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

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: DECISION ANALYSIS FRAMEWORK FOR SURFACE-BASED TEST (SBT) PRIORITIZATION

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We will discuss our approach to developing and implementing an SBT-prioritization framework

Agenda

Overview of the methodology

**Approach to implementation—
model development and data assessment**

Illustrative assessments and analysis

We are identifying major surface-based tests that should be started early during site characterization

Illustrative Study Results

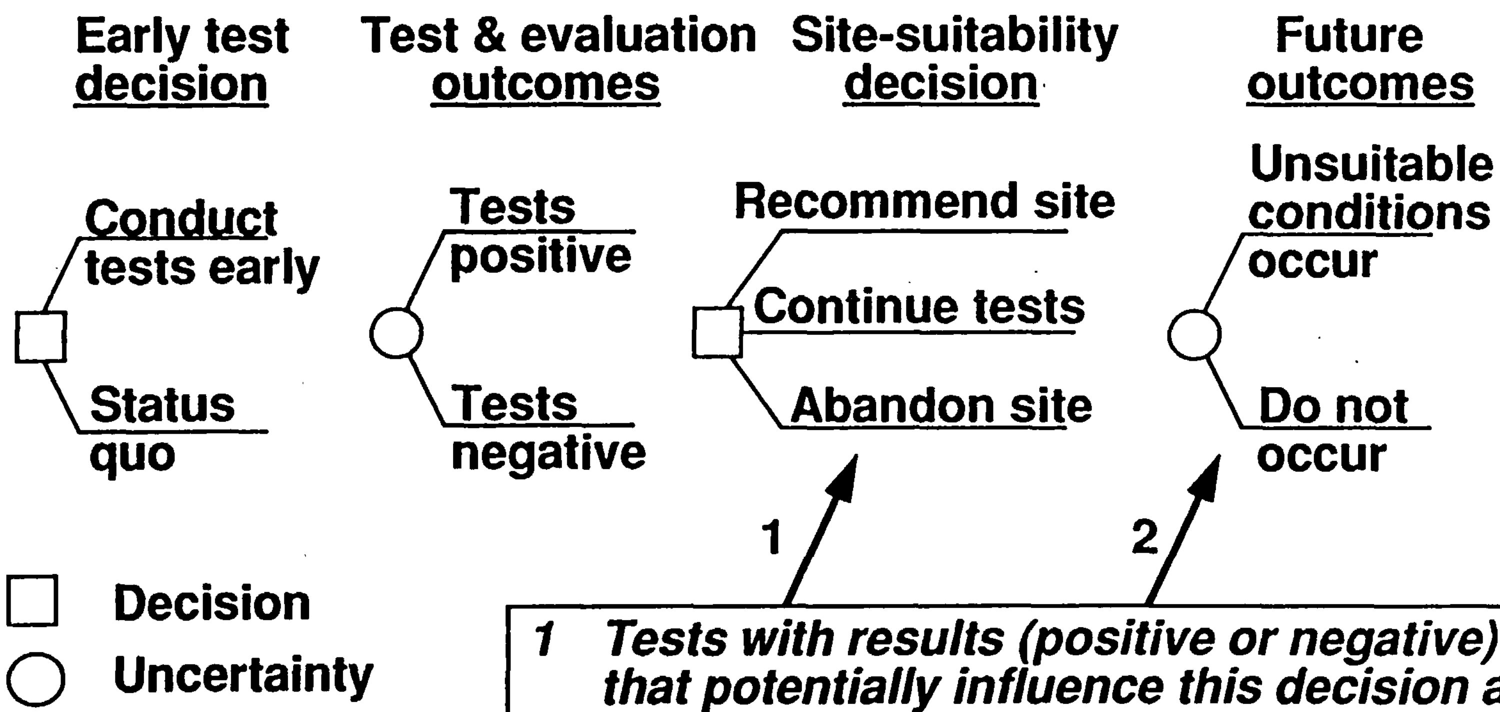
Priority	"Test"	Reason
1	Ground-water flow time in saturated zone	Parti[illegible]esolves uncertainty [illegible]l time
1	Ground-water chemistry near repository	[illegible]y resolves uncertainty [illegible]out source term
2	Carbon-14 retarda[illegible]	May resolve uncertainty
2	Matrix vs. frac[illegible]UZ	May resolve uncertainty
3	Historical clima[illegible]hange	Unlikely to resolve uncert.
3	...	...
3	...	...

Hypothetical results
(not based on analysis)

We use the term "test" to refer to any group of SCP tests that provides information about an uncertain factor

Our analysis identifies tests that significantly influence DOE decisions about site suitability

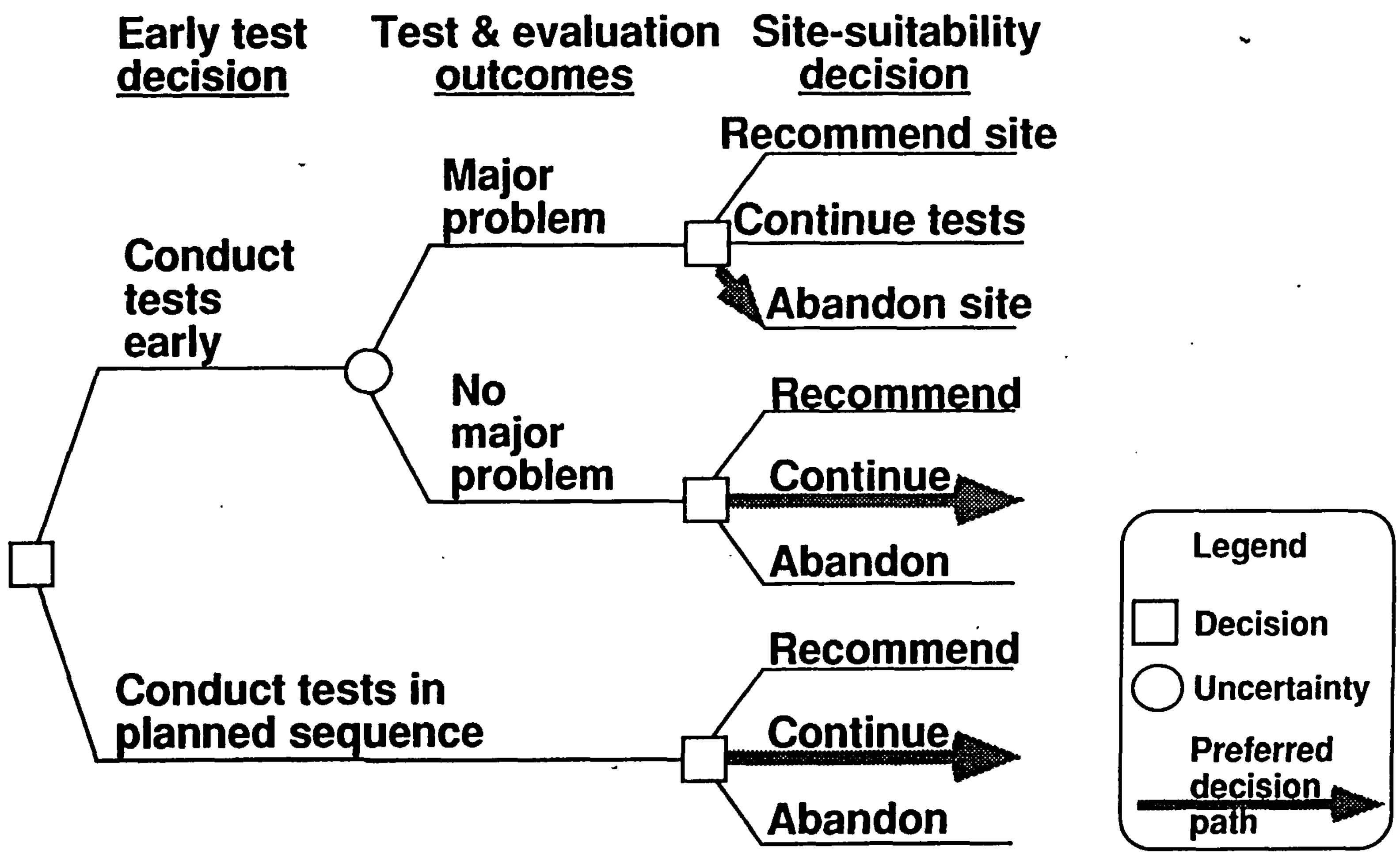
Simplified decision chronology



1 Tests with results (positive or negative) that potentially influence this decision are given early priority

2 Such tests reduce uncertainty about whether unsuitable conditions exist now will occur in the future

A simple decision tree shows how a test outcome might affect a decision about site suitability



Tests with outcomes that could change the preferred decision are said to have positive "value-of-information"

Our analytic framework is designed to answer: "Which tests can be early indicators of an unsuitable site?"

To answer the question, one must answer two essential questions:

- **Do existing data indicate the site is suitable or unsuitable?**
- **How likely are test results to change that conclusion?**

If test outcomes are unlikely to change the suitability decision, then there may be little technical value for further testing

Note: there may be *other reasons* for testing besides gathering information that could affect suitability decisions

Possible *other reasons* for testing

1 Facilitating other tests (e.g., drilling boreholes)
2 Initiating long-duration performance-confirmation tests
3 Gathering information for design or construction
4 Providing additional information required for licensing
5 Building scientific consensus and public confidence
6 ...

Priorities may need to be revised based on these considerations

We break down the two major questions and then develop models and data to provide the answers

- **Do existing data indicate the site is suitable or unsuitable?**
  - *What is the projected performance of the system?*
  - *How uncertain are we about performance?*
  - *Does the system meet performance criteria?*
  - *Is the site suitable or not?*

- **How likely are test results to change that conclusion?**
  - *What are the major* uncertain parameters at the site?*
    **(significant effect on performance and highly uncertain)*
  - *What tests can be done to resolve those uncertainties?*
  - *How accurate are those tests?*
  - *What specific test outcomes can change the decision?*
  - *How likely are those outcomes?*

A useful indicator of an unsuitable site is unacceptable postclosure performance of the total system

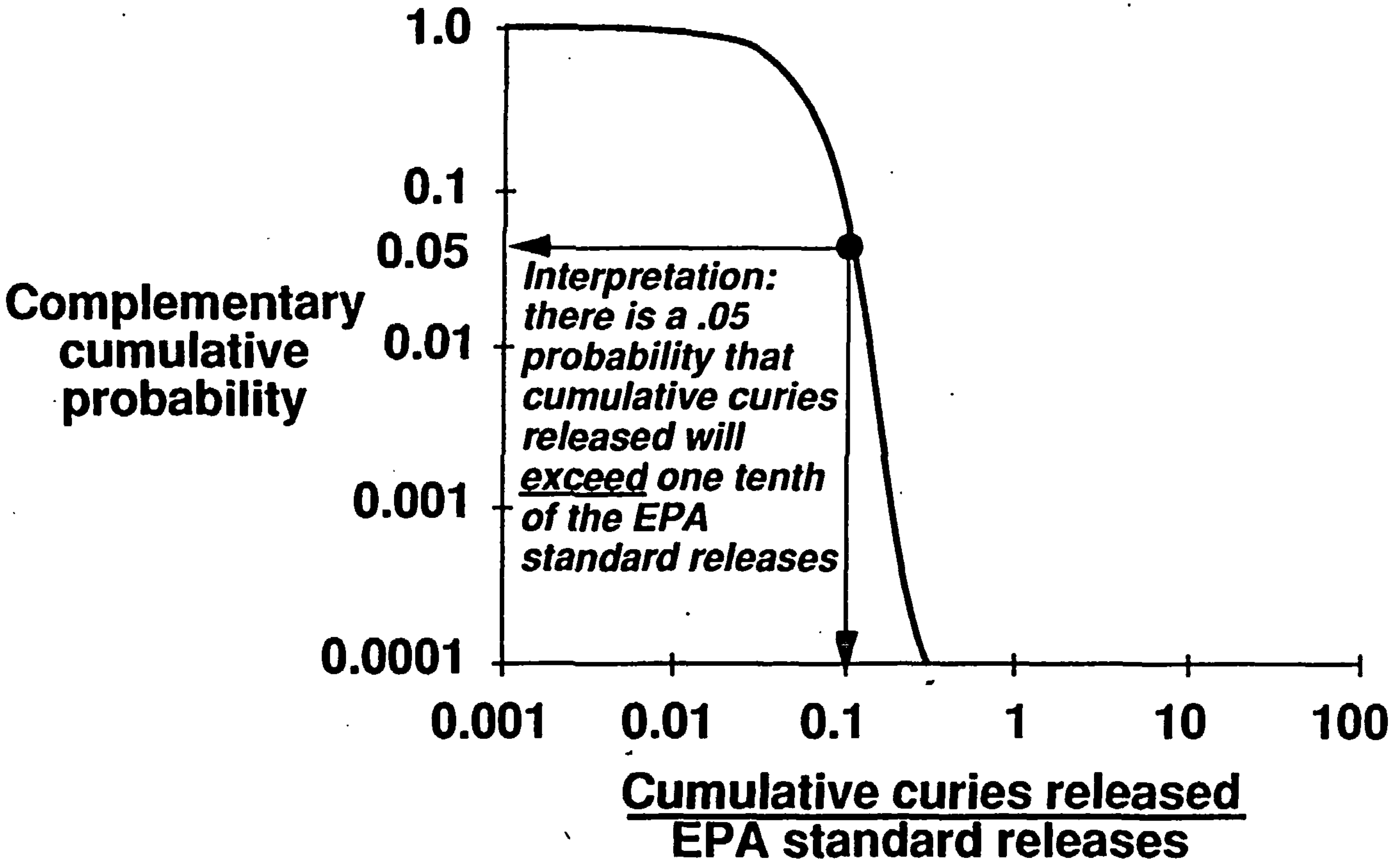
- **Do existing data indicate the site is suitable or unsuitable?**
  - *What is the projected performance of the system?*
  - *How uncertain are we about performance?*
  - *Does the system meet performance criteria?*
  - *Is the site suitable or not?*

- ***In this first analysis, we use cumulative curies released over 10,000 years as a proxy for all applicable performance measures***

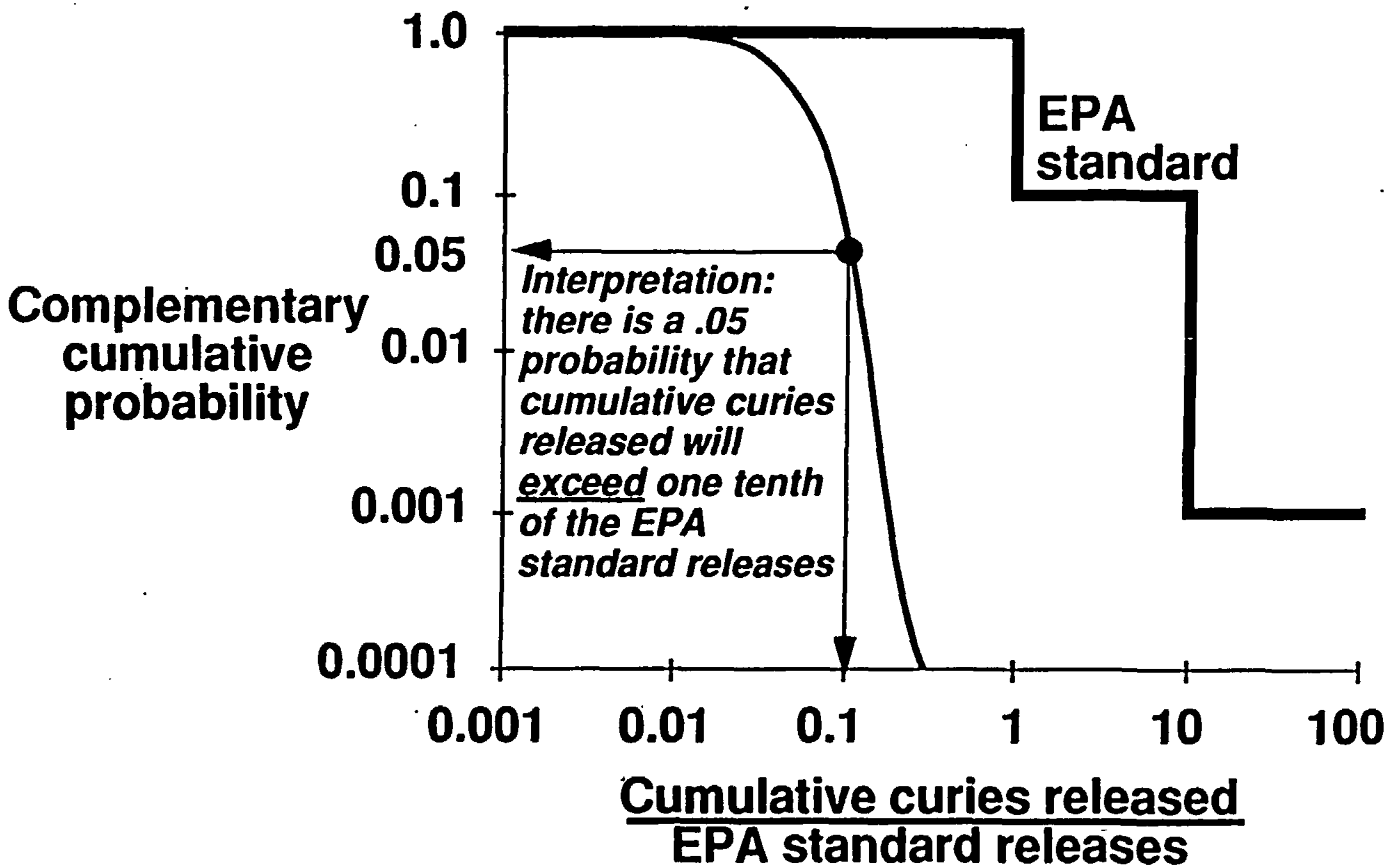
- ***Priorities may be revised to account for some tests not related strictly to total system postclosure performance***

Uncertainty in postclosure performance is represented using a complementary cumulative probability distribution

Illustrative postclosure performance curve



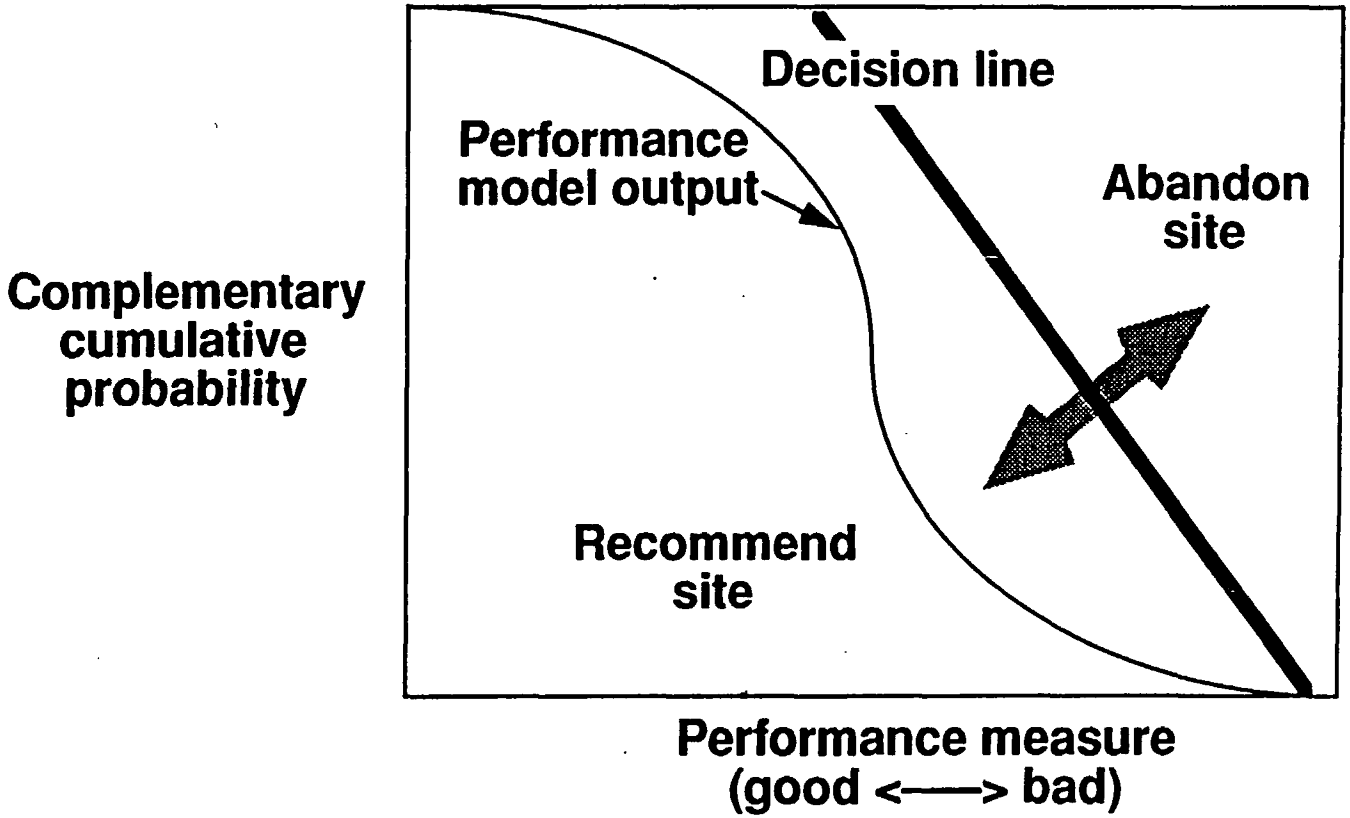
The "EPA standard" is one possible criterion for judging postclosure performance



This is the criterion we use in our analysis

Conceptually, one can construct a “decision line” to indicate where suitability decisions change

Illustrative suitability decision line



Next we consider the effects of testing on performance estimates and on suitability decisions

- **Do existing data indicate the site is suitable or unsuitable?**
  - *What is the projected performance of the system?*
  - *How uncertain are we about performance?*
  - *Does the system meet performance criteria?*
  - *Is the site suitable or not?*

➡ - **How likely are test results to change that conclusion?**
  - *What are the major* uncertain parameters at the site?*
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  - *What tests can be done to resolve those uncertainties?*
  - *How accurate are those tests?*
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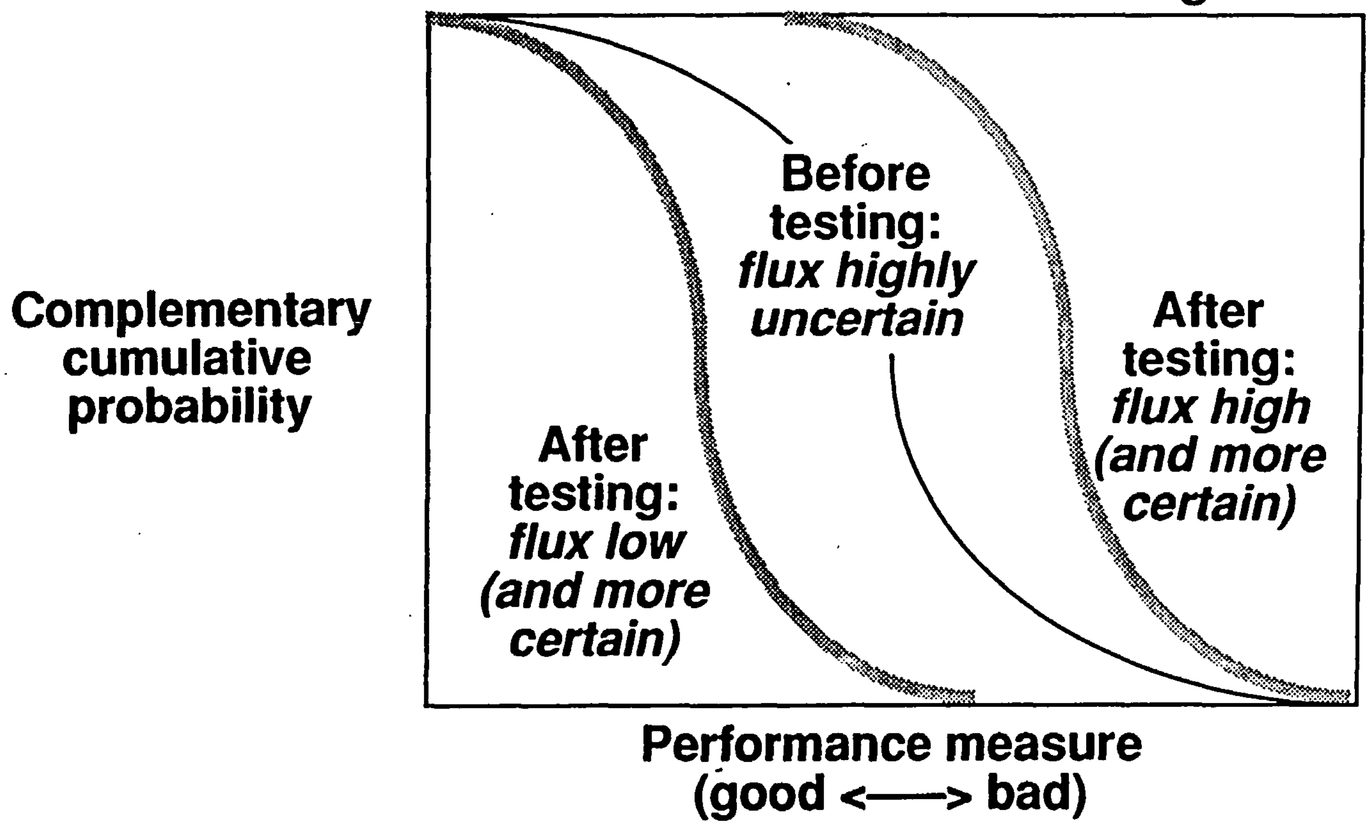
  - *How likely are those outcomes?*

We evaluate the potential effects of testing outcomes on estimates of "total system" performance

Illustrative effects of testing

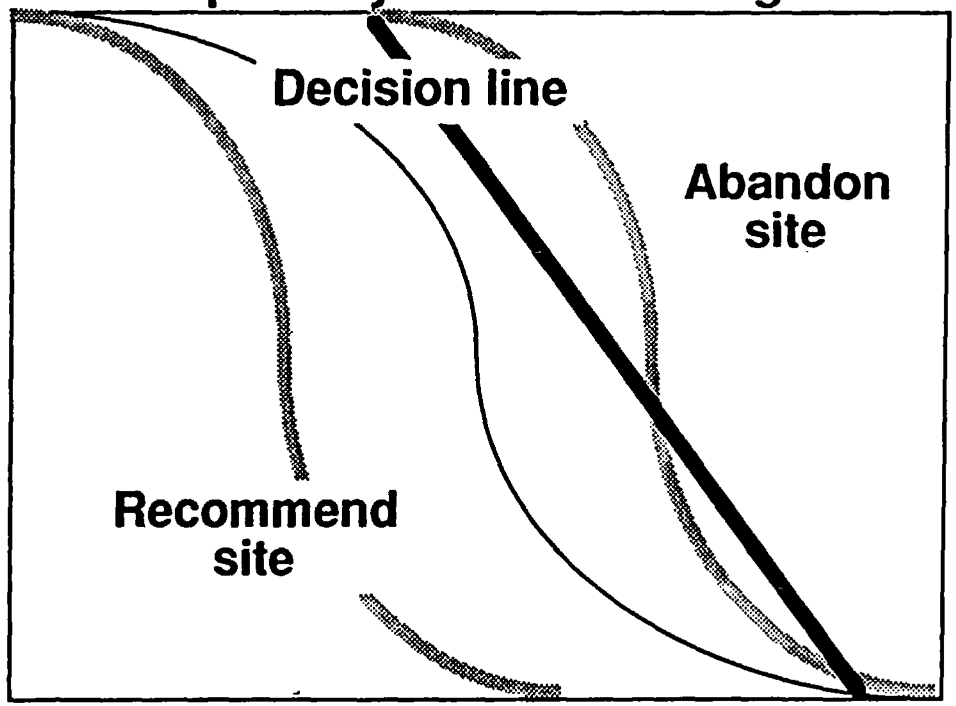


Here, performance is more certain after testing but is either better or worse than before testing

We then consider the effects of testing on repository decision making

Illustrative effect of testing on repository decision making

Complementary cumulative probability

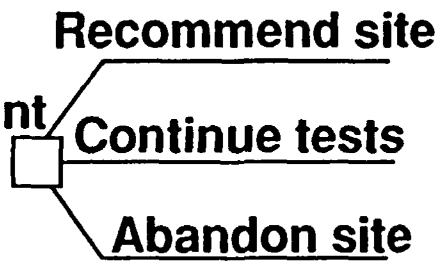


Performance measure (good <——> bad)

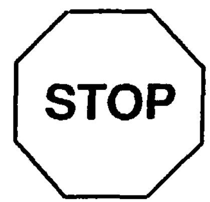
Testing costs and schedules are considered after analyzing decision impacts

Our results will show testing is valuable when it has the potential to affect a repository decision

- We will recommend
  - Conducting tests early if they have a significant chance of affecting site-suitability decisions



  - Stopping testing when the cost of testing exceeds its value



- Our initial application of the methodology focuses only on the value of information provided by the test, relative to postclosure performance

  There may be other benefits not reflected in this approach

- By focusing on the value of information and its effect on decisions, we avoid the often-futile quest for certainty

Next we will discuss our approach to implementing the methodology using models and assessed data

Agenda

Overview of the methodology

**Approach to implementation—
model development and data assessment**

Illustrative assessments and analysis

We are developing and implementing the methodology in five project tasks

Project Tasks

1) Methodology development
   (70% complete)

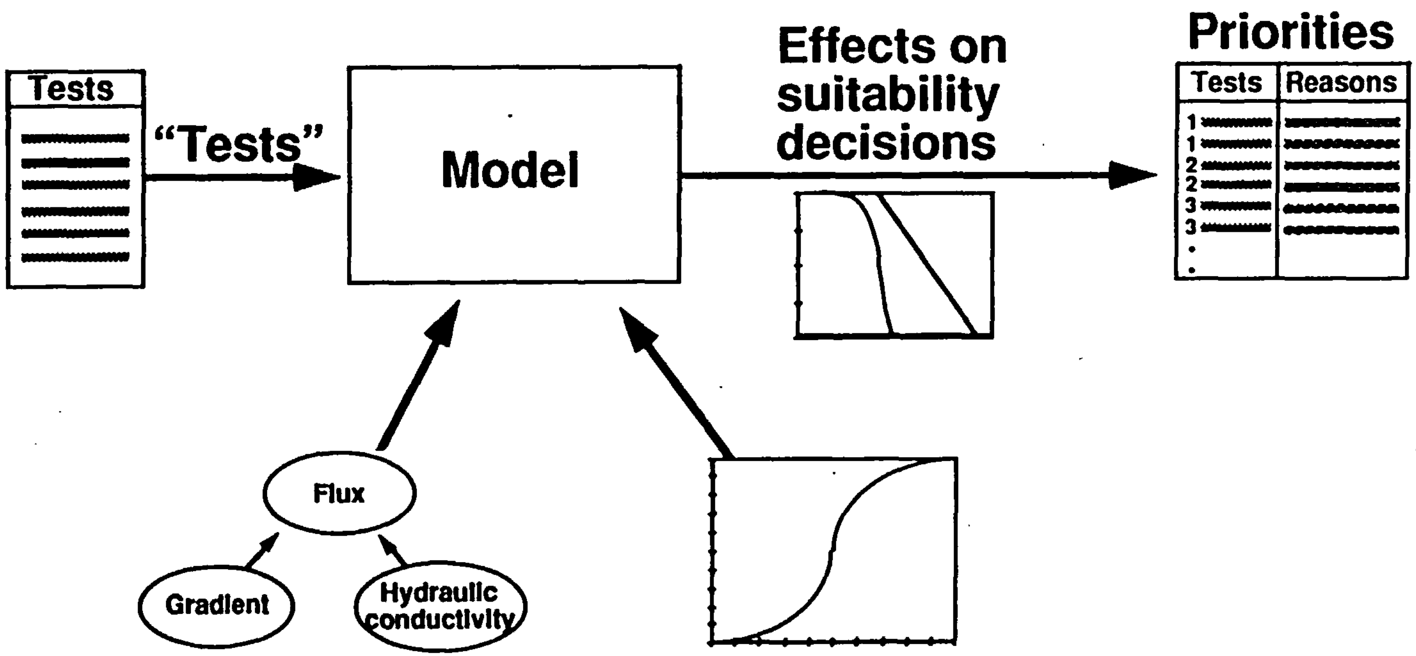
2) Model development *(50%)*

3) Numerical assessment *(50%)*

4) Analysis and review *(5%)*

5) Report preparation *(10%)*

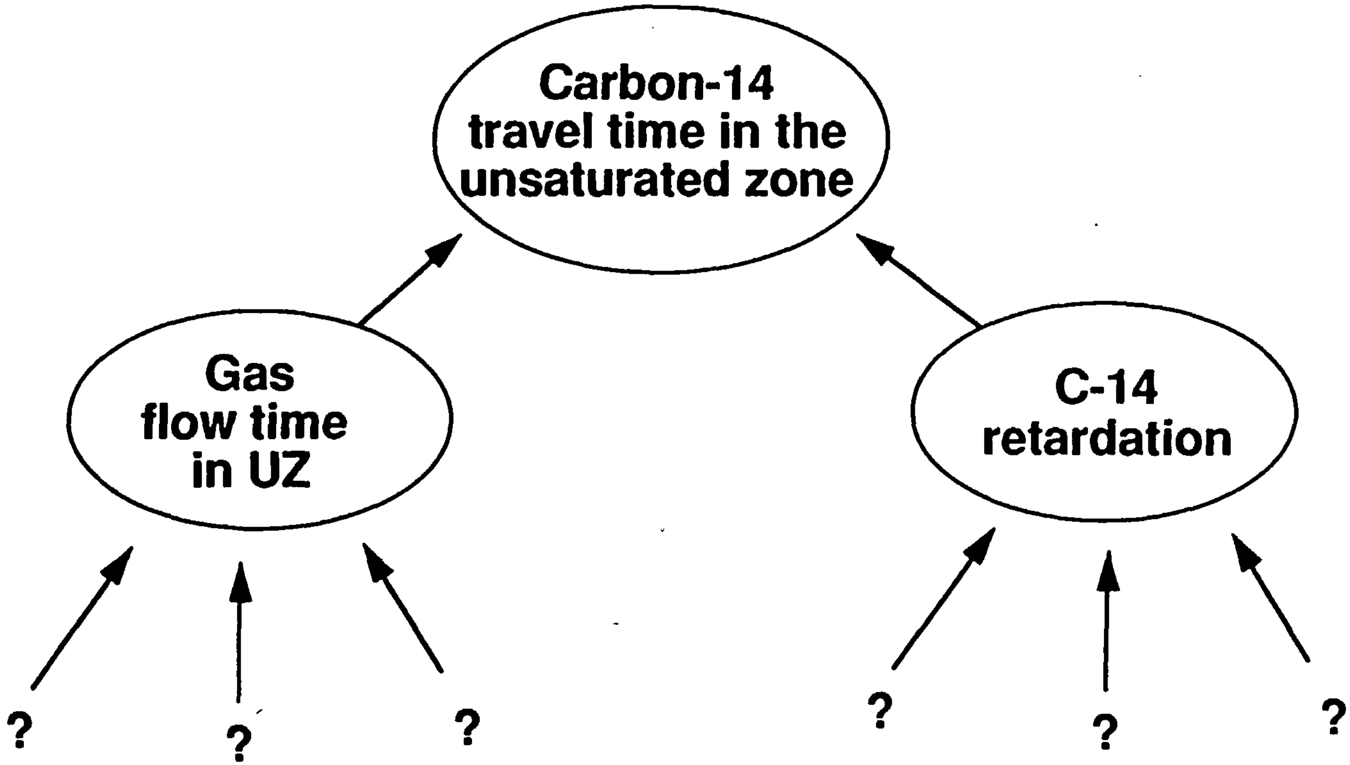
This schematic illustrates major components of our SBT-prioritization framework



Model structure
- Parameters
- Relationships

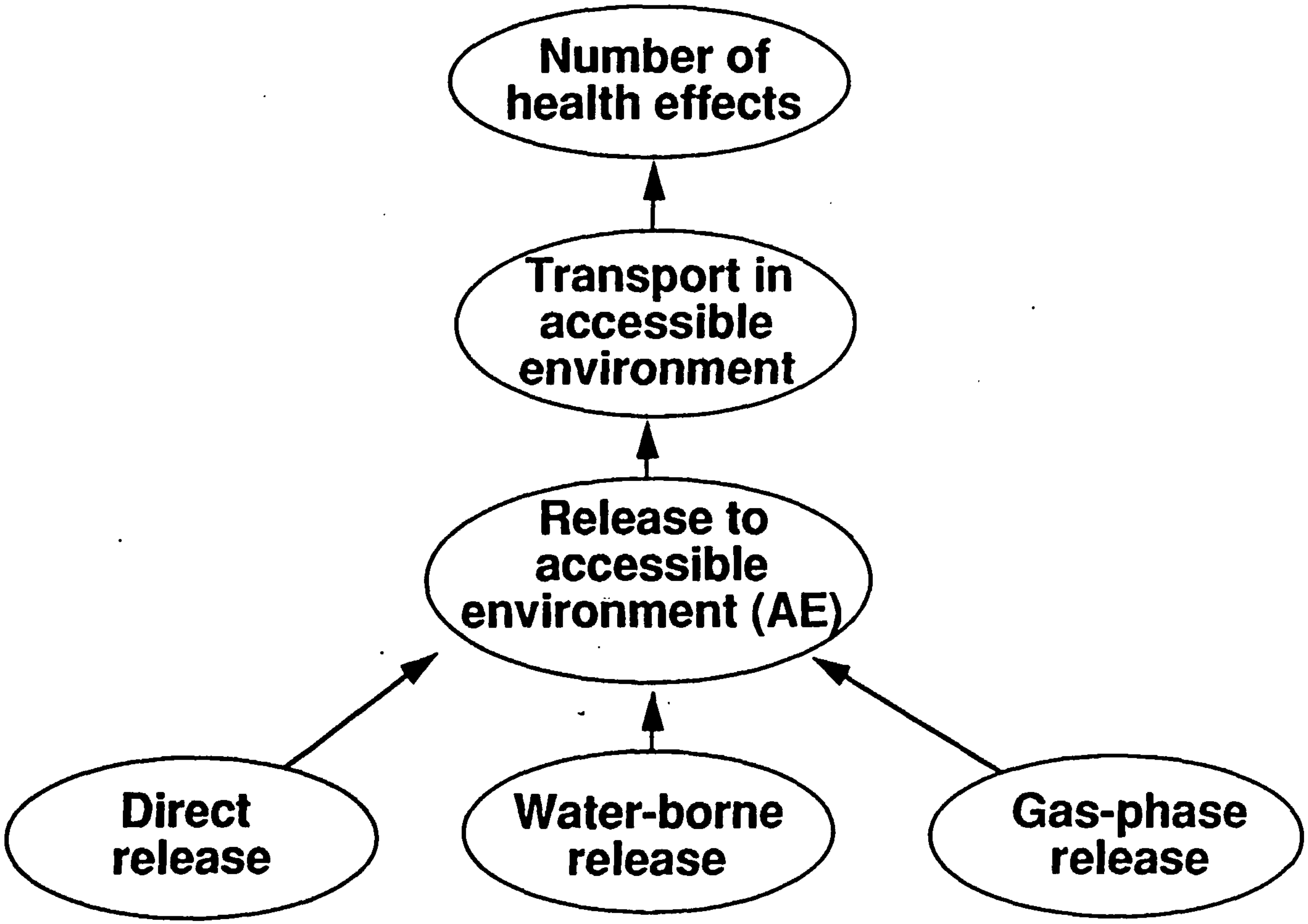
Assessed data
- Parameter uncertainty
- Test accuracy

We use "influence diagrams" to identify key model parameters and probabilistic relationships

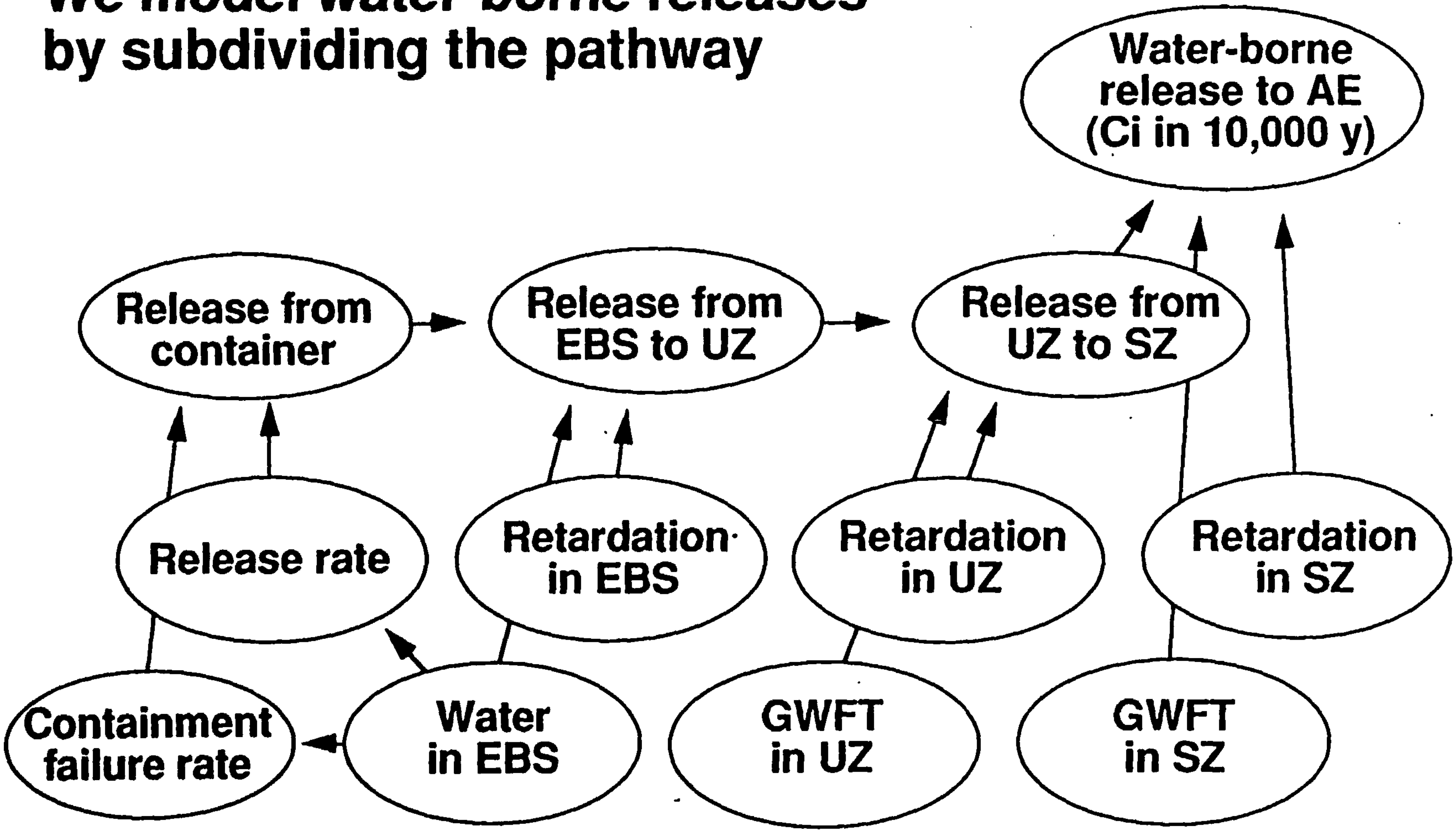


The diagrams are constructed from the top down.
The arrows have special meaning involving probabilistic dependence

Common influence diagrams have been constructed for use in the Calico Hills, Exploratory Shaft Facility, and Surface-based Testing Prioritization task forces



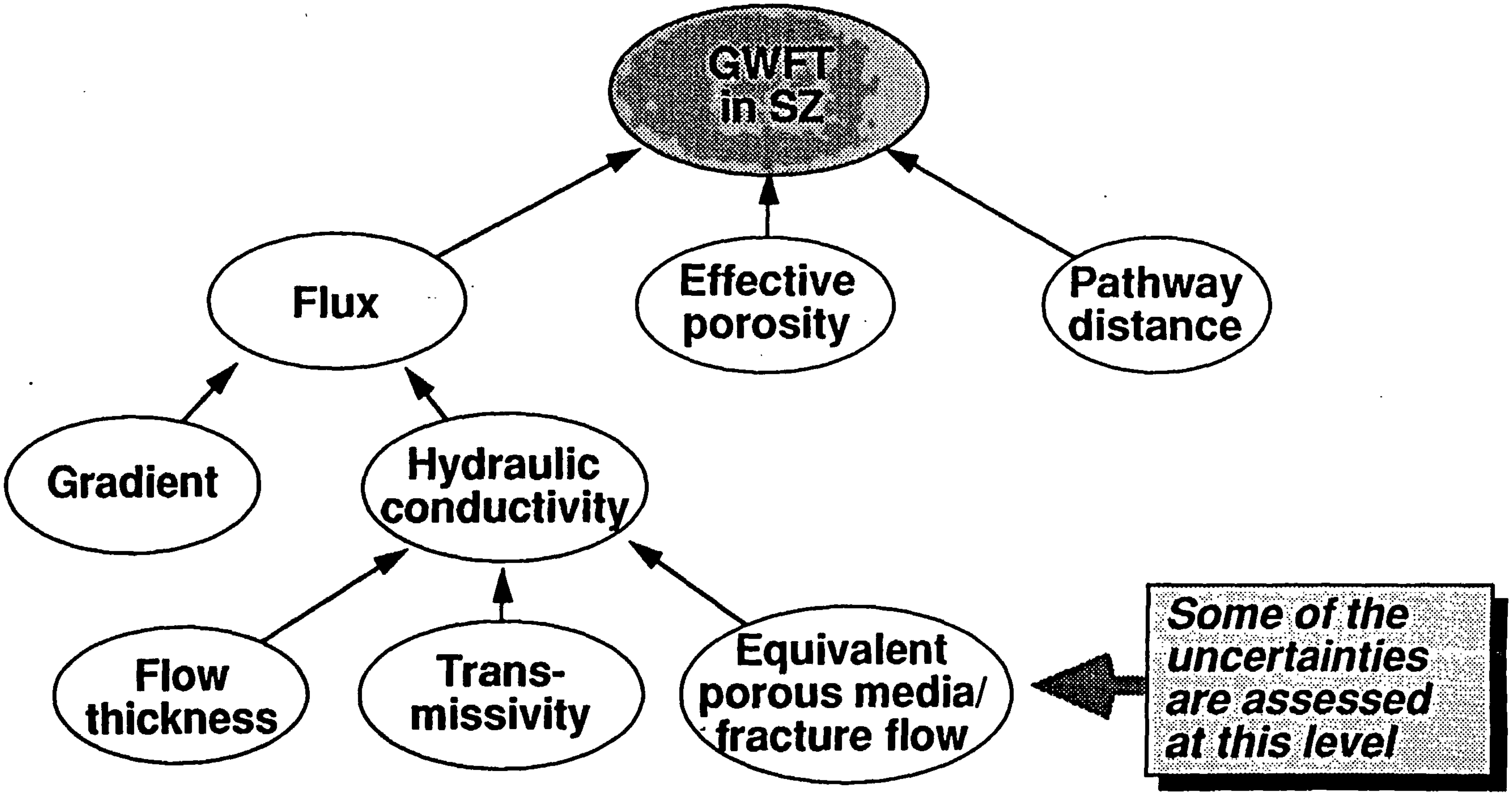
We model water-borne releases by subdividing the pathway



Abbreviations:

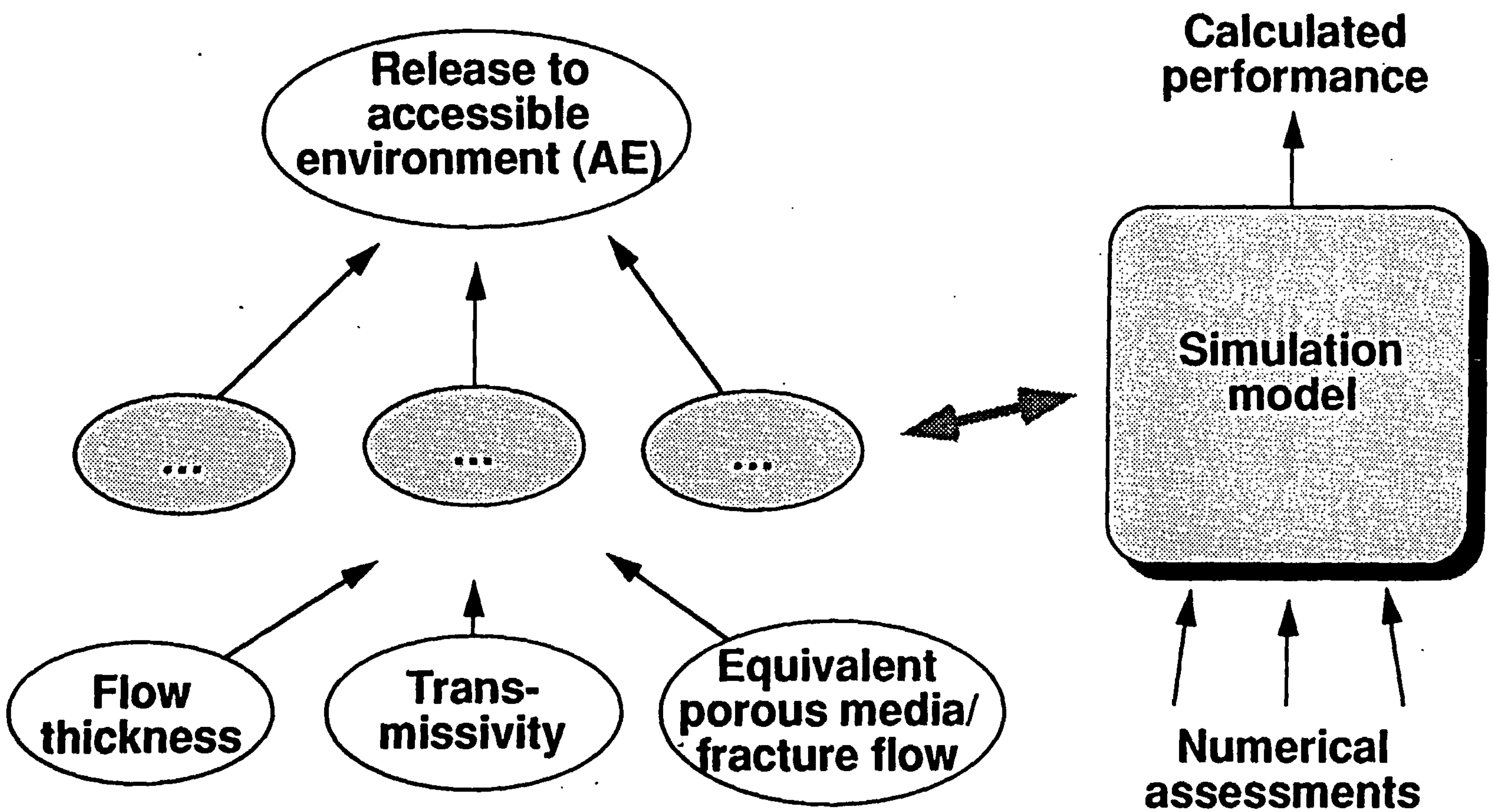
AE	Accessible Environment	Ci	curie
EBS	Engineered barrier system	GWFT	Ground-water flow time
SZ	Saturated zone	UZ	Unsaturated zone
WF	Waste form	y	Year

The diagrams are expanded downward to the level where uncertainties can be assessed accurately



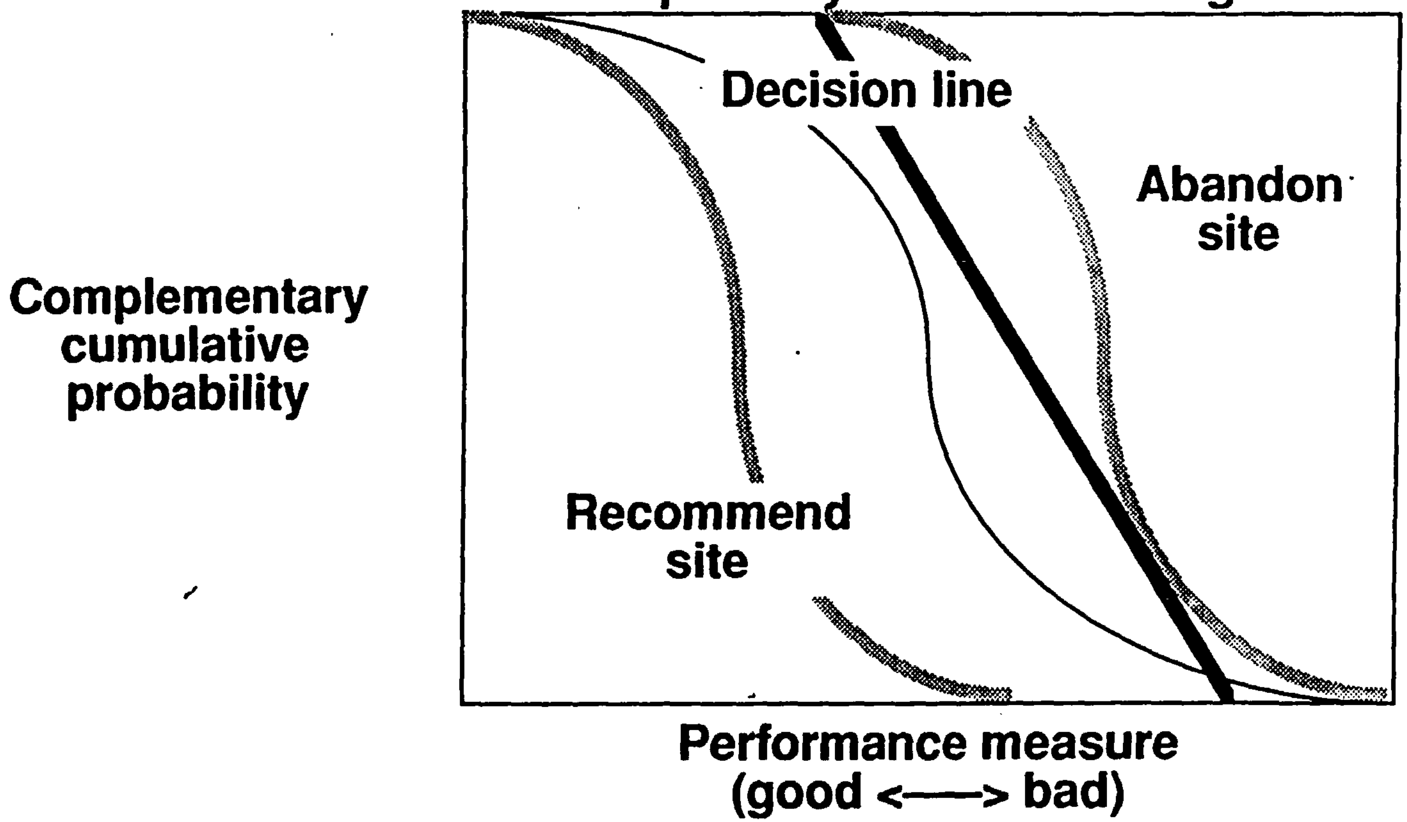
Abbreviations:				
	AE	Accessible Environment	EBS	Engineered barrier system
	GWFT	Ground-water flow time	SZ	Saturated zone
	UZ	Unsaturated zone		

A simplified model is used to calculate performance from assessments of key uncertainties



Combining calculated performance with judgments about tests shows the effects on decision making

Illustrative effect of testing on repository decision making



Testing costs and schedules are considered after analyzing decision impacts

Next we provide an illustrative example of our assessment, analysis, and results

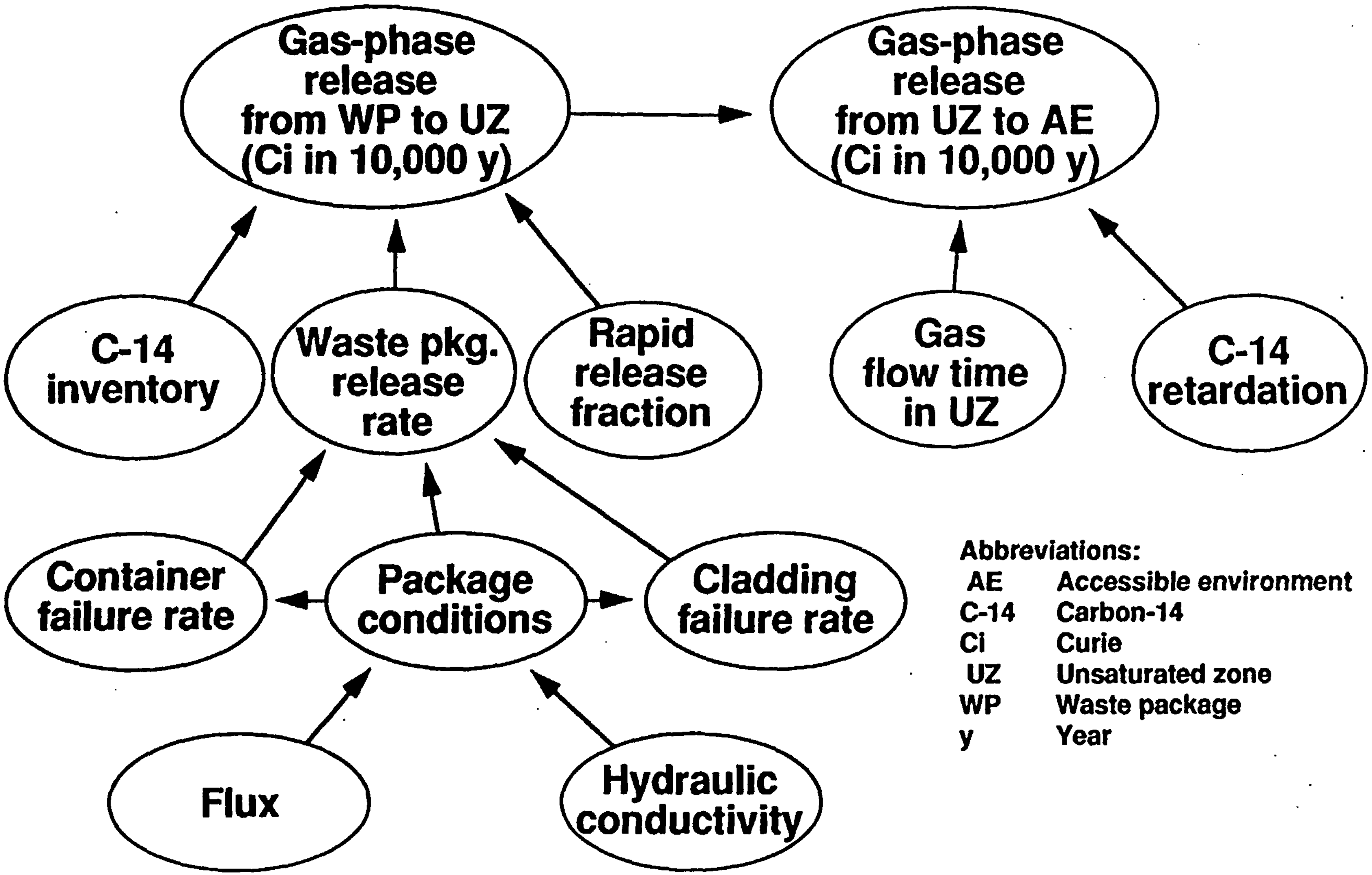
Agenda

Overview of the methodology

Approach to implementation—
model development and data assessment

Illustrative assessments and analysis

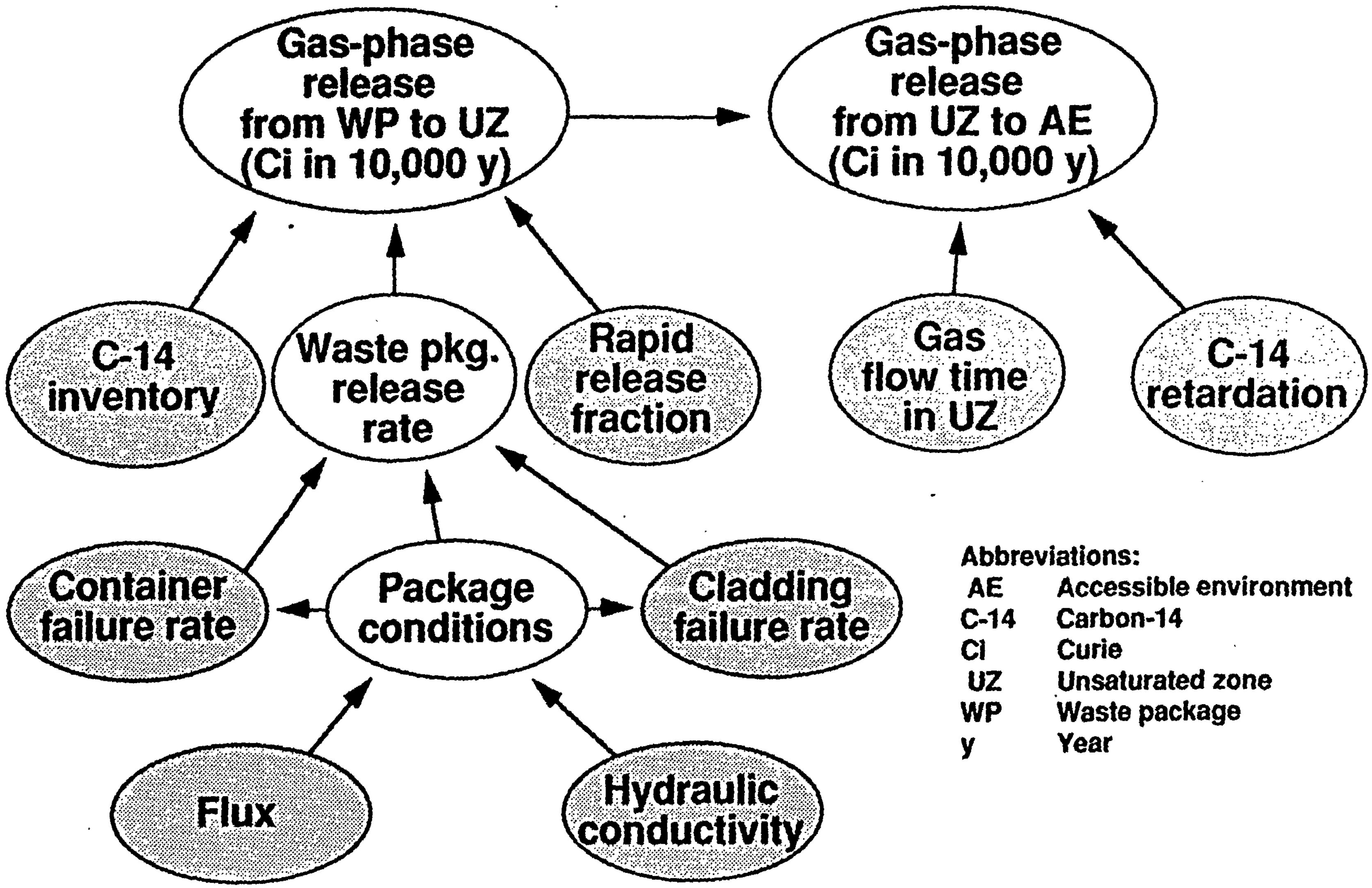
We illustrate data assessment and analysis using an example of gas-phase releases



Abbreviations:

AE	Accessible environment
C-14	Carbon-14
Ci	Curie
UZ	Unsaturated zone
WP	Waste package
y	Year

We assessed probability distributions on 8 key uncertainties related to gas releases



Abbreviations:

AE	Accessible environment
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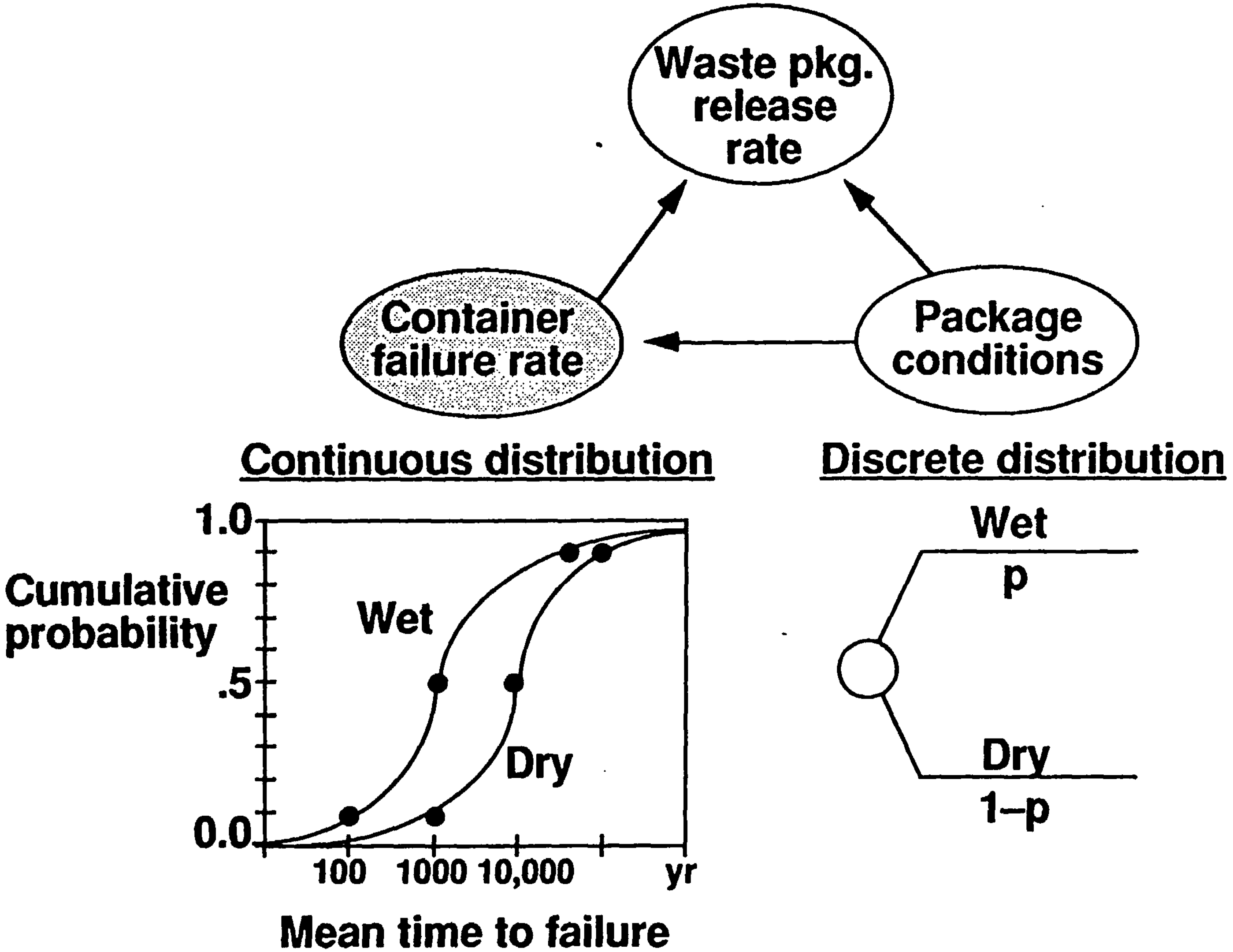
Most numerical assessments for the analysis are probability distributions on key uncertainties



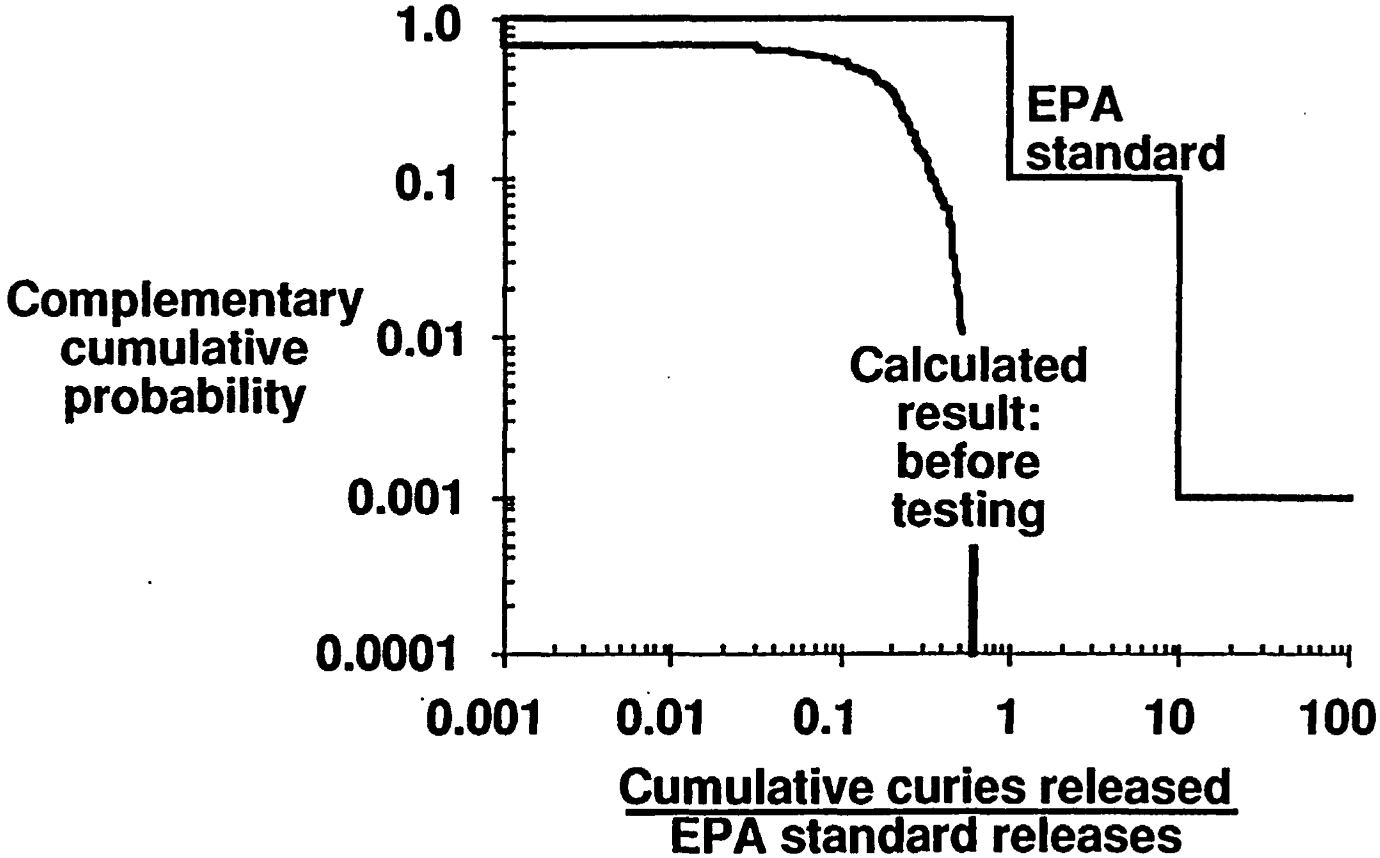
Initial assessments are 10, 50, and 90-percentile points to represent the entire probability distribution

Illustrative assessments

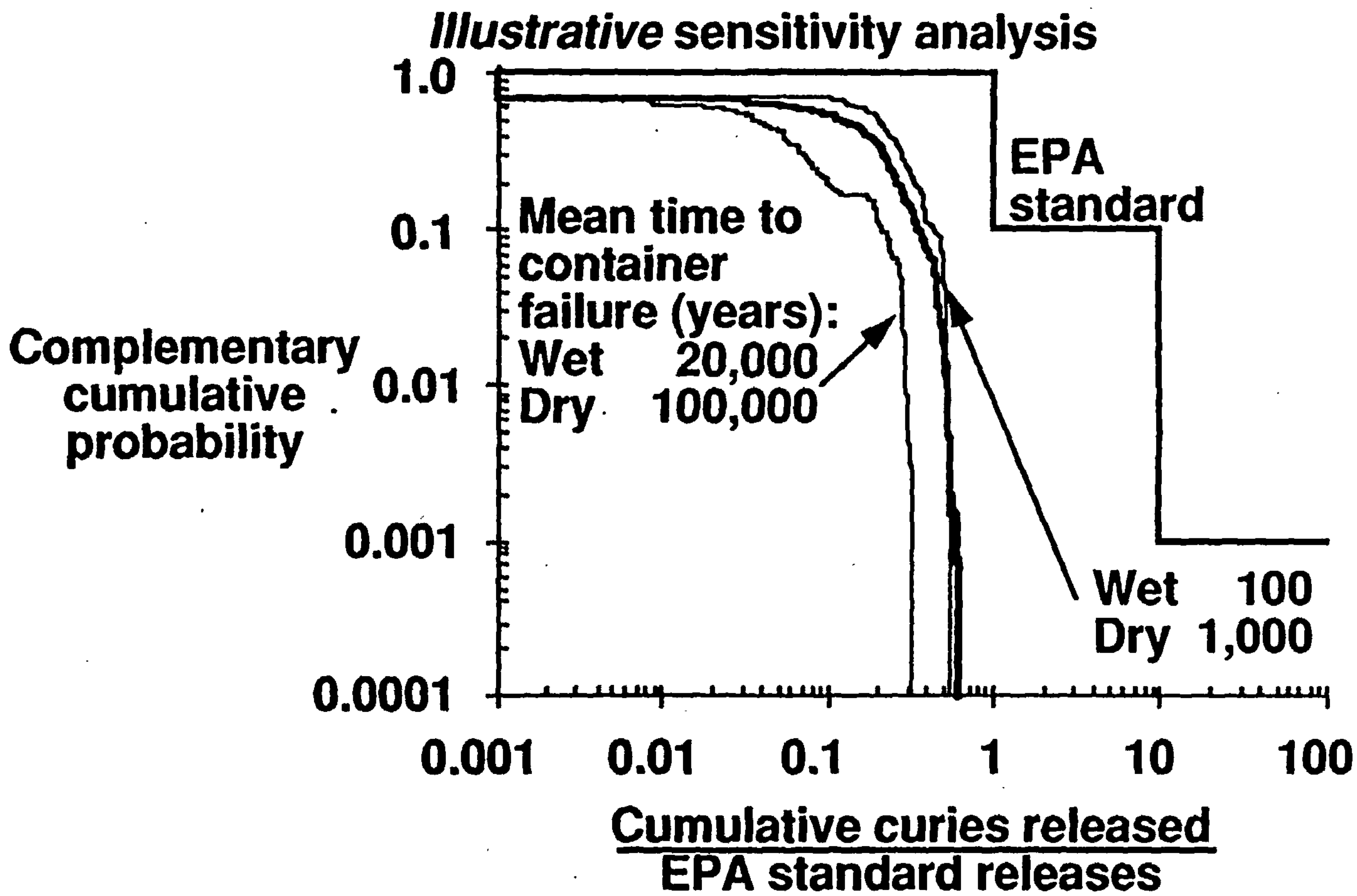
Typical base model assessments:	Percentile 10	50	90
C-14 inventory (ci/MTHM)	0.8	1.1	1.4
Rapid release fraction (percent)	1.	2.	3.5
Container failure rate (mean time to failure, in years)			
Wet or moist	100.	2,000.	20,000.
Dry	1,000.	10,000.	100,000.
Cladding failure half-life (years)			
Wet	5.	500.	1,000.
Dry	1,000.	10,000.	25,000.
Gas flow time in UZ (years)	10	50	300
C-14 retardation (multiplier)	1.	50.	500.
Flux (mm/year)	.1	.5	6.5
Sat. hydraulic conductivity (mm/yr)	.01	.5	10.

The "base model" computes a performance curve for gaseous release of carbon-14 (before testing)

Illustrative performance calculation

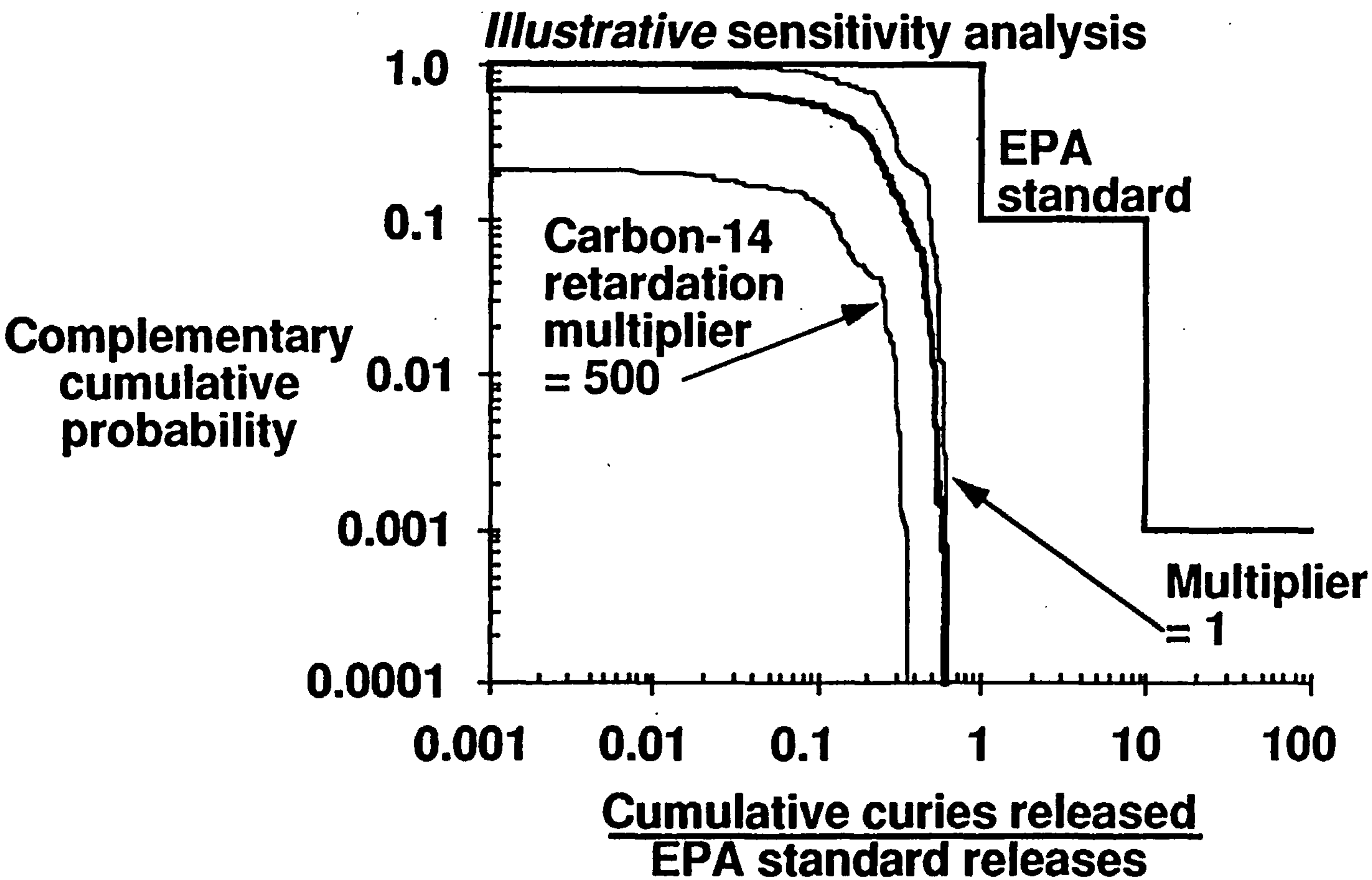


We can examine the sensitivity to uncertainty in container failure rates



The outer curves represent the shift in performance estimates that a "perfect" test might produce

The probability of "no release" is sensitive to the uncertainty in carbon-14 retardation



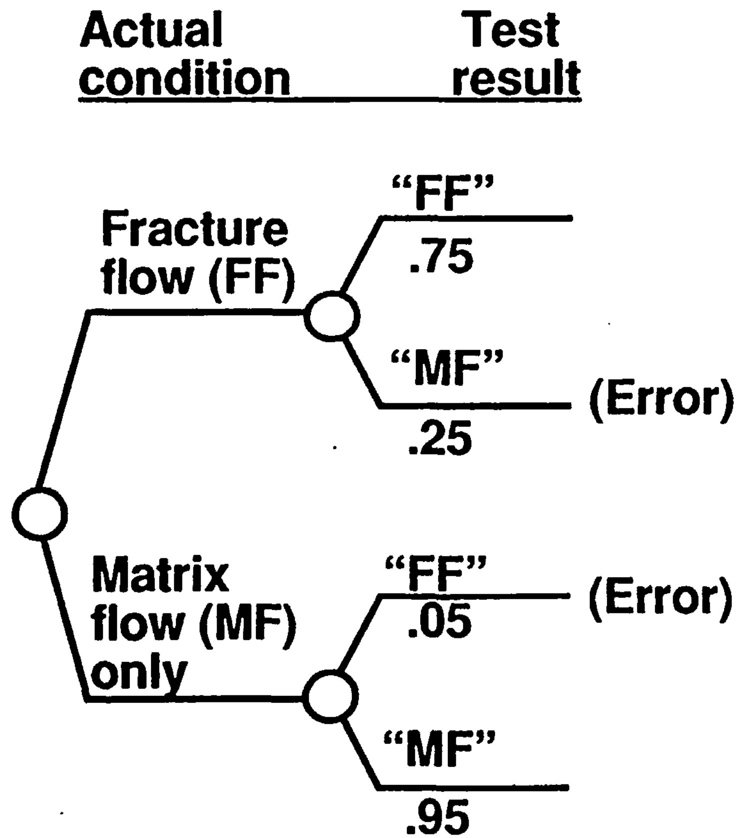
Neither sensitivity case causes a violation of the EPA standard

Next, we identify the categories of surface-based tests and we assess their accuracies

Test category *i*

- Infiltration testing
- Meteorological testing
- Geologic framework
- Conductivity measurements
- Water potential measurements
- ...

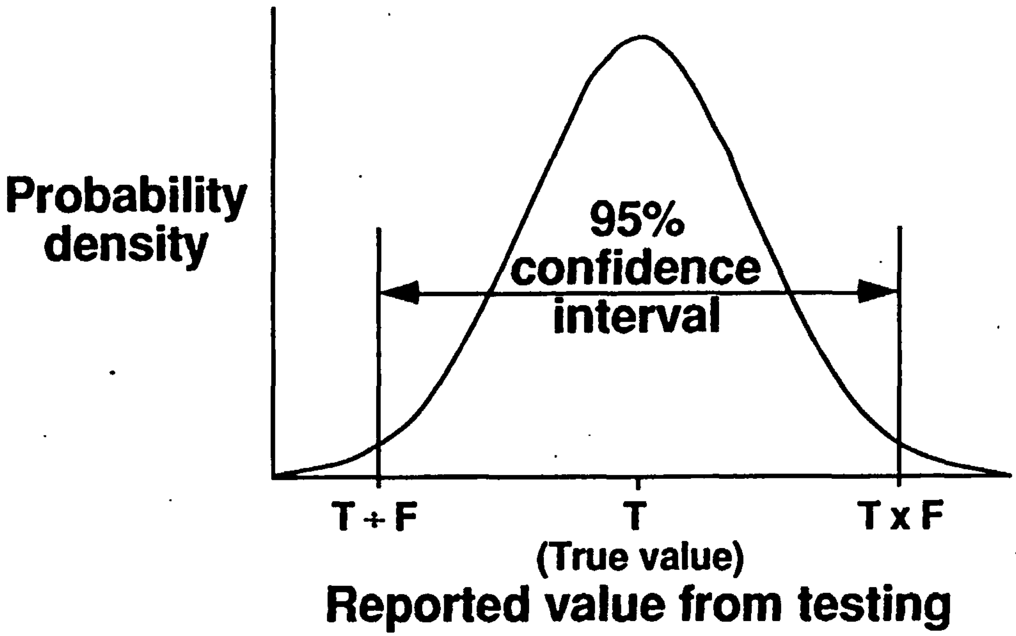
Illustrative **unsaturated zone accuracy assessment**



Testing for continuous parameters requires a different quantification of test accuracy

Possible assessment question:

What is the factor, F, such that if the *true* value of the variable is T, there is 95% chance that the *reported* value will lie in the interval T÷F to T x F?



Example:

Gas flow time

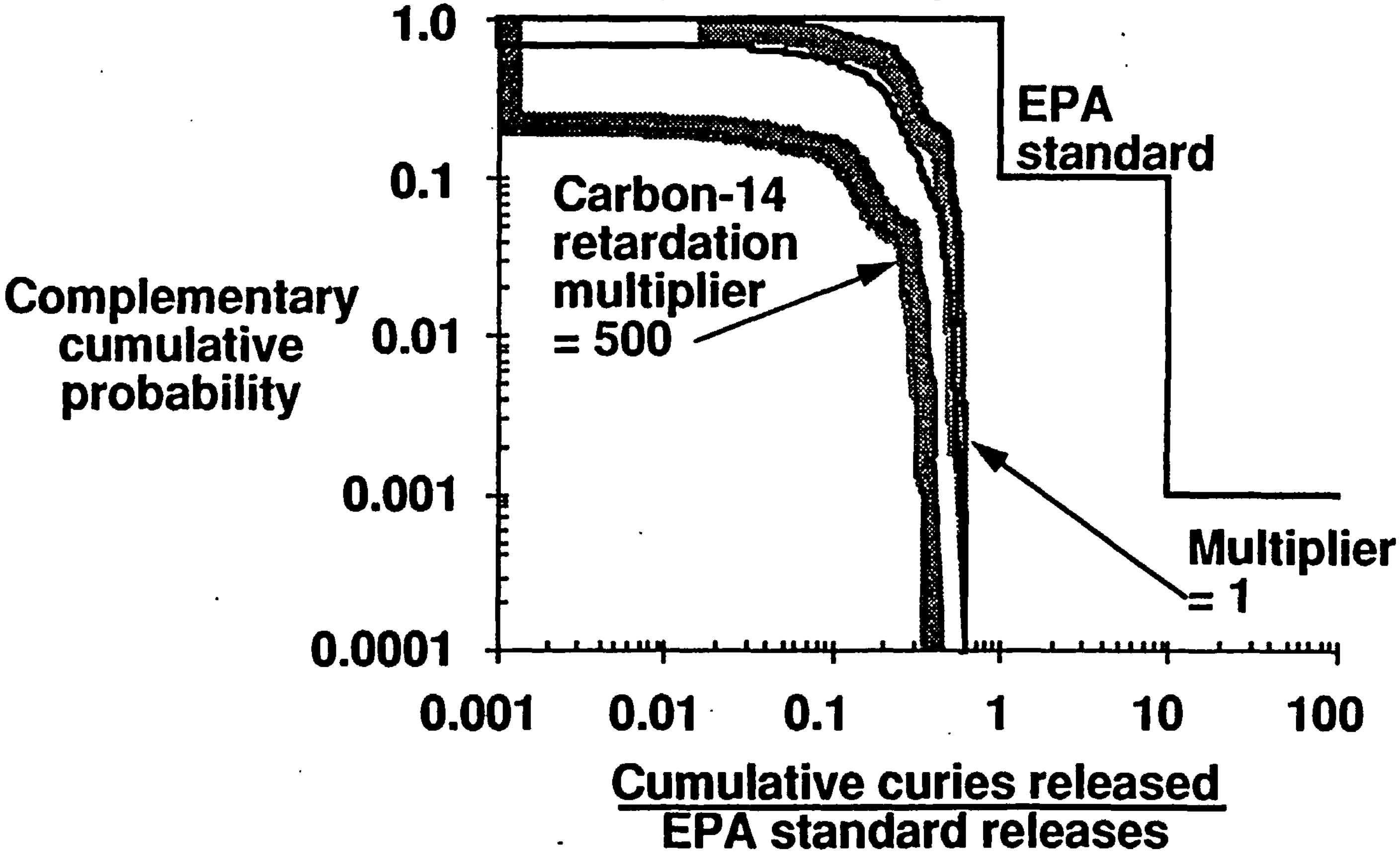
True value: T = 60 years

Testing accuracy:
F = "factor-of-2"

Meaning:
There is a 95% chance that the reported value will fall between 30 and 120 years.

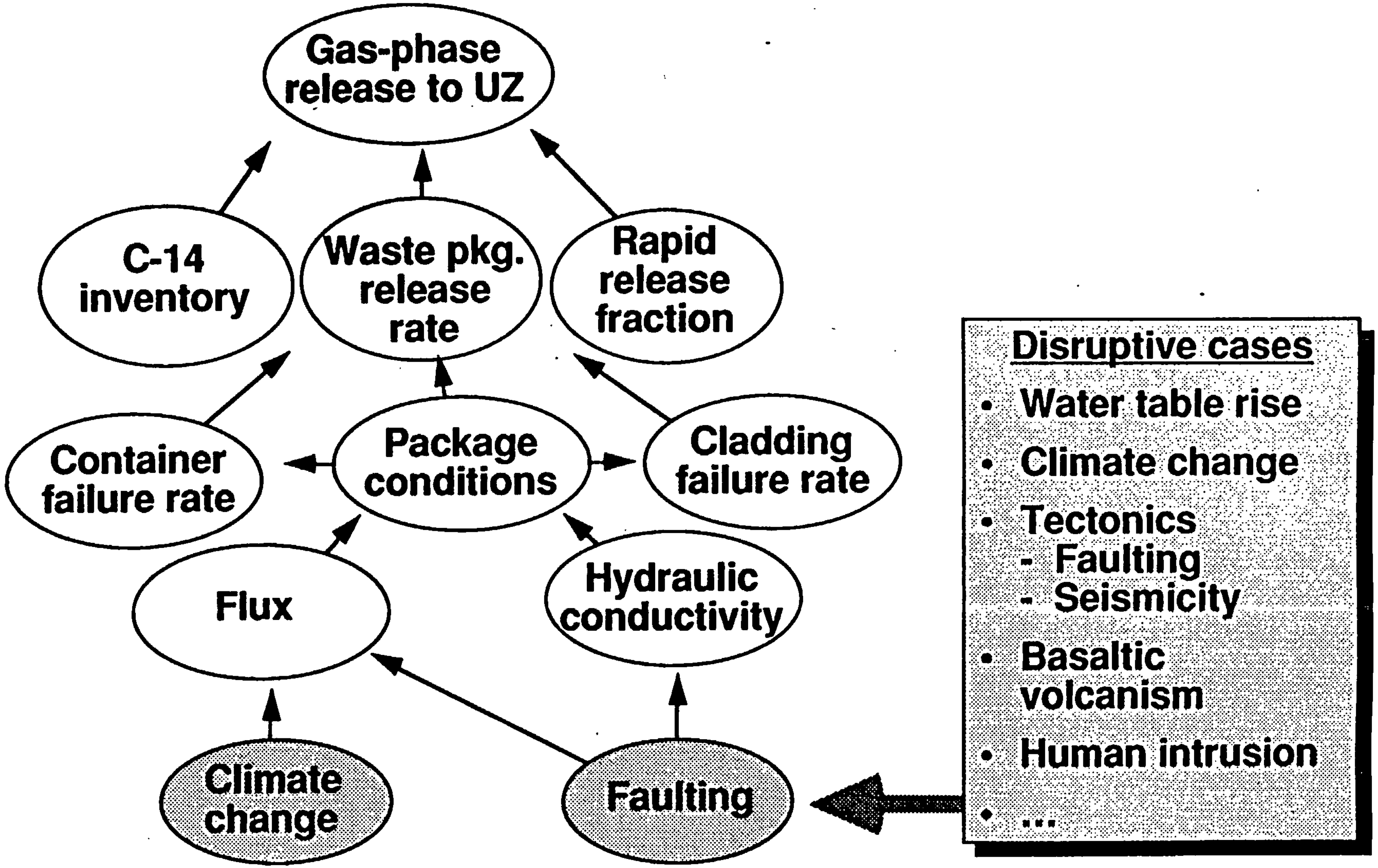
Recalculating performance with realistic test accuracies reduces the likelihood of affecting decisions

Illustrative effects of imperfect tests



The bands illustrate potential "narrowing" of the sensitivity range when test accuracies are considered (illustrative results—not calculated)

We also analyze the effect of disruptive cases and adverse conditions on the base model inputs

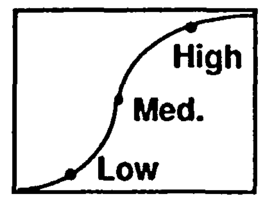


We assess the likelihood of disruptive cases and their effects on base model parameters

Illustrative assessment questions

- What is the disruptive case? — Climate change
- What is its likelihood (over 10,000 years)? — 0.1 (pluvial)
- How is its magnitude measured? — e.g., net infiltration (over 10,000 years)
- What is the uncertainty in magnitude, given that it occurs?

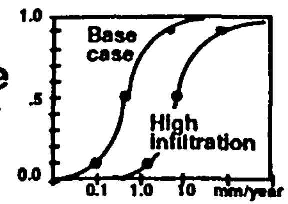
Cumulative probability



Net infiltration

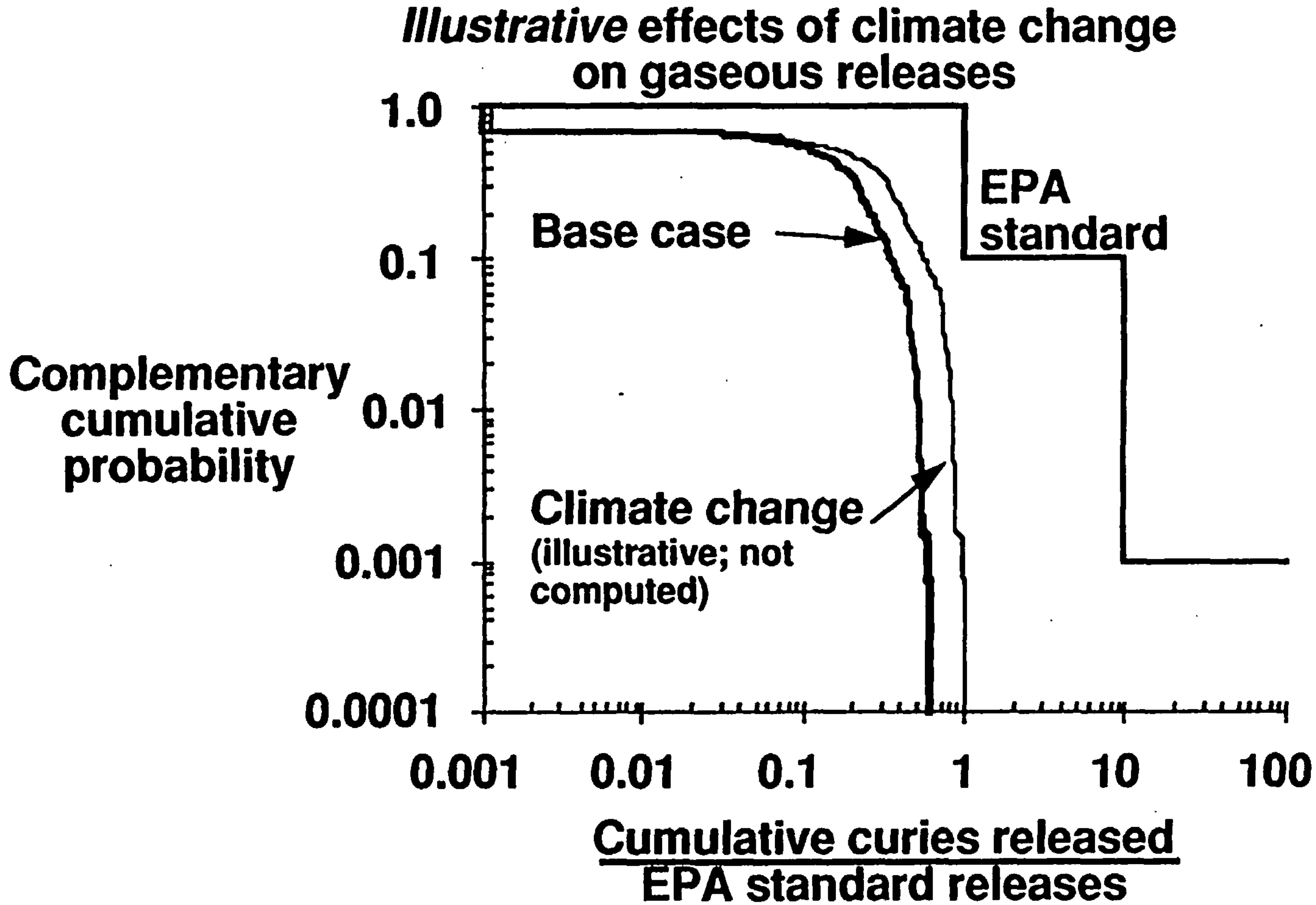
- What parameters does it affect? — Flux, ...
- What is the magnitude of the effect?

Cumulative probability



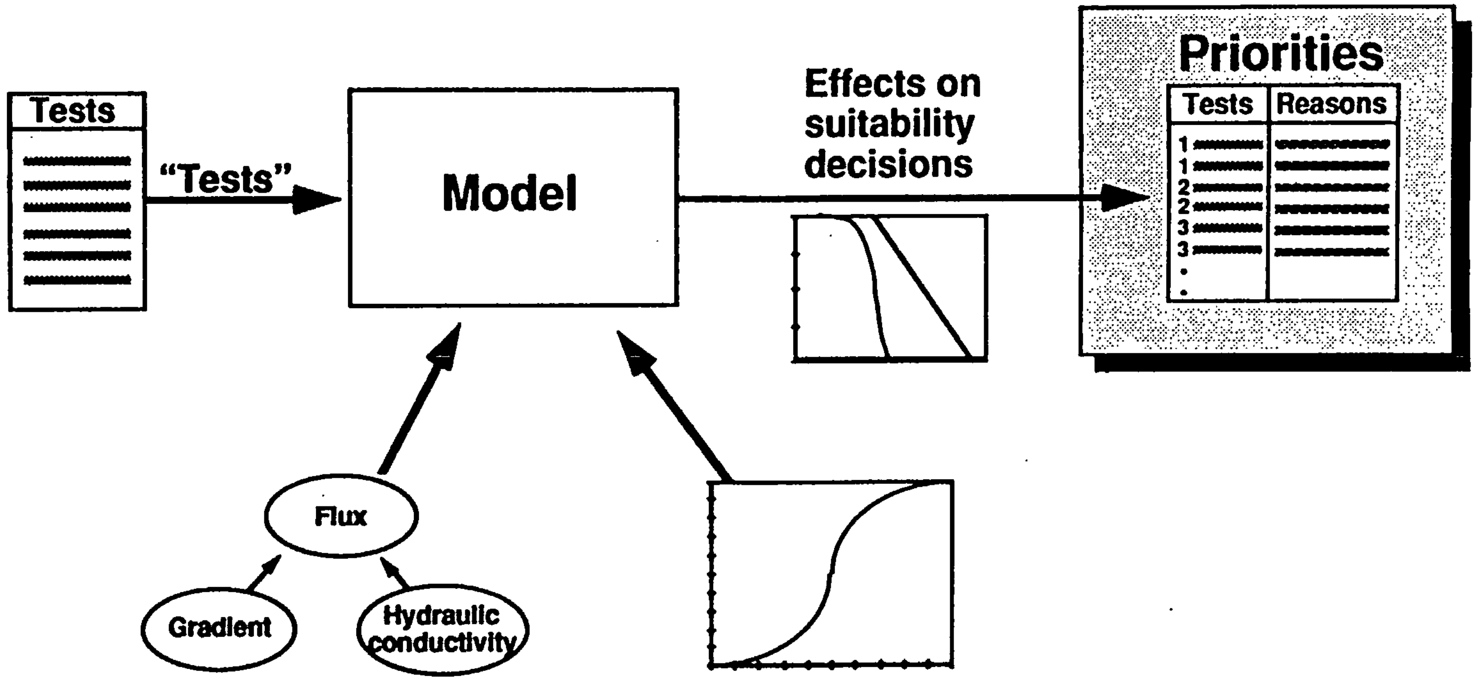
Flux

We determine the sensitivity of performance to various levels of climate change



We then assess the testing and accuracies for reducing uncertainty about climate change

Initial test priorities are established based on the probability that test results will change suitability decisions



Model structure
- Parameters
- Relationships

Assessed data
- Parameter uncertainty
- Test accuracy

The initial priorities need to be reviewed to take account of cost, schedule, and other testing criteria