QA:L

Civilian Radioactive Waste Management System
Management & Operating Contractor

Enhanced Design Alternative IV

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Prepared for:

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EXECUTIVE SUMMARY

This report evaluates Enhanced Design Alternative (EDA) IV as part of the second phase of the License Application Design Selection (LADS) effort. The EDA IV concept was compared to the VA reference design using criteria from the *Design Input Request for LADS Phase II EDA Evaluations* (CRWMS M&O 1999b) and (CRWMS M&O 1999f).

Briefly, the EDA IV concept arranges the waste packages close together in an emplacement configuration known as "line load". Continuous pre-closure ventilation keeps the waste packages from exceeding the 350°C cladding and 200°C (4.3.13) drift wall temperature limits. This EDA concept keeps relatively high, uniform emplacement drift temperatures (post-closure) to drive water away from the repository and thus dry out the pillars between emplacement drifts. The waste package is shielded to permit human access to emplacement drifts and includes an integral filler inside the package to reduce the amount of water that can contact the waste form. Closure of the repository is desired 50 years after first waste is emplaced. Both backfill and a drip shields will be emplaced at closure to improve post-closure performance.

To be considered as a candidate for selection, this EDA evaluation must meet screening criteria for post-closure performance (4.2.1). The post-closure performance, as measured by the peak dose rate, is less than the proposed screening criterion of 25 mrem/year as discussed in Section 6.1.1. Therefore EDA IV meets the screening criteria in 4.2.1.

The EDA IV concept includes more defense-in-depth layers than the VA reference design because of its backfill, drip shield, waste package shielding, and integral filler features. These features contribute to the low dose-rate to the public achieved during the first 10,000 years of repository life as shown in Figure 3.

Investigation of the EDA IV concept has led to the following general conclusions:

- The total life cycle cost for EDA IV is about \$21.7 billion which equates to a \$11.3 billion net present value (both figures rounded up).
- The incidence of design basis events for EDA IV is similar to the VA reference design.
- The emplacement of the waste packages in drifts will be similar to the VA reference design. However, heavier equipment may be required because the shielded waste package will be heavier.
- The heavier shielding will permit access to the emplacement drift by personnel after blast cooling and emplacement of neutron shielding to further reduce the radiation dose rate.
- The EDA IV concept is flexible in that it will permit storage of 63,000 MTU within the upper emplacement block and storage of up to 105,000 MTU if both upper and

lower blocks are used. As shown in Table 5, the concept is compatible with most other design alternatives and features.

Lastly, the EDA IV set of conceptual design parameters do not result in meeting all of the thermal goals with closure at 50 years. The drift wall temperature will exceed 200°C if the repository is closed at 50 years. A longer operating period (60-75 years) will be required until closure to meet the thermal goals.

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Contributors to this evaluation:

Jamie Park provided the information for Section 6.3.1 and Attachment I.

1. INTRODUCTION- PURPOSE, OBJECTIVE, AND SCOPE

1.1 Purpose & Objective

Five alternatives were selected for consideration during the second phase of the License Application Design Selection (LADS) process. Enhanced Design Alternative (EDA) IV is one of the alternatives being considered. The purpose of this evaluation is to discuss the benefits and liabilities to the repository by the selection of EDA IV. The objective of this evaluation is to provide sufficient information for managers to make a selection from among the five alternatives.

1.2 Scope

The scope of this document will develop the technical basis for the evaluation against LADS Phase II Evaluation Criteria by providing the following:

- Post-closure performance data which is defined as the peak dose rate within 10,000 years;

- Defense-in-Depth, defined as the quantitative evaluation of post-closure performance that could occur with the removal of any single barrier used as a part of the defense in depth argument (for example, the drip-shield barrier). The post-closure performance will meet the anticipated regulatory requirement with any single barrier neutralized;

- Qualitative evaluation of environmental considerations;

- Safety/License Probability including the following:
  - The safety margin which is the difference between the calculated performance and the anticipated regulatory standard,
  - The peak dose rate (central estimate) within 1,000,000 years,
  - The extent to which the design concepts can be clearly explained,
  - The extent to which the analysis of the alternative follows accepted methods,
  - The extent to which the post-closure functions can be demonstrated,
  - The extent to which there are regulatory or engineering precedents for design and construction,
  - The extent to which qualified data are likely to be available in the License Application time-frame (or prior to waste emplacement),
  - The extent to which high level design goals are violated.

- Cost and schedule data for each of the five project phases (site characterization and licensing, construction, operations, monitoring, and closure) including total system life cycle costs (+/- 50% for conceptual design) in 1999 dollars, net present value cost, and the number of years associated with each phase;

- Qualitative discussion of the constructability, operability, and maintainability of the alternative considering worker radiation safety/industrial safety, reliability/availability/maintainability/inspectability, throughput capacity, performance confirmation, construction methods, and the possibility that new Design Basis Events (DBE) would be created or existing DBEs would be negated; and

- Qualitative discussion describing the flexibility of the alternative which may include the impact of a requirement for increased disposal capacity (105,000 metric tons of uranium (MTU)), a longer pre-closure period (50 to 300 years), receipt of 5 year old waste, design changes such as a requirement to change from remote to human access, the need to add features to enhance performance, significantly different waste package sizes or waste streams, and the encountering of unanticipated natural features.

2. QUALITY ASSURANCE

This report evaluates EDA IV. This report was prepared under Quality Administrative Procedure QAP-3-5, *Development of Technical Documents* (CRWMS M&O 1998h) in accordance with the approved *Technical Document Preparation Plan* (CRWMS M&O 1999a). Enhanced Design Alternative IV was evaluated in the *Activity Evaluation to Support Development of Repository Design Alternatives* (CRWMS M&O 1998a) in accordance with QAP-2-0, *Conduct of Activities* (CRWMS M&O 1998g), and it was determined that the feature affects items on the *Q-List* (YMP 1998) and is therefore subject to the *Quality Assurance Requirements and Description* (QARD) (DOE 1998).

Enhanced Design Alternative IV is not specifically listed in the *Classification of the Preliminary MGDS Repository Design* (CRWMS M&O 1998b) and so a formal classification of the permanent item has not been performed in accordance with QAP-2-3, *Classification of Permanent Items* (CRWMS M&O 1998f). However, certain features of the design (such as waste packages, backfill, and drip shields) are listed as QA-2, Important to Waste Isolation. The waste package is also listed as QA-1, Important to Radiological Safety. The EDA IV configuration is inferred to have similar classifications.

3. METHOD/ DESCRIPTION OF SOFTWARE USED

This EDA IV evaluation is analyzed in accordance with the criteria used for evaluating all EDAs contained in the *Design Input Request for LADS Phase II EDA Evaluations* (CRWMS M&O 1999f) and conclusions are drawn about its ability to enhance repository performance. These criteria are included in the next section of this report (4.2.1). Enhanced Design Alternative IV will only be compared against these criteria. Appropriate section of the Viability Assessment (VA) reference design will be referred to, as needed, to highlight differences between it and EDA IV.

Word processing and spreadsheet software was used to produce this report. A description of software used to produce some of the Attachments is contained in the references for the Attachments.

4. INPUTS

The formal TBV and TBD tracking system described in Nevada Line Procedure NLP-3-15 *To Be Verified (TBV) and To Be Determined (TBD) Monitoring System* (CRWMS M&O 1998e) are not applicable to this report, although TBV/TBDs will be noted when used.

4.1 Parameters

4.1.1 Waste Package (WP) Shielding Thickness

A total thickness of about 30 cm of steel will provide a 200 mrem/hr gamma dose rate at the WP surface. This information is from *Shielding Characteristics of Various Materials on PWR Waste Packages* (CRWMS M&O 1999c, pg I-26). The 30 cm value can be determined by using the Primary Gamma (P. Gamma) curve and knowing that a VA reference design waste package is about 12 cm thick (CRWMS M&O 1999c, pg 11). If an additional 18 cm shield thickness is used, a value of less than 200 mrem/hr is read from the curve. The P. Gamma curve is used in the 0-20 cm range because the addition of the Secondary Gamma (S. Gamma) curve would not change the thickness of package needed. The S. Gamma curve is much less than the P. Gamma curve in the 0-20 cm range. Radiation protection against neutrons is provided by a shielding material that will overlay the waste package when required for personnel access.

This value is an upper bounding condition as the hottest type waste package (21-PWR: based on average heat output) is used from the *Controlled Design Assumptions Document* (CRWMS M&O 1998d, Key 004). Note that no reduction in shielding thickness has been taken for the integral filler.

4.1.2 Acreage of Repository Areas

Areas of the repository have the following acreage available:

Area	Acres
Repository Block	756
Drill Hole Wash Block	270
Abandoned Wash Block	310
Lower Block	760

The Repository Block information is from the *Repository Subsurface Layout Configuration Analysis* (CRWMS M&O 1997a, pg II-2). The other values are from the *Identification of Potential Repository Expansion Areas* (CRWMS M&O 1999d, pgs 6&10).

4.1.3 Thermal Edge Effects (TBV)

There is approximately a 10% difference between the average rockwall temperature in the middle of the repository and rockwall temperature on the edge of the repository at 50 years after emplacement. This information is from *Repository Subsurface Waste Emplacement and Thermal Management Strategy* (CRWMS M&O 1998c, Figure 7.6-12). Fifty years is used as this is the desired time period for closure of the repository as mentioned in Section 5 of this evaluation. The difference allows hotter waste packages to be placed on the edges of the repository and still meet thermal goals for the overall repository.

4.1.4 Number of Waste Packages

The number of waste packages for this EDA is specified in the *Design Input Transmittal for Enhanced Design Alternative I, IV, and V Input* (CRWMS M&O 1999e, pg 13, Worksheet 13) as 10,213. Worksheet 13 is used as it uses the same waste package arrival, thermal, and emplacement assumptions as the VA reference design.

4.1.5 Usable Length of Emplacement Drift

The usable length of emplacement drift is 123,469m for 120 drifts. This information is from the *Repository Subsurface Layout Configuration Analysis* (CRWMS M&O 1997a, Table I-2) and is used to calculate an average length of drift for emplacement.

4.1.6 Spacing of Emplacement Drifts for EDA IV

The spacing for emplacement drifts for EDA IV is 52.6m (rounded to 53m). This spacing will achieve an Areal Mass Loading of 85 MTU/acre as per the information included in the *Design Input Transmittal for Enhanced Design Alternative I, IV, and V Input* (CRWMS M&O 1999e, pg 13, Worksheet 13). During development of this EDA, an emplacement drift spacing of 56m was used for some calculations. Using a smaller spacing of the drifts would theoretically lead to a higher overall emplacement drift temperature. However, this higher temperature would take many years to develop because of the low thermal transmission coefficient of rock. It therefore should have no impact on the conclusions contained in this EDA.

4.1.7 Drip Shield

The dose-rate expected during the first 200,000 years of repository life is two orders of magnitude lower with a drip shield than without a drip shield. This information is determined from the EDA 3a (IIIa) 1,000,000-year Total Dose-Rate History curve contained in *Design Input Transmittal for Enhanced Design Alternatives I, II, IIIa, IIIb, IV, and V* (CRWMS M&O 1999I, Item 5, pg 65).

4.1.8 Dose-Rate for EDA IV

The dose-rate for EDA IV is found in Item 5, pages 68 and 69 of the *Design Input Transmittal for Enhanced Design Alternatives I, II, IIIa, IIIb, IV, and V* (CRWMS M&O 1999i).

4.1.9 Waste Package Weight

The empty 21 PWR waste package will weigh 94 metric tons from *Design Input Transmittal for Enhanced Design Alternative I, IV, & V Input* (CRWMS M&O 1999k). The weight of the waste is 16 metric tons from *Waste Container Cavity Size Determination* (CRWMS M&O 1997b, pg 27). The total weight of the 21 PWR waste package is therefore 110 metric tons (mt).

4.1.10 Temperatures for EDA IV

The temperatures for drift wall, waste package surface, and middle-of-pillar for closure at 50 and 75 years are shown in Figure 6. These temperatures were developed in the *ANSYS Calculation in Support of Enhanced Design Alternatives* (CRWMS M&O 1999j, pgs 36-43).

4.1.11 Thermal Degradation Curves

The thermal degradation curves in Figure 9 were developed in the *Design Input Transmittal for Enhanced Design Alternatives I, II, IIIa, IIIb, IV, and V* (CRWMS M&O 1999i, Item 1, pgs I-5 to I-8). Note that the temperatures are different than the ones from parameter 4.1.10. This disparity reflects different modeling techniques and is mentioned in this evaluation in Section 6.4.

4.1.12 Average Waste Package Thermal Output

The average waste package thermal output is 9.491 kW for the 18 kW Design Basis Fuel based on the *Design Input Transmittal Average Waste Package Thermal Output at Loading* (CRWMS M&O 1999o). The total number of waste packages for this calculation is 7,667.

4.1.13 Waste Package (WP) Cladding and WP Surface Temperature Difference

The difference between the WP cladding and WP surface temperatures is about 50°C with backfill at 50 years. This value is derived from a comparison of graphs in *Thermal Calculation of the Waste Package with Backfill* (CRWMS M&O 1999s). The maximum temperature difference between fuel cladding and surface temperature with backfill at 150 years is about 25°C and is found by comparing Figures 6.1-5 and 6.1-4 in the reference. The maximum temperature difference with backfill at 100 years is about 35°C and is found by comparing Figure 6.1-2 and 6.1-1 in the reference.

A straight-line interpolation for backfill at 50 years would be 45°C. This value is found by adding the difference between 35°C and 25°C to the 35°C temperature value. However, as shown in all figures, the temperature of the waste package is hotter during the period 0-50 years and thus the difference in temperature between the waste package cladding and surface should be more. The evaluation uses a difference of 50°C to reflect this hotter temperature. The reference above (CRWMS M&O 1999s) uses smaller emplacement drift and wider waste package spacing then EDA IV. These variations should have no affect on the difference between the waste package cladding and surface temperatures.

4.2 Criteria

4.2.1 The following criteria for *Design Input Request for LADS Phase II EDA Evaluations* (CRWMS M&O 1999b) and (CRWMS M&O 1999f, Item 1) will be used in assessing EDA IV:

- Screening Criteria

  1. Post-Closure Performance

- Evaluation Criteria

  1. Safety/ License Probability
  2. Cost/Schedule
  3. Construction, Operations, and Maintenance
  4. Flexibility

Any EDA that does not meet the screening criteria will be removed from further consideration, or further enhanced to ensure that it meets the screening criteria.

4.2.2 The maximum weight of a full waste package shall not exceed 83,000 kg (83 metric tons) from the *Canister Transfer System Description Document* (CRWMS M&O, Item 1.2.1.6) (TBV).

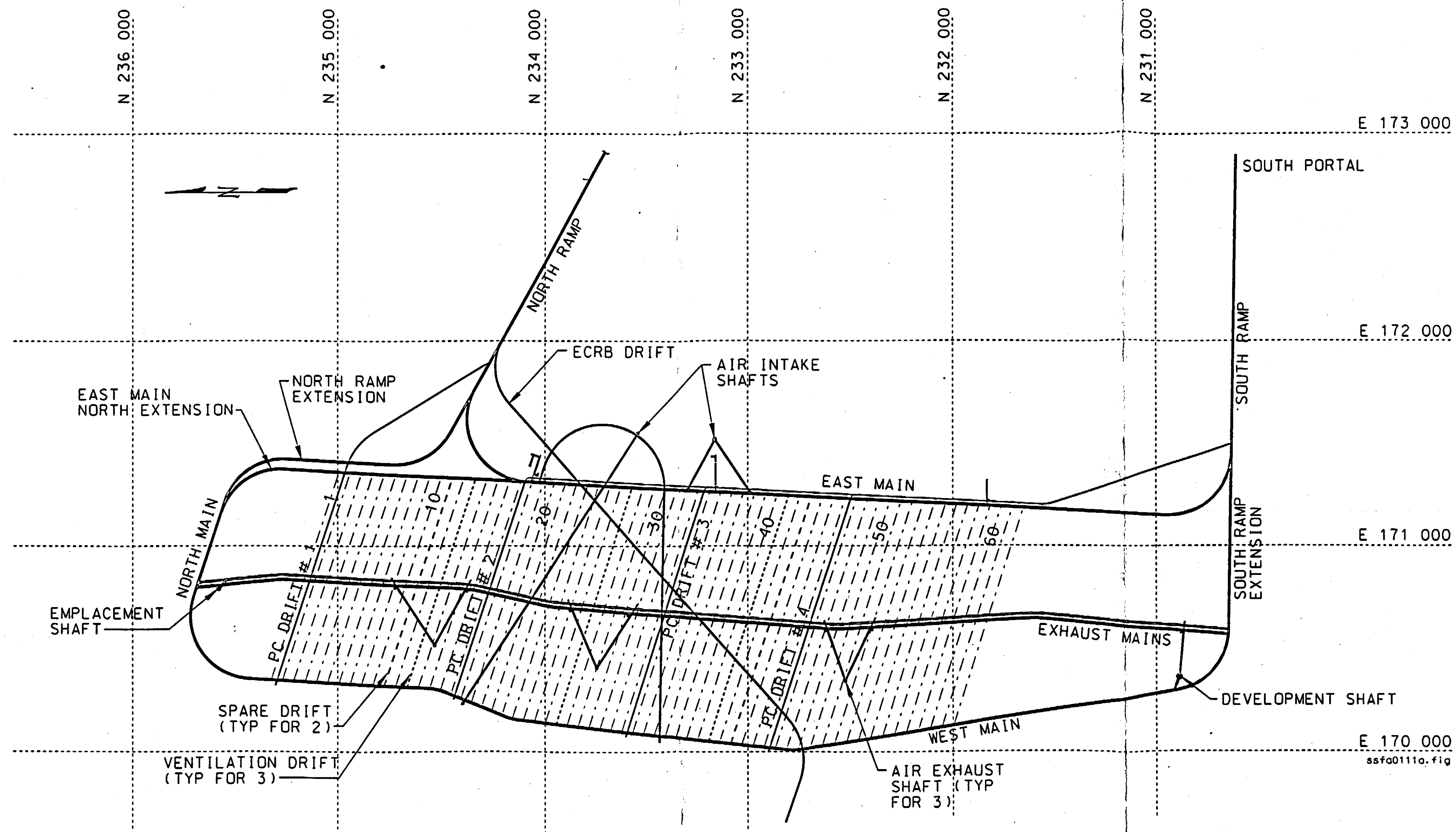
4.3 Assumptions

4.3.1 No Concrete Lining or Invert in Emplacement Drifts

There will be no concrete lining or concrete invert in the emplacement drifts. A metal invert will be used in place of the concrete invert. Rockbolts and mesh will be used for ground support in the emplacement drifts. Steel sets may also be required in some areas. This assumption removes the uncertainty on the long-term performance of the repository associated with using concrete. Concrete can cause a change in the pH of water that might contact the waste package. This assumption is based on existing data and does not have to be confirmed. The exact ground support configuration for the repository has not been determined and this assumption is for continuity between different EDAs. [Used in Section 5]

4.3.2 Repository Layout

The repository layout will be modified from that contained in the *Repository Subsurface Layout Configuration Analysis* (CRWMS M&O 1997a, pg 33) as shown in Figure 1. The spacing between emplacement drifts will be approximately twice the spacing between drifts contained in the reference. The total number of drifts will be reduced from 120 to 62 to keep the same approximate repository area as the VA and to keep a similar thermal loading (85 metric tons uranium/acre). There will be five additional shafts for ventilation from the *Updated EDA Ventilation Calculation* (CRWMS M&O 1999q). Shaft



NOTES:

1. 85 MTU/ACRE (4.1.6).
2. SPACING OF EMPLACEMENT DRIFTS = 53 m (4.1.6).
3. NUMBER OF DRIFTS = 62 (SECTION 6.4)
   57 EMPLACEMENT, 2 SPARE AND 3 VENTILATION DRIFTS = 62
   NUMBER OF SPARE AND VENTILATION DRIFTS SAME AS VA.

ALL DIMENSIONS ARE SHOWN IN METERS UNLESS OTHERWISE NOTED

FIGURE 1
EDA IV
85 MTU/ACRE - 53.0 m C/C (4.3.2)

locations are approximate and are located to balance the air flowing through each shaft. This assumption is based on existing data and does not have to be confirmed. The repository layout is conceptual for this evaluation. [Used in Figure 1]

4.3.3 Ventilation Rate

A continuous ventilation rate of 10 m^3/sec per emplacement drift has been assumed to make cost conservative estimates and for continuity between the different EDAs from *Updated EDA Ventilation Calculation* (CRWMS M&O 1999q). This rate allows preliminary sizing of the shafts and related equipment to occur for cost estimating purposes. This assumption is based on existing data and does not have to be confirmed. The ventilation design is conceptual for this evaluation. [Used in Section 6.3]

4.3.4 Waste Package Emplacement Method

Several different methods of waste package emplacement are under consideration. This alternative evaluation has chosen one of these methods as shown in Figure 7. This assumption is based on existing data and does not have to be confirmed. This method was chosen as it is similar to the VA reference design as discussed in the *Preliminary Waste Package Transport and Emplacement Equipment Design* (CRWMS M&O 1997c, pg 18) and thus new emplacement equipment or emplacement methods do not have to be developed for cost estimation purposes. [Used in Figure 7 and Section 6.3]

4.3.5 105,000 MTU Waste Stream

The 105,000 MTU waste stream from the *Design Input Request for LADS Phase II EDA Evaluations* (CRWMS M&O 1999f, pg 3) is assumed to be similar to the 63,000 MTU waste stream from the *Controlled Design Assumptions Document* (CRWMS M&O 1998d, Key 003). This simplifying assumption is based on existing data and does not have to be confirmed. This conceptual evaluation does not need an exact number to arrive at a determination of area needed for emplacement. [Used in Section 6.4]

4.3.6 Emplacement Drift Wall Temperature

The emplacement drift wall temperature should be kept below 200°C. This assumption is from the *Controlled Design Assumptions Document* (CRWMS M&O 1998d, pgs 4-28 & 4-29). The justification for this assumption is contained within the reference. [Used throughout]

4.3.7 Dose Rate Curves for EDAs III and IV

The dose rate curves for EDA III can be used for EDA IV because both have similar configurations as shown in the Design Input Request for LADS Phase II EDA Evaluations (CRWMS M&O 1999b, Item 1). [Used in Section 6.1.2].

4.3.8 Waste Package Thermal Output

The average thermal output from parameter 4.1.12 is 9.491 kW based on 7,667 packages. The assumption is made that the average thermal output will not change for the larger number of waste packages (10,213) (parameter 4.1.4) used in this evaluation. [Used in Section 6.4]

5. ENHANCED DESIGN ALTERNATIVE DESCRIPTION

Enhanced Design Alternative IV has the following characteristics from the *Design Input Request for LADS Phase II EDA Evaluations* (CRWMS M&O 1999b):

- Relatively high, uniform temperatures in the emplacement drifts to drive water away from the repository.

- Continuous ventilation to moderate the emplacement drift temperature below a value of 200°C (4.3.6) at the drift wall.

- A shielded waste package to permit human access into an emplacement drift (after cooling by ventilation air and placement of neutron shields over the waste packages).

- Backfill and a 2 cm thick titanium (Ti-7) drip shield will be placed over the waste package at closure to provide defense-in-depth for the repository.

- Close spacing (0.10 m) of waste packages within a drift (line loading), but 56m center-to-center spacing of the emplacement drifts to maintain an areal mass loading (AML) of 85 Metric Tons of Uranium (MTU)/Acre.

- The waste packages have an integral filler to prevent the build-up of water in the package void spaces in the event the waste package is breached. This filler also provides some radiation shielding to compliment the external shielding.

- Average waste package thermal output of 9.491 kW for the 18 kW Design Basis Fuel (4.1.12).

- The waste package will be 30 cm thick (4.1.1), carbon steel (A516) construction.

In conjunction with these specific characteristics, this alternative has several additional goals:

- Keep waste package cladding temperature below 350°C.

- Keep the total radiation dose rate from waste packages below 200 mrem/hr and below 100 mrem/hr if a neutron shield is used.

- Waste package lifetime greater than 10,000 years.

- Achieve closure at 50 years after start of emplacement.
- Dry out the pillars between emplacement drifts.
- Keep the emplacement drifts dry for thousands of years.

Figure 2 is a cross section of an emplacement drift with the EDA IV configuration. Figure 2 is from *Backfill Volumes for Enhanced Design Alternative Configurations* (CRWMS M&O 1999n, Fig 1) and includes depictions of the dripshield and rockbolts (4.3.1).

Table 1 is a comparison of important characteristics of the VA reference design and EDA IV. Some characteristics of EDA IV in Table 1 are different than those calculated in the evaluation. The numbers calculated in the evaluation should take precedence over numbers reported in Table 1.

Table 1. Comparison of Selected Items for the VA Reference Design and EDA IV

Characteristic	VA Reference Design	EDA IV (1)
Drift Spacing (m)	28 (2)	56
Number of Drifts	120 (2)	62 (Section 6.4)
Area (Acres)	741 (Section 6.4)	~ 740
AML (MTU/acre)	85 (3)	85
Drift Size (m)	5.5 (4)	5.5
Drip Shield	No	Yes
Backfill	No	Yes
Time to Closure (years)	100+ (5)	50
Drift Loading	Point (6)	Line

Notes: 1) All EDA values are approximate.
2) *Repository Subsurface Layout Configuration Analysis* (CRWMS M&O 1997a, pg 33).
3) *Repository Subsurface Waste Emplacement and Thermal Management Strategy* (CRWMS M&O 1998c, pg 27).
4) *Controlled Design Assumptions Document* (CRWMS M&O 1998d, Key 070).
5) *Controlled Design Assumptions Document* (CRWMS M&O 1998d, Key 016). Since retrieval is required for 100 years, the repository may not close during this period.
6) *Repository Subsurface Waste Emplacement and Thermal Management Strategy* (CRWMS M&O 1998c, pg 45).

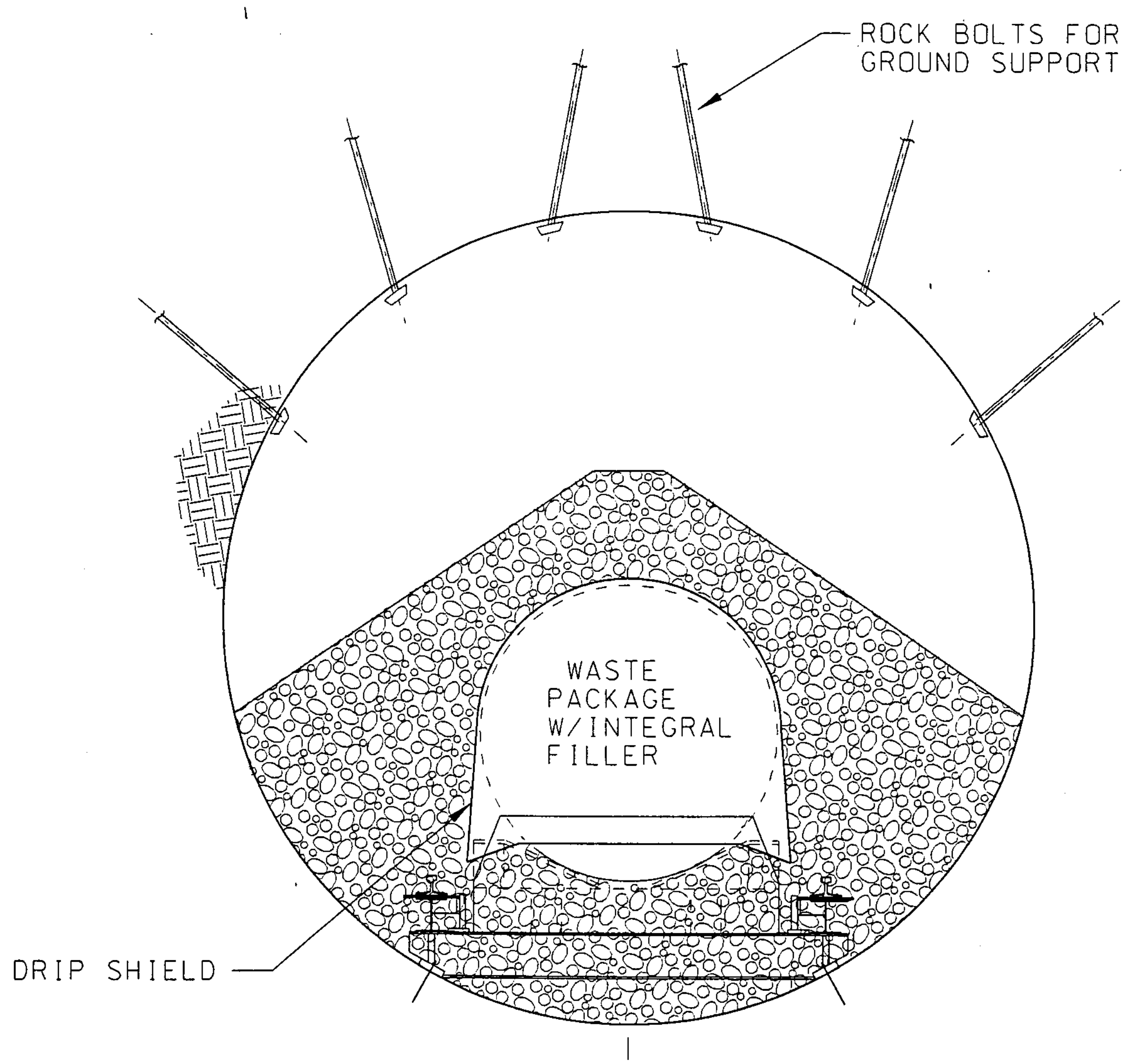


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FIGURE 2
CONCEPTUAL DESIGN
FOR EDA IV

6. EDA EVALUATION

This section will use the evaluation criteria contained within Criteria 4.2.1. This evaluation will rely heavily upon published sources of information and several supplemental calculations produced directly for this evaluation.

6.1 SAFETY/ LICENSING

6.1.1 Safety

The word "safety" refers to safety of the public. This safety is measured by the amount of radioactive dose estimated to effect a member of a critical group. This estimate is based upon computer projections. From Figure 3, a safety margin can be calculated. The safety margin is the difference between the anticipated performance during the first 10,000 years and the regulatory limit of 25 mrem/year. The safety margin for EDA IV is:

$$.0002 - 25 \approx -25 \text{ mrem/year}$$

Figure 4 shows the anticipated dose-rate curve for 1,000,000 years of repository life. The peak dose expected occurs at about 350,000 years and is about 1100 mrem/year.

6.1.2 Licensing

Enhanced Design Alternative IV may be more licensable then the VA reference design because the alternative provides more defense-in-depth protection. Table 2 illustrates this point.

Table 2. Defense-in-Depth Layers

EDA IV	VA Reference Design
Natural Barriers	Natural Barriers
Ground Support	Ground Support
Backfill	
Drip Shield	
Waste Package Shielding	
Waste Package	Waste Package
Thermal Gradient	Thermal Gradient
Filler Material	

The number of defense-in-depth layers shown in Table 1 make it unlikely that radioactive nuclides can be transported by groundwater away from the repository within a 10,000 year time-frame. This statement is supported by Figure 3, which shows a low dose-rate level during the first 10,000 years of repository life (solid line) and a much higher dose-rate (dashed line) if the protection of the waste package is not included. Figure 5 shows the dose-rate curve for EDA 3a (IIIa). The EDA 3a (IIIa) curve is used to determine the dose-rate difference for the drip shield since EDA IV and EDA III are similar (4.3.7).

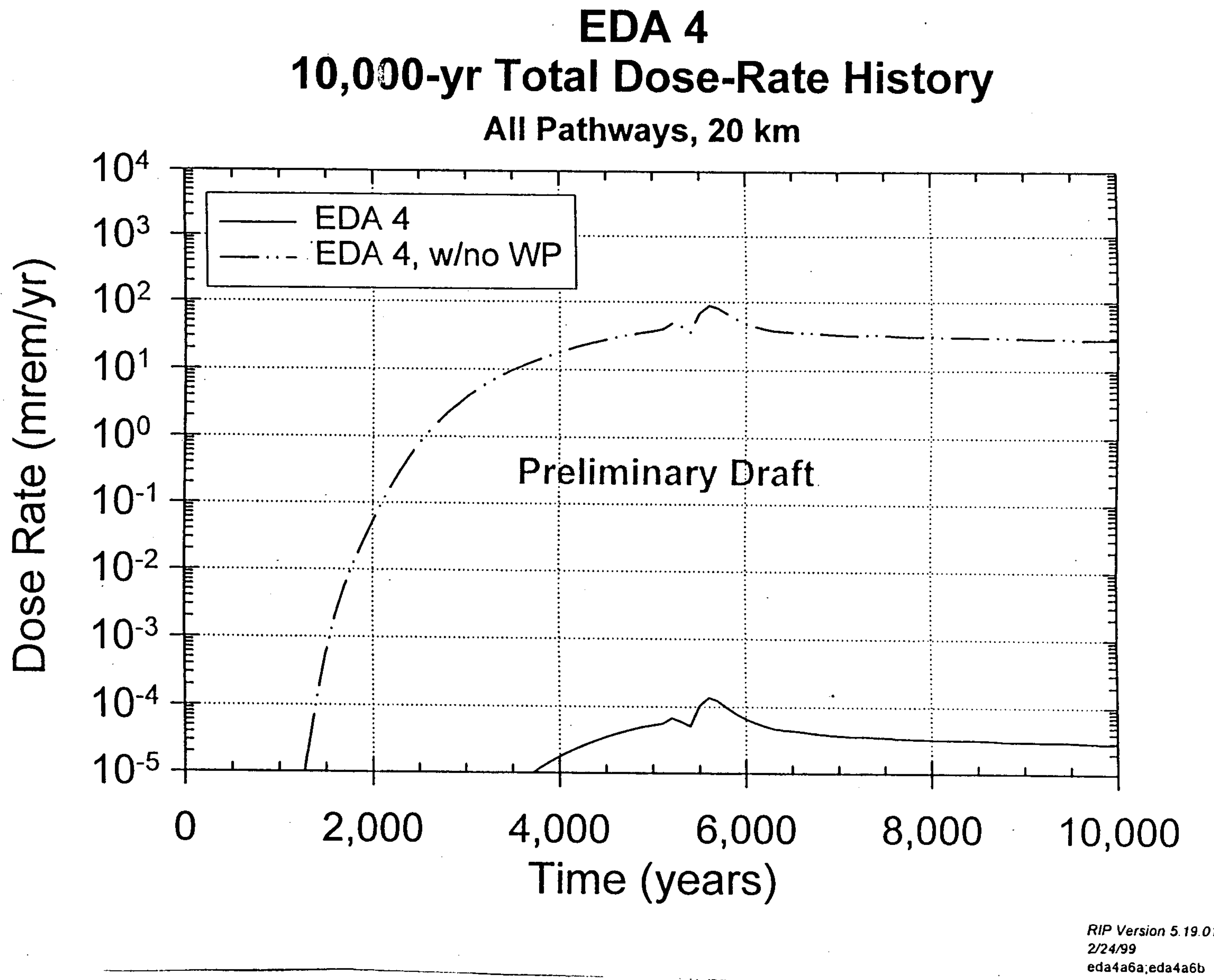


Figure 3. 10,000-Year Projected Annual Total Effective Dose Equivalent for EDA IV (4.1.8)

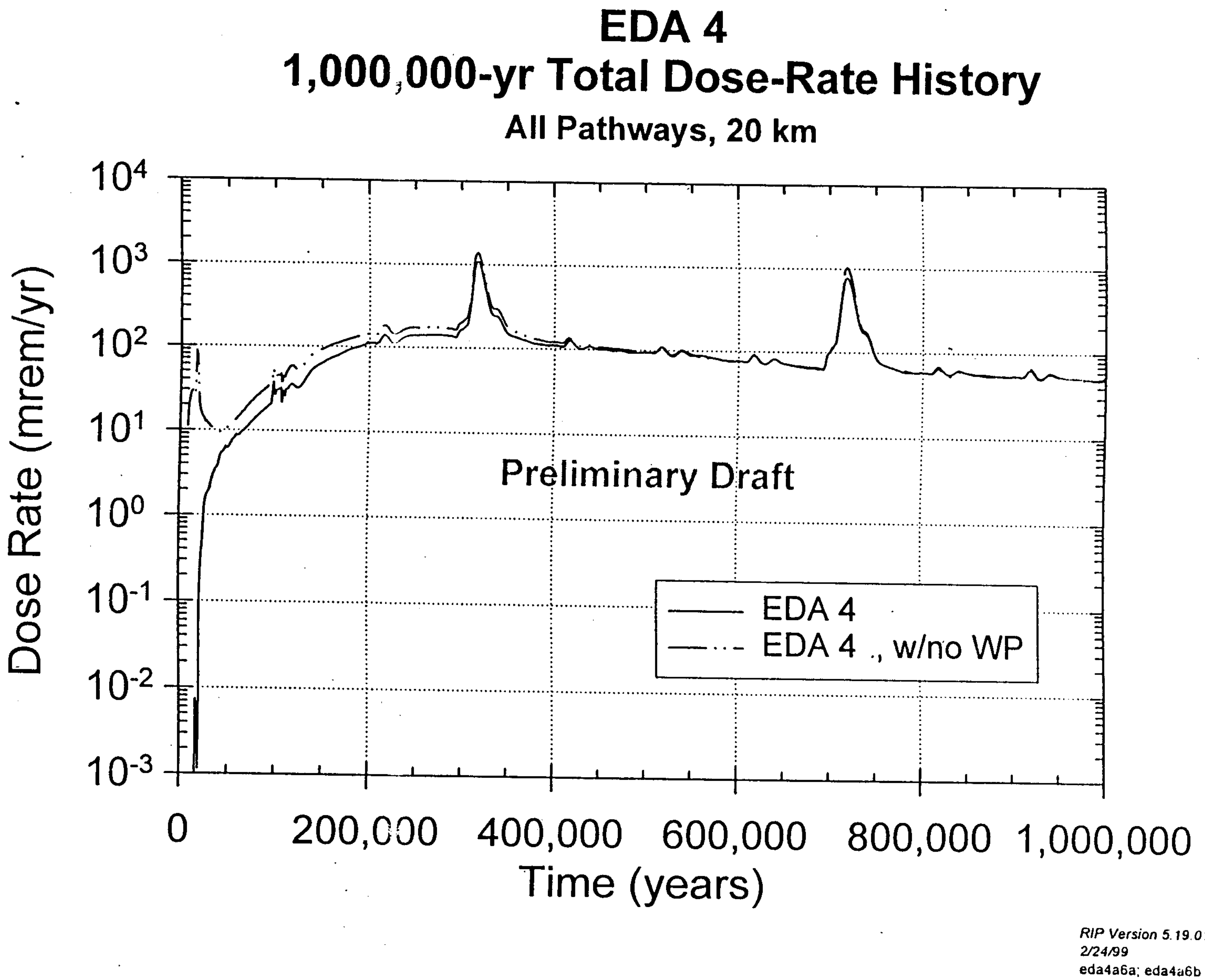


Figure 4. 1,000,000-Year Projected Annual Total Effective Dose Equivalent for EDA IV (4.1.8)

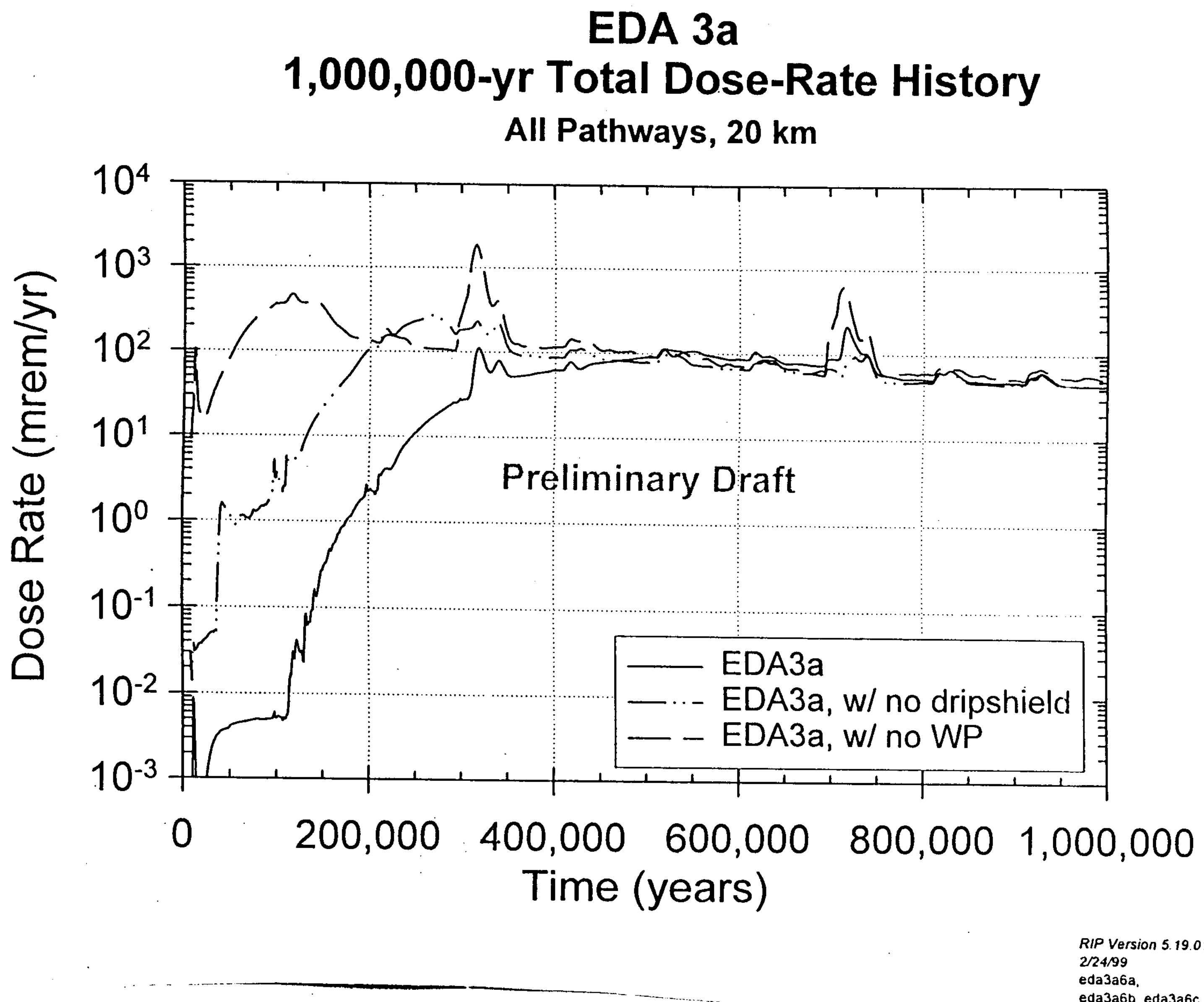


Figure 5. 1,000,000-Year Projected Annual Total Effective Dose Equivalent for EDA IIIa (4.1.7)

A measure of defense-in-depth is how much protection is provided by a particular layer. The protection provided by the waste package is shown in Figures 3 and 4. During the first 10,000 years the waste package provides almost 6 orders of magnitude reduction in dose-rate than the dose-rate with no waste package. The drip shield provides nearly two orders of magnitude reduction in dose-rate during the first 200,000 years for EDA IIIa (4.1.7). A similar reduction is inferred for EDA IV (4.1.7) during the first 200,000 years.

The function of each defense-in-depth layer is relatively straightforward and thus its design and post-closure functions can be explained and demonstrated. As will be discussed below, these functions can be demonstrated by standard analytical methods. Layer performance information in the form of qualified data should be available prior to waste emplacement. In the case of backfill this qualified information will be from the Engineered Barrier testing that is ongoing at the present time. The EDA IV concept does violate some high-level design goals for the Mined Geologic Repository as discussed in Section 6.4.

Installation of backfill will help protect the waste package and drip shield from rockfalls. Backfill will do little to prevent moisture from contacting the drip shields or waste packages over its lifetime. However, during the first 10,000 years the difference in temperature between the waste package surface and the surface of the backfill will keep the relative humidity low near the waste package. A Richards Barrier type backfill would largely prevent moisture from contacting the drip shield and waste package and should be considered as it provides an additional defense-in-depth layer. Ongoing Engineered Barrier System Testing may provide qualified data prior to waste emplacement.

The drip shield and waste package itself provide protection from moisture. Their corrosion rates are somewhat predictable using standard corrosion models. However, corrosion is highly dependent upon the amount of moisture (groundwater) that will be introduced into the emplacement drifts, drift temperature, pH, and the type of minerals dissolved in the groundwater.

The thermal gradient generated by the decay of radioactive material will provide a barrier to transportation of radioactive nuclides by groundwater during the first 10,000 years of repository life.. Thermal decay will heat the repository rock to over 100°C and will keep it above this temperature for thousands of years. Thus water will be kept away from the emplacement drifts. Figure 6 shows the middle of the pillar will be above 100°C at about 200 years after emplacement and stay above this temperature for about 4,000 years.

The integral filler will help to prevent water from entering the waste package should it be breached. Radionuclides may also be adsorbed depending on the type of filler chosen. The filler may also improve the thermal conductivity of the waste package as per the *License Application Design Selection Feature Evaluation Report: Additives and Fillers* (CRWMS M&O 1999g, pgs. iii-vi).

The EDA IV concept is new and unique and therefore there are no engineering or regulatory precedents for the whole concept. However, there is engineering and

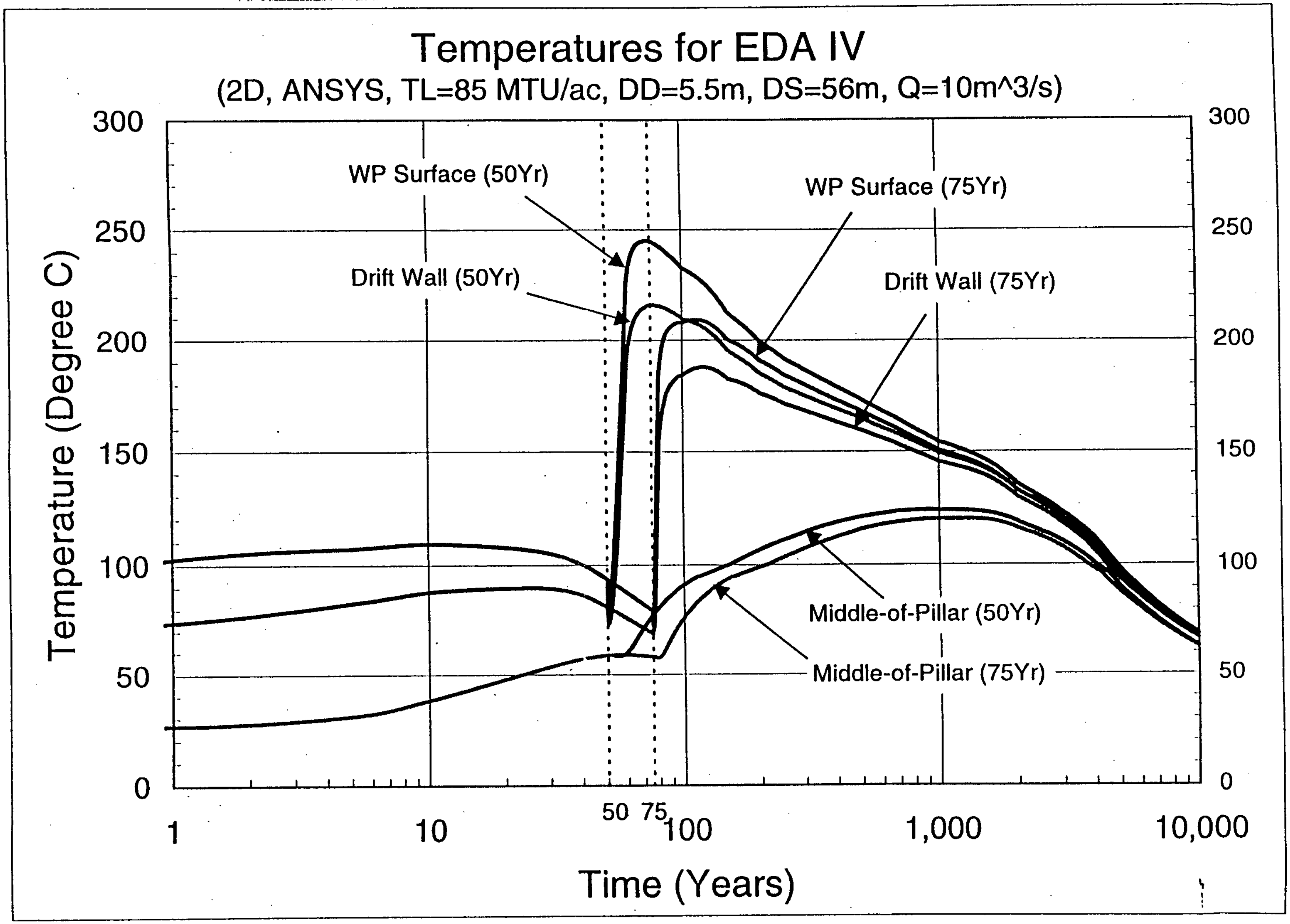


Figure 6. Temperatures for EDA IV (4.1.10)

regulatory precedents for parts of the concept, for example, ground support and backfill.

Both ground support and backfill have been used extensively in mining and tunneling projects and so there is a body of engineering information for their use. There is no nuclear regulatory precedent for the EDA IV concept. However, state or federal regulatory bodies do provide approval of overall projects and, therefore, indirectly provide approval of ground support and backfill features of the projects.

6.1.3 Environmental Considerations

Environmental considerations are described in Attachment I.

6.2 COST/ SCHEDULE

The cost information presented in this section is not subject to the requirements of *Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program (QARD)* (DOE 1998) as per the *Activity Evaluation to Support Development of Repository Design Alternatives* (CRWMS M&O 1998a). The cost information provided in Table 3 is divided into the five project phases (i.e., site characterization and licensing, construction, operations, monitoring, and closure).

Table 3. Total Life Cycle Costs by Phase

	$ Millions (1999 Dollars)
Phase	**Life Cycle Cost**
Site C. & Licensing	764
Construction	3,152
Operations	10,920
Monitoring	1,681
Closure	5,100
Total	21,617

Tables 3 and 4 are from the *Design Input Transmittal for License Application Design Selection (LADS) Cost Estimate Input for Enhanced Design Alternatives (EDA) I, II, III-a, III-b, IV, and V* (CRWMS M&O 1999l). The net present value of each phase is presented in Table 4.

Table 4. Net Present Value by Phase

	$ Millions (1999 Dollars)
Phase	**Net Present Value**
Site C. & Licensing	663
Construction	2,524
Operations	6,300
Monitoring	578
Closure	1,161
Total	11,226

The projected time frame for each phase is presented in Table 5.

Table 5. Time Frame for Each Phase

Phase	Years (From-To)	Number of Years
Site C. & Licensing	2002-2005	4
Construction	2005-2010	6
Operations	2010-2033	24*
Monitoring	2033-2060	28*
Closure	2060-2067	7

Note: * Beginning of closure is about 50 years after start of emplacement. Thermal management goals dictate that closure be extended beyond 50 years after start of emplacement. The costs associated with the extension are not shown because they are not in the scope of this evaluation.

6.3 CONSTRUCTABILITY, OPERABILITY, AND MAINTAINABILITY

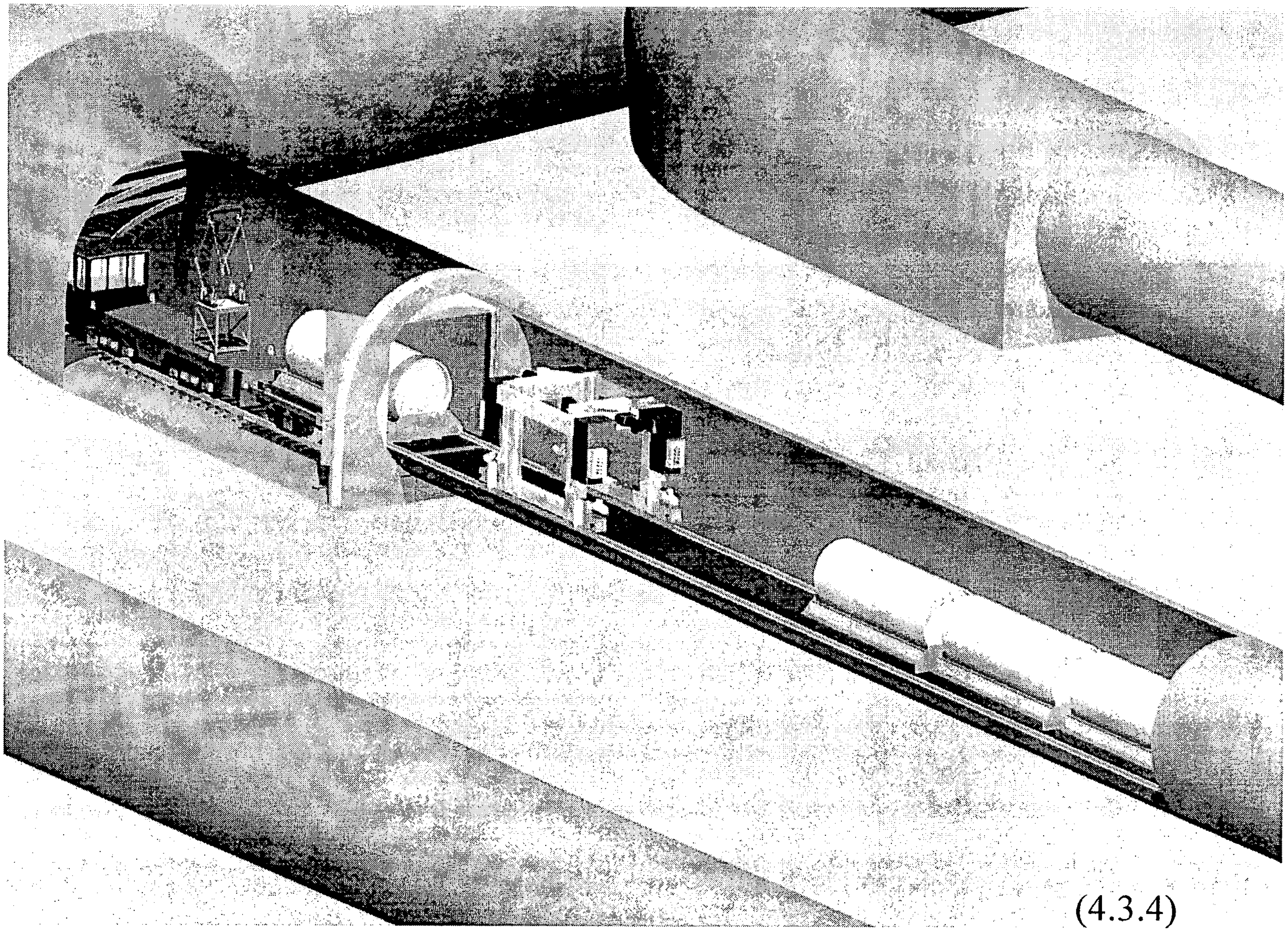
There are industrial safety benefits inherent in EDA IV. The alternative uses half as many drifts as the VA reference design (62 emplacement drifts for EDA IV versus 120 total emplacement drifts for the VA reference design). Figure 1 shows the layout of the EDA IV drifts and the *Repository Subsurface Layout Configuration Analysis* (CRWMS M&O 1997a, pg 33) shows the VA reference design. The amount of tunneling to be accomplished will be substantially less in the EDA IV concept. Therefore, the number of accidents expected for tunneling should be statistically less.

This alternative has the same number of waste packages as the VA reference design. Therefore, the number of accidents expected to be associated with this activity should be similar. The waste package will be larger and more heavily protected than the VA reference design. Therefore, the possibility of a breached waste package caused by transportation should be less with the EDA IV configuration.

The shielded waste package will not necessarily reduce the exposure of workers to radiation. The shielded waste package provides a similar radiation exposure compared to the shielded waste transporter in the VA reference design. The shielded waste package will allow the elimination of a shadow shield within the emplacement drift, but this elimination should not affect the radiation exposure of workers outside the drift. The shadow shield is used to reduce the radiation exposure to workers near the isolation door from the unshielded waste packages.

The EDA IV method of placing waste packages in drifts will be similar to the VA reference design as shown in Figure 7 (4.3.4). The VA reference design is described in *Preliminary Waste Package Transport and Emplacement Equipment Design* (CRWMS M&O 1997c, pgs 18-19). The EDA IV placement method is as follows:

- The waste package (WP) will be transported to the emplacement drift using locomotives and a WP transportation car.
- One locomotive will be uncoupled from the WP transportation car.
- The WP transportation car will backup up to the emplacement drift.



(4.3.4)

Figure 7
Waste Package Emplacement in Drift

concept5a.ppt

- The emplacement drift isolation door will open and the WP transportation car placed against the transfer loading dock.
- The waste package will be pushed on its pallet into the emplacement drift.
- A gantry will lift the waste package and move it down the drift for emplacement.
- After placement, the gantry will return to the isolation door to be ready for the next waste package.

The VA reference design differed in the fifth and sixth bullets. In the VA design the gantry lifted the WP over the shadow shield and transported it into position in the emplacement drift. A shielded 21 PWR waste package weights about 110 mt (4.1.9). The maximum weight of a non-shielded waste package for the VA reference design is about 83 metric tons (4.2.2) (TBV) and thus the emplacement gantry capacity will need to be increased.

The term "enhanced access" is used to refer to the ability of workers to enter an emplacement drift. The EDA IV concept includes enhanced access as one of its features. Enhanced access should not be used for routine inspection of the waste packages as this can be more safely be accomplished by using a remote inspection gantry as in the VA reference design from the *Preliminary Feedback on Enhanced Design Alternatives Summary* (CRWMS M&O 1999r). Enhanced access should only be used during an off-normal event where workers must enter the emplacement drift for some reason. That is, the task to be accomplished can not be completed remotely. The difficulty of sending workers into the emplacement drift, including blast cooling of the drift for temperature reduction and placement of neutron shields over the waste packages, will ensure that the enhanced access feature is used only rarely over the life of the repository. Workers should be able to access the emplacement drift after the start of blast cooling. Blast cooling is required to reduce the temperature to an acceptable level.

A total radiation dose of 200 mrem/hour without neutron shielding and 100 mrem/hour with neutron shielding is considered to be high based on *Radiation Exposure Concerns for Manned Inspection* (CRWMS M&O 1999p). If workers are exposed to this level on a regular basis the design would probably be ALARA (As Low As Reasonably Achievable) non-compliant (CRWMS M&O 1999p, pg 2). Personnel stay-times would be significantly limited in order to comply with regulatory dose limits.

The waste packages will be placed close together (line load) versus the point load type spacing in the VA reference design. The basic arrangement of the drifts will be similar to the VA reference design. Therefore, the reliability, availability, maintainability, and inspectability aspects of EDA IV will be similar to the VA reference design. The ability of the emplacement equipment to remove the waste packages should also be similar to the VA reference design.

The number of waste packages for EDA IV is the same as the VA reference design. The package will include shielding and thus will be larger than the VA reference design. This larger package will require additional welding at the surface facility and a slightly larger facility but this change should not affect the throughput capacity of the repository as a whole. The thicker waste package material may require that the package be formed in sections and welded together. The VA reference design requires less welding as the external shell can be rolled as one piece.

The emplacement drift arrangement is similar to the VA reference design. Therefore, the arrangement of drifts for performance confirmation activities should be similar to the VA reference design. The performance confirmation activities to be performed in the drifts should also be similar to the VA reference design. However, over $500 million in savings will be realized by reducing the performance confirmation period from 100 years in the VA reference design to the 50 years proposed in EDA IV *Design Input Transmittal for An Evaluation of EDA IV's Impact on Performance Confirmation* (CRWMS M&O 1999m, pg 7).

The ability of workers to enter the emplacement drifts for waste package inspection has been noted and is a slight advantage over the VA reference design (the VA does not permit human entrance into the emplacement drifts). However, there will be considerable preparatory activities required to allow this inspection. Preparatory activities include blast cooling the drifts to reduce the temperature and placement of a neutron shield over the waste packages. These activities will require weeks to accomplish and thus the ability to inspect the emplacement drifts is not a significant advantage to EDA IV. Inspection or repair could also be accomplished by relocating the waste packages to another emplacement drift.

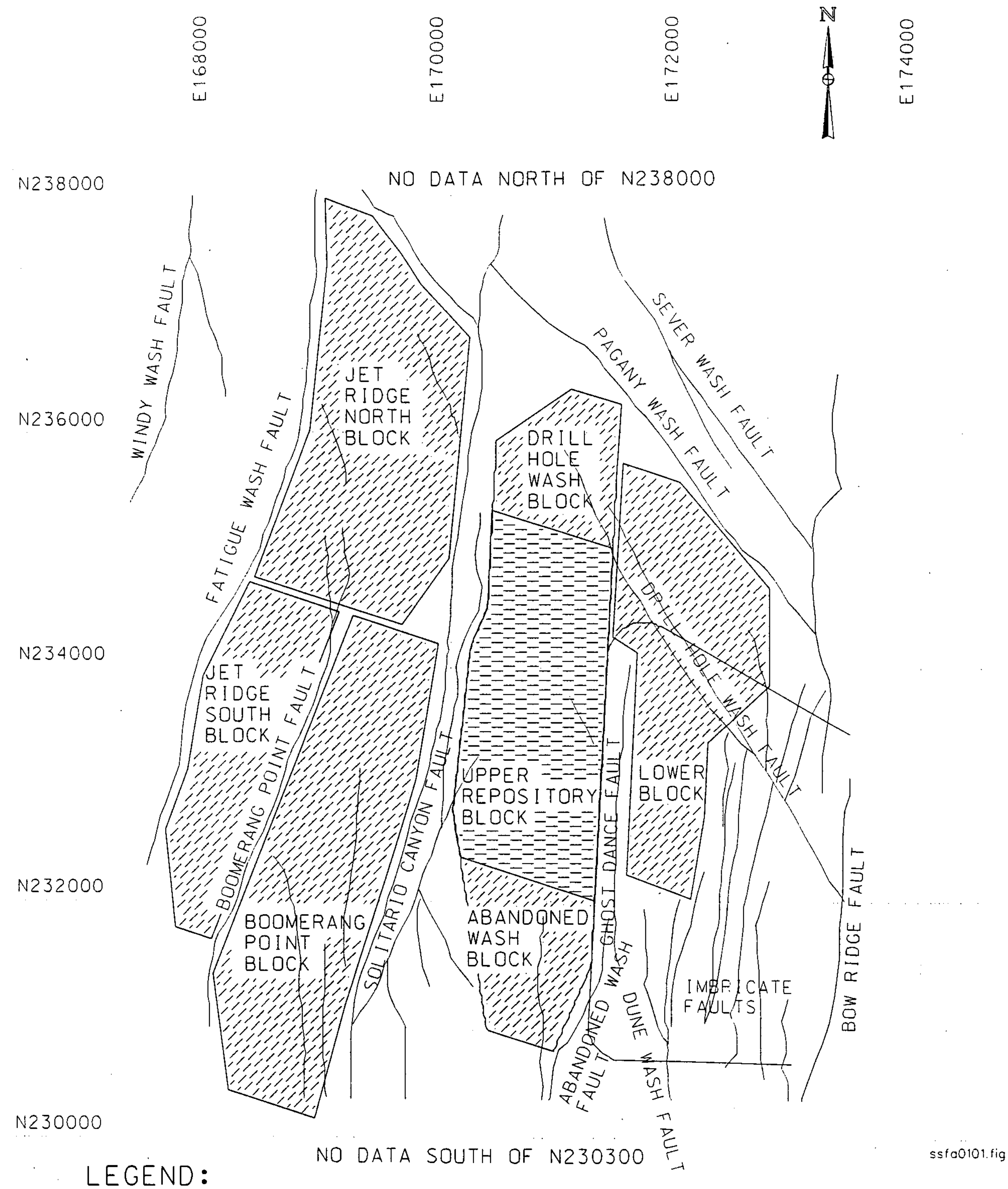
The configuration of the repository and method of placing the waste packages is similar to the VA reference design. Therefore, the incidence of Design Basis Events is similar in both cases *Design Input Transmittal for Design Basis Events (DBE) Evaluation of Enhance Design Alternative IV* (CRWMS M&O 1999h, Item 2, pg 1).

This EDA requires drip shields and backfill at closure. The drip shield will fit over the waste package and can be emplaced using the gantry.

6.4 FLEXIBILITY

Enhanced Design Alternative IV has a flexible configuration. That is, it can change its configuration and not prevent its ability to store waste in the repository.

Figure 8 shows possible areas where the VA reference design repository layout could be expanded. The calculation below shows the emplacement area required for both 63,000 metric tons of uranium (MTU) and 105,000 MTU repository capacities (4.3.5). The Areas north and south of the VA reference design repository could be used for expansion. Based upon an area mass loading of 85 MTU/acre (4.1.6), there is not sufficient room in the Drill Hole Wash Block, Upper Repository Block, and Abandoned Wash Block for 105,000 MTU storage (4.1.2). Another block will need to be opened to store this material.



LEGEND:

UPPER REPOSITORY BLOCK

POTENTIAL EXPANSION AREAS

FIGURE FROM:
IDENTIFICATION OF POTENTIAL REPOSITORY EXPANSION AREAS (CRWMS M&O, 1999d, pg 7)

0 250 500 1000 2000m
SCALE: 1 : 40,000
1 cm = 400m

FIGURE 8
POTENTIAL REPOSITORY EXPANSION AREAS (4.1.2)

The *Design Input Transmittal for Enhanced Design Alternative I, IV, and V Input* (CRWMS M&O 1999e, pg 13) shows the average length of a waste package as 5.48m. If waste packages are placed 0.10m apart, this yields a space requirement of 5.58m for each waste package. There are 10,213 waste packages (4.1.4) and thus the total length of emplacement drift required is:

$$10{,}213 \times 5.58\text{m} = 56{,}988 \approx 57{,}000\text{m}$$

There are 123,469m of usable drift length for 120 drifts (4.1.5) or:

$$123{,}469/120 = 1028.9 \approx 1025\text{m per emplacement drift}$$

The estimated number of emplacement drifts required is:

$$57{,}000\text{m}/1025\text{m/drift} = 55.6 \approx 57 \text{ emplacement drifts}$$

At a spacing of 53m between emplacement drifts (4.1.6), the area required for emplacement is:

$$57{,}000\text{m} \times 53\text{m} = 3{,}021{,}000\text{m}^2 \text{ or } 3{,}021{,}000\text{m}^2/4046.8\text{m}^2/\text{acre} = 747 \text{ acres}$$

This area for 63,000 MTU of 747 acres is similar to the upper repository block as shown on Figure 8 (4.1.2). Note that the required area calculated above does not include access mains or emplacement drift turnouts. As shown in Figure 1, the access mains require a significant percentage of the repository area (although this percentage has not been calculated for this evaluation). The 747 acres calculated above is similar to the 741 acres required for the VA reference design (63,000 MTU/ 85 MTU/acre ≈ 741 acres).

Assuming that the waste stream for 105,000 MTU is the same as that for 63,000 MTU (4.3.8), the required emplacement area is:

$$105/63 \times 747 \text{ acres} = 1{,}245 \text{ acres}$$

The total area available is (4.1.2):

$$756 + 270 + 310 = 1{,}336 \text{ acres}$$

This is sufficient room to emplace the waste packages, but not enough room to account for access mains, turnouts, spare emplacement drifts, or ventilation drifts. This conclusion is supported by a comparison between the area required for the emplacement drifts and the area required for access mains, spare, and ventilation drifts shown on Figure 1.

As shown on Figure 8, there are additional areas available for the emplacement of waste. To accommodate 105,000 MTU, the Lower Block area must be utilized.

A longer pre-closure period would be advantageous to this design as discussed below. The high-level goals of 1) closing the repository in 50 years, 2) backfill installation at closure, 3) cladding temperature below 350°C, and 4) drift wall temperature below 200°C (4.3.6) are not all compatible. This high-level goal incompatibility needs additional explanation as provided below.

The EDA IV concept includes the following sequence of events:

- Ventilation air will blow through the emplacement drifts to remove heat from the repository.
- Backfill and a drip shield will be installed and the ventilation air will stop at closure.
- The emplacement drift temperature will increase rapidly to some maximum value and then cool slowly over time.

The temperatures for the three items above are based on computer models that are, in turn, dependent upon assumptions made specifically for the models. Computer models are defined in the *ANSYS Calculations in Support of Enhanced Design Alternatives* (CRWMS M&O 1999j, pg 5) and *Design Input Transmittal for Enhanced Design Alternatives I, II, IIIa, IIIb, IV, and V* (CRWMS M&O 1999I, Item 2). The following model-specific assumptions are used as the basis for the following discussion on thermal effects.

- A ventilation rate of $10 m^3/sec$ per emplacement drift is used (4.3.3);
- Ventilation removes 50% of the heat generated by the waste package during the pre-closure period (CRWMS M&O 1999i, Item 2-9);
- A temperature of 50°C is achieved in the emplacement drift by the ventilation system at closure (CRWMS M&O 1999j, pg 29);
- The average waste package temperature degradation curve is used for thermal decay (versus, for example, a design basis fuel) (CRWMS M&O 1999j, pg 18);
- The repository rock temperature is initially at 25°C (CRWMS M&O 1999j, pg 28); and
- The waste package cladding experiences a 50°C higher temperature than the package surface for an average package (4.1.13).

Since none of the computer models used all these specific assumptions, different models produced different results. The model that came closest to meeting all the specific assumptions mentioned above the assumptions is shown as Figure 9. Figure 9 shows that the 50 year closure period, backfill, and cladding temperature below 350°C goals can be met. The additional goal of wall temperature below 200°C (4.3.6) is not met and should be more closely examined to see if it can be relaxed.

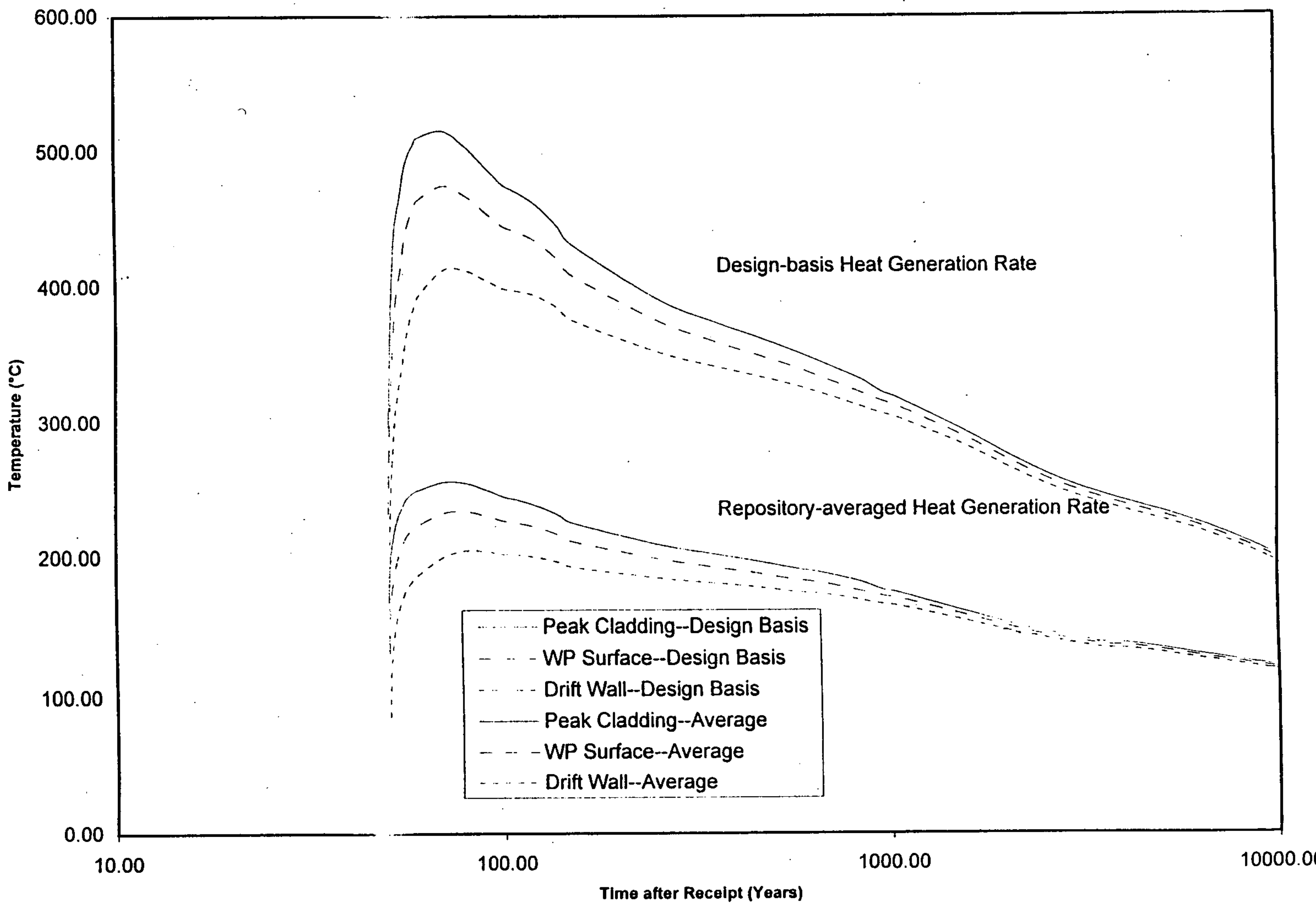


Figure 9. Thermal Degradation Curves for Average and Design Basis Fuel (4.1.11)

The waste package surface temperature peaks at about 230°C in Figure 9 and based upon the last assumption made above, the cladding temperature will be about 280°C. These temperatures are for an average package. Average means that 50% of the waste packages will be higher than this temperature and some of these packages will be much hotter than this temperature (i.e. design basis fuel, 5-year-old spent nuclear fuel (SNF)). Therefore, the cladding temperature goal of 350°C could be violated for at least some packages. The degradation of the cladding for these packages has been taken into account in the Performance Assessment models shown in Figures 3 and 4.

Since the emplacement drift is undergoing continuous ventilation prior to closure, the temperature will be kept lower than the no ventilation case. However, some of the modeling shows that the emplacement drift temperature will exceed 50°C at 50 years with 10 m^3/sec per drift (as shown in Figure 6). For example, Figure 6 shows a higher drift temperature at closure. This higher temperature at closure means that the waste package surface, waste package cladding, and emplacement drift temperature will all be higher. In this event, there may be a larger number of packages with a cladding temperature above 350°C.

Ways to reduce the drift temperature at closure are: to increase the ventilation rate, extend the time to closure, and waste package aging. Waste package aging is not part of EDA IV. The ventilation rate can be increased to reduce the initial drift temperature and come closer to the 50°C value. However, this still does not reduce the number of waste packages that will experience a cladding temperature higher than 350°C. Extending the time of closure beyond 50 years (i.e., closure in 60-75 years) will help in both reducing the number of packages that could experience a cladding temperature above 350°C and reducing the drift wall temperature below 200°C.

The EDA IV concept could allow the receipt of 5-year-old SNF, although EDA IV thermal goals would still not be met. The EDA IV concept allows a high temperature in the emplacement drifts at present. The 5-year-old SNF has a higher thermal output compared to older fuel. In order to balance the thermal load for the repository, this fuel could be placed along the outside edge of the repository or with a greater spacing between waste packages. The thermal edge effect is about 10% (4.1.3) (TBV), a package that is about 10% hotter than the majority of packages could be placed along the edge of the repository to help achieve thermal goals. The 10% edge value implies that the waste package spacing is the same as the other waste packages in the repository.

The EDA IV configuration is compatible with most of the design features and design alternatives mentioned as part of the LADS effort *Design Input Request for LADS Phase I Confidence Assessments* (CRWMS M&O 1999t). The present EDA IV configuration could not be redesigned as a low temperature alternative as the current waste packages are too large and hot.

Many other features could be added to the EDA IV configuration to enhance its performance. Table 6 shows the compatibility with other alternative and features (CRWMS M&O 1999t).

Table 6. Compatibility of EDA IV with other Alternatives and Features

Design Alternatives and Features	Compatibility
DA-1 Tailored WP Spatial Distribution	Compatible
DA-2 Low Thermal Load Design	Not-Compatible
DA-3 Continuous Post Closure Ventilation	Compatible
DA-4 Enhanced Access Design	Compatible
DA-5 Modified Waste Emplacement Mode Design	Compatible
DA-6 VA Reference Design	Compatible
DF-1 Ceramic Coatings	Compatible
DF-2 Drip Shields	Compatible
DF-3 Backfill	Compatible
DF-4 Aging & Blending of Waste	Compatible
DF-7 Continuous Pre-Closure Ventilation	Compatible
DF-8 Rod Consolidation	Compatible
DF-9 Timing of Repository Closure	Not-Compatible w/50 year closure
DF-10 Maint. Of U/G Features & Ground Support	Compatible
DF-11 Drift Diameter	Not-Compatible w/ smaller drifts
DF-12 Drift/ WP Spacing	Compatible
DF-13 Waste Package Self Shielding	Compatible
DF-14 Waste Package CRMs	Compatible
DF-15 Richards Barrier	Compatible
DF-16 Diffusive Barrier Under Waste Package	Compatible
DF-17 Getter Under Waste Package	Compatible
DF-18 Canistered Assemblies	Compatible
DF-19 Additives and Fillers	Compatible
DF-20 Ground Support Options	Compatible
DF-22 Near Field Rock Treatment	Compatible
DF-23 Surface Modifications	Compatible
DF-25 Repository Horizon Elevations	Compatible
DF-26 Higher Thermal Load	Compatible

The EDA IV concept is flexible enough to handle different waste package sizes and waste streams. The EDA IV waste package includes additional material for self-shielding and it should thus be able to handle a smaller waste package. The EDA IV waste stream is the same as the VA reference design. The alternative should be able to handle different waste streams, that is, waste that is younger or older than the VA reference design.

The EDA IV concept should be able to handle changing conditions because of its defense-in-depth features. For example, a climate change could increase precipitation and thus infiltration of groundwater into the emplacement drifts. The amount of radiation released during the first 10,000 years should not be different than in climates with no change in precipitation amount. A long-term climate change could impact this alternative. However, additional defense-in-depth layers (such as the Richards Barrier) could be added to the EDA IV concept to provide assurance that the radioactive release rate is kept to a low level.

The EDA IV concept includes backfill that may protect the waste packages against rockfalls caused by seismic activity. With respect to other types of unanticipated natural events such as volcanism, water table rise, or flooding, this alternative provides no more protection to the waste packages than that included in the VA reference design.

7. CONCLUSIONS/ RECOMMENDATIONS

This report evaluates Enhanced Design Alternative (EDA) IV as part of the second phase of the License Application Design Selection (LADS) effort. The EDA IV concept was compared to the VA reference design using criteria from the *Design Input Request for LADS Phase II EDA Evaluations* (CRWMS M&O 1999b) and (CRWMS M&O 1999f).

Briefly, the EDA IV concept arranges the waste packages close together in an emplacement configuration known as "line load". Continuous pre-closure ventilation keeps the waste packages from exceeding their 350°C cladding and 200°C (4.3.6) drift wall temperature limits. This EDA concept keeps relatively high, uniform emplacement drift temperatures (post-closure) to drive water away from the repository and thus dry out the pillars between emplacement drifts. The waste package is shielded to permit human access to emplacement drifts and includes an integral filler inside the package to reduce the amount of water that can contact the waste form. Closure of the repository is desired 50 years after first waste is emplaced. Both backfill and drip shields will be emplaced at closure to improve post-closure performance.

The EDA IV concept includes more defense-in-depth layers than the VA reference design because of its backfill, drip shield, waste package shielding, and integral filler features. These features contribute to the low dose-rate to the public achieved during the first 10,000 years of repository life as shown in Figure 3.

Investigation of the EDA IV concept has led to the following general conclusions:

- The total life cycle cost for EDA IV is about $21.7 billion which equates to a $11.3 billion net present value (both figures rounded up).
- The incidence of design basis events for EDA IV is similar to the VA reference design.
- The emplacement of the waste packages in drifts will be similar to the VA reference design. However, heavier equipment may be required because the shielded waste package will be heavier.
- The heavier shielding will permit access to the emplacement drift by personnel after blast cooling and emplacement of neutron shielding to further reduce the radiation dose rate.
- The EDA IV concept is flexible in that it will permit storage of 63,000 MTU within the upper emplacement block and storage of 105,000 MTU if both upper and lower blocks are used. As shown in Table 5, the concept is compatible with most other design alternatives and features.

Lastly, the EDA IV set of conceptual design parameters do not result in meeting all of the thermal goals with closure at 50 years. The drift wall temperature will exceed 200°C if the repository is closed at 50 years. A longer operating period (60-75 years) will be required until closure to meet the thermal goals.

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9. ATTACHMENTS

There is one (1) Attachment to this document.

Attachment I:	Environmental Considerations	(2 pages)

Attachment I
Environmental Considerations

The evaluation of environmental considerations for EDA IV is shown in this attachment.

1. Land use and ownership

Tuff spoil piles will be smaller compared to the VA reference design, as fewer emplacement drifts will be constructed. Backfill piles and drip shields will be stored on the surface at Closure prior to use in the emplacement drifts. An estimated two-month supply of backfill and drip shields would be stored. Additional space will be required on the surface to store the integral filler for the waste package. The concrete liner and invert will be replaced with a metal invert, rock bolts, and mesh. Therefore, the space reserved for the concrete precast yard will be eliminated. The area required for the batch plant can be reduced.

2. Air quality

Fugitive dust will be reduced because of the reduction in the tuff spoil piles. At Closure the equipment emissions due to backfill and drip shield installation will be more than the VA reference design. Radon-222 emissions will be reduced because less of the repository rock surface area is exposed in the emplacement drifts. Pre-closure ventilation will be increased compared to the VA reference design.

3. Hydrology, including surface water and groundwater

The thermal load from decaying waste packages will be similar to the VA reference design so no change to hydrology is anticipated. Waste packages will be made of 300 mm thick A516 carbon steel.

4. Biological resources and soils

The amount of disturbed land will be reduced because of smaller spoil piles. Additional outdoor lighting may be required for the installation of backfill and drip shields at Closure.

5. Cultural resources - No change from the VA reference design.

6. Socioeconomic

The reduction in excavation and different ground support system required for EDA IV will reduce the total manhours and the number of workers required for construction of the repository compared to the VA reference design. Backfill and drip shield installation will increase the number of workers at Closure.

7. Occupational and public health and safety

Public health and safety should be the same as the VA reference design. Occupational heath and safety should improve because of the fewer number of manhours required for repository construction. Operations will change from the VA reference design. Fewer drifts and no concrete liner or invert are replaced by waste package integral filler, a thicker waste package, metal invert, rock bolts, backfill, and drip shields.

8. Noise

At Closure, there will be an increase in the occupational noise due to installation of the backfill and drip shields. Overall, there will be a reduction on total noise due to the decrease number of drifts and elimination of the precast yard.

9. Aesthetics

The scenic quality of the area may be improved because of the reduction in the tuff spoil piles.

10. Utilities, energy, materials, and site services

The decreased number of drifts will substantially reduce the amount of utilities and energy required for EDA IV. However, utility usage will increase during closure relative to the VA reference design because of backfill and drip shield installation. Backfill will consist of 1.3 million m^3 for a single backfill or 1.7 million m^3 for a Richards Barrier backfill based on *Backfill Volumes for Enhanced Design Alternative Configurations* (CRWMS M&O 1999n, pg 33). The drip shields will consist of 2 cm thick Titanium 7 metal. Thickness of the waste packages will be increased to about 30 cm from the VA reference design of about 12 cm. There will be an integral filler in the waste packages. The elimination of the concrete precast liners will eliminate the materials and supplies required for this operation.

11. Management of repository generated waste and the use of hazardous materials – No change from the VA reference design.

12. Environmental justice – Not applicable

13. Summary of primary impacts on 3 thermal loads (high, medium, low)

This EDA is a high thermal load with an areal mass loading of 85 MTU/acre.

14. Summary of primary impacts on packaging options for transportation

This alternative will not affect the packaging options for waste transportation.

15. Summary of primary short term impacts (including operations, retrieval, and closure)

Backfill and drip shield will be installed at Closure. There will be some impact from the requirement for a larger waste package and filler during operations. Closure of the repository will occur about 50 years after emplacement versus 100 years in the VA reference design. About 10,213 waste packages will be required. About half of the waste packages will be 21 Pressure Water Reactor (PWR) type packages, about 30% will be 44 Boiling Water Reactor (BWR) type packages and the rest will be other sizes from *Design Input Transmittal for Enhanced Design Alternative I, IV, & V Input* (CRWMS M&O 1999e, pg 13). All waste packages will have an integral filler.

16. Summary of primary long term impacts (after closure)

This alternative may enhance post-closure performance.