Application of Structured Decision Making to Hanford Site Radiological Air Monitoring – 17924

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ABSTRACT

Radiological air monitoring is a component of an Environmental Surveillance (ES) program that has been in operation at the Department of Energy Hanford Site for several decades. The primary objectives of the ES program are protection of human health and the environment (on and off-site) as well as regulatory compliance. The ES program was designed decades ago when the plutonium-production reactors and related facilities at the Hanford Site were operational and air emissions were more widespread and significant than today. We employed a structured decision making (SDM) approach that integrates science with values and preferences to a Hanford Site air monitoring program decision. Specifically, a decision was necessary pertaining to the possible replacement of three air monitoring stations located in the 100 Area of the Hanford Site because the power line that supports these stations was near the end of its lifecycle. Although focused on this specific decision, the SDM model is more broadly applicable to decisions pertaining to adapting the air monitoring network to current Hanford operations.

The value focused thinking approach that underlies SDM facilitates transparent and defensible decision making, and aids in communicating monitoring rationale. Some of the fundamental objectives elicited from the decision makers regarding management options for the three air monitoring stations included maximizing the ability to measure releases, minimizing environmental impacts, and maximizing social and economic sustainability. The fundamental objectives were linked to six objectives that could be measured (quantified) to allow a decision-analytic solution to the decision problem. Value functions and preference weights were developed for each of the objectives measures based on information obtained during a project workshop as well as by review and analysis of environmental data. Lastly, a set of five management options was identified that might achieve at least one of the objectives.

A Bayes Network was developed as a solution to the decision problem pertaining to the three air stations (the 3 air stations decision). The Bayes Network describes the decision model graphically, and also serves as the computational engine for the decision analysis. The Bayes Network defines the relationship among the five management options and six objectives measures. In addition to the weights and value functions noted above, key inputs to the Bayes Network include a set of probabilities related to the different model states defined by the network. These include the probability of a significant release occurring, the probability that a release

would be detected under each of the five management options, and the probability of achieving the other objective measures under each management option. In this manner the Bayesian Network captures the uncertainty in the components of the decision model.

Replacing the three air monitoring stations with thermoluminescent dosimeters was identified as the preferred management option. A brief report was developed documenting the SDM model, including the workshop notes and analyses that were used to develop the objectives and model input variable values. This application demonstrates SDM's utility for supporting monitoring program decisions and, critically, providing a transparent and traceable basis for the decision. This relatively simple SDM model also provides a basis for an SDM model for monitoring decisions related to the more complex and holistic goal of achieving ES program objectives.

INTRODUCTION

Many of the sources for which the ES monitoring program was designed are no longer present or have far lower radioactive emissions than were common during Hanford's operational period. Among the changes in site conditions are:

- Major sources of air emissions on the Central Plateau related to plutonium processing are no longer operational;
- Active operations at the 100 Area reactors have ceased; and,
- Ongoing remedial activities in the 100 Area are generally complete and Records of Decision (RODs) are in progress or complete (i.e., potential sources for unplanned releases have been removed).

For at least the past decade, as emissions at the Hanford site have diminished, radionuclide concentrations at many onsite and perimeter monitoring locations have approached background levels found in the ambient environment remote from the Hanford Site, whereas when the Hanford Site was operating at or near full capacity [1] emissions concentrations were often noticeably greater than background levels. Similarly, calculated doses based on environmental transport modeling from routine emissions are orders of magnitude less than regulatory limits, and have been for more than a decade.

Annual radionuclide air emission reports summarize annual ambient air monitoring results for both point and fugitive emission sources on the Hanford Site. The predominant point and fugitive sources of radionuclide emissions are located in the 200 Areas and 300 Areas, with the Sludge Project at 100-K the primary source remaining along the River Corridor [1]. For more than 15 years, the predominant point source for routine emissions has been the stack at the 325 Facility in the 300 Area. Tritium and radon isotopes have been the dominant contributors to air pathway doses. The 200 West Area is considered the primary source of fugitive air emissions.

Near-field monitoring of the environment, which involves measurements at locations adjacent to these facilities and sources that have potential dispersible radioactivity, is performed as part of the air monitoring program. Far-field monitoring involves measurements at locations remote from these facilities and sources, including locations outside of the Hanford Site.

Ambient air sampling is the primary method used for monitoring the potential impacts of fugitive emissions in the near-field, and for monitoring the effects of point and fugitive emission sources in the far-field. Environmental data from other media samples are used as secondary indicators. In 2015, 60 near-field ambient air samplers operated as continuously as possible near facilities and work sites. The far-field air monitoring network consists of 40 sampling stations and evaluates radiological contaminants at locations in the environment on and off the Hanford Site. The locations of air monitoring stations are shown in Figure 1.

Due to the changed nature of Hanford Site operations and sources since the air monitoring program was established, there is an interest in optimizing the monitoring program so that it better represents current site conditions. This study specifically addresses three air monitoring stations that are serviced by a power line in the 100 Area of the Hanford Site. For brevity this is referred to as the “3 Air Stations” decision. The urgency of addressing the “3 Air Stations” decision is driven by the life cycle of the power line, which is coming to an end. The power line must be removed, and monitoring design options include replacement of the line to maintain the current air monitoring stations, replacement coupled with new options for installing monitoring stations, or not installing any replacement stations.

Evaluation of the options follows a decision analysis approach called Structured Decision Making (SDM) [2]. SDM follows a stepwise process that explains the context of the problem, addresses the concerns and values of the stakeholders and decision makers, translation of those concerns into statements of objectives, identification of options that achieve one or more of the objectives, specification of probabilities so that the options can be evaluated, and final running of the model to obtain the preferred option.

The process is based on agreeing on assumptions, model structure, and specification of model inputs. The results are a consequence of running the model once fully developed, and, using SDM, the results are technically defensible, transparent, and traceable, so that the results are always available for review and understanding of how the optimal decision was chosen. Relevant background information for the SDM process, and elicitation of objectives and decision options, was developed during a two-day workshop held in Richland, Washington on April 19-20, 2016. Background information including the monitoring history for these and similar stations at the

Hanford Site, calculated radiation doses based on air dispersion modeling, and regulatory framework.

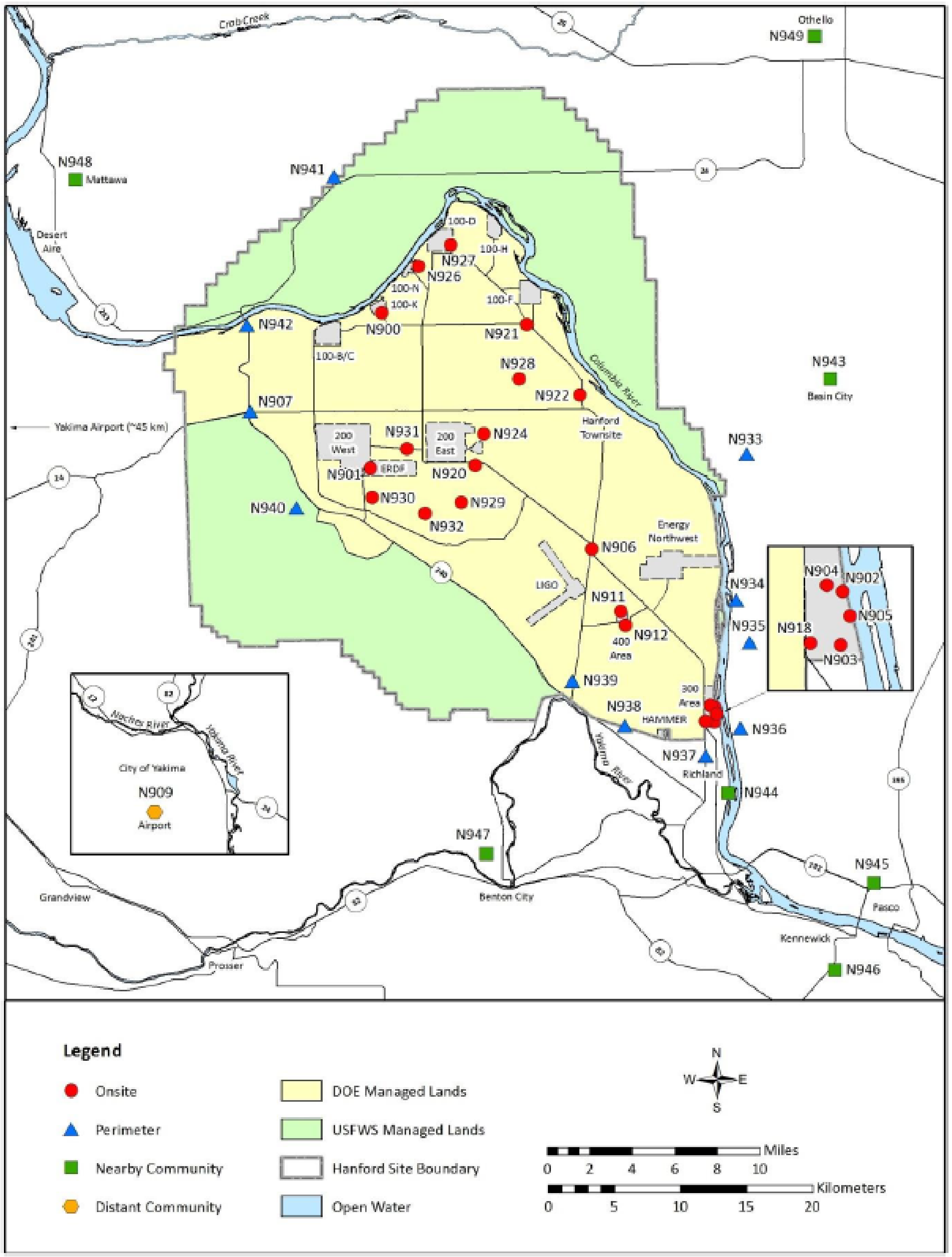

Figure 1. Hanford Site Ambient Air Sampling Locations, 3 Air Stations Indicated by N927, N921, and N922 [3]

DECISION LANDSCAPE

The decision landscape consists of factors that should be considered in the subsequent SDM analysis. These include the air concentrations and dose results from the historical data and modeling results, the desire to ensure that the solution will enhance public assurance, reduction in footprint, and sustainability, costs of the different options, and the fee that ES contractor could receive to achieve footprint reduction.

Consistent with decreasing routine air emissions due to the cessation of Hanford operations and the associated removal and remediation of sources, data analysis and dose calculations based on stack emissions both indicate that there is little value in ongoing monitoring related to routine emissions. The ability to detect gross beta and gamma activity at levels commensurate with ES programmatic reporting limits suggests that gross radioactivity measurements can be valuable for detecting and quantifying unplanned releases. Additionally, if the gross measurements can be correlated to air concentrations of specific radionuclides, these data can also be used for estimating doses.

Like analysis of air samples from monitoring stations, thermoluminescent detectors (TLDs) can be used to identify a signal from an unplanned release. The costs related to the use of TLDs is far less than the costs of air sampling, but the sensitivity of TLDs is also far poorer. TLDs have sufficient sensitivity to detect releases that approach regulatory levels of concern (100 mrem/year), but this is orders-of-magnitude lower than the sensitivity afforded by high-volume air sampling with the current air monitoring stations. That the value of identifying and quantifying releases increases as levels approach and exceed applicable thresholds is implied by the existence of these thresholds.

The scientific purpose of maintaining the three air stations under current Hanford Site conditions can only be to detect and quantify air concentrations related to unplanned releases. These releases will also need to be sufficiently noticeable that the air monitoring stations can distinguish the effect from background levels. TLD data in conjunction with radionuclide-specific data from nearer the source of a release can be used to support validation of modeled air concentrations at these distant locations in the event of an unplanned release. The location of the three air stations is downwind of the 200 Area and in the vicinity of White Bluffs and Hanford Townsite. The location is also close to the Columbia River which has public access points for fishing and boating. Hence, the location is relevant for estimating public doses in the event of a significant unplanned release.

Different options should address management factors such as sustainability of the options, flexibility for adaptive management, gaining public assurance and costs. All these factors are considered in the following SDM steps.

Development of the SDM Model

The approach to SDM modeling is developed using the following steps:

1. Describe concerns and values of the stakeholders and decision makers
2. Define objectives based on the decision landscape and the concerns and values of the stakeholders
    a. Translate concerns and values into fundamental objectives
    b. Develop measures or criteria that can be used to measure the objectives
    c. Specify value functions for each of the objectives measures (criteria)
    d. Specify preference weights for the objective measures (criteria)
3. Identify options that might achieve at least one of the objectives
4. Define management scenarios as plausible combinations of options
5. Evaluate the management scenarios
    a. Identify uncertain factors that affect the decision
    b. Connect the options to the objectives through probability modeling of the possible states of the system

The concerns and values are largely described in the Decision Landscape above. Implementation of each of the subsequent steps is described below.

The objectives are initially defined by capturing the essence of the decision landscape and discussion about concerns and values. Subsequent steps involve identifying measures that can be used as metrics for the objectives, specifying value functions for the objectives, and specifying preference weights. The fundamental objectives based on the prior discussions about the decision landscape and the concerns and values expressed by workshop participants are shown in Figure 2.

- **Optimize Environmental Surveillance Program (3 air station case study)**
  - **Maximize social sustainability**
    - Maximize public assurance
  - **Minimize environmental impacts**
    - Maximize Greenness
  - **Maximize monitoring flexibility**
    - Maximize flexibility
  - **Maximize economic sustainability**
    - Minimize cost
  - **Maximize ability to measure health impacts**
    - Detect unplanned releases

Figure 2. Objectives Hierarchy for the 3 Air Stations Decision

Each objective must be measurable, otherwise it cannot be evaluated. The measures identified for each objective are presented in Figure 3.

Objective Measures

New Measure | Delete Measure

Measure	Units
Costs	M dollars
Detect releases	yes/no
Fee for footprint reduction	yes/no
Flexibility	rank
Public assurance	rank
Sustainability score	score

Figure 3. Measures for the Objectives Hierarchy for the 3 Air Stations Decision

Once the measures for the objectives have been defined, the next step is to develop value functions that describe the value at different levels of each measure. Figure 4 shows all six value functions applied in the SDM process.

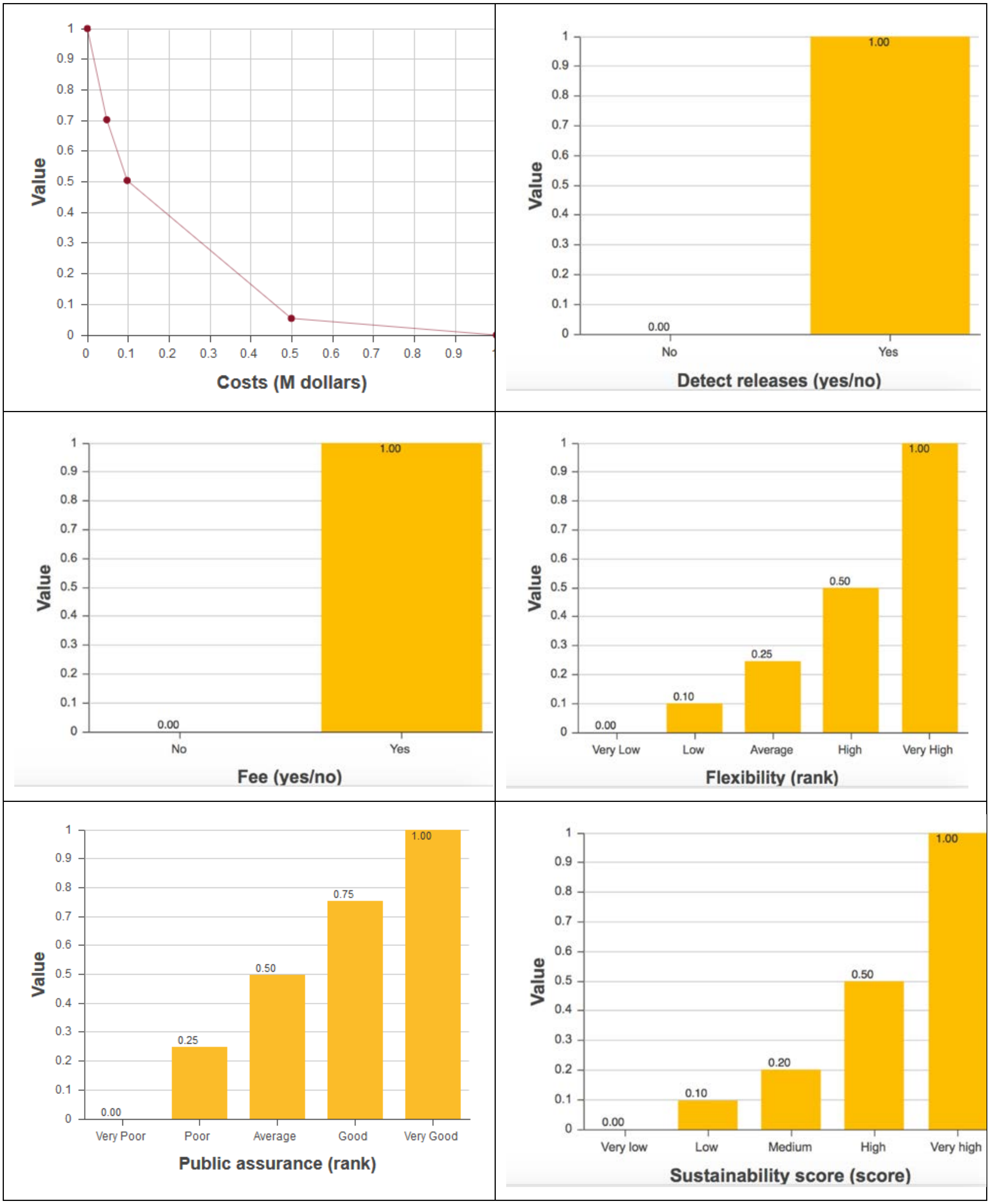

Figure 4. Values Functions for the Objectives Hierarchy for the 3 Air Stations Decision

The value functions are one of three specifications of the model that are necessary to perform the calculations needed to determine the recommended, or preferred, option. The next step in specification is weighting the objective measures to show the preference structure between the objectives. Weighting the objectives is achieved by first ranking the objectives, and then performing pairwise preference comparisons starting with the lowest ranked pair. Figure 5 shows the final preference weights.

Measure Rankings

	Measure	Units	Worst Case	Best Case	Weight Bar	Relative	Weight
1	Costs	M dollars	1	0		3.37	0.227
2	Detect releases	yes/no	No	Yes		3.37	0.227
3	Public assurance	rank	Very Poor	Very Good		3.37	0.227
4	Fee for footprint reduction	yes/no	No	Yes		2.25	0.151
5	Sustainability score	score	Very low	Very high		1.50	0.101
6	Flexibility	rank	Very Low	Very High		1.00	0.067

Figure 5. Preference Weights for the 3 Air Stations Decision

The next step is to identify options that might achieve at least one of the objectives and apply these to develop a set of management scenario. The following management scenarios were constructed from the five identified options (remove power line, replace stations, replace with solar stations, replace with TLD stations, move stations to grid):

1. Remove the power line and the associated three air monitoring stations (Remove)
    a. reduces energy use, hence providing some sustainability
    b. reduces monitoring costs
    c. guarantees the fee payment
2. Remove the power line and install a new power line to support the existing stations (Replace)
    a. Keeps the current potential to detect unplanned releases at the locations of the 3 Air Stations, but does not accrue the benefits associated with the other options.
3. Remove the power line replace stations with solar powered stations (Solar)
    a. reduces energy use, hence providing sustainability
    b. lower cost of implementation compared to replacing the power line
    c. maintains potential to detect unplanned releases
    d. provides flexibility because the solar stations are moveable
    e. guarantees the fee payment
4. Remove the power line and replace stations with TLDs mounted on stations (TLDs)
    a. reduces energy use, hence providing some sustainability
    b. lower cost of implementation compared to replacing the power line with solar stations

c. maintains potential to detect unplanned releases at levels approaching regulatory thresholds
d. provides flexibility because the TLD stations are moveable
e. guarantees the fee payment

5. Remove the power line and move the stations to the existing grid east of the Wahluke Unit of the Hanford Reach National Monument (Move)
    a. lower cost of implementation compared to replacing the power line
    b. maintains potential to detect unplanned releases, but with less sensitivity for the location of the 3 air stations
    c. guarantees the fee payment

Bayes Network

A Bayes Network was developed as a screening level solution to the 3 air station problem. The Bayes network describes the model graphically, and also serves as the computational engine for the decision analysis. Figure 6 shows the network. In the Bayes Network diagram, yellow boxes represent the decision options, green boxes represent the objective measures and pink boxes show the causal relationships linking options and objective measures. The lines, or edges, specifically depict the connections between objectives and options (scenarios) that were described in the previous section. For example, Fee is obtained for all of the options that involve removing the power line, but not for the option of Remove and Replace the power line.

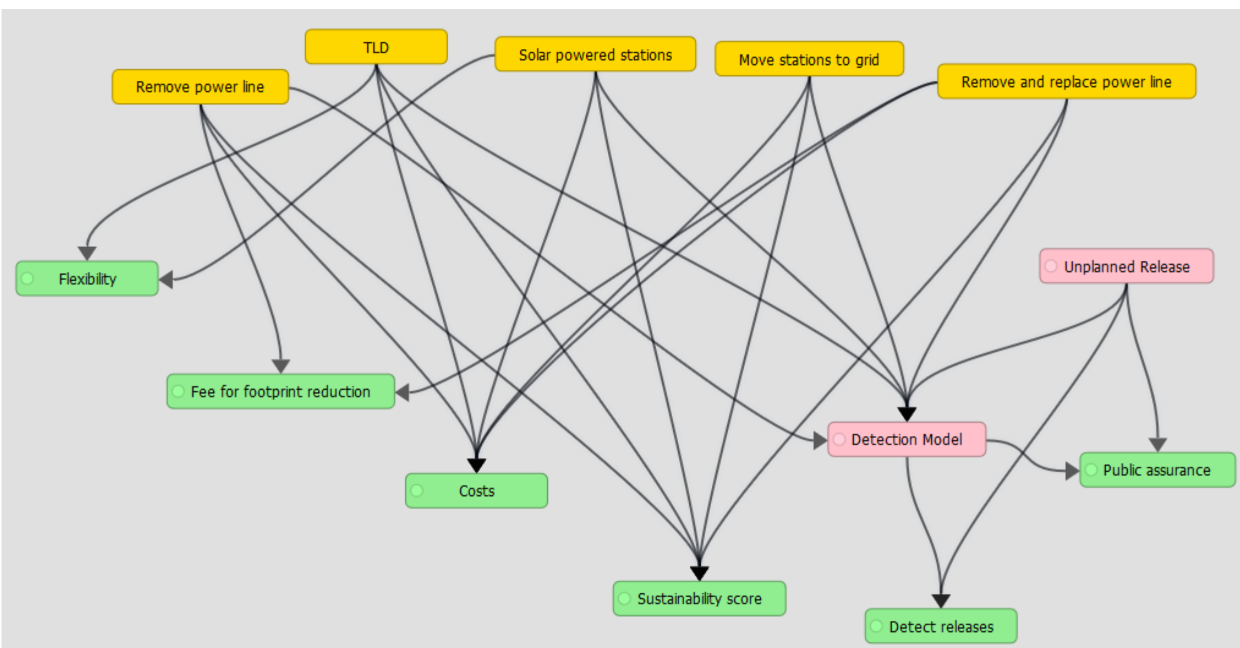

Figure 6. Bayes Network for the 3 Air Stations Decision

Probabilities are specified for the different possible states of the system, where the states are constrained by the relationships in the Bayes Net. These probabilities constitute the third of the three specifications of the Bayes Net model for calculating the preferred option, where the previous specifications included the value functions and the weighting of the objective measures. For brevity, the specific probabilities developed for the causal relationships linking options and objective measures (pink boxes) and the six measures (green boxes) are not tabulated.

RESULTS

A summary of the results is presented in Figure 7. Two of the options are extremely close in overall weighted expected value. “Replace with TLD stations” has a total weighted expected value of 0.51 and is therefore slightly preferred over “Remove power lines and stations”, which has a total weighted expected value of 0.50. But given the many assumptions and simplifications used in developing the model these results are practically equivalent. The third best option, “Replace with solar power stations”, has a total weighted expected value of 0.47 and would probably be a viable choice only if the probability of an unplanned release were judged to be much higher than 10%.

A comparison of “Replace with TLD stations” to “Replace with solar power stations” indicates a relative trade-off between cost and sustainability. Solar is considered more sustainable in the sense that it is more likely to achieve a good sustainability score, whereas TLDs are lower cost.

Note that the decision is not sensitive to the Objective Measures of “Public Assurance”, “Detect Release”, or “Fee for footprint reduction” (except for the option to Replace the power line). For the first two, this is largely because the probability of an unplanned release is very small (10%), which means that the probability of detecting an unplanned release is also very small. These objectives are, consequently, related more to the probability that an unplanned release does not occur, but the value associated with that outcome is quite small. The decision is far more sensitive to “Costs”, “Sustainability Score” and “Flexibility”.

CONCLUSIONS

The preferred option based on the SDM decision analysis model structure and specification is to remove the power line and replace the existing air monitoring stations with TLD monitoring stations. With the current model specification the difference between the preferred option and “Remove power lines and stations” is sufficiently small that minor changes in the inputs could change the preferred option. In effect, the analysis suggests that either of the two almost equally preferred options could be a reasonable choice. If larger changes were made to the current model structure or specification, the “Replace with solar power stations” option could also be a viable, particularly if the probability of an unplanned release were judged to be much higher than 10% and/or if the value of detecting an unplanned release was weighted higher. The number of TLDs is not specified in the SDM model, but the relatively low cost for this option indicates that having one, two or three TLDs would not strongly influence the model results.

A sensitivity analysis was performed to evaluate the sensitivity of the preferred option to changes in the probability of an unplanned release, which affects both objectives of being able to detect releases and public assurance. The base case value of the probability of an unplanned release is 0.1. Model results were evaluated for values of the probability of an unplanned release of 0.01, 0.2, 0.5, and 0.9. At unplanned release probabilities of 0.01, 0.1, and 0.2 the highest-ranking options are still "Replace with TLD stations" has a total weighted expected value of 0.51 and is therefore slightly preferred over "Remove power lines and stations". As the probability of an unplanned release increases to 0.5 and higher, "Replace with solar power stations" becomes the preferred alternative due to the greater expected value of its higher probability of detecting a release.

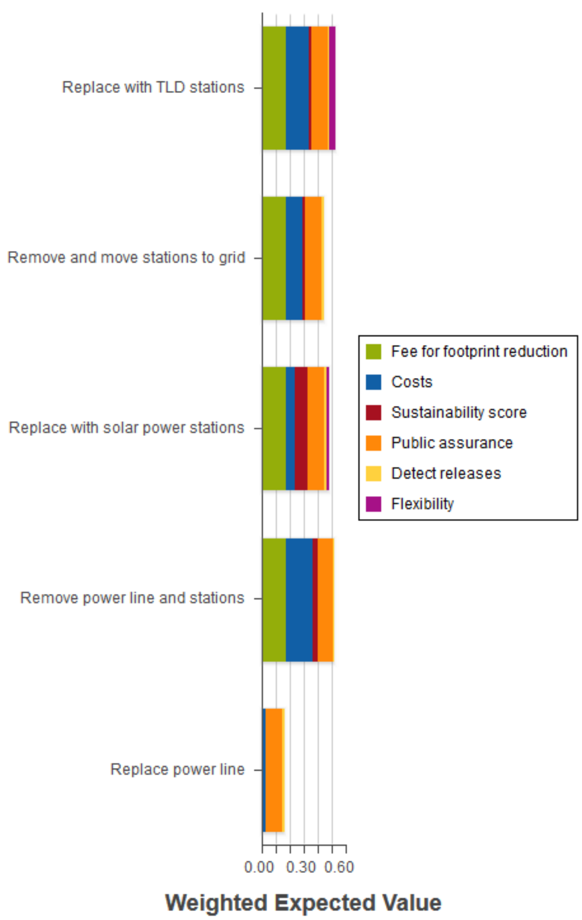

Figure 7. Evaluation of Decision Options

Ultimately, the number of locations and monitoring technology will be reassessed within the framework of optimization of the entire network. Efforts to optimize the monitoring network to reflect changing conditions on the Hanford Site have already begun [4]. The SDM approach affords an opportunity to ensure that stakeholder preferences guide all phases of the decision-making process and provides a transparent and traceable basis for each decision.

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