factors are often represented as boundary conditions or initiating events for processes within the disposal system domain.

The following categories are used:

1.1 Repository issues - decisions on design and waste allocation, and also events related to site investigation, operations and closure;
1.2 Geological processes and effects - processes arising from the wider geological setting and long-term processes;
1.3 Climatic processes and effects - processes related to global climate change and consequent regional effects;
1.4 Future human actions - human actions and regional practices in the post-closure period, that can potentially affect the performance of the engineered and/or geological barriers, e.g. intrusive actions, but not the passive behaviour and habits of the local population, see 2.4;
1.5 Other - a "catch-all" for anything not accommodated in 1.1 to 1.4, e.g. meteorite impact.

In general, there are few significant direct interactions between FEPs in the different categories of external factors.

LAYERS AND CATEGORIES OF THE CLASSIFICATION SCHEME (p 2 of 2)

Within the Disposal System Domain, Environmental and Radionuclide processes occur.

LAYER 2. DISPOSAL SYSTEM DOMAIN: ENVIRONMENTAL FACTORS

Disposal system domain environmental factors are features and processes occurring within that spatial and temporal domain whose principal effect is to determine the evolution of the physical, chemical, biological and human conditions of the domain that are relevant to estimating the release and migration of radionuclides and consequent exposure to man (see Layer 3).

The following categories are used:

2.1 **Wastes & engineered features** - features and processes within these components;
2.2 **Geological environment** - features and processes within this environment including, for example, the hydrogeological, geomechanical and geochemical features and processes, both in pre-emplacement state and as modified by the presence of the repository and other long-term changes;
2.2 **Surface environment** - features and processes within this environment, including near-surface aquifers and unconsolidated sediments but excluding human activities and behaviour, see 1.4 and 2.4;
2.4 **Human behaviour** - the habits and characteristics of the individual(s) or population(s), e.g. critical group, for which exposures are calculated, not including intrusive or other activities which will have an impact on the performance of the engineered or geological barriers, see 1.4.

Interactions between FEPs in the different categories of environmental factors may be very important.

LAYER 3. DISPOSAL SYSTEM DOMAIN: RADIONUCLIDE/CONTAMINANT FACTORS

Radionuclide factors are the processes that directly affect the release and migration of radionuclides in the disposal system environment, or directly affect the dose to members of a critical group from given concentrations of radionuclides in environmental media.

The following categories are used:

3.1 **Contaminant characteristics** - the characteristics of radio-toxic and chemo-toxic species that might be considered in a post-closure safety assessment;
3.2 **Release/migration factors** - the processes that directly affect the release and/or migration of radionuclides in the disposal system domain;
3.3 **Exposure factors** - processes and conditions that directly affect the dose to members of the critical group, from given concentrations of radionuclides in environmental media.

The boundaries between the different layers and categories are subjective and will depend on individual analysts' concepts and extent of models. This should not prevent a self-consistent assignment of FEPs within the International List itself or when mapping project FEPs to the International List.

0 ASSESSMENT BASIS

0.01 Impacts of concern
0.02 Timescales of concern
0.03 Spatial domain of concern
0.04 Repository assumptions
0.05 Future human action assumptions
0.06 Future human behaviour (target group) assumptions
0.07 Dose response assumptions
0.08 Aims of the assessment
0.09 Regulatory requirements and exclusions
0.10 Model and data issues

1 EXTERNAL FACTORS

1.1 REPOSITORY ISSUES
1.1.01 Site investigation
1.1.02 Excavation/construction
1.1.03 Emplacement of wastes and backfilling
1.1.04 Closure and repository sealing
1.1.05 Records and markers, repository
1.1.06 Waste allocation
1.1.07 Repository design
1.1.08 Quality control
1.1.09 Schedule and planning
1.1.10 Administrative control, repository site
1.1.11 Monitoring of repository
1.1.12 Accidents and unplanned events
1.1.13 Retrievability

1.2 GEOLOGICAL PROCESSES AND EFFECTS
1.2.01 Tectonic movements and orogeny
1.2.02 Deformation, elastic, plastic or brittle
1.2.03 Seismicity
1.2.04 Volcanic and magmatic activity
1.2.05 Metamorphism
1.2.06 Hydrothermal activity
1.2.07 Erosion and sedimentation
1.2.08 Diagenesis
1.2.09 Salt diapirism and dissolution
1.2.10 Hydrological/hydrogeological response to geological changes

1.3 CLIMATIC PROCESSES AND EFFECTS
1.3.01 Climate change, global
1.3.02 Climate change, regional and local
1.3.03 Sea level change
1.3.04 Periglacial effects
1.3.05 Glacial and ice sheet effects, local
1.3.06 Warm climate effects (tropical and desert)
1.3.07 Hydrological/hydrogeological response to climate changes
1.3.08 Ecological response to climate changes
1.3.09 Human response to climate changes

1.4 FUTURE HUMAN ACTIONS
1.4.01 Human influences on climate
1.4.02 Motivation and knowledge issues (inadvertent/deliberate human actions)
1.4.03 Un-intrusive site investigation
1.4.04 Drilling activities (human intrusion)
1.4.05 Mining and other underground activities (human intrusion)
1.4.06 Surface environment, human activities
1.4.07 Water management (wells, reservoirs, dams)
1.4.08 Social and institutional developments
1.4.09 Technological developments
1.4.10 Remedial actions
1.4.11 Explosions and crashes

1.5 OTHER
1.5.01 Meteorite impact
1.5.02 Species evolution
1.5.03 Miscellaneous and FEPs of uncertain relevance

2 DISPOSAL SYSTEM DOMAIN: ENVIRONMENTAL FACTORS

2.1 WASTES AND ENGINEERED FEATURES
2.1.01 Inventory, radionuclide and other material
2.1.02 Waste form materials and characteristics
2.1.03 Container materials and characteristics
2.1.04 Buffer/backfill materials and characteristics
2.1.05 Seals, cavern/tunnel/shaft
2.1.06 Other engineered features materials and characteristics
2.1.07 Mechanical processes and conditions (in wastes and EBS)
2.1.08 Hydraulic/hydrogeological processes and conditions (in wastes and EBS)
2.1.09 Chemical/geochemical processes and conditions (in wastes and EBS)
2.1.10 Biological/biochemical processes and conditions (in wastes and EBS)
2.1.11 Thermal processes and conditions (in wastes and EBS)
2.1.12 Gas sources and effects (in wastes and EBS)
2.1.13 Radiation effects (in wastes and EBS)
2.1.14 Nuclear criticality

2.2 GEOLOGICAL ENVIRONMENT
2.2.01 Excavation disturbed zone, host rock
2.2.02 Host rock
2.2.03 Geological units, other
2.2.04 Discontinuities, large scale (in geosphere)
2.2.05 Contaminant transport path characteristics (in geosphere)
2.2.06 Mechanical processes and conditions (in geosphere)
2.2.07 Hydraulic/hydrogeological processes and conditions (in geosphere)
2.2.08 Chemical/geochemical processes and conditions (in geosphere)
2.2.09 Biological/biochemical processes and conditions (in geosphere)
2.2.10 Thermal processes and conditions (in geosphere)
2.2.11 Gas sources and effects (in geosphere)
2.2.12 Undetected features (in geosphere)
2.2.13 Geological resources

2.3 SURFACE ENVIRONMENT
2.3.01 Topography and morphology
2.3.02 Soil and sediment
2.3.03 Aquifers and water-bearing features, near surface
2.3.04 Lakes, rivers, streams and springs
2.3.05 Coastal features
2.3.06 Marine features
2.3.07 Atmosphere
2.3.08 Vegetation
2.3.09 Animal populations
2.3.10 Meteorology
2.3.11 Hydrological regime and water balance (near-surface)
2.3.12 Erosion and deposition
2.3.13 Ecological/biological/microbial systems

2.4 HUMAN BEHAVIOUR
2.4.01 Human characteristics (physiology, metabolism)
2.4.02 Adults, children, infants and other variations
2.4.03 Diet and fluid intake
2.4.04 Habits (non-diet-related behaviour)
2.4.05 Community characteristics
2.4.06 Food and water processing and preparation
2.4.07 Dwellings
2.4.08 Wild and natural land and water use
2.4.09 Rural and agricultural land and water use (incl. fisheries)
2.4.10 Urban and industrial land and water use
2.4.11 Leisure and other uses of environment

3 RADIONUCLIDE/CONTAMINANT FACTORS

3.1 CONTAMINANT CHARACTERISTICS
3.1.01 Radioactive decay and in-growth
3.1.02 Chemical/organic toxin stability
3.1.03 Inorganic solids/solutes
3.1.04 Volatiles and potential for volatility
3.1.05 Organics and potential for organic forms
3.1.06 Noble gases

3.2 CONTAMINANT RELEASE/MIGRATION FACTORS
3.2.01 Dissolution, precipitation and crystallisation, contaminant
3.2.02 Speciation and solubility, contaminant
3.2.03 Sorption/desorption processes, contaminant
3.2.04 Colloids, contaminant interactions and transport with
3.2.05 Chemical/complexing agents, effects on contaminant speciation/transport
3.2.06 Microbial/biological/plant-mediated processes, contaminant
3.2.07 Water-mediated transport of contaminants
3.2.08 Solid-mediated transport of contaminants
3.2.09 Gas-mediated transport of contaminants
3.2.10 Atmospheric transport of contaminants
3.2.11 Animal, plant and microbe mediated transport of contaminants
3.2.12 Human-action-mediated transport of contaminants
3.2.13 Foodchains, uptake of contaminants in

3.3 EXPOSURE FACTORS
3.3.01 Drinking water, foodstuffs and drugs, contaminant concentrations in
3.3.02 Environmental media, contaminant concentrations in
3.3.03 Non-food products, contaminant concentrations in
3.3.04 Exposure modes
3.3.05 Dosimetry
3.3.06 Radiological toxicity/effects
3.3.07 Non-radiological toxicity/effects
3.3.08 Radon and radon daughter exposure

APPENDIX 2:

THE NEA FEP DATABASE ELECTRONIC VERSION 1.1(ea)

User Notes

A.1 History

Version 1.0 of the NEA FEP Database was a product of the NEA Working Group which operated between 1993 and 1997, see R&D Technical Report P97.

Version 1.0 was implemented on FileMaker Pro 3.0 and circulated for review and private use to members of the Working Group.

Version 1.1 has the following changes relative to Version 1.0:

- Some minor cosmetic changes are made as a result of Working Group review comments.
- Kristallin-I and WIPP 96 databases have been re-entered. (There were some minor errors in the WIPP data used in Version 1.0 and the Kristallin-I database has been finalised with minor changes since the production of Version 1.0).
- An additional project database, the AECL 'IRUS' database has been added.
- Improvements have been made to the database screens so that most operations that a user will require can be made by the use of on-screen buttons. Thus the FileMaker Pro menu bars and commands can be dispensed with.
- Version 1.1 is implemented on FileMaker Pro 4.0.

Version 1.1 will eventually be made available through the planned NEA FEP Database User Group.

This documentation describes Version 1.1(ea) which has been prepared specially for the Environment Agency. Version 1.1(ea) is produced as a "run-time" solution, i.e. it consists of a customised version of the FileMaker Pro software, produced under license from FileMaker Pro Inc., plus the data files.

The database includes text extracted from technical reports from several organisations. This is done with the permission of the organisations. The originating organisations retain copyright of the information where applicable.

The software is Year 2000 compliant.

A.2 Use

Getting Started

Please read the "NEAFEP" Software License (Appendix 2). We recommend that the database is used directly from the CD-ROM supplied. Alternatively, the software may be copied onto a hard disc, subject to the terms of the License. The version supplied is for use on an IBM compatible PC; if required, a Macintosh version can be supplied.

Simply run the application NEAFEP.exe. This will call the various data files as required. It is intended that the Database can be used without formal documentation and without prior knowledge of the nature of the Database. All operations are performed via screen buttons. "Advice" is given on most of the screens. Information screens describe the principle of the NEA FEP Database and how it is organised.

Organisation

"NEAFEP" calls the following data files:

- MASTER - introductory screens and main menu,
- DBINFO - information about the Database including the concept and definition of FEP categories of the International FEP List,
- PRINFO - information about the project FEP databases included,
- INTFEP - the International FEP List and glossary descriptions of each FEP,
- PROFEP - project specific FEP records, including descriptions as provided by the project,
- MAPPING - connection between international FEPs (IFEPs) and project-specific FEPs (PFEPs),
- REFERS - literature references to PFEPs provided by the projects.

Figure A.1 shows a map of the files and screens that can be accessed via the screen buttons.

Statistics

Figure A.2 shows statistics for Version 1.1 including a list of the included projects.

Figure A.3 shows the distribution of project-specific FEPs (PFEPs) across the categories of the International FEP List (IFEPs).

A.3 Problems

Please report any problems encountered using the Database, or suggestions for improvements, to:

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Figure A.1: NEA FEP Database (Version 1.1) - Screen Map

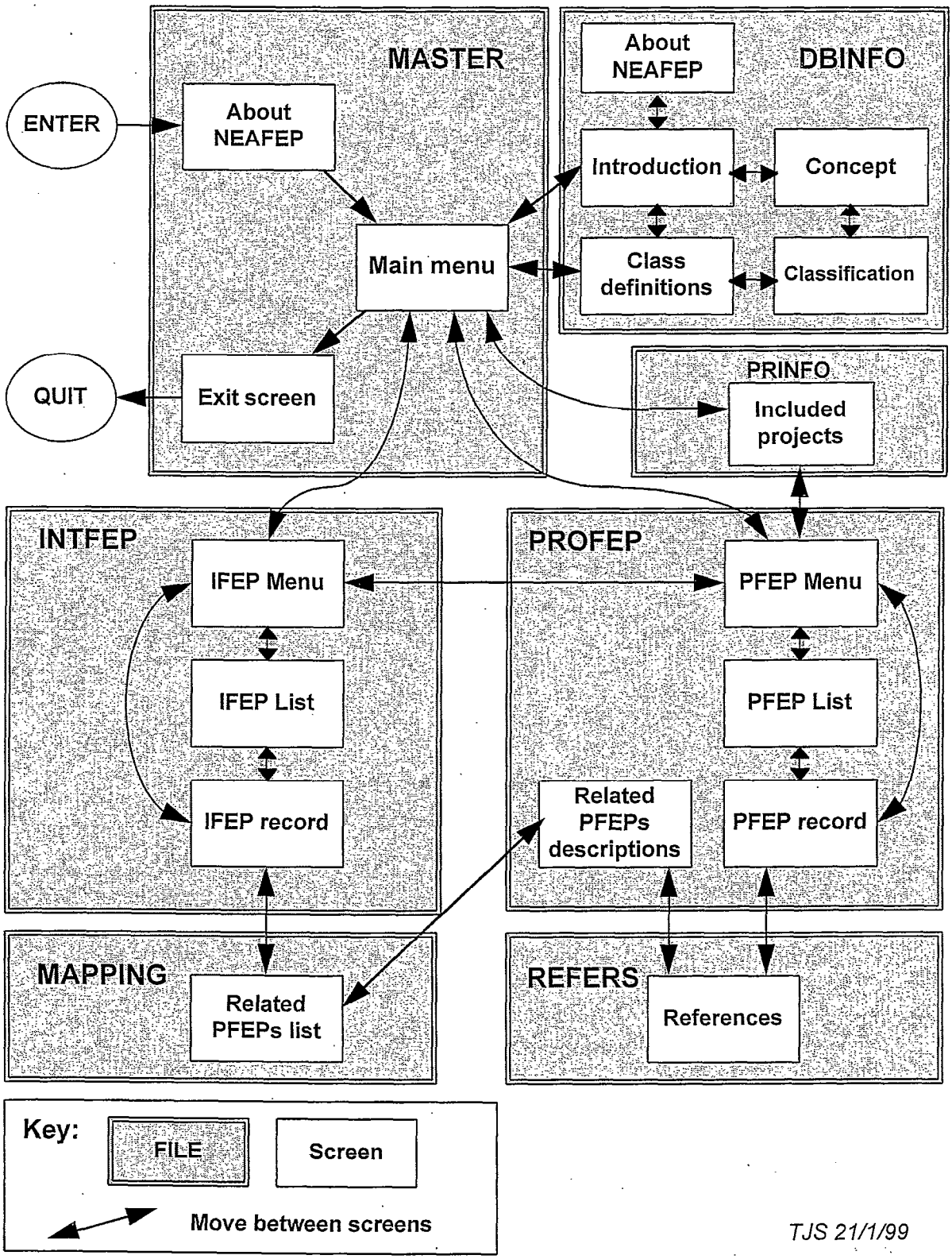


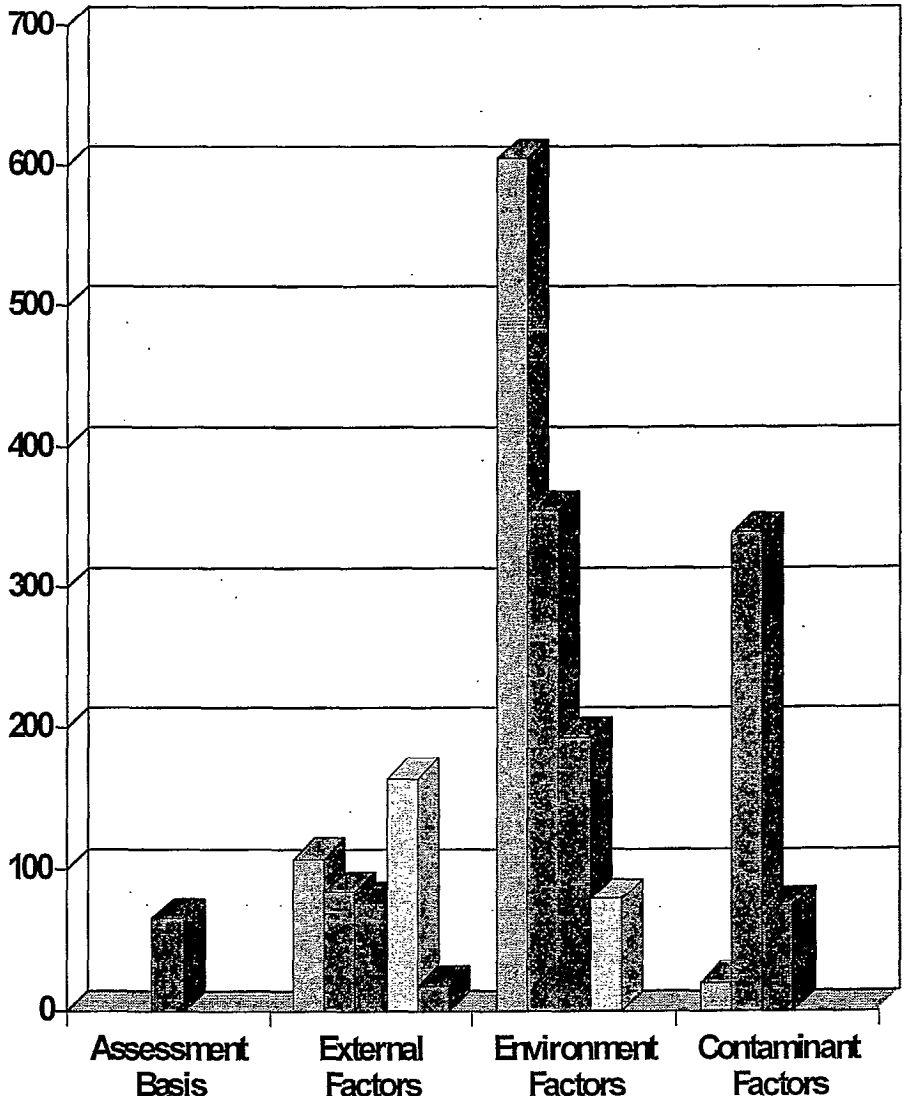
Figure A.2: NEA FEP Database - Statistics for Version 1.1

- 150 "International FEPs"
- Incorporates 8 projects and with over 1400 project-specific FEPs

Project	No. FEPs	No. refs.	No. maps
SKIB89 (Andersson (ed.) 1989)	158	-	249
NEA92 (NEA SWG 1992)	146	-	190
HMIP93 (Miller & Chapman 1993)	79	-	125
AECL94 (Goodwin et al.1994)	281	91	459
KRIS94 (Nagra 1994)	258	152	358
SITE94 (SKI 1996)	106	52	211
WIPP96 (USDOE 1996)	246	141	384
IRUS97 (Stephens et al. 1997)	144	91	213
Total	1,418	535	2190

Note: the number of maps is the number of binary matches between an IFEP and a PFEP.

Figure A.3: NEA FEP Database - Distribution of PFEPs over IFEP classes



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