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Findings of the ESF Alternatives Study

A. L. Stevens, L. S. Costin

Prepared by
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FINDINGS OF THE ESF ALTERNATIVES STUDY

by

A. L. Stevens
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ABSTRACT

This report presents a summary of the conduct and findings of the Exploratory Shaft Alternatives Study. The study basis and findings are presented in sufficient detail to allow the Department of Energy to make an informed decision as to the Exploratory Shaft Facility/Repository design option to be used as the basis for resumption of ESF Title II design. As a result of the desire for a rigorous, logically defensible analysis and the complexity of the required evaluation, a multi-attribute utility analysis was used as the primary decision-aiding tool. Over 2500 regulations, requirements and concerns were considered under four broad objectives. The analysis resulted in the ranking of 34 options, in accordance with the extent to which each option could achieve the objectives. Additional findings regarding design features that were identified as key elements in an options ability to provide good overall performance are also discussed.

This work was performed under the Sandia National Laboratories Nuclear Waste Repository Technology Department Quality Assurance Plan as a quality-affecting activity. WBS 1.2.6.1.1

Findings of the Exploratory Shaft Facility Alternative Studies

Executive Summary

The purpose of this report is to present the findings of the Exploratory Shaft Alternatives Study with sufficient detail to allow the DOE executive to make an informed decision as to the Exploratory Shaft Facility/Repository design option to be utilized as the basis for resumption of ESF Title II design.

This report was prepared in accordance with the Yucca Mountain Site Characterization Project Exploratory Shaft Facility Alternatives Study Implementation Plan, Rev. 1, December 20, 1990, prepared by SNL. It is considered to accurately represent the findings of the study, although the final report is in the compilation process, and is expected to be available in draft form in the March/April 1991 time frame.

Due to the desire for a rigorous, logically defensible analysis and the complexity of the required evaluation, (34 ESF/Repository options and approximately 2500 requirements and concerns) which had to be considered, multi-attribute utility analysis was used as the primary decision-aiding tool.

The analysis resulted in the ranking of the 34 options, in accordance to the extent of the adequacy with which expert panels estimated that each option would achieve the objectives. It should be noted that all of the options were considered to be adequate, although some options were ranked distinctly lower than the others (e.g., 9 and 26).

It is recognized that there are substantial uncertainties with respect to the actual performance of any option. The quantitative differences indicated between options are derived from the consensus best-professional judgments of expert panels selected for the study. It should be recognized that conducting the analysis using other expert panels would likely produce different quantitative differences (smaller or larger) and might or might not produce a different ranking.

To aid in the decision process, isometric drawings which portray each of the 34 options are included in an appendix. In the interest of report brevity, prose descriptions of the options have been omitted. If desired, detailed presentations on specific options will be provided.

In addition, your attention is directed to the November 20 presentation to the NWTRB. This presentation material includes the results of the evaluations by the expert panels in tabular form.

The decision will result in the placing of key features of the selected option under configuration control but does not preclude future changes. Rather, the key features will be baselined, and changes to those key features will be accomplished in accordance with the change control process, after review by appropriate technical disciplines. Selected key features will only be changed with the approval of the decision making executive.

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ACKNOWLEDGMENT

A large number of people have participated in the Exploratory Shaft Facility Alternatives Study. As one measure, over 200 people (from DOE, the participant organizations, subcontractors, and consultants) have been trained in the use of Sandia National Laboratories (SNL) QA procedures in support of this effort. Numerous others have participated under the QA procedures of their own organizations. The results presented in this report would not have been achieved without the enthusiastic and exemplary contributions of all members in this team effort. Within this number there are several key members of the team whose contributions we wish to specifically acknowledge. For leadership of the major tasks of the study: Al Dennis, SNL - study management and report preparation; Earl Gruer, SNL - development of options; Stephen Bauer, SNL - evaluatin process; and Mike Parsons, T&MSS - identification of requirements. For development and implementation of the decision-aiding methodology used for the study: Lee Merkhofer, Applied Decision Analysis and Paul Gnirk, RE/SPEC. For support to the expert panels in the evaluation process: Ned Elkins, LANL - testing requirements and schedules, Bill Kennedy, RSN - ESF configurations and construction methods, Brian Lawrence, PBQ&D - repository configurations and construction methods, Jim Scott, RSN - construction and operational schedules and costs, Ray Finley, SNL - Task 4 support and conduct of reviews, and Mike Voegele, T&MSS - support to the program viability panel. For guidance and encouragement to the study teams: Ted Petrie, Bob Waters, Max Blanchard, and Dave Dobson, all of the Yucca Mountain Site Characterization Project Office.

FINDINGS OF THE ESF ALTERNATIVES STUDY

1.0 INTRODUCTION

1.1 SCOPE OF THE STUDY

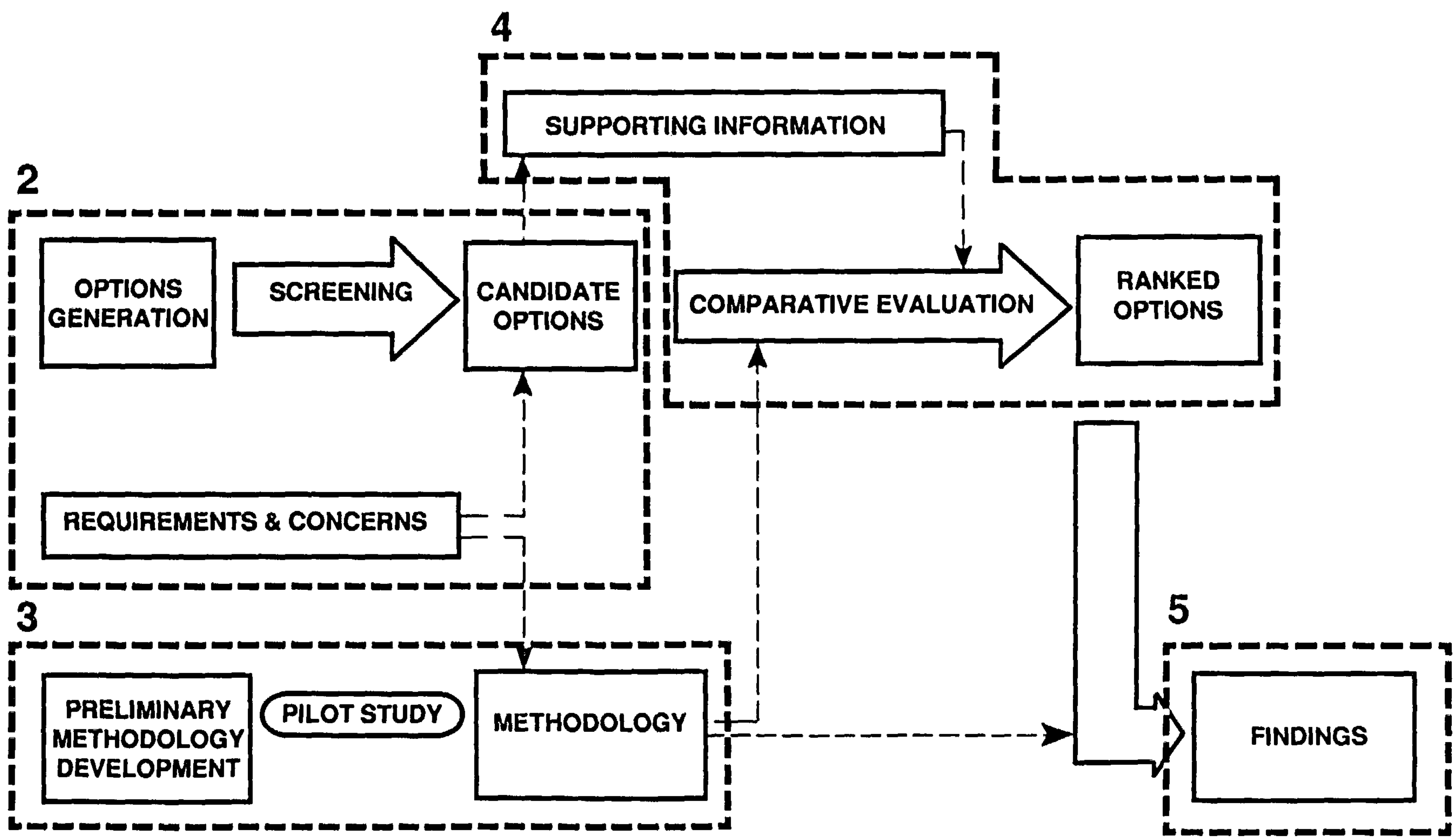
The Yucca Mountain Site Characterization Project Exploratory Shaft Facility Alternatives Study (ESF-AS) Implementation Plan directed Sandia National Laboratories (SNL) to lead a study that would identify various ESF/repository configurations and construction methods (together called options), identify all requirements and concerns applicable to the ESF and repository, and comparatively evaluate the options relative to those requirements and concerns. The Calico Hills Risk/Benefit Analysis, conducted in parallel and integrated with this study, addressed an NRC objection to the draft SCP, and provided a recommendation to this study that the selected option should be able to support extensive drifting in the Calico Hills rock unit. The ESF-AS incorporated these recommendations and further evaluated the benefits to the test program, as well as the waste isolation impacts for the features of each complete ESF option. The evaluation of the options has been completed and this report contains a summary of the findings from that evaluation.

The principal activities of the ESF Alternative Study are illustrated in Figure 1-1, and this report is structured according to the flow of those activities. Section 2 describes the evolutionary process that led to the selection of 34 ESF options that were comparatively evaluated. The decision methodology that provided the framework for the comparative evaluation is discussed briefly in Section 3, along with the rank order of the 34 ESF options in terms of their relative desirability. Section 4 is a compilation of the principal evaluation factors and design features that were found to be influential in establishing the rank ordering of the options. Finally, the findings of the Alternatives Study are summarized in Section 5.

1.2 QUALITY ASSURANCE

The ESF-AS was conducted under a qualified quality assurance (QA) program which meets the requirements of 10 CFR 60, Subpart G. The QA program has been approved by the Yucca Mountain Site Characterization Project Office and the Office of Civilian Radioactive Waste Management, and it has been accepted by the Nuclear Regulatory Commission. Reviews of all material prepared for and generated by the scoring process are in progress, and will be completed prior to issuance of the final report. The application of the QA program controls to the input and conduct of the study provides confidence in the quality of the results presented.

Figure 1-1
ESF ALTERNATIVES STUDY



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2.0 CANDIDATE ESF/REPOSITORY OPTIONS

2.1 GENERATION OF THE INITIAL SET OF OPTIONS

An option was defined as the combination of an ESF configuration and associated construction methods integrated with a repository configuration so as to provide compatible interfaces between the ESF and repository. That is, for each option the accesses and other ESF interfaces with a repository were defined in the context of a total ESF/repository system so that ESF accesses were compatible with and had integral functions in the repository. In the sense used here, configuration refers to the conceptual physical layout of accesses and underground works.

In the initial part of the study, all previous ESF and repository conceptual configurations were reviewed and new ESF/repository configurations were generated. New configurations were developed to address regulatory and other requirements, as well as to address comments and concerns expressed by the Nuclear Waste Technical Review Board (NWTRB) and the Nuclear Regulatory Commission (NRC). Therefore, all options are expected to meet the requirements of 10 CFR Part 60. In addition, a number of major design features were addressed in various ways within the new options so that a direct comparative evaluation of features, as they are embedded in a number of different ESF/repository systems, could be made.

2.2 PRELIMINARY SCREENING OF OPTIONS

After the previous ESF and repository configurations had been identified and new options prepared, a screening of options was conducted to reduce the number of possible options to a set that would be evaluated in detail. The screening was conducted by a panel of experts, according to the following steps:

1. Previous ESF and repository options were screened against a selected set of regulatory and site characterization testing requirements. The screening requirements were selected from the entire set of applicable requirements on the basis that it could be determined readily whether or not an option was in compliance.

2. Historic options passing the first stage of the screening and new options developed for the study were assigned to a number of classes defined on the basis of differences in major features.

3. One option was selected from each class to be in the final set. It insured that the range of features desired was well represented in the set of options to be evaluated.

As a result of this screening process and the subsequent review, 17 options were identified for further evaluation.

2.3 FINAL SET OF CANDIDATE OPTIONS

After the screening process had been completed, a series of events occurred that significantly altered the number and content of the options and required revision of the methodology used for comparative evaluation of the options. The events were:

(1) The Calico Hills Risk-Benefit Assessment Working Group provided input to the ESF-AS on June 30, 1990 that added extensive drifting in the Calico Hills unit to each of the ESF configurations.

(2) The NWTRB (in its First report to Congress) confirmed its previous recommendation for the addition of an east-west drift in the Topopah Spring unit to detect potential north-south trending faults.

(3) At an ESF-AS Management Panel meeting on August 8, 1990, the DOE directed the ESF-AS to evaluate each option considering two alternative characterization testing strategies. These were (a) primary emphasis on early access to the Topopah Spring unit, and (b) primary emphasis on early access to the Calico Hills unit.

On the basis of the first two events, the design configurations for the 17 ESF options were updated to include 19,000 ft. of exploratory drifting in the Calico Hills unit and an east-west drift in the Topopah Spring unit. The third event led to the development of 17 additional options to accommodate the two alternative characterization testing strategies. Isometric sketches of the 34 options are included in Appendix A. The testing strategy for options 1-17 consisted of the systematic progression of construction and site-characterization testing from the surface down the accesses to the Topopah Spring and then on down to the Calico Hills. In contrast, the testing strategy for options 18-34 was to proceed to the Calico Hills as rapidly as possible to make an early determination of suitability (or unsuitability) of the principal natural barrier, while conducting only those tests in the accesses necessary to acquire site data that would be irrecoverable if not acquired during initial construction. An option was now defined as a physical configuration and construction method (17 configurations) plus a testing strategy (two testing strategies per configuration). That is, under this definition, there are 17 pairs of options (1 & 18, 2 & 19, 3 & 20, etc.), where both members of a pair have the same physical configuration and construction method (See the Summary of Options table in Appendix A), but a different testing strategy. In a few cases, the physical configuration was modified to better address the objective of the second strategy. Within each strategy, early and late testing phases were to be defined so that the relative value of early information from each test strategy could be assessed for the purpose of an early determination of suitability. Additional details of the testingstrategies are given in the figure titled "Testing Groups and Sequences for Early/Late Exploration and Testing" in Appendix A. The principal design and construction features of the set of 34 candidate options are summarized in Table 2.1.

TABLE 2.1

SUMMARY OF THE PRINCIPAL DESIGN AND CONSTRUCTION FEATURES FOR THE 34 CANDIDATE ESF/REPOSITORY OPTIONS

OPTION #			E.S.F.								REPOSITORY				
			ACCESS 1		ACCESS-2		MAIN TEST LEVEL				ACCESSES		CONSTRUCTION METHOD		
			SIZE	CONST. METHOD	SIZE	CONST. METHOD	LAYOUT	CONST. METHOD	LOCATION	ELEVATION	SHAFTS	RAMPS (TBM)	RAMPS & DRIFTS	EMPL. AREA	TOTAL ACCESSES
18	1	BASE CASE	12' SHAFT	DRILL & BLAST	12' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2-20'	1-25' 1-23'	TBM	DRILL & BLAST	6
19	2	A1	16' SHAFT	-"-	25' RAMP	TBM	MODIFIED T II G.A.	-"-	-"-	-"-	2-25'	1-25' +ESF	-"-	-"-	5
20	3	A2	16' SHAFT	-"-	16' SHAFT	DRILL & BLAST	-"-	-"-	-"-	-"-	-"-	2-25'	-"-	-"-	6
21	4	A4 REV.1	16' SHAFT	-"-	12' SHAFT 25' RAMP	D&B TBM	-"-	-"-	-"-	-"-	1-25' ENLARGE ES-2 25'	1-25' +ESF	-"-	-"-	5
22	5	A5	16' SHAFT	-"-	25' RAMP	TBM	-"-	-"-	S	-"-	2-25'	-"-	-"-	-"-	5
23	6	A7	25' RAMP	TBM	25' RAMP	-"-	-"-	-"-	NE	-"-	-"-	IN ESF	-"-	-"-	4
24	7	B3, REV. 2-		SBM											
25	8	B3,REV.3-		V-MOLE											
26	9	B3,REV. 4-	16' SHAFT	BLIND BORE	-"-	-"-	-"-	MECH.	-"-	-"-	-"-	1-25' +ESF	-"-	TBM	5
27	10	B3,REV. 5-		RAISE BORE											
28	11	B3, REV. 6-		DRILL & BLAST											
29	12	B4	16' SHAFT	DRILL & BLAST	-"-	-"-	-"-	-"-	S	-"-	-"-	-"-	-"-	-"-	5
30	13	B7	25' RAMP	TBM	-"-	-"-	-"-	-"-	-"-	-"-	-"-	IN ESF	-"-	-"-	4
31	14	B8	16' SHAFT	DRILL & BLAST	-"-	-"-	-"-	-"-	-"-	-"-	1-25'	2-25' +ESF	-"-	-"-	5
32	15	C1	16' SHAFT	-"-	-"-	-"-	TWO LEVEL	-"-	NE	TWO LEVELS SAME AS REPOS.	3-25' ENLARGE ES-1-25'	1-25' +ESF	-"-	-"-	4
33	16	C4	16' SHAFT	-"-	-"-	-"-	-"-	-"-	S	-"-	2-25'	-"-	-"-	-"-	5
34	17	R11	12' SHAFT	-"-	12' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2-25'	2-25'	-"-	-"-	6

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2.4 REQUIREMENTS

As indicated in Figure 1-1, requirements were a major component of this study. Requirements, as a category, includes such things as (1) federal, state and local regulatory requirements, and (2) DOE orders, requirements documents, and guidance, as well (3) as concerns expressed by oversight agencies (e.g., NRC, NWTRB, State of Nevada). Appendix B contains a list of the source documents that were reviewed for individual requirements applicable to the ESF and repository as a basis for discriminating between options. These source documents contain approximately 2500 individual requirements. The review process resulted in approximately 250 requirements providing the basis for discrimination in the evaluation of options by the expert panels. These requirements were cross correlated with the factors that influence the probabilities and performance measures (in the influence diagrams) as described in Section 3.1.

3.0 COMPARATIVE EVALUATION

This section describes the methodology developed for the analysis of the 34 candidate options and the results of the comparative evaluation.

3.1 METHODOLOGY

The comparative evaluation was based on formal decision analysis. Prior to conducting the main analysis, a pilot study was conducted to test the feasibility of the approach and to identify the considerations that are most important for the analysis to address. The pilot study results suggested that the choice of an ESF option might significantly affect future uncertainties, such as the likelihood of license approval, and ultimate repository consequences, such as postclosure releases.

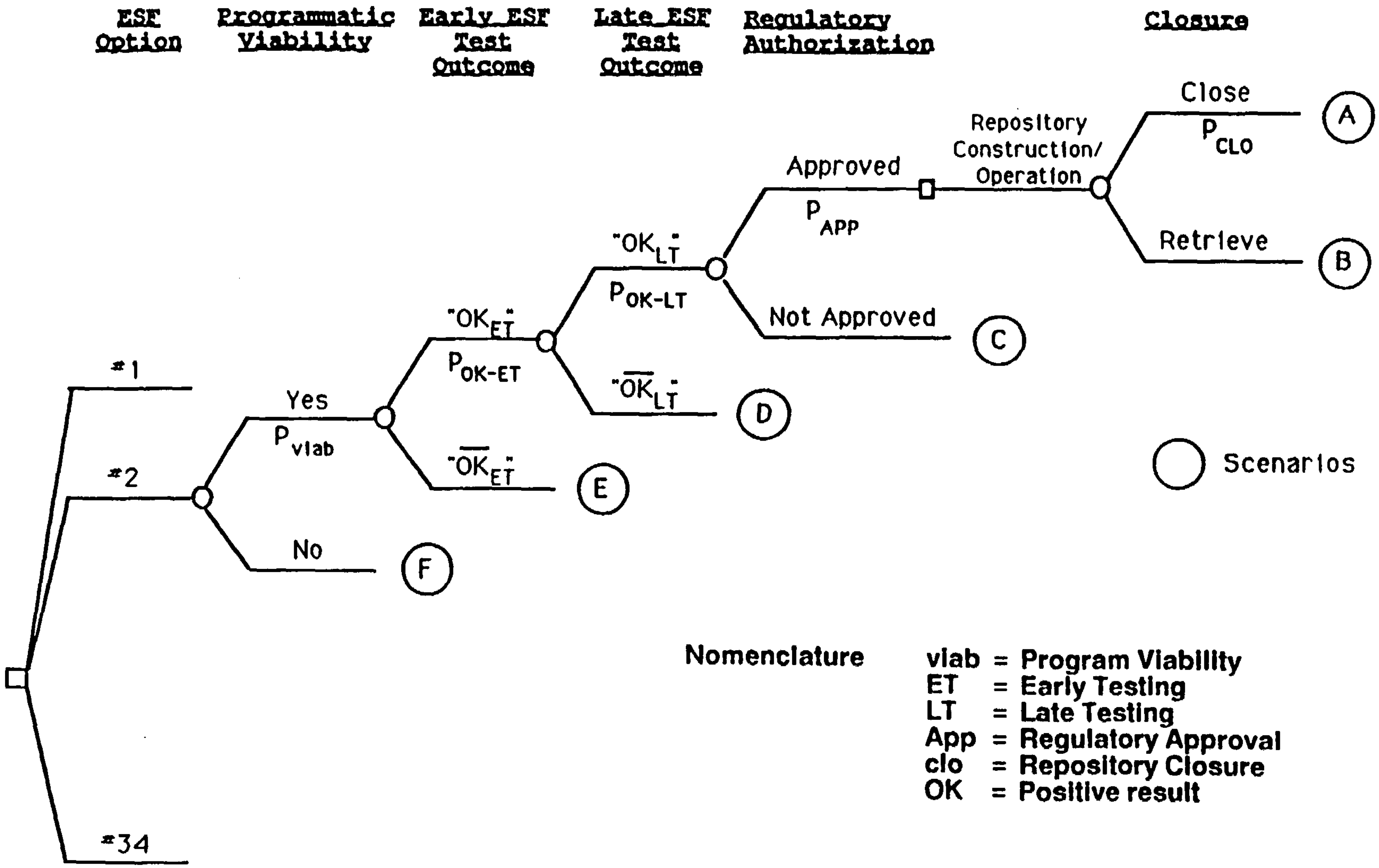
Accordingly, the main analysis consisted of two major components. First, the uncertain future events and decisions potentially impacted by the choice of an ESF option were identified. These uncertainties define 6 alternative future scenarios, which were represented in a decision tree, as shown in Figure 3-1. The analysis included an assessment of how the probabilities of each possible scenario depends on the selected option. Second, the end consequences of each possible future scenario were estimated. The types of consequences and measures defined for qualifying each are shown in Figure 3-2.

The consequences for each scenario were estimated by expert panels (see Table 3-1). Scaling and weighting functions were applied to the estimated numerical value of each measure for a given option and scenario and then summed to obtain an aggregate measure of the net benefit of that scenario. Net benefit is the benefit of getting to a particular end point in the tree (scenario), minus the consequences of getting there. The purpose of scaling the consequence measures is to allow them to be expressed in a common set of units and to weigh their relative value. In this analysis, all consequences were expressed as equivalent dollar amounts. Because the scaling factors represent a value judgment and not a technical judgment, a management panel, independent of the expert panels, was used to determine the scaling factors for each measure.

Figure 3-1

DECISION TREE

The impact of the ESF option on the likelihood of important down-stream decisions and uncertainties.



Nomenclature

viab	=	Program Viability
ET	=	Early Testing
LT	=	Late Testing
App	=	Regulatory Approval
clo	=	Repository Closure
OK	=	Positive result

Figure 3-2
MEASURES DEFINED FOR QUANTIFYING END CONSEQUENCES

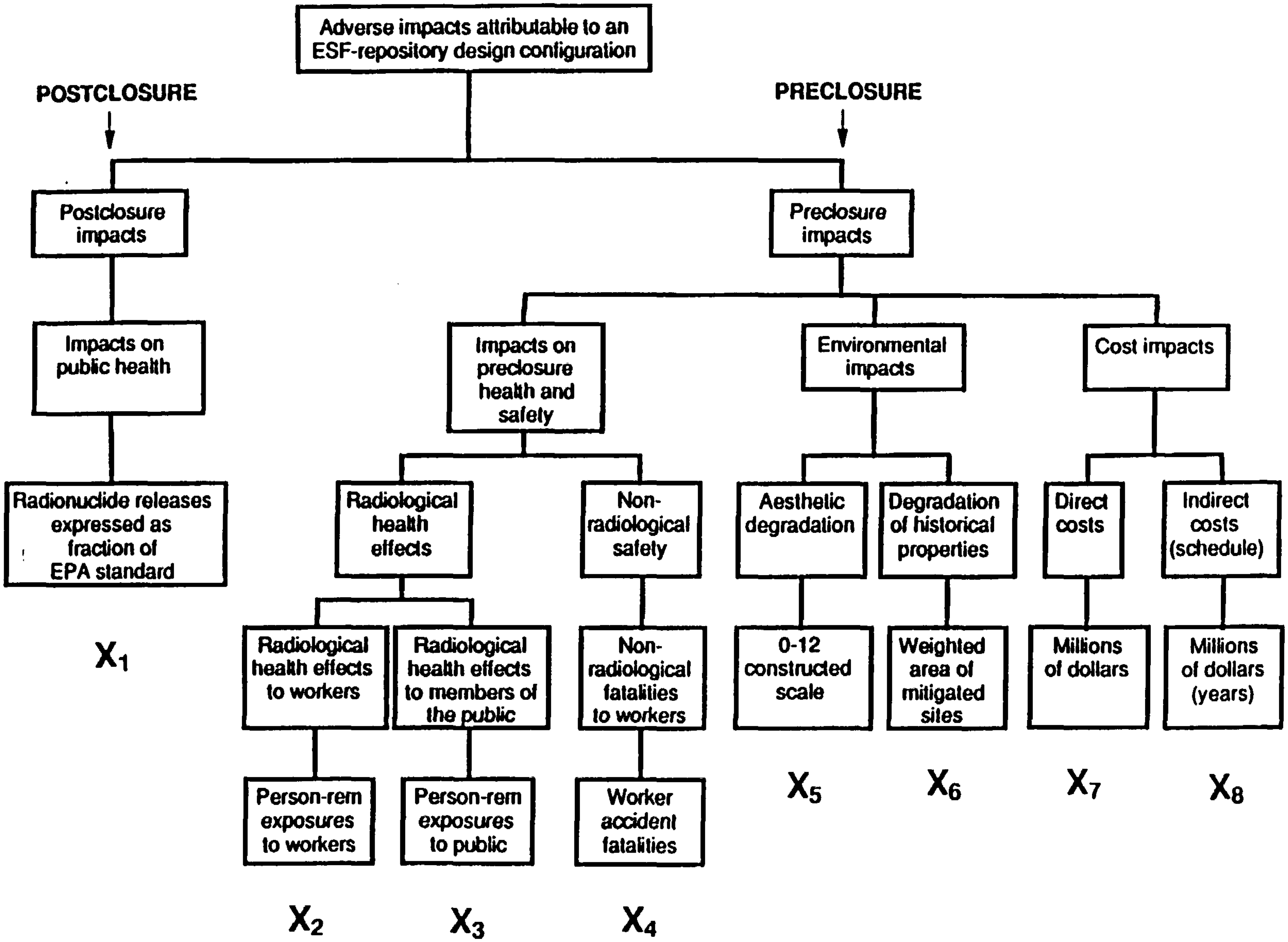


TABLE 3-1

EXPERT PANELS

Panel	Measures Evaluated
Postclosure Performance	Releases X_1 P_{OK}
Preclosure Radiological Health	Worker Exposure, X_2 Public Exposure, X_3
Preclosure Non-Radiological Health and Safety	Worker Accident, X_4
Environment	
- Aesthetic Properties	Aesthetic Degradations, X_5
- Historical Properties	Degradation of Historical Properties, X_6
- Biological Properties	(Non-discriminatory; not scored)
Socioeconomics	Non-discriminatory; not scored)
Cost and Schedule	Direct Costs, X_7 Indirect Costs, X_8 Cost and Schedule Input to Program Viability
Characterization Testing	P_{EFP}, P_{EFN}, P_{LFP}, P_{LFN}
Regulatory Approval	P_{APP}, P_{CLO}
Programmatic Viability	P_{viab}
Management	Weights

LEGEND

P_{OK} = Probability that site is suitable
P_{EFP} = Probability of an Early False Positive result from (early) testing.
P_{EFN} = Probability of an Early False Negative result from (early) testing.
P_{LFP} = Probability of a Late False Positive result for (late) testing.
P_{LFN} = Probability of a Late False Negative result from (late) testing.
P_{APP} = Probability of a Regulatory Approval
P_{CLO} = Probability of Repository Closure
P_{viab} = Programmatic Viability

NOTE:

Expert panels consisted of from 5 to 10 members drawn largely from within the DOE civilian waste management program participant and contractor community. Seven members of the technical panels came from outside of the DOE community. Members of each panel were selected on the basis of their expertise (education and experience) with respect to the topics addressed by the panel, and were selected by a controlled process.

The assumed benefit of obtaining a closed repository is somewhat arbitrary, but was assumed to be larger than the total consequences; otherwise, the analysis would indicate that the best option is the one that maximizes the probability of doing nothing (which would produce the least consequences). A benefit of $50 billion was assumed for scenario A (a closed repository). Scenario B (waste retrieved, but kept at site) was assigned a benefit of $2 billion. A zero benefit was assumed for all other scenarios. The value of the benefits assumed was found not to affect the ranking of the alternatives so long as the total benefit is larger than the total consequences.

The aggregate score for each option was determined by solving the decision tree. This amounts to multiplying the probability of each scenario through the tree by the net benefit of that scenario and summing over all scenarios. The overall score is then the expected net benefit of a particular option.

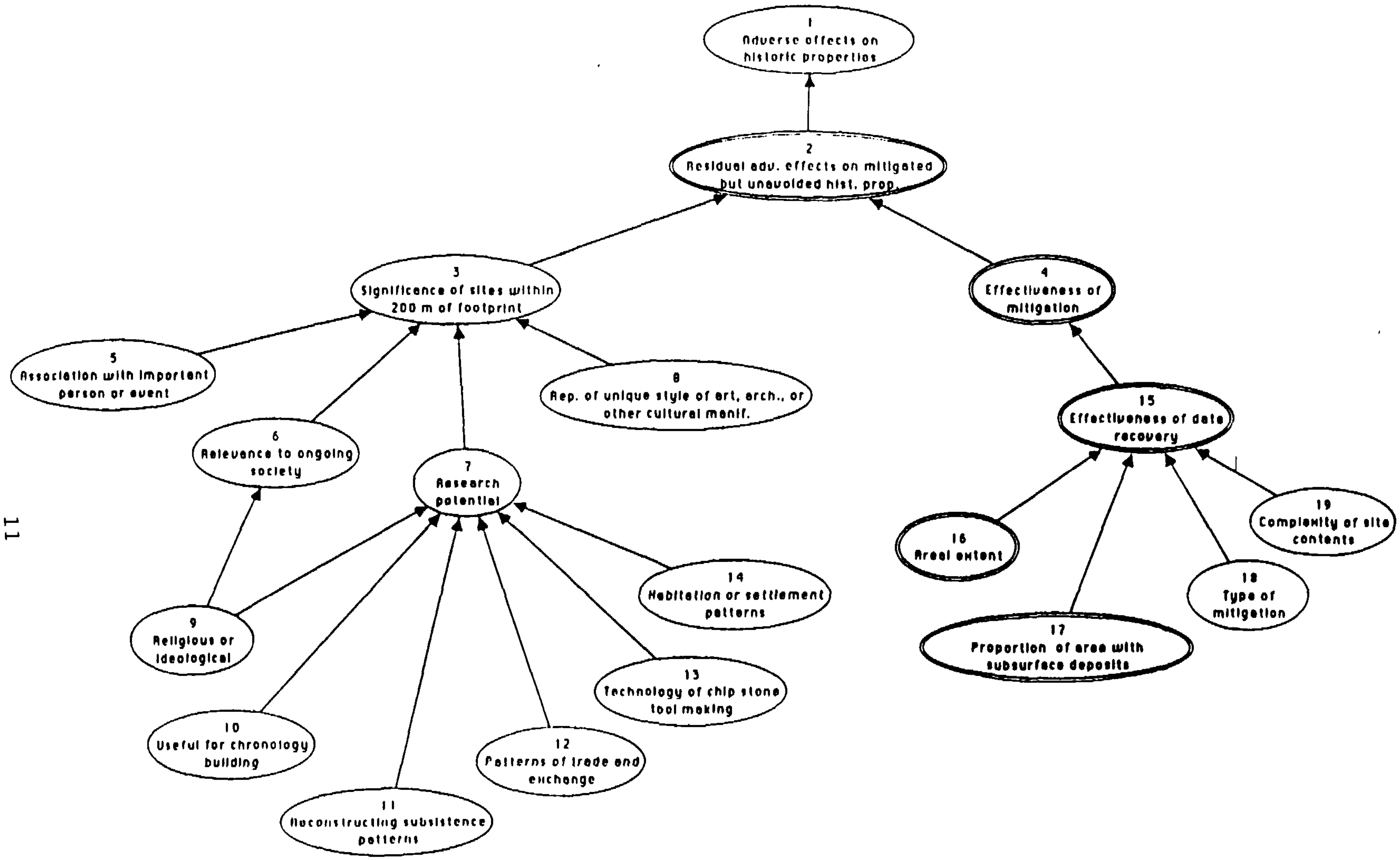
Because of insufficient data and large uncertainties in the numerical values that would be required to perform the actual quantitative evaluation, the estimates of probabilities and consequences were generated by expert panels (Table 3-1). When estimating a given consequence measure or probability, each panel was asked to provide a best estimate value, a high estimate and a low estimate. The best estimate value was used as input to the model to determine the overall score. The high and low values were used as the extreme values for the measure in sensitivity studies.

Before scoring, expert panels developed influence diagrams for each probability and consequence measure. This was done to determine the major factors that must be considered when evaluating an option with respect to a given performance measure. Figure 3-3 shows an example of an influence diagram used in this study (impacts on historical properties). The factors judged by the panel to be potentially significant discriminators are indicated by a double circle.

In addition to the influence diagrams, the panels were provided with a substantial amount of reference information regarding the options, the applicable requirements, previous analytical results, and other guidance. Once the influence diagrams were completed for each criterion, a subset of the applicable regulations, requirements, and other concerns that were determined to be potentially discriminatory (i.e. would allow for discrimination) between options were cross-correlated with the factors on the influence diagrams. This was done for two purposes: first, to assure that all applicable requirements, regulations, etc. were being taken into account in the assessments through evaluations against the criteria; and, second, to provide the evaluators information as to exactly what regulations, requirements, etc. should be considered during an evaluation against a particular criterion.

Once the evaluations were complete, a series of sensitivity studies was performed to assess the sensitivity of the ranking to input judgments and other assumptions. Analyses were also performed to determine which of the evaluation criteria were the most important or influential to determining the ranking.

Figure 3-3



Influence Diagram Draft 11 [5/24/90] - Historical Properties

3.2 RANK ORDERING OF THE ESF OPTIONS

Tables 3-2 and 3-3 show the best judgment consequence and probability estimates together with the resulting expected net benefit estimates. The precision of the numbers presented in the tables is a reflection of the precision deemed necessary by the panels to permit conveying the relative performance of the various options. Panels felt that relative performance could be estimated with greater precision than absolute performance. For example, the fact that a panel assigned a best-judgment estimate of .60 for one option and a best-judgment estimate of .61 for another option means that the panel believed that the second option was .01 units higher on the measurement scale. The fact that estimates might be provided to a precision of .01 units does not necessarily mean that the panel believed that the performance of an option could be estimated to a precision equal to or greater than + .01 units. Sensitivity analyses showed that the study conclusions were relatively insensitive to changes in absolute level (e.g., changing [.60 and .61] to [.50 and .51], respectively) but that rankings are relatively sensitive to changes in diffential estimates (e.g., changing [.60 and .61] to [.60 and .60], respectively).

An overall rank ordering of the options based on the best estimate judgments of the various panels, is presented in Table 3-2. The relative value of the options is quantified by a normalized figure of merit. The figure of merit used is based on the expected net benefit of each option as calculated by solving the decision tree with the best estimate values of each probability and consequence estimate (Table 3-3). The expected net benefit for each option was then normalized by scaling highest ranked option to 100 points and the lowest ranked option to 25 points in dimensionless units rounded to the nearest point. Thus, the option with the greatest expected net benefit received a normalized figure of merit of 100. It should be noted that this ranking was derived from consensus or majority views expressed by each panel. Alternative views (minority reports) were also recorded by several of the expert panels. The effect on the overall ranking of substituting a minority view for the majority view is discussed below.

The difference in calculated expected net benefit between the option ranked number one and the option ranked number two is approximately $1,079 million, based on an assumed benefit of $50,000 million for a closed (successfully completed) repository. This should be interpreted as meaning that, if the judgments of the expert and management panels are accepted, then the top ranked option is preferable to the second-ranked option by an amount equal to the preference given to saving $1,079 million. Thus, if the best-judgment consensus estimates of the technical panels and the value judgments provided by the management panel are accepted, then the logical conclusion is that the option ranked number one is preferable to the option ranked number two by an amount equal to the preference attributed to saving $1,079 million. It should be noted that all options are expected to meet the requirements of 10 CFR Part 60, however, there is considerable uncertainty over consequence and probability estimates. Thus, it is possible that the second-ranked option would produce a better outcome then the first ranked option. It is also possible that another set of expert panels would produce a set of technical and cost judgments that would lead to other cost differentials or an alternative ranking.

TABLE 3-2

ESF-AS
RANK ORDER OF 34 ALTERNATIVE DESIGN OPTIONS

Option	Normalized Figure of Merit	Overall Ranking*
30	100	1st
23	96	2nd
24	94	3rd
13	93	4th
6	91	5th
7	90	6th
2	85	7th
19	84	8th
25	82	9th
4	81	10th
21	80	11th
28	79	12th
22	73	13th
29	69	14th
32	69	15th
27	67	16th
20	67	17th
8	66	18th
31	65	19th
15	63	20th
33	63	21st
5	59	22nd
12	56	23rd
16	56	24th
3	56	25th
11	56	26th
1	50	27th
14	47	28th
10	46	29th
17	45	30th
18	45	31st
34	40	32nd
26	31	33rd
9	25	34th

*Assumes benefit of a functioning repository is $50 B or more.

Table 3-3
SUMMARY OF DECISION TREE CALCULATIONS

Option		PROBABILITIES {Prog. Viab}		{"OK-ET"}		{"OK-LT" / "OK-ET"}		{Approval}		{Closure}		{Scenario A}		Expected Net Benefit [$ million] *	
B.Case	1	0.55	26th	0.83	18th	0.89	30th	0.78	24th	0.995	30th	0.31	27th	12,080	27th
A1	2	0.73	15th	0.83	11th	0.91	2nd	0.93	4th	0.998	11th	0.51	7th	20,829	7th
A2	3	0.52	31st	0.83	13th	0.90	5th	0.89	9th	0.998	17th	0.35	26th	13,674	25th
A4-1	4	0.74	13th	0.83	16th	**0.92**	**1st**	0.87	12th	0.999	4th	0.49	10th	19,684	10th
A5	5	0.58	21st	0.84	9th	0.90	8th	0.85	15th	0.999	7th	0.37	22nd	14,501	22nd
A7	6	0.78	9th	0.83	15th	0.90	17th	0.93	3rd	0.999	3rd	0.54	5th	22,218	5th
B3-2	7	0.79	7th	0.82	25th	0.90	9th	0.92	5th	0.998	13th	0.54	6th	21,990	6th
B3-3	8	0.64	18th	0.83	24th	0.90	18th	0.85	15th	0.998	15th	0.40	19th	15,984	18th
B3-4	9	0.45	34th	0.74	33rd	0.84	33rd	0.67	33rd	0.991	34th	0.19	34th	6,142	34th
B3-5	10	0.58	22nd	0.78	32nd	0.89	24th	0.74	29th	0.996	28th	0.30	29th	11,139	29th
B3-6	11	0.56	24th	0.82	26th	0.90	6th	0.83	18th	0.997	23rd	0.35	25th	13,536	26th
B4	12	0.58	23rd	0.84	5th	0.90	11th	0.81	21st	0.998	8th	0.35	23rd	13,763	23rd
B7	13	0.81	6th	**0.85**	**1st**	0.91	3rd	0.89	9th	**0.999**	**1st**	0.55	4th	22,579	4th
B8	14	0.51	33rd	0.84	8th	0.90	7th	0.78	25th	0.998	12th	0.30	28th	11,370	28th
C1	15	0.54	28th	0.83	20th	0.90	10th	**0.95**	**1st**	0.999	5th	0.38	21st	15,454	20th
C4	16	0.53	29th	0.81	29th	0.89	23rd	0.90	7th	0.999	2nd	0.35	24th	13,725	24th
R11	17	0.56	25th	0.83	21st	0.90	13th	0.70	31st	0.997	25th	0.29	30th	10,981	30th
B.Case	18	0.52	32nd	0.82	28th	0.88	32nd	0.77	27th	0.995	31st	0.29	31st	10,956	31st
A1	19	0.77	10th	0.83	12th	0.89	26th	0.90	8th	0.997	18th	0.51	8th	20,404	8th
A2	20	0.67	17th	0.83	17th	0.89	27th	0.83	18th	0.997	21st	0.41	17th	16,322	17th
A4-1	21	0.77	12th	0.84	3rd	0.90	12th	0.84	17th	0.998	16th	0.49	11th	19,579	11th
A5	22	0.77	11th	0.84	4th	0.90	20th	0.78	25th	0.997	22nd	0.45	13th	17,760	13th
A7	23	0.87	3rd	0.83	14th	0.89	28th	0.90	6th	0.998	10th	0.58	2nd	23,306	2nd
B3-2	24	**0.90**	**1st**	0.82	27th	0.89	25th	0.86	14th	0.997	24th	0.57	3rd	23,006	3rd
B3-3	25	0.84	4th	0.83	23rd	0.90	16th	0.80	22nd	0.997	19th	0.50	9th	19,920	9th
B3-4	26	0.55	27th	0.74	34th	0.83	34th	0.66	34th	0.991	33rd	0.22	33rd	7,677	33rd
B3-5	27	0.83	5th	0.79	31st	0.89	31st	0.73	30th	0.996	29th	0.42	15th	16,340	16th
B3-6	28	0.79	8th	0.83	22nd	0.90	14th	0.82	20th	0.997	26th	0.48	12th	19,211	12th
B4	29	0.73	14th	0.84	7th	0.90	15th	0.79	23rd	0.997	20th	0.43	14th	16,921	14th
B7	30	0.89	2nd	0.85	2nd	0.91	4th	0.87	13th	0.999	6th	**0.60**	**1st**	**24,385**	**1st**
B8	31	0.70	16th	0.84	6th	0.90	21st	0.77	28th	0.997	27th	0.41	18th	15,862	19th
C1	32	0.62	19th	0.80	30th	0.90	19th	0.94	2nd	0.998	9th	0.42	16th	16,759	15th
C4	33	0.59	20th	0.83	19th	0.90	22nd	0.88	11th	0.998	14th	0.39	20th	15,306	21st
R11	34	0.53	30th	0.83	10th	0.89	29th	0.69	32nd	0.995	32nd	0.26	32nd	9,852	32nd

* Assumes benefit of functioning closed repository is $50 billion.

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3.3 SUMMARY OF RANKINGS UNDER VARIOUS MINORITY REPORTS

There were a number of cases in which panel consensus was not obtained when assessing the best judgment values for a measure. In some cases the differences between majority and minority views were a matter of degree. That is, the rationale leading to the assessment of a value was essentially the same, but the assigned value differed. In other cases, differences in rationale were sufficient to lead to considerably different results. A summary comparison of majority and minority views is given in Table 3-4.

It may be observed from Table 3-4 that, with the exception of the minority report on programmatic viability the ranking is largely insensitive to the disagreements that prevented panel consensus. The minority report on programmatic viability was provided by one member of the Programmatic Viability Panel who expressed a view that was considerably different from the remaining six-member majority. The minority view resulted in a large number of the options receiving a probability of 1.0, expressing the fact that he was certain any one of the number of options could be implemented. In addition, the minority view expressed concern that more emphasis should be given to the potential of early delays that may be caused by differences in options, and less emphasis given to other concerns.

As indicated in the table, the overall ranking of the options is very sensitive to the probabilities for programmatic viability. Two of the factors that apparently were important to panel members in assessing programmatic viability were resolution of NRC and NWTRB comments and concerns. However, only the NRC and NWTRB are able to determine the extent to which their real concerns are addressed.

4.0 ANALYSIS OF PRINCIPAL FACTORS AND FEATURES

4.1 INTRODUCTORY REMARKS

An initial objective of the ESF Alternatives Study was to comparatively evaluate design features, and as a result, identify those features that, if incorporated into a given option, would result in that option being more favorably rated. A list of potentially favorable features could then form the basis for developing new options, or altering existing options, to produce options that would rate better overall than any of the current options. The approach taken was to select options that displayed a wide range of specific features and different combinations of those features. Thus, the relative merit of trade-offs between design features (such as shafts versus ramps) could be evaluated in the context of their performance in the ESF/Repository system. The five principal design features that were incorporated into the set of 34 ESF options, along with the range of alternative configurations that include these features, are listed in Table 4-1. Section 4.2.1 provides a qualitative discussion of the relative merit of these features based on the results of the study.

Table 3-4

RANK ORDER OF OPTIONS UNDER VARIOUS MAJORITY/MINORITY REPORTS

MAJORITY BEST JUDGEMENT RANKING		Minority View for Prog. Viab.		Minority EFN View #1 (7 experts)		Minority EFN View #2 (2 experts)		Minority View on Retrieval		Revised Estimates for Testing Probabilities	
30	1st	13	1st	30	1st	23	1st	30	1st	30	1st
23	2nd	2	2nd	13	2nd	24	2nd	23	2nd	23	2nd
24	3rd	6	3rd	23	3rd	6	3rd	24	3rd	24	3rd
13	4th	23	4th	24	4th	30	4th	13	4th	13	4th
6	5th	19	5th	7	5th	7	5th	6	5th	6	5th
7	6th	4	6th	6	6th	2	6th	7	6th	7	6th
2	7th	7	7th	4	7th	13	7th	2	7th	2	7th
19	8th	5	8th	19	8th	19	8th	19	8th	19	8th
4	9th	21	9th	2	9th	25	9th	25	9th	4	9th
25	10th	24	10th	25	10th	28	10th	4	10th	25	10th
21	11th	15	11th	21	11th	21	11th	21	11th	21	11th
28	12th	12	12th	28	12th	32	12th	28	12th	28	12th
22	13th	3	13th	22	13th	27	13th	22	13th	22	13th
29	14th	20	14th	29	14th	4	14th	29	14th	29	14th
32	15th	29	15th	8	15th	20	15th	32	15th	32	15th
20	16th	32	16th	32	16th	22	16th	27	16th	27	16th
27	17th	14	17th	20	17th	29	17th	20	17th	20	17th
8	18th	22	18th	27	18th	8	18th	8	18th	8	18th
31	19th	28	19th	33	19th	15	19th	31	19th	31	19th
15	20th	31	20th	5	20th	33	20th	15	20th	33	20th
33	21st	30	21st	15	21st	31	21st	33	21st	15	21st
5	22nd	8	22nd	31	22nd	16	22nd	5	22nd	5	22nd
12	23rd	25	23rd	3	23rd	5	23rd	12	23rd	16	23rd
3	24th	16	24th	12	24th	11	24th	16	24th	12	24th
16	25th	11	25th	16	25th	1	25th	3	25th	3	25th
11	26th	33	26th	11	26th	12	26th	11	26th	11	26th
1	27th	18	27th	1	27th	3	27th	1	27th	1	27th
14	28th	1	28th	18	28th	10	28th	14	28th	14	28th
10	29th	17	29th	14	29th	18	29th	10	29th	10	29th
17	30th	10	30th	10	30th	17	30th	17	30th	17	30th
18	31st	27	31st	17	31st	14	31st	18	31st	18	31st
34	32nd	34	32nd	34	32nd	34	32nd	34	32nd	34	32nd
26	33rd	9	33rd	26	33rd	26	33rd	26	33rd	26	33rd
9	34th	26	34th	9	34th	9	34th	9	34th	9	34th

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Table 4-1

Alternatives of Major Design Features

Major Design Feature	Alternatives	
1. Means of Access	Shafts only Ramps only Shaft/ramp combination	
2. Location of Accesses	All in northeast All in south Combination of locations	
3. Location of Main Test Level (MTL) core area in Topopah Spring (TS)	Northeast South	
4. Excavation method of openings	Shafts	- Drill and Blast - Shaft Boring Machine - Blind Hole Drill - V-mole - Raise Bore
	Ramps	- Tunnel Boring Machine (TBM) - Road Header - Drill and Blast
	MTL(TS) Core Area	- Drill and Blast - Road Header - TBM *
	Exploratory Drifting in TS & CH	- Drill and Blast - Mobile Miner - TBM - Road Header
5. Total number of accesses	ESF accesses are an integrated subset of the total number of accesses for the repository	

* TBM not specifically considered for MTL excavation but is expected to be an acceptable alternative.

It was also recognized that other features not previously identified as being of potential importance, but incorporated in a number of options, might be identified as being favorable (or unfavorable) as a result of the comparative evaluation. Several of these features were indeed identified, as discussed, along with their merits, in Section 4.2.2.

As noted in Section 2.3, comments from the NWTRB and the NRC resulted in the incorporation of several changes to the options as the study was being implemented. The features, such as a second crossing of the Ghost Dance Fault, were incorporated in different ways in different options. Therefore, even though all options contained some of these features, a comparison of how they were incorporated was performed and is presented in Section 4.2.3.

Finally, an effort was made to identify potentially favorable features by analyzing the results of the comparative evaluation. As part of the sensitivity studies, the ranking of the options with respect to each individual performance measure was correlated with the aggregate ranking of the options. Measures that were demonstrated to affect the ranking and exhibit a high correlation to the overall ranking were judged to be the most influential in determining the overall ranking.

The factors that significantly influenced the measures were identified from the influence diagrams, and, in turn, these factors were connected to the design features. This process and the results are discussed in Section 4.3.

After the comparisons, both qualitative and quantitative, had resulted in identifying a set of potentially favorable features, the options were again examined to see if there was good correlation between the number of favorable features incorporated in the option and how well that option performed in the overall ranking. This comparison is presented in Section 4.4.

4.2 QUALITATIVE COMPARISON OF FEATURES INCLUDED IN THE OPTIONS

The options that were developed for evaluation included a range of configurations in response to the list of major design features presented in Table 4-1. Details of the configuration of each option are shown in the sketches and in Table 2-1. The sketch of each option (see Appendix A) emphasizes the ESF configuration (as shown in solid lines) as it is integrated into a repository configuration (as shown in dashed lines).

A qualitative evaluation of the major features was accomplished by assessing the relative merit of the individual forms of the major design features (Table 4-1) in conjunction with the rank order of the options. In addition to the major design features identified in Table 4-1, design features that were incorporated into various options emerged from the results of the comparative evaluation as being important to the ranking of options. In the following sections, the most favorable configurations for both the major design features and the additional design features are discussed.

4.2.1 MAJOR DESIGN FEATURES

Means of Access - The ranking of options (Table 3-2) indicates that options with two ramps are preferred (in the majority view). Ramp accesses have an advantage of providing site characterization data off the main block. On the other hand, the desirability of obtaining site characterization data in a column (shaft configuration) within the main block cannot be ignored. Configurations with two ramps and with a ramp-shaft combination are well represented in the top-ranked options. Options 4 and 21 have three accesses (with one dedicated to site characterization testing), and they rank high from the perspective of site characterization by itself.

Location of Accesses - Surface features of Yucca Mountain encouraged location of accesses at either the northeastern part of the main block, the southern part, or both. The ranking of options from the testing perspective indicates that accesses which permit the broadest spatial distribution of exposed rock enhance the value of site characterization data (large spatial coverage of data; reduced potential for test interferences; and locationally representative data). Based on preliminary analysis, locations of openings on the surface outside potential flood plains were assumed for each option. (More detailed analysis would be required prior to final location of accesses).

Location of Main (Core) Testing Area (MTL) - Some options include flexibility for location of the MTL at either end of the main block, as well as the ability to distribute tests along the long drift in the Topopah Springs (TS) unit. This flexibility may be useful during the design process and test development.

Excavation Method of Openings - The overall ranking clearly indicates that options using mechanical excavation (as opposed to drill-and-blast excavation) of the accesses and drifts ranked highest. The record appears to show that the excavation method for the MTL could be either drill and blast or mechanical mining. For instance, mechanical mining might be required in certain test areas to minimize mechanical or chemical disturbance to the rock.

Total Number of Repository Accesses - The overall ranking of the options clearly indicates that options with fewer repository accesses ranked highest. The ranking of options for release consequences is similar. From the repository operations perspective, four accesses appear to be the minimum acceptable number of openings for a viable repository that requires two separate ventilation systems (one for development mining and one for the emplacement area).

4.2.2 ADDITIONAL ESF/REPOSITORY DESIGN FEATURES

No Constructed Pathway for Gravity Flow of Water from the Repository (TS) Level to the Calico Hills (CH) Level - Option 30 was designed such that no shaft or internal ramp provided a direct-gravity flow pathway from the repository waste emplacement level to the underlying Calico Hills exploration level. This feature appears to be very favorable from the viewpoint of postclosure releases, and could be added to some other options.

Maximize the Distance from the Waste Emplacement Level to the Water Table - The "step-block" configurations of the waste emplacement areas of four options (15, 16, 32, and 33) were such that the distance from the waste emplacement horizon to the water table was nominally fifty percent greater for these options than for others. This feature was present in the highest-ranked options under the measure for postclosure releases. The ability to realize the advantages of this feature depends upon early surface-based borehole data confirming the elevation of the interface ("contact") between the waste emplacement host rock unit (TSw2) and the overlying rock unit (TSw1). If this elevation is confirmed, this feature may be incorporated into any of the repository designs.

Avoid Emplacement Drifts Crossing the Ghost Dance Fault - The "step-block" configurations of the waste emplacement area of four options (15, 16, 32 and 33) were such that no waste emplacement drifts were designed to cross the Ghost Dance fault. The importance depends on characteristics of the fault discovered during site exploration and testing. This feature may be incorporated into the repository design after site characterization is completed.

Large Exposure of Rock, Both On and Off the Main Block - A few options (30, 13 and 4) offer the advantage of providing exploration and testing of a large amount of the main block and adjacent blocks during both the early and total site characterization program. This results in increasing the amount of information about the site and reduces the likelihood of false indications about the conditions on the site (according to the majority opinion expressed by the characterization testing panel).

Flexibility for Early Exploration of Both the Topopah Spring and the Calico Hills Units - A number of options (4, 13, 24, 25 and 30 of the top-ranked options) offer the advantage of providing early completion of a suite of extensive underground tests and exploration of the major faults on both the Topopah Spring and Calico Hills levels simultaneously. This advantage accrues to those configurations that offer access construction with minimum testing interference, and with ventilation configurations capable of supporting operations at both levels.

4.2.3 FEATURES INCLUDED BY GUIDANCE

The following three features are included in all options (except the Base Case, Option 1) as a result of guidance issued for the development of options. The guidance was developed in response to concerns of the NRC and the NWTRB.

Two Intercepts of the Ghost Dance Fault in the Topopah Spring - This feature recognizes that the displacement of the Ghost Dance fault changes with position along the fault within the main block. One intercept is located toward the north end of the block, the other toward the south end, to permit characterization of at least two displacements.

East-West Drift in the Topopah Spring - This feature of the ESF configuration is included in the options to expose any yet undiscovered north-south trending faults within the Topopah Spring in the Main Block.

Larger Dedicated Main Test Level to Avoid Interferences in Testing - This feature was included in the options to permit all tests, including extended duration tests and any future performance confirmation tests, to be separated by sufficient distance to avoid any test-to-test or construction-test interferences.

4.3 RESULTS OF THE COMPARATIVE EVALUATION

The previous section describes, in a qualitative way, how certain features were related to the ranking of options. This section describes a more systematic analysis that was performed to identify features clearly related to an option performing better on the most important performance measures.

4.3.1 KEY MEASURES

As part of the sensitivity analysis, the ranking of options with respect to their evaluation against each performance measure was correlated with the aggregate ranking of the options. This was done to determine which of the measures were the most influential in determining the overall ranking. In this exercise, it was assumed that the magnitude of the correlation coefficient between a measure and the aggregate ranking was an indicator of the importance of that measure in the overall decision process. The highest correlation for any measure was for Programmatic Viability with a correlation of 0.91, which is extremely high. The other key measures were, in order of decreasing importance, (2) the likelihood of regulatory approval, (3) likelihood of repository closure, (4) postclosure performance, and (5) the outcome of characterization testing. It should be recognized that all these key measures were considered in the determination of Programmatic Viability.

4.3.2 IMPORTANT FACTORS RELATED TO THE KEY CRITERIA

The influence diagrams and other reference material (e.g. costs, schedules, etc.) used during scoring were consulted to identify important factors related to the key measures that were considered when assessing the options against those measures. In the influence diagrams, important factors are highlighted by being enclosed by double lines. Table 4-2 lists the principal factors associated with each of the key measure given in Section 4.3.1.

TABLE 4-2

Key Measures, Principal Factors, and Design Features

Key Measure	Principal Factors	Associated Design Features (Table 4-3)
Programmatic Viabilitity	• List of NWTRB Concerns from First Report • Meets NRC Concerns from SCA • Rapid Schedule for Testing in • Both TS and CH	1, 3, 5, 6, 8, 9, 10, 11
Regulatory Approval	• Early Site Suitability Tests • Capability for Extended Duration Tests • Ability to Conduct High Level Waste Tests • Releases • Residual Uncertainty in Characterization Testing • Environmental Factors	1, 4, 5, 9, 10, 11
Repository Closure	• Large Exposure of Rock (Real Estate) Both On and Off the Block • Residual Uncertainty in Characterization Testing	9, 11
Postclosure Performance	• Repository Configuration - Avoidance of Potentially Adverse Feature • Repository Location - Distance to Water Table • Number and Type of Accesses • Nature and Extent of Calico Hills Penetration	3, 6, 7, 8
Characterization Testing	• Location Representativeness • Ability to Characterize Units Above CH • Large Spatial Coverage • Adequate Space for Test Flexibility • Low Potential for Test Interference	1, 2, 4, 5, 9, 11

4.3.3 DESIGN FEATURES RELATED TO KEY MEASURES

Based on the factors identified as being important to the evaluation of options relative to key measures (Table 4-2), design features were identified that, if incorporated into an option, would likely cause that option to be more favorably rated when considering one or more of the specific factors identified in Table 4-2. The design features that were identified are listed in Table 4-3. Table 4-3 should, by no means, be considered a complete listing of all design features that could be potentially favorable. As with any design process, important factors, such as those given in Table 4-2, can be addressed in a multitude of ways by numerous different features. Rather, Table 4-3 contains features that could be identified in specific options as having resulted in the option being rated more favorably against one or more of the key measures (Table 4-2). The relationship of design features to the important performance measures from which they were identified is provided in the last column of Table 4-2. The numbers listed in that column correspond to the numbers assigned to the design features listed in Table 4-3. For example, reading across the second entry in Table 4-2 and then to Table 4-3, the following flow is intended: the ability to achieve regulatory approval was principally influenced by the ability of an option to support early site suitability tests, high level waste tests, extended duration tests, releases, and residual uncertainty in characterization testing. Those five factors were better satisfied by options that had a ramp (feature 1), flexibility of MTL location, mechanical mined accesses, etc.

The specific features listed in Table 4-3 were identified from several sources. The first source was the specific major features that were intentionally varied from option to option (Table 4-1). These features are identified in the table by descriptor MF. Other features were identified by members of expert panels as being important to the evaluations performed by that panel (discussed in Section 4.2.2). These features are given a panel name descriptor, P for performance assessment panel, etc. Finally, features with a descriptor G were incorporated in all options, except the base case because of guidance to satisfy specific concerns of the NRC and NWTRB (discussed in Section 4.2.3).

Caution is recommended when trying to reach conclusions regarding combinations of preferred features based on those identified in Table 4-3. For example, the fact that the inclusion of a shaft and a ramp are both considered individually favorable, does not imply that a shaft-ramp combination would be the most favorable for an ESF configuration. The fact that a feature is favorable depends considerably on how that feature is integrated with the system. Further discussion of the potential for improving options based on the features identified in Table 4-3 is given in Section 4.5.

4.4 COMPARISON OF FEATURES INCLUDED IN OPTIONS

The features identified in Table 4-3 were compared with the top-ranked options as a means of checking whether the features did appear consistently in the options that seemed to be most favorably evaluated. Table 4-4 is a correlation of the potentially favorable features with a number of top-ranked options. It can be seen that none of the top ranked options contain all of the potentially favorable features. Approaches to refining or improving a selected option are addressed in the following section.

TABLE 4-3

Potentially Favorable Design Features

Feature Number	Description	Source Descriptor
1	Inclusion of a Ramp(s)	MF
2	Inclusion of a Shaft(s)	MF
3	Minimize Repository Accesses (including ESF Openings)	MF
4	Flexibility of MTL Location (NE or S)	MF
5	Emphasize Mechanical Excavation of Accesses and Drifts	MF
6	No Direct "Gravity Line" Between Emplacement Area (TSw2) and the CH Unit	P
7	Maximize Distance Between Repository and Water Table (a repository feature)	P
8	Avoid Emplacement Drifts Intersecting Ghost Dance Fault (a repository feature)	P
9	Large Exposure of Rock	R, T
10	Flexibility to Drift Early in Either the TSw2 or CH	T, V
11	Include Major Features Identified From SCA and NWTRB First Report: a) Two Intercepts of Ghost Dance Fault at Repository Horizon b) E-W Drift Across Block at Repository Horizon c) Larger Dedicated MTL for Avoidance of Interference and to Allow Possible Replication and Confirmation Testing	G

NOTE: Descriptors are:
Major Feature - MF
Post closure Panel - P
Testing Panel - T
Programmatic Viability Panel - V
Regulatory Panel - R
Design Guidance - G

Table 4-4
IDENTIFICATION OF FAVORABLE FEATURES IN HIGHLY RATED OPTIONS

TOP-RANKED OPTIONS: RANK	OPTION	1 NUMBER OF RAMP(S)	2 NUMBER OF SHAFT(S)	3 NUMBER OF ACCESSES	4 MTL LOCATION FLEXIBILITY	5 MECHANICAL MINED ACCESSES	6 NO GRAVITY FLOW PATHWAY FROM TS UNIT TO CHn	7 MAXIMIZE DISTANCE FROM EMPLACEMENT LEVEL TO WATER TABLE	8 AVOID EMPLACEMENT DRIFTS CROSSING GHOST DANCE FAULT	9 MAXIMIZE EXPOSED ROCK -- ON AND OFF BLOCK	10 FLEXIBILITY FOR EARLY DRIFTING IN TS OR CH OR BOTH	11 2 INTERCEPTS OF GHOST DANCE FAULT IN TS	12 E-W DRIFT IN TS	13 LARGER MTL AREA TO AVOID INTERFERENCES
1	30	2	0	4	✔	✔	✔			✔	✔	✔	✔	✔
2	23	2	0	4		✔						✔	✔	✔
3	24	1	1	5		✔					✔	✔	✔	✔
4	13	2	0	4	✔	✔				✔	✔	✔	✔	✔
5	6	2	0	4		✔						✔	✔	✔
6	7	1	1	5		✔						✔	✔	✔
7	2	1	1	5								✔	✔	✔
8	19	1	1	5								✔	✔	✔
9	25	1	1	5		✔					✔	✔	✔	✔
10	4	1	2	5						✔	✔	✔	✔	✔
• • •	• • •													
20	15	1	1	4				✔	✔			✔	✔	✔

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4.5 ADDITIONAL ANALYSIS

In Sections 4.1-4.3, a number of factors that were highly correlated with the rank order of the options were identified. How well an option rated against each of these factors depended somewhat on whether the option contained certain design features. As a result of that analysis, a number of design features were identified that are considered to be potentially favorable and may enhance an option's performance in the overall comparative analysis. As part of the post-analysis of the scoring results, an effort was made to determine whether the addition of a favorable feature or the alteration of an existing feature, so as to make it more favorable, would have resulted in any of the highly ranked options being improved. Only qualitative assessments were performed in this effort.

Some modification of highly rated options could improve certain features without significant chance of degrading the option overall. One suggested modification is raising the repository relative to the water table. A second feature that is suggested is a repository design that reduces from the base case the drifting through the Ghost Dance Fault. The addition of major features would require detailed analyses to balance the favorable and adverse effects of the feature.

Although future modifications of a selected option were not the subject of this study, any such modifications may be accomplished in accordance with the design control process. Selected key features that may be considered for change will be subject to engineering trade-off studies during the design phase. It is expected that conventional engineering and mine design methodologies will be used to refine or improve all features of the selected baselined option. As an example, engineering trade-off studies may suggest that certain test areas of an option with a drill and blast MTL be excavated mechanically to minimize chemical or mechanical disturbance to the rock to be tested.

5.0 FINDINGS

The findings of the ESF Alternatives Study are as follows:

1. The study considered and screened a large number of alternatives to produce 34 ESF/repository options which were then formally evaluated against a wide range of criteria.

2. The rank order of the options was determined primarily from the relative probabilities assessed for programmatic viability. Other key measures, such as regulatory approval, likelyhood of repository closure, postclosure performance and characterization testing were considered in assessing progrmmatic viability.

3. The rankings under the majority and minority views are as expressed in Table 3-4.

4. The top ranked option indicated in Table 3-4 is consistent with the value judgments expressed by the management panel and the technical judgments expressed by all but three members of the technical panels. Only one technical panel member provided a view that produces a substantially different ranking. Even under this view, many of the same options are concluded to be highly rated.

5. A number of design features were identified that appear to enhance the overall performance of particular options.

APPENDIX A

SUMMARY OF THE PRINCIPAL DESIGN AND CONSTRUCTION FEATURES FOR THE 34 CANDIDATE ESF/REPOSITORY OPTIONS

OPTION #			E.S.F.								REPOSITORY				
			ACCESS 1		ACCESS-2		MAIN TEST LEVEL				ACCESSES		CONSTRUCTION METHOD		
			SIZE	CONST. METHOD	SIZE	CONST. METHOD	LAYOUT	CONST. METHOD	LOCATION	ELEVATION	SHAFTS	RAMPS (TBM)	RAMPS & DRIFTS	EMPL. AREA	TOTAL ACCESSES
18	1	BASE CASE	12' SHAFT	DRILL & BLAST	12' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2-28'	1-25' 1-23'	TBM	DRILL & BLAST	6
19	2	A1	16' SHAFT	-"-	25' RAMP	TBM	MODIFIED T II G.A.	-"-	-"-	-"-	2-25'	1-25' +ESF	-"-	-"-	5
20	3	A2	16' SHAFT	-"-	16' SHAFT	DRILL & BLAST	-"-	-"-	-"-	-"-	-"-	2-25'	-"-	-"-	6
21	4	A4 REV.1	16' SHAFT	-"-	12' SHAFT 25' RAMP	D&B TBM	-"-	-"-	-"-	-"-	1-30' ENLARGE [illegible]	1-25' +ESF	-"-	-"-	5
22	5	A5	16' SHAFT	-"-	25' RAMP	TBM	-"-	-"-	S	-"-	2-25'	-"-	-"-	-"-	5
23	6	A7	25' RAMP	TBM	25' RAMP	-"-	-"-	-"-	NE	-"-	-"-	IN ESF	-"-	-"-	4
24	7	B3, REV. 2-		[illegible]											
25	8	B3,REV.3-		V-MOLE											
26	9	B3,REV. 4-	16' SHAFT	BLIND BORE	-"-	-"-	-"-	MECH.	-"-	-"-	-"-	1-25' +ESF	-"-	TBM	5
27	10	B3,REV. 5-		RAISE BORE											
28	11	B3, REV. 6-		DRILL & BLAST											
29	12	B4	16' SHAFT	DRILL & BLAST	-"-	-"-	-"-	-"-	S	-"-	-"-	-"-	-"-	-"-	5
30	13	B7	25' RAMP	TBM	-"-	-"-	-"-	-"-	-"-	-"-	-"-	IN ESF	-"-	-"-	4
31	14	B8	16' SHAFT	DRILL & BLAST	-"-	-"-	-"-	-"-	-"-	-"-	1-25'	2-25' +ESF	-"-	-"-	5
32	15	C1	16' SHAFT	-"-	-"-	-"-	TWO LEVEL	-"-	NE	TWO LEVELS SAME AS REPOS.	[illegible] ENLARGE [illegible]	1-25' +ESF	-"-	-"-	4
33	16	C4	16' SHAFT	-"-	-"-	-"-	-"-	-"-	S	-"-	2-25'	-"-	-"-	-"-	5
34	17	R11	12' SHAFT	-"-	12' SHAFT	DRILL & BLAST	TITLE II G.A.	DRILL & BLAST	NE	SAME AS REPOS.	2-28'	2-25'	-"-	-"-	6

ESFSUM6P.A01/11-20-90

TESTING GROUPS AND SEQUENCES FOR EARLY/LATE EXPLORATION AND TESTING

	OPTIONS 1-17	OPTIONS 18-34
EARLY TESTING+	1. TESTS IN ACCESSES 2. EXPLORATION OF 3 FAULTS IN TS AND EAST-WEST EXPLORATORY DRIFTING	1. CRITICAL* TESTS IN SCIENCE ACCESS 2. EXPLORATION OF 3 FAULT CROSSINGS IN CH
LATE TESTING	3. TESTS IN MTL IN TS 4. EXPLORATION OF 3 FAULTS IN CH 5. OTHER EXPLORATION & TESTS IN CH, INCLUDING SOLITARIO CANYON FAULT 6. DEFERRED TESTS IN ACCESSES	3. EXPLORATION OF 3 FAULTS IN TS, INCLUDING EAST-WEST EXPLORATORY DRIFTING 4. OTHER EXPLORATION & TESTING IN CH 5. TESTS IN MTL IN TS 6. DEFERRED TESTS IN ACCESSES

+ CONDUCT 1 & 2 AS MINIMUM (CONDUCT 3, 4, 5, AND 6 ON A NON-INTERFERENCE BASIS WITH 1 & 2 AS OPTIONS PERMIT).

* CRITICAL TESTS ARE SITE SUITABILITY TESTS IN WHICH DATA ARE IRRETRIEVABLE IF NOT OBTAINED AS CONSTRUCTION EXPOSES THE AREAS TO BE TESTED.

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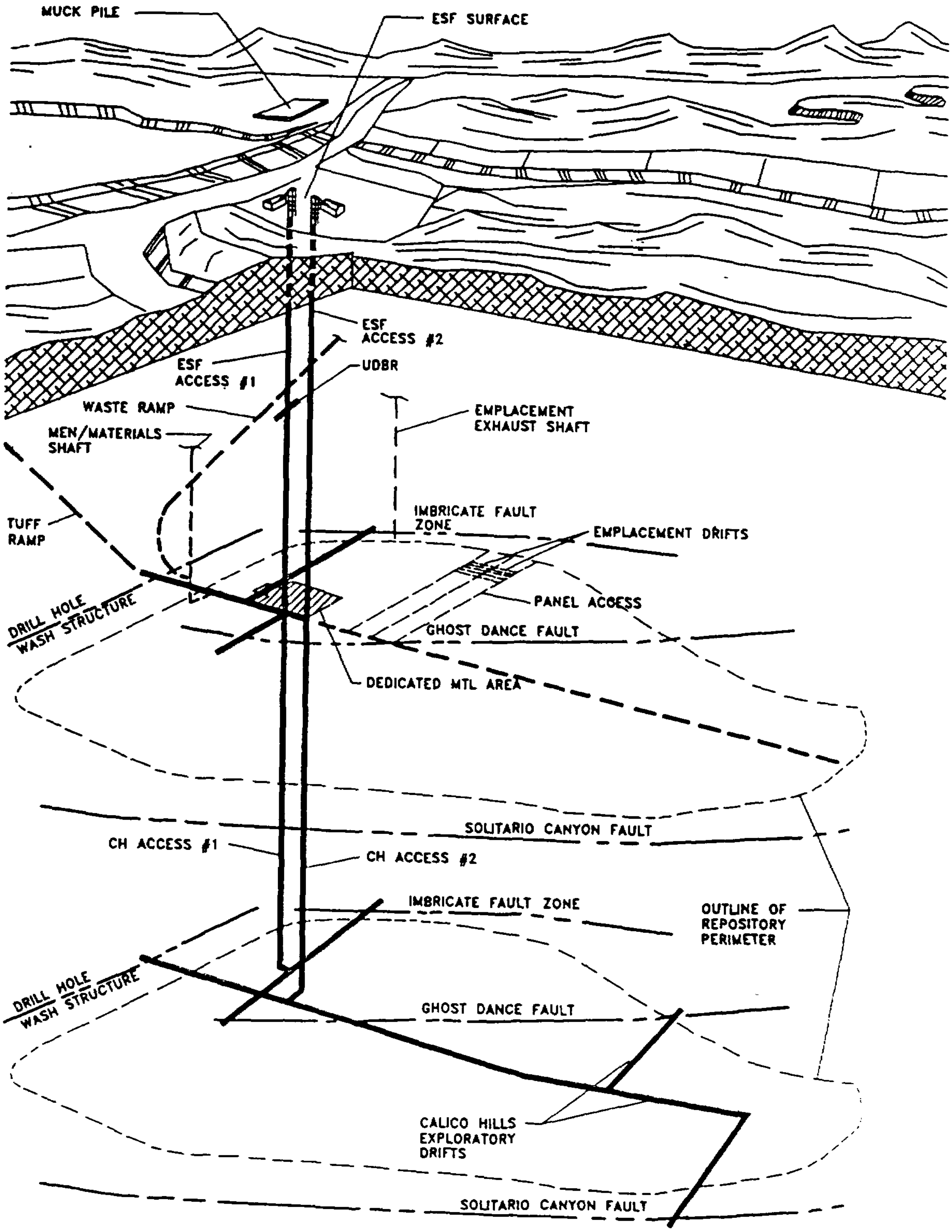

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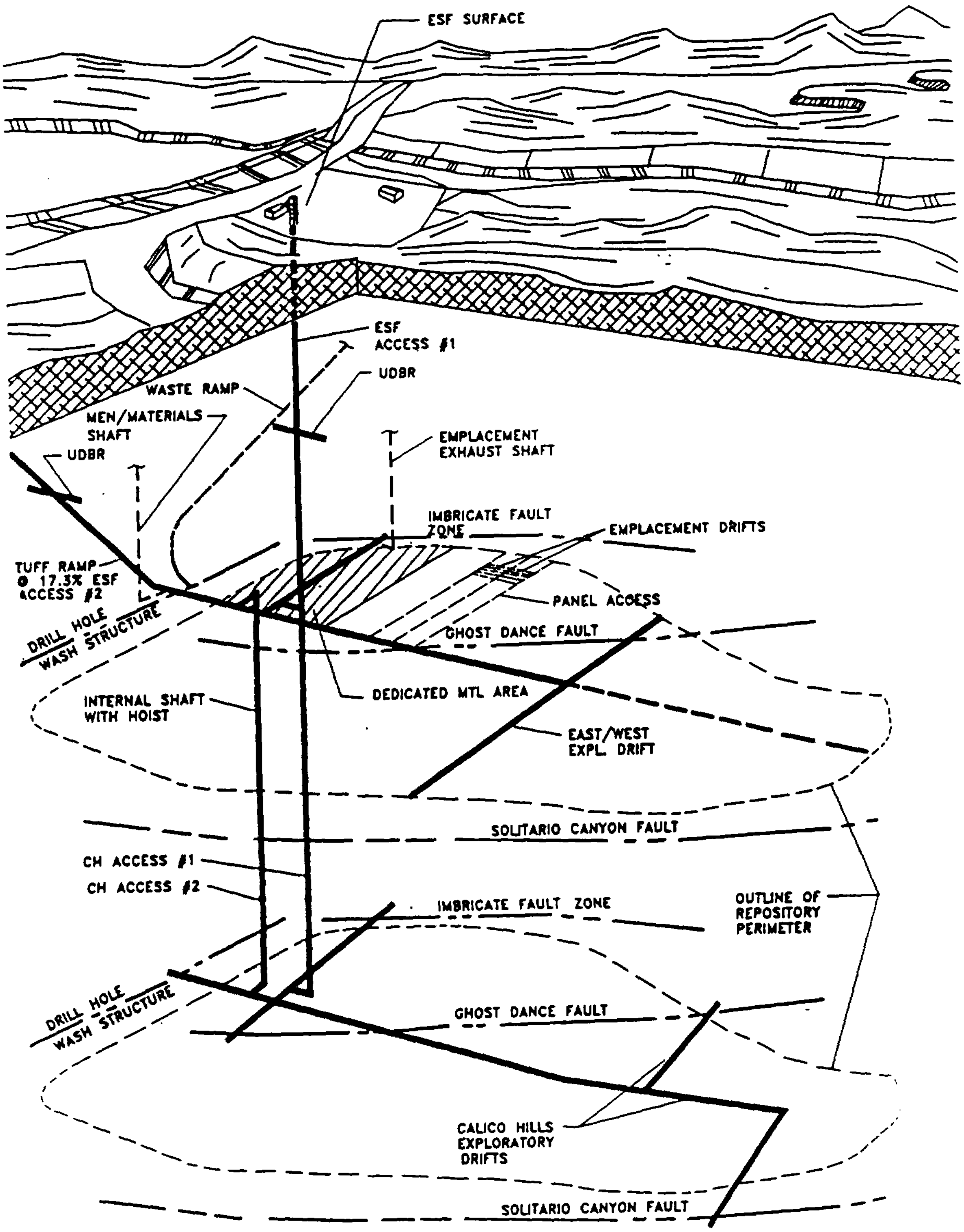

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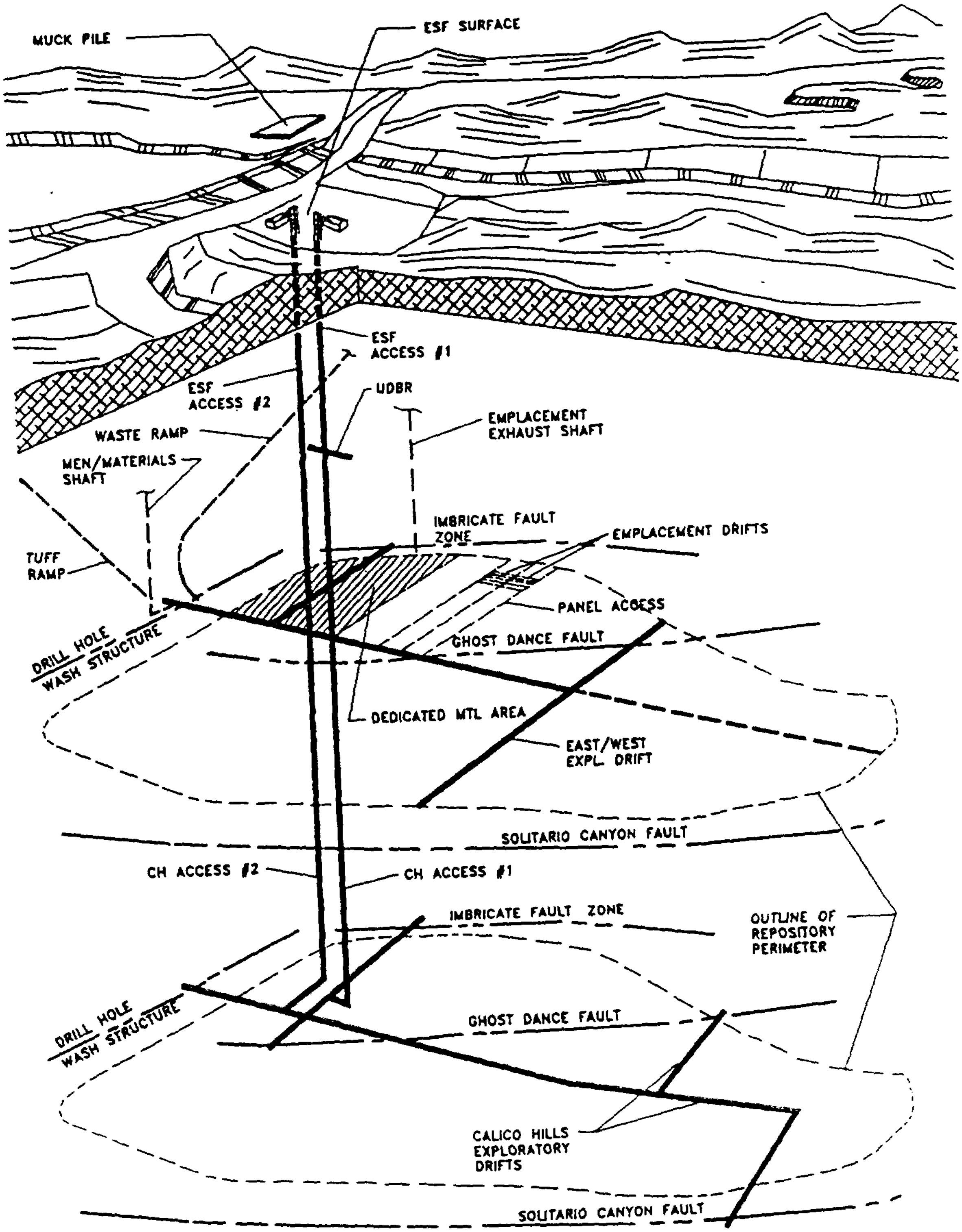

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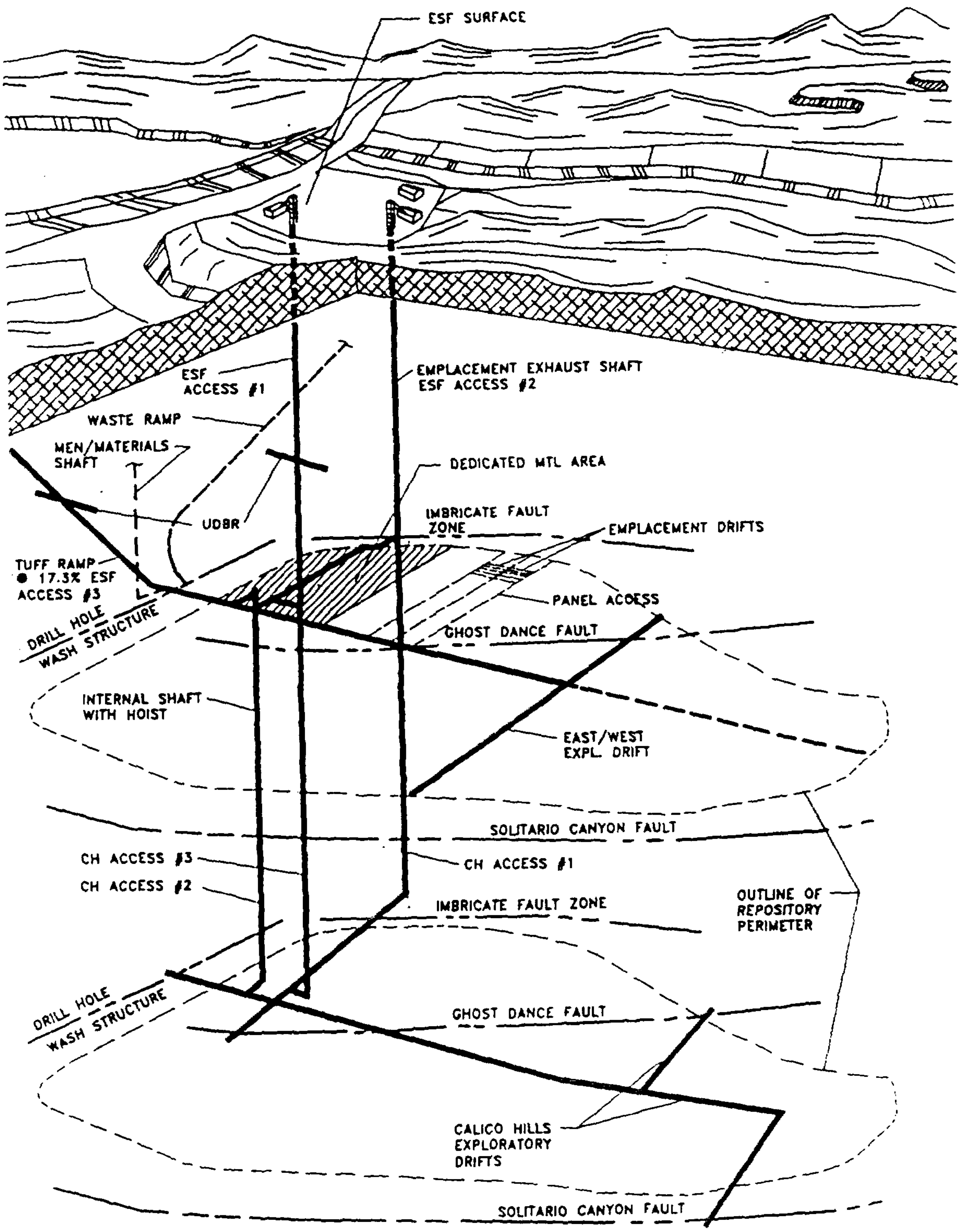

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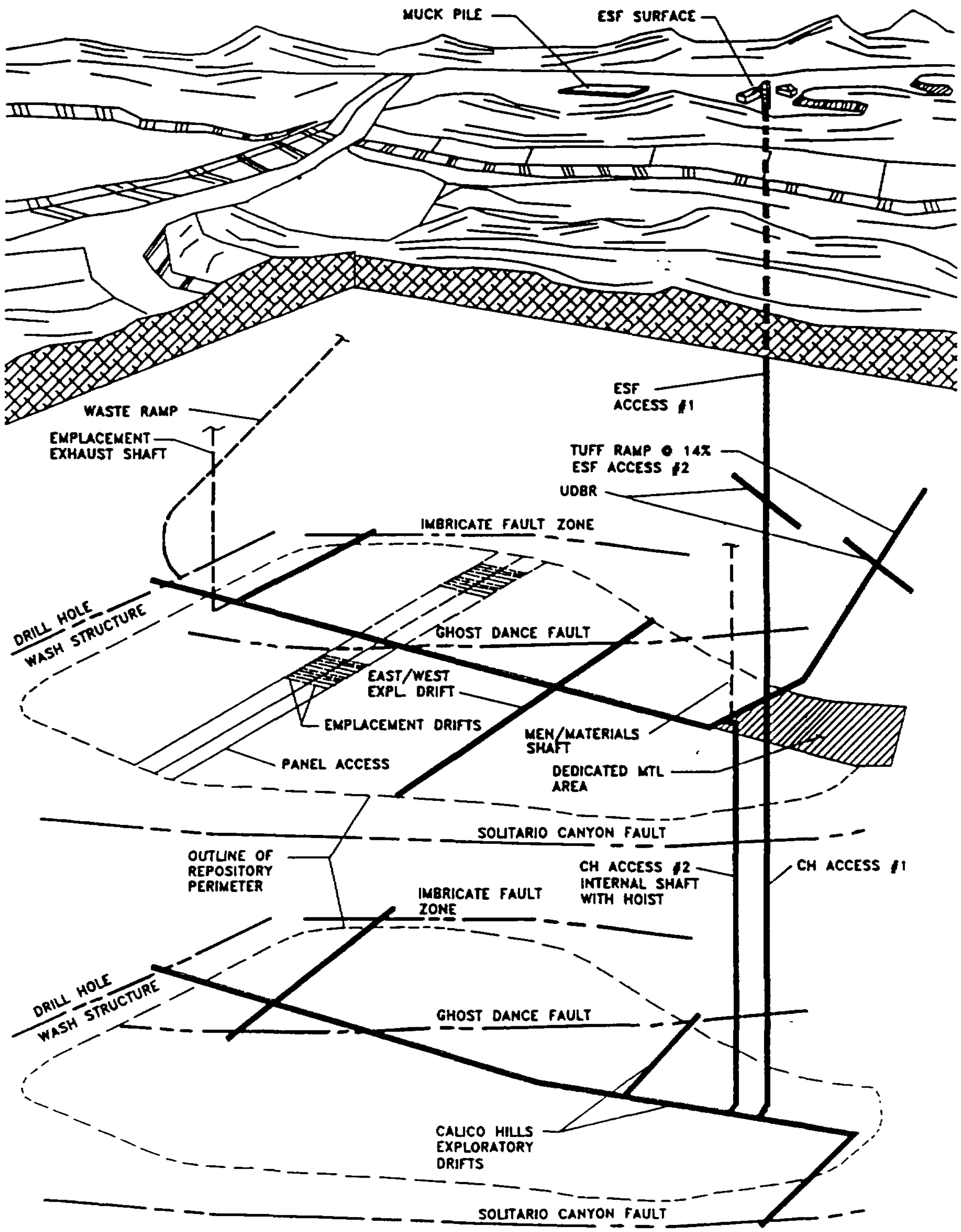

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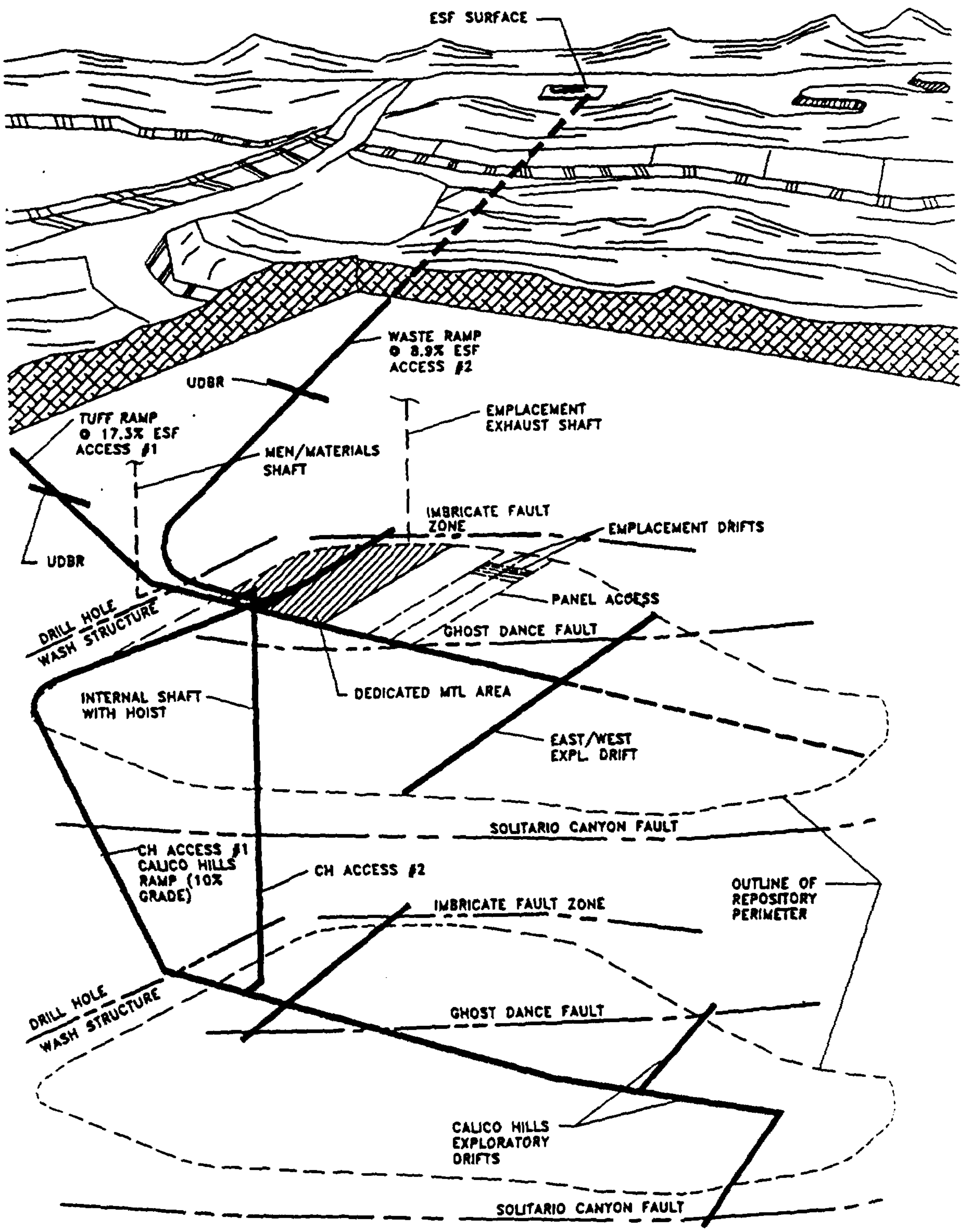

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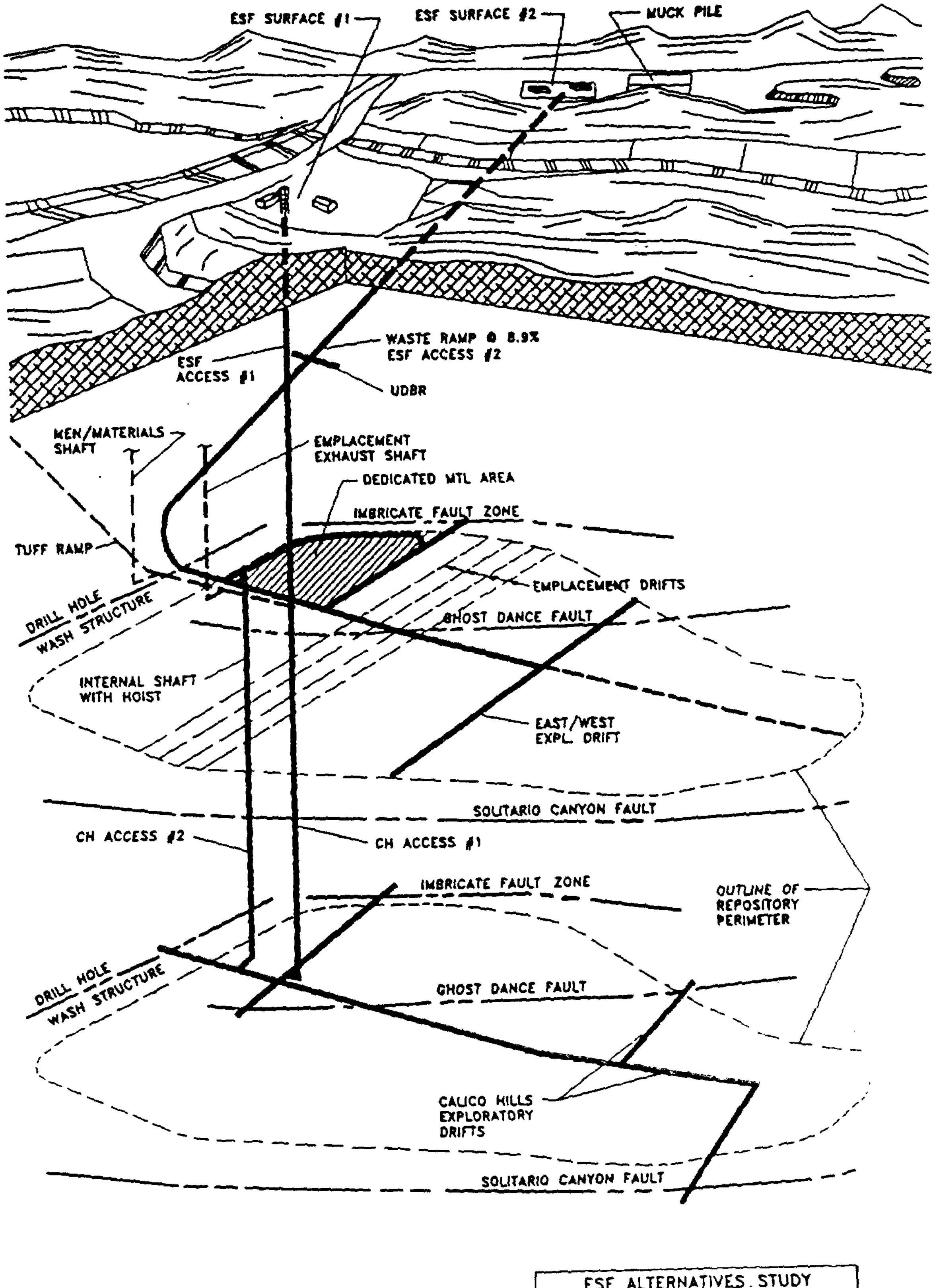

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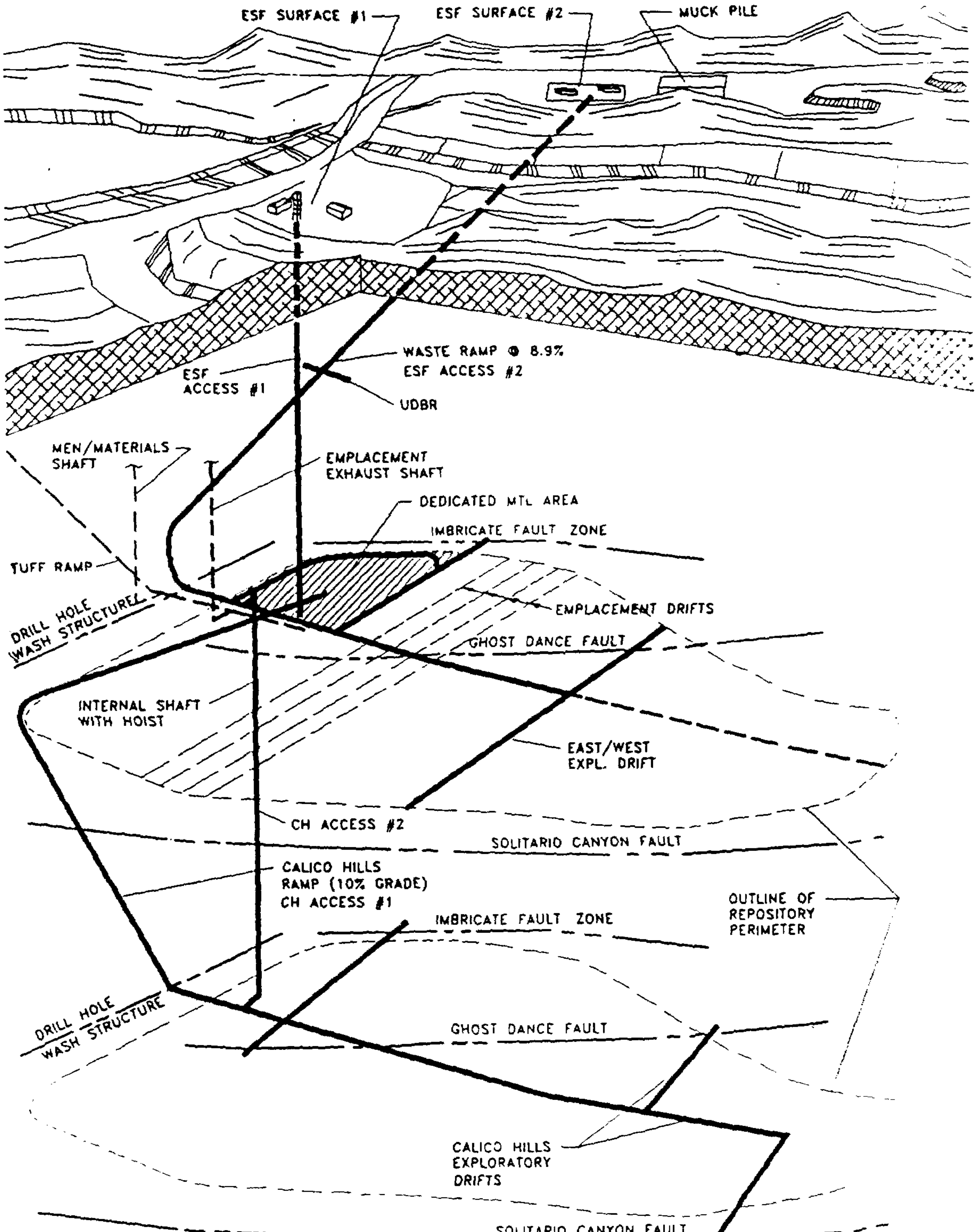

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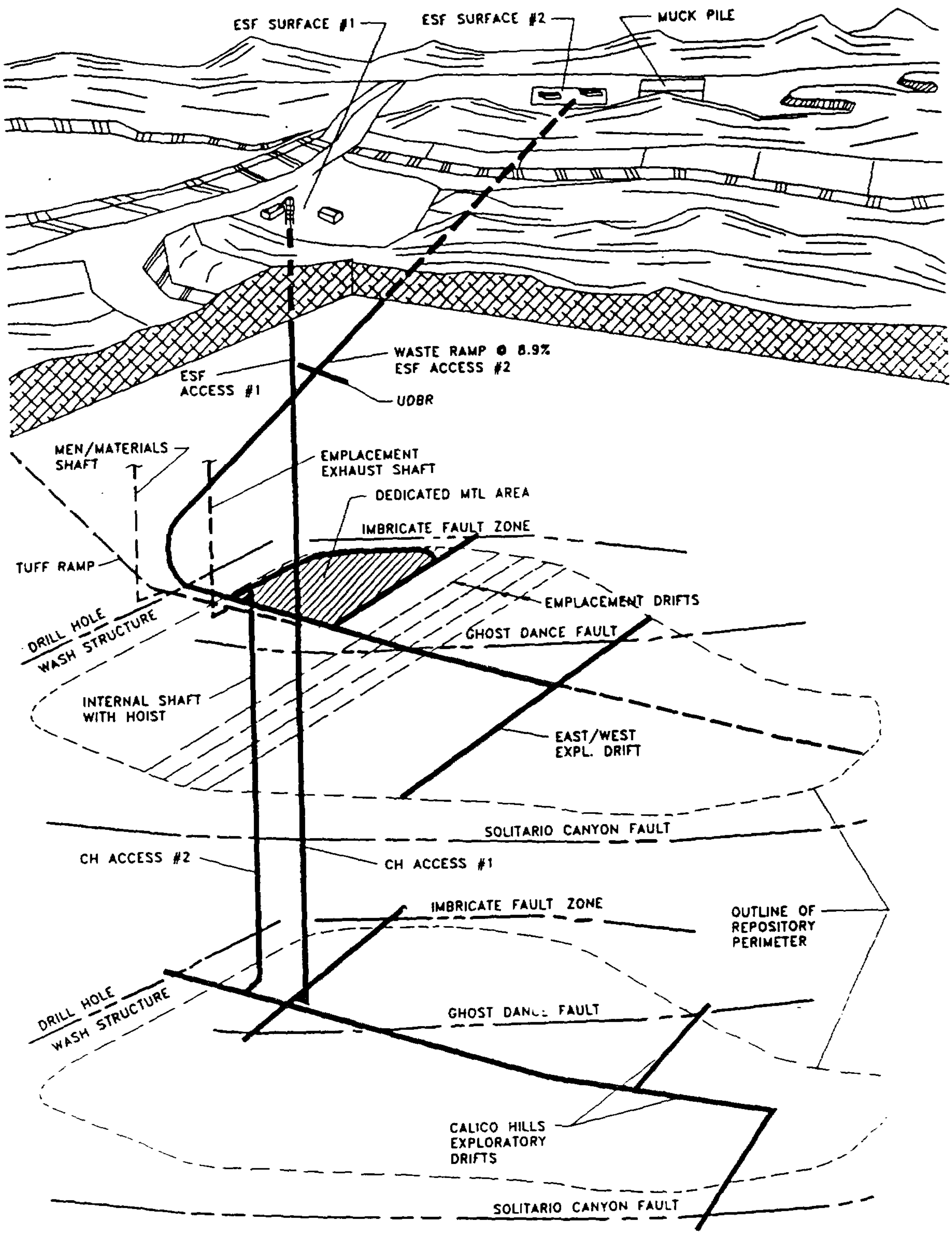

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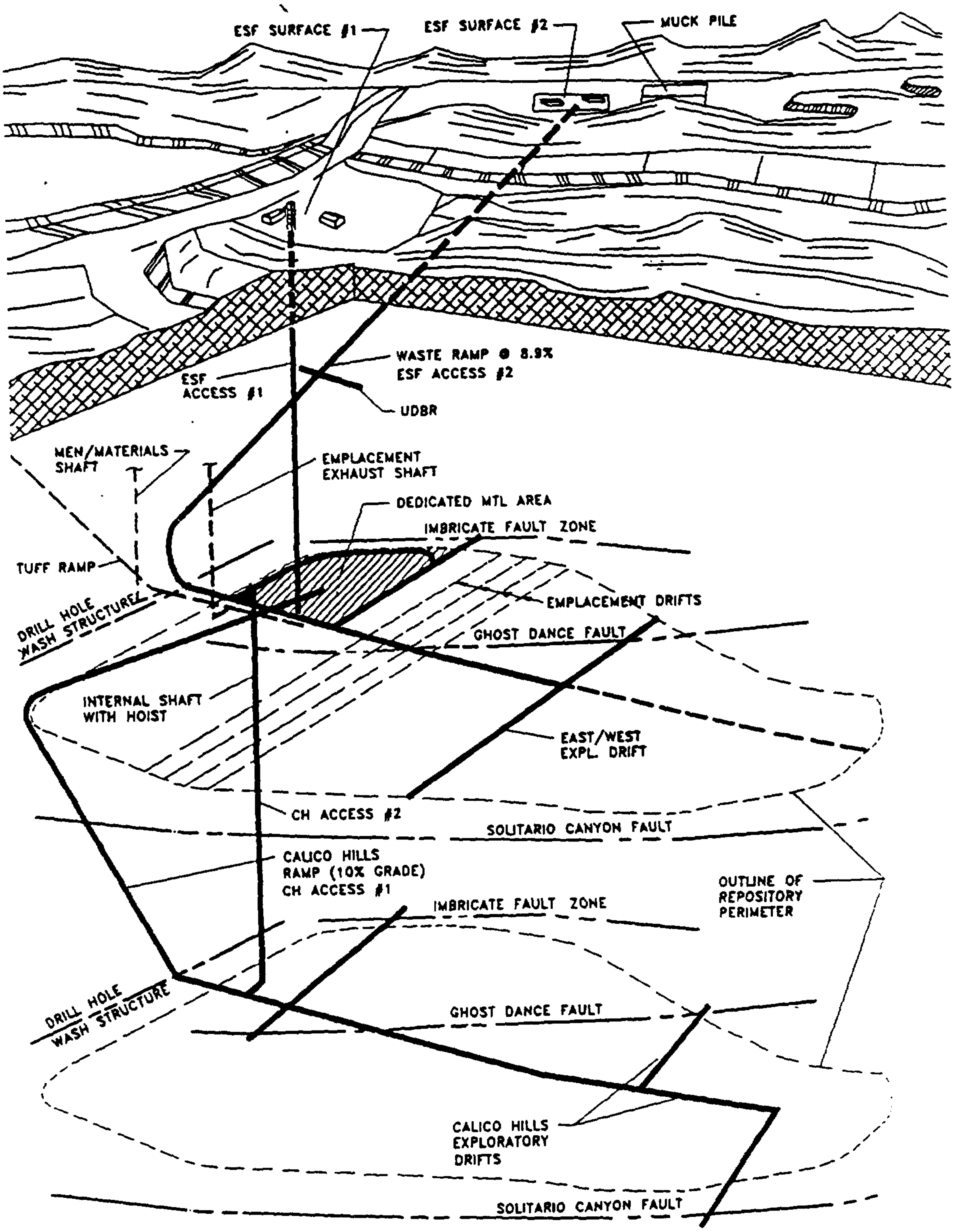

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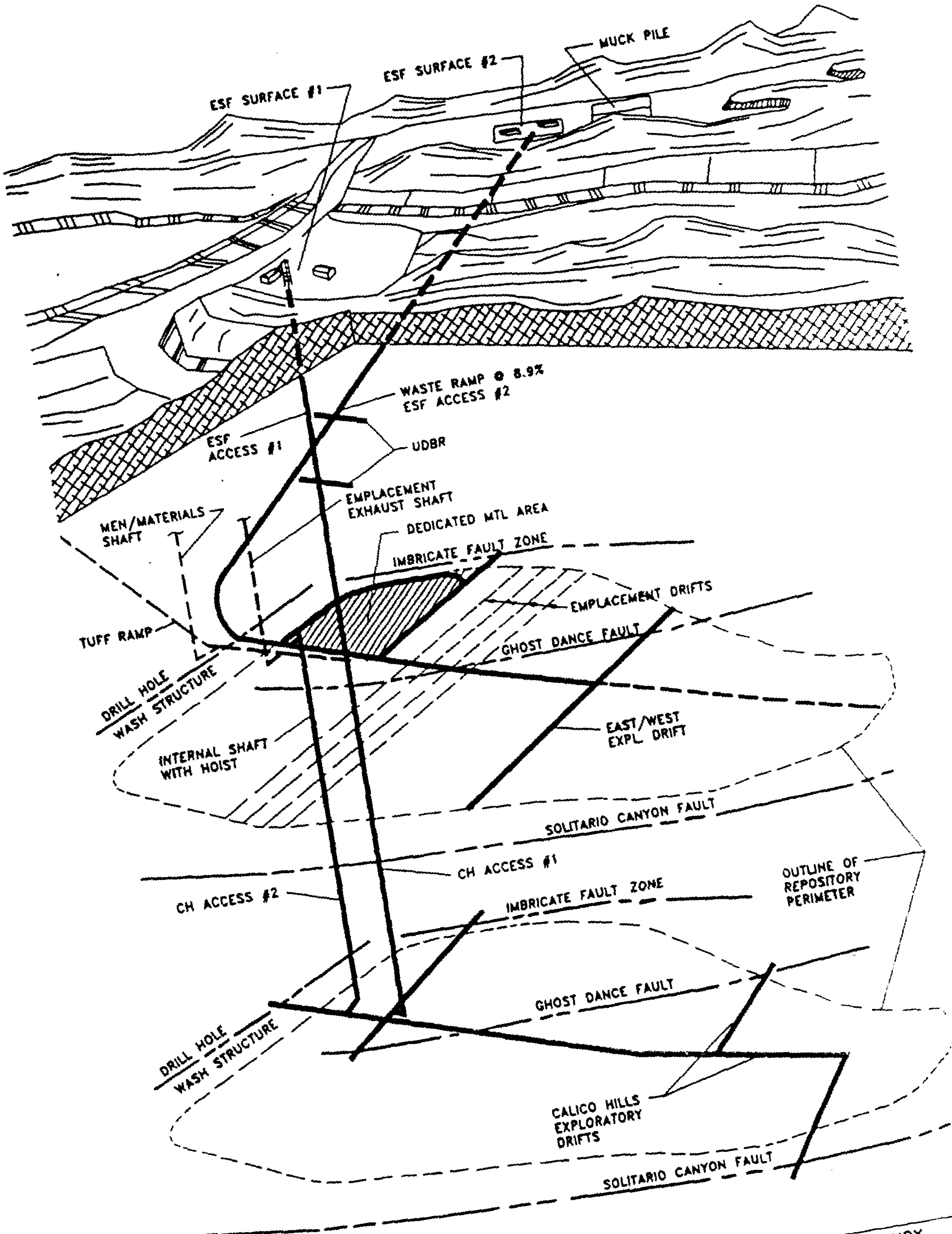

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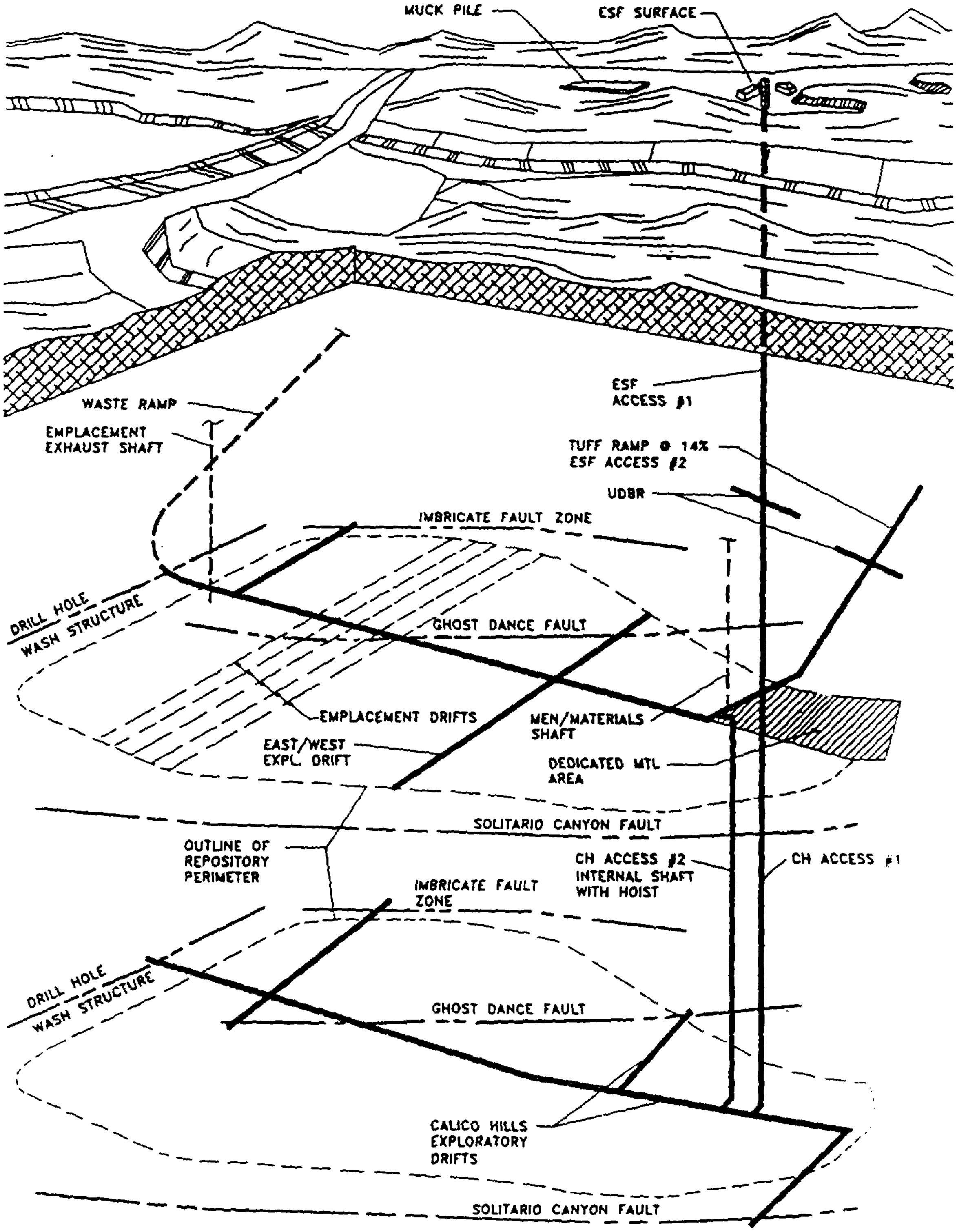

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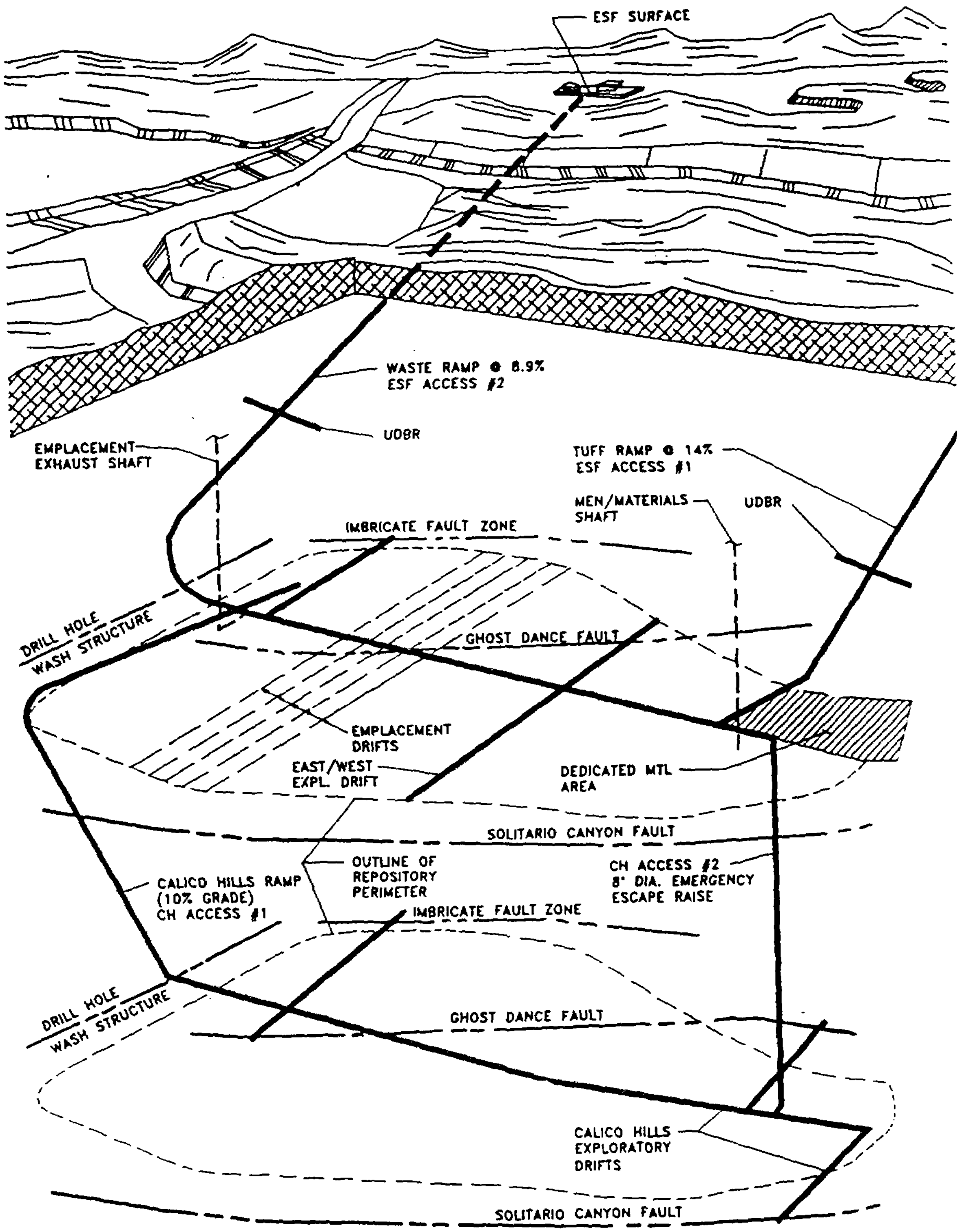

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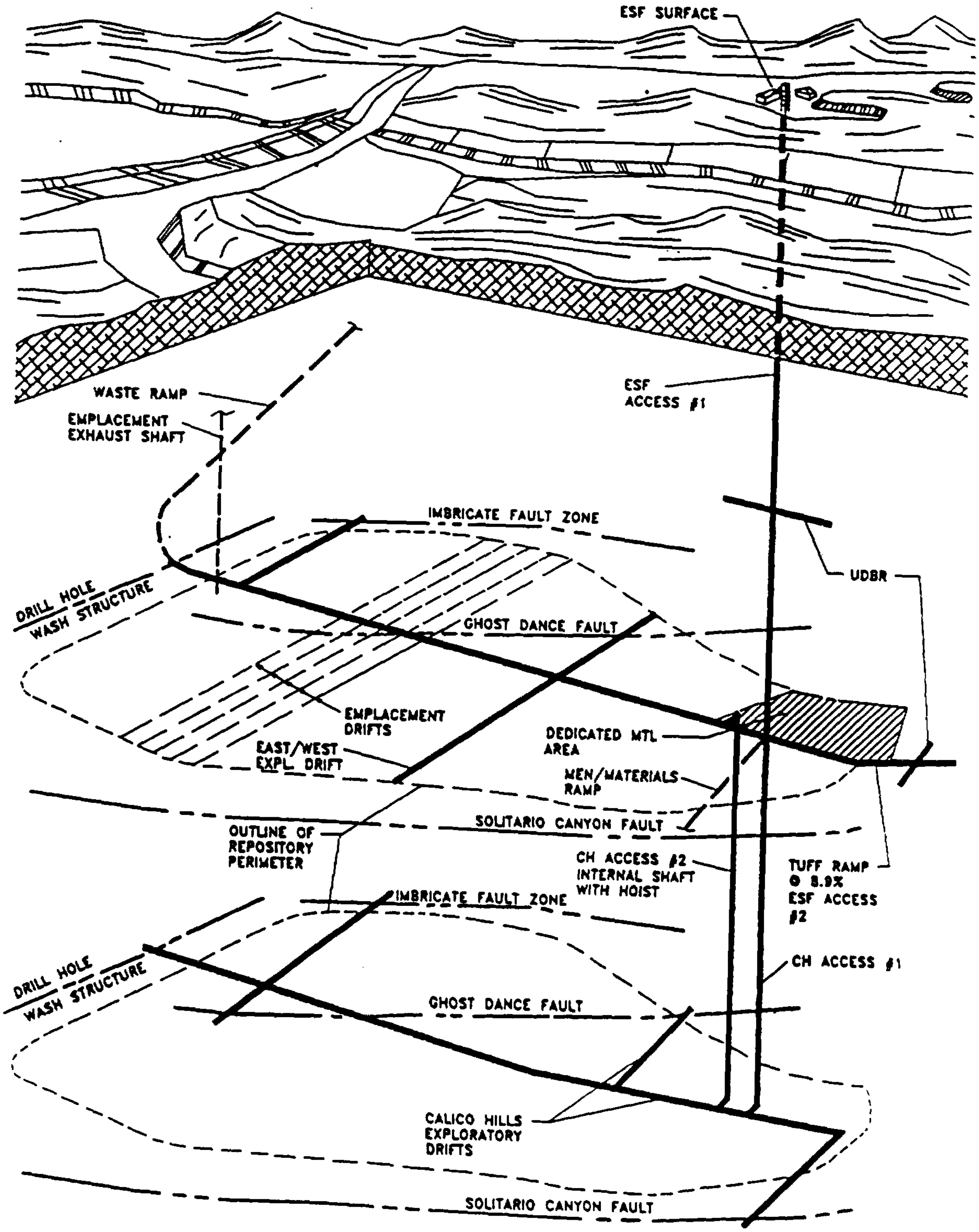

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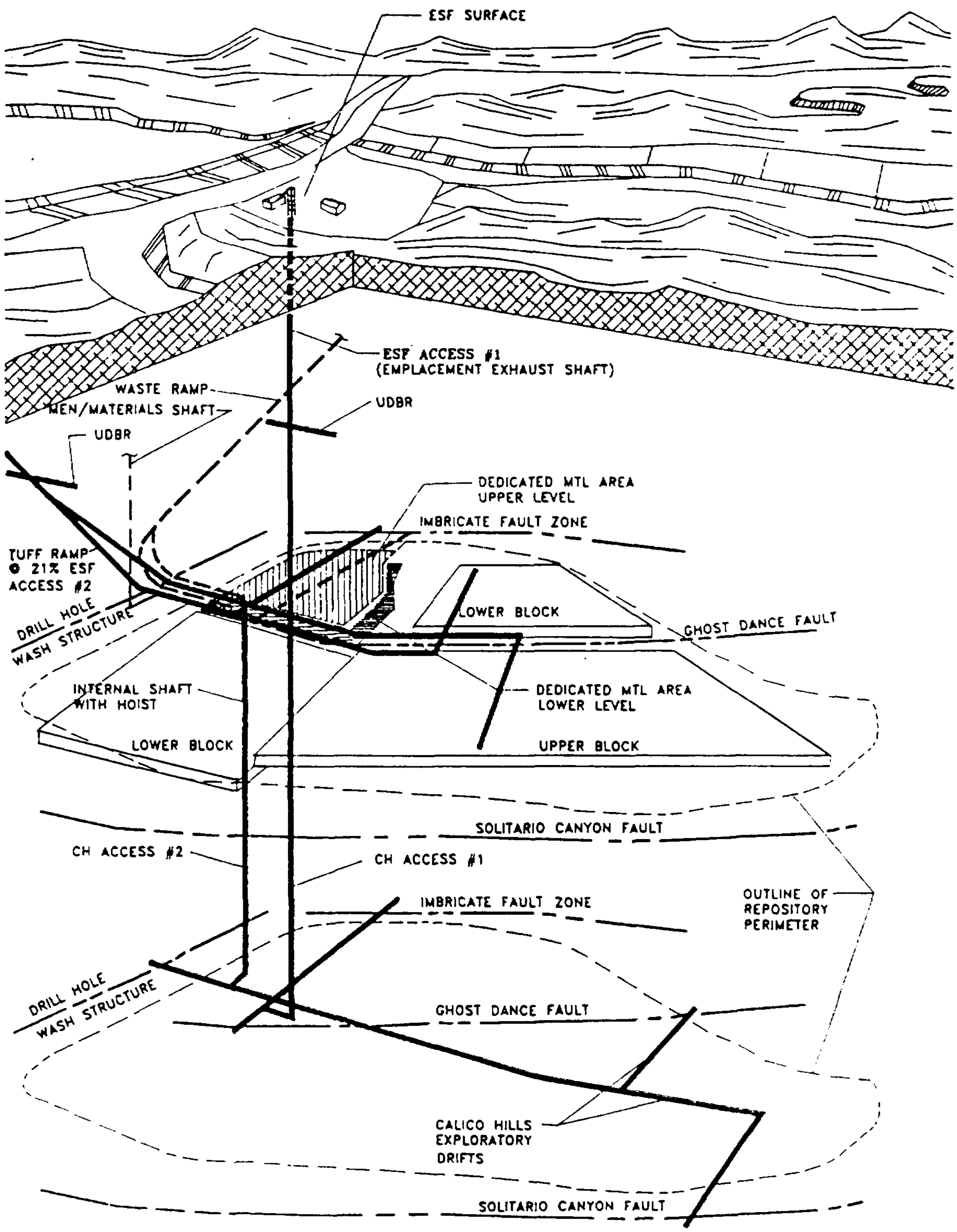

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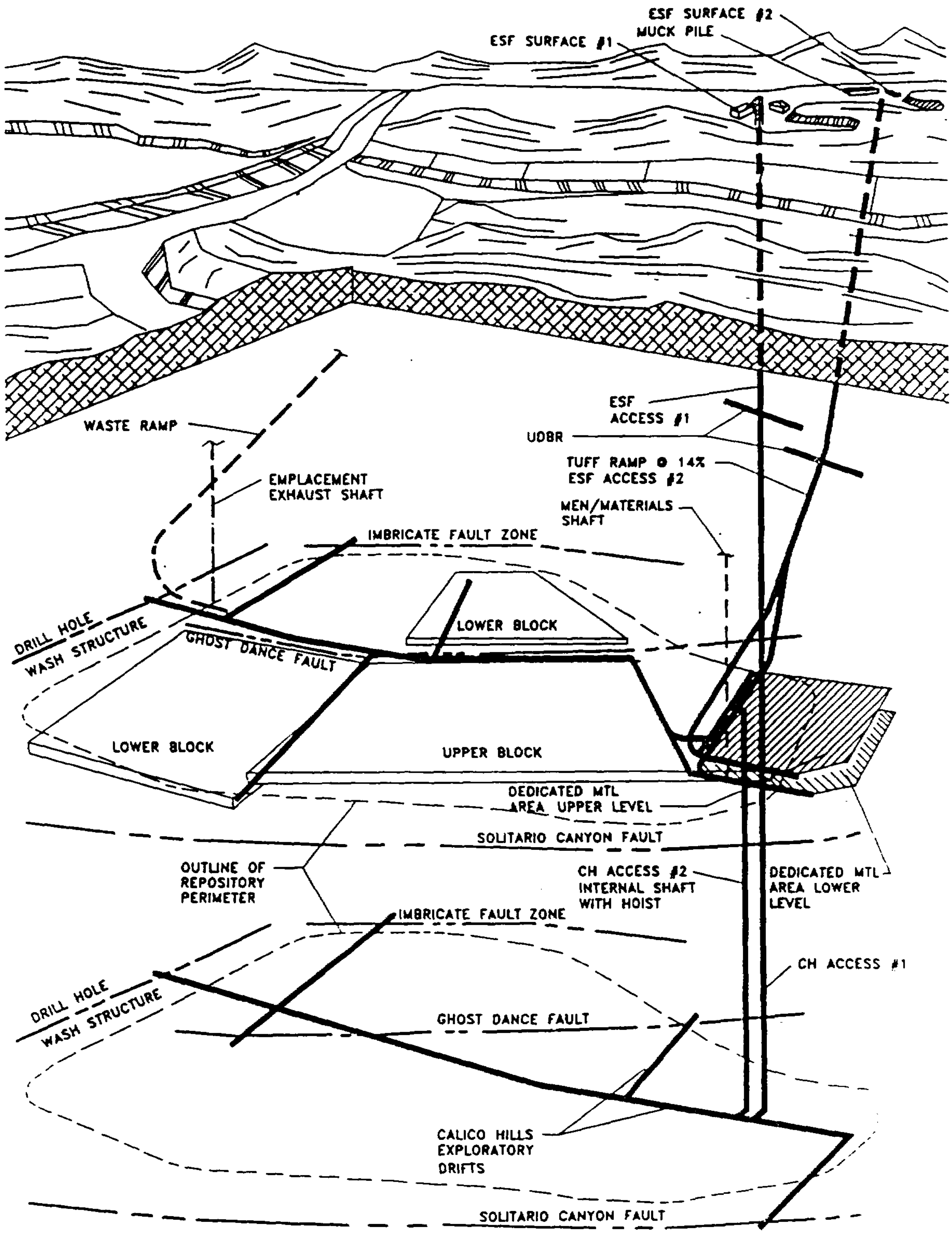

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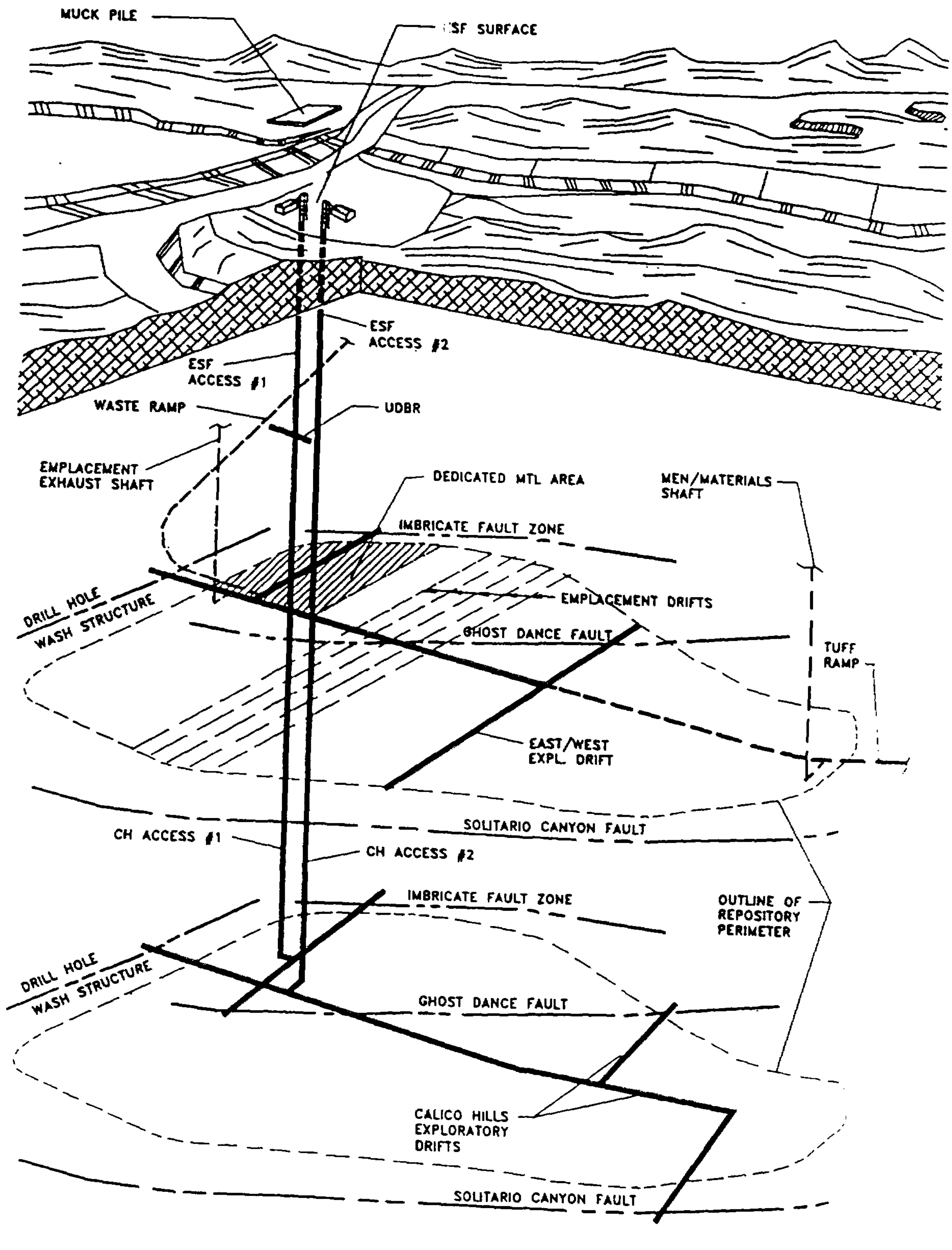

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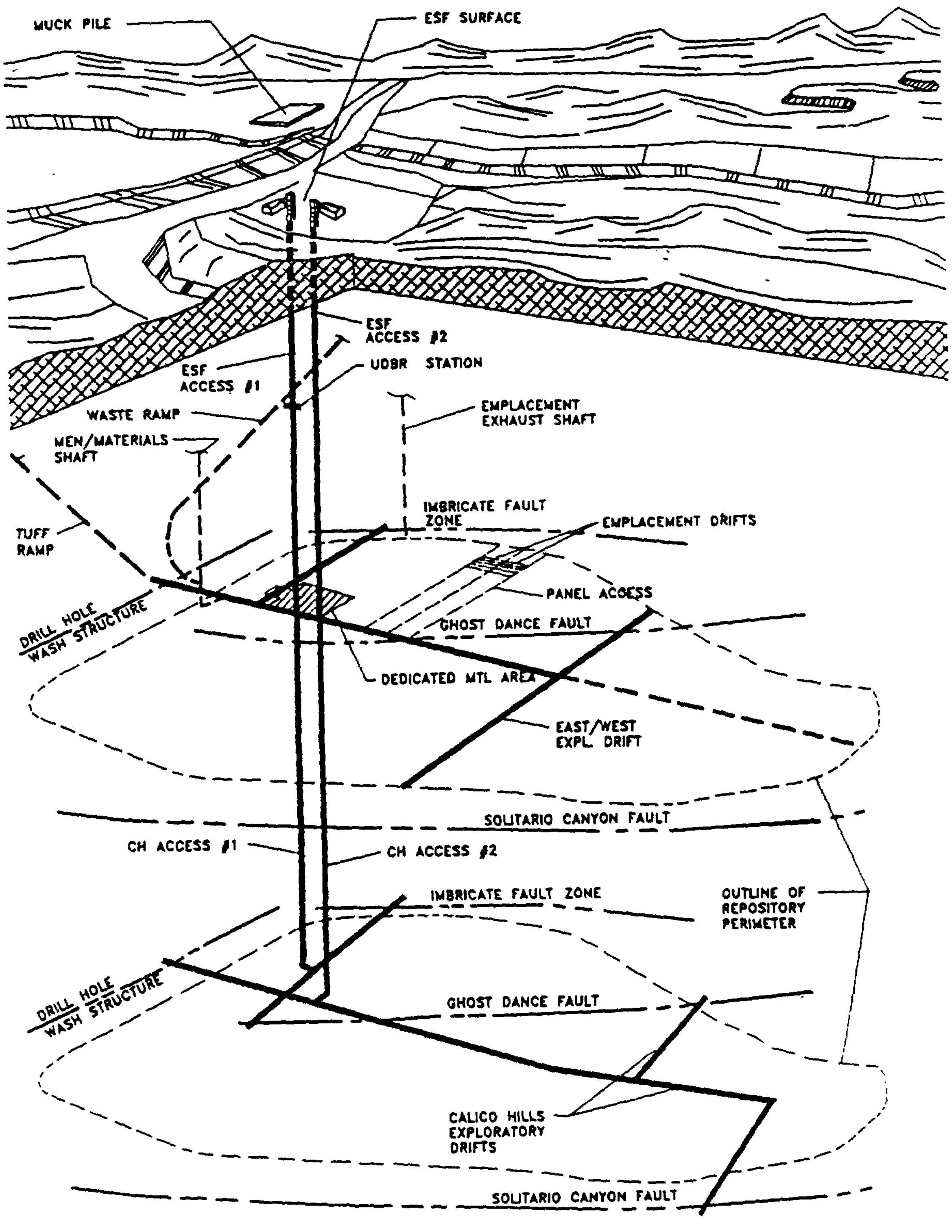

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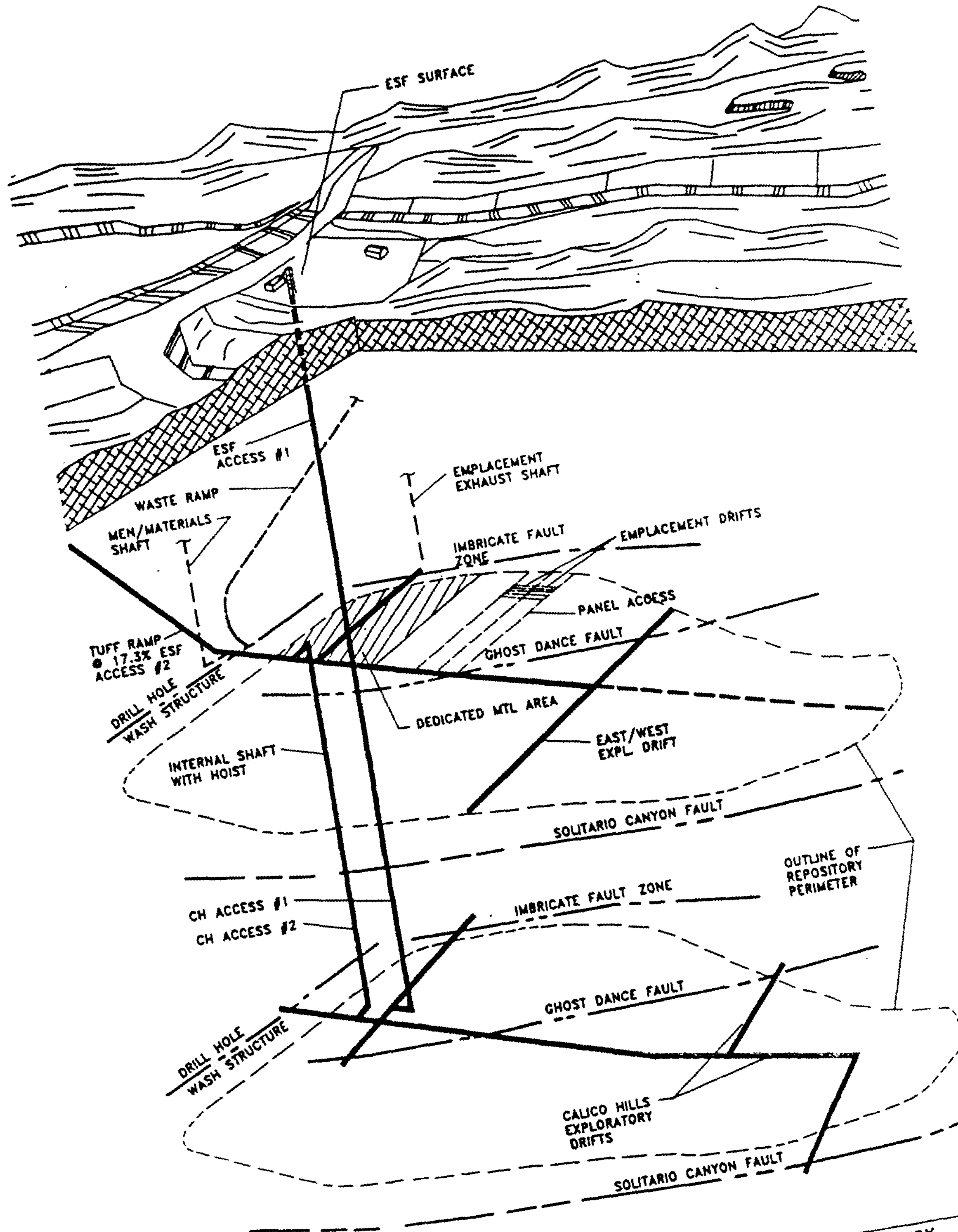

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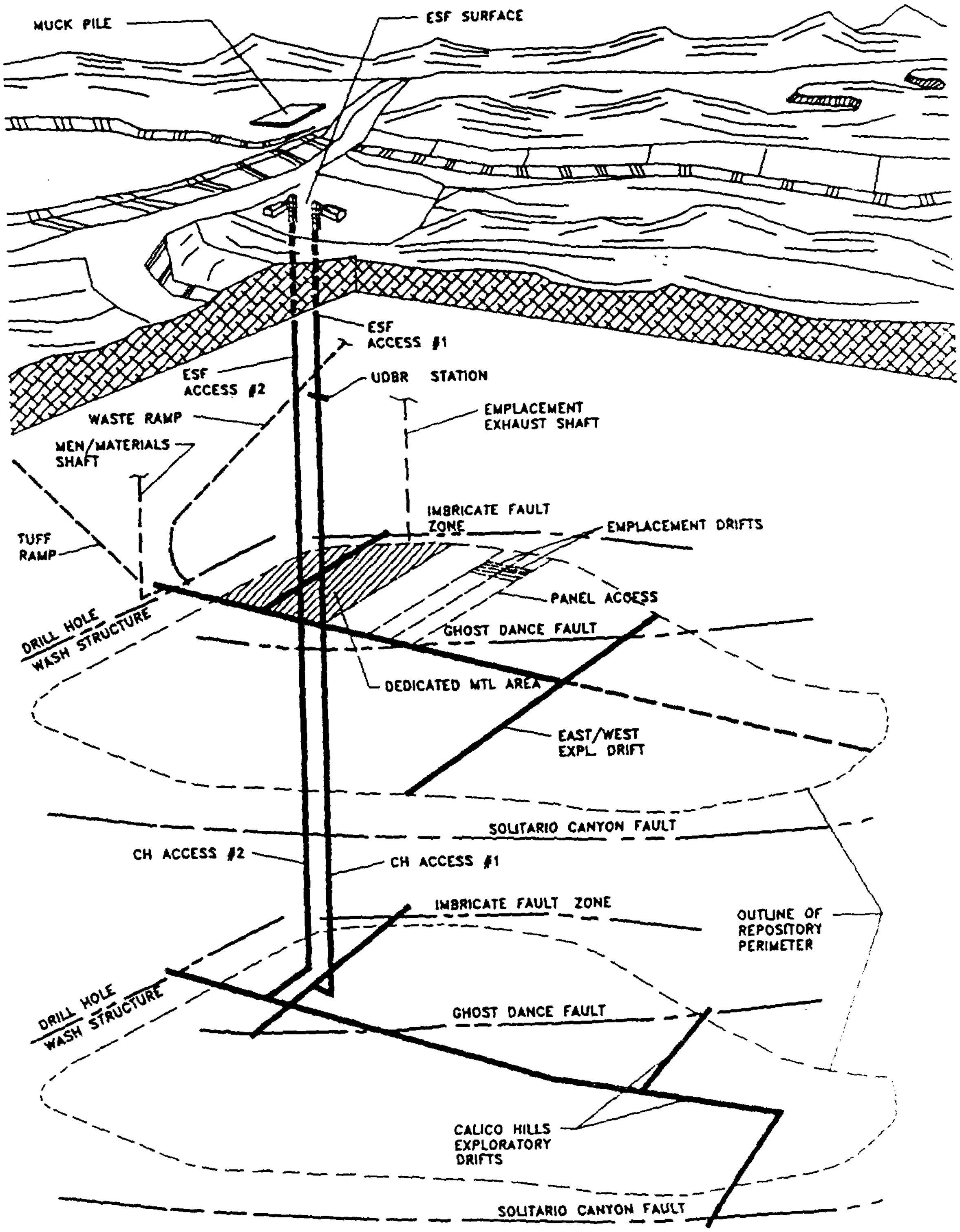

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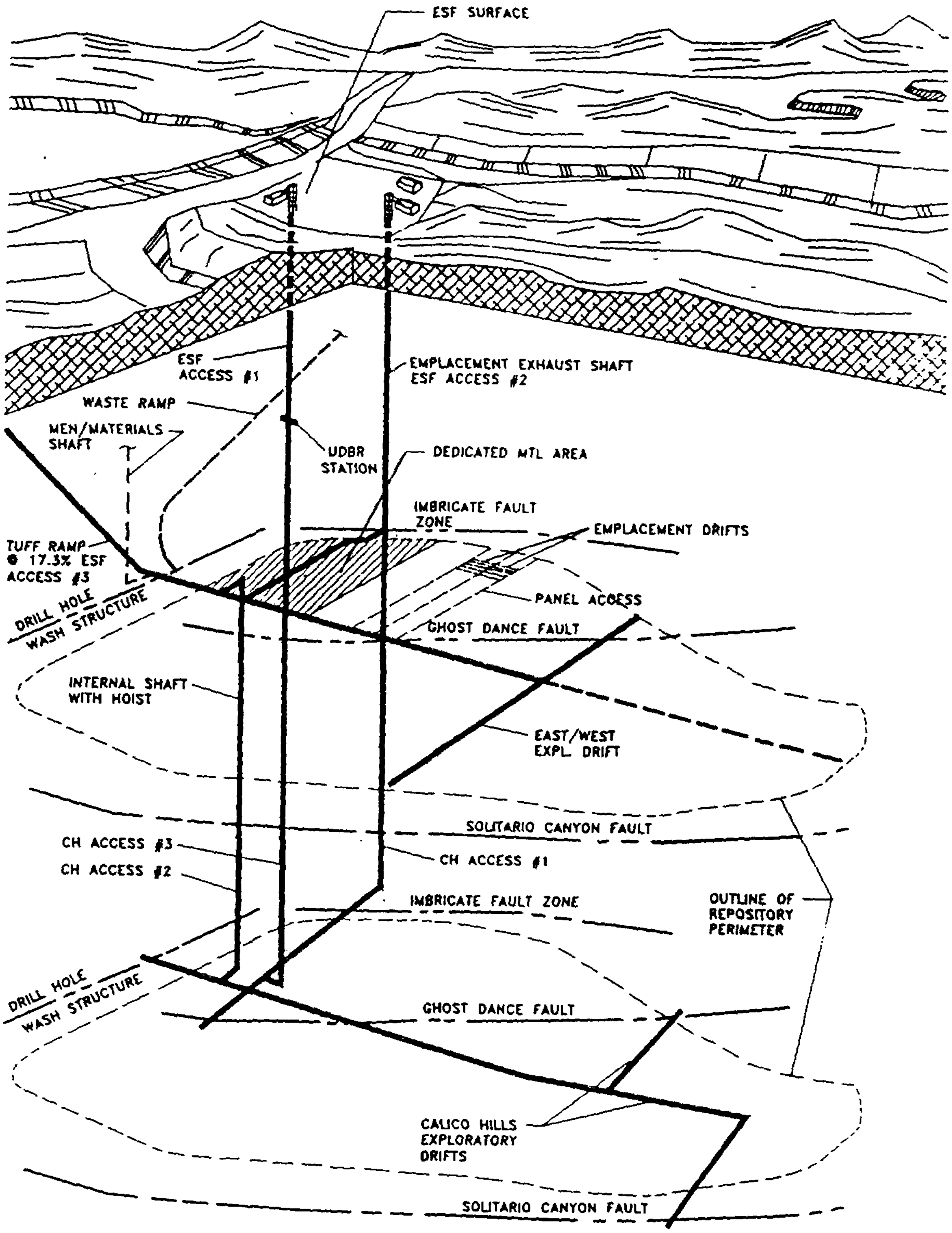

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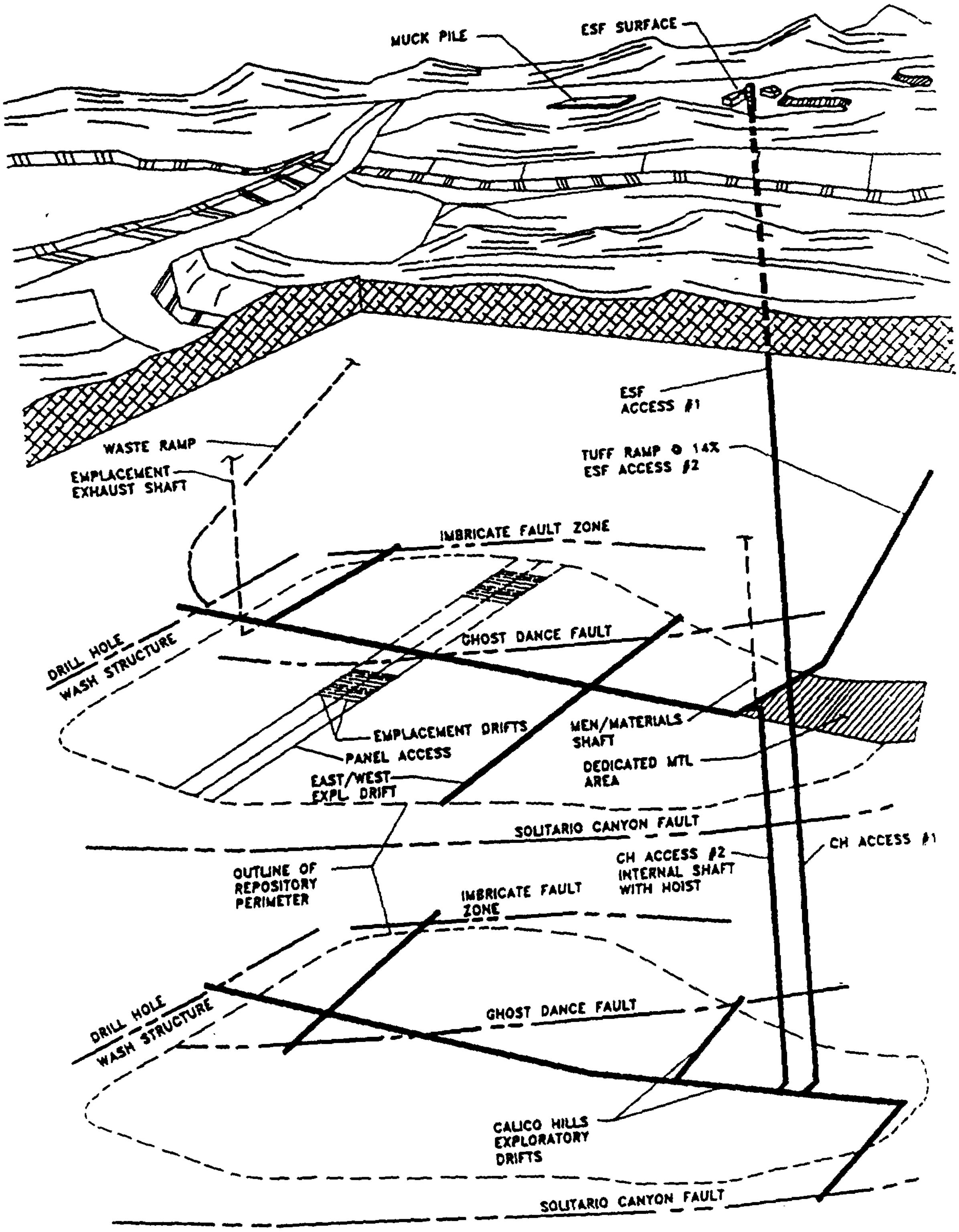

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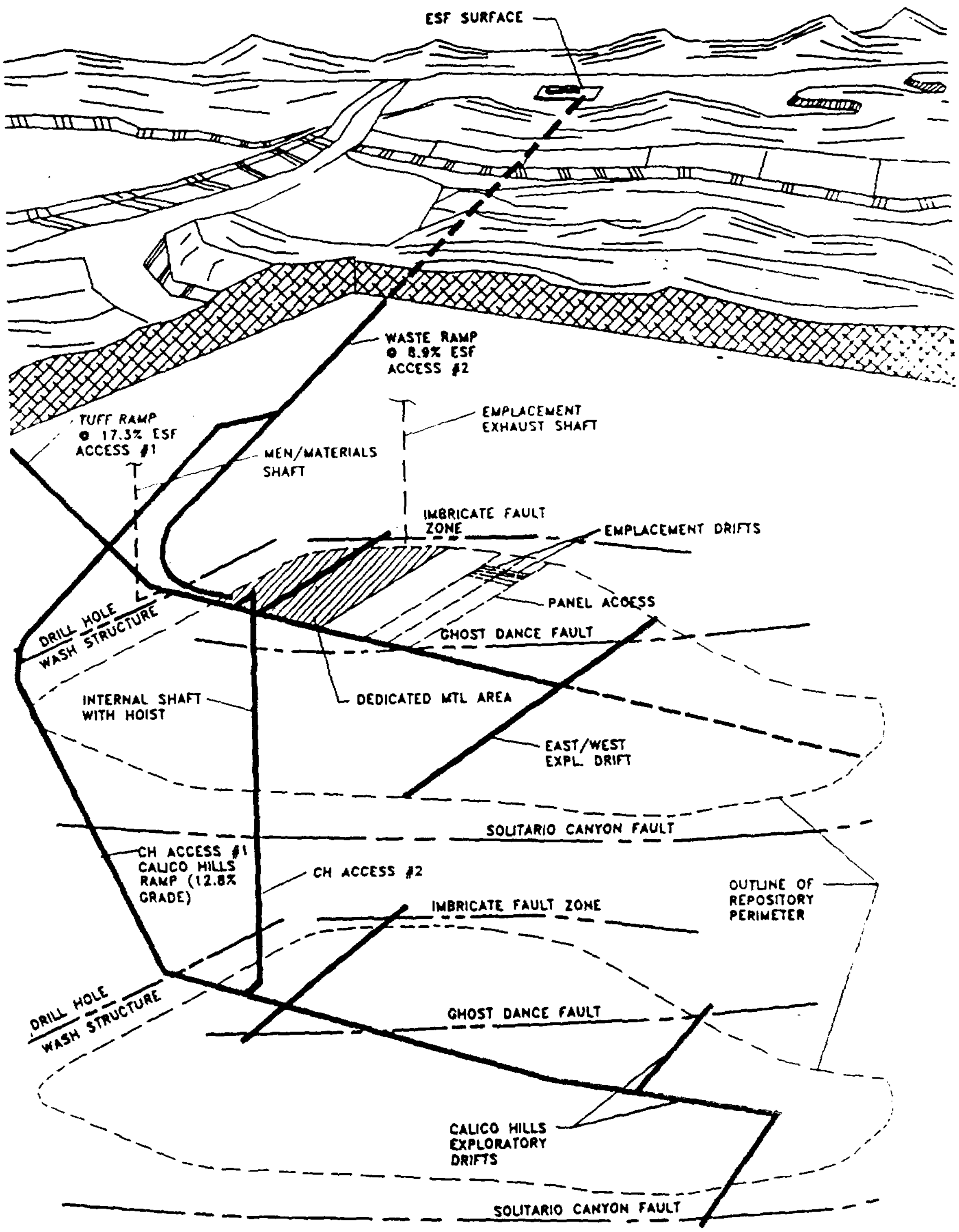

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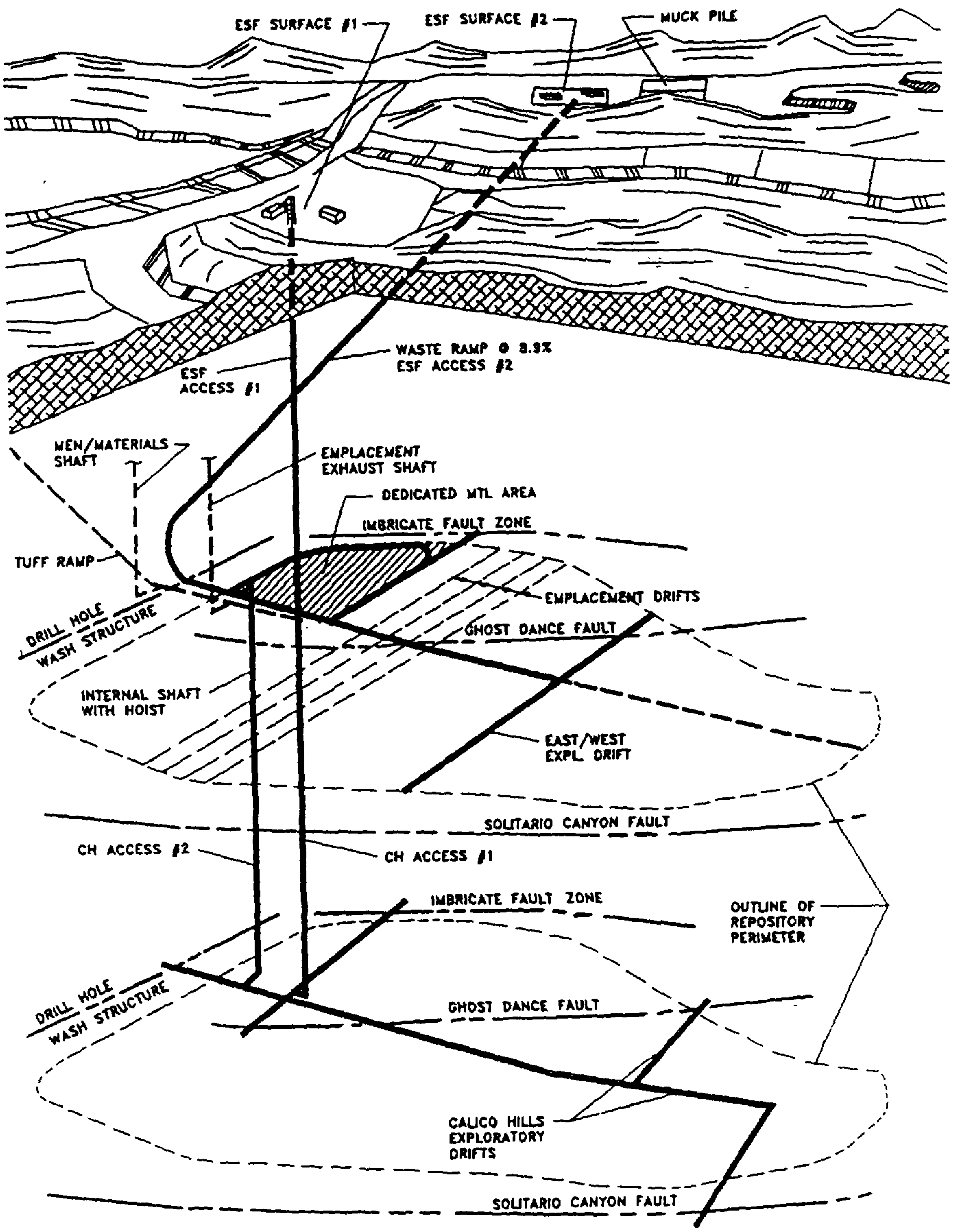

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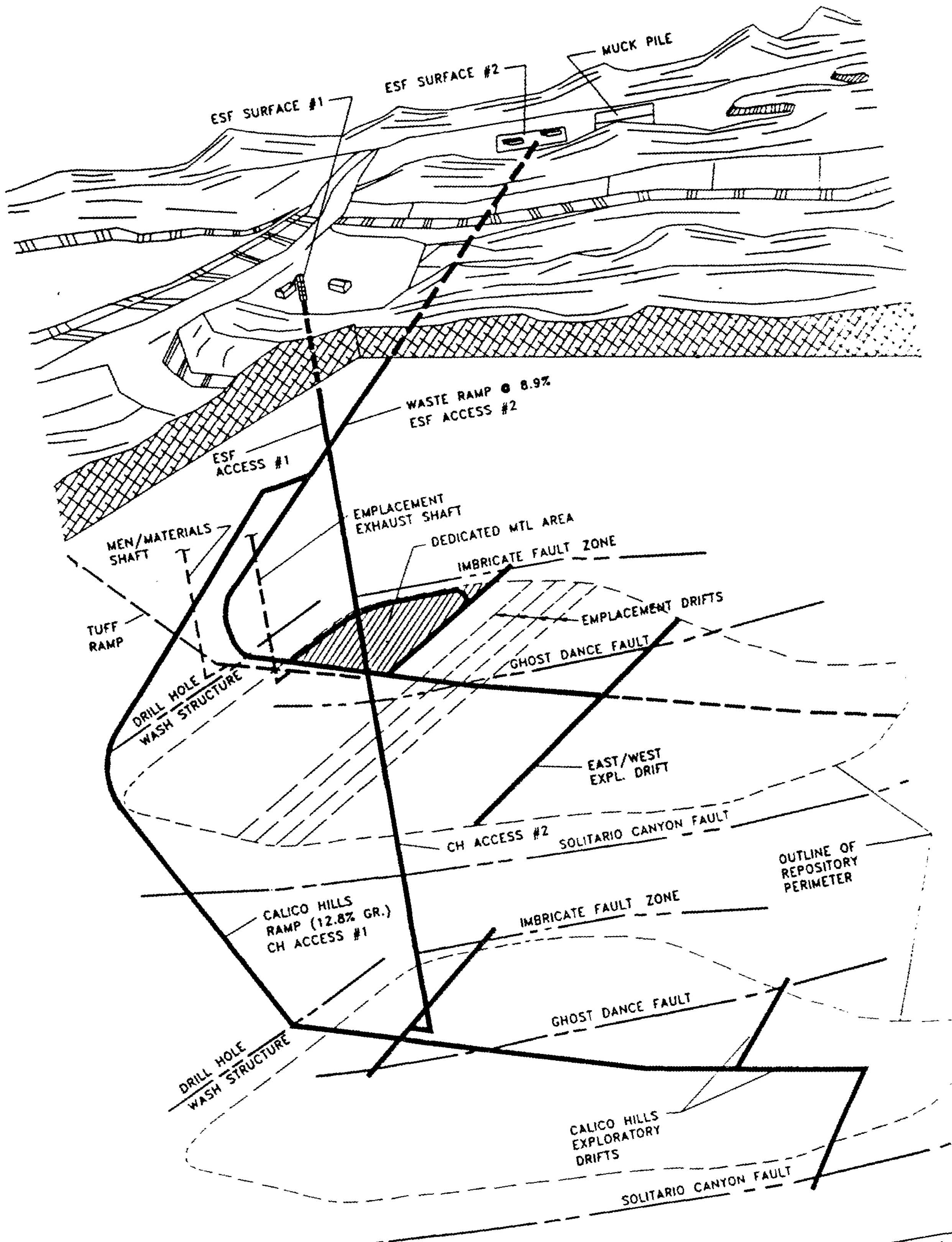

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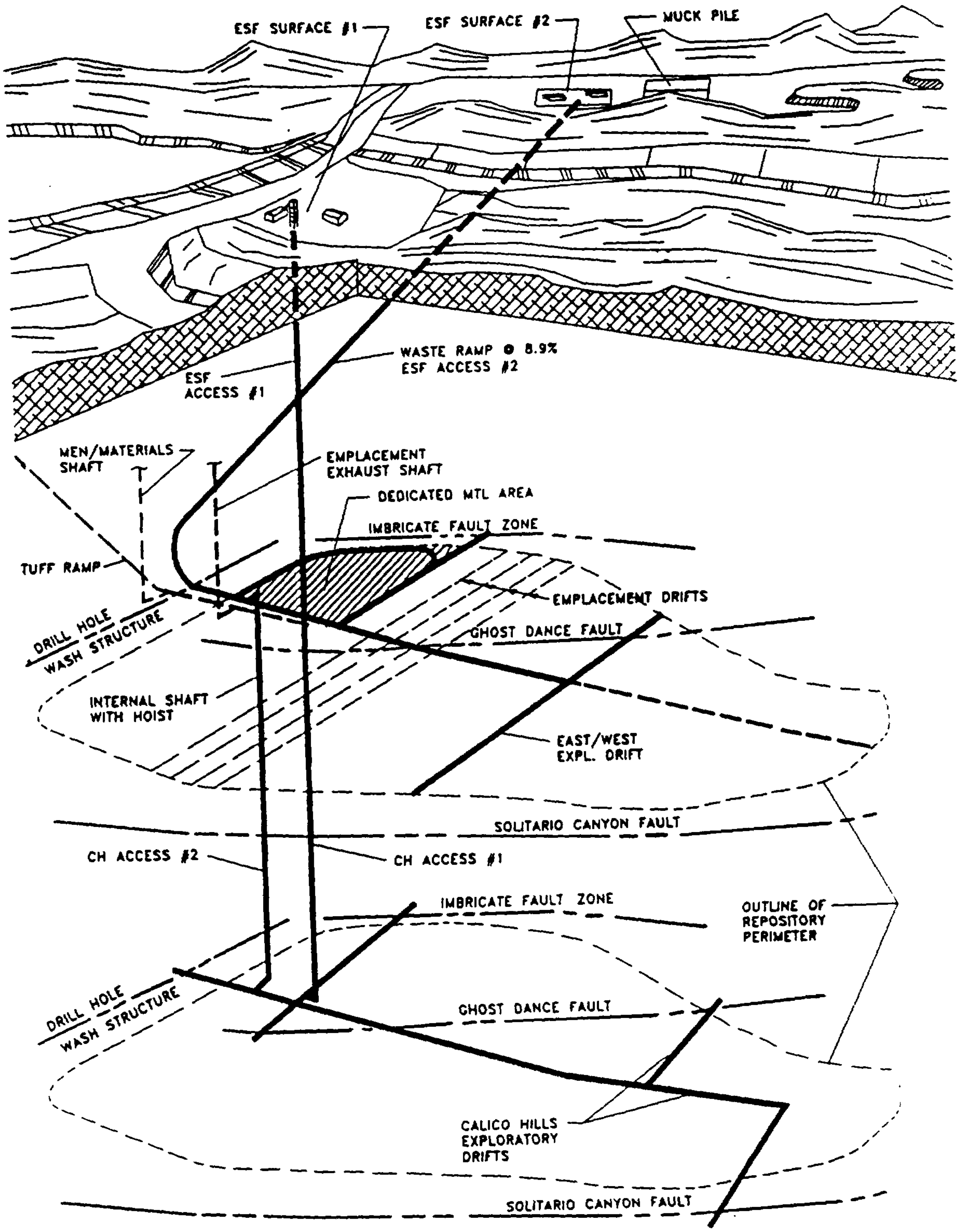

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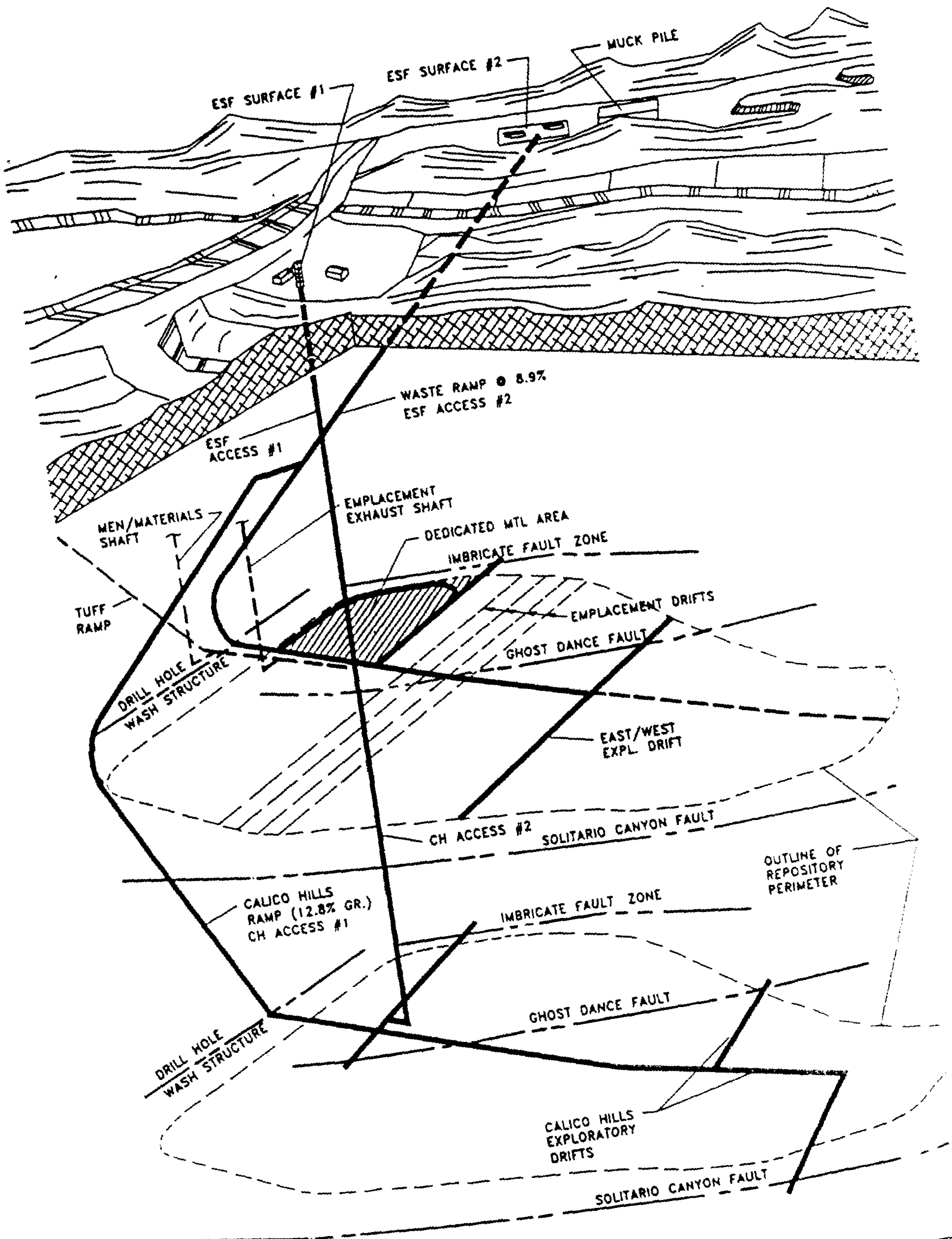

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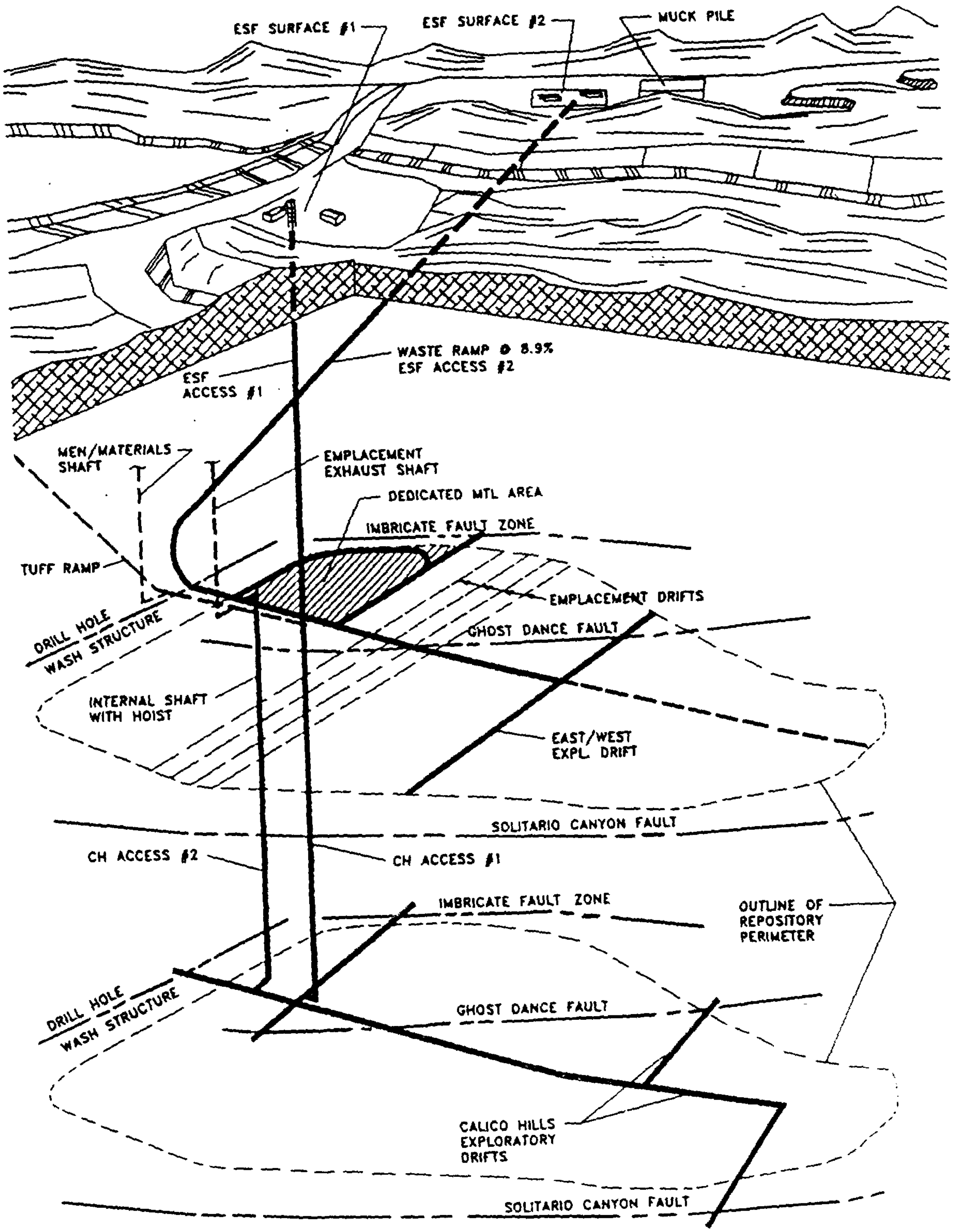

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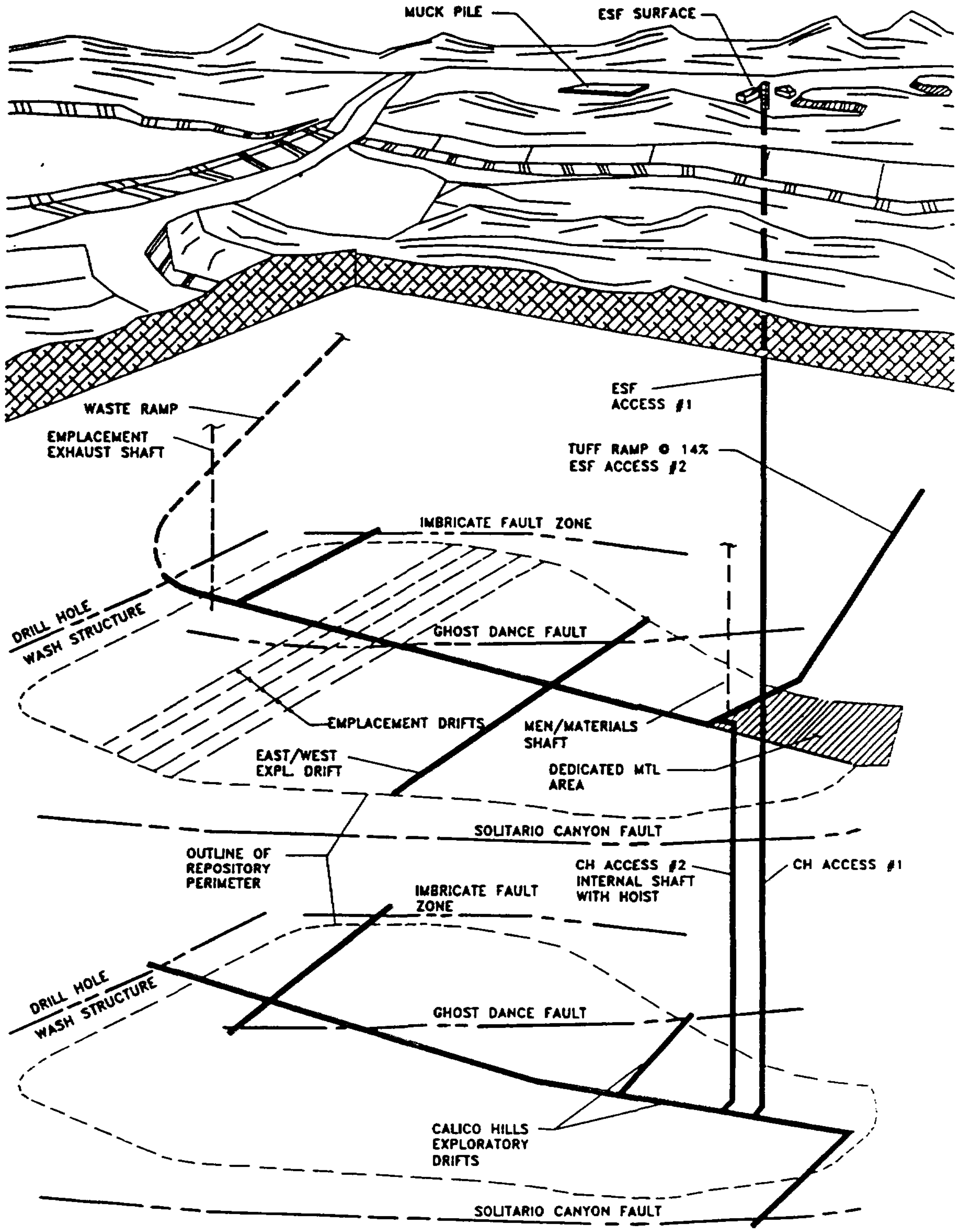

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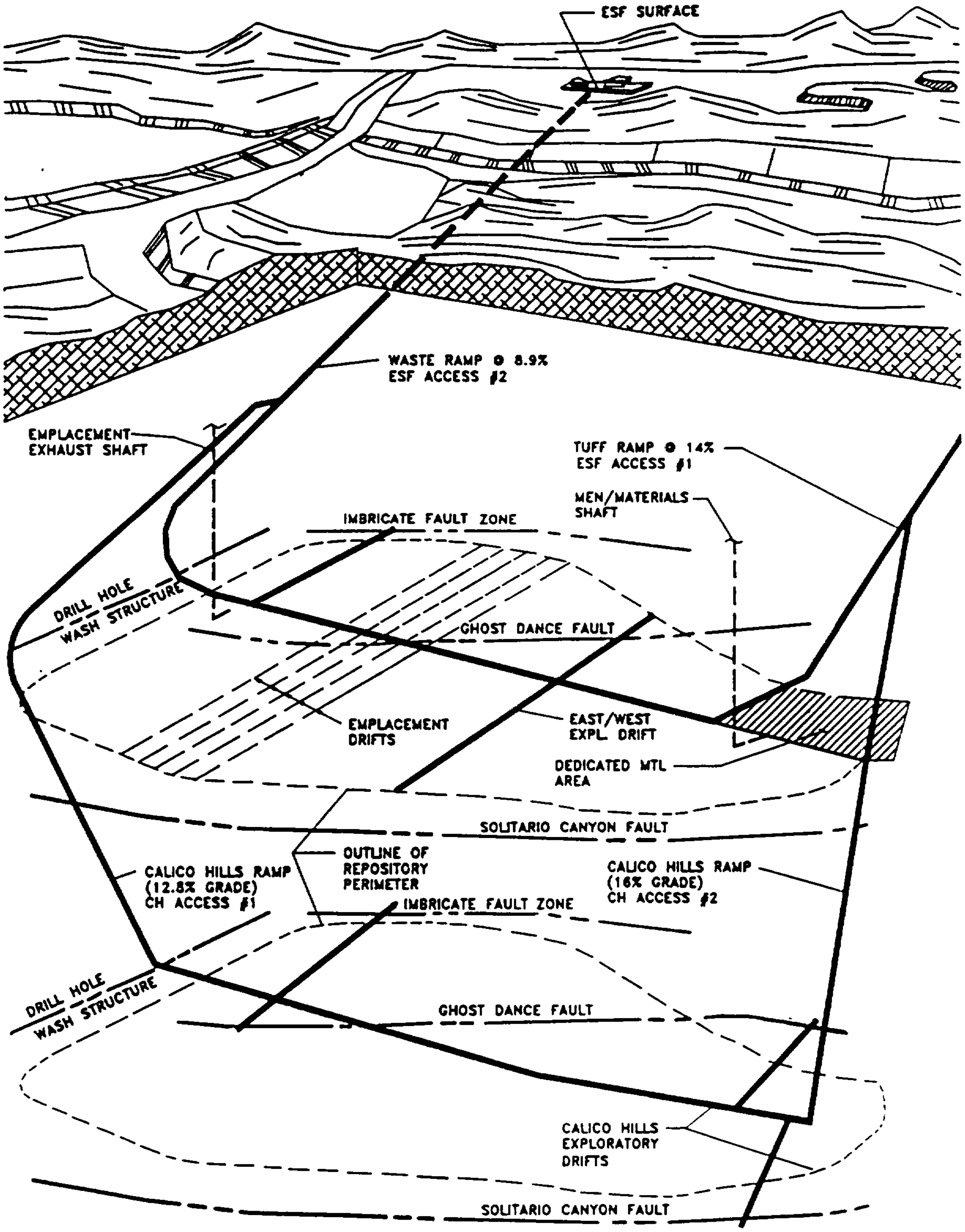

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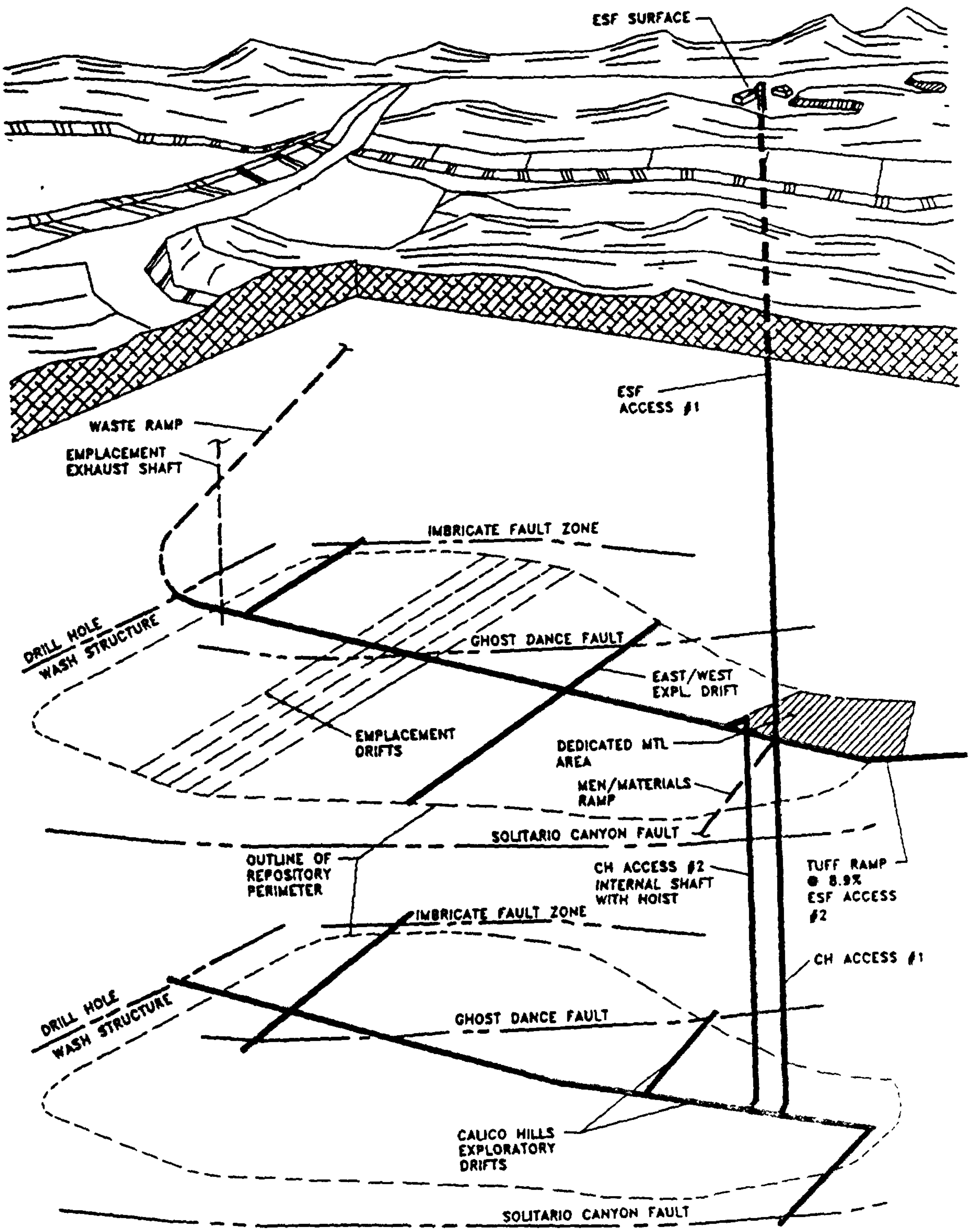

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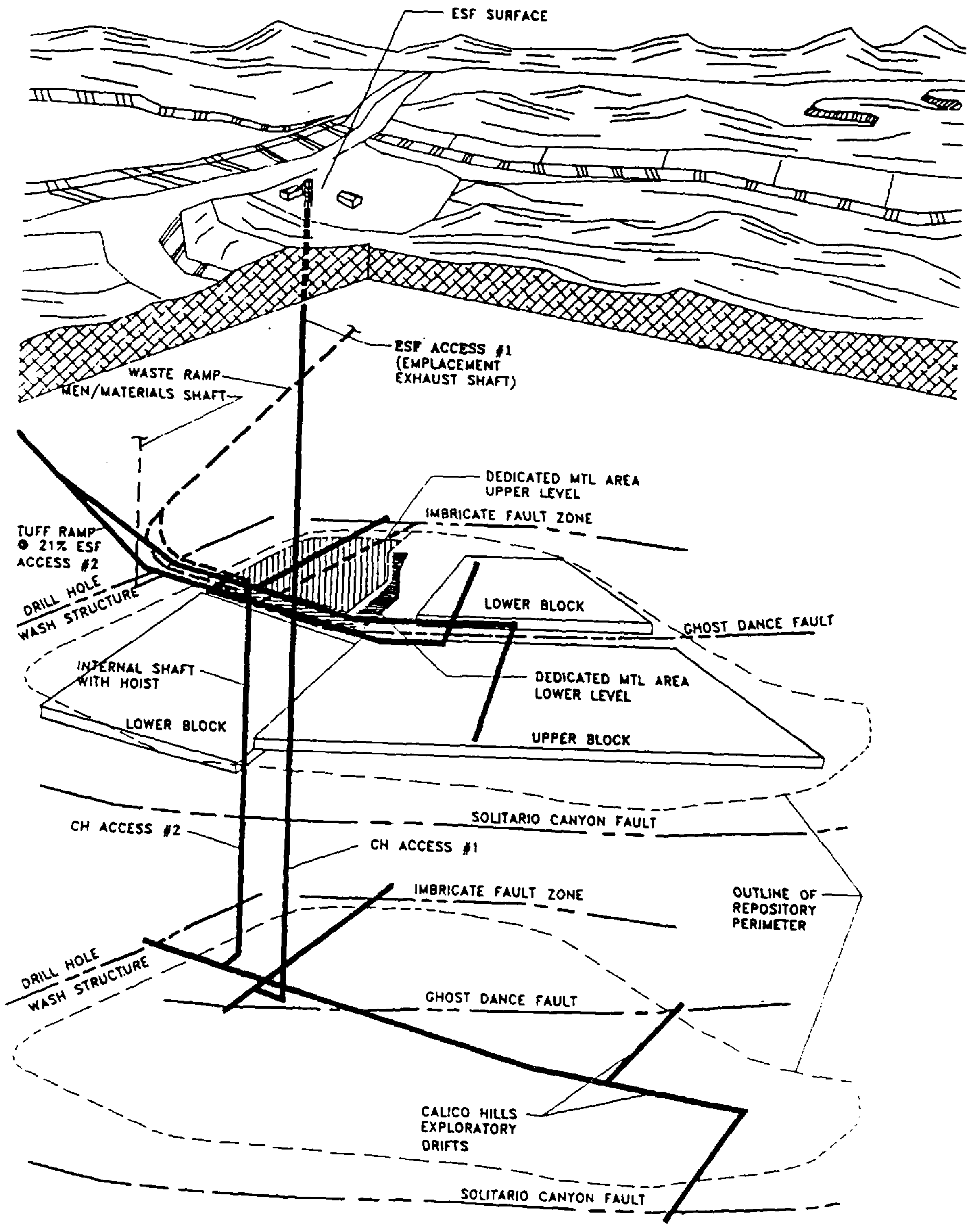

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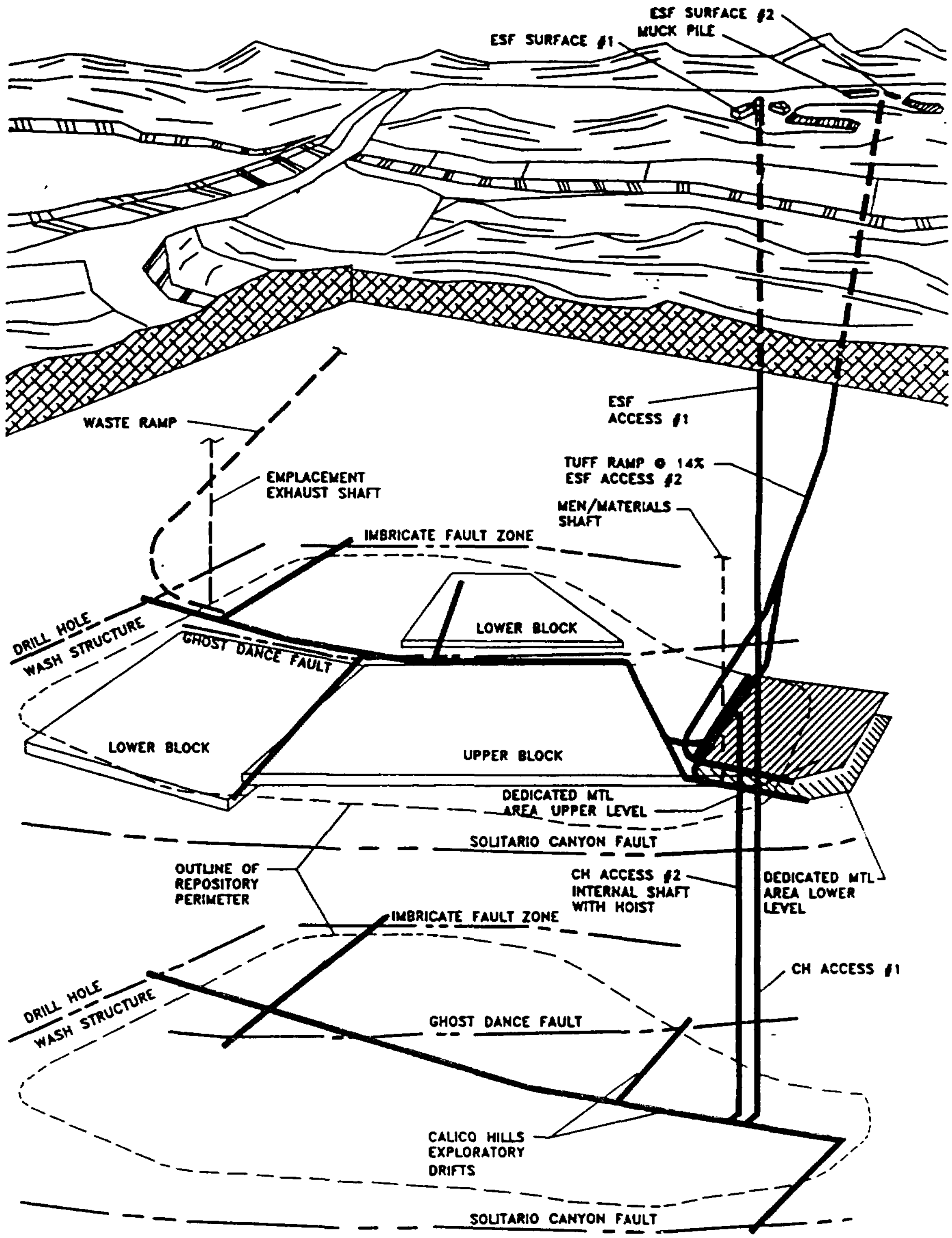

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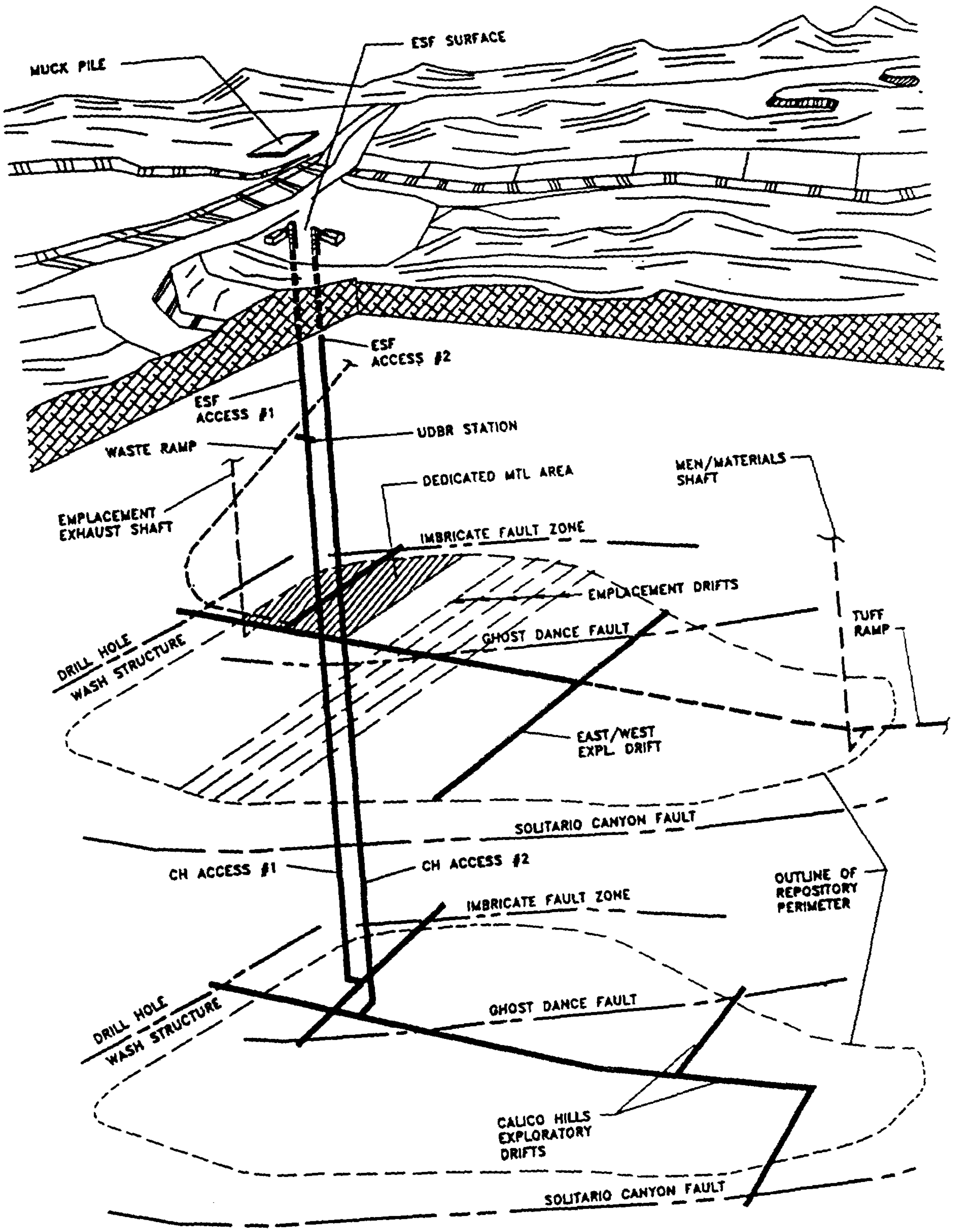

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ESF ALTERNATIVES STUDY TASK NO. 4
OPTION NO. R-11
ISOMETRIC SCENARIO #2
DATE ______

APPENDIX B

APPENDIX B

LIST OF REQUIREMENTS DOCUMENTS

- 10 CFR 60, Disposal of High-Level Radioactive Waste in Geologic Repositories
- 10 CFR 960, General Guidelines for Recommendation of Sites for Nuclear Waste Repositories
- 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes
- Nuclear Waste Policy Act (1982) and Amendments (1987)
- 10 CFR 20, Standards for Protection Against Radiation
- 29 CFR 1910, Occupational Safety and Health Standards (OSHA)
- Criteria from the Design Acceptability Analysis of ESF Title I Design
- Transcript of DOE Briefing to nuclear Waste Technical Review board Structural Geology and Geoengineering Panel), April 11-12, 1989: Four comment forms were generated from the transcript.
- Recommendations from the NWTRB Report to congress and DOE (3/90): Recommendations A, B, C, D, E, J
- NUREG 1347: NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada
- Generic Requirements Document (OGR/B-2)
- Repository Design Requirements (RDR, Rev. D)
- Subsystem Design Requirements Document (SDRD, Rev. 1)
- California Administrative Code. Tunnel (CTSO Title 8) and Mine (CTSO Title 8) Safety Orders
- Nevada Mine Safety and Health Standards (NRS Title 46)
- 30 CFR Chapter I, Mine Safety and Health Administration (MSHA): 30 CFR Safety and Health Standards - Underground Metal and Nonmetal Mines
- State of Nevada comments on Statutory Draft of SCP
- Site Characterization Plan (Portions only)

APPENDIX B

LIST OF REQUIREMENTS DOCUMENTS (continued)

- DOE Orders:
  6430.1A (General Design Criteria)
  4700.1 (Project Management)
  5400 Series (Environmental)
  5500 Series (Emergency Planning)
  1000 Series (Management and Administration)
  1100 Series (Organization, etc.)
  1200 Series (External Relationships)
  1300 Series (Management Systems and Standards)
  1500 Series (Travel and Transportation)
  2200 Series (Accounting)
  4200 Series (Procurement)
  5100 Series (Planning, Programming, Budgeting)
  5300 Series (Telecommunications)
  5700 Series (Energy Programs and Policies)
  DOE/EP 0108 Standard for Fire Protection . . .
  DOE/EP 0043 Standard on Fire Protection . . .
  DOE/0051/1 Electrical Safety Criteria . . .
  DOE/EV 0132 Environmental Compliance Guide
  DOE/EV 06194-3 DOE Explosive Safety Manual

APPENDIX C

Information from the Reference Information Base Used in this Report.

This report contains no information from the Reference Information Base.

Candidate Information for the Reference Information Base

This report contains no candidate information for the Reference Information Base.

Candidate Information for the Site & Engineering Properties Data Base

This report contains no candidate information for the Site and Engineering Properties Data Base.

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