PRA in Support of Options Analysis for Long-Term Waste Disposition

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What scares the living wits out of me?

- **The way in which risk/performance assessments are done**

What's the problem?

- Bad decisions
  - Conservatism "everywhere" (the proverbial onion)
- Leads to insufficient use of resources
- And wasting money
  - Fiscal state of the Country – GAO concerns
- Negative impact not only on immediate decisions, but also on "upstream" decisions
  - Nuclear energy, nuclear medicine, land use, etc.
- Negative effect on energy policy
- Consequence is climate change

Is there a better way?

- Frame risk assessments in terms of the decision problems they support
- Don’t focus only on compliance
- Focus on optimization in a decision context
  - Remove conservatism everywhere
- Engage stakeholders in the decision process

This will make better use of our resources, and will cut the costs of achieving DOE’s long-term project goals and objectives

Theme of this Technical Exchange

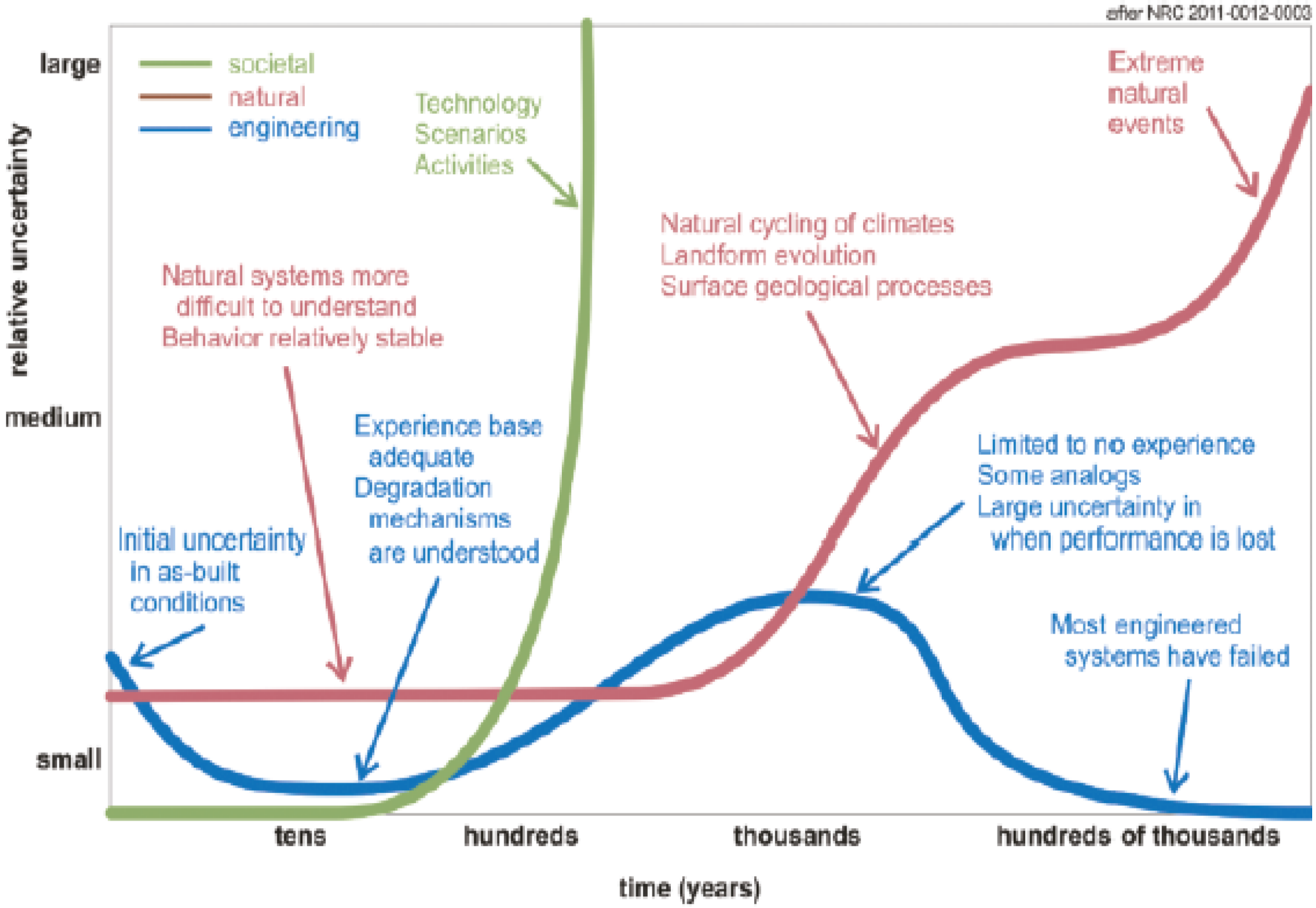
- "Risk-Informed" Decisions Using PRA with an Understanding of Behavior of Certain Key Risk-Driving Radionuclides
- Involves:
  1. Risk assessment
  2. Decision analysis
  3. Probabilistic modeling
     - Statistics
  4. Uncertainty and Sensitivity analysis

Risk Assessment technical issues for PA

- Very long time frames
  - Fate and transport modeling need
  - Climate change impacts?
- Dynamic probabilistic modeling
  - Model abstraction (simplification – ROMs)
  - Scaling
  - Correlation
- How to evaluate human health risk?
  - Dose vs risk
  - LNT hypothesis
  - Population basis over time (ALARA)

Risk Assessment regulatory issues for PA

- Differences among regulations
  - CERCLA and DOE O 435.1 have very different approaches to (P)RA (compliance periods, etc.)
- Performance objectives
  - In the range of hormesis effects for radionuclides?
  - Not measurable in public health
- How to evaluate risk?
  - Mean of the peaks – peak of the means?
    - But both can be very conservative
  - Normalize using a population basis over time (ALARA)



"Technical Analysis Supporting Definition of Period of Performance for Low-Level Waste Disposal" NRC-2011-0012-0003

Other possible issues?

- The main uncertainties are not in engineering and environmental aspects – they are in social aspects
- Possible reasons to think about PA differently – more aligned with CERCLA?
  - Uncertainties increase into the future
  - Society will change rapidly, but models do not (cannot) account for that
  - Technology will improve
  - Social discounting is natural
- Optimal decision making should address these types of issues

Current Approach

1. Science (fate and transport modeling focus)
   - Hydrology, hydrogeology, geochemistry, soil science, plants, animals, etc.
2. Risk/dose assessment
   - Human health – risk or dose
   - Ecological risk
3. Statistics and Decision Analysis
   - Bayesian for decision modeling
4. Stakeholder engagement/communication

Paradigm Shift

1. Stakeholder engagement/communication
2. Statistics and Decision Analysis
   - Bayesian for decision modeling
3. Risk/dose assessment
   - Human health – risk or dose
   - Ecological risk
4. Science (fate and transport modeling focus)
   – Hydrology, hydrogeology, geochemistry, soil science, plants, animals, etc.

Decision Analysis – Basic Principles

- Decisions are made by evaluating decision risk
- Human health and environmental risk are components of decision risk for some types of problems (environmental, food safety)
- Some decisions should be made with respect to populations rather than individuals
- Decision risk decreases with time (social discounting) – need “insurance” to address possible future concerns
- Modeling is performed in the context of decision risk

What is Decision Analysis?

- "Formalized common sense"
- A set of tools for structuring and analyzing complex decision problems
- An approach for making logical, reproducible, and defensible decisions in the face of:
  - Technical complexity
  - Uncertainty
  - Costs and value judgments
  - Multiple, competing objectives

Stakeholder driven Decision Analysis

- Actively involve stakeholders at *all stages* of the decision process (instead of only at later stages, which is more typical)
- Identify objectives, decision options, and events that define the decision problem
- Clearly communicate judgments about costs and values, uncertainty (probabilities), and decision risks

Benefits of being pro-active

- Effective engagement of stakeholders, including communities, leads to more effective decision making
  - Less cost
  - No redo
  - Ownership by all involved
- Essentially aimed at consensus building

Paradigm Shift

- **Stakeholder engaged Structured Decision Making (SDM)**
- Requires involving the stakeholders up front
- Aimed at optimization; not just compliance
- Removes conservatism
- Adds technical defensibility, transparency and traceability to the “softer” aspects
- Finds cost-effective solutions

Site-specific Decision Making

Site-specific factors can make a difference in distinguishing site performance

Site-specific, stakeholder engaged, structured decision making = common sense

Decision Analysis Cycle

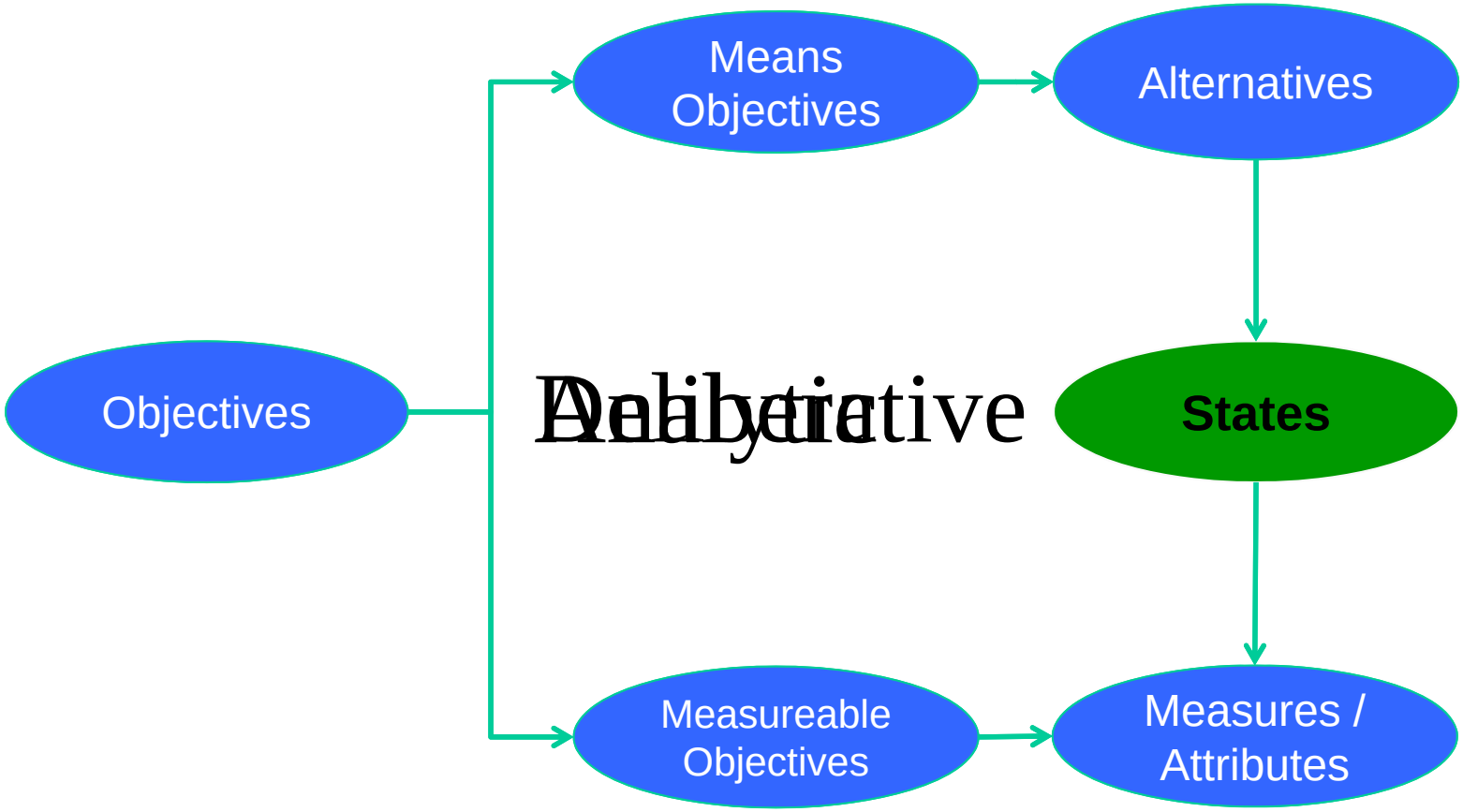
- Identify objectives and decision options
- Build a model with available information
  - Probabilistic model (uncertainty)
  - Costs and value judgments
- Evaluate model – uncertainty analysis
- Perform sensitivity analysis and value of information analysis
- Can decision be made or should more information be collected? (gets at confidence in the decision)
- **Iterate**

Open, transparent, defensible…

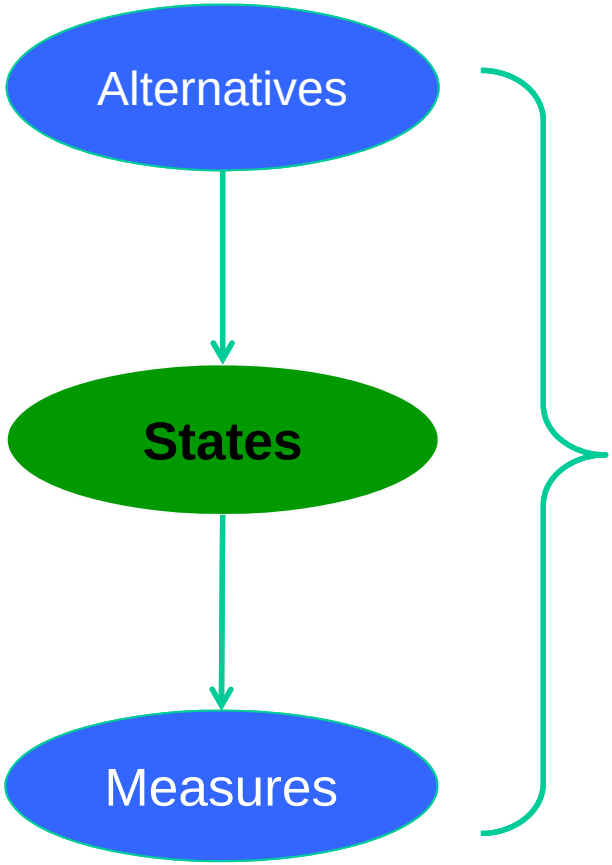
Fully operationalizes the Scientific Method

“Bayesian DQOs”

Decision Analysis Cycle



Decision Analysis Cycle



- Deterministic
- Monte Carlo Simulation
- Bayesian Belief Network

Causal Consequence using Modeling

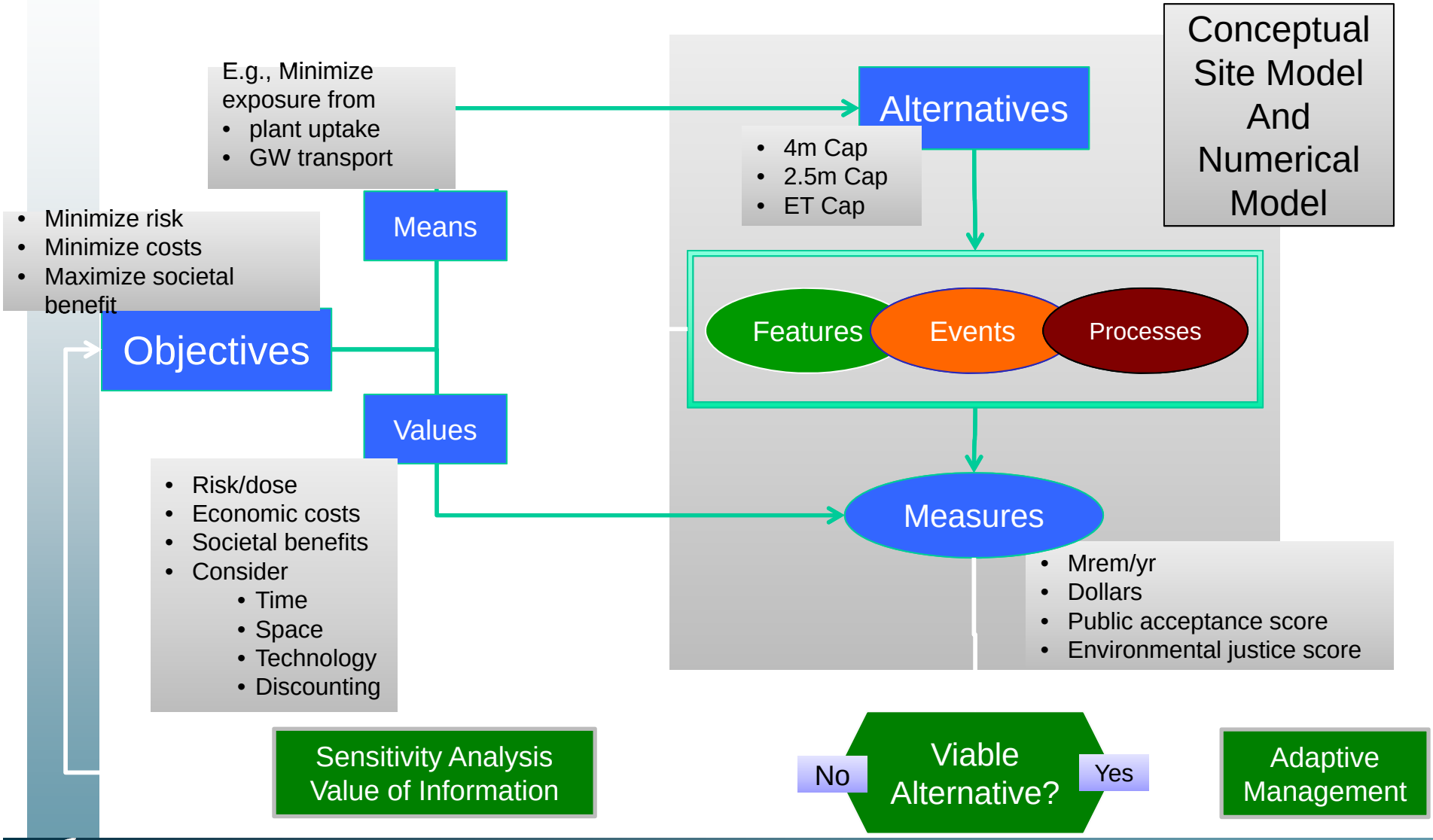
- Simple Analytical relationships
- Model Abstraction

GoldSim

FEHM

…

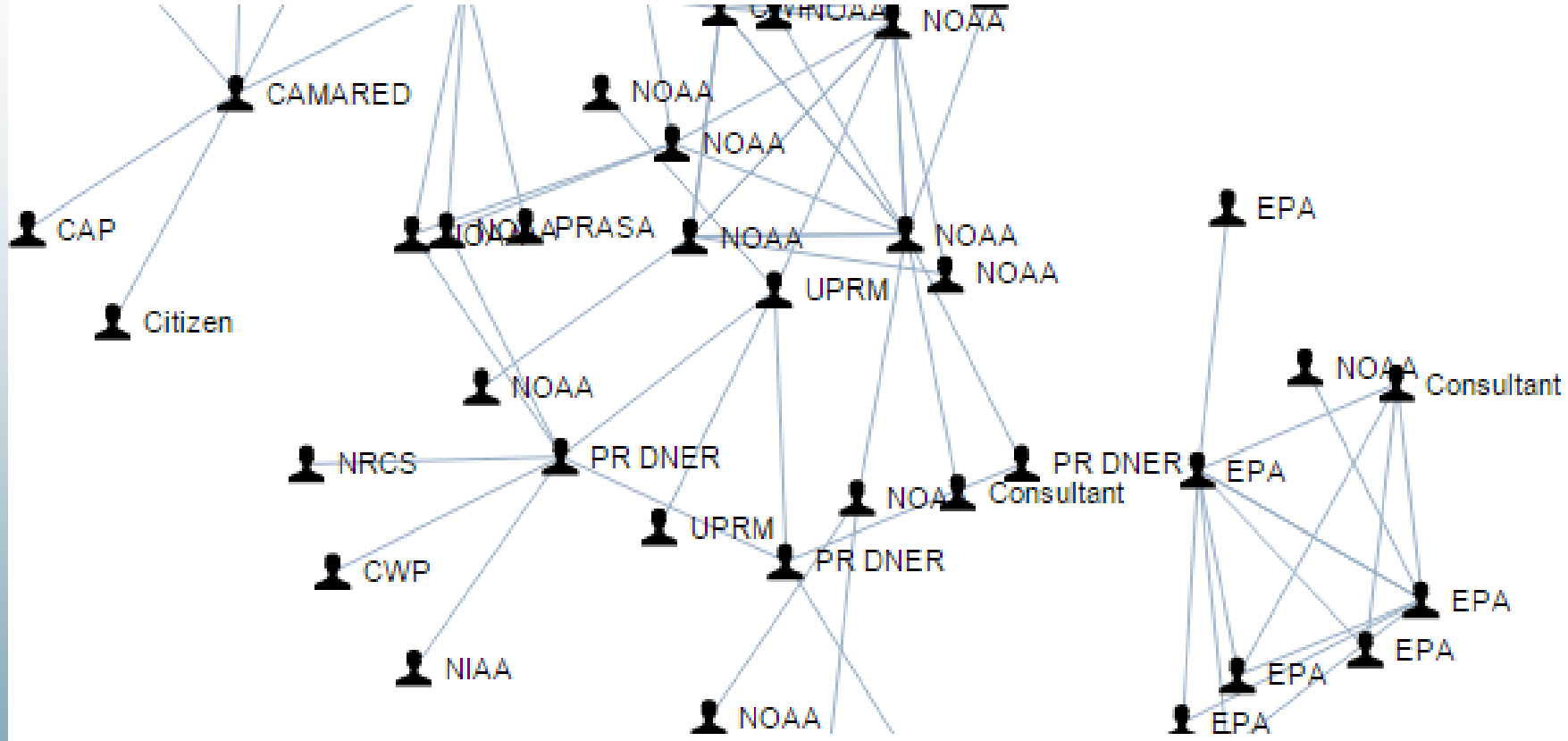
Decision Analysis Flow



1. Understand Context

- Describe the problem
  - Decision Landscape
  - Social Network
  - Regulations
  - Map
  - Scientific setting, initial CSM
  - Cost constraints
  - Timetable

Social Network



How stakeholders, decision-makers, and the scientific community interact

NEPTUNE AND COMPANY *Conceptual Modeler*

Screening Tool | Screen by Subgraphs: | Screen Out All | Summary Report | Filter: clif

Screen	Name
undecided	cliff retreat

FEP: cliff retreat (undecided)

Description of cliff retreat.

References:

Links to papers referencing cliff retreat

Notes:

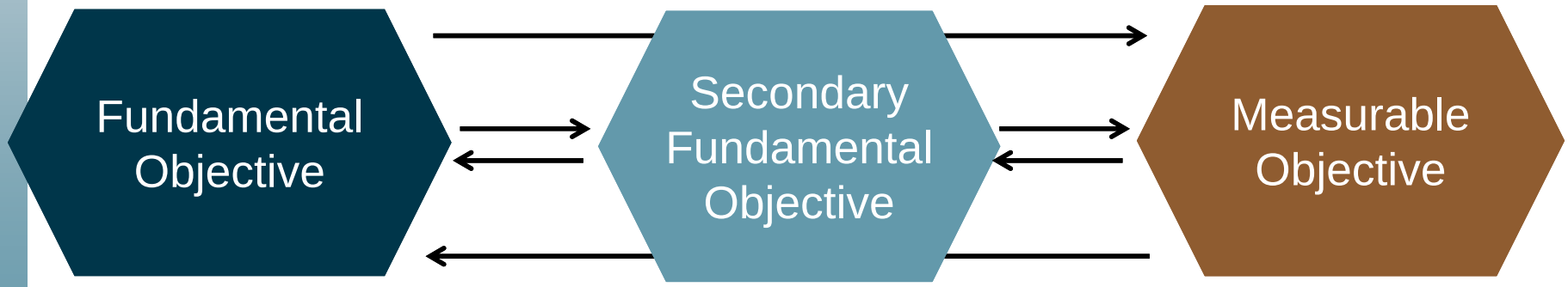
Discussion of why FEP should be included/excluded from this conceptual site model.

Concept Subgraph | Child Depth: 2 | Parent Depth: 2

Example: Cliff Retreat

2. Define Objectives

- Values-Focused thinking approach
- “Values are what we fundamentally care about in decision making. Alternatives are simply means to obtain our values” (Ralph Keeney)
- Elicit decision objectives while focusing on what matters to the stakeholders



Developing Objectives

More art than science….

1. Write down all the stakeholder concerns that could be addressed for the decision (GiSdT provides a Scratchpad tool for collecting these general thoughts and concerns).
2. Convert these concerns into succinct objectives.
   - Minimize impact on human health might be a **fundamental** objective,
   - Human health impacts might be **measured** by minimizing radiation dose.
3. Clarify what is meant by each objective.
   - Even “minimize radiation dose” is not adequately defined – dose to whom? In what time frame?
4. Test objectives to see if they capture the concerns.

Eliciting Objectives

There are no "rules"…e.g.,

1. Describe something that matters to you for this problem:
   - *Stakeholder desire to protect family from radiation poisoning*?
2. Is radiation poisoning the only health concern?
   - *Cancer is identified as a health concern*.
3. Does your concern about your family extend to others?.
   - *Yes, it extends to the local population – we are all potentially affected.*
4. Does this extend beyond local residents?
   - *Yes, it includes visitors*.
5. *How might health effects be measured*?
   - Number of deaths, or hospital visits because of illness that is related to radiation.

That's good, but the impact has already occurred. Can health effects be predicted instead?

- Radiation dose could be used to predict future deaths/illnesses

Resulting Objectives Hierarchy

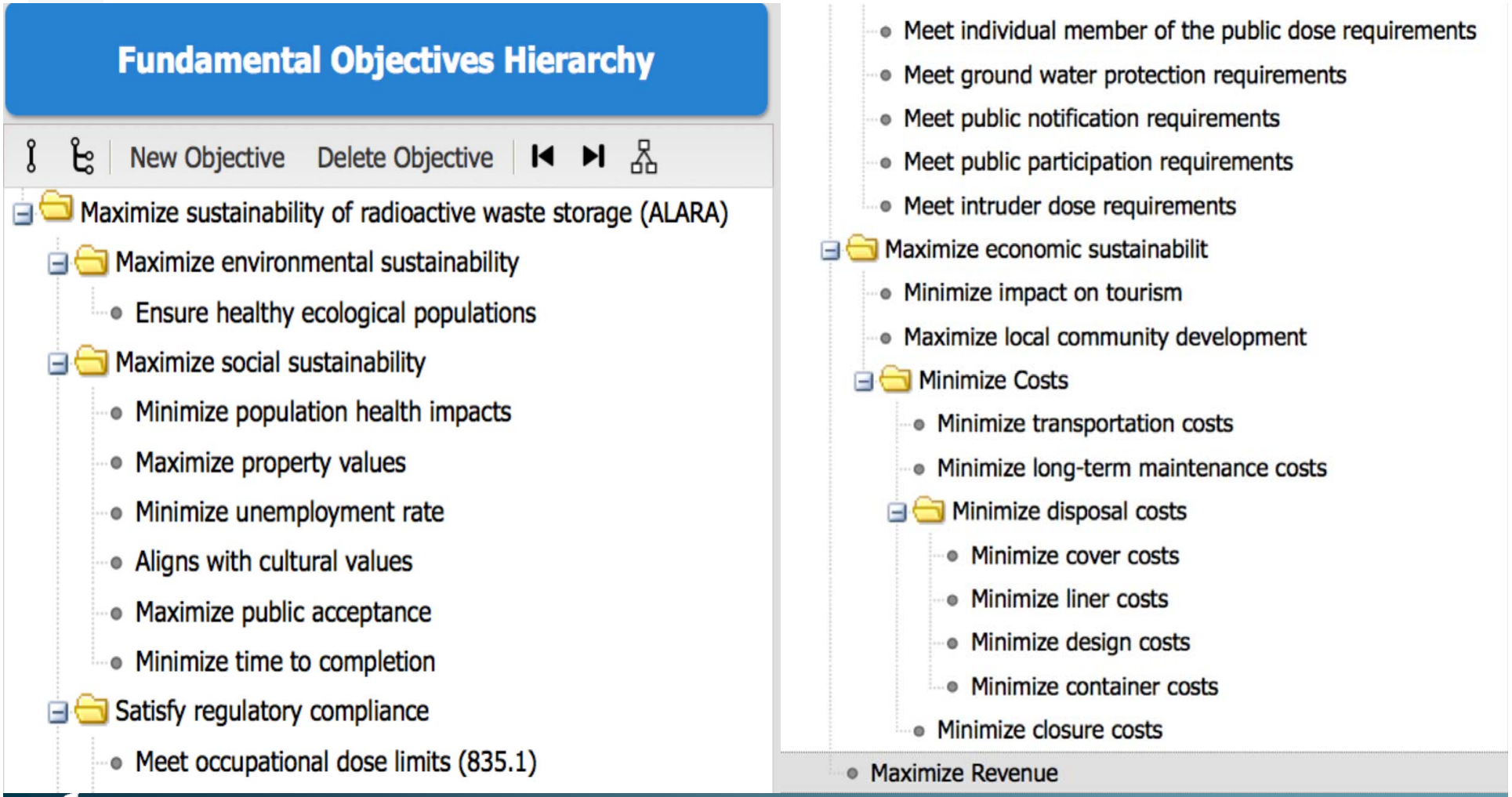
- Fundamental objective – Maximize social sustainability
- Secondary fundamental objective – Minimize population health impacts
- Measurable objective – Minimize amount of additional radiation exposure
- Measure – Radiation dose to the population

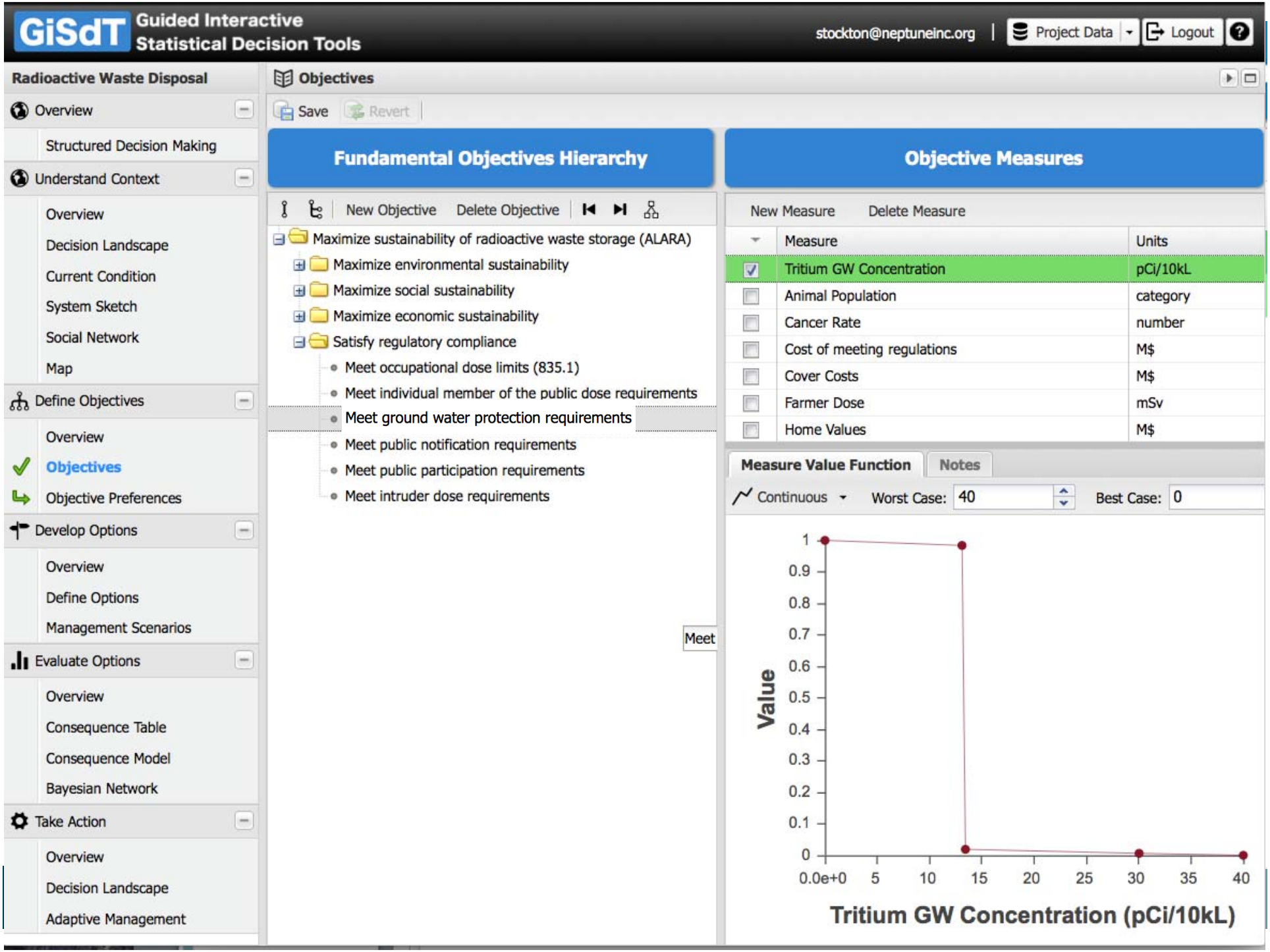
Another Example Objectives Hierarchy

An example that moves in the opposite direction from measureable attribute to fundamental objective might produce an objectives hierarchy that looks like (presumably with a different stakeholder group):

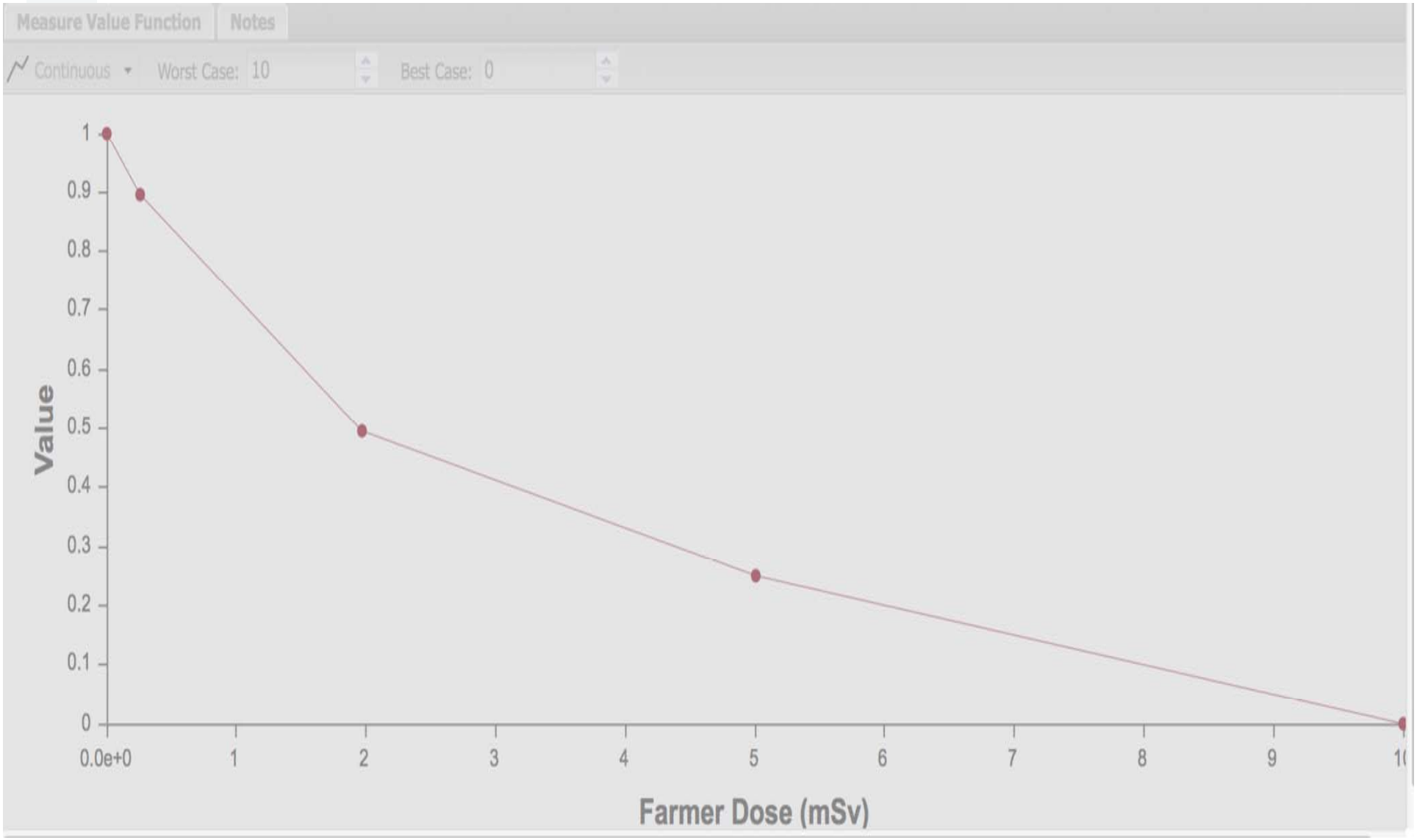
- Measure – Cost of implementing cover design
- Measureable objective – minimize cover costs – *why*?
- Secondary fundamental objective – minimize disposal costs – *why*?
- Fundamental objective – part of minimizing overall costs – *why*?
  - Because the costs are paid for with taxpayer money.

Objectives Hierarchy in GiSdT




GiSdT
Guided Interactive
Statistical Decision Tools
stockton@neptuneinc.org
Project Data
Logout
Radioactive Waste Disposal
Overview
Structured Decision Making
Understand Context
Overview
Decision Landscape
Current Condition
System Sketch
Social Network
Map
Define Objectives
Overview
Objectives
Objective Preferences
Develop Options
Overview
Define Options
Management Scenarios
Evaluate Options
Overview
Consequence Table
Consequence Model
Bayesian Network
Take Action
Overview
Decision Landscape
Adaptive Management
Objectives
Save
Revert
Fundamental Objectives Hierarchy
New Objective
Delete Objective
Maximize sustainability of radioactive waste storage (ALARA)
Maximize environmental sustainability
Maximize social sustainability
Maximize economic sustainability
Satisfy regulatory compliance
Meet occupational dose limits (835.1)
Meet individual member of the public dose requirements
Meet ground water protection requirements
Meet public notification requirements
Meet public participation requirements
Meet intruder dose requirements
Meet
Objective Measures
New Measure
Delete Measure
Measure
Units
Tritium GW Concentration
pCi/10kL
Animal Population
category
Cancer Rate
number
Cost of meeting regulations
M$
Cover Costs
M$
Farmer Dose
mSv
Home Values
M$
Measure Value Function
Notes
Continuous
Worst Case:
40
Best Case:
0
Value
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0e+0
5
10
15
20
25
30
35
40
Tritium GW Concentration (pCi/10kL)

(Normalized) Value Functions



Radioactive Waste Disposal

- Overview
  - Structured Decision Making
- Understand Context
  - Overview
  - Decision Landscape
  - Current Condition
  - System Sketch
  - Social Network
  - Map
- Define Objectives
  - Overview
  - Objectives
  - **Objective Preferences**
- Develop Options
  - Overview
  - Define Options
  - Management Scenarios
- Evaluate Options
  - Overview
  - Consequence Table
  - Consequence Model
  - Bayesian Network
- Take Action
  - Overview
  - Decision Landscape
  - Adaptive Management

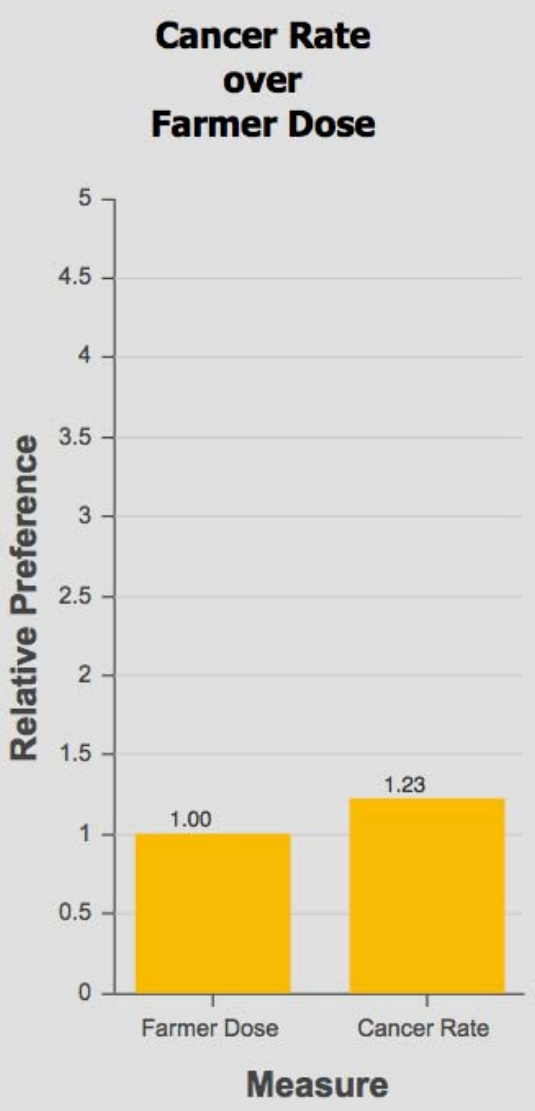
Objective Preferences

Save | Revert | Weight Measures

Measure Rankings

	Measure	Best Case	Worst Case	Weight Bar	Relative	Weight
1	Cancer Rate	0	25		4.12	0.181
2	Farmer Dose	15	0		3.37	0.148
3	Tritium GW C...	0	40		2.80	0.123
4	Tritium spring...	10	0		2.29	0.101
5	Impacts sacre...	10	0		1.89	0.083
6	Total Closure ...	0	10		1.69	0.074
7	Cover Costs	0	10		1.40	0.061
8	Total Disposal...	30	130		1.20	0.053
9	Public Notific...	10	0		1.00	0.044
10	Public Accept...	5	1		1.00	0.044
11	Meet Schedule	0	365		1.00	0.044
12	Public Meetings	10	0		1.00	0.044

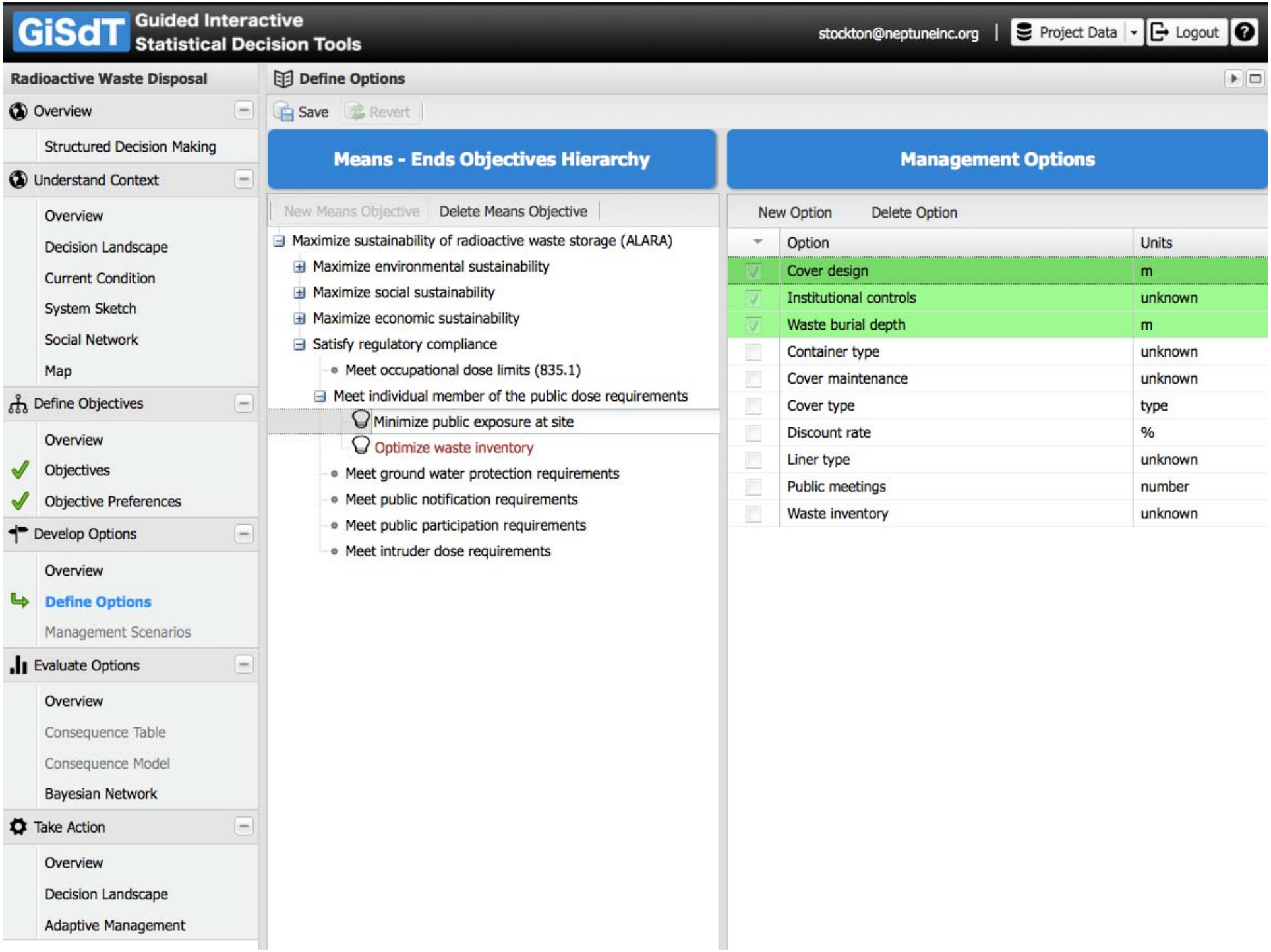
Cancel | Weight | Finish



3. Identify Options

Connect Options to Objectives…

- What can be done to achieve the objectives?
- What "switches" are available?
  - Institutional controls
  - Engineered Controls
  - Waste processing
  - Transportation
  - Public meetings
- Often, both single and groups of options should be considered.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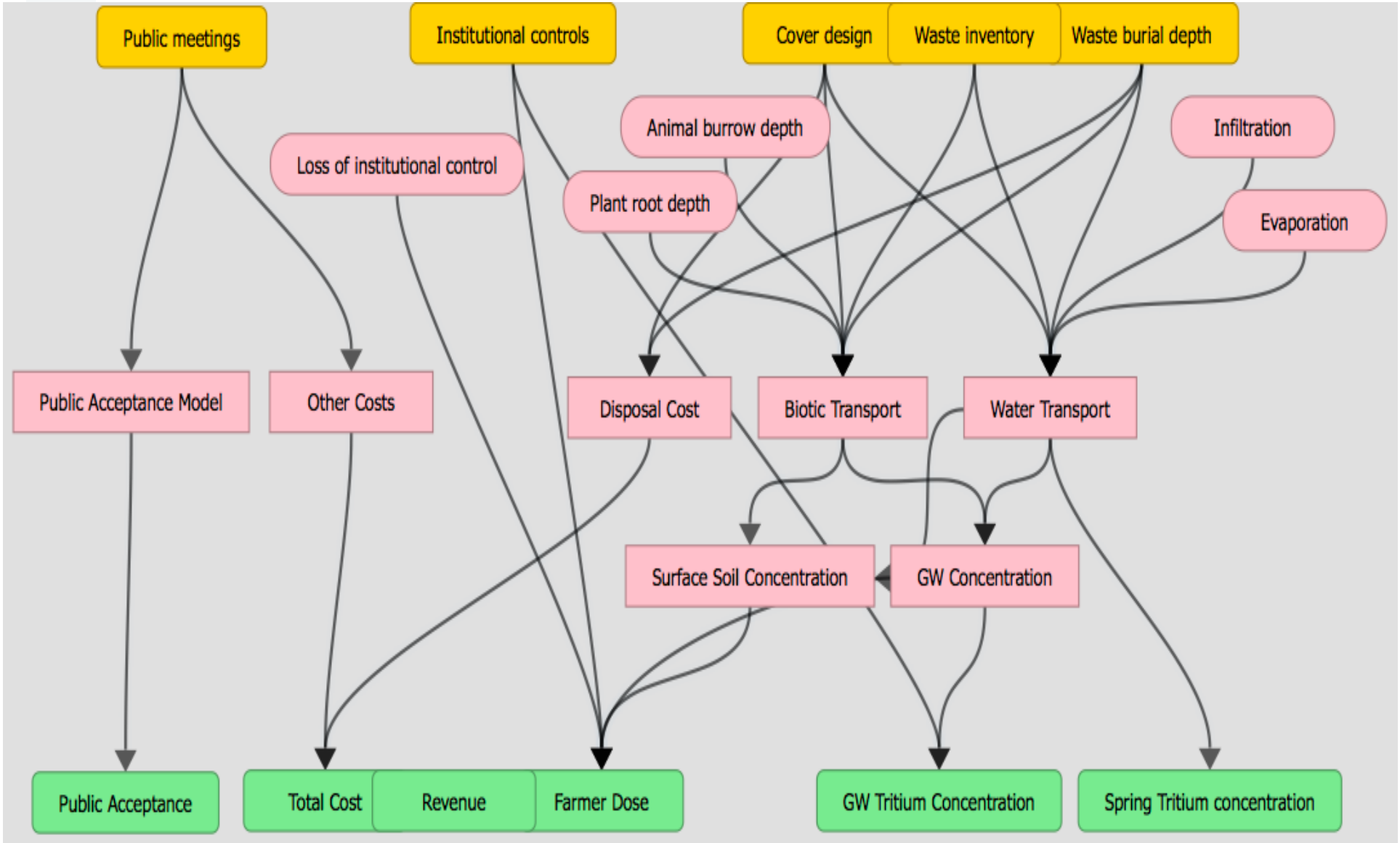
Optimize waste inventory
Meet ground water protection requirements
Meet public notification requirements
Meet public participation requirements
Meet intruder dose requirements
Management Options
New Option
Delete Option
Option
Units
Cover design
m
Institutional controls
unknown
Waste burial depth
m
Container type
unknown
Cover maintenance
unknown
Cover type
type
Discount rate
%
Liner type
unknown
Public meetings
number
Waste inventory
unknown

4. Evaluate Options

- Connect Options to objectives
- Evaluate options through the objectives measures
- This is where the science comes in…
  - Measurements/data/information
  - Numerical environmental models
    - Rigorous framework for inclusion of model uncertainties – that is, the models are probabilistic
    - Address spatial and temporal scaling, correlation and other difficult statistics issues

Options ➔ Models ➔ Objectives



Stakeholder Aspects?

- Can engage in Steps 1-4
  - Does not mean they are decision makers
- Stakeholders are usually engaged more in stage setting (including aspects of the CSM) (Step 1) and concerns/values (2) than in options (3) or science (4)
  - Science is the domain of subject matter experts
- Level at which objectives are considered and, hence, stakeholder engagement is performed can vary depending on the project, and the decision makers roles/views on how and when to engage stakeholders

5. Take Action

- Once the decision model has been evaluated the remaining steps in the decision analysis process include:
  - Uncertainty analysis
  - Sensitivity analysis
    - Used for model evaluation and value of information
  - Choosing the optimal decision option (or management scenario) or collecting more data/information (including model refinement as necessary)
  - Iterate if necessary

Sensitivity Analysis - briefly

- Modern methods allow global sensitivity analysis on probabilistic non-linear non-monotonic models
- We use gradient boosting, but have tested various other methods
- We are working on a method using discretized Bayes nets
- See presentation and paper at WM2015

Benefits of a SDM approach

- Stakeholder concerns captured in a structured systematic program
- Easier to understand
- Easier to communicate and explain
  - Because it represents what we think we know and our uncertainties about that
    - I.e., it's honest
  - Rather than what we know to be wrong, inaccurate, or mis-applied
- Consequently, more difficult to disagree
  - Helps avoid redo, or another stone

Thoughts?

- Remove "*conservatism on top of conservatism on top of conservatism….*" – otherwise GIGO

It is fine to make conservative decisions, but not to make difficult decisions based on "conservative" models

- Properly separate value-judgments from analytical side of a decision problem
  - Leads to more honesty and transparency about how and why decisions are made

SDM Paradigm Shift

Turns the focus…

- From a conservative to a “realistic” analysis
- From starting with the decision-science before the natural/physical science
  - that is, from putting “Why?” before “What?”
- From an alternatives-focus to a **values-focus**

Results in solutions that

- Are optimal – uses resources effectively
- Are safe and compliant
- Are defensible and transparent

Needs?

- Skill sets and capacity in fields such as decision analysis and social sciences
- Research into statistical issues for long term dynamic probabilistic modeling
  - Need to be technically correct
- As this approach evolves, resources are needed that can address these technical capabilities in PA and PRA development and in technical reviews

In Summary...

Performance Assessment

can serve

Structured Decision Making

in the presence of

Values and Uncertainty.