U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: THERMAL STRUCTURAL EFFECTS ON UNDERGROUND EXCAVATIONS

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AGENDA

1. GENERAL DESCRIPTION
2. WHY IMPORTANT TO ESF
3. EXTENT OF WORK COMPLETED FOR TITLE I
4. RESULTS, SUFFICIENCY IN REGARD TO TITLE I
5. PLANNED WORK FOR TITLE II
6. WHEN TO BE COMPLETED

GENERAL DESCRIPTION

DEVELOPMENT AND APPLICATION OF METHODS FOR THERMAL AND STRUCTURAL ANALYSES OF UNDERGROUND EXCAVATIONS

- 2-D UNDERGROUND OPENING CROSS SECTIONS
- 3-D UNDERGROUND INTERSECTIONS
- 3-D REPOSITORY SCALE CONDITIONS

WHY IMPORTANT TO ESF?

- ESF EXCAVATIONS AND REGIONS TO BECOME PART OF POTENTIAL REPOSITORY
- SHOW COMPLIANCE IN TITLE II WITH 10 CFR PART 60

EXTENT OF WORK COMPLETED FOR TITLE I (SEE ESFDR APPENDIX I)

- FAR-FIELD THERMAL EFFECTS PREDICTED
- SHAFT AND COLLAR THERMAL STRESS PREDICTED
- CREEP POTENTIAL ASSESSED

GENERAL ANALYSIS APPROACHES

- 3-D THERMOELASTIC
- FINITE ELEMENT
- DISTINCT ELEMENT

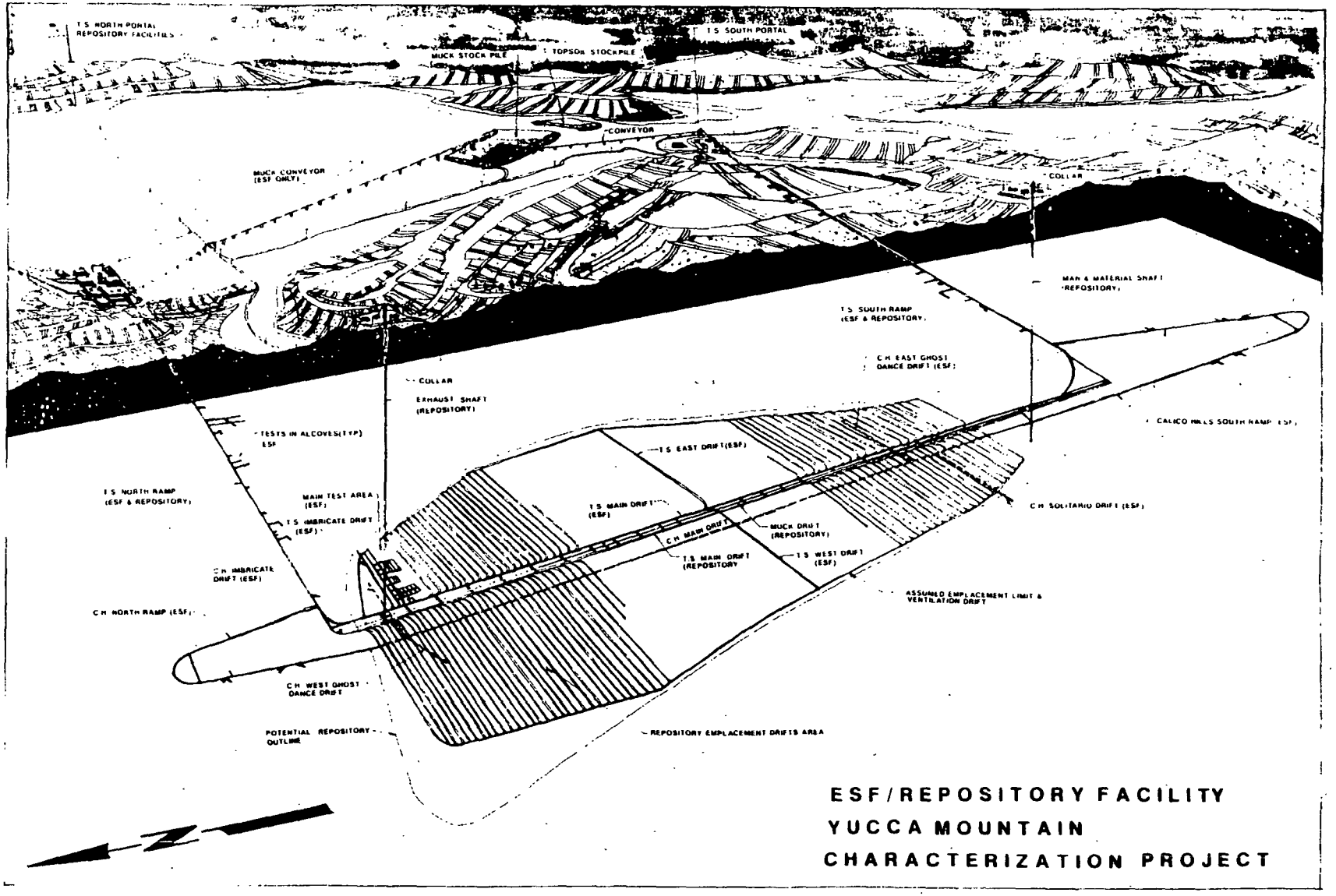
RESULTS, SUFFICIENCY IN REGARD TO TITLE I

- METHODS
- ANALYSIS RESULTS

3-D THERMOELASTIC

- SINGLE HOMOGENEOUS ISOTROPIC MATERIAL
- CONSTANT THERMAL PROPERTIES
- CONSTANT STRUCTURAL PROPERTIES
- EXPONENTIALLY DECAYING HEAT SOURCES

ESF/REPOSITORY FACILITY



ESF/REPOSITORY FACILITY
YUCCA MOUNTAIN
CHARACTERIZATION PROJECT

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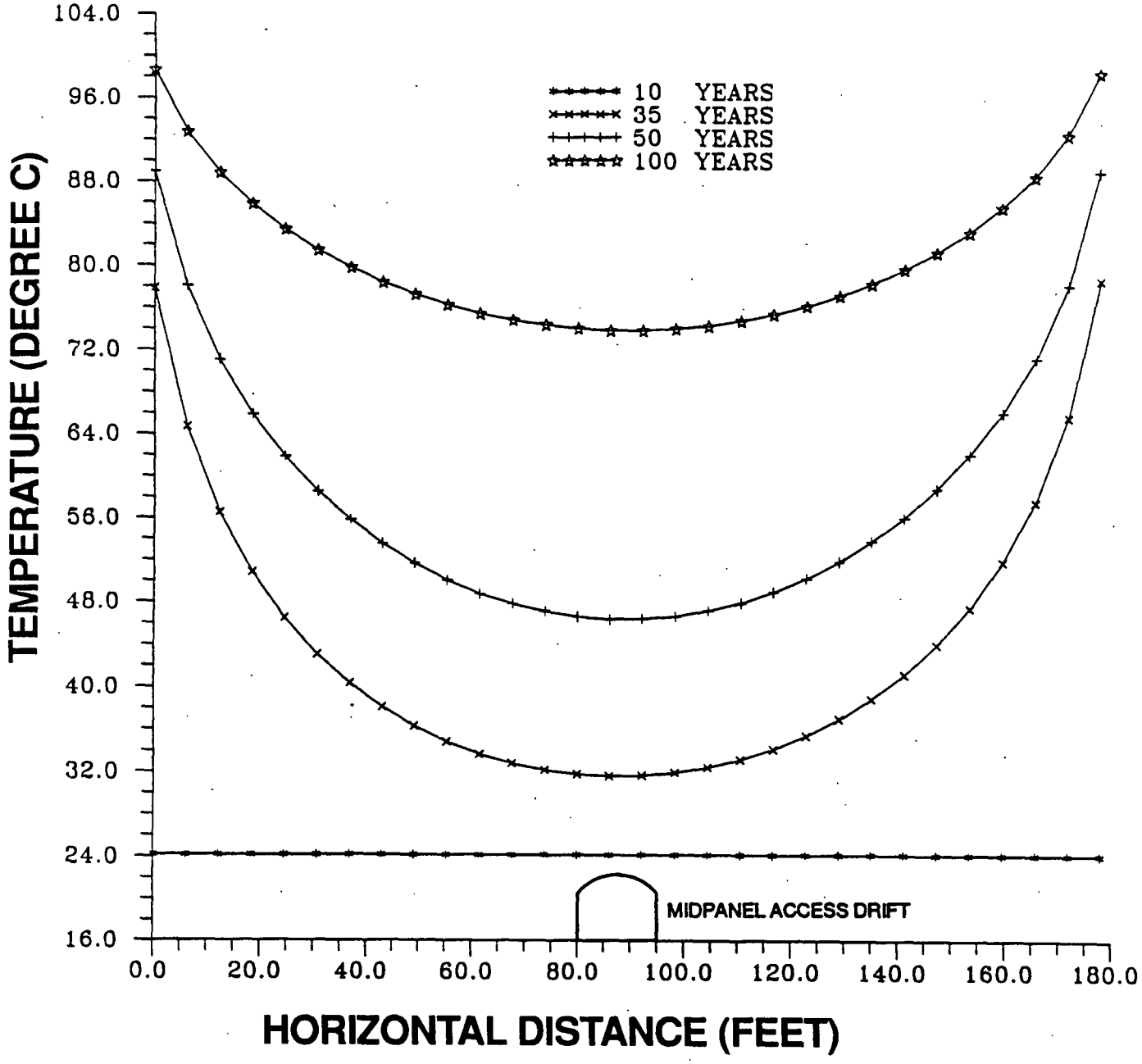
CALCULATE

$$\sigma, \varepsilon, T = f(t, [x, y, z])$$

σ = Stress
ε = Strain
T = Temperature
t = Time

TEMPERATURES AT MIDPANEL ACCESS DRIFT



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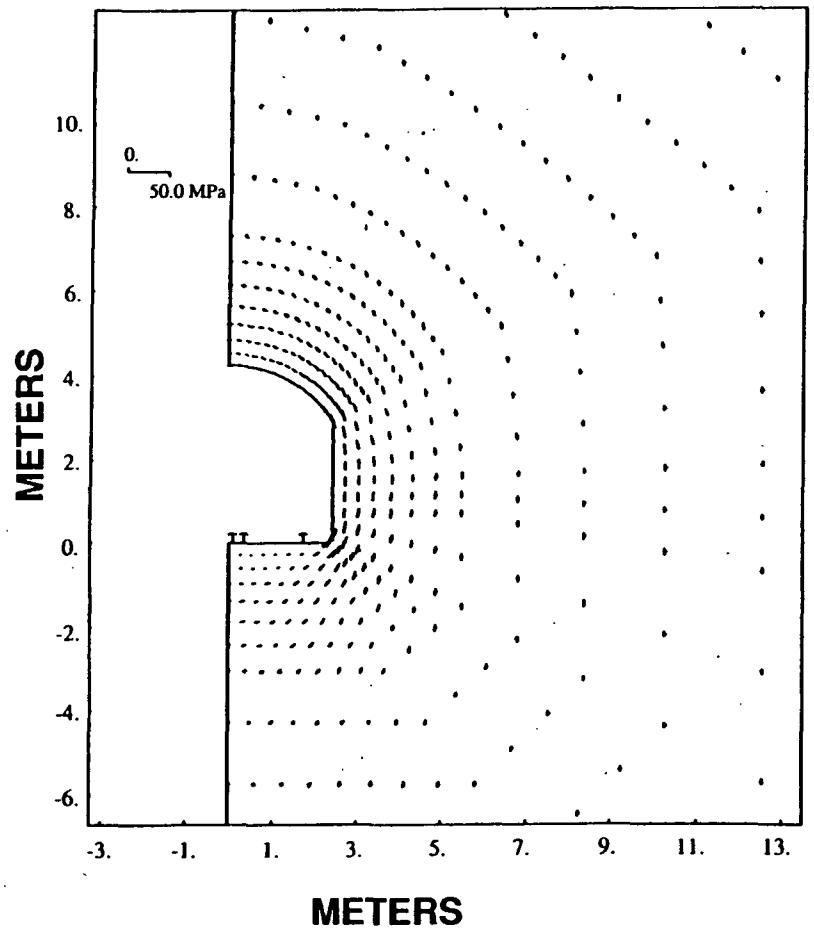
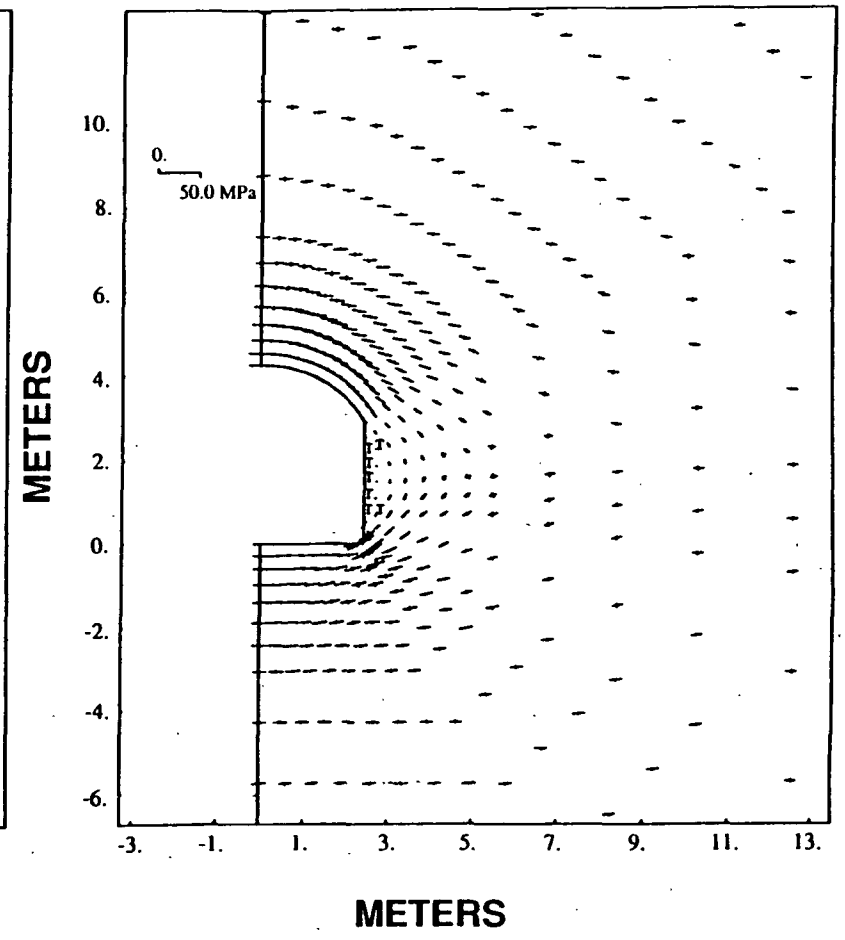
STRESS VECTORS FOR MIDPANEL ACCESS DRIFT



EXCAVATION



100 YEARS

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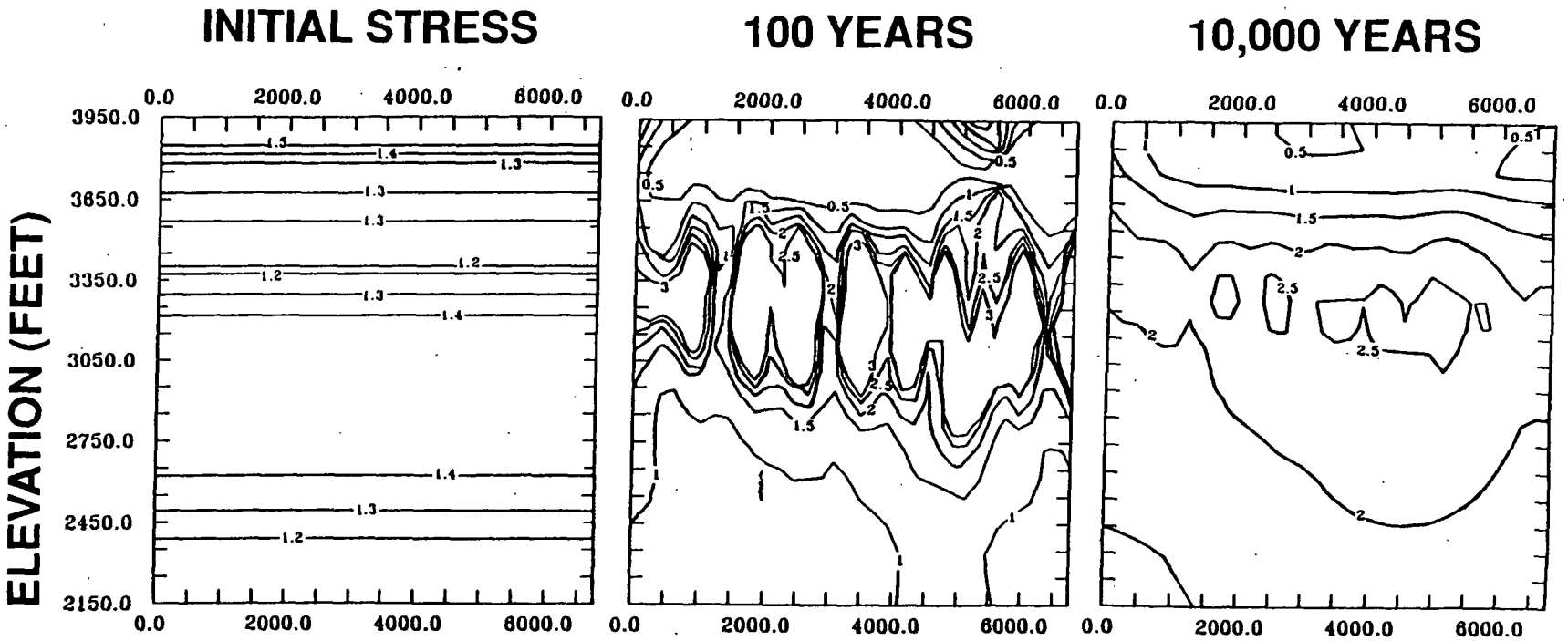
GHOST DANCE FAULT
FACTOR OF SAFETY FOR SLIP



DISTANCE ALONG STRIKE A'-A (FEET)

NORTH

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FINITE ELEMENT ANALYSIS

- PRIMARILY 2-D
- 3-D ABOUT TO COME ON LINE
- NON LINEAR THERMAL, STRUCTURAL BEHAVIOR

THERMAL ANALYSES

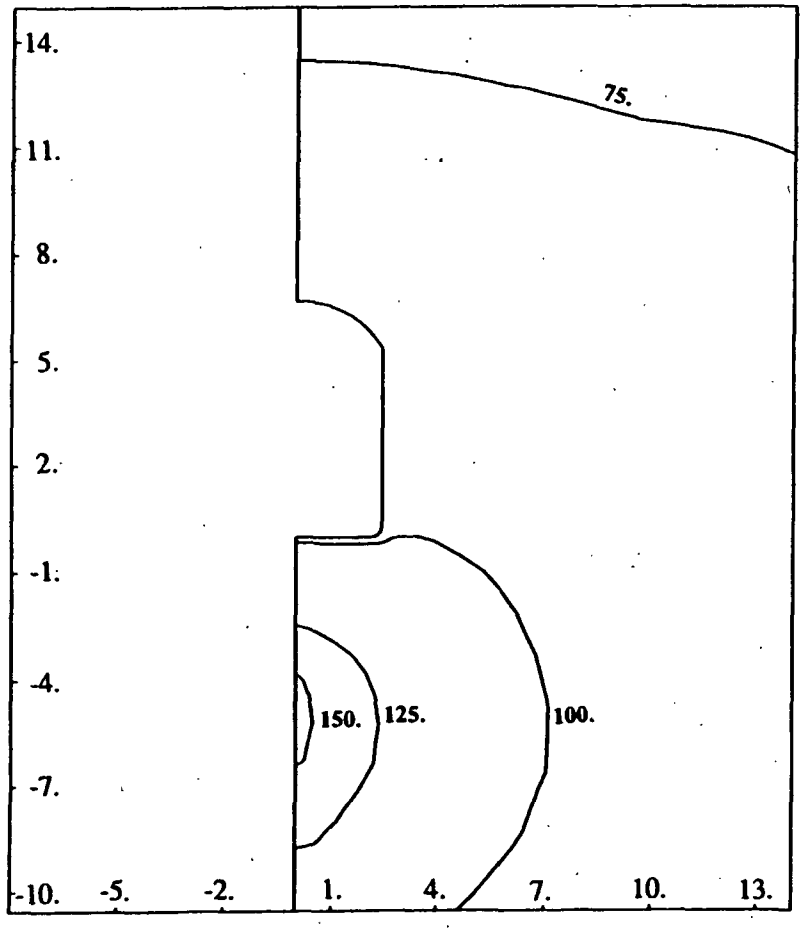
CONDUCTION - THE HEAT TRANSFER MECHANISM

$$K, Cp, = f(T)$$

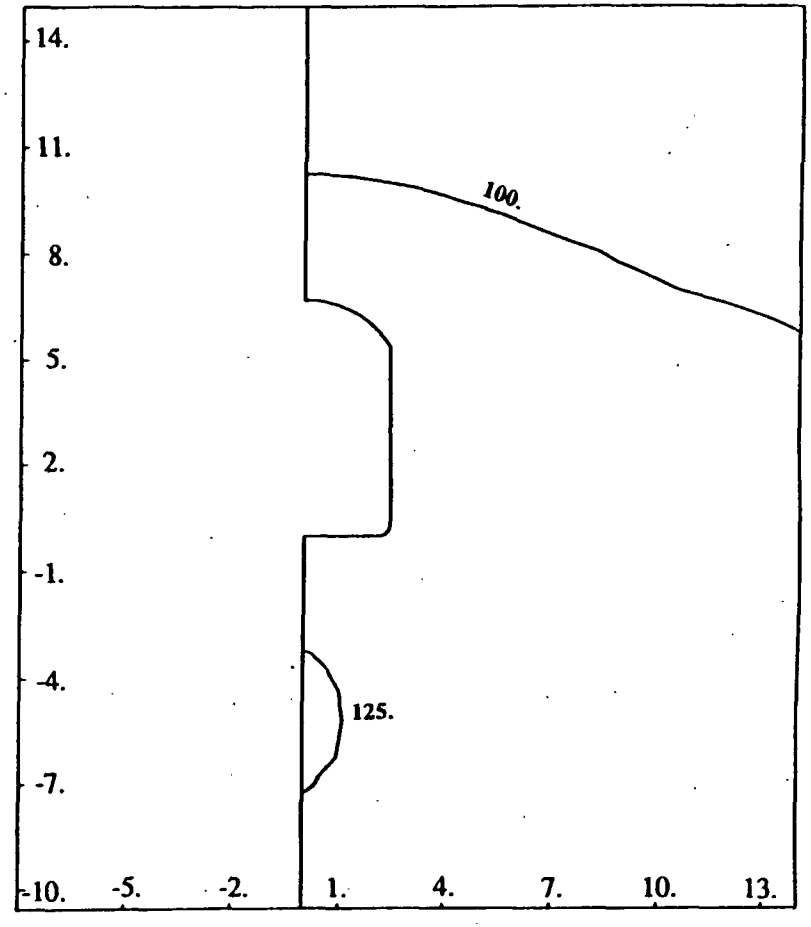
K = CONDUCTIVITY
Cp = HEAT CAPACITY
T = TEMPERATURE

TEMPERATURE

25 YEARS AFTER EMPLACEMENT



100 YEARS AFTER EMPLACEMENT



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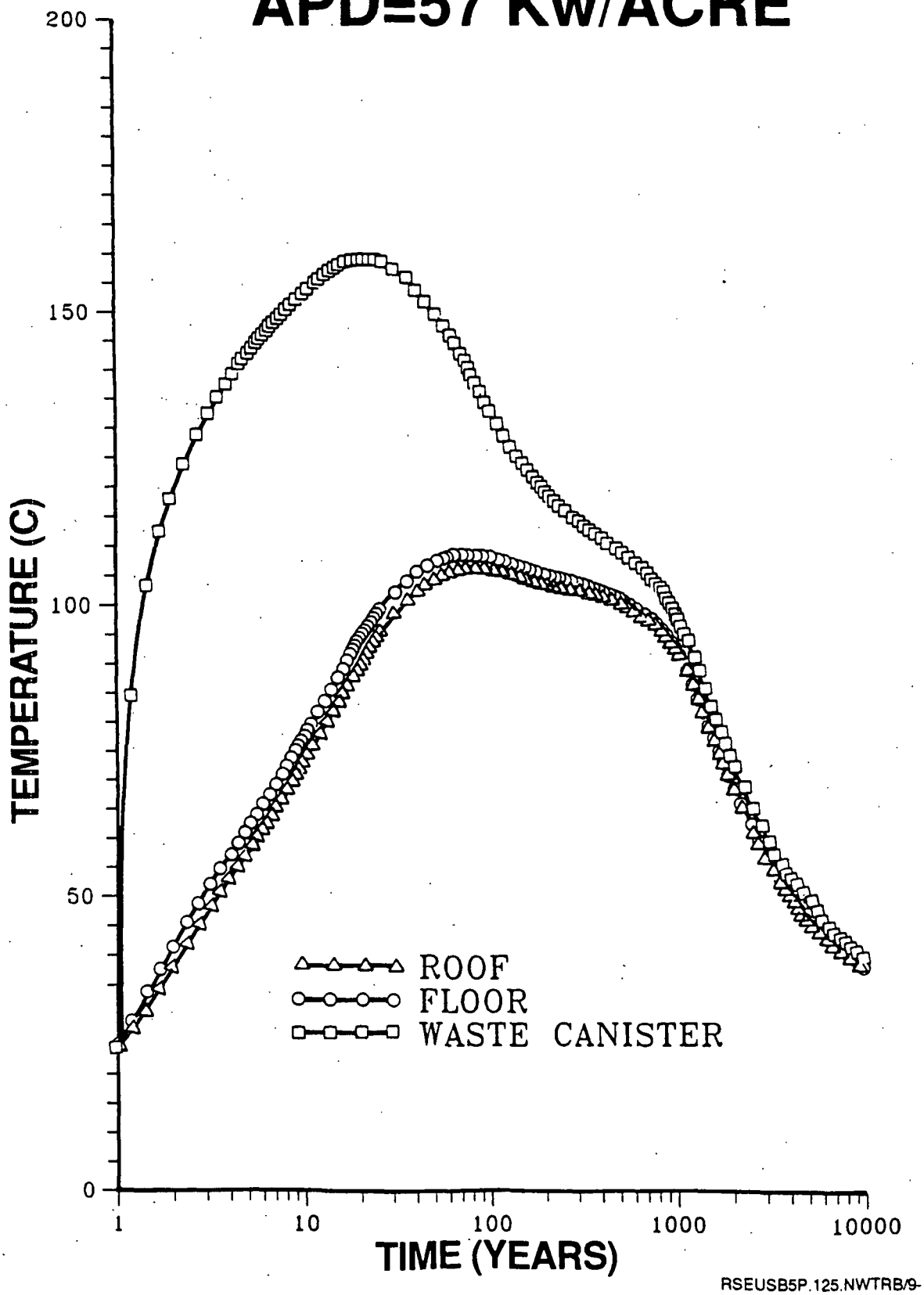
VERTICAL EMPLACEMENT DRIFT
APD=57 Kw/ACRE



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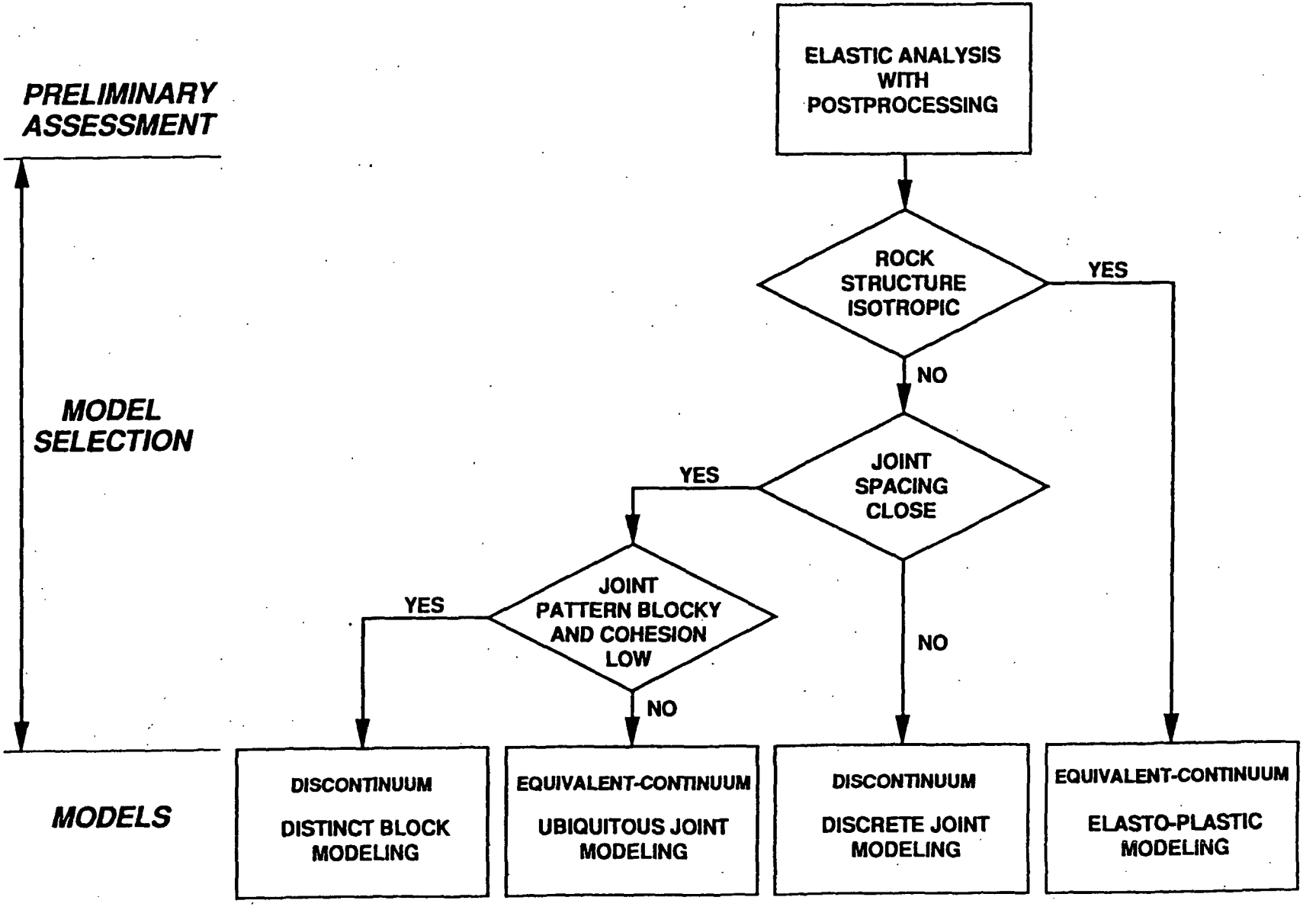
STRUCTURAL ANALYSES

- ELASTIC
- JOINTED ROCK MASS RESPONSE
- CONSIDERS NON LINEAR JOINT SHEAR AND NORMAL STIFFNESS
- $\alpha = f(T)$

α = COEFFICIENT OF THERMAL EXPANSION
T = TEMPERATURE

SELECTION OF APPROPRIATE ROCK MODEL FOR DESIGN ANALYSIS



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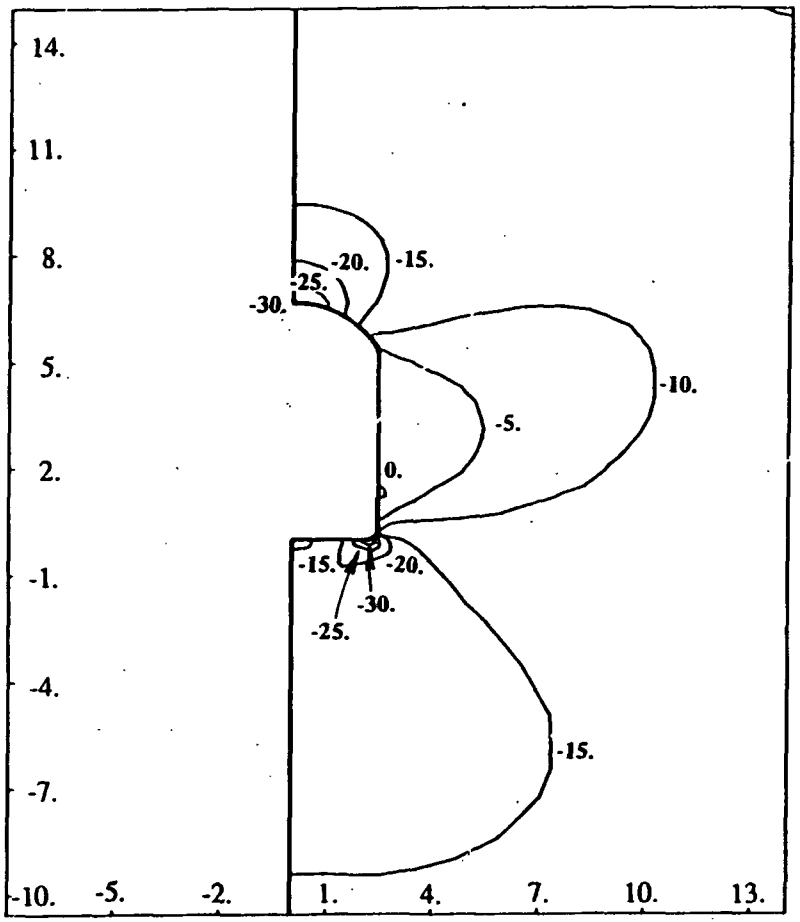
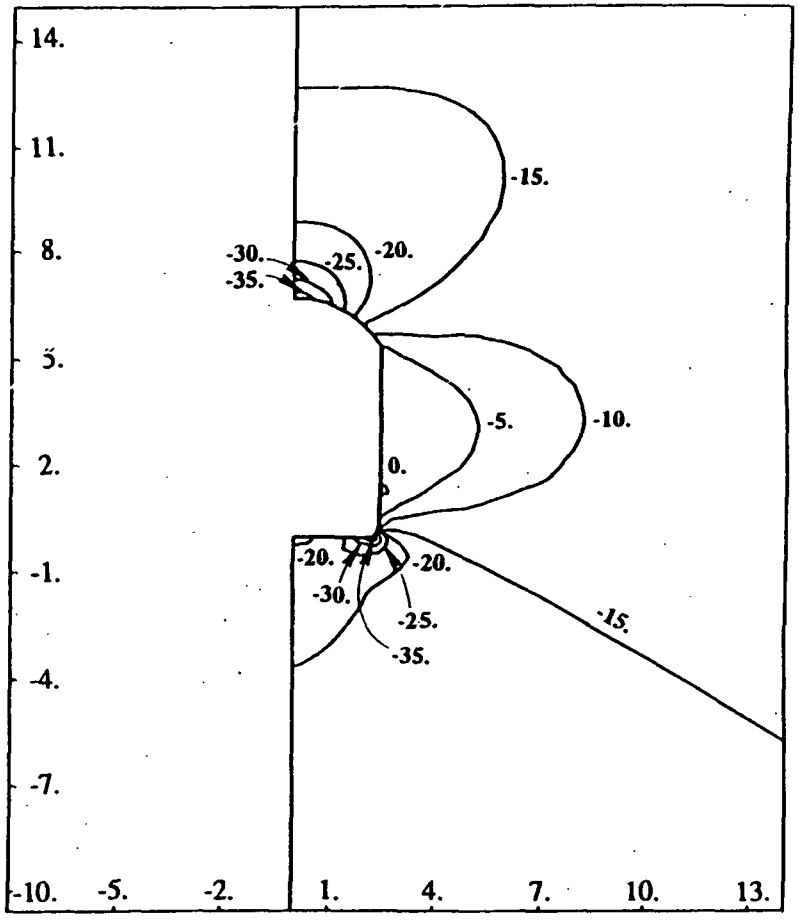
HORIZONTAL STRESS

25 YEARS AFTER EMPLACEMENT



100 YEARS AFTER EMPLACEMENT



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THERMAL STRUCTURAL EFFECTS ON UNDERGROUND EXCAVATIONS SUMMARY

1. σ, ε, $T=f(t, [x, y, z])$

2. QUANTIFICATION POSSIBLE

3. (1) SHALL BE INCORPORATED INTO DESIGN PROCESS

CONCLUSIONS

- TITLE I DESIGN IS NOT INCONSISTENT WITH THE RESULTS TO DATE
- DEVELOPMENT AND APPLICATION OF ANALYSIS METHODS CONTINUING
- METHODS SHALL BE USED IN ANALYSES TO SUPPORT TITLE II DESIGN COMPLIANCE WITH 10 CFR PART 60

PLANNED WORK FOR TITLE II THERMAL STRUCTURAL ANALYSES

- THERMAL (TEMPERATURES)
  - ALLOWABLE THERMAL LOADING - APD COMBINED NEAR / FAR-FIELD AREA REQUIREMENTS AND SITE FLEXIBILITY
- STRUCTURAL (EXCAVATION/SEISMIC/IN SITU/ THERMAL)
  - EXCAVATION SEQUENCING
  - MTL EXCAVATION SEQUENCING (DETERMINATION OF PILLAR LOADS)
  - PARAMETER STUDY ON DRIFT SPACING USING DIFFERENT CONSTITUTIVE MODELS
  - SURFACE PREPARATION-RIPPING
  - SURFACE BLASTING EFFECTS
  - SUBSURFACE BLASTING EFFECTS

PLANNED WORK FOR TITLE II THERMAL STRUCTURAL ANALYSES

(CONTINUED)

- THERMAL STRUCTURAL (COUPLED)
  - FAR-FIELD REPOSITORY, WITH TIME SEQUENCED WASTE EMPLACEMENT
  - SHAFT WITH/WITHOUT LINER
  - RAMP WITH/WITHOUT GROUND SUPPORT
  - HEATED ROOM TEST ANALYSIS
  - THERMAL STRESS TEST ANALYSIS
  - CANISTER SCALE HEATER TEST ANALYSIS
  - POTENTIAL FOR TIME DEPENDENT DEFORMATION
  - SEAL SHAFTS, BOREHOLES, RAMPS, DRIFTS
  - BOREHOLE STABILITY

PLANNED WORK FOR TITLE II THERMAL STRUCTURAL ANALYSES

(CONTINUED)

- THERMAL/OPERATIONAL (OPERATIONS)
- EXCAVATION
- UNDERGROUND
- DATA

SCHEDULE TO COMPLETE WORK

- WORK BEGUN AS PART OF TITLE I
- FAR-FIELD ANALYSIS FIRST
- CROSS SECTION AND INTERSECTION ANALYSES TO BE COMPLETED TO SUPPORT INDIVIDUAL TITLE II DESIGN PHASES