

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

**NUCLEAR WASTE TECHNICAL REVIEW BOARD  
STRUCTURAL GEOLOGY & GEOENGINEERING PANEL MEETING**

**SUBJECT: INTEGRATED TEST  
EVALUATION**

**PRESENTER: DR. J. RUSSELL DYER**

**PRESENTER'S TITLE  
AND ORGANIZATION:**

**DIVISION DIRECTOR, REGULATORY AND  
SITE EVALUATION DIVISION  
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT  
LAS VEGAS, NEVADA**

**PRESENTER'S  
TELEPHONE NUMBER: (702) 794-7586**

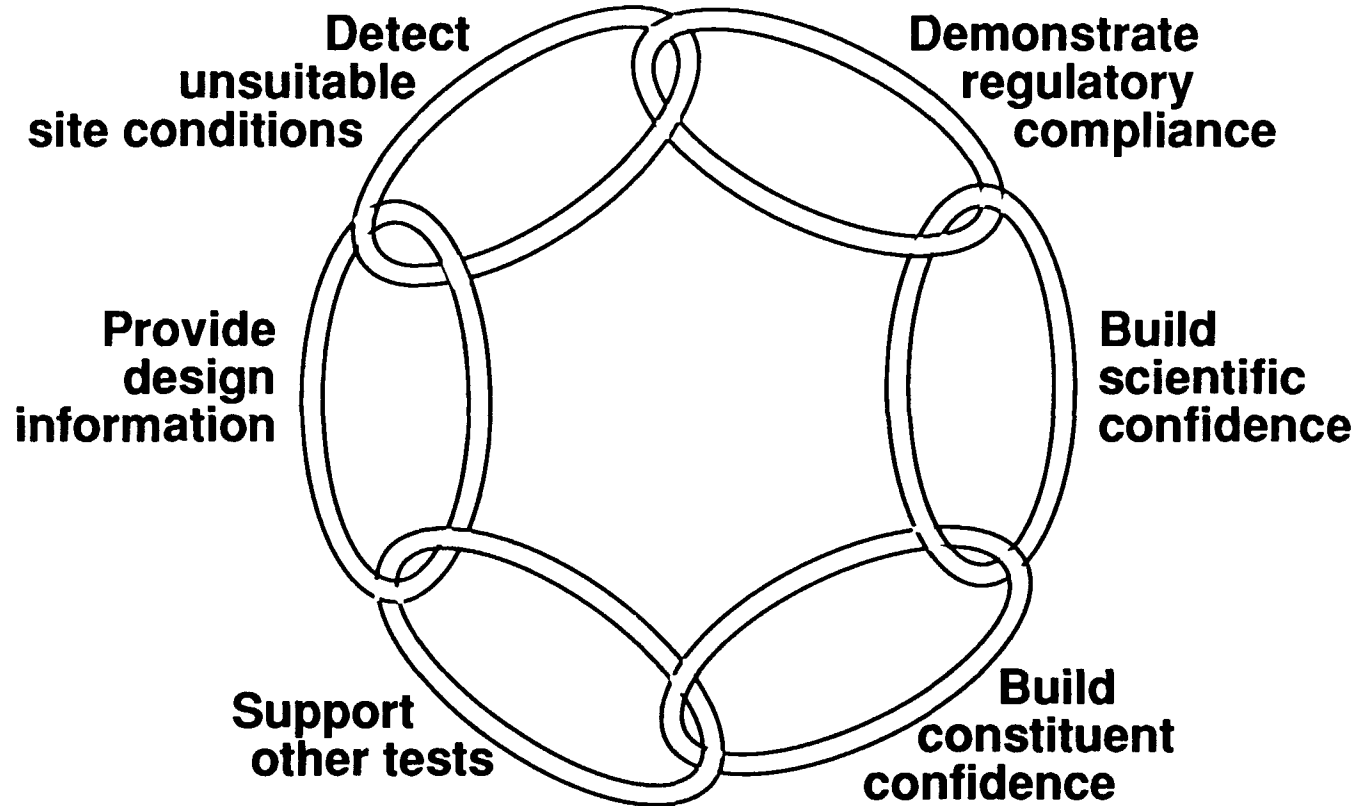
**PLAZA-SUITE HOTEL • LAS VEGAS, NEVADA  
NOVEMBER 4 - 5, 1992**

# **The ITE task helps prioritize site-characterization “tests”**

## **Objectives**

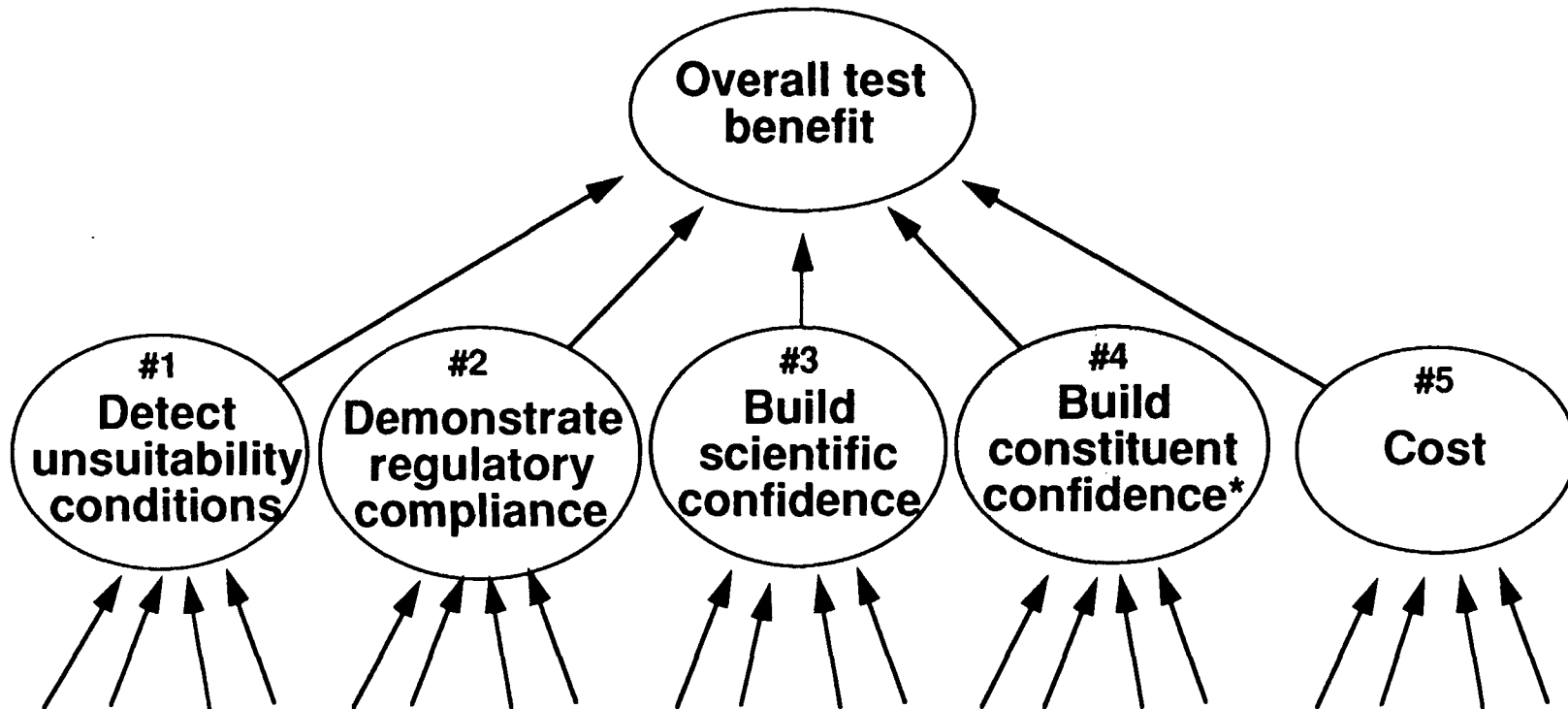
- **Assist the Regulatory and Site Evaluation Division (RSED) Director in making budget allocation and planning decisions**
- **Produce a prioritized list of “tests” for FY93**
  - **“Tests” will be evaluated at the study plan, activity, or test-package level**
  - **Prioritization will be based on site-suitability, regulatory, confidence-building, cost, and schedule criteria**
- **Incorporate the results of recent and on-going studies (ESSE, TPT, CHRBA, ESFA, TSPA)**
- **Develop a systematic and pragmatic approach that can be applied iteratively**

# There are many interrelated reasons for testing



***A defensible testing program must satisfy these reasons for testing, account for external influences, and meet budget and other constraints***

**This influence diagram illustrates the five evaluation criteria considered in ITE**



**These criteria are related most directly to site suitability**

***\*Not evaluated in current model***

***Each criterion is further broken down into other factors used to rank study plans.***

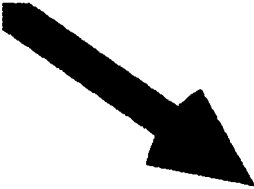
## **The initial application of the framework demonstrated the evaluation method and produced insights**

- **Considered 104 studies; quantitatively evaluated 56 studies**
- **Applied all evaluation criteria except constituent confidence**
- **Assessed technical judgments from ten technical experts representing six participant organizations**
- **Produced an initial evaluation, associated insights, and set of recommendations**

***Quantitative assessments were conducted following a formal procedure for eliciting expert judgment***

**“Tests” are first evaluated according to each criterion, then results are aggregated to produce an overall ranking**

|                             |  |                                 |           |           |           |           |           |
|-----------------------------|--|---------------------------------|-----------|-----------|-----------|-----------|-----------|
| <b>#5 Cost &amp; Sched.</b> |  | <b>Cost; Time</b>               |           |           |           |           |           |
| <b>Study Plan</b>           |  | <b>#1</b>                       | <b>#2</b> | <b>#3</b> | <b>#4</b> | <b>#5</b> |           |
| <b>#4 Const. Confid.</b>    |  | <b>Constituent Groups</b>       |           |           |           |           |           |
| <b>Study Plan</b>           |  | <b>#1</b>                       | <b>#2</b> | <b>#3</b> | <b>#4</b> | <b>#5</b> |           |
| <b>#3 Sci. Confid.</b>      |  | <b>Scientific Groups</b>        |           |           |           |           | <b>.6</b> |
| <b>Study Plan</b>           |  | <b>#1</b>                       | <b>#2</b> | <b>#3</b> | <b>#4</b> | <b>#5</b> | <b>.5</b> |
| <b>#2 Reg. Confid.</b>      |  | <b>Performance Objectives</b>   |           |           |           |           | <b>.6</b> |
| <b>Study Plan</b>           |  | <b>#1</b>                       | <b>#2</b> | <b>#3</b> | <b>#4</b> | <b>#5</b> | <b>.9</b> |
| <b>#1 Unsuitability</b>     |  | <b>Unsuitability Conditions</b> |           |           |           |           | <b>.6</b> |
| <b>Study Plan</b>           |  | <b>#1</b>                       | <b>#2</b> | <b>#3</b> | <b>#4</b> | <b>#5</b> | <b>.5</b> |
|                             |  | .3                              |           |           | .5        |           | <b>.9</b> |
|                             |  |                                 | .8        | .4        |           |           | <b>.4</b> |
|                             |  |                                 |           |           | .6        |           | <b>.9</b> |
|                             |  | .2                              |           | .7        | .5        |           | <b>.4</b> |
|                             |  |                                 |           |           | .9        |           |           |
|                             |  |                                 | .5        |           | .4        |           |           |



| <b>Overall Evaluation</b> | <b>Criteria</b> |           |           |           |           |              |
|---------------------------|-----------------|-----------|-----------|-----------|-----------|--------------|
| <b>Study Plan</b>         | <b>#1</b>       | <b>#2</b> | <b>#3</b> | <b>#4</b> | <b>#5</b> | <b>Total</b> |
|                           | .3              | .2        | .5        | .2        | .7        | <b>.39</b>   |
|                           | .5              | .8        | .4        | .4        | .5        | <b>.53</b>   |
|                           | .3              | .1        | .7        | .3        | .6        | <b>.40</b>   |
|                           | .2              | .4        | .7        | .2        | .5        | <b>.40</b>   |
|                           | .4              | .2        | .8        | .4        | .9        | <b>.54</b>   |
|                           | .7              | .5        | .4        | .6        | .4        | <b>.53</b>   |
| <b>Weight</b>             | <b>.3</b>       | <b>.2</b> | <b>.2</b> | <b>.1</b> | <b>.2</b> |              |

# Here are the “top 20” studies based on Criteria #1, #2, and #3

| <b>Unsuitability</b>                       | <b>Regulatory Compliance</b>                | <b>Scientific Confidence</b>               |
|--------------------------------------------|---------------------------------------------|--------------------------------------------|
| Surface-based UZ percolation               | Surface-based UZ percolation                | Surface-based UZ percolation               |
| <i>ESF UZ percolation</i>                  | <i>ESF UZ percolation</i>                   | <i>ESF UZ percolation</i>                  |
| UZ Hydrochemistry                          | <b>WP Environment Hydrology</b>             | Site SZ Flow System                        |
| <b>WP Environment Hydrology</b>            | <b>Postemplacement Environment Changes</b>  | Site-specific subsurface info              |
| Gaseous Radionuclide Transport             | Site SZ Flow System                         | <b>EBS Field Tests</b>                     |
| UZ infiltration                            | <b>Man-made Materials</b>                   | Quaternary Regional Hydrology              |
| Site SZ Flow System                        | UZ Hydrochemistry                           | Site Area Faulting                         |
| <b>Postemplacement Environment Changes</b> | Site-specific subsurface info               | Faulting Near Facilities                   |
| Stratigraphic Units                        | <b>EBS Field Tests</b>                      | <b>Demonstrate Applicability</b>           |
| <b>Structural Features</b>                 | UZ infiltration                             | Natural Resources                          |
| SZ Hydrochemistry                          | UZ Fracture Flow                            | Volcanic Features                          |
| UZ Gaseous Movement                        | SZ Hydrochemistry                           | UZ infiltration                            |
| Modern Regional Climate                    | Dissolved Species                           | UZ Fracture Flow                           |
| <b>Mineralogy and Petrology</b>            | Quaternary Regional Hydrology               | Stratigraphic Units                        |
| Batch Sorption                             | Stratigraphic Units                         | <b>Structural Features</b>                 |
| Dissolved Species                          | <b>Structural Features</b>                  | Regional SZ Flow System                    |
| <b>Water Movement Test</b>                 | Regional SZ Flow System                     | Batch Sorption                             |
| Regional SZ Flow System                    | <b>WP Environment Mechanical Attributes</b> | <b>WP Environment Hydrology</b>            |
| Lake, Playa, and Marsh                     | <b>Water Movement Test</b>                  | <b>Postemplacement Environment Changes</b> |
| Terrestrial Paleoecology                   | Diffusion                                   | <b>Man-made Materials</b>                  |

**Italics= ESF test**

**Bold= ESF test and SBT**

**Our basic product is an “evaluation matrix,” which scores “tests” according to evaluation criteria**

**Evaluation Matrix**

| “Tests” (SCP study plans)                      | Evaluation Criteria                     |                                  |                                  |                        |                              | Overall Score |
|------------------------------------------------|-----------------------------------------|----------------------------------|----------------------------------|------------------------|------------------------------|---------------|
|                                                | Detect Unsuitable Conditions (Computed) | Regulatory Compliance (Computed) | Scientific Confidence (Computed) | Constituent Confidence | Cost & Schedule (\$ million) |               |
| Geohydrology/Hydrochemistry                    |                                         |                                  |                                  |                        |                              |               |
| 8.3.1.2.2.1 Unsaturated zone (UZ) Infiltration | .001                                    | .02                              | .40                              | 1                      | -4                           | <b>0.2</b>    |
| 8.3.1.2.2.2 Water movement test                | .000                                    | .01                              | .20                              | 1                      | -6                           | <b>0.1</b>    |
| 8.3.1.2.2.3 Surface-based UZ percolation       | .004                                    | .11                              | .35                              | 1                      | -45                          | <b>-0.1</b>   |
| 8.3.1.2.2.7 UZ hydrochemistry                  | .003                                    | .04                              | .20                              | 1                      | -7                           | <b>0.1</b>    |
| 8.3.1.2.2.8 UZ fracture flow                   | .000                                    | .02                              | .40                              | 1                      | -6                           | <b>0.2</b>    |
| <b>Weights for combining columns</b>           | <b>1.0</b>                              | <b>.2</b>                        | <b>.3</b>                        | <b>.2</b>              | <b>.01</b>                   | <b>1.7</b>    |

*The weights can be changed to reflect changing priorities*



# Integrated Test Evaluation Model

|                                                       |                                            | Trade-off weights→ |            |            |              |           |             |        |  |
|-------------------------------------------------------|--------------------------------------------|--------------------|------------|------------|--------------|-----------|-------------|--------|--|
| <b>Integrated Test<br/>Evaluation Model</b><br>9/5/92 |                                            | 5                  | 7          | 2          | -.001        | .14       |             |        |  |
|                                                       |                                            | Utility #1         | Utility #2 | Utility #3 | Utility #5   | Overall   | Cumu-       | Cumu-  |  |
|                                                       |                                            | Detect             | Regulatory | Scientific | Cost         | Utility   | lative      | lative |  |
|                                                       |                                            | Unsuitability      | Compliance | Confidence |              |           | 1993        | total  |  |
|                                                       |                                            | Conditions         |            |            |              |           | cost        | cost   |  |
| SCP #                                                 | Study                                      | (max 1.0)          | (max 1.0)  | (max 1.0)  | (\$ million) | (max 100) | (\$million) |        |  |
|                                                       | <i>Program overhead cost</i>               |                    |            |            |              |           | 26          | 207    |  |
| 8.3.1.2.2.4                                           | <i>ESF UZ percolation</i>                  | .004               | .13        | .65        | 32           | 16        | 27          | 239    |  |
| 8.3.1.2.2.3                                           | <b>Surface-based UZ percolation</b>        | .004               | .13        | .65        | 41           | 16        | 29          | 280    |  |
| 8.3.1.2.3.1                                           | Site SZ Flow System                        | .000               | .06        | .65        | 11           | 12        | 31          | 291    |  |
| 8.3.1.4.3.1                                           | Site-specific subsurface info              | .000               | .04        | .65        | 5            | 11        | 32          | 296    |  |
| 8.3.4.2.4.4                                           | <b>EBS Field Tests</b>                     | .000               | .03        | .65        | 22           | 11        | 32          | 318    |  |
| 8.3.1.5.2.1                                           | Quaternary Regional Hydrology              | .000               | .02        | .65        | 13           | 10        | 33          | 332    |  |
| 8.3.1.17.4.6                                          | Site Area Faulting                         | .000               | .01        | .65        | 2            | 10        | 33          | 334    |  |
| 8.3.1.17.4.2                                          | Faulting Near Facilities                   | .000               | .01        | .65        | 0            | 10        | 34          | 334    |  |
| 8.3.1.9.2.1                                           | Natural Resources                          | .000               | .00        | .65        | 3            | 9         | 34          | 337    |  |
| 8.3.1.8.5.1                                           | Volcanic Features                          | .000               | .00        | .65        | 4            | 9         | 35          | 341    |  |
| 8.3.1.3.7.2                                           | <b>Demonstrate Applicability</b>           | .000               | .00        | .65        | 35           | 9         | 36          | 376    |  |
| 8.3.4.2.4.2                                           | <b>WP Environment Hydrology</b>            | .003               | .11        | .27        | 13           | 9         | 37          | 389    |  |
| 8.3.1.2.2.1                                           | UZ infiltration                            | .001               | .03        | .46        | 4            | 8         | 38          | 393    |  |
| 8.3.1.2.2.8                                           | UZ Fracture Flow                           | .000               | .03        | .46        | 7            | 8         | 39          | 400    |  |
| 8.3.4.2.4.1                                           | <b>Postemplacement Env. Changes</b>        | .000               | .07        | .27        | 10           | 7         | 40          | 410    |  |
| 8.3.1.2.1.3                                           | Regional SZ Flow System                    | .000               | .02        | .46        | 2            | 7         | 40          | 412    |  |
| 8.3.1.4.2.2                                           | <b>Structural Features</b>                 | .000               | .02        | .46        | 18           | 7         | 42          | 430    |  |
| 8.3.1.4.2.1                                           | Stratigraphic Units                        | .000               | .02        | .46        | 13           | 7         | 44          | 443    |  |
| 8.3.1.3.4.1 & .3                                      | Batch Sorption                             | .000               | .01        | .46        | 8            | 7         | 45          | 451    |  |
| 8.3.4.2.4.x                                           | <b>Man-made Materials</b>                  | .000               | .05        | .27        | 11           | 7         | 45          | 462    |  |
| 8.3.1.2.2.7                                           | UZ Hydrochemistry                          | .003               | .04        | .27        | 7            | 6         | 46          | 469    |  |
| 8.3.1.2.3.2                                           | SZ Hydrochemistry                          | .000               | .02        | .27        | 2            | 5         | 46          | 470    |  |
| 8.3.4.2.4.3                                           | <b>WP Environ. Mech. Attributes</b>        | .000               | .02        | .27        | 3            | 5         | 46          | 474    |  |
| 8.3.1.3.5.1 & .2                                      | Dissolved Species                          | .000               | .02        | .27        | 11           | 5         | 47          | 485    |  |
| 8.3.1.2.2.2                                           | <b>Water Movement Test</b>                 | .000               | .02        | .27        | 5            | 5         | 48          | 490    |  |
| 8.3.1.3.6.2                                           | Diffusion                                  | .000               | .01        | .27        | 2            | 5         | 48          | 492    |  |
| 8.3.1.3.8.1                                           | Gaseous Radionuclide Transport             | .003               | .01        | .27        | 0            | 4         | 48          | 492    |  |
| 8.3.1.8.5.2                                           | Igneous intrusive Features                 | .000               | .01        | .27        | 1            | 4         | 48          | 493    |  |
| 8.3.1.3.2.1                                           | <b>Mineralogy and Petrology</b>            | .000               | .01        | .27        | 10           | 4         | 49          | 503    |  |
| 8.3.1.3.6.1                                           | Dynamic Transport                          | .000               | .01        | .27        | 8            | 4         | 49          | 511    |  |
| 8.3.1.17.4.4                                          | NE trending faulting                       | .000               | .00        | .27        | 1            | 4         | 50          | 512    |  |
| 8.3.1.2.2.5                                           | <i>Diffusion Tests</i>                     | .000               | .00        | .27        | 4            | 4         | 50          | 516    |  |
| 8.3.1.15.1.8                                          | <i>In Situ Verification</i>                | .000               | .00        | .27        | 3            | 4         | 50          | 519    |  |
| 8.3.1.17.4.3                                          | Faulting within 100 km                     | .000               | .00        | .27        | 3            | 4         | 50          | 522    |  |
| 8.3.1.15.1.5                                          | <i>Excavation Investigations</i>           | .000               | .00        | .27        | 14           | 4         | 50          | 536    |  |
| 8.3.1.15.1.7                                          | <i>In Situ Mechanical</i>                  | .000               | .00        | .27        | 16           | 4         | 50          | 552    |  |
| 8.3.1.15.1.6                                          | <i>In Situ Thermomechanical</i>            | .000               | .00        | .27        | 36           | 4         | 50          | 588    |  |
| 8.3.1.3.2.2                                           | <b>Mineral Alteration</b>                  | .000               | .01        | .17        | 3            | 3         | 51          | 591    |  |
| 8.3.1.3.4.2                                           | <b>Biological Sorption</b>                 | .000               | .00        | .17        | 4            | 3         | 51          | 595    |  |
| 8.3.1.2.2.6                                           | UZ Gaseous Movement                        | .000               | .00        | .07        | 1            | 1         | 51          | 595    |  |
| 8.3.1.5.1.1                                           | Modern Regional Climate                    | .000               | .00        | .07        | 0            | 1         | 52          | 596    |  |
| 8.3.1.5.1.2                                           | Lake, Playa, and Marsh                     | .000               | .00        | .07        | 4            | 1         | 52          | 600    |  |
| 8.3.1.3.3.2                                           | Mineral Evolution Kinetics                 | .000               | .00        | .07        | 2            | 1         | 52          | 602    |  |
| 8.3.1.5.1.4                                           | Paleoenvironmental History                 | .000               | .00        | .07        | 0            | 1         | 52          | 602    |  |
| 8.3.1.2.1.1                                           | Meteorology for Regional Hydrology         | .000               | .00        | .07        | 1            | 1         | 52          | 604    |  |
| 8.3.1.5.1.3                                           | Terrestrial Paleocology                    | .000               | .00        | .07        | 2            | 1         | 52          | 605    |  |
| 8.3.1.17.4.8                                          | Stress Field                               | .000               | .00        | .07        | 1            | 1         | 52          | 606    |  |
| 8.3.1.15.2.1                                          | <i>Ambient Stress</i>                      | .000               | .00        | .07        | 0            | 1         | 52          | 607    |  |
| 8.3.1.15.1.3                                          | <b>Rock Mechanical Properties</b>          | .000               | .00        | .07        | 6            | 1         | 53          | 613    |  |
| 8.3.1.17.4.5                                          | Detachment Faults                          | .000               | .00        | .07        | 1            | 1         | 53          | 614    |  |
| 8.3.1.15.1.2                                          | <b>Lab Thermal Expansion</b>               | .000               | .00        | .07        | 2            | 1         | 53          | 616    |  |
| 8.3.1.15.1.1                                          | <b>Lab Thermal Properties</b>              | .000               | .00        | .07        | 5            | 1         | 53          | 620    |  |
| 8.3.1.15.1.4                                          | <b>Fracture Mechanical Properties</b>      | .000               | .00        | .07        | 7            | 1         | 54          | 627    |  |
| 8.3.3.2.2.1                                           | <b>Seal Material Development</b>           | .000               | .00        | .07        | 58           | 1         | 55          | 685    |  |
| 8.3.1.9.1.1                                           | Surface Markers                            | .000               | .00        | .00        | 0            | 0         | 55          | 685    |  |
| 8.3.1.14.2                                            | Soil and Rock Properties (All Surf. Char.) | .000               | .00        | .00        | 1            | 0         | 55          | 686    |  |

- ESF = Italic Type*  
 **SBT & ESF = Bold Type**

## **This effort produced a decision framework for integrated test evaluation**

- **Evaluates the benefits of site-characterization studies based on their ability to**
  - **Detect unsuitability conditions**
  - **Demonstrate regulatory compliance**
  - **Build scientific confidence**
  - **Minimize cost**
- **Includes an evaluation model that can be used to**
  - **Record assessments of the effectiveness of studies**
  - **Evaluate studies**
  - **Test the sensitivity of results to input assumption**
  - **Determine how many studies can be conducted for a given budget**
- **Is designed to facilitate reassessment of studies, based on**
  - **Changing priorities**
  - **New information as site characterization progresses**
  - **Revised study plans**