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

NUCLEAR WASTE TECHNICAL REVIEW BOARD
HYDROLOGY AND GEOCHEMISTRY PANEL MEETING

SUBJECT: CALCULATIONAL APPROACH TO PRE-WASTE-EMPLACEMENT GROUND-WATER TRAVEL TIME

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LAS VEGAS, NEVADA
SEPTEMBER 12-13, 1994

OUTLINE

- What causes the travel-time distribution?
- Domains considered in the analyses
- Approach to definition of the disturbed zone
- Approach to unsaturated zone travel time
- Approach to saturated zone travel time
- Total ground-water travel-time distributions
- Determination of significance of travel times less than 1,000 years
- Is travel-time the only product?
- Schedule

WHAT CAUSES THE TRAVEL-TIME DISTRIBUTION ?

Variability of Material and Flow Properties

- Heterogeneity along the flow path
- Variability of percolation flux
- Dispersion and matrix diffusion along the flow path

Areal Extent of

- Disturbed zone
- Particle entry points on the water table
- Accessible environment

Uncertainty

- Uncertainty in boundary conditions, conceptual flow models, and parameters

DOMAINS CONSIDERED IN THE ANALYSES

- Disturbed zone
  - Volume in which post-closure repository-induced changes have a significant effect on performance
- Unsaturated zone
  - Between the disturbed zone and the water table
- Saturated zone
  - Between the area of the water table below the repository and the accessible environment

APPROACH TO DEFINITION OF THE DISTURBED ZONE

- Define potential for repository-induced changes
- Evaluate repository-induced changes
- Evaluate effects of repository-induced changes on transport parameters
- Evaluate consequences of altered transport parameters on performance
- Develop criteria to determine significance of consequences
- Determine extent of the disturbed zone

DEFINITION OF POTENTIAL FOR REPOSITORY-INDUCED CHANGES

- Only consider changes that may have an effect on post-closure repository performance (i.e., radionuclide transport)
  - Hydraulic conductivity
  - Retardation
  - Percolation flux
- Processes affecting transport parameters
  - Mechanical/thermomechanical
  - Hydrothermal
  - Thermochemical
    - Mineralogical
    - Dissolution/precipitation
    - pH/Eh

EVALUATION OF REPOSITORY-INDUCED CHANGES

- Conduct mechanical, thermomechanical, and hydrothermal analyses to determine physical changes caused by construction and heat and the volumes in which they occur
  - Temperature
  - Stress/strain
  - Moisture content
  - Percolation flux
- Conduct analyses to determine the geochemical changes caused by construction and heating and the volumes in which they occur
  - Mineralogical
  - Dissolution/precipitation
  - pH/Eh

EVALUATION OF EFFECTS OF REPOSITORY-INDUCED CHANGES ON TRANSPORT PARAMETERS

Determine zones of altered hydraulic conductivity, percolation flux, and retardation

- Effects of mechanical and thermomechanical changes on
  - Fracture aperture and matrix porosity
- Effects of temperature on
  - Moisture content and percolation flux
- Effects of geochemical changes on
  - Fracture aperture, matrix porosity, and radionuclide retardation

EVALUATION OF CONSEQUENCES OF ALTERED TRANSPORT PARAMETERS ON PERFORMANCE

Conduct performance assessment using altered transport parameters and their associated "incremental" volumes to

- Determine the "incremental" change in
  - Cumulative release to the accessible environment
  - Dose to an individual at the accessible environment
- Conduct sensitivity analyses of performance
  - Evaluate the effects of uncertainty on the range of performance

DEVELOPMENT OF CRITERIA TO DETERMINE SIGNIFICANCE OF CONSEQUENCES

Develop criteria using expert judgment

- Criteria apply to both the disturbed zone and travel times less than 1,000 years
- Criteria should be broadly accepted by the technical community
- Example criteria
  - An increase of some percentage in
    - Mean integrated release
    - Mean dose to an individual
  - Some percentage of the standard deviation of
    - Mean integrated release
    - Mean dose to an individual

DETERMINATION OF EXTENT OF THE DISTURBED ZONE

- Apply significance criteria to determine whether consequences are significant
- Determine the range of the extent of the disturbed zone based on the range of consequences and significance criteria

APPROACH TO UNSATURATED ZONE TRAVEL TIME

- Evaluate flow paths using deterministic models
- Select flow paths for stochastic analyses
  - One-dimensional columns
  - Two-dimensional cross sections
- Develop travel-time distributions using stochastic models
  - Conduct sensitivity analyses on columns and cross sections
- Schematic example

EVALUATION OF FLOW PATHS USING DETERMINISTIC MODELS

- Initiate flow paths from discrete locations corresponding to the repository
- Evaluate travel times along flow paths
- Conduct sensitivity analyses of travel time and flow paths
  - Properties of faults
  - Spatial variability in percolation flux
  - Conceptual flow models
  - Spatial heterogeneity in material properties
  - Spatial averaging of flow parameters

SELECTION OF FLOW PATHS FOR STOCHASTIC ANALYSES

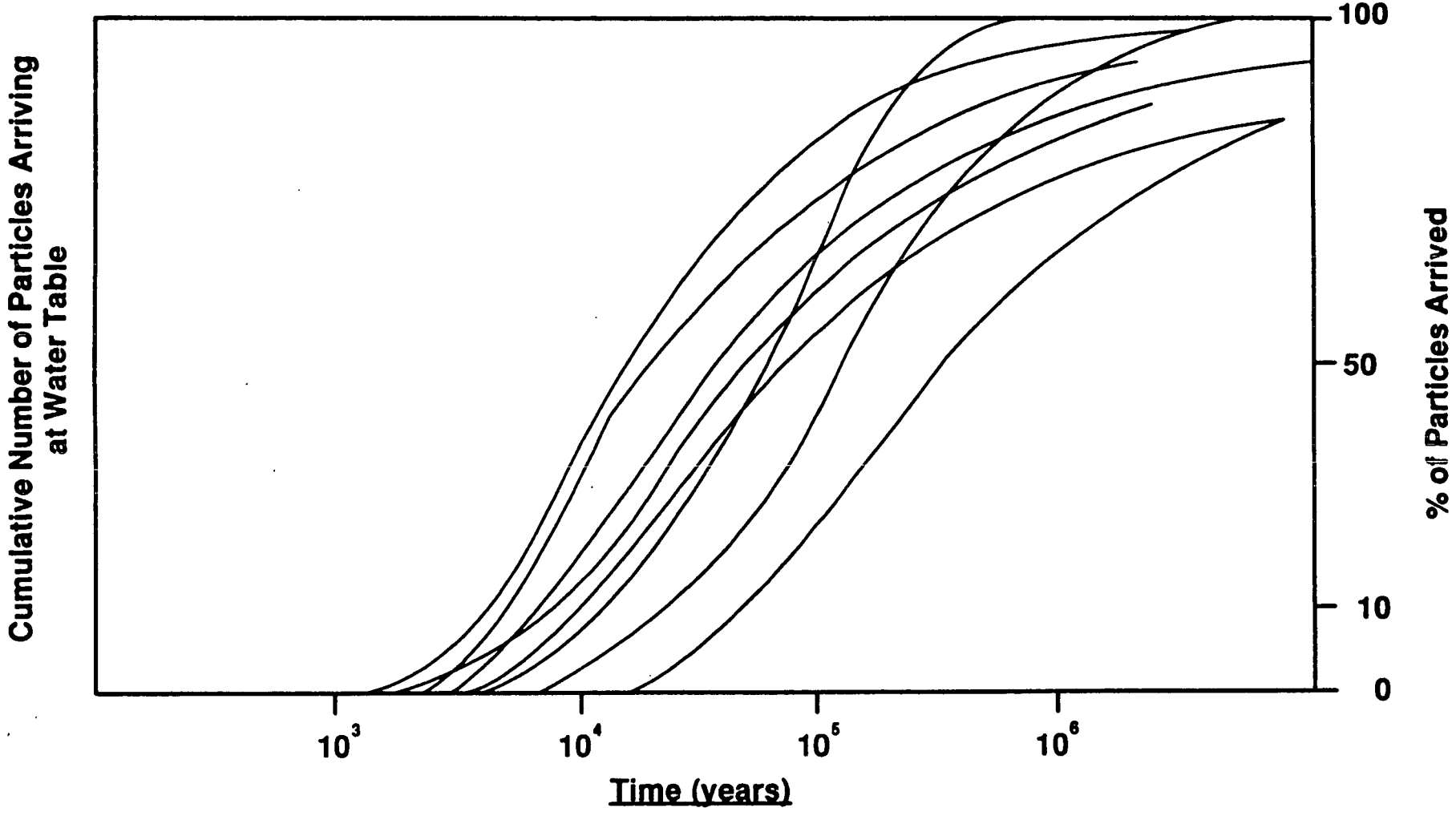
- Use results of sensitivity analyses to select representative columns and cross sections between the repository and the water table
- Each column and cross section based on its location has representative
  - Stratigraphy
  - Percolation flux
  - Property distributions

DEVELOPMENT OF DISTRIBUTIONS USING STOCHASTIC MODELS

- Conduct multiple realizations of travel time at each selected location (column or cross section) for each parameter set to produce the travel-time distributions
- Evaluate the sensitivity to
  - Conceptual flow model
    - Equivalent permeability, dual porosity, dual permeability, and discrete fracture
  - Flow and transport properties
  - Percolation flux
  - Stratigraphy
  - Correlation among parameters

SCHEMATIC EXAMPLE

Particle breakthrough curves at the water table



APPROACH TO SATURATED ZONE TRAVEL TIME

- Evaluate site-scale boundary conditions using regional deterministic model
- Analyze flow paths using deterministic site-scale models
- Evaluate travel times along flow paths using stochastic models

EVALUATION OF SITE-SCALE BOUNDARY CONDITIONS USING REGIONAL DETERMINISTIC MODEL

- Conduct analyses using the regional-scale model to test different hydrogeologic conceptual models (i.e., cause of steep hydraulic gradient)
  - Analyze the effects of various conceptual models and fault properties on site-scale boundary conditions
  - Develop site-scale boundary conditions for each conceptual model

ANALYSIS OF FLOW PATHS USING DETERMINISTIC SITE-SCALE MODELS

- Evaluate the effects of parameter distributions and uncertainties on flow path direction and travel time
  - Location and type of boundary conditions
  - Geometry and properties of faults
  - Flow conceptual model
    - Fractured continuum
    - Equivalent continuum
  - Transport parameters
    - Dispersion
    - Matrix Diffusion
- Select representative flow paths for stochastic analysis

EVALUATION OF TRAVEL TIMES ALONG FLOW PATHS USING STOCHASTIC MODELS

- Conduct multiple realizations of travel-time from points on the water table below the repository to the accessible environment
- Conduct sensitivity analyses using two-dimensional stochastic models to investigate uncertainties in
  - Conceptual flow models
  - Flow and transport properties
  - Correlation among parameters
  - Boundary conditions
- Conduct sensitivity analyses using one-dimensional stochastic models along selected flow paths

TOTAL GROUND-WATER TRAVEL-TIME DISTRIBUTIONS

- Convolve travel-time distributions for the unsaturated and saturated zones considering
  - Conceptual models
  - Parameter variability/uncertainty
  - Correlation among parameters
  - Location
    - Location of UZ distribution must be consistent with particle initiation points for the SZ
- Analyze the effects of different convolution schemes on short travel times

DETERMINATION OF SIGNIFICANCE OF TRAVEL TIMES LESS THAN 1,000 YEARS

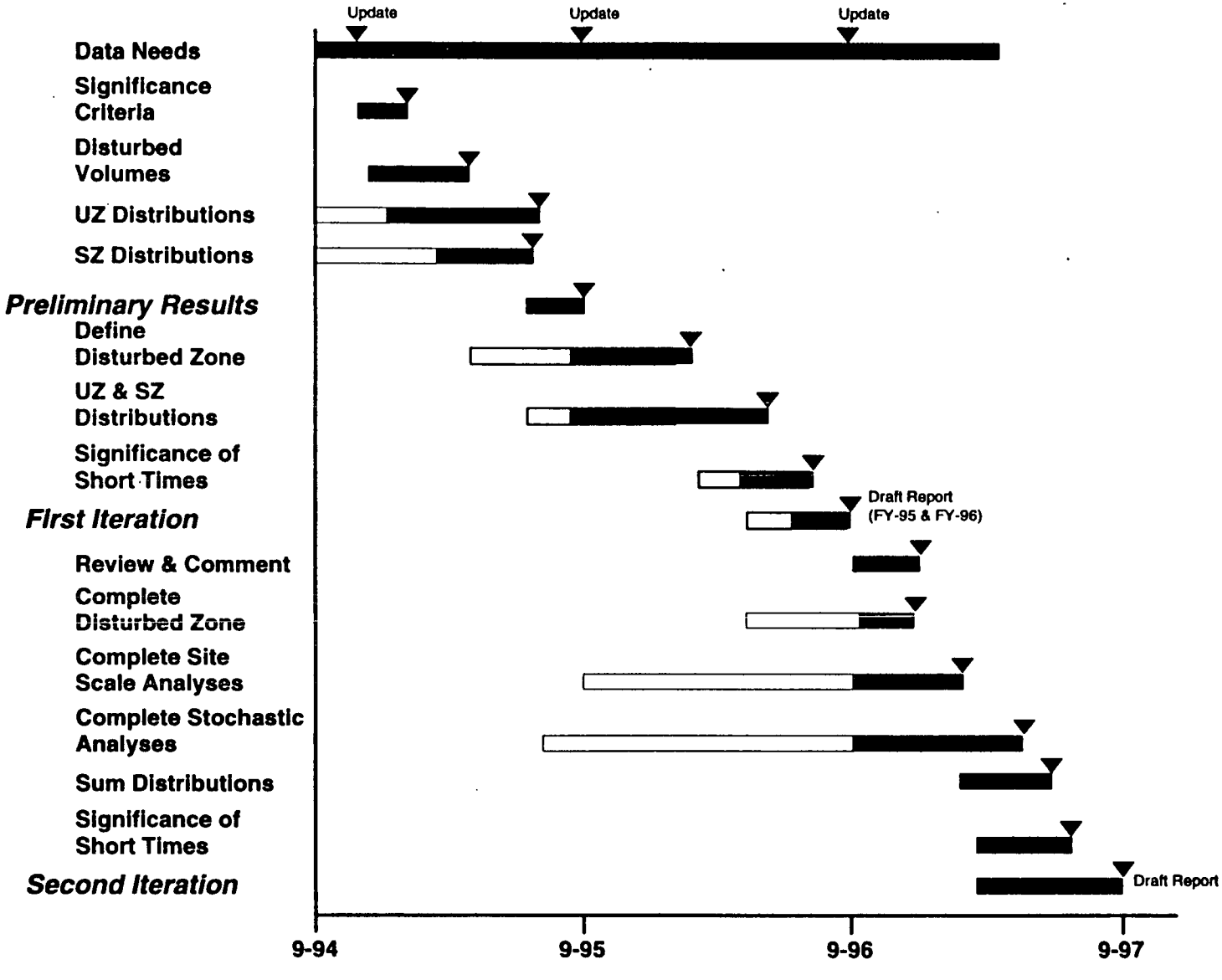
- Conduct performance assessment to determine the effects of ground-water travel time pathways that are less than 1,000 years
  - Integrated release to accessible environment
  - Dose to an individual
- Analyze the effects of uncertainty
  - Travel time pathways that are less than 1,000 years
- Compare results with significance criteria

IS TRAVEL-TIME THE ONLY PRODUCT?

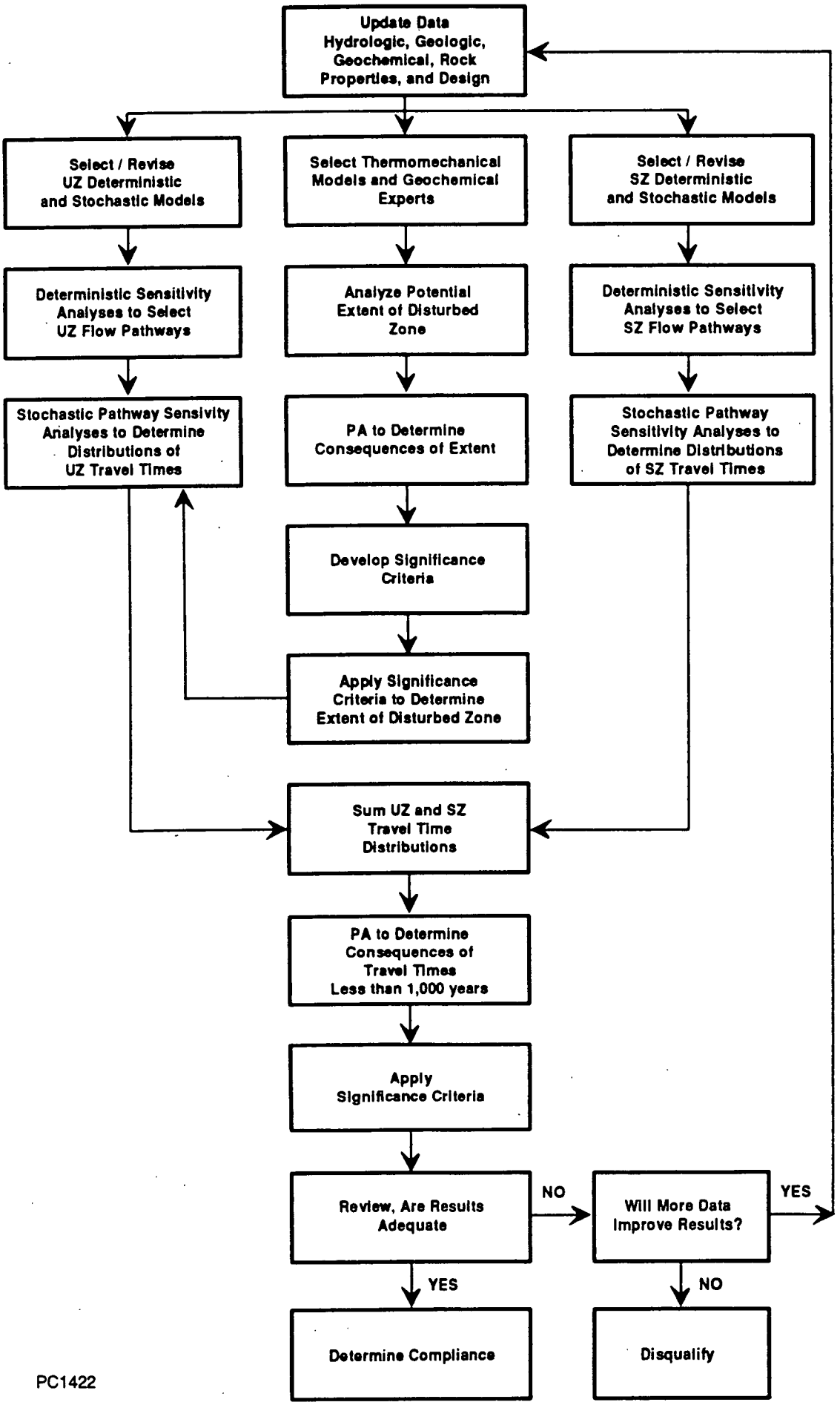
Primary Products of the Analyses

- Uncertainty analysis of aqueous flow at Yucca Mountain
  - Ground-water travel time
- Sensitivity analyses of aqueous flow at Yucca Mountain
  - Site characterization
- Analyses of ground-water flow (uncertainty) applicable to post-closure performance for
  - Low thermal loads
  - Long times

PROPOSED SCHEDULE



Calculation of Ground-Water Travel Time



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