RETRIEVAL OF NUCLEAR WASTE FROM A LAND BASED DEEP REPOSITORY

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ABSTRACT

The current conceptual design for the UK land based deep repository is one in which waste packages are grouted into large caverns as emplacement proceeds. All such waste will ultimately be retrievable and indeed it is recognized that there could be a requirement to retrieve waste packages for social, political or technical reasons but this has to be achieved without prejudicing long term safety. A feasibility study has been carried out to determine methods of retrieval and the implications in terms of repository operation, repository costs, safety and overall program.

Consideration has been given to methods of retrieving waste packages from the current repository design and from designs which have been adapted to aid retrieval. An essential precursor to retrieval is the ability to monitor the waste to show that retrieval is necessary and the study has also outlined waste monitoring methods for a number of scenarios.

The paper leads to the conclusion that significant improvements could be made to the current repository design to enhance retrieval but these would result in cost penalties associated with lower packing efficiencies and the need for additional underground space. There would also be a penalty associated with the radiological dose commitment to workers involved in the retrieval operation.

INTRODUCTION

The current conceptual design for the UK land based deep repository is one in which waste packages are grouted into large caverns as emplacement proceeds. The Costain-Arup-Electrowatt consortium carried out design studies for UK Nirex Ltd, investigating a number of potential settings and geological environments (1). All emplaced waste will ultimately be retrievable and indeed it is recognized that there could be a requirement to retrieve waste packages for social, political or technical reasons, but that this must be achieved without prejudicing long term safety. The basic concept of the repository, however, remains the final disposal of waste, and retrieval does not satisfy this requirement.

A feasibility study has been carried out to determine methods of retrieval and the implications in terms of repository operation, repository costs, safety and overall program.

Consideration has been given to methods of retrieving waste packages from the current repository design and from designs which have been adapted to aid retrieval. A precursor to retrieval on technical grounds is the ability to monitor the waste to show that retrieval is necessary and the study has also outlined waste monitoring methods for various scenarios.

CURRENT REPOSITORY CONCEPT

The current conceptual design of repository is shown in Fig 1, and consists of 26 large caverns each 250m long by 25m wide and 35m deep. The caverns were arranged on a grid pattern at about 500m depth in hard rock. The repository would be accessed by shaft from a surface waste receipt and processing facility.

The design accommodated the disposal of a range of waste types in various boxes and drums, with weights up to 65 tones and maximum package dimensions of 4m x 2.4m x 1.8m. As configured the caverns were divided into bins and, as each layer of packages was completed in a bin, that layer was covered with cementitious backfill. All packages were lifted into the cavern through a hatch by an electric overhead travelling crane which then transferred the package to its respective bin. A twistlock type of package/crane engagement was used for lifting and packages were emplaced as close together as practical. Once the bins were filled a floor was cast over the bins and the cavern crown roof space was filled with further packages, using either a modified crane or a remotely operated mobile. This space was then also filled with cementitious backfill.

Once the cavern had been filled the cavern service equipment was moved to another cavern and the service spaces backfilled. When all the caverns were filled all the access tunnels and shafts were eventually plugged and backfilled. During the operational phase of the repository, construction of new caverns would proceed in parallel with emplacement.

DESIGN BASIS FOR RETRIEVAL

Design Alternatives

Methods were developed for monitoring and subsequently retrieving waste packages from the following alternative repository designs:-

a) The current repository design in which no specific design features have been included to aid retrieval.

b) A repository in which the basic design remains un-

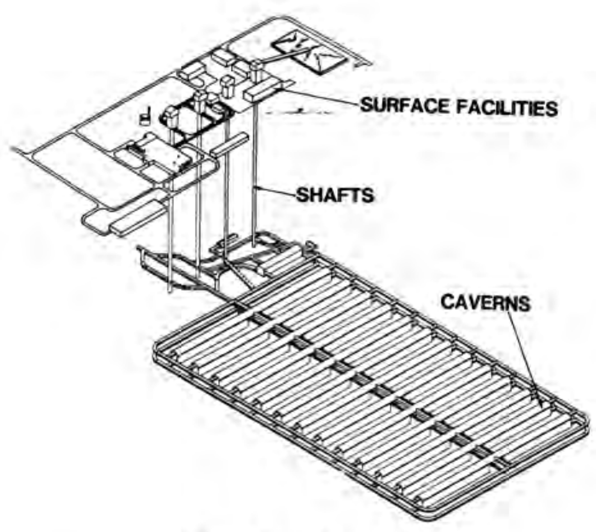

Fig. 1. Hard Rock Site.

changed, but design modifications have been included which would assist any subsequent requirement for retrieval.

c) A repository in which backfilling has been deferred until after the operating period, and in which significant design changes have been introduced to facilitate retrieval.

TIME SPANS

The stage at which retrieval was initiated would have a significant bearing on the factors affecting retrieval, and the ability to carry it out. Various phases of the repository life were therefore considered:-

- the operating period (0 - 50 years).
- the post operational period, under management and monitoring, but prior to sealing of access tunnels and shafts (50 - 60 years).
- the post closure period, after the repository has been sealed and decommissioned (60 -100 years).
- the period during which waste and repository degradation is assumed to have taken place (100 + years).

Retrieval Scenarios

It was apparent that for each time span and design alternative, various retrieval scenarios could apply.

It was therefore necessary to scope these scenarios by reference to specific cases, and the following were chosen as typical:-

Scenario A -Recovery of waste packages from an operational cavern prior to backfilling -no contamination.

Scenario B -Retrieval of waste packages from an operational cavern after a dropped load incident with package damage and possible release of contaminants.

Scenario C -Retrieval of packages from an uncontaminated, backfilled cavern.

Scenario D -Retrieval from a contaminated, backfilled cavern.

These scenarios represent progressively more complex environments in which to carry out retrieval, and can be applied to the repository alternatives and timespans as applicable.

FACTORS AFFECTING RETRIEVAL

In order to establish the feasibility and implications of retrieval it was necessary to identify the major factors relating to the retrieval operation. This enabled subsequent downstream consequences on design and operation of the repository under the various scenarios to be considered. The following parameters were identified:-

a) Monitoring as a trigger for retrieval;

b) Safety;

c) Access to packages being retrieved;

d) Backfill removal and package release;

e) Routing of retrieved packages;

f) Restricting the spread of contamination;

g) Secondary wastes;

h) Effect on repository logistics;

i) Effect on repository construction;

j) Effect on surface facilities, waste receipt building and ventilation services;

m) Costs and program.

It was recognized that each of these parameters could interrelate with other factors and have a wide range of subsidiary implications on the operation and design of the repository. It was not possible in this paper to consider all the combinations. Instead the major components that were found to influence design and operations have been addressed, and proposed modifications coming from these studies have been highlighted.

Figs 2 - 4 show flow diagrams of the three major functions of retrieval, namely: access to the packages, backfill removal and release of the packages, and routing of retrieved packages. The options and significant related areas are shown. Table I presents a qualitative assessment of the

TABLE I
Scenario Time Span Applicability and Qualitative Assessment On Repository Functions

SCENARIOS

TIME SPANS	A	B	C	D
Operational 0 - 50 years	✓	✓	✓	✓
Post-operational 50 - 60 years			✓	✓
Post Closure 60 - 100 years			✓	✓
Long Term 100 + years				✓
Access to Packages	Easy	Fairly Easy	Difficult	Difficult
Backfill Removal	N/A	N/A	Difficult	V.Difficult
Routing of retrieved packages	Easy	Easy	Fairly Difficult	Difficult
Decontamination/Overpacks	N/A	Yes	Not Essential	Yes
Secondary Wastes	No	Possibly	Minor	Major
Effect on Logistics	Minor	Minor	Could be major	Could be major
Effect on Construction	None	Probably none	Major if new vaults/ accesses required - otherwise limited	
Effect on Surface Facilities	None if waste transferred underground - but significant if brought to surface for treatment			
Effect on Safety	Minor	Some	Complex	V. Complex
Timescale	Days	Weeks	Years	Years
Costs	V. Low	Low	High	V. High

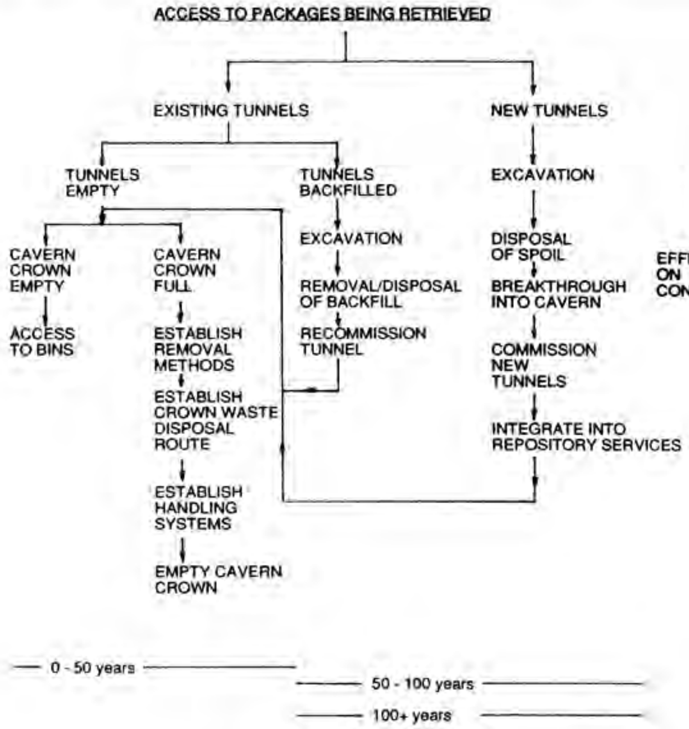

Fig. 2. Access to Packages Being Retrieved.

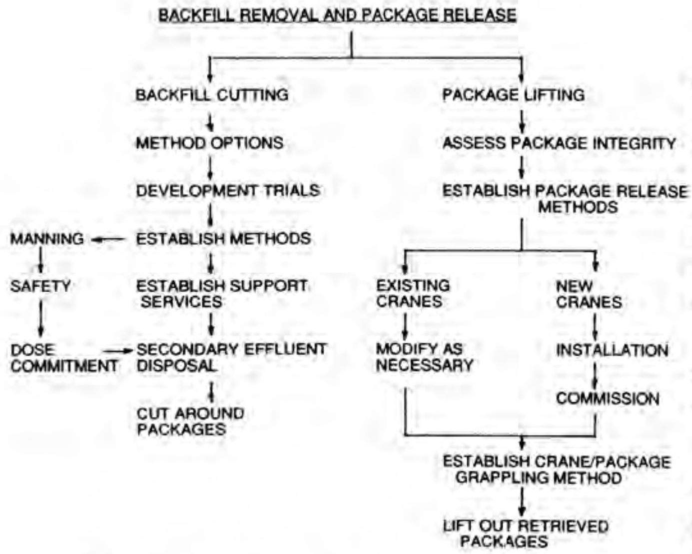

Fig. 3. Backfill Removal and Package Release.

factors affecting retrieval for the various scenarios and time frames being considered.

MONITORING AND RETRIEVAL FROM AS-DESIGNED REPOSITORY

In the current repository concept monitoring of the repository was confined to health physics requirements,

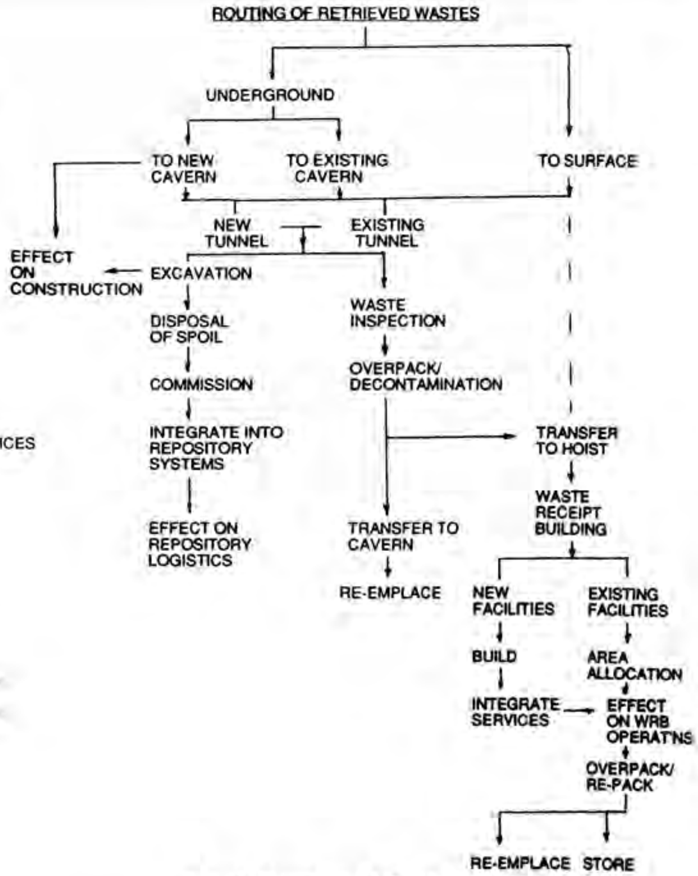

Fig. 4. Routing of Retrieved Waste.

monitoring of ventilation air, and monitoring of water collected in drains. It was envisaged that caverns would be inaccessible to man (Alara) and consequently all monitoring equipment would either have to be placed at the ends of the cavern where it could be reached for servicing, (e.g mounted on the travelling crane) or maintained remotely or designed in such a way that it could be withdrawn for maintenance.

Monitoring was therefore very restricted and could only be used as a trigger for retrieval whilst the repository remains open.

The retrieval of waste is considered under the various scenariosare the following.

Retrieval Scenario A - Retrieval of Packages From an Operational Cavern

Under this scenario packages were assumed to be undamaged, unbackfilled and uncontaminated. This was the simplest case to be considered with the number of packages to be retrieved varying from one, to an ungrouted bin layer. Retrieval would simply be the reverse of the emplacement procedure and no radiological safety implications or significant handling or logistics problems were envisaged.significant handling or logistics problems were envisaged.

Retrieval Scenario B - Retrieval of a Dropped Load From an Operational Cavern.

The dropped load represented a specific retrieval requirement, the conditions of which could vary depending on any damage or release that occurred as a result of the drop. The number of packages to be retrieved would be limited to those in the vicinity of the impact. If the dropped load impacted and damaged packages already grouted in, and there was a requirement for these to be retrieved, then retrieval was covered under Scenarios C or D.

The access and routing of retrieved packages would make use of existing repository facilities. Any immediate release of contamination would be limited to the cavern and contained by the ventilation and filter system. Contaminated packages leaving the cavern would be placed in a vault shield box or larger overpack and transferred to the surface for treatment using the existing systems and services. These would need to be increased to deal with the overpack The major problem of this scenario would be grappling of the dropped or damaged packages, recognizing that the normal lifting features could have failed or been damaged. Some modification to the crane could be required to enable it to pick up these packages. Alternatively special frames or clamps could be attached to the package to allow it to be lifted onto a pallet for subsequent conventional handling through the repository.

Retrieval under this situation could have radiological safety implications, depending on the release of activity from the dropped load. Access to the particular area would be limited by the activity from the surrounding waste. Similarly time scales for retrieval would be dependent on the damage incurred and the ability to grapple the packages.

Retrieval Scenario C - Retrieval of Uncontaminated Packages But After Backfilling

In this scenario it was assumed that the region of retrieval was uncontaminated and there was no loss of package integrity. It was considered that the major contributing factor to the problems of retrieval would be associated with removing the backfill. The access options are shown in Fig 2. In the longer timeframes it would be necessary to excavate new access tunnels or re-excavate the original backfilled tunnels. The first task would be to gain access to the top of the relevant bin, by removing the LLW grouted into the cavern crowns. Methods of removing grout from around the sides of the packages would need to be developed together with means of releasing packages from the inaccessible surfaces. Once released from their surroundings,the packages would have to be grappled and moved clear. Fig 3 shows the operations which would also be applicable to package handling in the bin once access to the top of the bin had been achieved.

In the existing design, packages were stacked as close as feasible in order to obtain maximum space utilization and minimize the backfill requirements. This would restrict access between packages for backfill removal and package release. The use of cutting equipment around closely packed items might damage the packages and result in a release of activity. In order to lift packages from the bin using the existing hoist systems it would also be necessary to clean the backfill out of the twistlocks or other lifting features. A wide range of possible methods were considered for backfill removal, many based on current developments for nuclear plant decommissioning. The generation of secondary wastes in the form of dust and cutting lubricants would add to the potential problems and would influence a final choice of method.

It was concluded that remote backfill removal techniques could be developed, probably based on water jetting to avoid damage to the packages, and assuming the backfill was soft enough to allow realistic rates of cutting. However significant development would be required and the operation would be lengthy, difficult and relatively costly.

The handling of the retrieved packages themselves would be minimized by using a transfer pallet. The options for routing the retrieved waste back through the repository system are shown in Fig 4.

The overall effects on repository operations would depend on the extent of the retrieval. The continued operation of the repository would in all cases rely on having space available in which to place retrieved waste and, where the retrieval cavern could not be used for further emplacement, available new cavern space to maintain throughput.

Fig 5 shows the implications on repository operations assuming either intermittent emplacement and retrieval, or emplacement stopped whilst retrieval takes place.

The radiological implications of retrieval under Scenario C involve the carrying out of complex operations in an active environment, but without the associated hazard of contamination. The potential dose commitment would depend on the level of remote operation that could be engineered, but is likely to be significant over the extended time span that would be needed to carry out the operation.

Scenario D - Retrieval of Contaminated Packages After Backfilling.

This situation was basically similar to the previous scenario except that it was complicated by contamination of the retrieval bin. The requirement to retrieve could have been triggered by monitoring showing release of contamination, or contamination could have been encountered when the waste was accessed. Once retrieved, waste could either be

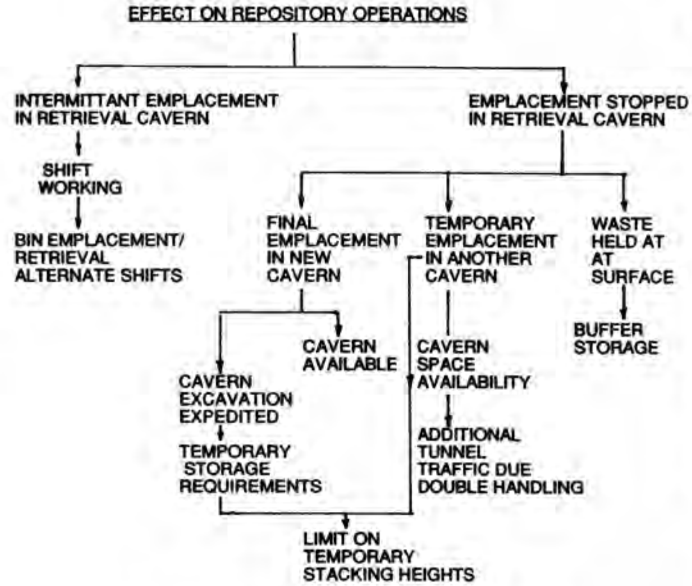

Fig. 5. Effect on Repository Operations.

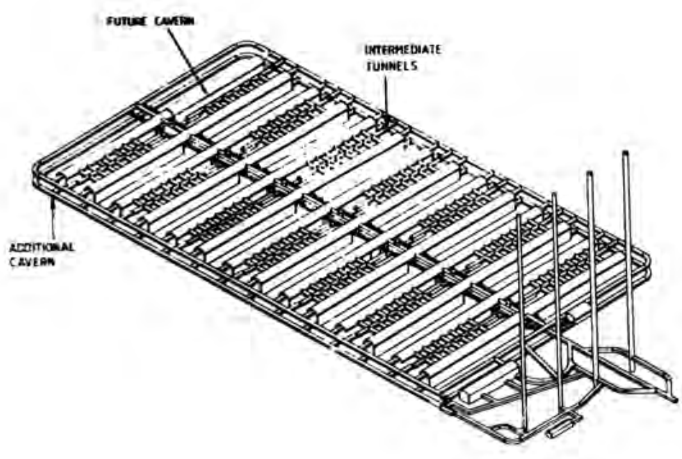

Fig. 6. Overall View of Caverns with Additional Access Tunnels.

decontaminated or overpacked to prevent contamination spread. The need to set up a substantial decontamination facility to support the retrieval operation would depend on the number of packages to be retrieved.

If the reason for retrieval was associated with a problem identified from monitoring, it would be unlikely that waste could be re-emplaced without some remedial action. The development of an underground treatment area adjacent to the retrieval cavern was considered. This would limit the impact on other repository operations and reduce the potential risk of spreading contamination. However for limited bin retrieval the overpack option, if radiologically acceptable, would be economically preferable.

The radiological safety aspects of retrieval from a contaminated area and the subsequent need to carry out decontamination would make this situation a particularly high risk operation, monitoring and over the long period of the retrieval task which could extend into many years.

REPOSITORY MODIFICATIONS TO IMPROVE MONITORING AND RETRIEVAL

The repository design could be enhanced to improve retrieval both by easing the access to the packages and by easing their removal once access had been achieved. Similarly modifications to the design could enhance the ability to monitor the repository and packages.

Monitoring

The requirement to retrieve could be initiated by information gathered from monitors in and around the repository. Different levels of monitoring would apply depending on the philosophy being pursued. Three general monitoring situations were identified.

a) Monitoring in caverns during the cavern operations.

b) Monitoring of backfilled and closed caverns during the operational life of the repository.

c) Monitoring for as long as reasonably practical after repository closure to ensure the repository was conforming to expectations.

The first two would be primarily concerned with maintaining a safe environment in the cavern or repository during its working life, and as such would relate to protection of equipment maintenance staff and others required to work underground. The third would involve a significantly

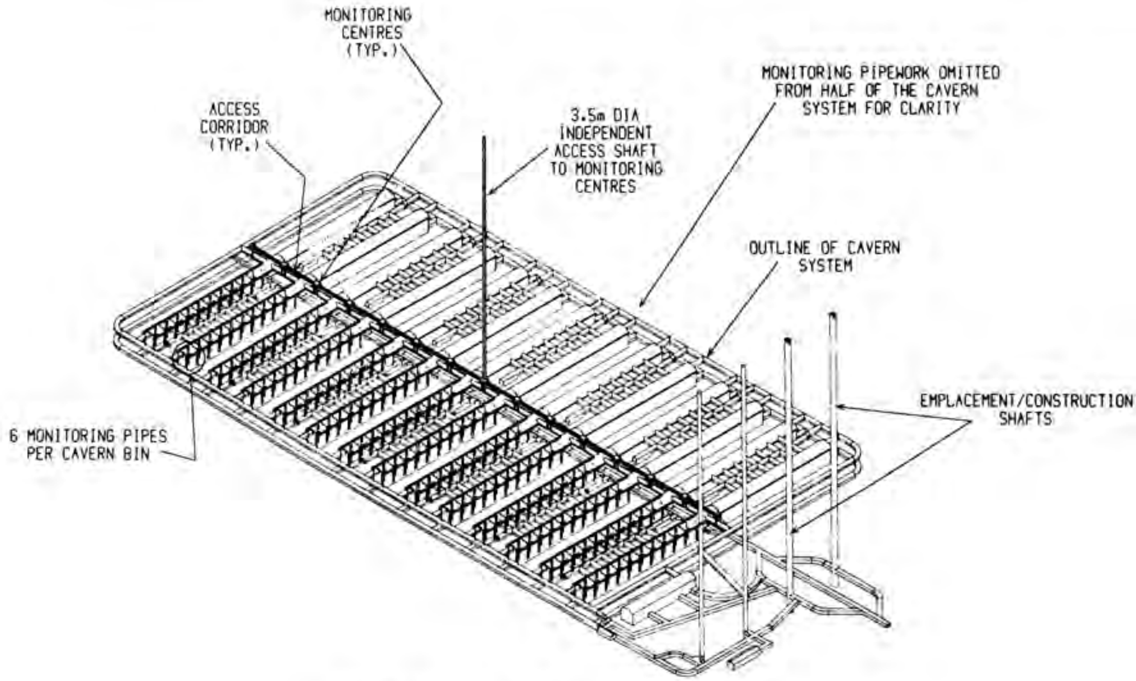

Fig. 7. Pipework Monitoring System.

greater capital investment and would be primarily concerned with post closure monitoring and inspection.

From these three situations a number of practical monitoring options have been considered:-

i) Built in monitors on drains and vents at existing access points.within caverns

ii) As (i) but with additional access points.

iii) Crane mounted monitors with drill sample capability into cavern bins.

iv) Crane mounted monitors accessing built in ports in the waste structure.

v) Additional man-access routes around the repository to service monitoring equipment.

vi) Retrieve waste to inspect and monitor.

vii) Fully independent multi-access pipe system for pre- and post-closure monitoring.

Items (i) - (iv) are suited to monitoring an operational cavern (Scenarios A and B, 0-50 years). Items (v) and (vi) are applicable to any area of the repository during its operational phase (all Scenarios 0-50 and 50-60 years. Item (vii), being independently accessed from the surface, could be engineered to enable monitoring within the repository to be carried out after repository closure. A schematic arrangement of this system is shown in Fig. 7. Pipe crawlers would be used to access various regions within the repository and these would be controlled from the monitoring centers which themselves would be accessed from the surface via a single man-access shaft.

As listed, the monitoring options become progressively more complex and expensive to incorporate and develop, but in turn would provide increasing levels of information over longer periods. Item (vii) would require substantial development and items (i), (ii) and (v) are, therefore, the preferred options for enhancing repository monitoring. This means that monitoring beyond the repository operational life would require the access tunnels and shafts to be kept open, thus extending the post operational period.

Access to Packages

A number of possible design features could be built into the repository to improve access to any particular region of the repository. This access could either be achieved through the cavern crown space, or could involve constructing additional tunnels to provide regular access points to the caverns.

In the original design concept the cavern crown was filled with LLW and backfilled with a cementitious grout. Consequently any access to the underlying bins would necessitate the removal of what could be a large number of cavern crown packages. The simplest option would be to leave the crown space empty during the operational phase and then fill with a weak cementitious backfill at closure. This would allow ready access over the shorter time frames and a relatively simple removal of the backfill in the longer time scenarios. The major disadvantages of this option were

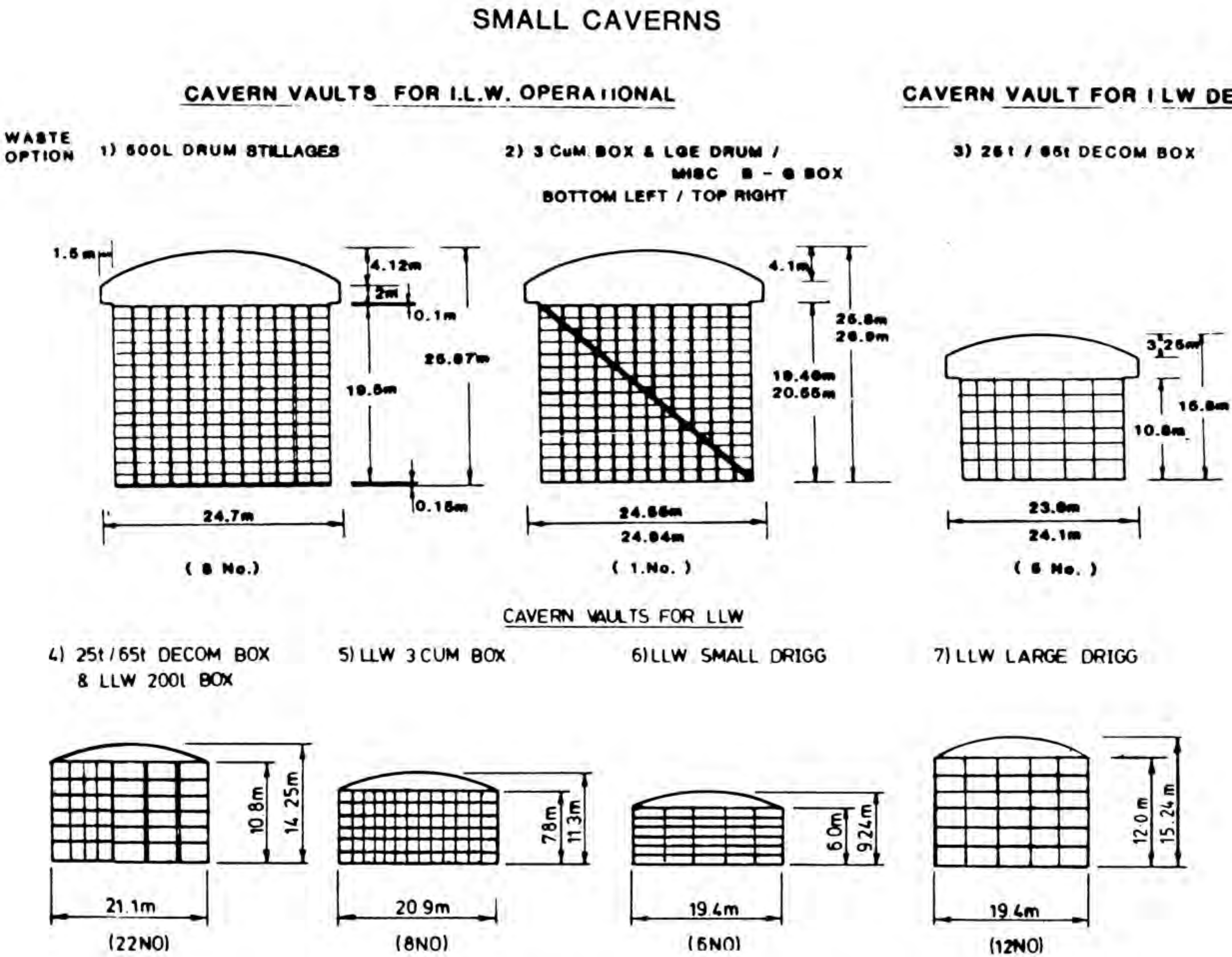

Fig. 8. Emplacement & Retrieval from Small Caverns-Proposed Scheme.

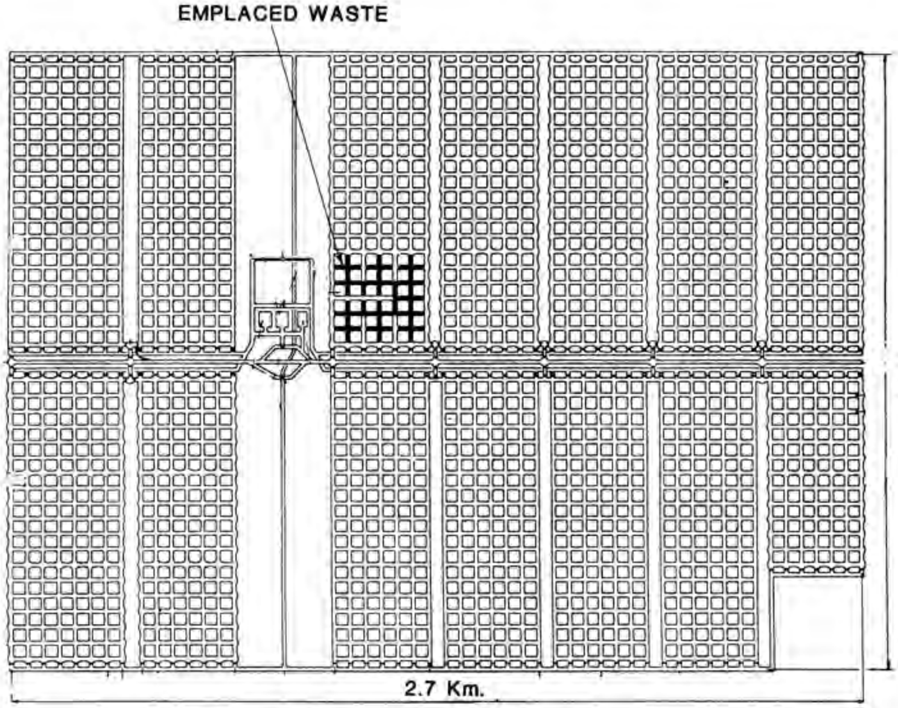

Fig. 9. Interlocking Tunnel Layout.

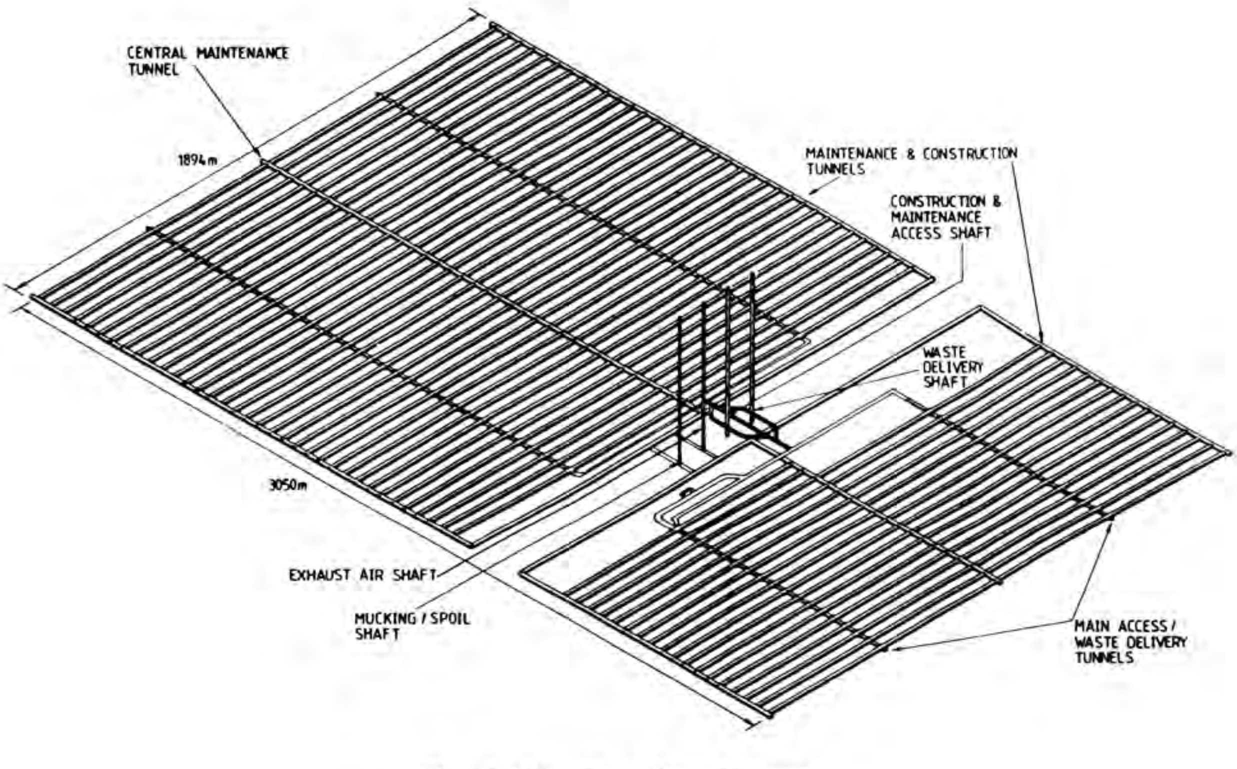

Fig. 10. 400 m Short Tunnel Layout.

the wasted cavern space in the crown, with an associated requirement for additional cavern excavation, and the large quantities of backfill needed during cavern closure. Both of these items would add significantly to the cost of the repository.

Intermediate options between the two limits of filling the cavern crowns with packages and backfilling, and leaving them empty have been considered.

The LLW package could be emplaced in the crown with the backfill either delayed or omitted completely. If delayed then the packages could be removed relatively easily to gain access to the bins. However it would be difficult to get the backfill to flow into the filled crown area over the full length of the cavern, when backfill was eventually carried out. Delay or omission of backfill would increase package corrosion rates and omission would also reduce the alkaline content of the repository thus possibly affecting long term safety.

The alternative of constructing additional access tunnels is shown schematically in Fig. 6. These tunnels would be connected via a hatchway to the main repository spine tunnel and would offer access at regular points into the caverns at the top of the bin level as shown. This option would involve significant additional excavation with a corresponding effect on costs and construction programme. The access points to the cavern would normally be sealed and break through would be carried out near to the packages that were to be retrieved. Advantages of this system would be that the tunnel system would provide a large number of potential monitoring points throughout the repository, and the tunnels themselves would provide a useful area for local storage of retrieved waste and for setting up the retrieval operations. As before the cavern crown area would need to be cleared locally to provide access to the bin. However the additional tunnels would enable the number of crown packages requiring removal to be kept to a minimum. Having entered the crown space, the ease of bin access would then be determined by the way in which the crown space had been used.

The option of filling the cavern roof space with packages but deferring the backfill became more attractive, since the additional tunnels would enable the crown backfill to be more readily achieved on closure, and the crown packages could be easily removed with mobiles during the operational period to provide bin access. During the repository closure the subsidiary tunnels would also be backfilled but, in the longer post-closure timeframe they would still offer a preferential route for re-excavation to any cavern or bin from which retrieval was required.

Package Removal

A number of options have been identified to make package removal easier and these are listed as follows:-

a) Increase the gap between packages to facilitate backfill removal, and to ease package release and grappling.

b) Accurate recording of package location relative to each other and bin walls, to avoid damage to surrounding packages during backfill cutting.

c) Provision of access "tunnels" between or among packages. These would offer preferential excavation routes in the bin being retrieved.

d) Modified package lifting. The current design of twistlock would fill with grout during backfill, making it inoperable. A design based on lifting packages from underneath would give greater security during retrieval.

e) Package segregation. By strictly segregating package types and batches, retrieval would be more likely to be confined to a limited area should retrieval of a particular waste stream or package type be required.

f) Package wrapping to facilitate grout removal and package release from the surrounding backfill. The use of a surface release agent, either in the form of a chemical spray or plastic overwrap, would assist in releasing packages from a backfilled bin environment.

g) Package design. Smooth surfaces would ease backfill removal, but could make grappling of the package more difficult. Open stillages would be particularly difficult to break free from cementitious backfill and should therefore be avoided.

h) Backfill design. A cementitious backfill was originally proposed to provide an alkaline environment. The use of a weak or loose backfill would facilitate package removal.

Any or all of the above options could be adopted to improve package removal. The major advantages and disadvantages of the options are listed in Table II. The disadvantages mostly center around the need for additional cavern space and the cost of implementation. The table indicates that the qualitative improvement in retrievability is roughly proportional to the cost of implementation, except for a change in backfill. The use of a non-cementitious, loose type of backfill would significantly improve retrieval at a relatively low cost, but could have a significant impact on long term safety. The other seven options listed could all be addressed at the design stage in conjunction with appro-

TABLE II
Summary of Options and Effect on Repository Parameters

	EFFECT ON CAVERN SPACE	EFFECT ON BACKFILL REQUIREMENTS	EFFECT ON PACKAGE COSTS	EFFECT ON LOGISTICS	OTHER COSTS	EFFECT ON SAFETY DURING RETRIEVAL	EFFECT ON RETRIEVAL TIMESCALES	EFFECT ON MONITORABILITY	QUALITATIVE OVERALL RANKING	1 BEST 8 WORST
a) Increase in package spacing	MAJOR INCREASE	LARGE ADDITIONAL QUANTITY	NONE	SOME	SIGNIFICANT	SOME	REDUCED	SOME	IMPROVED RETRIEVAL AT SIGNFCNT COST	5
b) Accurate package location	MINOR INCREASE	LITTLE	SOME INCREASE	SOME	SOME INCREASE	SOME IMPROVE MENT	SOME REDUCTION	MINOR IMPRV' MENT	V LTD RETRIEVAL IMPROVEMENT AT LTD COST INCREASE	7
c) Access tunnels in bin	POSSIBLY SIGNFCNT	ADDN QUANTITY	NONE	MINOR	INCREASE	MINOR IMPROVE MENT	SMALL REDUCTION	NONE	V LIMITED RETRIEVAL IMPROVEMENT AT SOME COST INCREASE	9
d) Modified Package Lifting	MINOR	MINOR	INCREASE	MINOR	SOME INCREASE	COULD BE SIGNIFI CANT	SOME REDUCTION	NONE	SOME IMPROVEMENT AT LIMITED COST	2
e) Package Segregation	SOME	POSSIBLY SIGNIF-ICANT	NONE	MAJOR	SIGNFCNT INCREASE	SOME IMPROVE MENT	POSSIBLY MAJOR REDUCTION	SOME IMPROV EMENT	SOME IMPROVEMENT AT LIMITED COST	5
f) Package Wrapping	NONE	NONE	SIGNIF ICANT INCREASE	SIGNIF ICANT	SIGNFCNT INCREASE	SOME IMPROVE MENT	POSSIBLY MAJOR REDUCTION	NONE	IMPROVEMENT AT A COST	3
g) Package Design	POSSIBLY SOME	POSSIBLY SOME	SIGNIF ICANT INCREASE	NONE	N/A	MINOR IMPROVE MENT	SOME REDUCTION	NONE	LIMITED IMPROVEMENT AT LOW COST	8
h) Backfill - Non Cementit-ious very soft or loose	NONE	N/A	N/A	COULD BE SIGNFCNT	MAY INCREASE	COULD BE SIGNFCNT	COULD BE VERY SIGNIFICANT	VARIA-BLE	MAJOR IMPROVEMENT POTENTIAL AT LIMITED COST	1
i) Cavern Crown Empty	MAJOR	MAJOR	NONE	MINOR	SIGNIFCNT INCREASE	IMPROVED	SIGNIFICANT REDUCTION	IMPRO-VED	IMPROVED RETRIEVAL AT SIGNIFICANT COST	3

priate trials in order to obtain a better assessment of their suitability.

REPOSITORY DESIGNED FOR RETRIEVAL DURING OPERATIONAL PHASE

It was apparent from the analysis of the options to improve retrieval in the existing design of repository, that any improvements would be limited by the problems associated with removing the backfill. In addition major improvements in retrievability were achieved at the expense of other repository related parameters as indicated on Table II.

A third phase of study was therefore undertaken in which it was assumed that backfill would be deferred until after the 50 year operating period of the repository, and that vault design and emplacement systems could be modified to improve retrieval.

Various vault design options had been previously considered as part of the original conceptual design study (1). These options were re-analyzed with specific reference as to their suitability for monitoring and retrieval. The results of this analysis indicated that the favored concepts of caverns and tunnels were still prime candidates under the revised groundrules, but with specific modifications to improve retrieval. Three concepts were established for further investigation:-

a) Small caverns,

b) Interlocking tunnels,

c) Short tunnels

The basic design layouts are shown in Figs. 8, 9, and 10 - respectively.

Small Cavern System

This design utilized caverns with a smaller cross-section than the maximum possible, from the rock mechanics point of view. As in the current repository design the caverns would be typically 250m long and waste would be separated into four categories. Emplacement would be by overhead crane or fork lift. It would be necessary to limit the unbackfilled stack height so that it was compatible with the package strength. The cross section area of individual caverns would be sized to give a high packing efficiency for particular waste packages.

The mechanical equipment and systems requirements would be the same as for the original design, except that, where fork lifts were used, some packages could require modification. As configured a total of 62 smaller caverns would be required and, to reduce the costs of cavern services, it was envisaged that caverns would be ganged together in small groups.

Retrieval from an unbackfilled small cavern system would be performed by simple reversing the emplacement procedure. Speed of retrieval from any point in a cavern would be considerably increased if a longitudinal access pathway for either the fork lift or the loaded crane was left through the middle of the waste stack. However this would reduce the overall packing efficiency and increase the cost of the repository.

At the end of the operational life of the repository, backfilling would be carried out . This would necessitate the inclusion of backfill access pipes at the cavern construction stage that would allow backfill to be undertaken with confidence after at least 50 years.

The major advantages of the small cavern system when compared with the other 2 options would be:

a) Relatively high packing efficiency, with no additional stack support requirements

b) Ease of retrieval during the repository operational phase.

c) Little additional equipment development required for either emplacement or retrieval.

d) relatively low cost

The major disadvantage would be in engineering the placement of the backfill at closure. In addition, the problems of retrieval after backfill would be similar to those identified for the original design.

Interlocking Tunnels

This system would comprise a network of intersecting tunnels (Fig 9) similar to a block and pillar excavation. By emplacing waste in sections of the interlocking tunnels, the remaining tunnels would be used for access during retrieval. The availability of access could be traded off against the utilization of the tunnels. It was envisaged that each waste category would be allocated an area of interlocking tunnels which could be operated with its own services and sealed from other areas. The tunnels would be D shaped, and typically 10m wide. Emplacement of waste would utilize a remote mobile system and retrieval would again be the reverse of emplacement. The major problem of this system would again be backfilling at repository closure. In order to fill regions of tunnels with realistic pours of backfill it would be necessary to build retaining walls at intervals and access for the backfill would need to be designed into the repository to enable it to be pumped into the tunnels.

The main advantages of interlocking tunnels when compared with the other options would be;-

a) Access for retrieval could be varied for different wastes by leaving more or fewer tunnels as access routes.

b) Emplacement and retrieval during repository operation would be relatively straightforward.

c) Limited drop heights would reduce the risks from dropped loads.

However the costs of this system would be higher than other options, and retrieval after closure and backfill would be difficult to carry out.

Short Tunnel System

Short tunnels would be typically 400m in length, and access for retrieval would be achieved more readily than for large caverns. Nevertheless, even at 400m retrieval of packages could necessitate the removal of a large number of items to gain access. The backfilling of long tunnels at closure would also be difficult unless a corresponding backfill access system was constructed above the tunnels during the initial construction phase.

DISCUSSION

Of the schemes assessed, the small caverns were considered to offer the best option since they closely followed the technology of the original conceptual design and so had the smallest impact on costs and safety. In addition monitoring of small unbackfilled caverns using the drains and the ventilation system would be easier to achieve than the other two options and would enable problem areas to be pinpointed more accurately. When compared with large caverns monitoring and waste handling, during both operation and retrieval, would probably be easier with alternatives to the overhead travelling crane worth re-examining. However, packing efficiency would be lower and cost would be higher.

CONCLUSION

The Study has considered retrieval from an underground repository based on three alternative design assumptions and considering four retrieval scenarios. The work has shown that retrieval from a deep underground repository is technically feasible using techniques and methods currently being developed for decommissioning of nuclear plant. The major problems would be the excavation of the waste from the backfill and restricting the spread of contamination. Though retrieval could be engineered from the current large cavern repository design, incorporation of a number of modifications at the design stage could improve the practicality of retrieval. In general the cost of these modifications increases along with the benefits they might offer in terms of improved retrieval. Similarly, repository design modifications could be included which would improve the monitorability of the waste but, again, at a cost. Although a complex post-closure monitoring system is theoretically feasible, the preferred option would be to increase the timespan for monitoring by extending the post-operational period thus enabling less complex monitoring techniques to be used.

In the existing design concept, retrieval during the operational period could take up to fourteen years to retrieve the contents of one bin from a backfilled cavern, and incur a cost of 3% of the total repository cost. In the post-operational period the cost would rise to 12% and the timescale would nearly double.

Modifications to the existing repository design to improve monitoring and ease retrieval would reduce the timescales for retrieval to about four years. However, although the cost of undertaking retrieval would be reduced, the modifications to the repository design would result in a total increase in costs of about 10%. It was considered in this case that the intermediate tunnel access with the cavern crowns left empty represented the best solution to ease retrieval for a repository based on the existing conceptual designs.

Repository concepts, designed specifically to enable waste to be monitored and retrieved during the operating period, have been developed in which backfilling has been delayed and in which retrieval has been further improved by adopting designs based on small caverns or tunnels. For the three alternative repository designs considered, the small cavern design would add about 15% to the cost of the basic repository, with the other two options increasing the repository cost by about 50%. However, the retrieval timescales and costs would be lower than for the existing or modified designs during the period over which backfilling was deferred. It was concluded that the small caverns provided the safest and most cost-effective route to retrieval from an unbackfilled repository.

The practicality of retrieval has been assessed in isolation from the radiological and post-closure safety implications. Although the operational radiological implications of retrieval from a repository in which backfilling has been delayed would be less than if backfill had to be removed, retrieval in either case would result in significant dose to operators and could have implications for post-closure safety.

REFERENCES

1. M. Myall, E. Tufton, D. Vande Putte. An integrated approach to radwaste repository design. Waste Management 89 Conference, Tucson