Decision-Based Planning

What is Decision-Based Planning?

Decision-based planning in the environmental restoration process focuses data collection on obtaining information relevant to the following fundamental questions:

- Does the site pose a real or potential risk to human health or the environment?
- If there is a risk, how can the risk be mitigated or eliminated?
- Is there a specific legal requirement beyond CERCLA that necessitates an action regardless of risk (e.g. clean closure under RCRA)?
- If there is a specific legal requirement beyond CERCLA, what needs to be done to meet the requirement?

The initial decision that needs to be made is usually broad, such as those posed above. The answers to these broad questions are obtained by asking a series of questions that are narrow, specific and answerable with a yes or a no. A plan for gathering, processing and interpreting data intended to provide resolution to each of the specific questions is developed. This plan allows the restoration team to move from abstract concepts to specific, concrete observations that can be used in problem resolution.

The goal of decision-based planning is to be able to answer these questions as quickly and as cost-effectively as possible. Decision-based planning focuses data collection activities on collecting only data that is necessary to answer these questions. If the results of the data collection activity will not change a decision that is made, then these data are unnecessary. For example, if the decision is whether a plume of groundwater contamination requires remediation, the first question is whether there is a risk. If the concern is human health risk, the only contaminant distribution data necessary are the data that identify the area over which the concentrations exceed the risk target. Data collected to determine the exact distribution of contaminants within this area are unnecessary and will not change the decision on whether the plume poses a risk.

Problem Statements and Decision Rules

Decision-based planning requires a clear, concise statement of the problem that requires resolution. The problem statement is an effective tool for communication because it focuses on the decision-making process. It provides linkage to the key decisions that need to be made at any point in time by specifying the condition requiring a response, reflecting the current conceptual model of the site and evolving as knowledge is gained.

Example Problem Statements

- Lead is found in excess of the preliminary remediation goal, 400 mg/kg, in the top 2 feet of soil over an area greater than one-quarter acre that is anticipated to be developed for residential use.
- Groundwater quality data confirm contamination beneath the installation above the MCL for TCE while historic practices indicate a strong likelihood that a portion of the contamination is present as DNAPL. Off-site migration is indicated, but not confirmed, and the nature of residual source material in the vadose zone is unknown.

Problem definition becomes the "if" part of an "if…then" decision rule. A decision rule includes:

- A statement of the unacceptable risk or condition (i.e. problem definition)
- The action that will be taken
- When necessary, the data required (or sufficient) to support the decision

Example Decision Rule

- If lead is found in excess of the preliminary remediation goal, 400 mg/kg, in the top 2 feet of soil over an area greater than one-quarter acre that is anticipated to be developed for residential use, then soils will be excavated to reduce the mean concentration below 400 mg/kg.

Decision rules are an accepted manner of linking together problem statements, likely response actions, and data required to support the decision. They clearly communicate how the restoration team intends to respond to a given set of circumstances and what thresholds or key factors will lead to taking a specific action (i.e. they summarize the decision logic).

Managing Uncertainties

Inherent uncertainties associated with the investigation and remediation of uncontrolled hazardous waste sites is the most significant challenge to effective decision-based planning. As the RI/FS guidance states (EPA, 1988):

Data are not necessary, if regardless of the results, the decision will not change (i.e. data must have the potential to change a decision before they are necessary). Only the information required to meet clearly defined objectives is collected. As soon as these objectives are met, data collection ceases. The saying "If a little is good, a lot is better" does not necessarily hold for data collection. Additional data collection activities require time and therefore delay implementation of the response. Hence, data must materially affect the quality of the decision being made if they are to justify the delays inherent in collecting them.

During site investigation activities, sampling plans should be focused on collecting only those data that are required to make decisions regarding the need for remedial action and, if necessary, the extent and type of remediation. While additional characterization data will usually reduce uncertainties regarding site conditions, these uncertainties may or may not be important in developing a remediation plan. For example, uncertainties regarding the depth and lateral extent of soil contamination may be critical if an excavation remedy is under consideration, since conservative assumptions based on limited data may result in expensive over-action. In this case, the cost of additional sampling can be weighed against the potential benefits (in terms of reduced excavation costs) to determine if the sampling is warranted. However, uncertainties regarding the nature of hazardous constituents in a heterogeneous landfill may not be critical if the presumptive remedy is containment, since the results of additional analysis are unlikely to affect the remedy.

Where there are data gaps, it is important to first determine if they constitute data needs (i.e. do they resolve significant uncertainties). In order to accomplish that, it is best to determine how the data will be used and then what amount, kind and quality of data are needed for that use. As discussed below, the Conceptual Site Model (CSM) serves as a tool to help identify unnecessary or unproductive data collection efforts. Data associated with incomplete or nonviable pathways are unnecessary and can be eliminated from plans. Conversely, data to complete knowledge of viable pathways is important. Data collection should target those areas of uncertainty that currently prevent completion of the problem statement and subsequently selection and design of the response.

> *"The objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to gather information sufficient to support an informed risk management decision regarding which remedy, including no further action, is the most appropriate for a given site."*

Why is Good Problem Definition Important in Decision-Based Planning?

Poor problem definition results in the following problems:

Poor project focus

- Overly extensive or ineffective investigation (e.g. trying to remove insignificant uncertainties)
- Extended remedy selection process

Poor project execution

- not fixing the problem
- fixing a non-problem
- fixing the problem at greater cost than needed

Poor project closeout

- inappropriate exit strategy
- prolonged site closeout
- inappropriate or inadequate contingency plans

How is Decision-Based Planning Implemented?

Decision-based planning is implemented using the Data Quality Objectives (DQO) process. The DQO process is a seven-step iterative planning approach used to prepare plans for environmental data collection. The DQO process is described in detail in the Environmental Protection Agency's guidance document "Data Quality Objectives Process for Hazardous Waste Site Investigations" (EPA, 2000).

Conceptual Site Model

A significant component of the DQO process and thus decision-based planning is the CSM. The CSM is a functional description of the contamination problem and is used as a framework to identify what is known about the site and what is not known (uncertainties). Sometimes called a conceptual site ***exposure*** model, the CSM identifies the source-pathway-receptor relationships that are required to present a risk. A hydrogeochemical conceptual site model is a subset of the site exposure model and is used primarily to characterize and determine whether there are current or potential future pathways along which contaminants could migrate from the source to the receptor at concentrations that could pose a risk.

In the simplest terms, a conceptual site model is an overall description of the processes and circumstances that are responsible for the magnitude and distribution of site contamination. In general, it starts with a description of the geology and hydrogeology at a scale thought to be relevant to the particular site under study. Points of recharge and discharge, surface and groundwater interactions, and a water balance estimate are usually included in the hydrogeology. A second feature is a description of known or potential source areas and the probable chemicals of concern, and a hypothesis as to how the contaminants entered the subsurface, how they may be distributed, and in what directions and at what rates they may be migrating; both in the vadose zone and in the groundwater zone or zones. The third key feature of a CSM is explicit identification of current and possible future receptors of the contamination. A conceptual model is a description of the site as an interconnected system comprised of several sub-systems, the interdependence of which is given explicit consideration.

While there are many different forms of a CSM that the project management team may elect, a good CSM accomplishes the following five objectives:

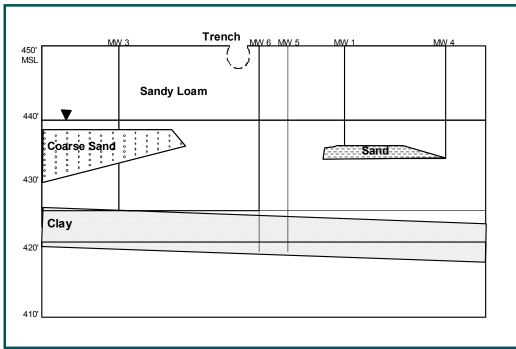
- Identifies and locates contaminants, sources, release and transport mechanisms, transport pathways, intake routes, and receptors
- Delineates contaminant, concentrations in media, and flux rates by pathway in narrative and graphical forms
- Quantifies background concentrations for each formation or unit
- Explicitly recognizes and highlights uncertainties (known and unknown conditions)
- Evolves with data and other information (new site-use history information)

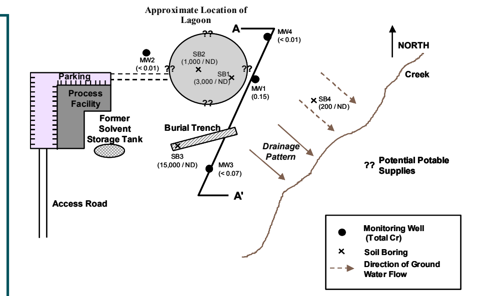
A CSM benefits from use of multiple formats to best portray available information. A good narrative summary is the best means of describing the Area of Contamination (AOC), its history, the nature of sources, quantitative aspects of migration pathways, and the identity of ecological and human receptors as well as the circumstances under which exposure is anticipated. The narrative should be simple and concise. When data are presented, they should be synoptic, but representative of key findings relative to the problem statement and potential risks. The CSM will be a major part of any communications with stakeholders and, therefore, should be written without a lot of technical jargon or misleading information.

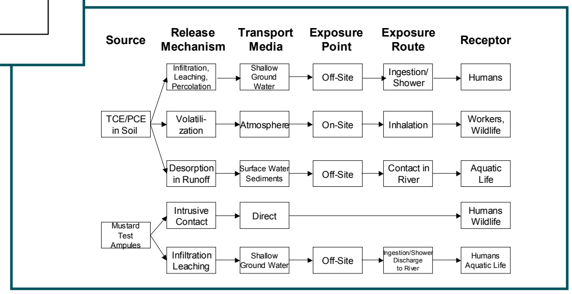
Examples of Graphical Conceptual Site Models

Maps should always be included in a CSM. At a minimum, maps should include relative position of sources, pathway determinants and near-field boundary constraints, surface water features, prevailing wind pattern, and plume contours. When multiple contaminants are present, it may be necessary to produce separate maps of each contaminant group to keep from obscuring data through multiple overlays. If subsurface contamination is present, a vertical profile of the site should be included. Fence diagrams or representative boring logs may suffice, but simplified forms focused on the most important features are best to facilitate communication with stakeholders.

A standardized summary wire diagram format has been developed for use in EPA documents. These depictions show at a glance the identity of completed pathways, including their source, release mechanisms, transport mechanisms, intake routes and receptors. This provides a handy summary, but not a substitute for the entire CSM package. Quantitative aspects, spatial relations, and unique features that impact on the true nature of resultant exposure are not included in the wire diagram. Moreover, it serves more to summarize the findings of investigations than to focus remaining activities.







Example Conceptual Site Models

Clearly a CSM does not simply appear in final form. Rather, it is the result of an evolutionary process in which hypotheses are advanced, tested, and modified as more data is obtained. CSMs change as more is learned, and become increasingly more detailed and reliable. Among the many benefits of a CSM is that it forces a focus, discipline and consistency on the entire process of data collection and decision-making. Decisions concerning data collection, remediation and so on are guided by the conceptual site model, and are made with specific objectives in mind that give full consideration to the system as a whole. CSMs are used to clearly identify and define the problem and focus data collection activities to determine whether there is a problem and how to mitigate the problem. Good conceptual models must be grounded in sound theory and underpinned with sound and sufficient data. The CSM should be initiated at the start of a project and carefully maintained and updated throughout the life of site activities. CSM development must be viewed as an explicit part of the remediation process

In those cases of highly complex subsurface systems, parameter definition may require unobtainable amounts of detailed characterization data. In these cases, it is important to understand which processes are actually dominating the behavior of the system and to define parameters appropriate to those processes. Understanding which characteristics control fate and transport behavior in the subsurface and also understanding how those characteristics can be measured at the appropriate scale over large subsurface volumes using both indirect and direct techniques is one of the most important parts of CSM development.

Sites that are very large in spatial extent and exhibit intra- and inter-site variations in geologic and hydrologic conditions are common at Army bases. Heterogeneity arises from the spatial variability in geological, chemical, and biological properties of the subsurface. A fundamental understanding of these properties, and especially the geological framework is a necessary prerequisite to understanding the fate and transport of contaminants. Heterogeneity may occur at several spatial scales in complex subsurface systems, but they may control contaminant fate and transport processes only at one or a few scales. The primary knowledge gaps are in understanding 1) the heterogeneity scales that govern these processes; 2) how to characterize this heterogeneity without having to perform an exhaustive characterization of the subsurface; 3) and how to represent this heterogeneity in a meaningful way, specifically how does the heterogeneity of the subsurface impact our understanding of risk and our ability to effectively mitigate the risk. In many cases, the heterogeneity is such that the subsurface can never be completely characterized or remediated. In these cases, alternative approaches to uncertainty management, such as contingency planning, will need to be implemented.

Summary

Decision-based planning provides a focus to restoration programs. Using the tools discussed above ensures that data collection activities are targeted toward answering key questions and support key decisions. Decision-based planning is essential to efficient and effective completion of restoration efforts.

Development of problem statements and decision rules clearly define the objectives of the investigative program and criteria for making decisions to keep the program focused on an end goal.

More Information

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