KR9700333

DESIGN AND OPERATIONAL EXPERIENCE OF LOW LEVEL RADIOACTIVE WASTE DISPOSAL IN THE UNITED KINGDOM

P D Grimwood
Low Level Waste Management Services
British Nuclear Fuels plc

ABSTRACT

Low level radioactive wastes have been disposed of at the Drigg near-surface disposal site for over 30 years. These are carried out under a disposal authorisation granted by the UK Environment Agency. This is augmented by a three tier comprehensive system of waste controls developed by BNFL involving wasteform specification, consignor and wastestream qualification and waste consignment verification. Until 1988 wastes were disposed of into trench facilities. However, based on a series of integrated optioneering studies, new arrangements have since been brought into operation. Central to these is a wasteform specification based principally on high force compaction of wastes, grouting within 20 m^3 steel overpack containers to essentially eliminate associated voidage and subsequent disposal in concrete lined vaults. These arrangements ensure efficient utilisation of the Drigg site capacity and a cost-effective disposal concept which meets both national and international standards.

1. INTRODUCTION

Low level radioactive wastes (LLW) have been disposed of in the United Kingdom in near-surface facilities for over 30 years. This has mainly been at the Drigg disposal site on the Cumbrian coast, some six kilometres to the south of the Sellafield nuclear reprocessing and waste management site. The Drigg site, owned and operated by British Nuclear Fuels plc (BNFL), also receives waste from a wide range of sources throughout the UK. Disposals until the late 1980s were solely by tipping essentially loose wastes into excavated trenches. More recently, trench disposals have been phased out in preference to emplacement of containerised, conditioned wastes in concrete vaults.

This paper reviews BNFL's experience in operating and developing the site. The regulatory controls for the site and the system of controls prior and during waste receipt are then described. The nature and arisings of wastes and approaches to their characterisation are discussed. This is followed by consideration of past and future developments associated with LLW practices including waste packaging and conditioning and vault design. Finally, supporting monitoring and technical support work are briefly outlined.

2. REGULATORY ASPECTS

In the UK, Government policy is "to favour early disposal because in general this carries a lower risk to workers in the nuclear industry and to the public". This has been confirmed by successive government reviews. On this basis, for many years now low level wastes have been disposed of in near-surface facilities.

Disposals of radioactive wastes in the UK are governed by the Radioactive Substances Act 1960. Under the terms of the Act, certain wastes can be disposed of other than to Drigg-type facilities. These are principally:

(a) Very Low Level Wastes are exempt from consideration if they contain less than 400 Bq/kg or certain other levels for specific nuclides.

(b) Small amounts of solid radioactive wastes are authorised for disposal with ordinary refuse. The limits for these so called "dustbin disposals" are 400 KBq in any 0.1m^3 and 40 KBq per article; alpha emitters and Sr-90 are usually excluded from such disposals.

(c) Within certain limits and provided "special precautions" are employed, some wastes can be disposed of at suitable landfill sites. Typical limitations are that no sack of waste contains more than 4 MBq of radionuclides of half-life greater than one year and 40 MBq if less than one year half-life, except if the activity is solely C-14 and/or H-3 the limit is 200 MBq. In addition, there may be a limit of 0.4 MBq of long-lived activity per article.

These dustbin and special precaution disposals are only granted authorisations where the regulators are satisfied that they present no hazard either to the operators of the disposal practices or to members of the general public.

In the UK low level wastes (LLW) are defined as those wastes containing radioactive materials other than those acceptable for local disposal, but not exceeding 4 GBq/t alpha or 12 GBq/t beta/gamma. With the exception of a disposal facility associated with the operations at the Dounreay fast reactor research site on the north coast of Scotland, essentially all LLW in the UK is disposed of at the Drigg site.

There are two principal statutory bodies which stipulate controls for the Drigg site. Firstly, the Environment Agency (EA) which authorises both disposal of the wastes and discharges to the environment. Secondly, nuclear site safety issues are licensed by the Nuclear Installations Inspectorate (NII).

The main features of the Drigg disposal authorisation can be summarised as:

- Only solid, radioactive waste to be disposed
- Consignment and annual activity limits
- Best practicable means to be used to:
  - Compact wastes
  - Limit activity migration
  - Collect and monitor leachate
- Marine discharge plus stream concentration limits
- Monitoring of wastes and the environment
- Keeping of records

Some of these directly control the nature of wastes, whilst others give rise to controls indirectly by placing certain requirements on the impact of the wastes and hence on site management practices.

The authorisation is subject to periodic review and has developed over the years since it was first issued in 1958. The most significant development has been that in the earlier authorisations the primary control was on the specific activity and radiation levels of the wastes and not explicitly on the total quantities to be disposed of. More recently, annual disposal limits have been included in the authorisation derived principally from the assessed total radiological capacity and a postulated operational lifetime for the site. These annual disposal limits are (TBq):

Uranium	0.3	I-129	0.05
Ra-226 + Th-232	0.03	Tritium	10
Other alpha	0.3	Other nuclides	15
C-14	0.05		

The main requirements in terms of environmental discharges are those associated with the leachate discharge and are:

- Volume and rate of discharge
- Alpha, beta and tritium content
- Chemical oxygen demand
- Suspended solids content
- pH range
- Total iron content
- Free of oil and grease

In order to demonstrate compliance with these conditions, BNFL are required to install and maintain the necessary discharge and sampling equipment and to keep appropriate records.

Lastly, the Site Licence issued by the NII is principally associated with the safe operation of the site as a nuclear facility throughout its operational phase. The licence covers such issues as management arrangements, training, operating conditions, inspection and maintenance requirements, dose assessment, record keeping and emergency procedures.

As well as the Drigg disposal authorisation, separate authorisations control inter-site transfers - ie disposals - from all sites consigning wastes to Drigg. These authorisations contain numerical limits on both the activity and volume of the waste and a range of qualitative clauses relating to waste management practices.

3. WASTE CONTROLS SYSTEM

A three tier system of controls consisting of specification, qualification and verification has been developed relating to disposals at the Drigg site :

- **Specification** - All LLW accepted for disposal must comply with the wasteform and procedural specification produced by BNFL as the disposal site operator. This specification has been developed so that all waste consignments, as well as meeting the regulatory requirements, are controlled to ensure operational and long term safety objectives are addressed.

- **Qualification** - All LLW has to be produced under approved waste generator quality assurance arrangements which detail the effective management and control of the waste from its generation to its acceptance by BNFL for disposal at Drigg.

- **Verification** - All waste generators are subject to a programme of audit and waste receipt monitoring which confirm the implementation of the quality assurance arrangements.

3.1 Specification

The waste specification is a key document as it includes all the technical and operational requirements which the waste generator has to comply with for their waste to be accepted for disposal. LLW accepted for disposal at Drigg must conform to the "Conditions for Acceptance by British Nuclear Fuels plc of Radioactive Wastes for Disposal at Drigg" and these requirements are also included in the contractual arrangements for LLW disposals. The principal features are:

- Definition of solid LLW
- Materials to be excluded or made safe
- Radioactivity limits
- Fissile content limits
- Waste conditioning requirements

- Packaging and labelling requirements
- Quality assurance requirements
- Procedural and documentation aspects

Of particular note is that disposals must only be of "solid radioactive waste which has been treated or packaged in such a way as to render it so far as is reasonably practicable insoluble in water and not readily flammable". Details of the requirements include, for example, the need to exclude or make safe certain items such as pyrophoric materials, combustible metals, pressurised gas cylinders and other identified materials. Also, in order to ensure annual disposal limits to the Drigg site are complied with and that the radiological capacity of the site is not exceeded, a system of prior notification and allocation of radiological disposal capacity is operated.

Any departures from these standard Conditions for Acceptance can only be made by specific written request to, and agreement from, BNFL. Any such requests are considered on a case by case basis but in all instances any variations must ensure both full compliance with the disposal authorisation and careful evaluation to ensure good waste management practices and acceptable environmental implications. Further guidance to consignors is also provided on specific topics in the form of Drigg Guidance Notes, for example on essential design features for containers and issues associated with acceptance of ion-exchange resins.

3.2 Qualification

BNFL as the disposal site operator needs to be assured that there is effective management and control of the LLW from its generation to its acceptance by them. Therefore the consignor is required to have in place a Quality Assurance (QA) system detailing these arrangements. The QA documentation is approved by BNFL before wastes can be consigned. Periodic reviews of the QA documentation are required to ensure that any revisions in the waste specification and in the consignor's operational practices are incorporated.

Most LLW can be readily grouped by the waste generator into wastestreams, where the waste in each particular wastestream has similar characteristics. The characteristics on which to base the wastestreaming system can either be physical (e.g. combustibility, compactability) or radionuclide composition, ie the waste "fingerprint". This system is used for both the disposals at Drigg and also for the UK National Radioactive Waste Inventory.

For LLW disposals to Drigg, before the first consignment of any wastestream (or changed wastestream) is accepted, the consignor provides information to BNFL on the physical, chemical and radiochemical composition of the waste in that stream in the form of a "wastestream characterisation". This can be either included with or separate from the general description of the QA arrangements. The characterisations are then reviewed by BNFL both for their technical content and to assess the acceptability of the individual wastestreams for disposal at Drigg.

3.3 Verification

The third tier of control is verification. Verification is the method by which BNFL as the waste disposal site operator confirms that the waste specification has been complied with and that the waste has been managed by the generator as detailed in their QA arrangements. It is done by means of consignment documentation checking, audit and waste receipt monitoring.

Each waste consignment from a generator is accompanied by a disposal form which includes the following sections:

- Consignment identification
- Consignment information
- Description of waste
- Description of package
- Radioactivity
- Fissile content
- Monitoring information
- Certification

For each waste consignment, the consignment disposal form is manually checked for completeness and entered on a computer system which checks a number of factors including that relevant consignor approvals are in place and that radioactivity and other limits would not be exceeded. If problems are found, the waste consignment is not accepted for disposal until they are resolved.

To ensure that the QA arrangements are being complied with, a programme of LLW consignor audits has been established. These audits are carried out by a team of QA, Operations and Technical personnel. Each audit consists of a full documentation review and a "walk-through" of the consignor's LLW management system and will include inspection of wastes. Audits are generally carried out before the first consignment of waste from a new waste generator and at an approximate frequency of three years thereafter.

If non-conformances are found during an audit, these are agreed with the waste generator and the action required to be taken is documented and a programme established. If it is considered that further disposals under the existing arrangements would not meet the waste specification, the generator would be suspended from consigning further waste until the action is completed.

Finally, waste receipt monitoring is carried out on all LLW received for disposal at Drigg and is applied to three levels of detail defined as level 1, 2 and 3 monitoring :

- Level 1 Monitoring. This is the measurement of entire consignments (radiation levels, contamination monitoring and weight) and observations during handling and processing of the waste. All waste consignments undergo level 1 monitoring.

- Level 2 Monitoring. This is the non-destructive assay of entire consignments on a container by container (200 litre drum or 1m^3 box) basis by real time radiography, high resolution gamma spectroscopy, passive and active neutron counting. The assay results are then collated for each waste consignment by a computer system and a consignment report produced.

A representative programme of consignments from waste consignors undergoes level 2 monitoring. The emphasis for this is directed to wastes from high volume and/or high activity consignors and using feedback from audits. The level 2 monitoring is carried out in a purpose built facility in the Waste Monitoring and Compaction (WAMAC) facility on the following basis :

In real time radiography, X-ray images of the waste drum/box are produced and recorded at a variety of viewing angles to allow identification of waste items contained within them. The waste drum/box can also be gently rocked which allows the presence of free liquids to be identified (free liquids are a prohibited waste). Very dense materials, such as lead, which could be used as shielding are also identified and flagged for special attention.

The high resolution gamma scanner is used to identify and quantify gamma emitting radionuclides such as fission products, activation products and some fissile material. A germanium detector scans vertically each rotating waste drum/box to obtain the overall measurements of the contents.

The passive neutron counting system measures time correlated neutrons such as those generated by the spontaneous fission of Pu-240, Pu-242 etc.

The active neutron counting system measures fissile nuclides, such as U-235 and Pu-239, in a waste drum/box by bombardment by neutrons from a neutron generator and detection of the resultant induced fission neutrons.

- Level 3 Monitoring. This is the destructive assay of a sample from a waste consignment for physical, chemical and radiochemical determination. A representative programme of consignments from waste consignors undergoes level 3 monitoring, including use of the results from the level 2 inspection.

The waste receipt monitoring results are compared with regulatory limits, the BNFL specification and the consignment declarations to confirm customer conformance. In the event of non-conformance, then discussions are held with the waste consignor and corrective actions sought. In the more significant cases no further consignments are accepted until improvements have been established.

This comprehensive series of controls is intended to give assurance to BNFL as the operator, to regulatory authorities and to members of the public that wastes consigned to Drigg are fully controlled and hence has an important role in ensuring confidence in waste disposal practices.

4. WASTE ARISINGS AND CHARACTERISTICS

Low level radioactive wastes arise from a wide range of establishments and practices in the UK. These include:

- nuclear power plants

- nuclear fuel manufacture and processing sites
- radioactive waste management operations
- radiopharmaceutical manufacture
- research sites
- hospitals and universities
- industrial users of radioactive materials
- decommissioning work

The wastes comprise a wide range of materials, including paper, packaging materials, reactor wastes, scrap equipment and rubble/soil. The arisings of LLW have decreased from about 35,000m^3/year in the mid to late 1980s to about 10,000m^3/year currently. The decrease has been achieved despite increasing fuel reprocessing, waste management and decommissioning work. This reflects the continuing emphasis and measures to minimise raw waste arisings, together with the introduction of new waste compaction facilities. Typical levels of activity in recent years are, in overall terms, about 0.2 TBq alpha and 5 TBq beta/gamma emitting nuclides disposed of annually.

As identified in Section 3.2, each type of waste from each establishment must have an approved waste characterisation prior to the first consignment being made. The information which needs to be in the wastestream characterisation includes :

- Wastestream number and name
- Description of the process giving rise to the LLW
- Physical and chemical composition of the LLW including how prohibited materials are either excluded or made safe
- Details of the conditioning and packaging of the LLW
- Method of activity assessment
  - basis e.g. dose rate conversion
  - fully referenced derivation
  - limitations and how non-conforming wastes are assessed
  - consideration of potential uncertainties
- Radionuclide fingerprint
  - how determined e.g. by sampling and analysis
  - consideration of possible uncertainties
  - individual radionuclides to be recorded
  - short lived radionuclides excluded unless not in equilibrium
  - justification for radionuclides not included e.g. below de minimis levels

For most LLW it is not possible to directly assay the activity content and radionuclide composition of a consignment. Use therefore has to be made of a known property of the waste which can be directly measured and related to the activity content. This relationship is identified and justified in the wastestream characterisation.

The most common forms of relationship are:

- Where the dose rate measurement from the waste (usually in a bag or a drum) is proportional to its activity content. For this to be valid the waste must contain a gamma emitter so that the radiation can penetrate the container and also reduce self-shielding errors. This information will already be known from the radionuclide fingerprint of the waste. The radiation measurement/activity content relationship can be derived by either mathematical models, simulation tests or destructive analysis of waste whose radiation levels have been measured. It is possible to apportion this to individual radionuclides including non-gamma emitters by reference to the fingerprint.

- Where the specific activity of the waste can be shown to be constant, and so its activity content is proportional to its weight. For this to be valid a series of samples of the waste will have been taken and analysed. The results of these analyses will form the radionuclide fingerprint. A measurement of the weight of the waste will therefore yield total activity and individual nuclide data.

- Where the specific activity is not constant and the radiation produced is either alpha or soft beta. This is the most difficult waste to assess activity in, and generally involves an extensive destructive sampling campaign to produce activity concentration and radionuclide composition data. A fixed activity is then assigned per unit volume of waste.

Having established such relationships, routine monitoring of waste in terms of dose rate, weight or volume can be used to assess the activity content and hence to complete the necessary consignment documentation. It is however important to stress the need to maintain discrete wastestreams prior to this monitoring stage and to ensure regular review, and update as necessary, of the technical basis of the activity quantification.

5. WASTE CONDITIONING AND DISPOSAL DEVELOPMENTS

Until 1988 all wastes were disposed of at Drigg by tumble tipping into trenches cut into a clay layer which exists some 5 to 8m below ground in the area of the site consented for disposal by the local planning authority (the northern area representing about a third of the Drigg site). Trenches 1 to 6, each about 25m wide and up to 750m in length, and Trench 7, a triangular area of land on the east side of the site (Figure 1) have been filled with wastes. The last trench was completed in 1995. A total of about 800,000m^3 of wastes has been disposed of to the trenches. After disposal the wastes were covered by at least 1m of cover materials in order both to complete the trench and provide a stable surface for their progressive filling. Subsequently an interim cap was installed over the completed trenches comprising an earth mound, graded to 1 in 25, covered by an impermeable membrane and a minimum of 0.5m of soil. Groundwater cut-off walls of a cement bentonite mix have also been constructed beneath the cap around the north and east of the completed trenches in order to prevent lateral migration of groundwater. The run-off water from the cap is collected in perimeter drainage channels and routed to the site stream. The surface of this cap has been seeded with grass and mixed shrubs both to stabilise the topsoil, minimise erosion and gulleying, and also to encourage evapotranspiration. Surveillance of the cap is being carried out and where necessary any damage, for example caused by differential settlement, will be made good. It is recognised that this cap is of limited life and in due course, prior to site closure, this interim cap will be superseded by a final cap incorporating a longer-term, low permeability barrier.

Leachate from the trenches used to discharge into a stream and hence to the nearby estuary. Whilst monitoring of adjacent farmland showed no significant exposure from this route, it was recognised that the potential existed in the longer-term and that it would be preferable to route leachate directly to sea. A leachate management system was therefore installed, including refurbishment of leachate drains, provision of holding tanks with flow-proportional sampling equipment and a pipeline to allow pumped discharge of leachate to sea. This enables discharges to be controlled and sampled. Tests at sea have confirmed the original design performance specification of the 1.2 km marine outfall. Surface run-off waters from the newer disposal vaults (discussed below) are also routed via the marine discharge system.

Together with this upgrading of the management of the trenches, BNFL introduced a new wasteform specification and the use of engineered concrete vaults. This programme, with optioneering evaluation studies, was designed to consider the principal components:

- Waste Conditioning
- Waste packaging
- Vault design

These optioneering studies were carried out in an integrated manner in order to achieve the optimum combination of these three key components and set a cost-effective solution for future LLW disposals in the UK. In carrying out these studies the important criteria included:

- Technology availability
- Costs
- Operational aspects
- Workforce and public doses during operation
- Transport implications
- Effect on site volume capacity
- Long term performance and environmental impact

5.1 Waste Conditioning

A number of waste conditioning options were considered including:

- Low force compaction
- High force compaction
- Incineration
- Rotary calcination
- Melting
- Grouting

Based on the criteria given earlier, the preferred solution was the combination of high force compaction of wastes with grouting of the resultant pucks in product containers. This strategy ensures both excellent volume reduction, and hence vault utilisation efficiency, and also minimum residual voidage associated with the wasteform.

This high density, low voidage wasteform has been a principal aspect in developing the new disposal concept for Drigg disposals. The wasteform must provide good support for the closure cap over very long periods of time. This is so that once the container and vault structures degrade as they must over time, then localised differential settlement of the cap will not occur, and that settlement will be both gradual and relatively uniform across the vaults.

The Waste Monitoring and Compaction (WAMAC) facility, at Sellafield nearby to Drigg, has the capability and capacity to offer a service to compact LLW from throughout the UK. The nature of the wastes to be conditioned is very variable and for some wastestreams includes a wide range of materials including metallic items and concrete for example from decommissioning projects. In overall volume reduction terms, it is these components which often determine final product volumes. In the WAMAC facility, the fraction of wastes which can be compacted has therefore been maximised by providing a size reduction capability and by the ability to compact not only 200l drums of waste but also wastes loaded into nominal $1m^3$ boxes. The principal stages in the WAMAC process are illustrated in Figure 2 and the plant layout shown in Figure 3.

On receipt at WAMAC, the documentation associated with each consignment is passed to the control room. Details from the documentation is entered onto the waste tracking and inventory control computer system and a range of verification acceptance checks carried out. The tracking system subsequently records waste movements throughout the WAMAC and Drigg Grouting facilities and enables the inventory of each product container to be individually identified and recorded.

The WAMAC facility has the ability to receive both "loose" waste, in agreed transport containers, and also wastes packaged in either 200l drums or nominal $1m^3$ boxes. The size of the box has been chosen as the maximum practical for processing and the dimensions optimised with respect to loading in the standard overpack. The boxes are made of mild steel and contain internal anti-reassertion louvres to retain pre-compaction plates (Figure 4). Drummed or boxed wastes are unloaded at ground floor level by docking a full height ISO container directly onto the building. "Loose" wastes, principally in 5 or $10m^3$ capacity skips, are delivered by skip-lift vehicles and tipped into one of three receipt troughs on the upper floor level.
Wastes in troughs are handled by one of three remotely operated mechanical grab devices. Wastes can be loaded directly into boxes, or alternatively, can be size reduced either by a shredder unit or via use of hydraulically operated cutting tools. Any item which cannot be size-reduced can be routed directly to the product loading area. Softer-type wastes are precompacted within the boxes before further waste is loaded into the box and the lid emplaced.

Throughout the processing the wastes are subject to level 1 waste receipt monitoring as described in Section 3.3 and prior to high force compaction, drums and boxes of wastes can be diverted for monitoring level 2 (non-destructive assay) and level 3 (intrusive examination and assay).

Drums and boxes are high force compacted (Figure 4), at up to 5000t force, in a dual bolster compactor. Any minor quantities of liquid generated during compaction are collected and subsequently absorbed into purpose developed cement bentonite blocks in the base of product containers. The box and drum pucks produced by the compactor are loaded into product containers (discussed below) and a lid fitted prior to monitoring and despatch by rail to the Grouting Facility at Drigg.

The Grouting Facility, illustrated in Figure 5, consists principally of four bays into each of which an overpack can be placed. Each overpack contains a grouting port. This consists of a removable flange and beneath it, a baffle arrangement to ensure a satisfactory flow of grout. Grouting serves the purpose of filling internal voidage and providing a cap across the external upper surface. A very low viscosity grout made up of pulverised fuel ash, cement and a superplasticiser has been developed and extensively tested. The grouted product is shown in Figure 6.

5.2 Waste Package Development

Four principal container design schemes representing a range of options were evaluated. These were small and large sizes and metal and concrete construction. The preferred solution was identified as a nominal $20m^3$ external volume, half-height ISO (International Standards Organisation) steel container. The relatively large size of overpack has been selected to minimise the number of handling operations, and hence cost and dose uptake, whilst a metal container is considered preferable to concrete ones in order to ensure maximum utilisation of vault disposal space. Metal containers also result in lower gross package masses prior to grouting. An important consideration was also the ability of the container to meet Transport Regulations during shipment to Drigg both from Sellafield and other establishments across the UK.

The large metal container concept was then optimised in terms of minimising voidage associated with the container structure and giving relatively uniform load distribution across its base. Residual voidage after grouting has been minimised by redesign from standard ISO containers in particular of the base assembly and side panels. Relatively uniform load distribution was considered in order to essentially eliminate point loads on the vault base from a stack of containers of up to 42 tonnes each plus the overlying closure cap. In order to achieve this the load is distributed through the wasteform itself rather than the container structure, hence the use of a top grouting area across the surface of the container (Figure 6).

As well as the standard half-height ISO container, a small number of additional designs have now been developed. In particular a third-height container for use with very dense wastes, such as metal plates, enabling the 42 tonnes handling limit to be met and a nominal $10m^3$ capacity variant for easier handling and use in smaller areas. The external dimensions and volumes of these containers are shown below:

Container design	Height (m)	Width (m)	Length (m)	Volume (m^3)
Half-height (No 2910)	1320	2438	6058	19.50
Third-height (No 2989)	880	2438	6058	13.00
ISO-skip (No 2921)	1725	1950	3400	11.44

All these container designs have been through value engineering assessments to optimise the design and minimise costs. They have also all successfully been assessed against the requirements of the IAEA Transport Regulations.

5.3 Vault development

The first disposal vault at Drigg was introduced in 1988 and was essentially an extrapolation of the trench disposal system in that it is below ground and underlain by a clay layer. In particular it allows the orderly emplacement, by fork lift truck, of the containerised wastes. This first vault has a total capacity of $180,000m^3$ and consists of three bays each of about 60m width, 200m length and 5m depth. The vault consists of a concrete base and walls and an underlying drainage layer. Surface run-off water and drainage beneath the base are collected and sampled independently prior to routing to the marine discharge system described earlier.

This first vault is still in use and, with the reduced rates of waste arising, is now expected to remain in operation until at least 2005. Vault design and optimisation work has continued however to assist with future planning and an updated design developed for future vaults is shown schematically in Figure 7. This retains the concept of open vaults, each of capacity of about $50,000m^3$ equivalent to about five years of disposals. The vaults will be stacked six high rather than the four high in the current vault. Backfilling between containers is not carried out on an ongoing basis, but the containers close-stacked in arrays. Caps on the vaults will be constructed directly onto the containers using an initial gravel infill and cover layer and subsequent bulk-fill, impermeable and surface layers.

For large items of waste which it is impractical to size reduce into containers, in-vault grouting is carried out. At present this is done on a campaign basis in areas of the current, open vault using mobile grout facilities. However, as shown in Figure 7, future vault designs will include dedicated cells for in-vault grouting. Large items will be emplaced as they arise in the cells using installed craneage and mobile roof covers. Grouting will then be carried out in successive layers and, on completion of each cell, the equipment advanced to the next area.

5.4 Post-Closure Measures

Following completion of disposals into each vault (or bay in the case of Vault 8), interim caps similar to that over the trenches will be installed to form an integrated cap over the entire disposal area. In this way operational disposals are expected to continue to about the middle of the next century. It is then planned that the site be maintained for a period of the order of 100 years or more during which operational facilities would be progressively decommissioned and long-term site closure features constructed. The detailed nature of these features will be developed with time in order to take into account good environmental and engineering practices and enabling future developments of relevance to be taken into account. Nevertheless, BNFL have an engineering evaluation studies programme to develop and evaluate appropriate closure measures (see Section 7).

Planning for site closure includes consideration of remedial work associated with drainage systems on site including the marine pipeline, the installation of further groundwater cut-off walls and a final closure cap. The latter will be emplaced when it is judged settlement is substantially complete and will incorporate a band of low permeability material such as clay. The profile and construction of the cap will be designed to:

- minimise infiltration through the cap and the build-up of gas beneath it
- minimise the effects of the environment, eg erosion, desiccation, freeze/thaw
- inhibit intrusion by man, plant roots or burrowing animals

Following installation of the cap, a period of maintenance and monitoring is anticipated as a component of an overall site repository and environmental monitoring programme. Monitoring and security will then be maintained until such times as the results confirm that the facilities have stabilised sufficiently that the residual risk, as evaluated by a final safety case, demonstrates that restrictions on access to the site are no longer required. At that time, the final records associated with the site will be completed and lodged with the appropriate regulatory authority.

6. ENVIRONMENTAL MONITORING

During the operational phase of a near-surface disposal facility, the UK regulatory requirement includes that the dose to the most exposed group of the general public does not exceed 300 μSv/year. As part of good operational practices and in order to demonstrate compliance with this limit, BNFL carry out a comprehensive monitoring programme both on the Drigg site and in the surrounding area. This monitoring programme includes:

- Groundwaters
- Surface waters
- Sediments
- Air
- Milk
- Marine foodstuffs

The amounts of activity discharged from Drigg are however very low and in practice it is impossible to assess the impact of Drigg through environmental monitoring alone because of the much larger discharges from Sellafield. It is possible to estimate their impact by modelling and this indicates a critical group annual dose of about 0.01 μSv. Monitoring of the principal pathways by which the public may be exposed confirms the minimal impact of Drigg operations.

7. TECHNICAL SUPPORT WORK

For a number of years now a programme of technical work has been carried out in support of the Drigg site. This has two primary purposes. Firstly, to underpin and progress the engineering and waste management developments, and secondly, to ensure the necessary information and numerical models are available to provide radiological impact assessments. Indeed, these two objectives are inter-related and the results of comparative risk assessments have been and will be used in selecting preferred development options.

With the successful implementation of the waste conditioning strategy outlined above, the primary objective of the current technical studies is to ensure an up-to-date radiological assessment methodology and supporting input data. The other principal objective is to underpin the longer-term development of post-closure measures. This technical work is more fully described in the accompanying paper to this Workshop. However, in summary the technical work includes:

- Updating of estimates of the site inventory at closure
- Engineering risk assessments of the performance of key engineering features
- Supporting experimental studies of engineering features
- Provision of gaseous and near-field source term/release data
- Continued collection and interpretation of site characterisation data
- Provision of geosphere chemistry data
- Development of the post-closure assessment methodology
- Scenario formulation, including for climate change
- Computer code development and testing
- Supporting safety case justification

This methodology and the supporting database will be used in further evaluation of development options and in the preparation of submissions necessary for the periodic reviews of the disposal authorisation.

8. CONCLUSION

The BNFL Drigg near-surface disposal facility has been in successful operation for the disposal of UK low level wastes for over 30 years. A significant development programme has defined a wasteform and vault strategy which is now in operation and provides for efficient utilisation of the Drigg site capacity and a cost-effective disposal concept which meets both national and international standards.

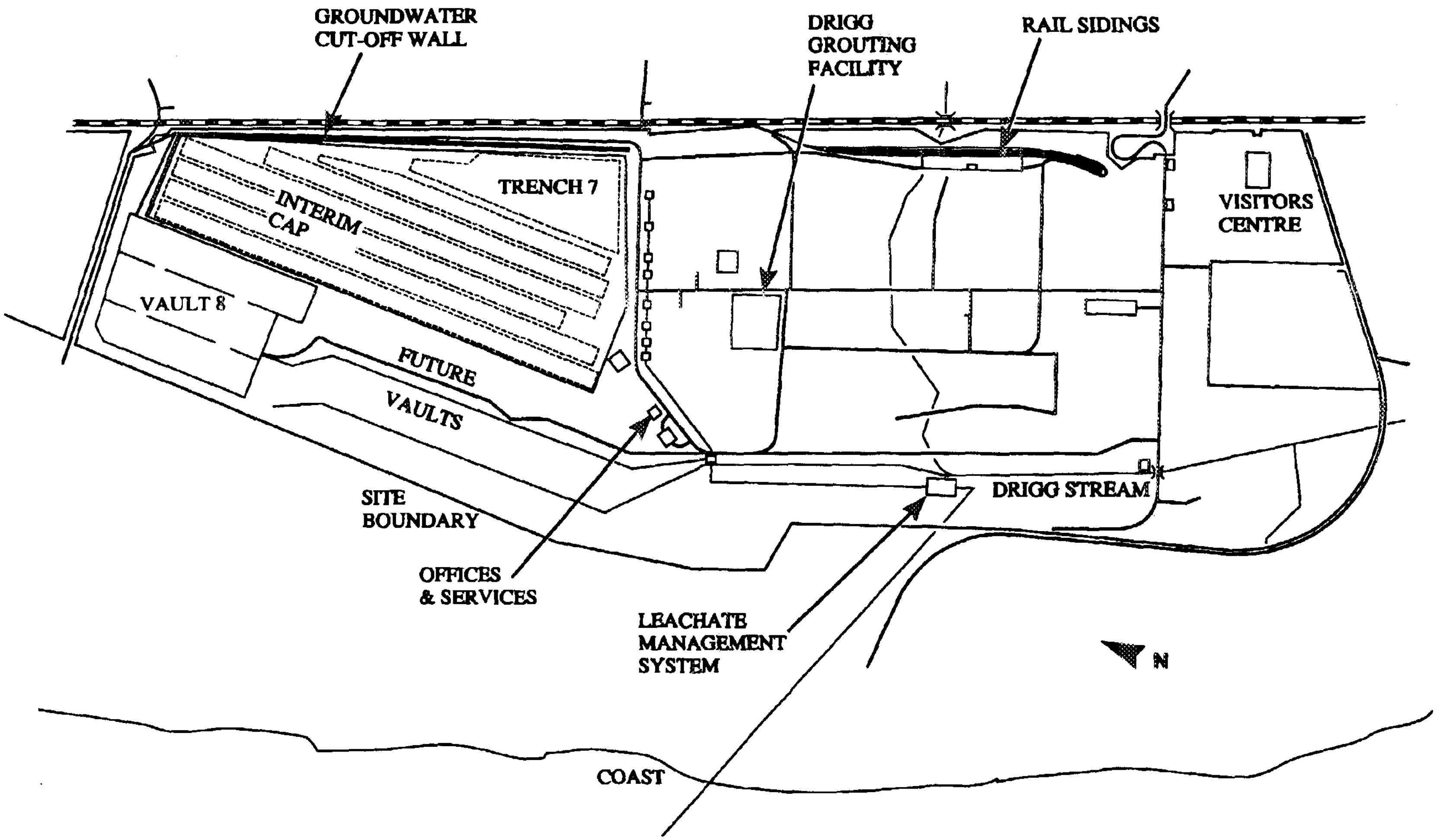

FIGURE 1: PRINCIPAL FEATURES OF THE DRIGG SITE

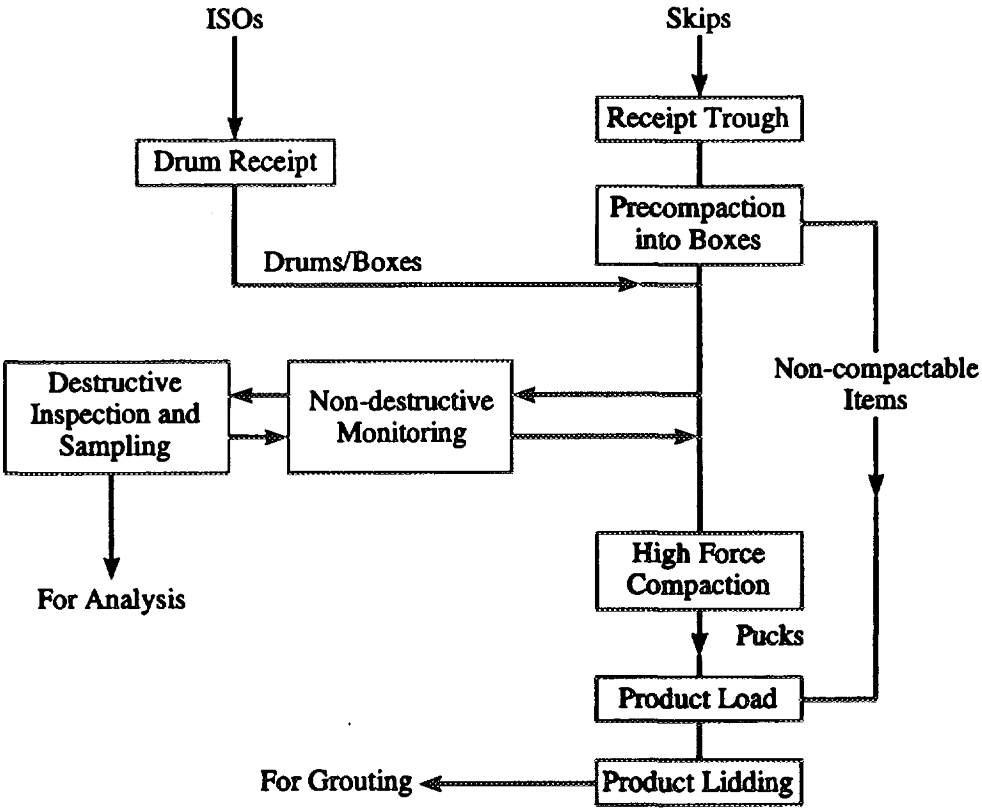

FIGURE 2: PRINCIPAL STAGES OF THE WAMAC PROCESS

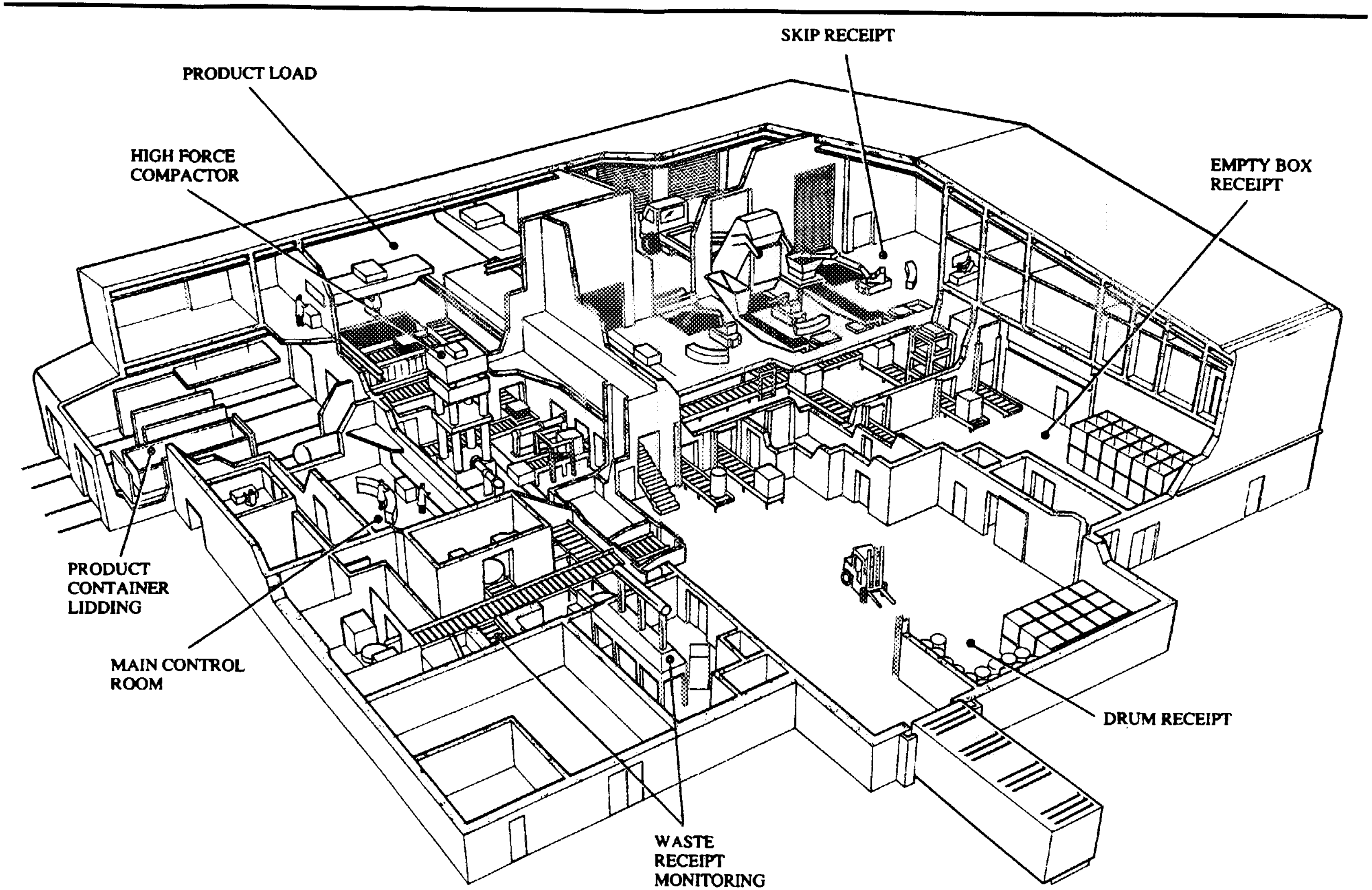

FIGURE 3: LAYOUT OF THE WAMAC FACILITY

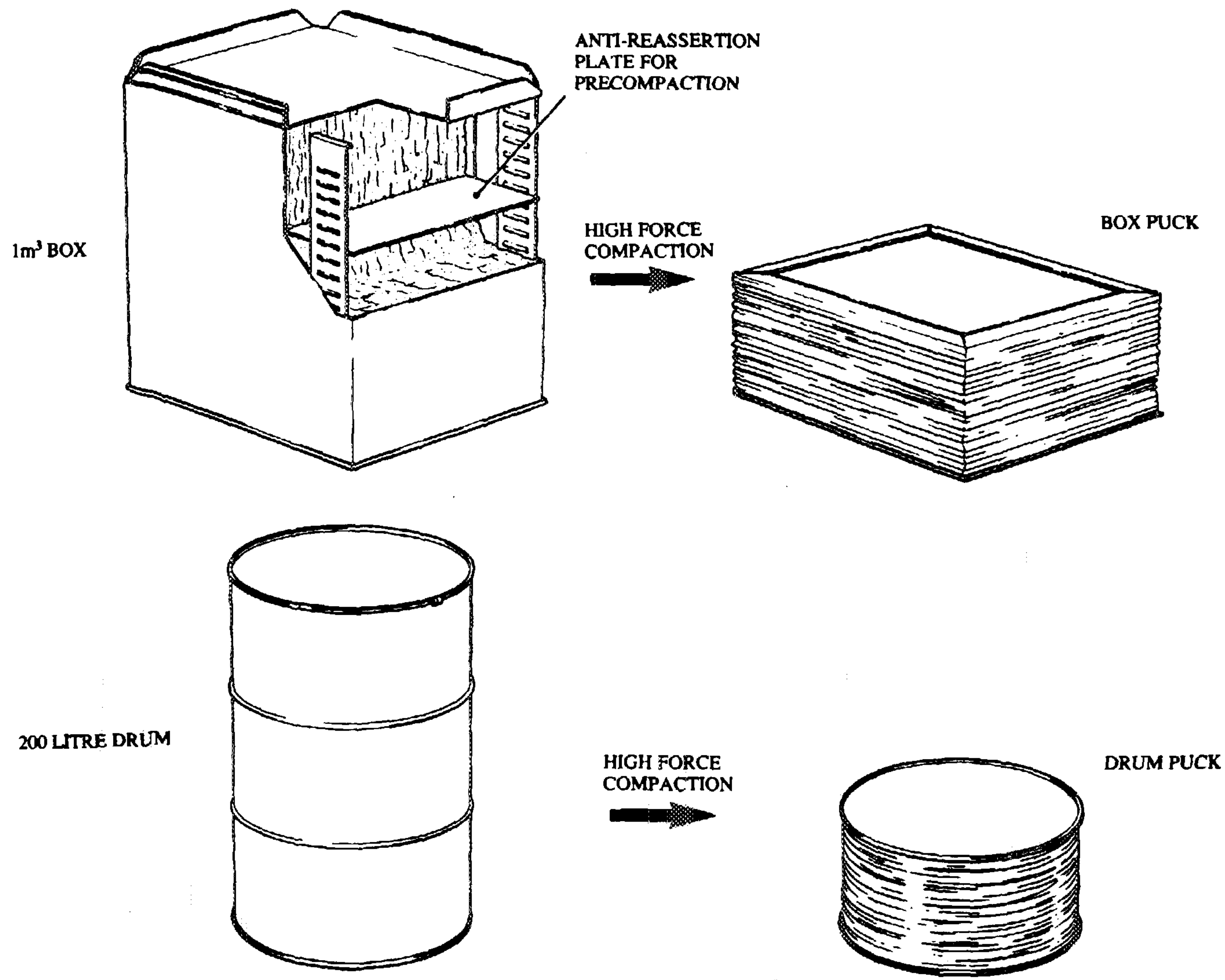

FIGURE 4: LLW CONTAINERS AND RESULTING PUCKS

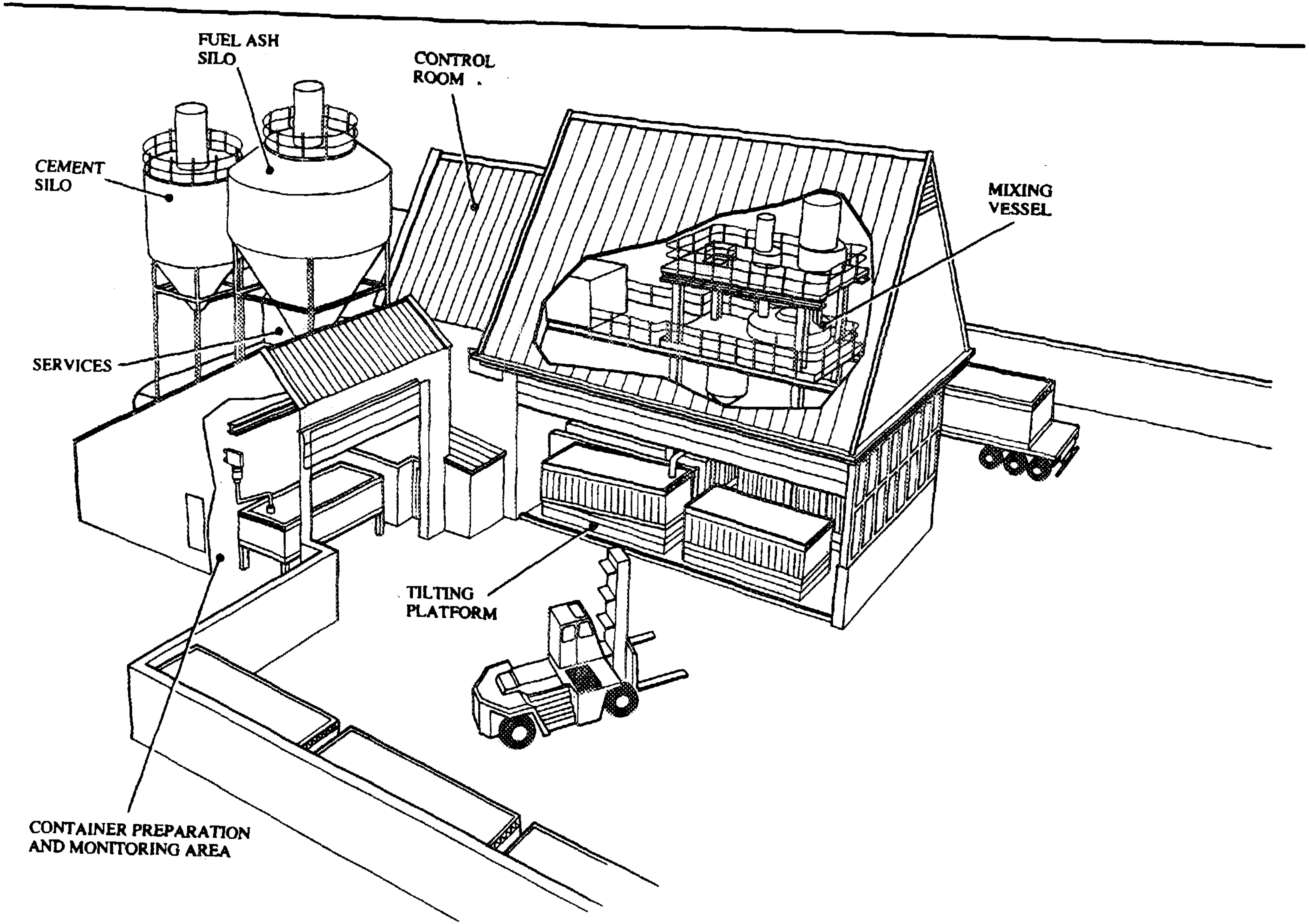

FIGURE 5: DRIGG GROUTING FACILITY

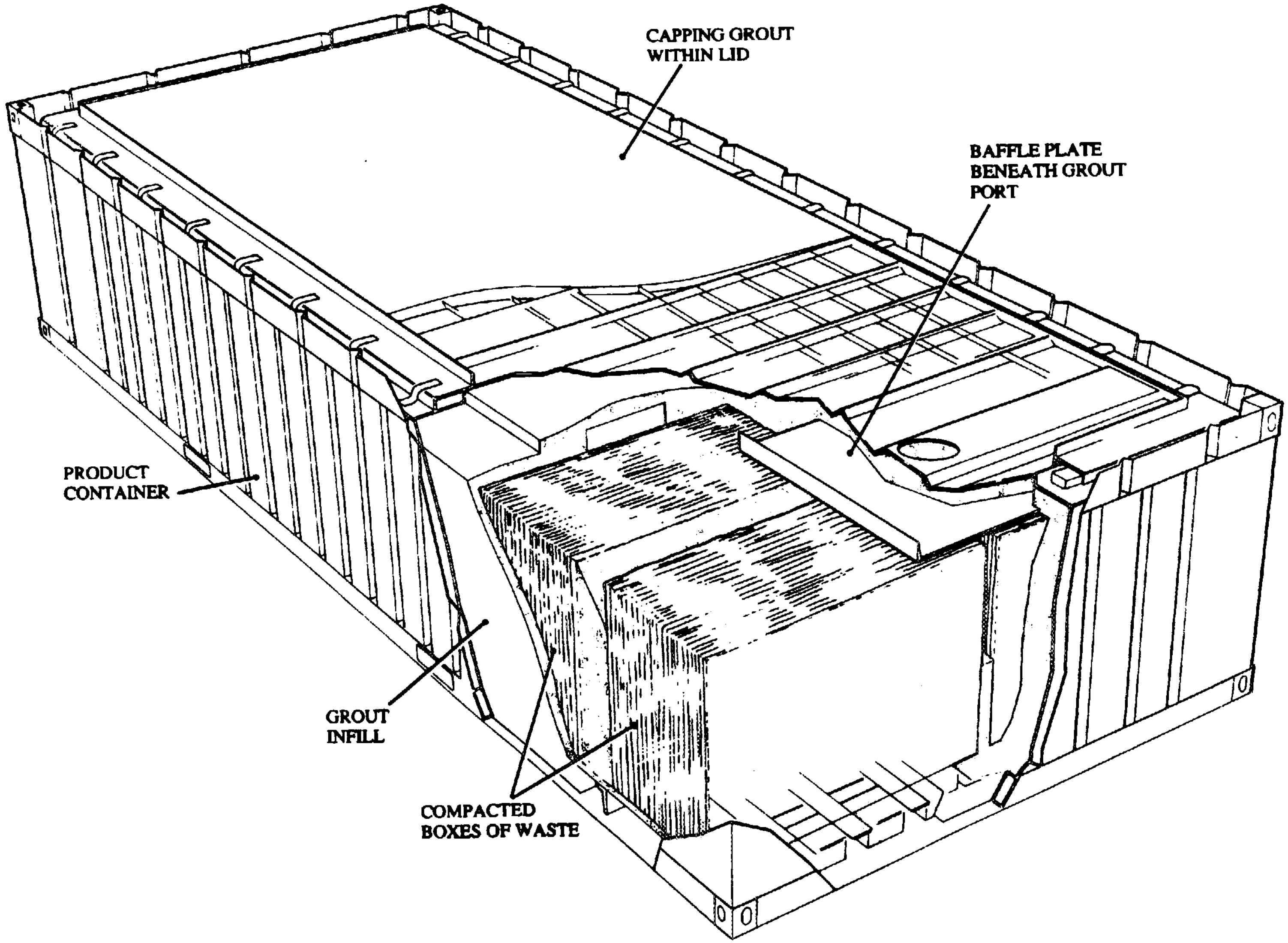

FIGURE 6: FULLY GROUTED PRODUCT CONTAINER

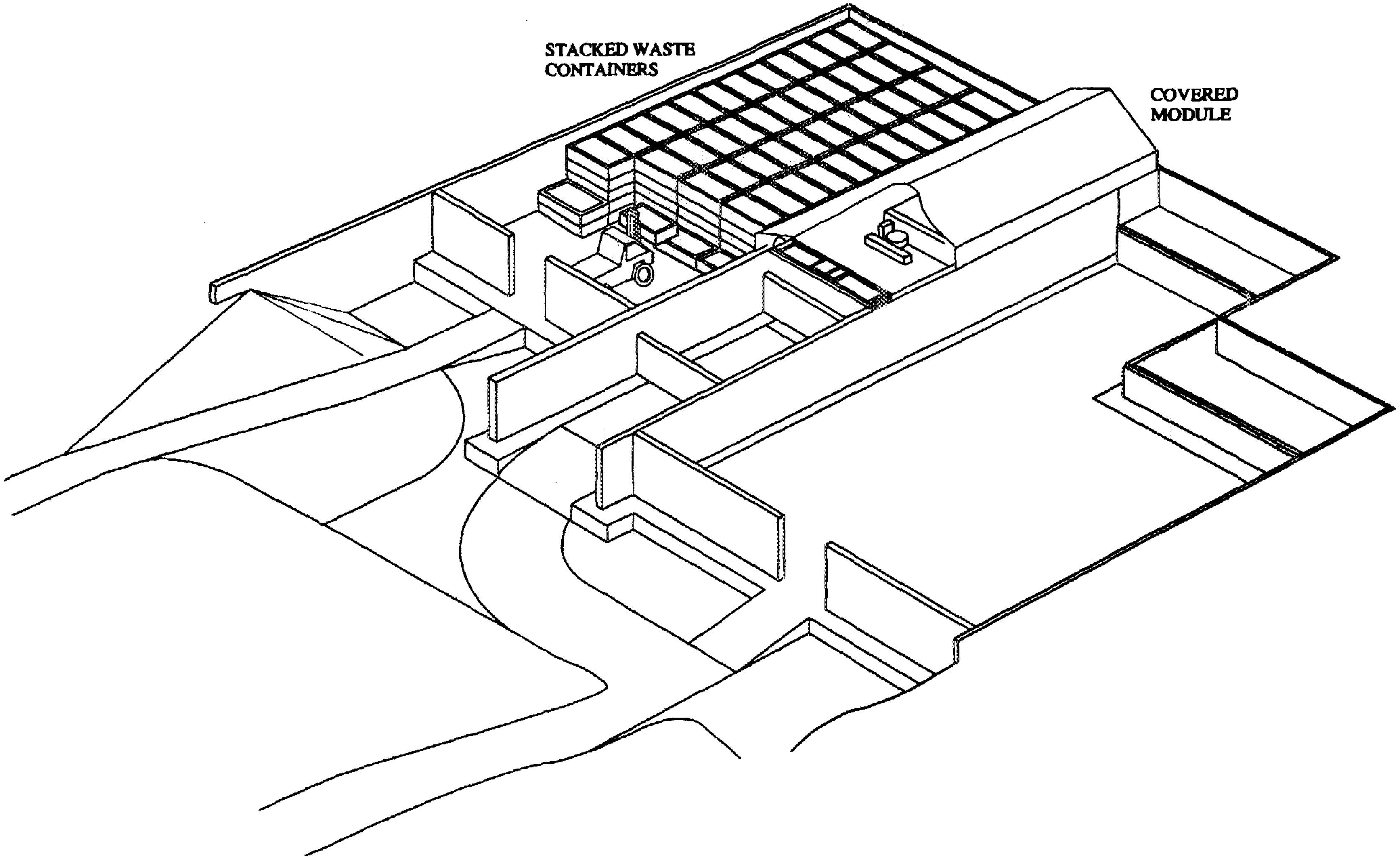

FIGURE: 7 FUTURE VAULT DESIGN