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(Volume 8)

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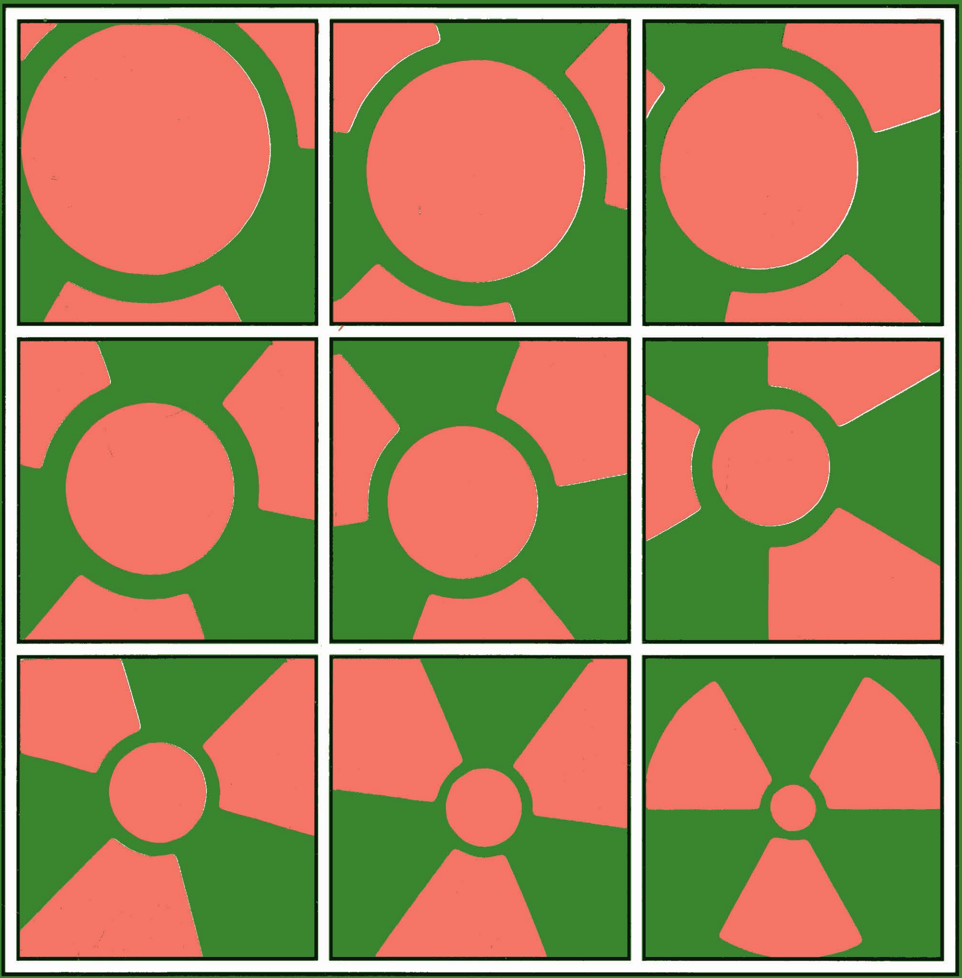

Report

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(Volume 8)

Cost and radiological impact associated with near-surface disposal of reactor waste (Spanish concept)

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Final report

Work performed as part of the shared cost programme (1985-89) on management and disposal
of radioactive waste of the European Communities

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FOREWORD

This report deals with the determination of the cost and the radiological impact associated to a near surface disposal site for reactor waste based on a Spanish concept. This study is part of an overall assessment study aiming at evaluating a selection of management routes for LWR waste based on economical and radiological criteria.

Actually the assessment study was implemented through complementary contributions provided by nine organisations and companies, i.e.
CEN - Fontenay-aux-Roses, INITEC - Madrid, KAH - Heidelberg, BELGATOM - Brussels, TASK R&S - Ispra, SGN - St. Quentin-en-Yvelines, EDF/SEPTEN - Villeurbanne, FRAMATOME - Paris-la-Défense, GNS - Essen, co-ordinated by the Commission of the European Communities (Brussels).

The main achievements of the assessment study have been summarised by BELGATOM-Brussels.
These different contributions are published as EUR Reports in 1992 (listed as below):

VOL. N°	MAIN AUTHORS	ORGANISATION	TITLE	EUR REPORT N°
1	R. Glibert	BELGATOM	Assessment of Management Alternatives for LWR Wastes : Main achievements of the joint study	14043 EN/Vol 1
2	E. de Saulieu C. Chary	SGN EDF	Assessment of Management Alternatives for LWR Wastes : Description of a French scenario for PWR waste	14043 EN/Vol 2
3	S. Santraille K. Janberg H. Geiser	FRAMATOME - GNS	Assessment of Management Alternatives for LWR Wastes : Description of German scenarios for PWR and BWR wastes	14043 EN/Vol 3
4	J. Crustin R. Glibert	BELGATOM	Assessment of Management Alternatives for LWR Wastes : Description of a Belgian scenario for PWR waste	14043 EN/Vol 4
5	B. Centner	BELGATOM	Assessment of Management Alternatives for LWR Wastes : Assessment of the radiological impact to the public resulting from discharges of radioactive effluents	14043 EN/Vol 5
6	G.M. Thiels S. Kowa	TASK R & S KAH	Assessment of Management Alternatives for LWR Wastes : Cost determination of the LWR waste management routes (Treatment/Conditioning/Packaging/Transport Operations)	14043 EN/Vol 6
7	J. Malherbe	CEA	Assessment of Management Alternatives for LWR Wastes : Cost and radiological impact associated to near surface disposal of reactor waste (French concept)	14043 EN/Vol 7
8	N. Sanchez-Delgado	INITEC	Assessment of Management Alternatives for LWR Wastes : Cost and radiological impact associated to near surface disposal of reactor waste (Spanish concept)	14043 EN/Vol 8

SUMMARY

As part of the joint study aiming at assessing management routes on the basis of economic and radiological criteria this work focuses on the cost and radiological impact assessment for the final disposal phase of reactor wastes in below ground vaults.

The facility is assumed to be located in an area which had been excavated previously for mining explotation.

The lower level of the disposal site is assumed to be located 5 meters above the water table and to be capable of accepting 120000 m^3 of conditioned wastes in 68 concrete vaults of two different types to accomodate weakly and highly active packages. The waste streams considered consist of ion exchange resins, filters, core components, technological wastes and trash.

Total capital cost of the facility per unit waste volume in 1993 Ecus is 899 (37%) and operating cost 1585 (63%). Major contributors to total costs are site works, with 17%, direct labour with 32% and vault construction with 15%.

The approach adopted for estimating the occupational exposure was based on a per shipment basis and most significant data have been adapted to the specific design.

The results of these calculations show that projected annual collective doses range between 0.21 to 0.65 person-Sv/a and from 5.24E-5 to 1.64E-4 person-Sv/m^3 for the two types of source terms and packages assumed. Accordingly annual average individual doses range from 1.05E-2 to 3.27E-2 Sv/a and 2.62E-6 to 8.18E-5 Sv/m^3.

Maximum individual and collective doses to members of the public during the stage of operation of the facility and in the long term have been estimated.

The maximum value of annual effective committed dose corresponds to the age group of infants, with the value of 1.14 E-5 Sv/a (1.14 mRem/a) most of it coming from the ingestion of Ni-59 in contaminated milk. This maximum value occurs 960 years after the closure of the installation.

The maximum doses to adults are an order of magnitude lower, with a value of 1.91 E-6 Sv/a (0,19 mRem/a) at 1184 years after the closure of the installation.

The annual expected collective committed dose for the reference inventory is 5.91 E-3 Man-Sv/a at 2660 years disposal time and committed collective dose integrated in 10^7 years is 55.47 Man-Sv.

For a 1 TBq inventory for each nuclide, the maximum annual committed dose is 1.32 E-2 Man-Sv/a due to I-129 and occurs at 333 years of disposal time. Maximum committed collective dose integrated in 10^7 years is 2.08 Man-Sv due to Np-237.

TABLE OF CONTENTS

1. INTRODUCTION

As part of the joint study aiming at assessing management routes on the basis of economic and radiological criteria, this work focuses on the cost and radiological impact assessment for the disposal of reactor wastes in below ground vaults.

The main goals of this work are:

- Determine the radiological impact both short term and long term associated to a disposal facility of the below ground type for reactor wastes. The following main release pathways have been taken into account: ground water migration of radioactive elements, surface water releases and atmospheric releases. Three different stages in the life of the installation have been considered: operation of the facility, institutional control phase and free use of the land after termination of the license.

- Determine the radiological burden to the facility operators.

- Cost assessment related to the disposal of LWR waste products in below ground vaults, including capital and operating costs.

Waste acceptance criteria have been put forward in terms of specific activity limits, matrix types, leaching rates, mechanical properties, drum sizes, etc... so as to accomplish protection goals for the public.

A reference disposal facility layout has been drawn-up and the operations to be carried out (sorting out the waste products, waste conditioning provisions, etc...) have been assessed in a detailed way as needed for the cost and radiological impact assessment.

In the coming sections of this report a description of the evaluation performed is presented.

2. GENERAL SITE AND WASTE DESCRIPTION

Figure 1 represents the general layout of the disposal facility and shows the disposal vaults area and other installations for general services.

The facility is assumed to be located in an existing excavated zone for mining or other purposes.

2.1. HYDROGEOLOGICAL DESCRIPTION

The water table level in the reference site is assumed to be located in stationary state 5 meters below the excavation level.

Aquifer permeability is assumed to be 10^{-2} cm/s in a homogeneous and isotropic media, covered with a layer of permeability 10^{-7} cm/s and 5% slope, reaching the surface 1000 m. away.

2.2. DISPOSAL AREA DESCRIPTION

2.2.1. Disposal Vaults

A vault is a disposal structure made in reinforced concrete with parallelepipedic form, consisting of a lower slab and peripheral walls, as shown in figures 2 and 3.

Two types of vaults are envisaged: single vaults, to accomodate weakly or very weakly active packages and special vaults, for highly active packages.

The support plate placed under the lower slab allows to recover infiltration water through the long-term cover and its collection in the Infiltration Water Control Network.

Each row of vaults is protected by a movable roof.

The movable roof covers the storage structure as well as the trailer unloading corridor. This covering satisfies three objectives:

- Protection of the packages

- Improvement of work conditions

- Support for the remote controlled handling mechanisms (overhead crane, lighting, TV cameras, telephone, etc).

Vault structure allows the protection of waste packages against rain water during the whole operational period until the upper slab is placed. After vault operation is completed waste packages are protected by means of a provisional cover formed by a low-permeability membrane.

Vault design satisfies the seismic, mechanical and radiological requirements specified.

To optimize the storage capacity of the vaults, metallic drums are placed in sucessive layers according a triangular network layout. Each layer shall be separated from the following by means of an adequate thickness of concrete.

For a total volume of wastes of 120000 m^3, 64 vaults of 3750 m^3 each are required. The foreseen site houses 68 vaults with inner dimensions of 25 x 20 x 7.5 meters.

Once the vault is filled, the upper concrete slab will be poured and the impermeable protective membrane will be placed. The concrete for these operations will be prepared in a concrete mixing plant located at the site.

2.2.2. Final Configuration of the Area

When all the vaults are filled, the dismantling of the facilities will be carried out and demolition products will be disposed of in the vaults that are not going to be used for reactor waste disposal.

Works necessary for drainage control will be completed and the filling and compaction until definitive configuration will be done according to figures 4 and 5. In figure 5, drainage scheme, the barriers against the entrance of water are shown, as well as potentially contaminated water controls to be treated, if necessary, before release to natural flows.

The total area occupied in the final configuration is 350000 m^2.

In the definitive configuration maintenance must be minimal with stable structures resistant to atmospheric and natural agents.

2.3. GENERAL DESCRIPTION OF THE FACILITY AND WASTES

2.3.1. Functions of the facility

The main function of the facility is to collect solid reactor wastes generated by the operation during 30 years of 20 GWe LWR's both PWR's + BWR's. Wastes are to be disposed of for a period of at most 300 years in safe conditions both for the members of the public and the environment.

Other functions are:

- The reception and control of wastes.
- The conditioning of damaged waste packages after incidents or accidents.

2.3.2. Characteristics of wastes and packages

Characteristics of solid wastes to be disposed of in the facility are based on the inputs provided by other contractors and annual amounts generated per reactor are the following according to different data sources:

	VOLUME			
	1		2	3
WASTE TYPE	PWR	BWR	BWR	PWR
. Primary Resins		5 m^3/a	5 m^3/a	2 m^3/a
Highly active	10 m^3/a			
Low active	20 m^3/a			
. Primary Filters		20 m^3/a	20 m^3/a	20 u/a
RCV	10 u/a			
PTR	20 u/a			
. Normal Equip. Comb + Comp (*)	260 m^3/a	260 m^3/a	260 m^3/a	125 m^3/a
. Normal Equip. Non Comb + Comp	100 m^3/a	100 m^3/a	100 m^3/a	125 m^3/a
. Normal Equip. Comb + Non Comp	20 m^3/a	20 m^3/a	20 m^3/a	
. Normal Equip. Non Comb + Non Comp	20 m^3/a	20 m^3/a	20 m^3/a	

(*) Density before compactation 0,15 g/cc

Considering the volumes mentioned above, raw quatities of wastes generated range from approximately 400 m^3/a to 250 m^3/a. Conservatively an annual generation of conditioned wastes prior to packaging of 200 m^3/reactor has been assumed.

Waste packages to be accepted in the disposal facility would be mainly 200 l metalic drums, 400 l concrete containers and 5 m^3 metal boxes for technological wastes.

Wastes may be inmobilized in various inmobilization matrixes:

Compactable wastes may not be inmobilized, but just compacted in their corresponding packages.

Radiological characteristics of packages regarding surface dose rate and external contamination of packages are presented below:

. Surface dose rates

	maximum	average
Highly active packages	5 rad/h	3 rad/h
Weakly active packages	200 mrad/h	100 mrad/h
Very weakly active packages	50 mrad/h	10 mrad/h

Highly active packages are stored in special vaults with thicker shielding walls while low activity packages are stored in simpler vaults with thinner shielding walls.

Special vaults have higher design standards regarding seismicity and quality assurance.

. Surface contamination

Although waste packages received in the facility are supposed clean, means are provided to decontaminate both packages and transportation casks and vehicles if neccesary.

Surface contamination standards required are as follows:

beta gamma emmitters	10^{-4} uCi/cm^2
alpha emmitters	10^{-5} uCi/cm^2

Labelling requirements correspond to the usual standard for this type of packages.

Waste packages received in the site are supposed to be adequately conditioned for disposal, according to acceptance criteria. Nevertheless, conditioning means are provided for dealing with packages which could become damaged due to falls or other accidents.

Conditioning procedures include:

- Waste compacting for compactable wastes.

- Waste immobilization of damaged drums in higher volume packages by adding hydraulic binding material.

- Waste immobilization for technological waste if requiered.

2.4. DESCRIPTION OF BUILDINGS AND EQUIPMENTS

Table I contains a description of the different buildings integrating the facility and a general list of the main equipment which have been taken into account for the economic evaluation of the facility.

2.5. FUNCTIONAL DESCRIPTION

Figure 6 shows the path to be followed by the waste packages in the facility.

2.6 PERSONNEL ORGANIZATION

The personnel organization chart is shown in figure 7. The total amount of workers estimated at the facility will be 108, distributed in different activities as indicated in the flow chart.

TABLE I

MAIN BUILDINGS AND EQUIPMENT

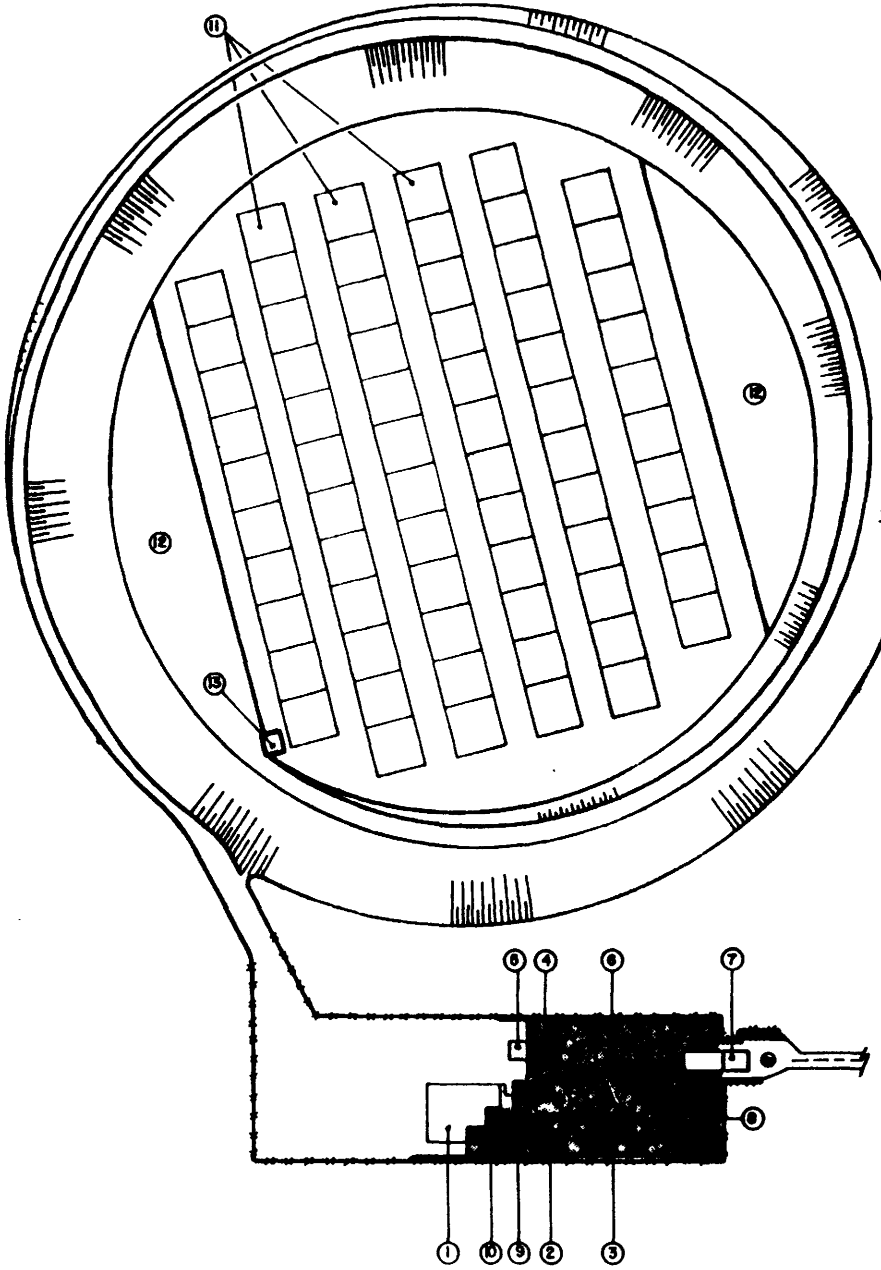
Building	Equipment	Characteristics
Conditioning Building	Area	2479 m^2
	Unloading gantry crane	25 MT; 180 drums/day
	Loading gantry crane 2 MT	
	Roller belt (approx. 80 m) and turning and hoisting tables	
	Compaction press	Power 1,000 MT Capacity: 30 drums/ /hour
	Hydraulic conglomerant production equipment	6 m^3/day
	2 Radioactive aqueous effluent storage tanks	
	Capacity:	30 m^3 each
	Type :	Vertical athospheric
	3 Aqueous effluent surveillance tanks	
	Capacity:	50 m^3 each
	Type :	Vertical athospheric
	4 Aqueous effluent pumps	
	HVAC system:	
	8 Air conditioners	
	19 Air filtering units	
	10 Room air exhausters	
	5 Smoke exhausters	

Building	Equipment	Characteristics
	Ducts, dampers and valves air aconditioning system	
	Mobile handling equipment	
	Control rool equipment	
General Service Building	Laundry equipment	Three 20 kg washing machines
	Dressing equipment	For 55 persons
	Laboratory equipment	For three laboratories
	Medical equipment	
	Health Physics equipment	
	HVAC equipment:	
	2 Air conditioning units 3 Air exhausters 1 Smoke exhauster 40 Fan-coils	
	Ducts, dampers and valves for the HVAC system	
	Computer terminals (2 units)	
Technical Service Building	Water treatment equipment:	
	1 Industrial water tank	200 m^3
	1 Drinking water tank	30 m^3
	HVAC equipment:	
	1 Air pressurizing unit 1 Smoke exhauster 6 Space heaters	
	6 Air exhausters	
	Duct and auxiliary items	
	Heating and cooling equipment for	

Building	Equipment	Characteristics
	Main transformer	1600 KVA, 20000/380V
	20 kV switchgear	
	Emergency generator unit	
	2 Air compressors	
	1 Air accumulator tank	3 m^3
	Motor-operated fire protection pump	1.500 lpm
	Diesel-operated fire protection pump	100 lpm
	Fire protection system pressuring pump	100 lpm
	Fire protection system tank	150 m^3
Vehicle Maintenance and Decontamination Workshop	Area	400 m^2
	Vehicle washing equipment	
	Vehicle workshop equipment	
	Mechanical workshop equipment	
	Electrical and instrumentation workshop equipment	
	Health Physics equipment	
	HVAC equipment:	
	2 Air conditioning units 3 Fan coils 5 Air exhausters Ducts and auxiliary items	

Building	Equipment	Characteristics
Administration Building	Area	700 m^2
	Computer, furniture and office equipment	
	HVAC equipment: 2 Air conditioning units 3 Air exhausters 1 Smoke exhauster 1 Autonomous air conditioningunit. Computer room 30 Fan coils	
	Ducts and auxiliary items	
Access Control and Firefighting Building	Firefighting vehicles and material	
	Firefighting and miscellaneous material	
	Control station equipment	
	HVAC equipment: 1 Autonomous air conditioning unit 3 Air exhausters 1 Smoke exhauster 9 Heating batteries 3 Space heaters	
	Ducts and auxiliary items	
Storage Operation Control Station	Area	144 m^2
	1 Autonomous air conditioning unit 3 Heating batteries Control room equipment	

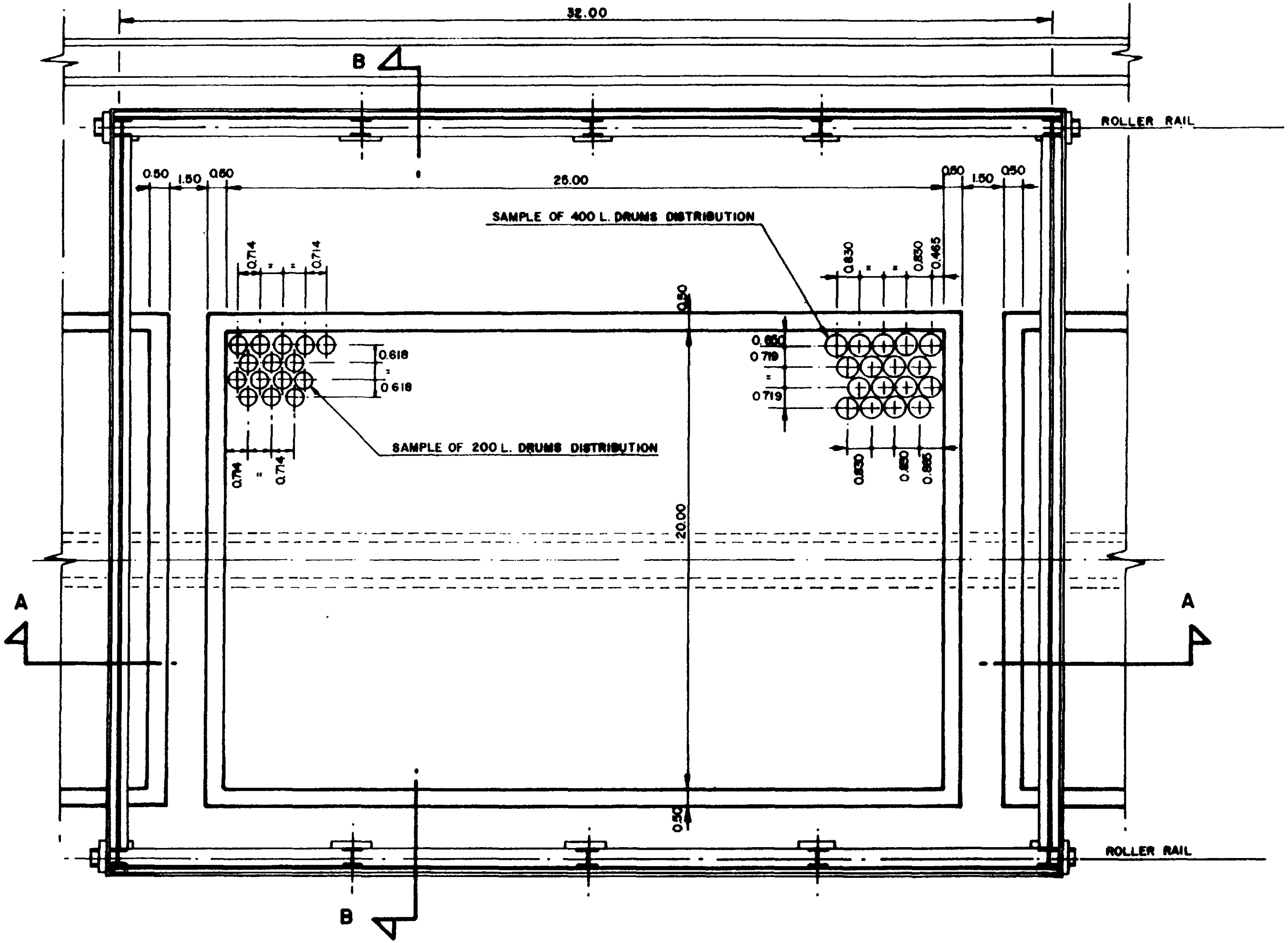
Building	Equipment	Characteristics
General	Electrical distribution and equipment (except main transf., emergency diesel and 20 kV switchgear)	
	Firefighting and fire detection (except pumping equipment and tank)	
	Public alert system	
	Telephone system	
	Piping network and valves	
	Health physics	
	Boundary detection and video system	
	General instrumentation	



LEGEND

① CONDITIONING BUILDING
② GENERAL SERVICES BUILDING
③ TECNNICAL SERVICE BUILDING
④ MAINTENANCE WORKSHOP
⑤ VEHICLES DECONTAMINATION
⑥ ADMINISTRATION BUILDING
⑦ ACCESS CONTROL BUILDING
⑧ PARKING AREA
⑨ PERSONNEL DECONTAMINATION AND LABORATORIES
⑩ WASTE CONDITIONING CONTROL STATION
⑪ VAULTS
⑫ STORAGE AUXILIAR SERVICES
⑬ STORAGE OPERATIONS CONTROL STATION
▭ UNCONTROLLED AREA
CONCRETER MIXER
RAIN AND INFILTRATION WATER COLLECTION POND

FIGURE-1
GENERAL LAYOUT



FIGURE–2
VAULT PLANT

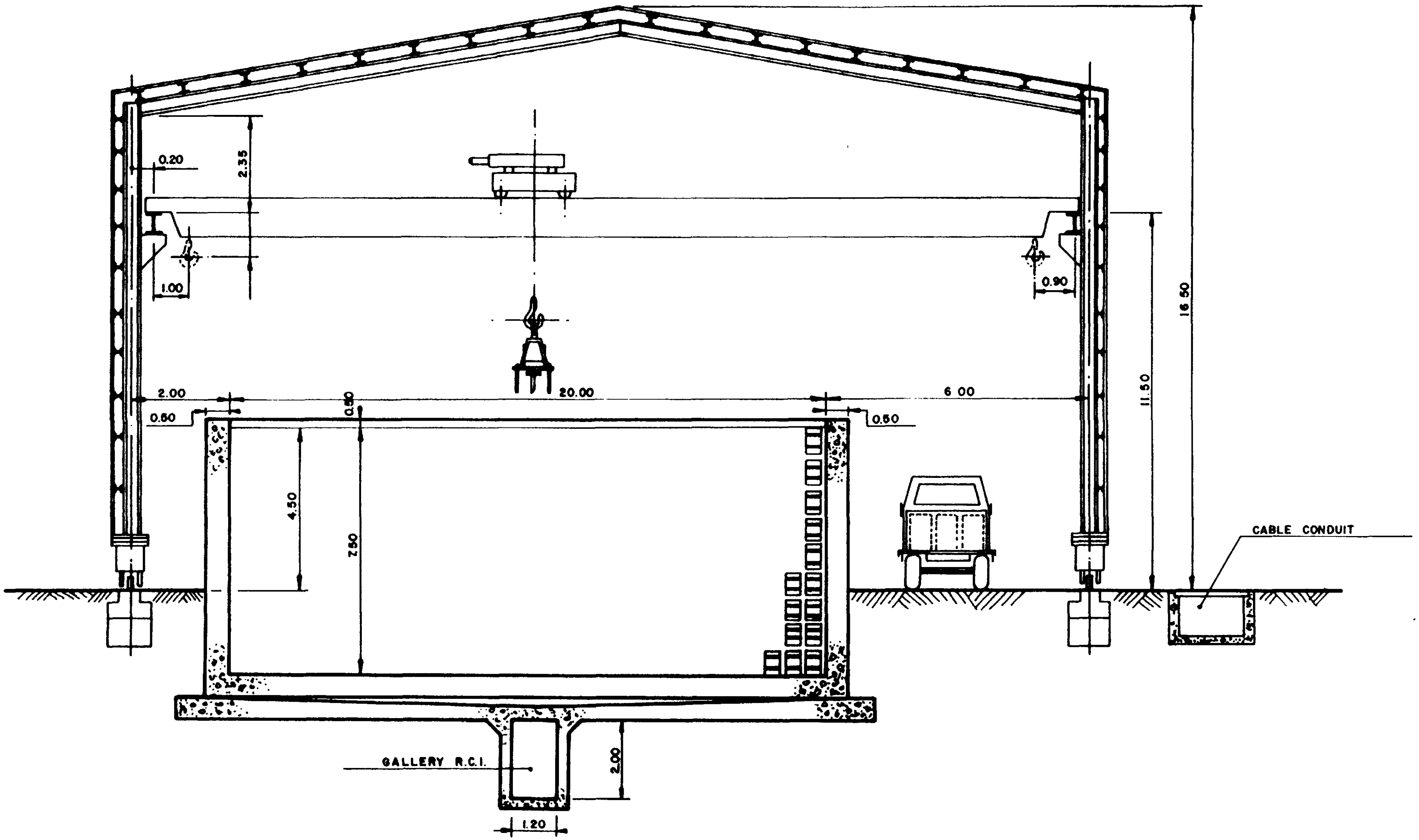


FIGURE-3
VAULT SECTION

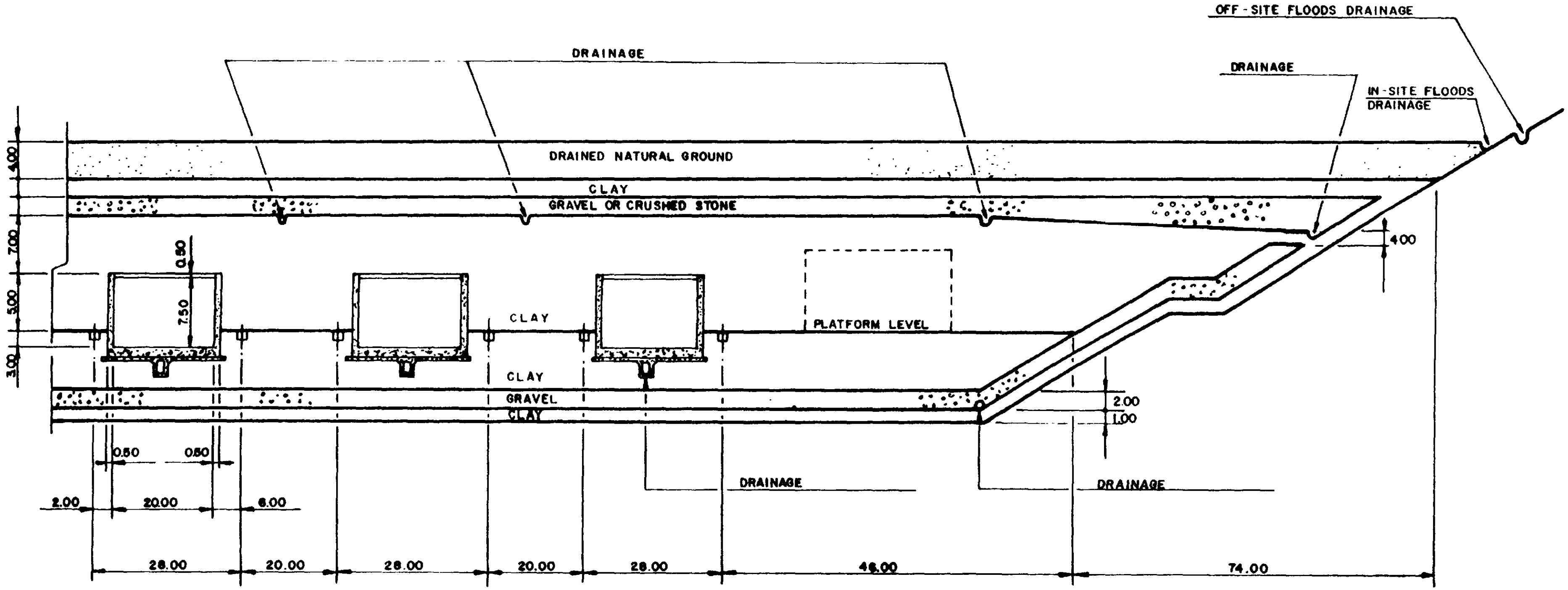


FIGURE-4

DISPOSAL AREA FINAL

LEGEND

① SELECTION OF SITE WITU DEEP WATER TABLE LEVEL SO THAT DISPOSAL VAULTS ARE NOT AFFECTED BY WATER

② IF SMALL WATER FLOWS SHOULD EXIST IN UPPER LEVELS, DIVERSION WORKS AND IMPERMEABILIZATION SEREENS SHOULD BE IMPLEMENTED

③ OFF-SITE FLOODS DRAINAGE

④ IN-SITE FLOODS DRAINAGE

⑤ DRAINEGE OF POTENTIAL INFILTRATION WATER THROUGH TOP SURFACE LAYER.

⑥ INFILTRACTION WATER SYSTEM DRAINAGE TO CONTROL POAD Nº1

⑦ SITE EXCAVATION DRAINAGE TO CONTROL POAD Nº2

⑧ DEEP DRAINAJE OF WATER TABLE TO EXIT Nº3 IF NECESSARY OR ELSE EQUIVALENT FLOW CONTROL

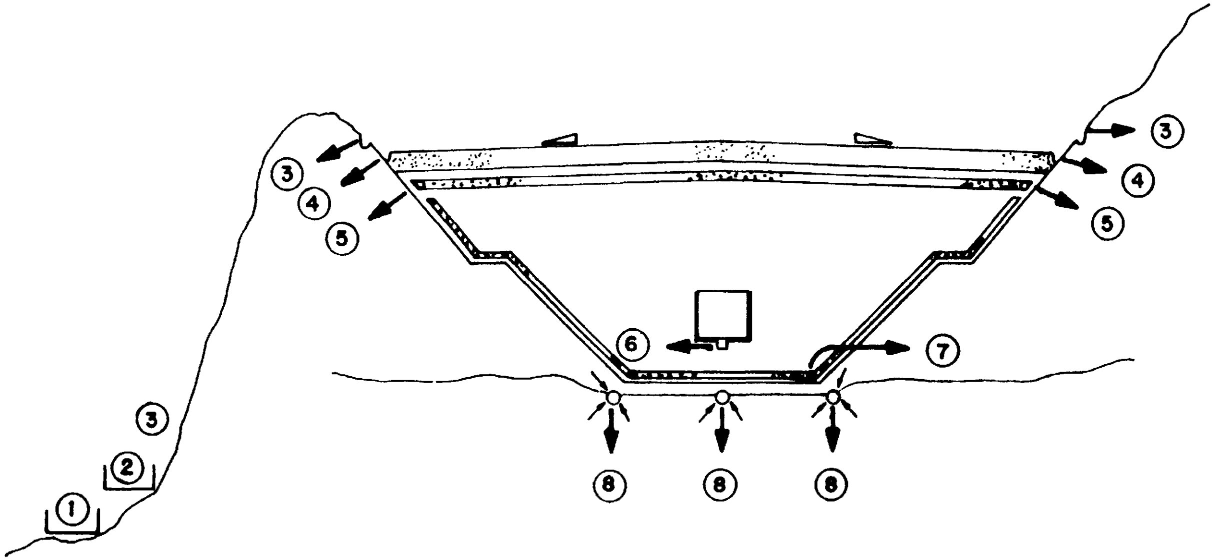


FIGURE-5

DRAINAGE PROCEDURE DIAGRAME

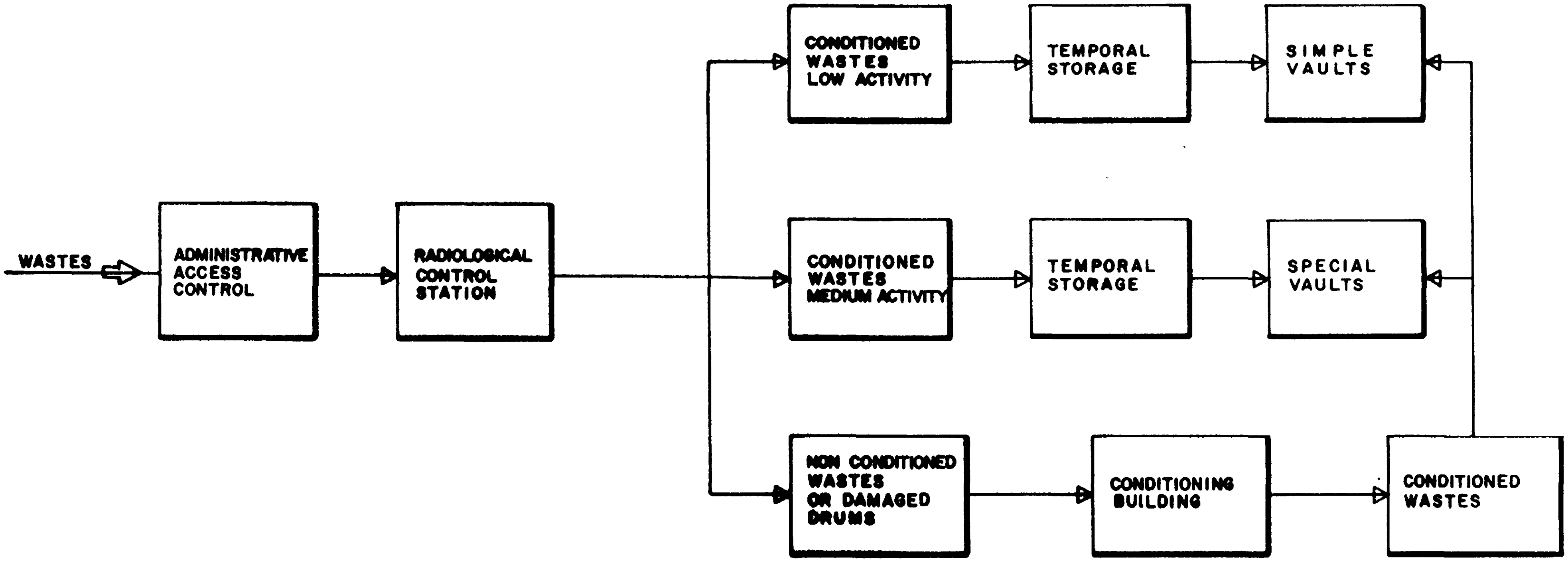


FIGURE - 6

GENERAL WASTES FLOW CHART

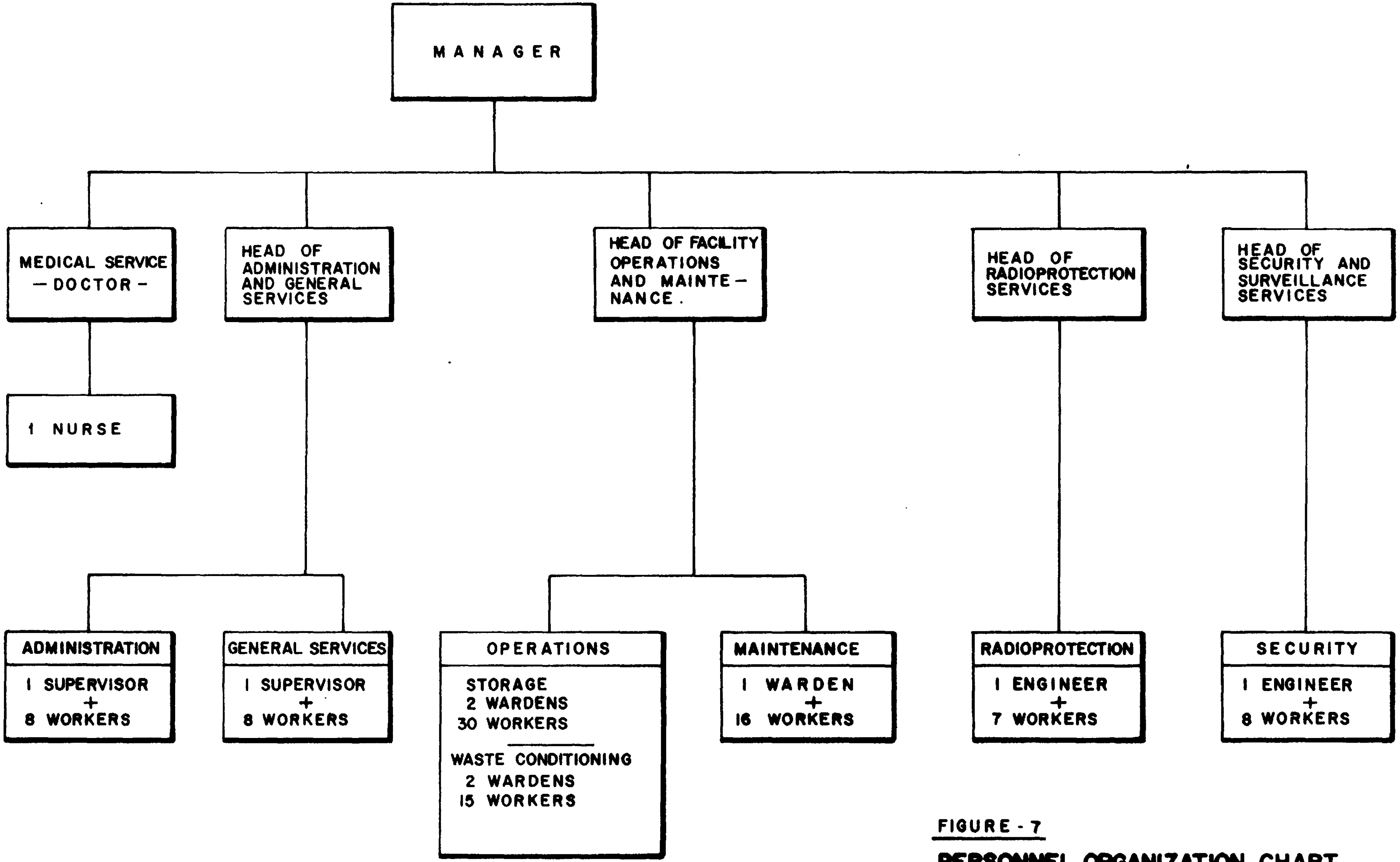


FIGURE - 7

PERSONNEL ORGANIZATION CHART

3. OCCUPATIONAL EXPOSURE

Occupational exposure has been determined on a per shipment basis for the two types of packages envisaged to be accepted in the faciliting.

A list of operational tasks for major activities has been developed for each package type.

Major activities include reception of shipments, transportation to the disposal site, waste disposal, monitoring and closure of the facility, and are listed in table V. The following information has been taken into account for estimating occupational exposure.

- Workers involved in the performance of each task.

- Representative distances from workers to waste packages while performing each task.

- Time required to complete the task.

- Exposure rates at representative distances from the waste packages, assuming that exposure to a 1R would result in a dose equivalent of 1 rem.

The worker requirements for the various operations have been estimated taking into account the specific characteristics of the facility as well as references of other operating facilities.

Representative distances from waste to workers were based in the review of the activities to be performed and the facility layout. For most waste handling activities, workers are located at varying distances from the waste at different times, thus the distances selected: 1 m, 3 m and 5 m, represent close, intermediate and distant contact with waste packages. Doses calculated represent mean values.

The time required to complete a task is also given in table V for each shipment. For certain tasks, such as backfilling and area survey operations, completion times are not associated to a shipment of waste. Completion times for these cases have been estimated by two different methods as a function of the type of activity. The first method divides the time required for a certain activity performed on a daily basis, e.g. area survey, by the average number of shipments per day in the facility. In the second case, for activities that are performed a few number of times over the life of the facility, such as operations associated to closure, the estimated time for completing them was divided by the number of shipments required to fill the facility.

Average concentrations of representative radionuclides in low level wastes are given in table II.

Two cases have been analyzed for two different radioactivity spectra. In the first case the specific activities correspond to the values and spectrum used in the radiological impact analysis (See chapter 4). In the second case, the values and spectrum correspond to the ones supplied by other contractors of the project.

Table III summarizes characteristics of the reference package types provided by process designers.

Data in tables II and III were used to calculate the radiation exposure rates from several waste package configurations using a gamma shielding computer code.

Waste package configurations considered are shown in figures 8 and 9.

Three separate estimations of exposure have been performed taking into consideration the three types packages of mentioned. Weighting factors are to be applied for obtaining the exposure when the three types of packages are handled at the facility.

It has been assumed that a shipment consists of a total of 48 drums arranged in 12 pallets of 4 drums each and that 417 shipments are handled each year. This study assumes that there is no difference in waste handling techniques among the wastes with different radioactivity content.

The results obtained are shown in table V for the source terms and types of containers (metal drums and concrete container) considered in the study.

Projected annual collective doses range between 0.21 to 0.65 person-Sv/a and from 5.24 E-5 to 1.64 E-4 person-Sv/m^3 for the different sources and packages considered. Accordingly annual average individual doses range from 1.05E-2 to 3.27E-2 Sv/a and 2.62E-6 to 8.18E-5 Sv/m^3.

TABLE II

AVERAGE CONCENTRATIONS FOR REPRESENTATIVE RADIONUCLIDES IN WASTES

	Concentrations			
	Rad. Impact Values		Contractors Input	
Isotope	(Ci/m^3)	(Bq/m^3)	(Ci/m^3)	(Bq/m^3)
H-3	9.25 - 3	3.42 + 8		
C-14	1.89 - 3	7.00 + 7		
Co-58			8.3 - 1	3.07 + 10
Mn-54			6.0 - 2	2.22 + 9
Fe-59			4.5 - 3	1.67 + 8
Ni-59	1.22 + 1	4.51 + 11		
N-63	1.24	4.59 + 10		
Co-60	9.50 - 3	3.51 + 8	2.8 - 1	1.04 + 10
Sr-90	3.38 - 3	1.25 + 8		
Nb-94	1.23 - 4	4.55 + 6		
Tc-99	2.73 - 5	1.01 + 6		
Ag-110m			6.0 - 2	2.22 + 9
I-129	7.34 - 5	2.72 + 6		
Cs-134			7.45 - 2	2.76 + 9
Cs-135	2.73 - 5	1.01 + 6		
Cs-137	7.30 - 1	2.70 + 10	1.6 - 1	5.92 + 11
Np-237	7.36 - 11	2.72		
U-238	3.01 - 6	1.11 + 5		
Pu-238	6.95 - 3	2.57 + 8		
Pu-239	9.17 - 3	3.39 + 8		
Pu-241	1.84 - 1	6.81 + 9		
Am-241	4.62 - 5	1.71 + 6		

TABLE III

PACKAGE TYPES

Type	Material	Volume (m^3)	Wall thickness (cm)
Drum	Steel	0.2	0.15
CI Container	Concrete	0.95 (inner)	15
CIV Container	Concrete	0.5 (inner)	15

TABLE IV

DOSE RATE AT DEFINED DOSE POINTS FOR DIFFERENT SOURCES
(METAL DRUMS)

ARRANGEMENT 1

	Dose Rates (mrem/h)		
	P1	P2	P3
Source 1	20.6	2.9	1.1
Source 2	90.4	13.4	5.1

ARRANGEMENT 2

	Dose Rates (mrem/h)					
	P1	P2	P3	P4	P5	P6
Source 1	34.0	5.7	2.2	45.2	12.0	5.2
Source 2	153.3	26.1	10.2	204.8	54.4	23.6

Source 1 : Radiological Impact values

Source 2 : Project contractors values

TABLE IV

(CONCRETE CONTAINERS)

		Dose Rates (mrem/h)		
		P1	P2	P3
CI	Source 1	1.2-2	4.1-3	2.04-3
	Source 2	8.9-2	3.1-2	1.6-2
CIV	Source 1	2.2-3	8.3-4	4.2-4
	Source 2	2.1-2	7.8-3	4.0-3

TABLE V
SUMMARY OF RESULTS

				DRUMS				CONCRETE CONTAINERS			
	No. Persons	Distances (m)	Time (Min/Sp)	DOSE RATE (mSv/h)		DOSE (Person Sv/Sp)		DOSE RATE (mSv/h)		DOSE (Person Sv/Sp)	
				S1	S2	S1	S2	S1	S2	S1	S2
1. Receiving shipment											
. Survey of shipment	1 (Tech)	1	10	0.45	2.04	7.55-5	3.42-4	1.2-4	8.9-4	2.0-8	1.49-7
		3	5	0.12	0.54	9.96-6	4.52-5	4.1-5	3.1-4	3.40-9	2.57-8
. Check-in truck	1 (QA)	1	2	0.45	2.04	1.49-5	6.76-5	1.2-4	8.9-4	3.96-9	2.94-8
		3	5	0.12	0.54	9.96-6	4.52-5	4.1-5	3.1-4	3.40-9	2.57-8
. Waste transport to interim storage	1 (Heavy EQ)	1	5	0.45	2.04	8.75-5	1.70-4	1.2-4	8.9-4	9.96-9	7.39-8
		3	10	0.12	0.54	2.0-5	9.08-5	4.1-5	3.1-4	6.85-9	5.18-8
	1 (Tech)	3	5	0.12	0.54	9.96-6	4.52-5	4.1-5	3.1-4	3.40-0	2.57-8
2. Shipment transportation to disposal site	1 (Heavy EQ)	3	10	0.12	0.54	2.0-5	9.08-5	4.1-5	3.1-4	6.85-9	5.18-8
3. Waste disposal	1 (Tech)	*	120	0.75-2		1.5-4					
	1 (Heavy EQ)	*	120	0.75-2		1.5-4					
4. Monitoring activities	2 (Tech)	N.A.	10	2.5-2		1.0-5					
		1	5	0.45	2.04	7.5-5	3.4-4	1.2-4	8.9-4	1.99-8	1.58-7
5. Facility closure and backfill operations											
. Add backfill	2 (Heavy EQ)	N.A.	5	2.5-2		4.2-6					
. Site reclamation	2 (Heavy EQ)	N.A.	5	2.5-3		4.2-7					
6. Support activities											
. Waste conditioning	2 (Tech)	N.A.	40	7.5-3		10-5					
. Maintenance operations	1 (Maint)	N.A.	10	7.5-3		1.25-6					
	1 (Maint)	N.A.	5	2		1.7-4					
. Decontamination	1 (Tech)	N.A.	30	2.5-2		1.2-5					
	1 (QA)	N.A.	30	7.5-3		3.7-6					
	1 (Foreman)	N.A.	30	7.5-3		3.7-6					

* Operation from Control Station

Sp Shipment

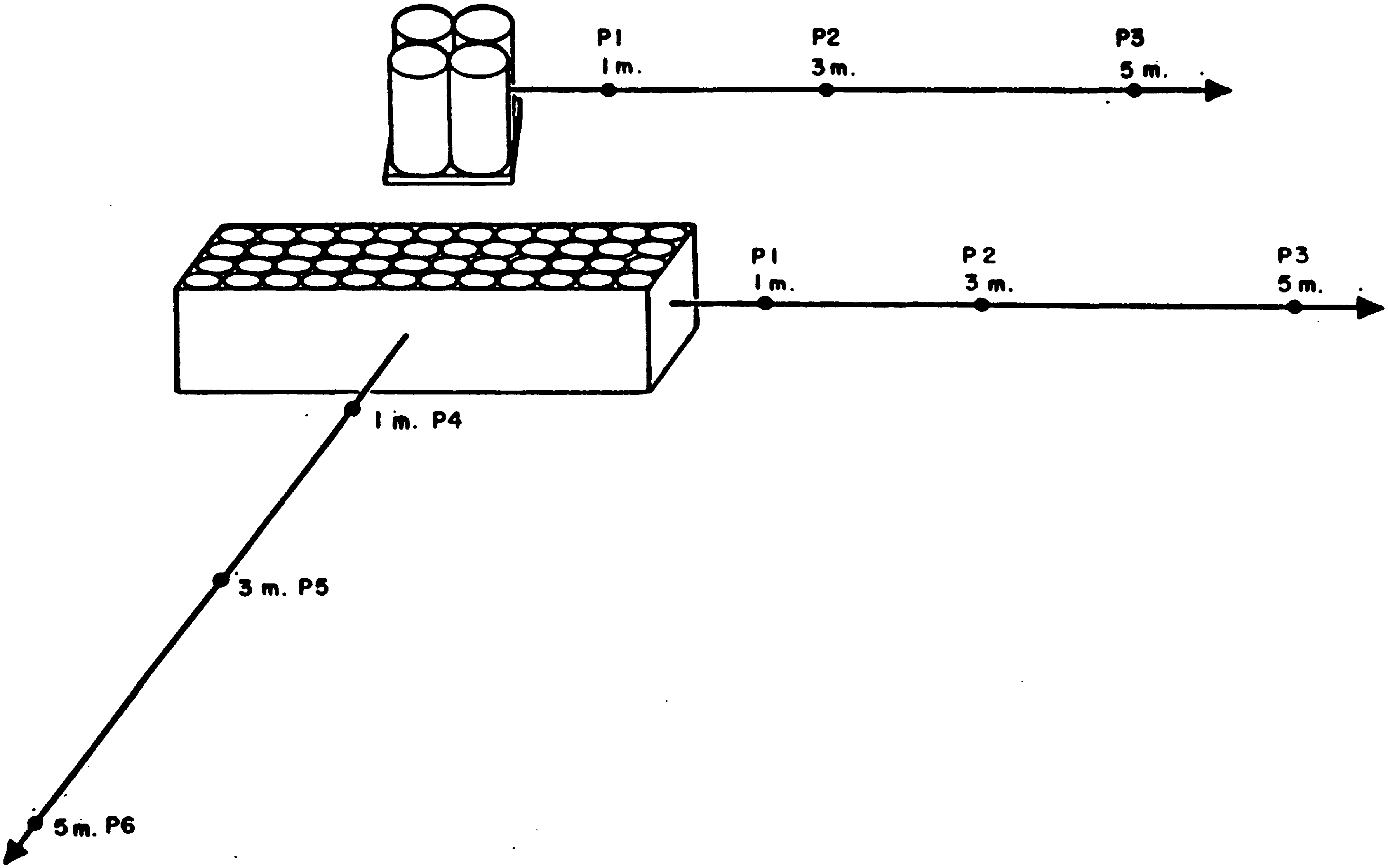


FIGURE 8
Waste Packages Configurations

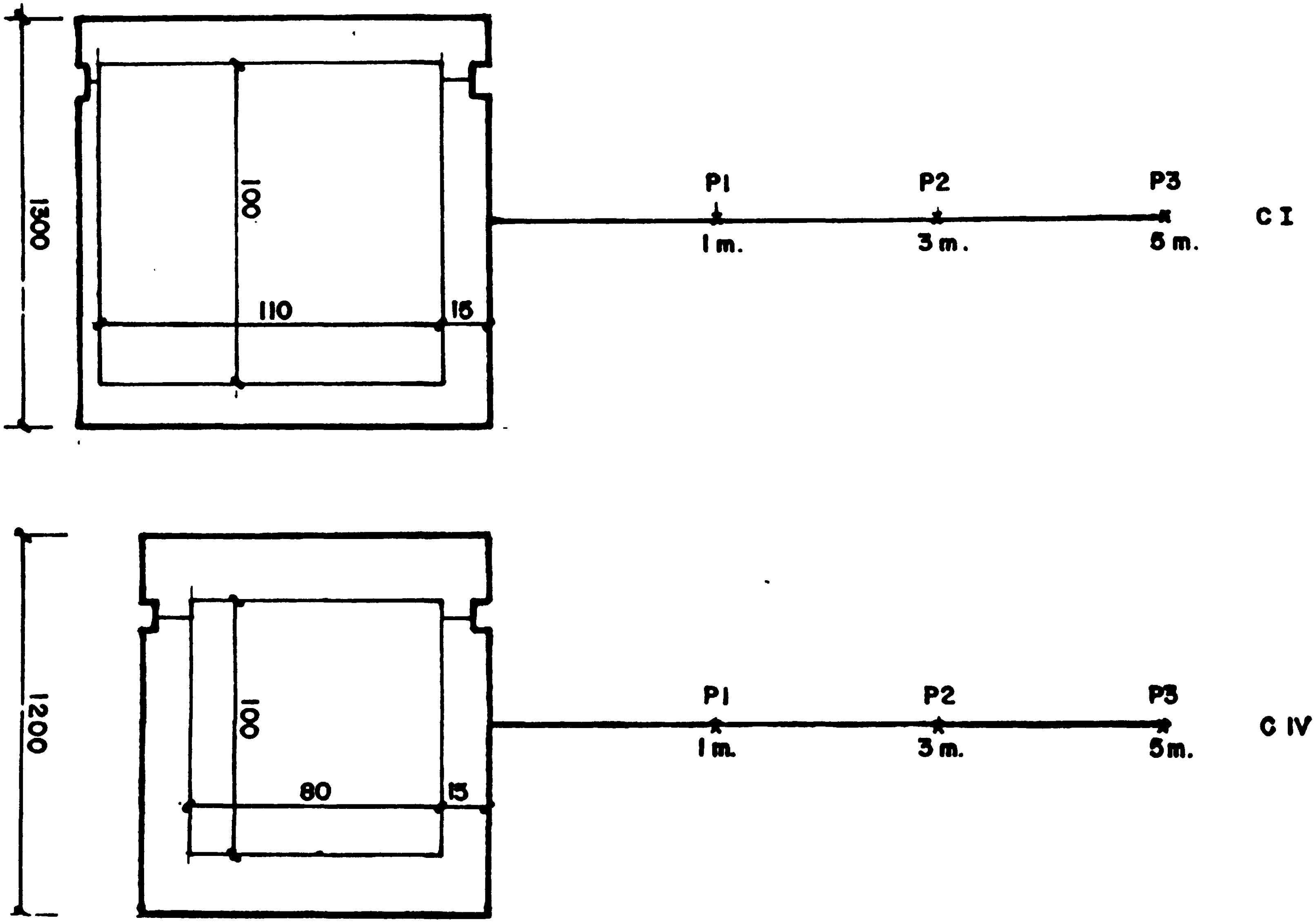


FIGURE 9
Waste Packages Configurations

4. RADIOLOGICAL IMPACT TO THE PUBLIC

The main hypothesis used in the definition of the "normal evolution scenario" such as capacity and operation time have been already presented in previous sections. Other hypotesis are the following.

- The calculation of the total activity in the different waste streams for the radionuclides considered (T1/2 5 years) is based on the models and normalized data of (1).

- The values for the "Annual Lixiviation Fractions" used in the analysis correspond to those specified as maximum acceptable for concrete inmobilized waste in the acceptance criteria (2).

- A period of institutional control over the disposal site is assumed, extending over 300 years after the closure date. The cover against infiltration is assumed to remain effective during this period.

- It is assumed that the degradation of waste packages follows a normal law, characterized by a means time (time at which 50% of the packages will be degraded) and the standard deviation.

- It is assumed that only the degraded packages are subject to lixiviation by percolating water.

- It is assumed, conservatively, that after the end of the institutional control period the lixiviation rate of the degraded packages corresponds to the full values of the acceptance criteria, regardless of the effective values of water infiltration and soil saturation. During the institutional control period, it is assumed that the lixiviation rate of the degraded packages corresponds to 13% of the full values, fraction that corresponds to the initial saturation percentage of the clay in the cover.

- Water that percolates and lixiviates the waste packages is assumed to reach the underlying aquifer, where it is transported and diluted with the general ground water flow.

- It is assumed that the aquifer discharges to a river located at a short distance (1 Km) from the disposal site. The activity discharged is mixed there uniformly with the river flow.

- It is assumed that a certain distance downstream from the discharge area, water is pumped from the river and used for human and animal consumption, as well as for irrigation of a piece of land in which vegetables for human and animal consumption are grown.

The specific methodology used in the individual dose calculation is based on that presented in (3), that reflects the practical implementation of the recommendation of reference (2) and is conformed to standard practices in dose calculation.

4.1. ASSESSMENT OF MAXIMUM INDIVIDUAL DOSES

The expected calculated inventory of radionuclides in the wastes received and stored during the 30 years of operation of the facility are shown in the Table VI.

A summary of other calculation hypothesis and parameters is presented in table VII.

In Table VIII a summary of the maximum annual effective committed doses for each age group are presented.

The maximum value of annual effective committed dose corresponds to the age group of infants, with the value of 1.14E-5 Sv/a (1.14 mRem/a) most of it due to the ingestion of Ni-59 in contaminated milk. This maximum value corresponds to a time of 960 years after the closure of the installation.

The maximum doses to adults are an order of magnitude lower, with a value of 1.91E-6 Sv/a (0,19 mRem/a) at 1184 years after the closure of the installation.

In addition to the doses due to the expected inventory, those due to individual inventories of 1TBq for each one of the most important radionuclides have been calculated.

The radionuclides with a greater radiological impact on a 1 TBq basis are, in this order, I 129, Nb 94, Cs135, Tc99, Np237 and, Pu239, their maximum values ranging from 3.2E-6 to 2.08E-8 Sv/a and times of maximum from 8 to 2980 years after closure.

4.2. ASSESSMENT OF COLLECTIVE DOSES

The calculation of collective doses received by the population potentially affected by the disposal facility has the following scopes:

- In a first calculation, the annual expected collective committed doses, both for the expected inventory and for 1 TBq of each nuclide, have been calculated, based on the results of individual doses and the model and assumptions presented below.

- Time integrated collective committed doses over a time span of 10^7 years have been calculated by numerical integration of annual doses.

- Since most of the dose is received via ingestion of contaminated food, the collective dose calculation has been centered on an ingestion scenario defined as follows:

  . Contaminated water percolates through the disposal facility reaching eventually a small river, located 1 Km from the site, with an average flow of 1 m^3/s. This river discharges into a larger one 10 Km downstream the infiltration discharge point.

  . A 10 meters wide strip of land on one of the banks of the small river banks is used for farming, stretching over the 10 Km distance up to the discharge on the intermediate river. River water is used for irrigation.

  . The intermediate river, with an average flow of 50 m^3/s. discharges into a large river 90 Km downstream its confluence with the small river.

  . A strip of land, 500 m wide and 90 Km long, on one of the banks of the intermediate river is used for farming and it is irrigated with river water.

  . The large river, with an avergange flow of 500 m^3/s, discharges into the sea 100 Km downstream of the confluence with the intermediate river.

  . A strip of land, 1 Km wide and 100 Km long, situated on one of the banks of the river is used for farming and it is irrigated with river water.

  This model is depicted schematically in figure 10.

The following assumptions are made with regard to the dose calculations:

- The number of persons potentially exposed in each one of the areas (river banks) is assumed to be equal to the population potentially fed by the farming products obtained in the area.

- It is assumed that each area lives in autarchy, i.e. there is no export nor import of food, being produced in the area 100% of each food type required.

- The required farming surface for each age group has been determined using the corresponding food consumption rates and terrain yield.

- The number of each age group individuals supported by each area is calculated using the assumed age group distribution.

- Representative individual annual committed doses for each one of the areas are calculated from the maximum exposed individual results considering dilution as the only reduction factor, and are assumed to be uniform in each area. Collective committed doses are calculated multiplying the number of individuals exposed by representative doses.

- Time integrated collective committed doses are calculated assuming that the population exposed is constant during the integration period of 10^7 years.

The calculation results are presented in Table IX for the expected inventory.

Maximum annual committed collective dose is 5.91E-3 Man Sv/a and occurs at 2660 years disposal time.

Committed collective doses integrated in 10^7 years is 55.47 Man-Sv.

Maximum annual committed colletive dose for 1TBq inventory for each nuclide occurs for I-129 and is 1.32E-2 Man Sv/a at 333 years disposal time.

Committed collective doses integrated over a period of 10^7 years is 2.08 Man-Sv for Np-237.

TABLE VI

EXPECTED INVENTORY

BASES:

- 20 GWE (75% PWR, 25% BWR), 30 Yrs Operation
- NUREG-1759 Spectra and normalized quantities
- Alfa Activity normalized to 0.1 CI/TM (0.01 CI/TM after 300a)
- Total waste volume = 120000 M^3
- Total waste mass = 240000 TM

EXPECTED INVENTORY IN 30 YEARS

Nuclide	CI	TBQ	BQ/m^3
H 3	1.11E+3	4.11E+1	3.42E+8
C 14	2.27E+2	8.40E+0	7.00E+7
FE 55	1.61E+6	5.96E+4	4.97E+11
NI 59	1.14E+3	4.22E+1	3.51E+8
CO 60	1.46E+6	5.40E+4	4.51E+11
NI 63	1.49E+5	5.51E+3	4.59E+10
NB 94	1.48E+1	5.48E-1	4.55E+6
SR 90	4.06E+2	1.50E+1	1.25E+8
TC 99	3.27E+0	1.21E-1	1.01E+6
I 129	8.81E+0	3.26E-1	2.72E+6
CS 135	3.27E+0	1.21E-1	1.01E+6
CS 137	8.76E+4	3.24E+3	2.70E+10
U 238	3.61E-1	1.34E-2	1.11E+5
PU 238	8.34E+2	3.09E+1	2.57E+8
U 239	1.10E+3	4.07E+1	3.39E+8
PU 241	2.21E+4	8.18E+2	6.81E+9
AM 241	5.55E+0	2.05E-1	1.71E+6
NP 237	8.83E-6	3.27E-7	2.72E+0
U 235	4.57E-2	1.69E-3	1.41E+4
PU 242	2.40E+0	8.88E-2	7.40E+5
AM 243	3.74E-1	1.38E-2	1.15E+5
CM 243	2.17E-1	8.03E-3	6.69E-4
CM 244	4.70E+0	1.74E-1	1.45E+6

TABLE VII

EXPECTED INVENTORY, RIVER CASE

CHARACTERISTICS OF CONTAINERS USED

TYPE 1: Concrete Vaults

Half Life = 500 (a) .... STD. Dev. = 150 (a)
Total volume in
Storage = 120000 (m^3) .... Filling time = 30 (a)

SITE HYDROGEOLOGICAL CHARACTERISTICS (NON SATURATED ZONE NOT TAKEN INTO ACCOUNT)

Saturated zone parameters

Hydraulic conductivity (k) (m/day)	8.6400
Hydraulic gradient	0.0500
Longitudinal dispersivity (m)	90.0000
Transversal dispersivity (m)	9.0000
Effective porosity	0.2200
Soil density (g/cm^3)	1.6000

EVALUATION POINTS PARAMETERS

N	Name	Distance (m)	Type	Width (m)	Depth (m)	Flow (m^3/d)
1	River	1000.00	River	20.00	86.400.	1.73E + 06

TABLE VII (Cont.)

EXPECTED INVENTORY, RIVER CASE

RIVER SCENARIO SPECIFICATION

Annual Average River Flow (m^3/a) ...... 3.15E + 07

EXPOSURE PATHWAY: DRINKING WATER

Adult annual intake (l/a)	438,0
Children annual intake (l/a)	306,0
Infant annual intake (l/a)	198,0

IRRIGATION SCENARIO CONSIDERED

EXPOSURE PATHWAY: INHALATION IN FIELD

Annual adult presence time (h/a)	2000,00
Annual children presence time (h/a)	1000,00
Annual infant presence time (h/a)	365,0

Air mass loading option selected with 0.10 (mg/m^3)

EXPOSURE PATHWAY: TERRESTRIAL FOOD INGESTION

	Annual usage factors (Kg/a or l/a)		
Food type	Adult	Child	Infant
Leafy vegetables	9.5	10.0	0.0
Leguminous	9.5	10.0	0.0
Potatoes and roots	76.0	80.0	0.0
Fruits	42.0	44.2	0.0

TABLE VII (Cont.)

EXPECTED INVENTORY, RIVER CASE
CHARACTERISTICS OF CONTAINERS USED

	Annual usage factors (Kg/a or 1/a)		
Food type	Adult	Chield	Infant
Wheat	51.0	53.7	0.0
Eggs	19.0	7.4	0.0
Milk	110.0	170.0	170.0
Cow meat	39.0	15.2	0.0
Pork	29.0	11.3	0.0
Poultry	8.5	3.3	0.0

EXPOSURE PATHAWAY: FISH INGESTION

Adult annual ingestion (Kg/a)	6.9
Children annual ingestion (Kg/a)	2.2
Infant annual ingestion (Kg/a)	0.0

EXPOSURE PATHAWAY: ACUATIC INVERTEBRATE INGESTION

Adult annual ingestion (Kg/a)	1.0
Children annual ingestion (Kg/a)	0.3
Infant annual ingestion (Kg/a)	0.0

TABLE VIII

SUMMARY OF MAXIMUM ANNUAL EFFECTIVE COMMITED DOSES

	Population Group		
	Adults	Children	Infants
Max. annual dose (sv/a)	8.722E-07	9.351E-07	6.786E-07
Time of maximum (years)	2.658E+03	3.768E+02	3.768E+02

TABLE IX

RESULT OF COLLECTIVE DOSES CALCULATION (EXPECTED INVENTORY, RIVER CASE SCENARIO)

a) Maximum annual committed collective doses (Man-Sv/a) and time of occurrence (years) per population group.

Adults	Time	Children	Time	Infant	Time	Total	Time
5.30E-03	2660	6.05E-04	2660	3.56E-06	1780	5.91E-03	2660

b) Committed collective doses integrated in 10E+7 years (Man-Sv):

55.47

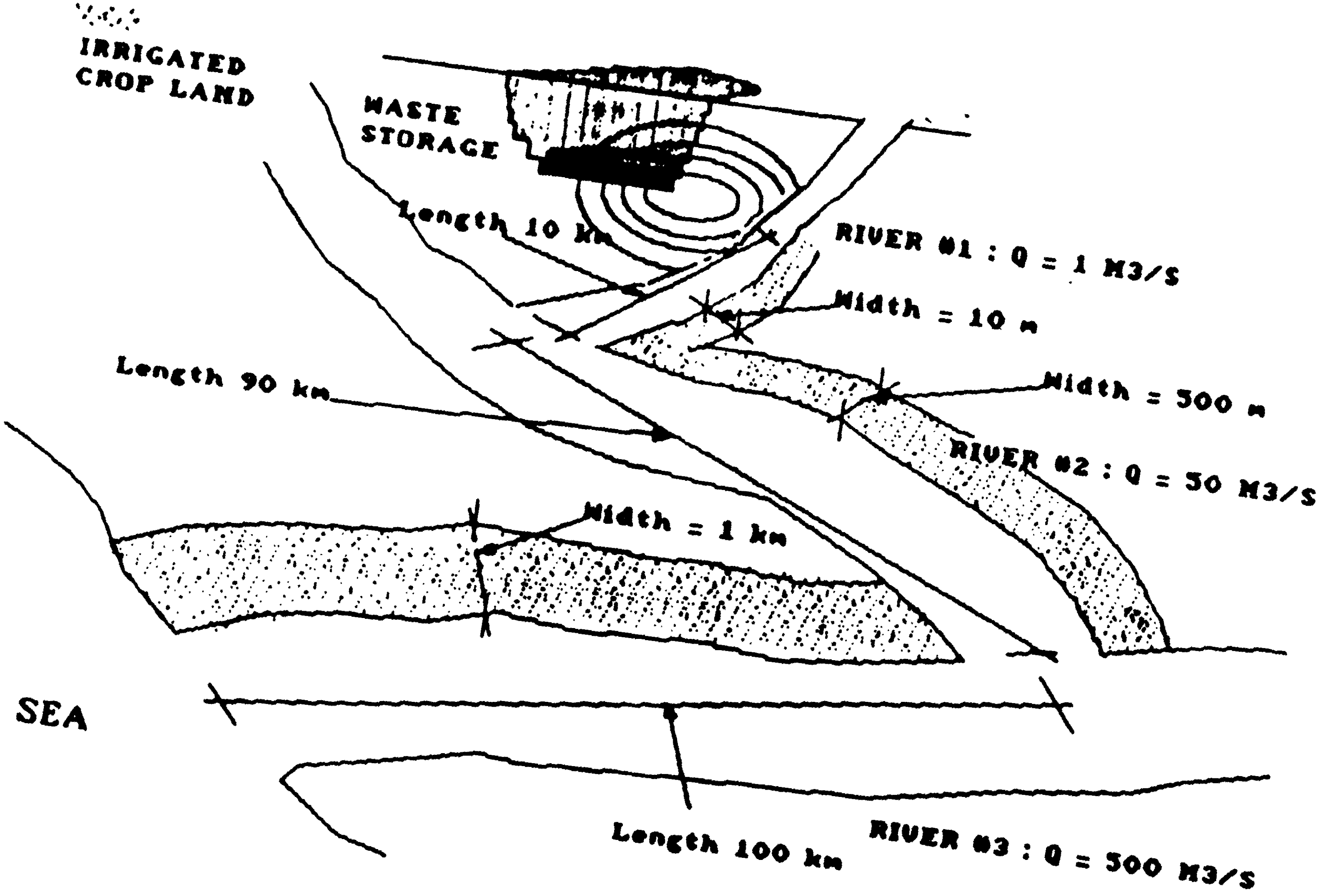


FIGURE 10
Collective Dose Model

5. COST ASSESSMENT

The objective of this chapter is to evaluate the cost of a Below Ground Vault facility based on the capacity linked to the operation of a 20 GWE PWR Nuclear Park.

Concerning capital cost the following assumptions have been made:

- Site works include acquisition and preparation costs.

- 20% of civil wworks in vaults construction is carried out before start up date.

- QA and indirect labour are calculated as a percentage of direct cost from civil works, vaults construction and major equipment and bulk materials.

- Architectural and engineering services are assumed to represent 16.2% of the direct capital cost.

Concerning operating costs the following assumptions have been made:

- Salary scales for operator are assumed of 13 ecu/h and for higher labour categories 25 ecu/h.

- 80% of civil work in vault construction is performed along the life of the facility.

- Decommissioning cost has been converted into a constant annual cost which should be invested at 10% of interest rate.

The actualization procedure is based on the following assumptions:

- Date of actualisation	01.01.93 (start-up)
- Construction period	3 years (1990-1993)
- Annual rate of interest	8% a^{-1}
- Annual rate of inflation	3% a^{-1}
- Return on investment (provissions for decommissioning)	10% (Nominal)
- Spot price	130.9 Pta/Ecu

Money was assumed to be borrowed at the middle of the duration period of each activity and paid back at the end of the construction period.

The cost determination sheme provided in (4) has been followed.

Decommissioning costs have been evaluated on the following basis:

- Investment required	61137 Kecu$_{89}$
- Inflation rate	3% (e)
- Expected ROI	10%
- Decommissioning cost (30 years after start-up)	162157 Kecu$_{2022}$

- Decommissioning annual cost:

$$C = \frac{162{,}157}{1{,}1 \times \frac{1{,}1^{30} - 1}{1{,}1 - 1}} = 896\ \mathrm{Kecu}_{93}$$

- Decommissioning cost per cubic meter is 224 $\mathrm{Ecu/m^3}$

Total cost per unit volume of waste is 2484 Ecu_{93}.

Breakdown of cost is represented in figures 11, 12, 13 and 14.

Operating costs are major contributors to total cost with 63%, being direct labour the most significant (32%). Next in order of importance is site works, including site preparation activities prior to construction and final activities, such as construction of the cover layers. They contribute with 17% to total cost.

Vault construction activities are split in capital and operating costs and altogether represent 15% of total cost.

In this total, 10% corresponds to construction of single vaults and 5% to special vaults.

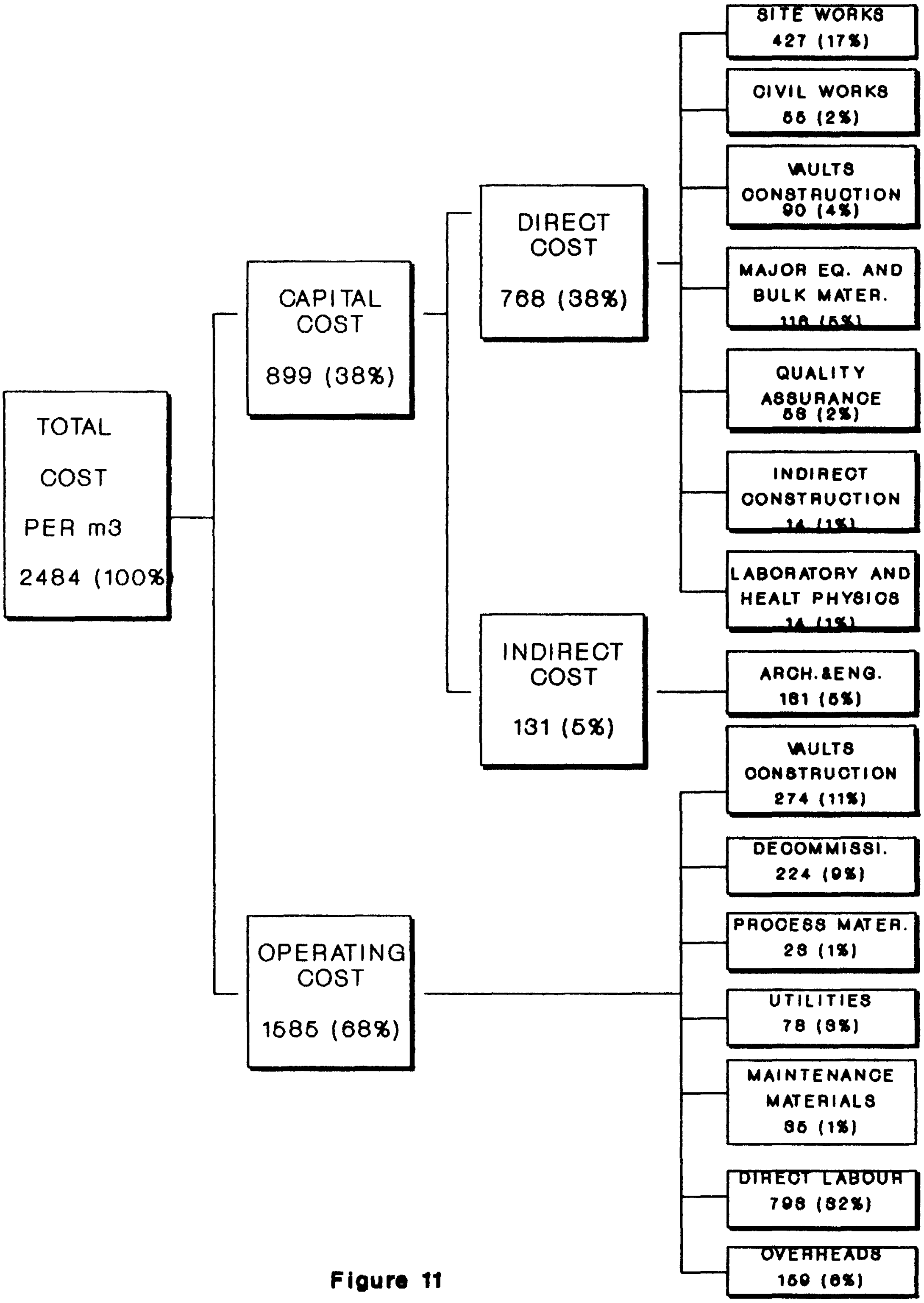


Figure 11

UNIT CAPITAL AND OPERATING COST

CONTRIBUTION TO THE TOTAL COST (ECU/m3 OF WASTE)

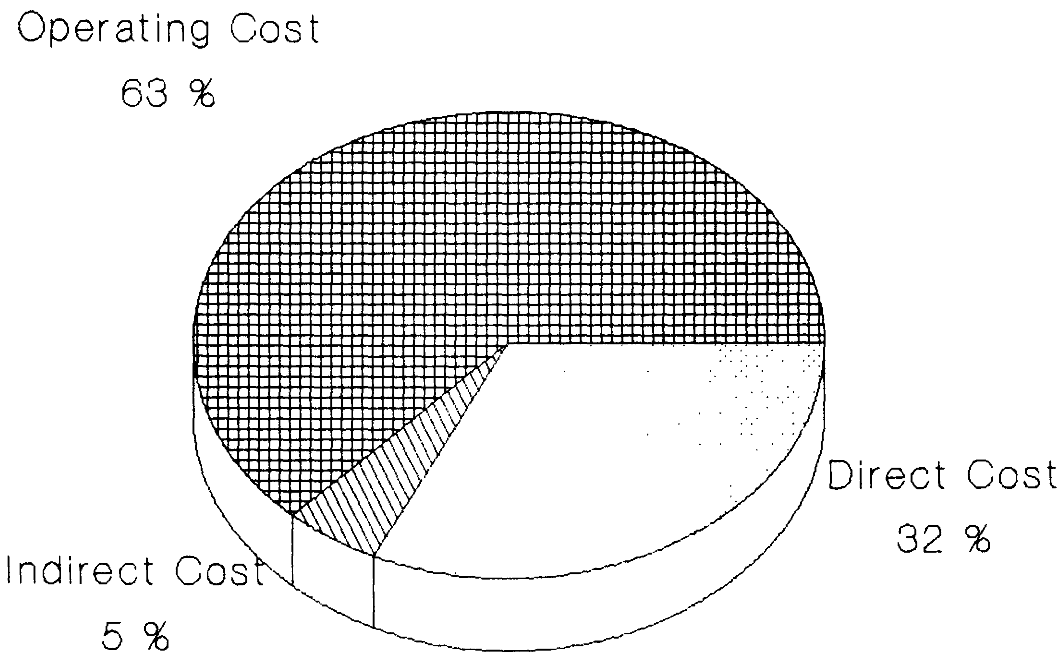


Figure 12

Total Costs Structure

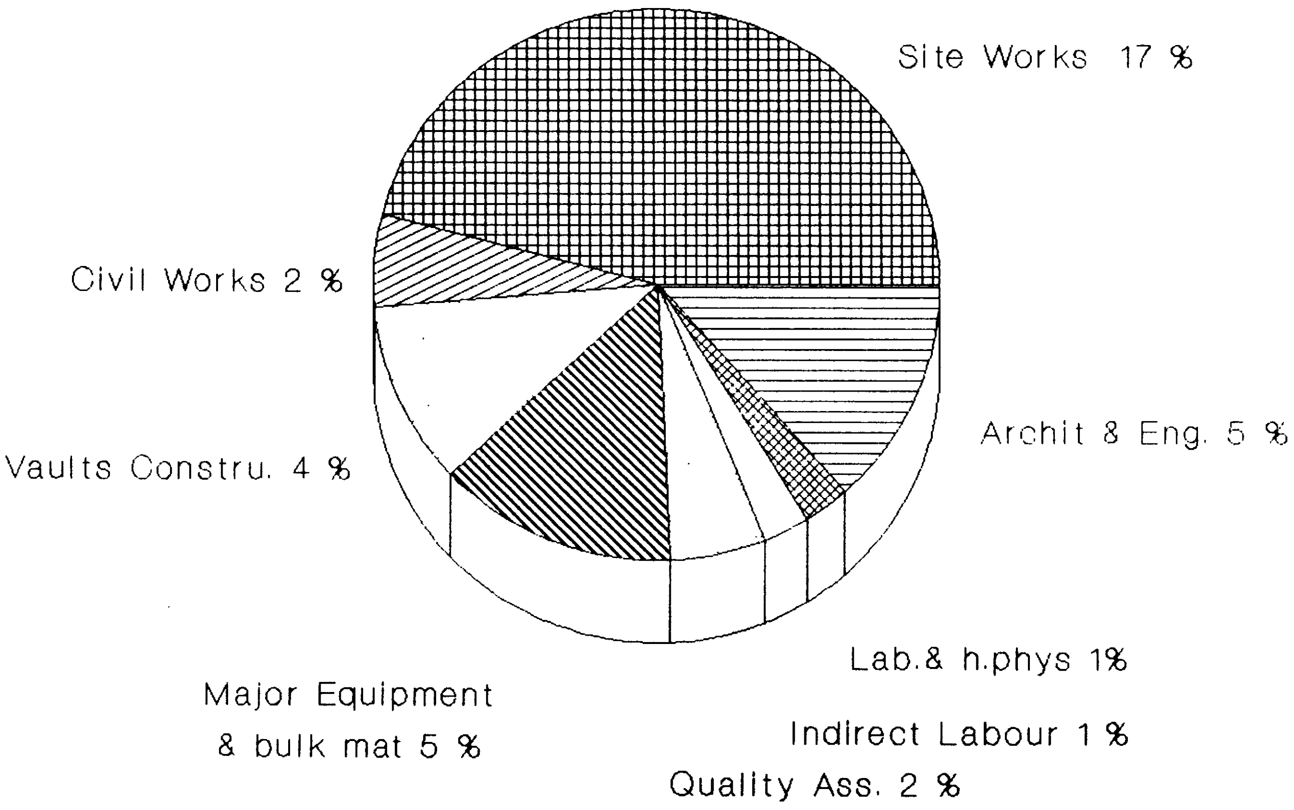


Figure 13

Capital Cost Structure

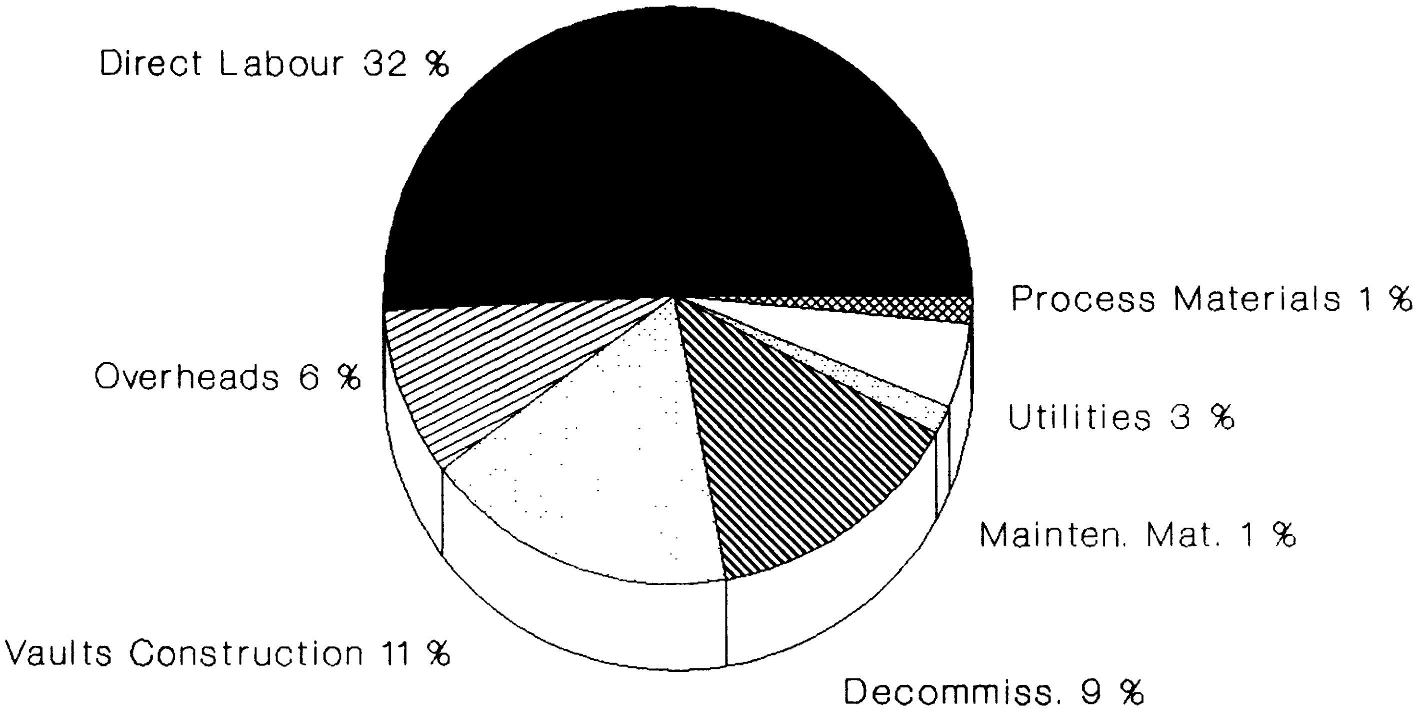


Figure 14

Operating Cost Structure

6. CONCLUSIONS

Disposal of reactor wastes in below ground vaults is a near surface disposal option which has been assessed in terms of radiation protection and cost.

The construction and operation of a below ground disposal facility involves more costly techniques than those required for above ground options, even if no excavation is required and this overall costs are significantly high (2484 Ecu_{93}/m^3 of conditioned waste).

On the other hand the maximum value of annual effective committed dose to the critical members of the public for the limiting inventory of radioactivity is 1.14×10^{-2} mSv/a, well below ICRP limits (1 mSv/a).

Occupational exposure has not been found to be significantly different from other disposal alternatives since it is largely due to maintenance, monitoring and shipment survey activities.

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EUR 14043 – Assessment of management alternatives for LWR wastes
(Volume 8)
Cost and radiological impact associated with near-surface disposal of reactor waste (Spanish concept)

S. Alamo Berna, N. Sanchez Delgado

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This report deals with the determination of the cost and the radiological impact associated with a near-surface disposal site (Spanish concept) for low and medium-level radioactive waste generated during operation of a 20 GWe nuclear park composed of LWRs for 30 years.

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