Decision Tool For Landfill Remediation

August 1999

Prepared for:
Air Force Center for Environmental Excellence
Technology Transfer Division
(AFCEE/ERT)
3207 North Road
Brooks AFB, TX 78235-5363

MITRETEK SYSTEMS

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Executive Summary

The Air Force is responsible for a large number of landfills that must be remediated, removed, or closed. Such efforts are generally expensive, and informed and cost-effective decisions depend on knowledge of the remedial decision process for landfills, as well as familiarity with the requirements and opportunities that the process affords. This report traces the overall remedial decision process for landfills through flowcharts, textual descriptions of the process, and explanatory notes that accompany the flowcharts. In addition, this report identifies both the process requirements and the opportunities for selecting cost-effective alternative solutions based on site-specific factors, regulatory requirements, and current guidance. This report is part of a four-document series concerning landfill remediation decisions. The other three documents *Landfill Covers for Use at Air Force Installations*, February 1999, *Survey of Air Force Landfills, Their Characteristics, and Remediation Strategies*, July 1999, and *Landfill Remediation Project Managers Handbook*, Fall 1999 also address important considerations for making effective remedial decisions for Air Force landfills.

Making remedial decisions for a landfill is a complex process that involves gathering and evaluating existing data, determining whether remediation is warranted or required, and deciding whether the containment presumptive remedy is appropriate for the landfill's source area. The *source area* is an area that may be a continuing concern because it might serve as a source of contaminants of concern (COCs) that could be released to the environment unless they are either removed from the landfill or contained through the presumptive remedy.

A *presumptive remedy* is a preferred remedy or a set of remedies that is presumed to be the most appropriate method for addressing a specific type of site. The presumptive remedy for landfills is containment. The remedial decision process for each landfill can be streamlined substantially if the existing data are sufficient to justify the containment presumptive remedy. If the available information is not sufficient or the containment presumptive remedy is clearly not appropriate, then fully developed and potentially expensive conventional remedial investigations (RIs), feasibility studies (FSs), or engineering evaluation/cost assessments (EE/CAs) may be needed to determine whether remediation is warranted or required and, if so, to evaluate the remedial alternatives.

The containment presumptive remedy streamlines the decision process and is likely to be applicable to the majority of Air Force landfills. Thus, deciding whether to use the presumptive remedy is an important step in the decision process. Limited information that clearly shows that the waste in a landfill has contaminated other media and is a potential threat to human health or the environment is usually sufficient to justify selecting the presumptive remedy. Selecting the presumptive remedy also depends on evaluating several important site-specific factors to determine whether it is appropriate and likely to be the best option compared to other alternatives (e.g., excavation and off-site disposal of the landfill contents).

The containment presumptive remedy most readily applies if the contents of the landfill meet the definition of municipal-landfill–type wastes. The contents of an Air Force landfill that contains military-specific wastes can still meet the definition of municipal-landfill–type wastes if the military-specific wastes do not necessarily pose higher risks than industrial wastes commonly found in municipal landfills. However, the presumptive remedy may also be applicable to a landfill with contents that do not meet the municipal-landfill–type definition if containment can be shown to be appropriate for the landfill.

The containment presumptive remedy for a landfill is accomplished by constructing and implementing some or all of the following five components of the presumptive remedy:

- Landfill cover
- Landfill gas collection and treatment system
- Source-area groundwater control system
- Leachate collection and treatment system
- Institutional controls

The remediation requirements to be met by these components must be developed in a site-specific manner. Defining these requirements allows the selection of presumptive remedy components that are both needed and likely to be effective at the landfill. Each component selected is designed to be both an integral part of the overall presumptive remedy and compatible with the likely overall final remedy. Innovative technologies are considered when they offer the potential for superior performance and/or lower costs and when they meet the goal of protecting human health and the environment.

A landfill cover is a critical component of the presumptive remedy at most landfills. A new landfill cover is likely to be needed if the existing cover is insufficient to meet the site-specific remediation requirements. A new cover may consist of any one of the following, as appropriate for the specific landfill:

- Enhancement of the existing cover
- Alternative covers, such as the evapotranspiration (ET) cover
- A conventional single- or double-barrier cover

A gas collection and treatment system will not ordinarily be required for a landfill unless the site-specific remediation requirements include specific objectives that will not be met through other presumptive remedy components selected for the landfill. Conventional barrier-type covers are more likely than other covers to require gas control systems. One or more groundwater control systems may be needed if lateral flow of groundwater or vertical infiltration of surface water through the selected cover can leach COCs from the wastes. A leachate collection system is also a possible presumptive remedy component at a landfill where leachate samples from nearby seeps contain COCs above established standards. Further, institutional controls can constitute a useful component of the presumptive remedy to supplement and help protect the long-term integrity of the engineering components.

A risk assessment is conducted to evaluate the complete exposure pathways that the components of the presumptive remedy are not likely to address adequately. An RI/FS or EE/CA is performed with the limited objective of identifying unacceptable risks that may be associated with these pathways.

Uncertainties about the landfill contents—for instance, the possible existence of unbreached drums—may require long-term monitoring of groundwater, surface water, leachate, air, or sediment. The principal objective of such monitoring is to ensure long-term effectiveness and to prompt correction of any failures that may occur in the remedy in the future.

This decision tool describes the remedial decision process for landfills. The core of this decision tool is Section 3, *Decisions for Landfill Remediation*, which consists of 15 figures that present a step-by-step approach to landfill remediation decision-making. It should be possible to obtain definitive answers to most of the questions posed in these figures. However, the discussion in Section 2 (*Landfill Remediation*)—and the notes in Section 4 (*Explanatory Notes for Decision Tool Figures*) may be relied upon for further assistance when definitive answers are not obvious. A glossary and a list of references are also included in the document for this purpose.

Taken together, the discussion, figures, and notes of this decision tool present a comprehensive guide through the decision process. However, not all of these steps and notes will be needed to arrive at a decision for a specific landfill. Typically, following the steps outlined in **Figure 1** (Landfill Remediation Flow Chart) for a given landfill—and referring only to the cited figures and notes needed in the decision process for that landfill—will trace a relatively simple path through a limited number of figures and notes.

1 Introduction

The Air Force is responsible for a large number of landfills that must be remediated, removed, or closed. These efforts are generally expensive, and informed and cost-effective decisions depend on knowledge of the remedial decision process for landfills, as well as familiarity with the requirements and opportunities that this process affords. This report traces the overall remedial decision process for landfills through flowcharts, textual descriptions of the process, and explanatory notes that accompany the flowcharts. In addition, this report identifies both the process requirements and the opportunities for selecting cost-effective alternative solutions based on site-specific factors, regulatory requirements, and current guidance. This report is part of a four-document series concerning landfill remediation decisions. The other three documents—*Landfill Covers for Use at Air Force Installations*, February 1999, *Survey of Air Force Landfills, Their Characteristics, and Remediation Strategies*, July 1999, and *Landfill Remediation Project Managers Handbook*, Fall 1999 also address important considerations for making effective remedial decisions for Air Force landfills.

The areas of concern at a landfill site can be divided conceptually into two major categories: (1) the source area and (2) the receptor contact points to which contaminants can migrate from the source area.

The "source area" refers to the area where the landfill contents are located. Contaminants now found at a receptor contact point some distance from the landfill may originate in the source area. Further, this area may be a current or future source of contaminants to which human or ecological receptors may be exposed if the contaminants in the source area are not removed or contained. On the other hand, if the source area no longer serves as an actual or potential source of releasable contaminants, the landfill may be a likely candidate for a no-further-action decision.

Making remedial decisions for a landfill is a complex process that involves gathering and evaluating the existing data, determining whether remediation is warranted or required, and deciding whether the containment presumptive remedy is appropriate for the source area. If the existing data are sufficient to justify the presumptive remedy, the remedial decision process for the landfill can be streamlined substantially. If the existing information and the results of any limited additional investigation are not sufficient or if the presumptive remedy is clearly not appropriate, then a remedial investigation (RI) may be needed to determine whether remediation is warranted or required or a feasibility study (FS) or engineering evaluation/cost analysis (EE/CA) may be required to evaluate the remedial alternatives.

This decision tool includes four major sections that describe the remedial decision process for landfills. Section 1 introduces the decision tool process, and Section 2 discusses the process more fully. The core of this decision tool is Section 3, which consists of 15 figures that outline the decision tool process. Section 4 provides the notes that are referenced in the

figures; these notes provide greater detail and additional information regarding the decision tool process. The document also includes a list of the references that provide the basis for this decision tool, as well as a glossary that further defines the terminology used in the figures.

The figures are designed in such a way that it should be possible to obtain definitive answers to most of the questions posed. Where the answers are not definitive, the discussion in Section 2, the notes in Section 4, the references, and the glossary may be relied upon for further assistance.

The main figure in Section 3 is **Figure 1**, which provides a summary of the overall decision process. **Figure 1** refers to **Figures 2, 3, 5, 6, 7,** and **14** for more detailed information. Each of these six figures returns to the point in **Figure 1** where it is cited. Similarly, **Figures 3, 6, 7,** and **14** cite other figures. Each cited figure provides a more detailed illustration of the decision tool process and returns to the citation point or another specified point in the original figure.

Taken together, the discussion of Section 2, the figures of Section 3, and the notes of Section 4 present a comprehensive guide through the decision process for landfill remediation. However, not all of these steps and notes will be needed to arrive at a decision for a specific landfill. Typically, following the steps outlined in **Figure 1** for a given landfill—and referring only to the cited figures and notes needed in the decision process for that landfill—will trace a relatively simple path through a limited number of figures and notes. For example, if the presumptive remedy is found to be clearly inappropriate for a landfill in **Figure 1**, then only **Figure 14** and **Figure 15** will have further relevance for that landfill.

2 Landfill Remediation

2.1 Decision Process Overview for Air Force Landfills

As indicated in **Figure 1**, the decision process for a landfill begins with two principal questions:

- Is remediation warranted or required at the landfill?
- If so, is the presumptive remedy appropriate for the landfill?

The answers to these questions depend on gathering and reviewing existing information, performing a site visit, and developing and refining a conceptual site model (CSM) as fully as possible, based on the information available about the landfill and surrounding areas. The answer to the first question will provide the justification for either a "no further action" decision or a decision to remediate the landfill. If there is sufficient evidence to support a decision to remediate, then the answer to the second question will indicate whether the RI/FS or EE/CA process can be streamlined through the application of the presumptive remedy for landfills. The principal objective at this early stage of the decision process is to answer the first question—and also answer the second question if remediation is clearly warranted or required—by relying to the extent possible on existing data and any additional information obtained through a site visit (**Figure 2**). Little additional source investigation should be needed to provide answers to these questions because Air Force landfills typically have already been investigated sufficiently. As indicated in **Figure 2**, **Note 7**, securing additional data may require the following:

- Sampling groundwater from existing wells
- Sampling leachate from nearby seeps[1]
- Sampling surface or subsurface soils
- Sampling landfill gas in the soil or ambient air

For most landfills, the available information will be sufficient either to support a no-further-action decision or to justify a decision to remediate.

A no-further-action decision is appropriate for a landfill if the available information clearly shows that no complete pathways exist or that all of the complete pathways pose negligible risks to human health and the environment. However, remediation can be justified if the concentrations of one or more contaminants clearly exceed an appropriate standard or if another condition provides clear justification for remediation (**Figure 1**, **Note 1**).

[1]Sampling leachate from Air Force landfills may not be possible because Air Force landfills typically have no liners and, thus, leachate can move through the vadose zone when unsaturated. Further, water collected from seeps near unlined landfills may not be representative of leachate from the main body of the waste.

The potentially costly conventional RI (**Figures 14** and **15**) must be performed if the first question cannot be answered with sufficient certainty based on the existing information and the results of any limited additional investigation. The goal of this conventional process will be to determine whether or not remediation is warranted through additional site characterization and a fully developed baseline risk assessment.

Further, the potentially costly conventional FS or EE/CA process must be performed if remediation is warranted or required but the second question cannot be answered with sufficient certainty. At this stage, the conventional process will determine the appropriate remedial and/or removal action(s) for the landfill through the use of a complete technology identification and screening step. This step will include identifying and screening all technologies normally identified and screened in a conventional FS or EE/CA, including the components of the presumptive remedy and a number of other possible technologies.

2.2 The Presumptive Remedy for Landfills

A presumptive remedy is a preferred remedy or a set of remedies that are presumed to be the most appropriate for addressing a specific type of site based on historical patterns of remedy selection and the U.S. Environmental Protection Agency's (EPA's) scientific and engineering evaluation of performance data on technology implementation for the site type. The presumptive remedy for landfills is containment. The following subsections discuss the nature of the presumptive remedy, gathering and evaluating the information needed to support a presumptive remedy decision, justifying the decision to remediate, and determining the appropriateness of the presumptive remedy for an Air Force landfill.

2.2.1 Nature of the Presumptive Remedy

Containment of the landfill contents is accomplished through the construction and/or implementation of some or all of the following five components of the presumptive remedy:

- Landfill cover
- Landfill gas collection and treatment system
- Source-area groundwater-control system
- Leachate collection and treatment system
- Institutional controls

The presumptive remedy enables streamlining the RI, risk assessment (see **Section 2.7**), FS, and/or EE/CA(s) for the landfill. Existing data are relied upon to the extent possible to determine whether the presumptive remedy is appropriate for a landfill. To the extent possible, the existing data are also relied upon to develop a streamlined focused feasibility study (FFS) and/or EE/CA(s). The FFS is streamlined by evaluating only the need for and likely effectiveness of each of the five presumptive remedy components against the No Further Action alternative for the landfill. Little source investigation should be needed to support this effort unless the available information indicates the need to investigate hotspots.

Streamlining the process in this way saves time, money, and other resources that would otherwise be expended to complete a conventional RI/FS or EE/CA for the landfill. However, it is important also to emphasize that the final remedy—including the presumptive remedy and other remedial and removal actions—must address all complete exposure pathways and Contaminants of Concern (COCs) for both human health and ecological receptors.

The presumptive remedy streamlines the decision process and is likely to be applicable to the majority of Air Force landfills. Thus, deciding whether to use the presumptive remedy is an important step in the decision process for landfills at Air Force bases.

2.2.2 Information Needed to Support a Presumptive Remedy Decision

As noted above, the information used to characterize the landfill and to determine the applicability of the presumptive remedy will consist of existing data to the extent possible (**Figure 2**). The relevant information about the landfill includes the types and distribution of wastes that have been disposed of at the landfill, soil and groundwater contamination, the operating history of the landfill, monitoring data, state permit and/or closure information, land use or reuse plans, and the size or volume of the contents of the landfill. If the presumptive remedy is being considered as a likely base-wide strategy, the number of landfills on the facility will also be important.

Little new source investigation should be needed to determine whether the presumptive remedy is appropriate. As indicated in **Figure 2**, **Note 5**, focused source-area investigations may be needed if the available information indicates the need to characterize known or suspected hotspots (e.g., a highly contaminated area smaller than about 100,000 cubic yards within a much larger landfill). Likewise, focused source-area investigations may be needed to evaluate the option to excavate and dispose of the contents of a relatively small landfill (e.g., smaller than about 100,000 cubic yards) as an alternative to the presumptive remedy.

2.2.3 Justification for the Presumptive Remedy

The decision to use the presumptive remedy for a landfill usually depends on the existence of information that clearly shows that there are likely exposures and the concentrations of contaminants in media at or near the landfill exceed risk-based concentrations, applicable or relevant and appropriate requirements (ARARs), or other relevant standards or guidance levels. The presumptive remedy is a viable option if the available information indicates that the concentrations of one or more contaminant in the groundwater, leachate, or landfill gas at the landfill boundary clearly exceed an appropriate standard or if another condition provides clear justification. If this information clearly indicates that remediation is warranted or required, then a fully developed quantitative baseline risk assessment is not needed to justify the presumptive remedy. As indicated in **Figure 1**, **Note 1**, the presumptive remedy can be readily justified by limited information that clearly shows that the waste in a landfill has contaminated other media and is a potential threat to human health or the environment. For example, the finding that a

landfill contaminant clearly exceeds its maximum contaminant level (MCL) at the landfill boundary provides sufficient justification for the presumptive remedy if the contaminant can migrate to enter a current or future drinking-water supply.

2.2.4 Appropriateness of the Presumptive Remedy

Selection of the presumptive remedy for a landfill depends on the consideration of several important factors to determine whether the presumptive remedy is appropriate and likely to be the best option compared to alternatives such as excavation and off-site disposal of the landfill contents. These factors are discussed in the following subsections.

2.2.4.1 Landfill Size and Land Use Plans

If the landfill is relatively small, then reasonably anticipated land uses and preferred future reuses are especially important considerations (see **Figure 3** and **Notes 8** and **9**). A rule of thumb is that a relatively small landfill contains less than about 100,000 cubic yards (e.g., about 4 acres, 15 feet deep, or 2 acres, 30 feet deep).

Relatively small landfills are likely candidates for excavation and off-site treatment and/or disposal of the landfill contents, depending on land use or reuse plans and the practicality of excavating the contents. As indicated in **Figure 3**, **Note 10**, the practicality of excavating depends, in turn, on site-specific factors, such as hydrogeology, volume of contents, and the safety and cost of excavation and disposal. Evaluating excavation as an alternative to the presumptive remedy requires balancing the long-term benefits of lower operation and maintenance costs and unrestricted land use against the initial high capital construction costs and risks associated with excavation and disposal.

The presumptive remedy is not likely to be the most appropriate alternative for a relatively small landfill unless the presumptive remedy is compatible with current land uses or preferred reuse options and/or if excavation is not a practical alternative.

2.2.4.2 Municipal Landfill-Type Wastes

The presumptive remedy is most readily shown to be applicable if the contents of the landfill meet the definition of municipal-landfill–type wastes (**Figure 4**). Municipal-landfill–type wastes (1) are characterized by relatively low risks (except for hotspots), (2) are impractical to treat, and (3) at Air Force landfills, typically consist primarily of wastes that are commonly found in municipal landfills (**Figure 4**, **Note 13**).

As indicated in **Figure 4**, **Note 12**, the presumptive remedy allows excavation and on-site consolidation, treatment, or off-site disposal of occasional hotspots or any wastes in contact with groundwater (if required by state regulations) that may contain industrial hazardous wastes and/or high-hazard military-specific wastes. The presence of hazardous wastes in the hotspots at an Air Force landfill does not preclude the landfill contents from meeting the definition of municipal-landfill–type wastes (see *Application of the CERCLA Municipal Landfill Presumptive Remedy to Military Landfills*, U.S. Environmental Protection Agency, 1996).

Further, the low-hazard military-specific wastes are generally no more hazardous than some industrial wastes in municipal landfills (**Figure 4**, **Note 14**). The presence of low-hazard military-specific wastes does not preclude the landfill contents from meeting the definition of municipal-landfill–type wastes. If military-specific wastes are present, military waste experts should be consulted.

The contents of an Air Force landfill that contains military-specific wastes can still meet the definition of municipal-landfill type wastes if the military-specific wastes do not necessarily pose higher risks than the industrial wastes commonly found in municipal landfills (**Figure 4**, **Note 15**).

Further, municipal landfills characteristically contain lesser quantities of hazardous wastes than other wastes. Likewise, an Air Force landfill with contents that meet the definition of municipal-landfill–type wastes will contain lesser quantities of hazardous wastes (industrial and/or military-specific) than other wastes (**Figure 4**, **Note 16**).

2.2.4.3 Landfills with Contents not Meeting Municipal-Landfill Type Definition

Some Air Force facilities have a relatively high level of industrial activity (e.g., major aircraft repair depots). There may be a higher proportion and wider distribution of industrial and/or military-specific hazardous wastes at these facilities. Landfills at these facilities are less likely to meet the definition of municipal-landfill–type wastes.

However, the presumptive remedy may also be applicable to a landfill with contents that do not meet the municipal-landfill–type definition if containment can be shown to be an appropriate remedy for the landfill (**Figure 3**, **Note 11**). For example, the presumptive remedy may be appropriate if site investigation or attempted treatment may cause greater risks than leaving the waste in place because ordnance is present in the landfill. Conversely, the presence of a high water table or a sensitive ecosystem may cause the presumptive remedy to be less desirable than other options.

2.3 Hotspots

"Hotspots" are occasional, small, and highly contaminated areas relative to other areas of a site. Hotspots are found at sites where the contamination is unevenly distributed. Generally, hotspots are areas where the risks associated with the overall contamination at a site could be reduced substantially and cost-effectively through focused excavation and/or treatment. In addition, hotspots that are not excavated or treated prior to implementation of the containment presumptive remedy may be areas most likely to compromise the presumptive remedy at a landfill. Thus, efforts to identify, characterize, and evaluate remedial alternatives specific for hotspots in a landfill can yield an opportunity to reduce the risks quickly and substantially; it can also help to ensure the integrity of the contaminant presumptive remedy, if needed.

As indicated in **Figure 5**, **Note 20**, if hotspots are known to be present, they should be treated as unique sites within a landfill. Any additional sampling efforts should be focused on

further characterizing the known or suspected hotspot(s) in the landfill. These limited investigations may consist of the following:

- Conducting geophysical and/or soil-gas surveys to delineate hotspots
- Excavating test pits or drilling soil borings to confirm the nature and extent of hotspots (if the absence of ordnance and other high-hazard military-specific wastes in these areas is known with sufficient certainty)
- Collecting and analyzing soil samples to determine the characteristics of the hotspots

As indicated in **Figure 1**, a plan should be developed to excavate and/or treat hotspots prior to implementing the presumptive remedy, if needed. As indicated in **Figure 1**, **Note 2**, excavation will be required if one of the following options is selected for the hotspot(s) materials:

- On-site consolidation
- Ex-situ treatment
- Off-site disposal

Excavation and on-site consolidation are usually performed to relocate materials from hotspot(s) in outlying areas of the landfill into more central areas of the landfill contents to minimize the cover size. On-site consolidation does not require treatment because Resource Conservation and Recovery Act (RCRA) land disposal restrictions (LDRs) do not apply (see Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites, U.S. Environmental Protection Agency, 1991). If excavation of the hotspot(s) is not required or not practicable, then the conclusions should be documented that, based on the available information, (1) no on-site hotspots amenable to excavation and/or treatment exist, and (2) the presumptive remedy is sufficient to protect human health and the environment.

2.4 Presumptive Remedy Action

Selection of the presumptive remedy for a landfill requires an effort to involve the stakeholders, consider their input, and gain their acceptance of the presumptive remedy. It also involves the execution of a streamlined FFS or EE/CA focused on achieving the goal of containing the landfill wastes. A critical step of the FFS or EE/CA is the comparative evaluation of likely combinations of the presumptive remedy components against the No Further Action alternative. Evaluating the No Further Action alternative at this stage is required by EPA's National Contingency Plan. The following subsections address this process and discuss the evaluation of a landfill cover, gas collection and treatment system, and groundwater controls as likely components of the presumptive remedy for a landfill.

2.4.1 Stakeholder Involvement

As noted in **Figure 6** and **Note 21**, the community and local, state, and federal regulators must be notified that the presumptive remedy is being considered before drafting an RI/FS or

EE/CA work plan. It is important for all stakeholders to understand the differences between the presumptive remedy and the usual cleanup process, as well as the benefits of the presumptive remedy process. As mentioned above, the decision to use the presumptive remedy can be for one landfill or as part of a base-wide strategy, depending on the nature of the wastes, the landfill size, the land reuse potential, public acceptance, and other factors.

2.4.2 Remediation Requirements

As indicated above and in **Figures 1** and **6**, an FFS or EE/CA should be developed to evaluate the components of the presumptive remedy against the No Further Action alternative for the landfill. As indicated in **Figure 1**, **Note 3**, the presumptive remedy requirements should be developed in a site-specific manner. This procedure depends on numerous site-specific factors, including landfill waste type, quantity, and age; climate; landfill history and geologic setting; local surface water and groundwater use; and regulatory requirements.

The requirements for a specific landfill may include one or more of the following:

- Estimating the amount of water that previously percolated through the landfill contents
- Minimizing infiltration of water into the landfill contents
- Controlling gas emissions
- Controlling erosion
- Promoting surface drainage
- Collecting, removing, treating, and/or disposing of leachate
- Preventing surface water run-on
- Protecting barrier-type covers from freeze/thaw effects
- Protecting covers from burrowing animals
- Preventing direct human contact with landfill contents
- Preventing the scattering of waste by wind, water, or scavengers
- Removing wastes in contact with groundwater
- Restricting access to the site
- Minimizing odors

Defining these requirements allows the selection of presumptive remedy components that are needed and are likely to be effective.

If the No Further Action alternative is found to be appropriate and acceptable at this point in the process, then this conclusion should be documented (**Figure 1**). Otherwise, the conclusion should be fully documented that one or more of the components of the presumptive remedy are needed and are likely to be effective (**Figure 7**).

As indicated in **Figure 1**, **Note 4**, combinations of presumptive remedy components should be used—as appropriate for the site—to protect human health and the environment. Each component selected should be designed to be both an integral component of the overall presumptive remedy and compatible with the likely overall final remedy. Innovative

technologies should be considered when they offer the potential for either superior performance or lower costs toward the goal of protecting human health and the environment from contaminant releases. The selected presumptive remedy components are often combined with other actions (for example, supplying a community with an alternative water supply to prevent or eliminate current or imminent exposure) to form a complete remedy. The final remedy (1) should include the presumptive remedy components selected in combination with other remedial and removal actions and (2) must address all complete exposure pathways and COCs for both human and ecological receptors potentially exposed to the COCs.

2.4.3 Landfill Cover

A landfill cover is a critical component of the presumptive remedy at most landfills. As noted in **Figure 8**, constructing a new landfill cover is likely to be needed if the existing cover is insufficient to meet site-specific requirements to prevent surface water infiltration, direct contact with the landfill contents, or surface erosion. As noted in **Figure 9** and **Notes 25-28**, a new cover may consist of any of the following, as appropriate for the specific landfill:

- Enhancement of the existing cover (e.g., regrading or revegetating existing fill on a landfill in which a substantial portion of the contents lie below a water table that cannot practicably be lowered)
- Alternative covers—such as the ET cover—that meet or exceed site-specific requirements for preventing direct contact with wastes, minimizing erosion, or controlling infiltration (These covers may satisfy the requirements more reliably and for substantially less construction and maintenance costs than a conventional single- or double-barrier cover)
- Conventional single- or double-barrier cover

2.4.4 Landfill Gas Collection and Treatment System

Few Air Force landfills produce significant amounts of gas because most of these landfills are more than 20 years old. A gas collection and treatment system will ordinarily not be required for a landfill unless the site-specific remediation requirements include specific objectives that will not be met through the other presumptive remedy components selected for the landfill. Conventional barrier-type covers are more likely than other covers to require gas control systems.

As noted in **Figure 10**, a passive landfill gas venting system may be needed to achieve one or more of the following requirements at a specific landfill:

- Reduce human health risks associated with uncontrolled landfill gas emissions
- Prevent pressure buildup under the landfill cover, which can damage the overlying vegetative cover
- Reduce the potential for uncontrolled gas emissions or pressure buildup at landfills in

which the wastes have a high organic matter content

However, an active gas collection system may be required if one or more of the following conditions apply:

- Landfill gas may migrate from the landfill and accumulate in homes or other buildings to create explosion or inhalation hazards.
- Reuse plans include public access to the landfill after closure.
- Excessive odors must be controlled.

At some sites, compliance with ARARs may require active gas collection unless waivers can be obtained.

2.4.5 Groundwater Control System

As indicated in **Figure 11**, one or more groundwater control systems may be needed if either of the following conditions apply:

- Lateral groundwater flow can leach contaminants from the wastes directly into groundwater.
- Surface-water infiltration through the selected cover can leach contaminants from the wastes and contaminate groundwater.

As indicated in **Figure 11**, **Notes 31** and **32**, the type of groundwater control system(s) selected will depend on whether one or both of these conditions apply, as well as other site-specific factors.

2.5 Leachate Collection and Treatment System

As indicated in **Figure 12**, a leachate collection system is a possible presumptive remedy component if leachate samples from the landfill perimeter or from the contents of the landfill contain COCs. Selecting a leachate collection and treatment system under these circumstances would depend on whether or not a COC in the leachate is likely to contaminate groundwater or surface water sufficiently to exceed an Applicable or Relevant and Appropriate Requirement.[2] However, sampling or collecting leachate from Air Force landfills may not be possible because these landfills typically have no liner and, in many situations, sufficient leachate does not accumulate to permit either sampling or collection for treatment.

2.6 Institutional Controls

As indicated in **Figure 13**, institutional controls can constitute a useful component of the presumptive remedy to supplement and help protect the long-term integrity of the engineering

[2]For example, an MCL or non-zero maximum contaminant level goal (MCLG) in drinking water, or an ambient water quality criterion (AWQC) in the waters of a nearby wetland.

components of the presumptive remedy. These controls may include deed restrictions, fencing, and sign posting. Institutional controls should be considered especially if one or more of the following remediation requirements apply to a specific landfill:

- Preventing development of the landfill surface in the future
- Preventing trespassing
- Reducing or preventing exposure to uncontrolled landfill gas emissions
- Reducing or preventing exposure to landfill gas emitted from a venting system
- Reducing liability
- Controlling groundwater use

2.7 Streamlined Risk Assessment

As indicated in **Figure 6** and **Note 23**, a risk assessment should be conducted to evaluate only the complete exposure pathways that the components of the presumptive remedy will not address. An RI/FS or EE/CA, as described in **Figures 14** and **15**, should be performed but with the limited objective of identifying unacceptable risks associated with these pathways. If the presumptive remedy will address all of the complete pathways, then the conclusion that the presumptive remedy alone will be sufficient to protect human health and the environment from contaminants in the landfill should be fully documented, as indicated in **Figure 6**.

2.8 Long-Term Monitoring

As indicated in **Figure 1**, uncertainties about the landfill contents (for instance, uncertainties about the existence of unbreached drums) may require long-term monitoring of groundwater, surface water, leachate, air, or sediment. The principal objectives of monitoring would be to ensure the long-term effectiveness of the remedy and the prompt detection and correction of any failures that may occur in the remedy in the future. If needed to address these uncertainties, a long-term monitoring program should be integrated into the overall presumptive remedy and the likely final remedy.

3 Decisions for Landfill Remediation

Flowcharts detailing the decision tool process are provided on the following pages. The text of the notes indicated on these charts is located in Section 4.

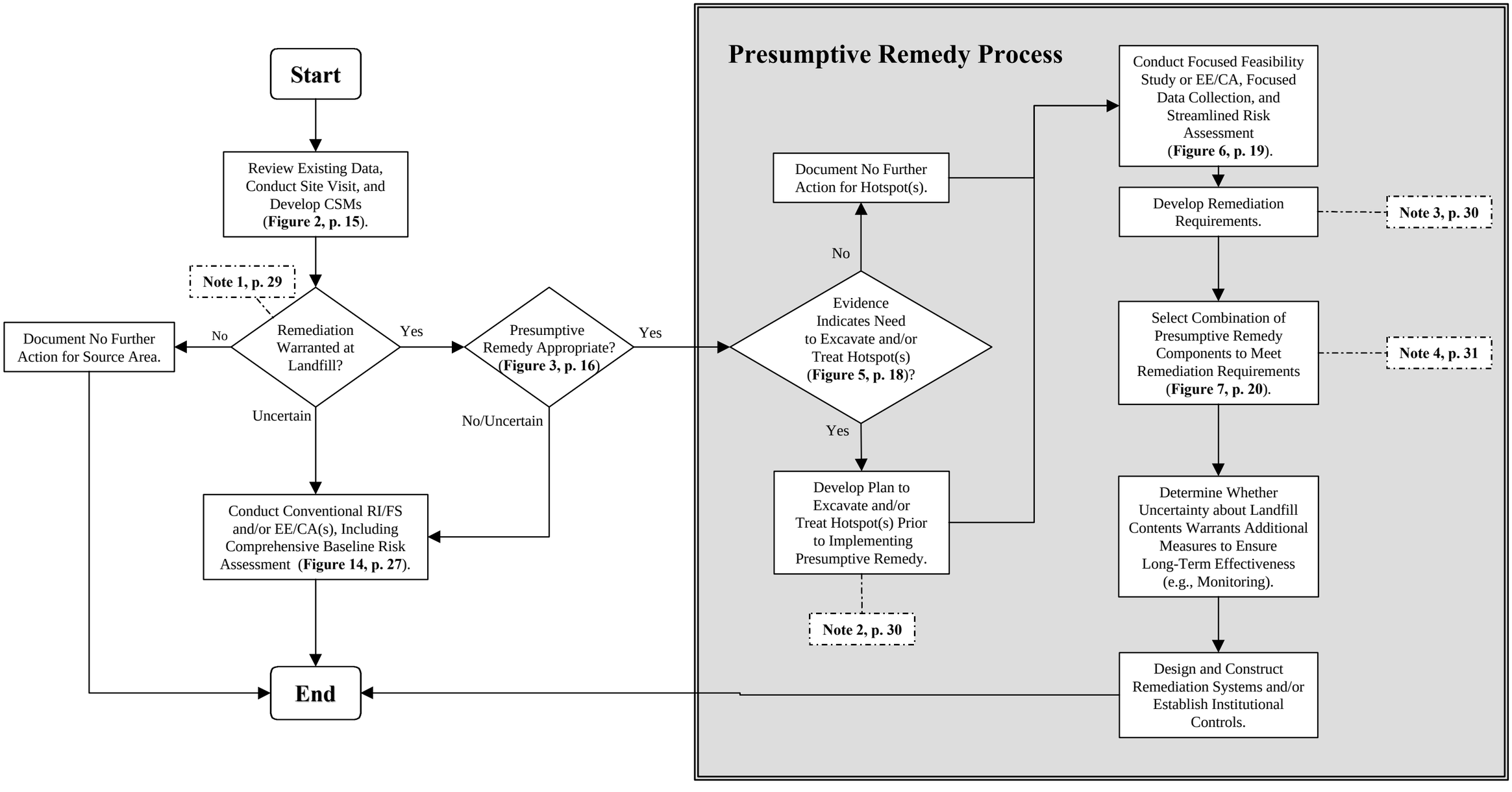

Figure 1. Landfill Remediation Flow Chart

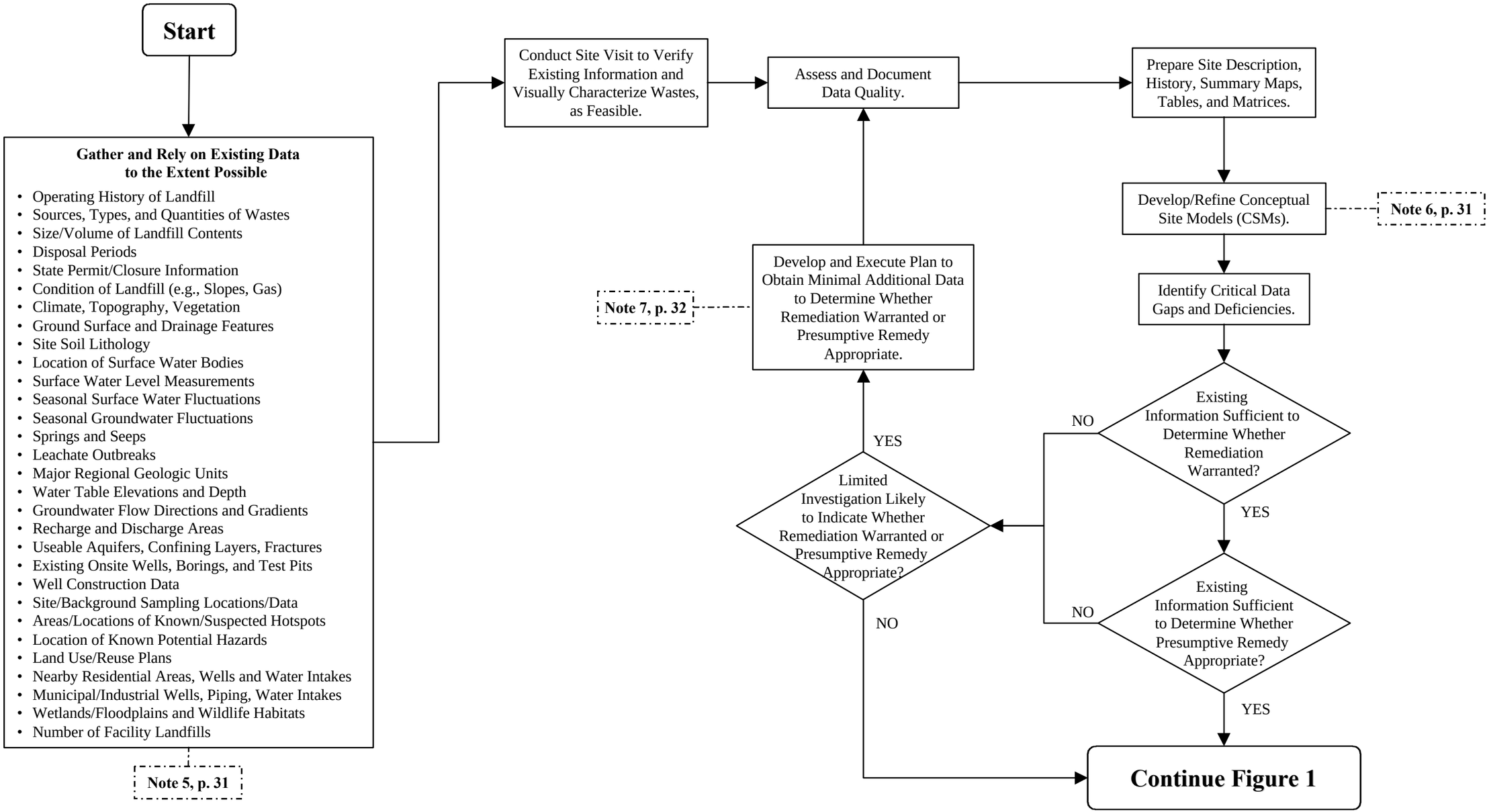

Figure 2. Landfill Characterization

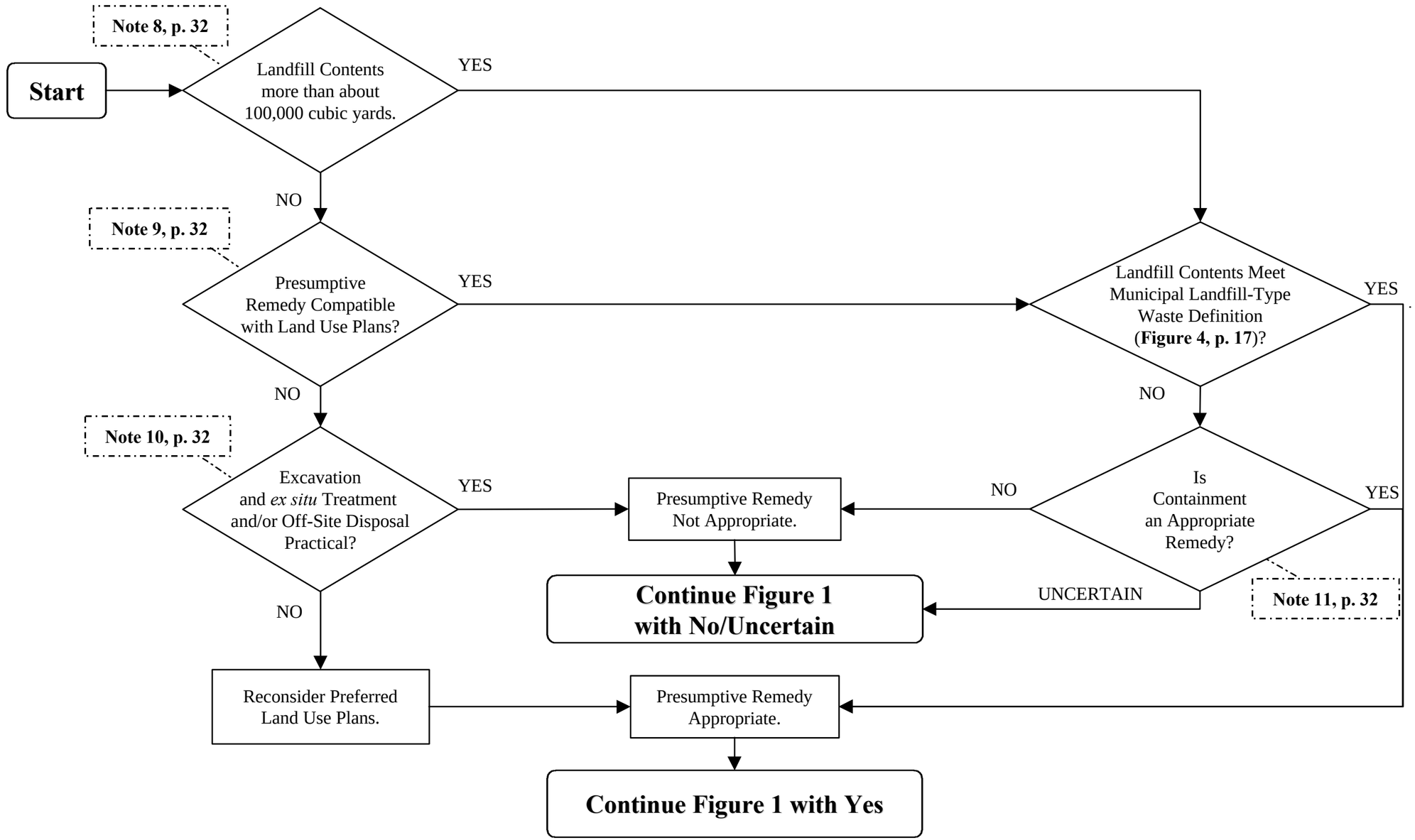

Figure 3. Presumptive Remedy Decision

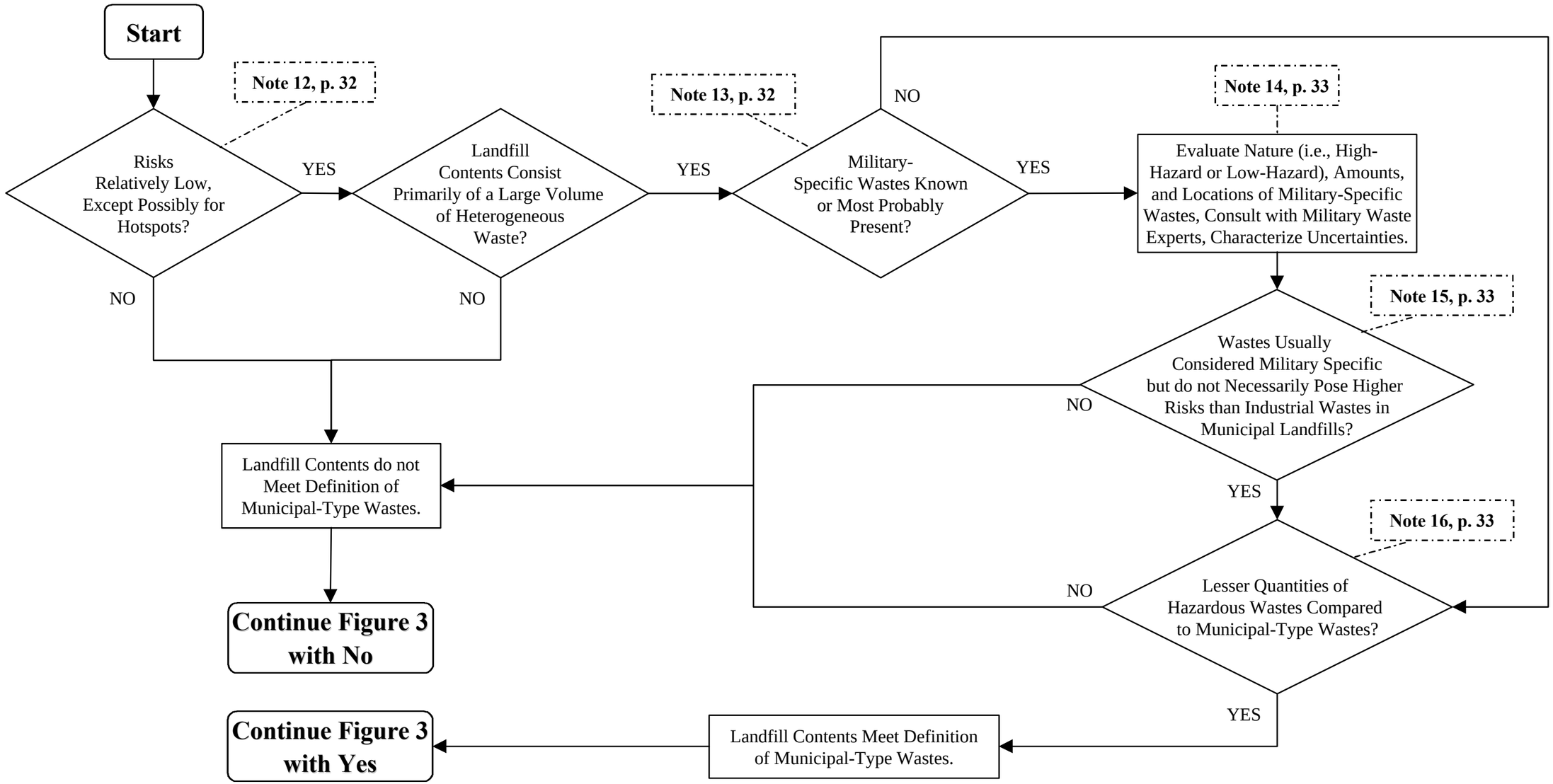

Figure 4. Municipal-Type Wastes Criteria

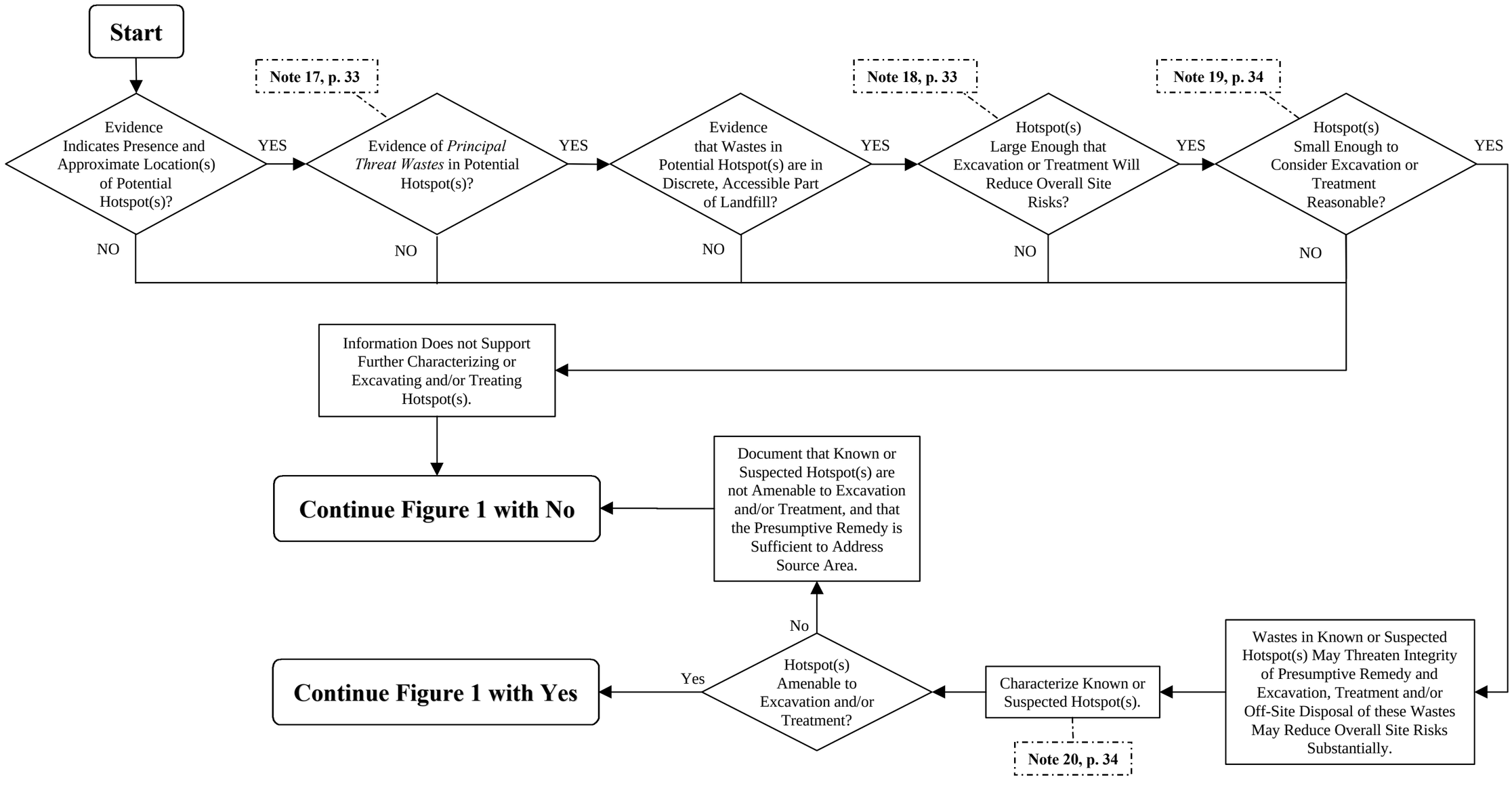

Figure 5. Hotspot Decisions

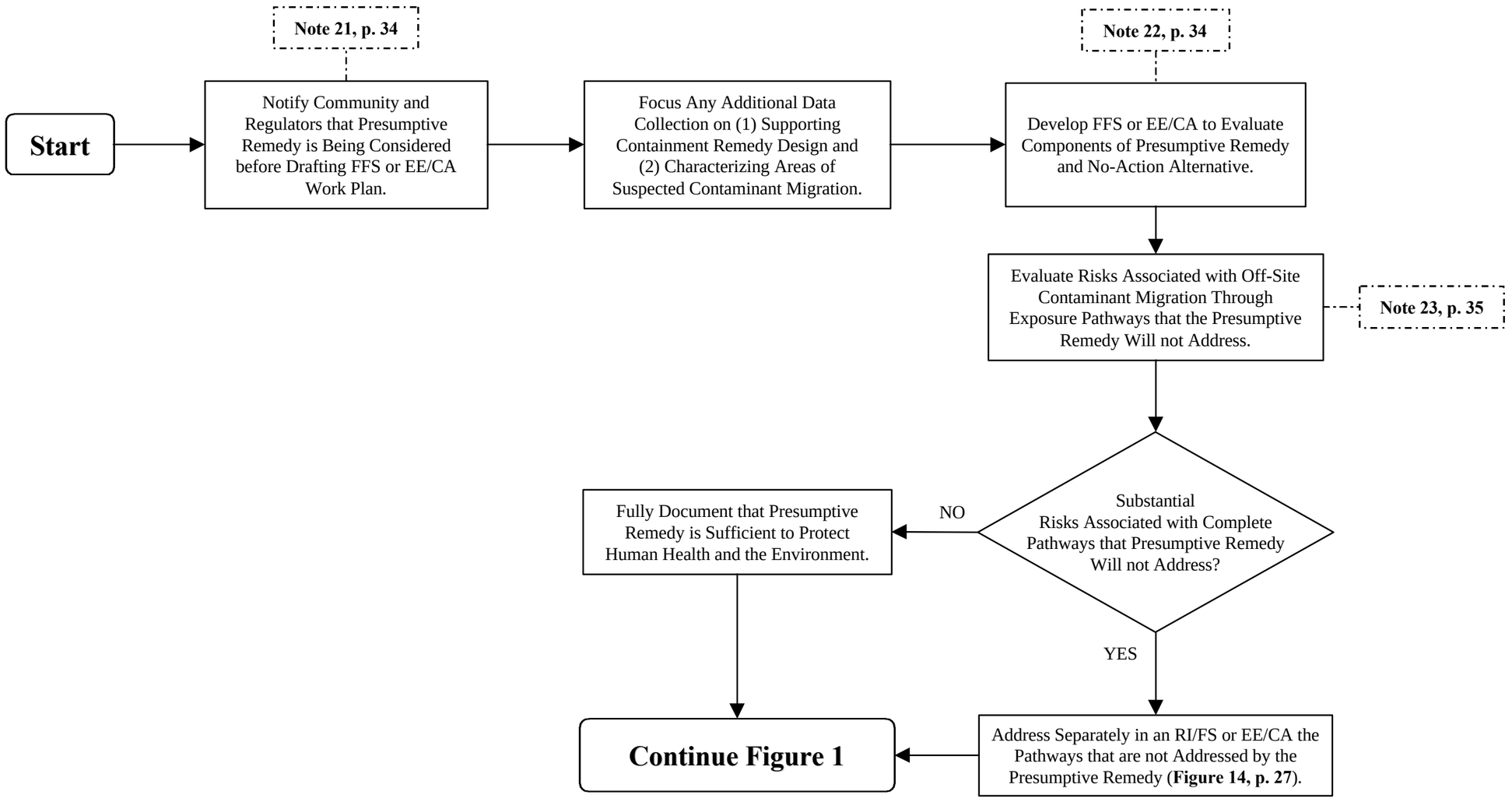

Figure 6. Presumptive Remedy Focused Feasibility Study

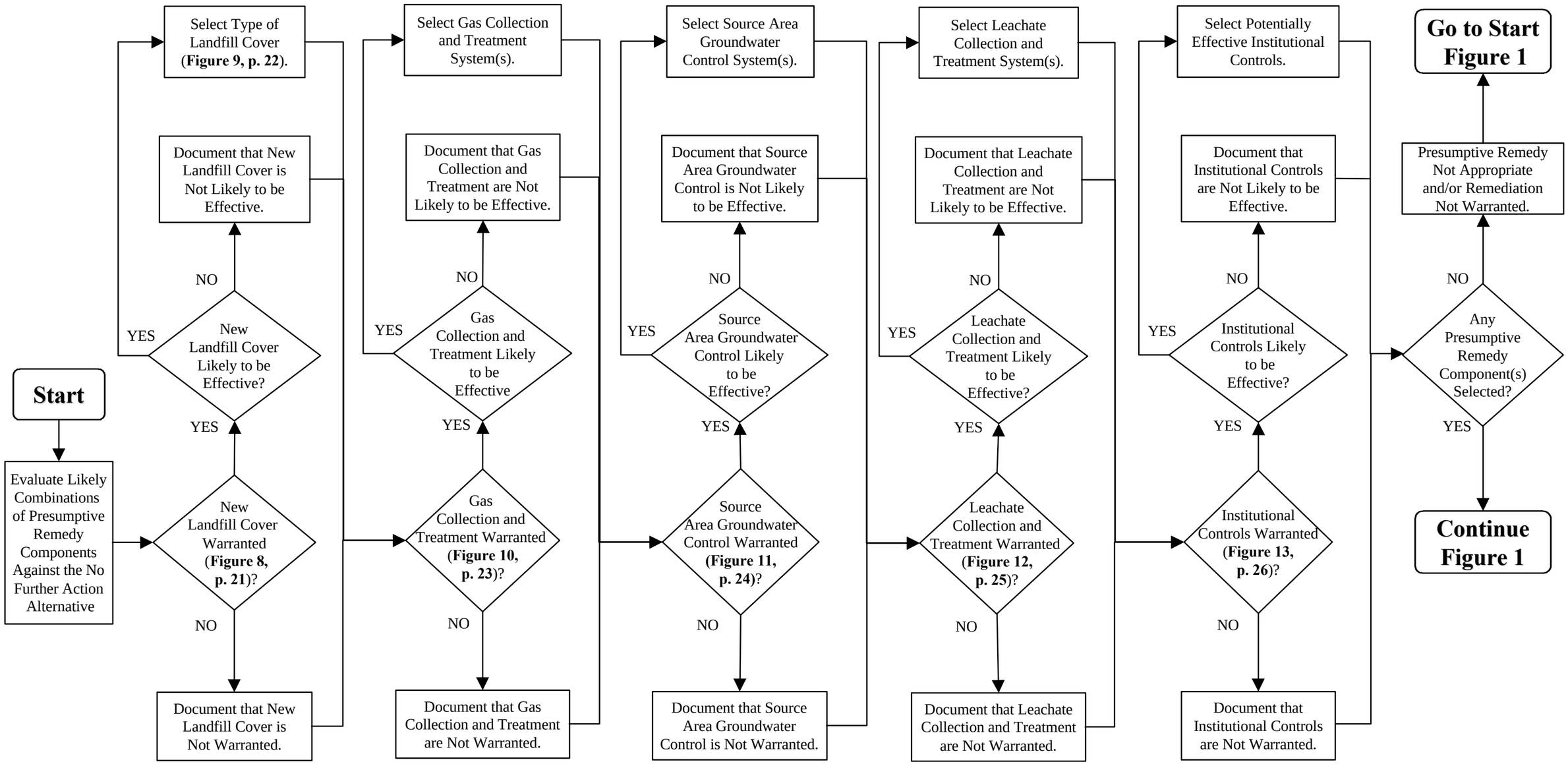

Figure 7. Presumptive Remedy Component Selection

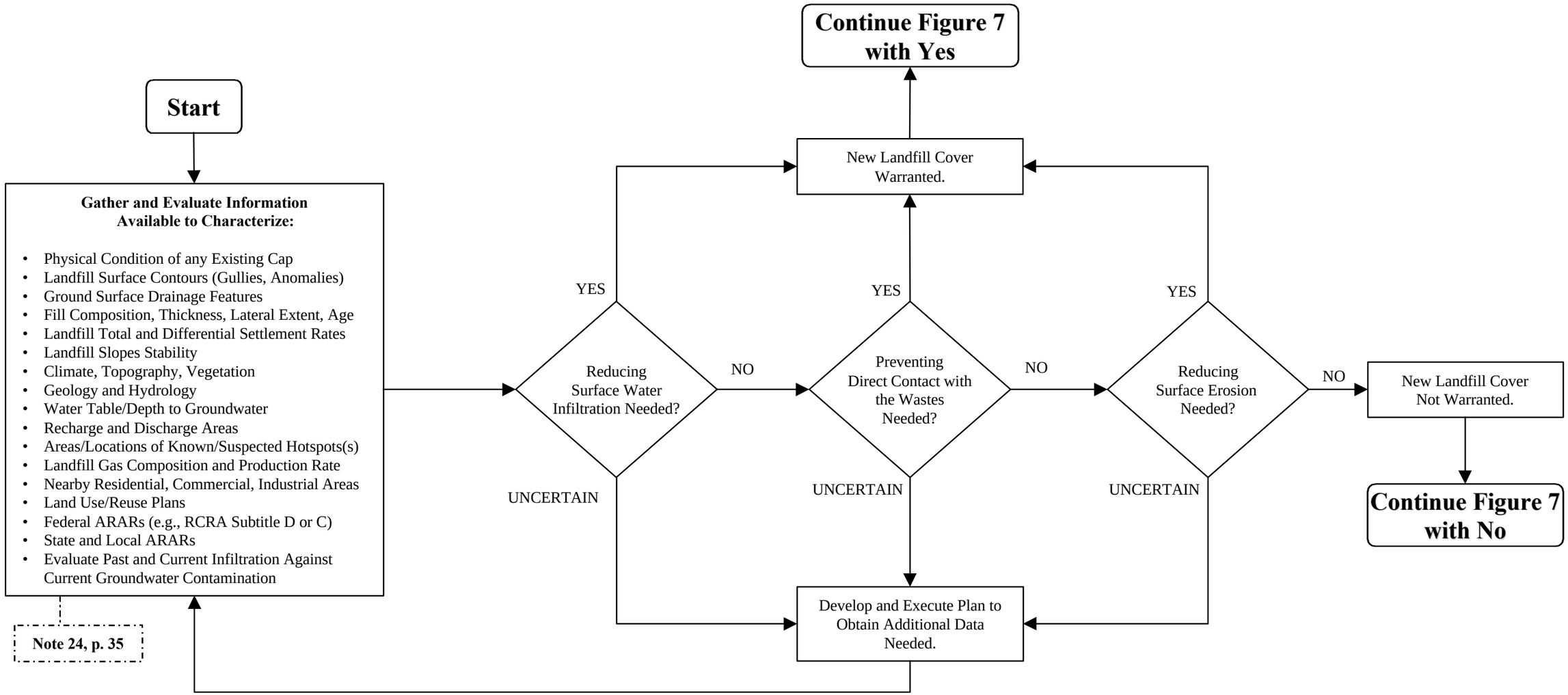

Figure 8. New Cover Decisions

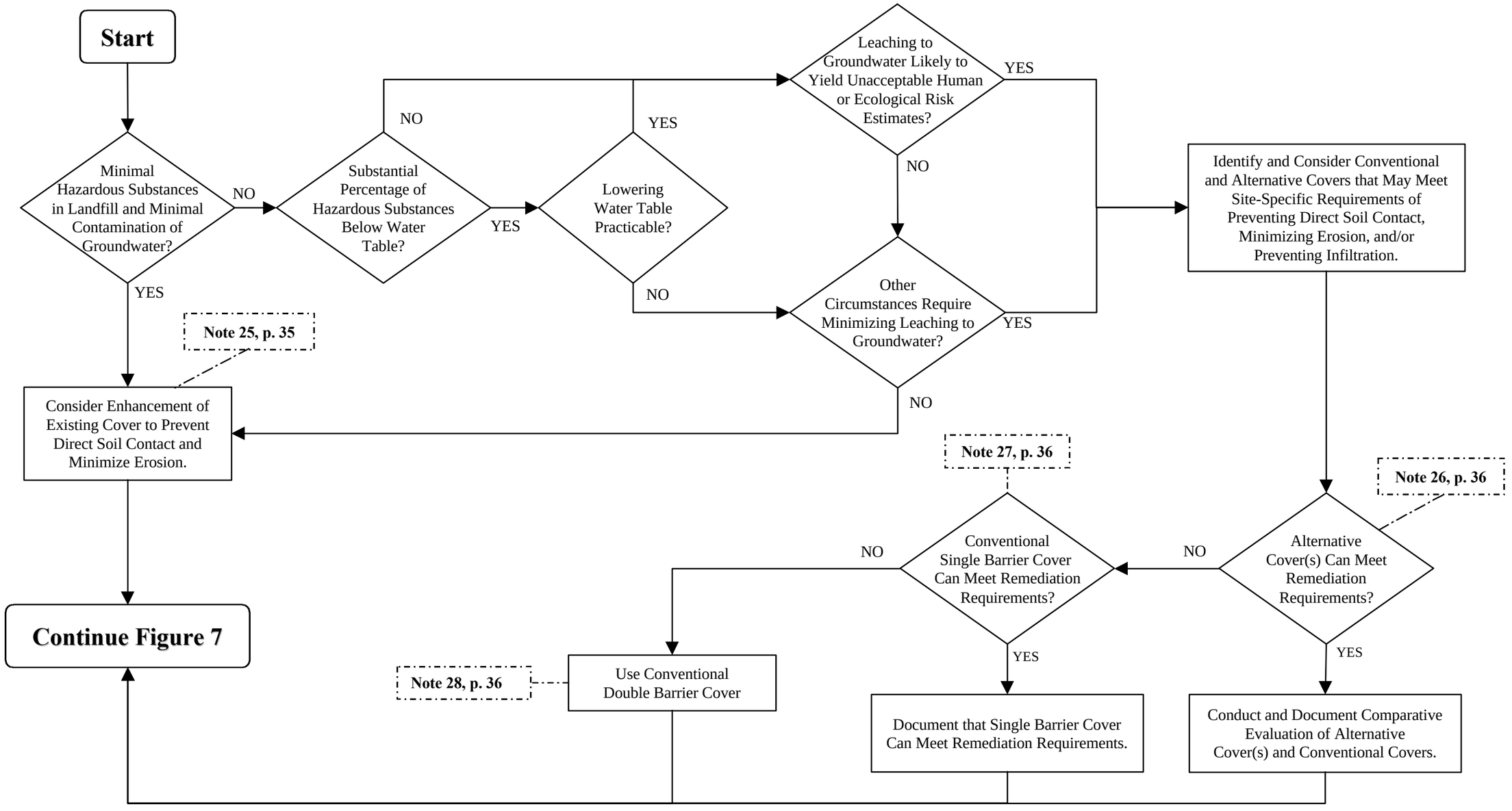

Figure 9. Landfill Cover Type

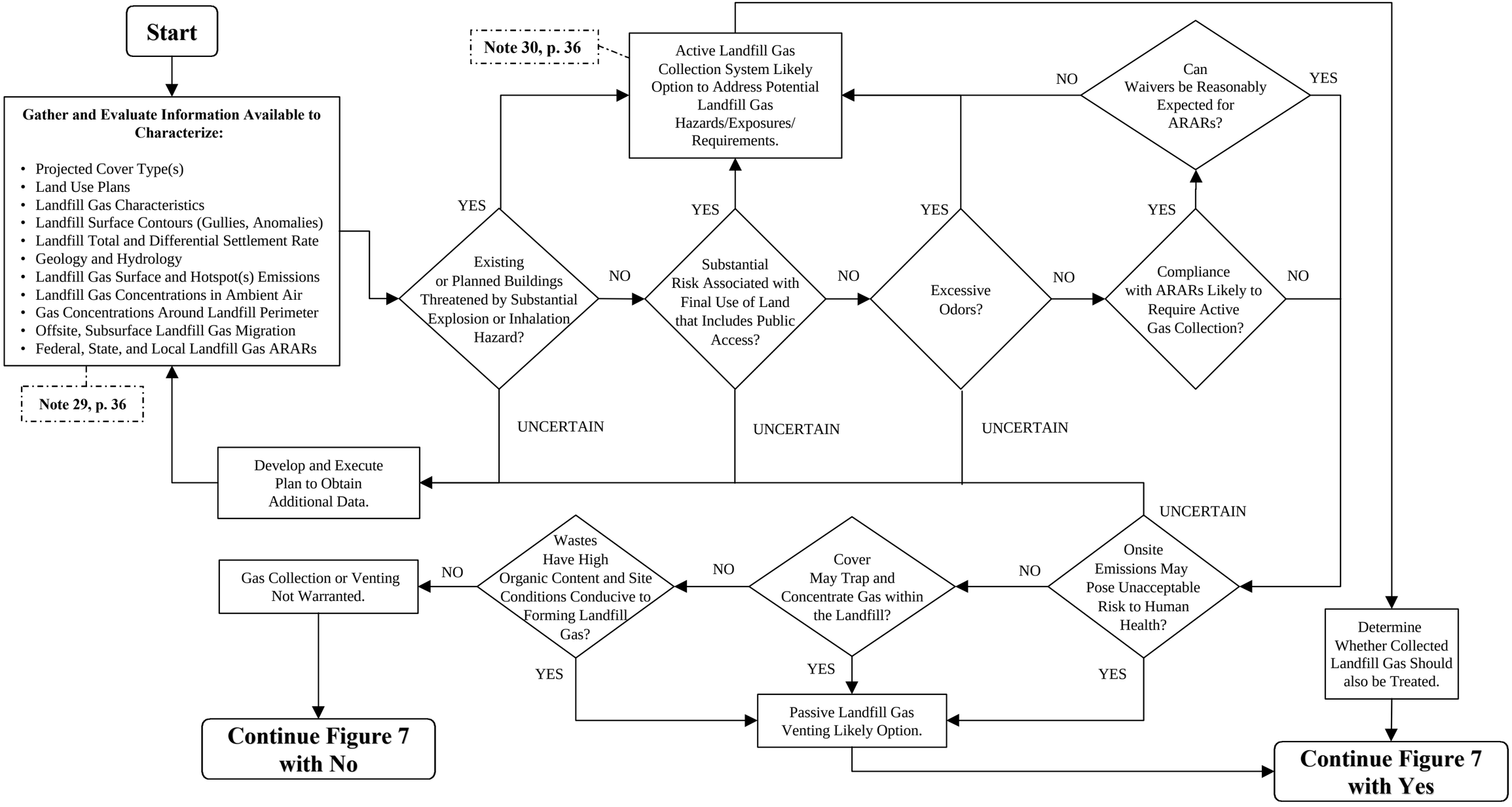

Figure 10. Landfill Gas Decisions

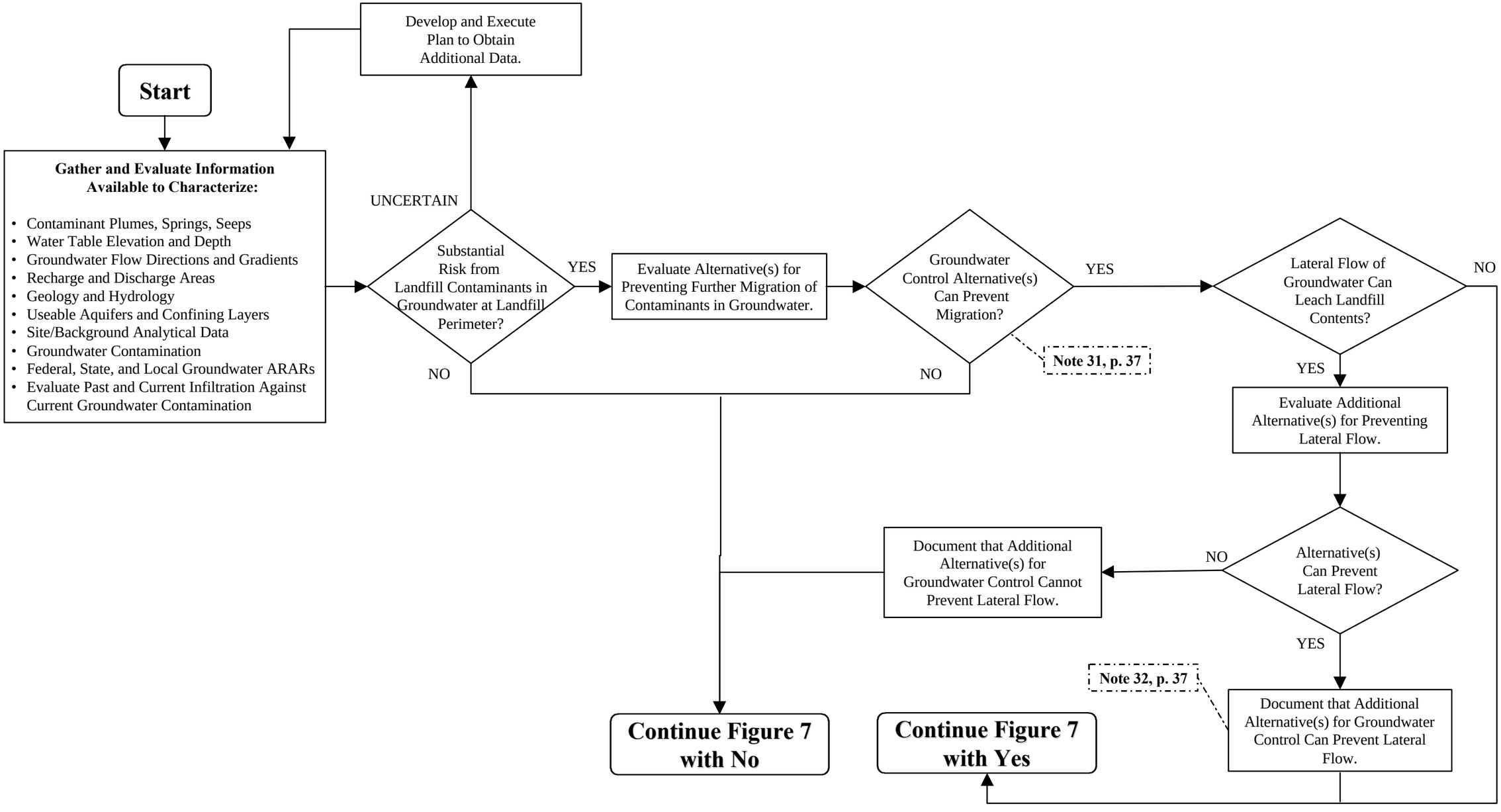

Figure 11. Groundwater Control Decisions

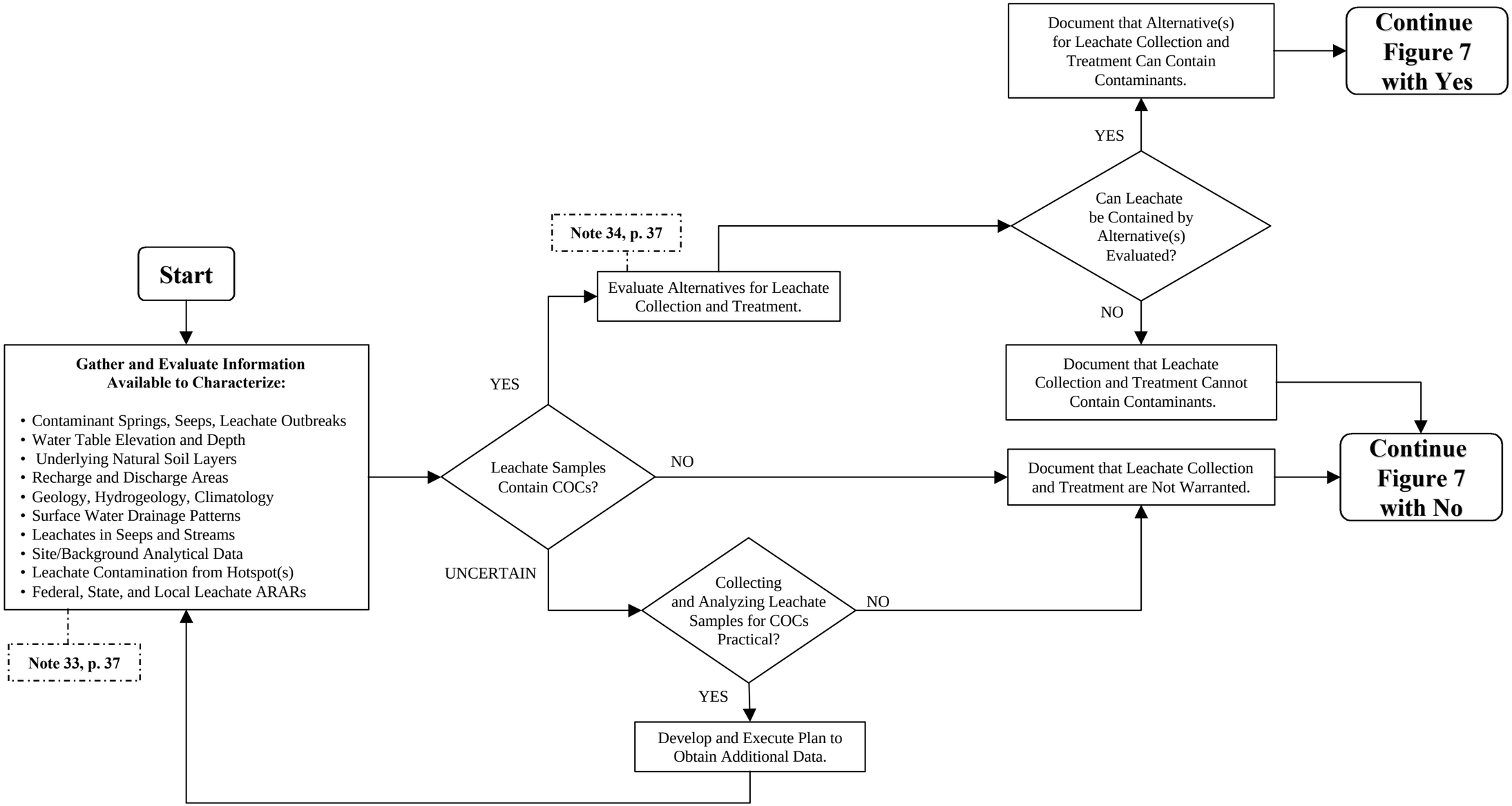

Figure 12. Leachate Collection and Treatment Decisions

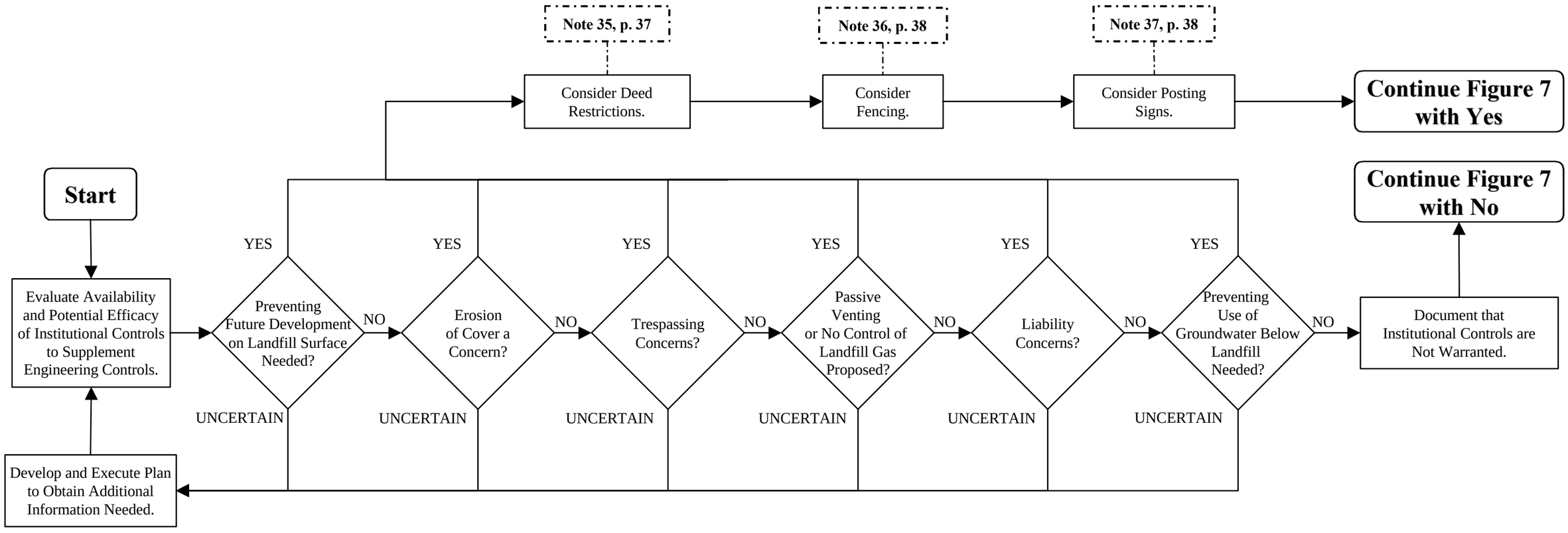

Figure 13. Institutional Control Decisions

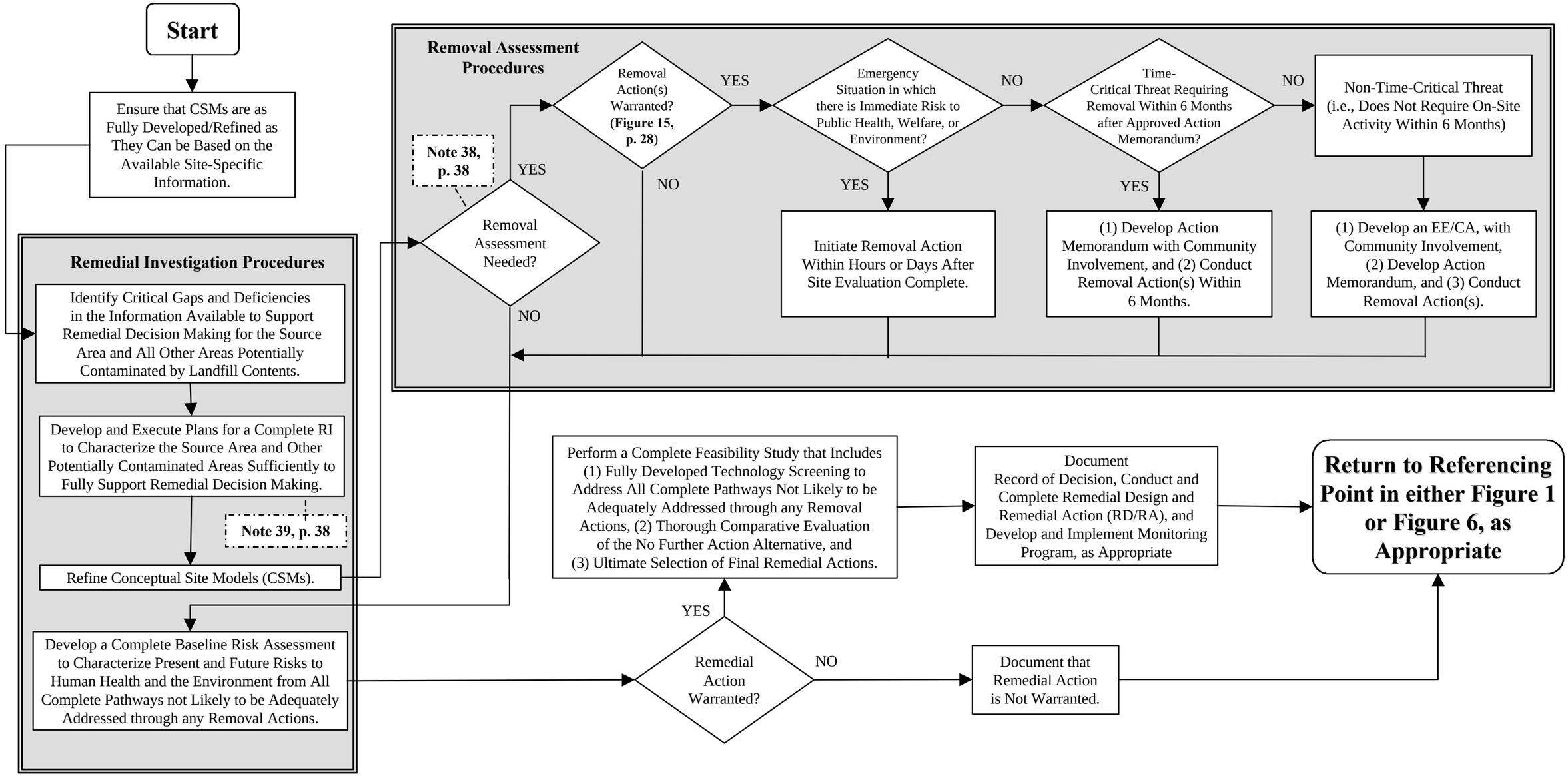

Figure 14. Conventional Remediation Decisions

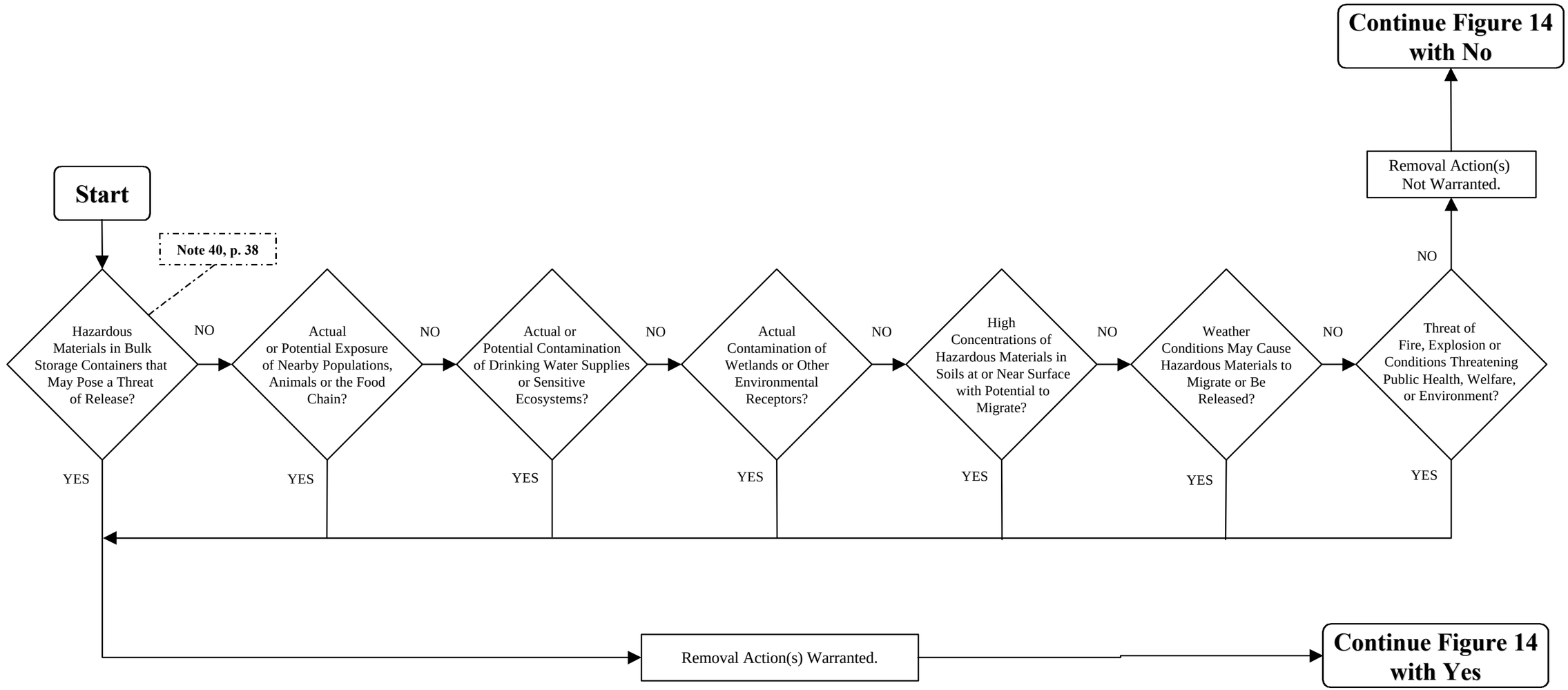

Figure 15. Removal Action Decisions

4 Explanatory Notes for Decision Tool Figures

4.1 Figure 1: Landfill Remediation Flowchart

Note 1: If remediation is not warranted, then a no-further-action decision is appropriate. The No Further Action alternative is clearly appropriate for a landfill if the available information is sufficient to show that there are no complete pathways or that all of the complete pathways are negligible because they do not threaten either human health or the environment. However, remediation can be justified if the available data indicate that (1) concentrations of one or more contaminant in groundwater, surface water, leachate, sediment, soil, soil gas, or landfill gas at the landfill clearly exceed an appropriate standard or (2) another condition provides clear justification (thus, a fully developed quantitative baseline risk assessment is not needed). For example, remediation is justified if one or more of the following conditions are found:

- A contaminant from the landfill is present in groundwater or leachate at the landfill boundary at concentrations clearly exceeding the contaminant's MCL or non-zero MCLG and may contaminate a current or future drinking-water supply.
- A landfill contaminant without an established MCL or non-zero MCLG is present in groundwater or leachate at the landfill boundary at concentrations clearly exceeding drinking water concentrations representing one-in-a-million to one-in-a-thousand cancer risks and may contaminate a current or future drinking water supply.[3]
- A landfill contaminant without an established MCL or non-zero MCLG is present in groundwater or leachate at the landfill boundary at concentrations clearly exceeding a hazard quotient of 1 and may contaminate a current or future drinking water supply.[4]
- A contaminant from the landfill is present in the surface water of an adjacent wetland at concentrations exceeding an appropriate AWQC.
- A contaminant from the landfill is present in the sediment of an adjacent wetland at concentrations exceeding an AWQC for aquatic life.
- A landfill gas emission clearly exceeds an appropriate state air quality standard.
- Direct contact with landfill contents is likely because the landfill slopes are unstable or waste is exposed.

For most landfills, the available information will be sufficient to either support a no-further-action decision or justify a decision to remediate.

[3]For example, a cancer-risk–based EPA Region IX preliminary remediation goal (PRG) or EPA Region III risk-based concentration (RBC) may be exceeded in the groundwater.

[4]For example, a non-cancer-risk–based EPA Region IX PRG or EPA Region III RBC may be exceeded in the groundwater.

If the available information is not sufficient to support a remedial decision, the landfill will require additional site characterization and fully developed baseline risk assessments in a conventional RI or EE/CA to determine whether remediation is warranted or required.

Note 2: Excavation is needed for consolidation, *ex situ* treatment, or off-site disposal of hotspot material or for any required removal of wastes in contact with groundwater. Excavation is also an option when treatment is not practicable or necessary. Excavation and on-site consolidation are usually performed to relocate materials from the hotspot(s) in outlying areas of the landfill into the landfill contents to minimize the cover size. On-site consolidation does not require treatment because RCRA LDRs do not apply. Treatment options include thermal (e.g., on-site incineration), physical (e.g., solidification/fixation), and innovative (e.g., soil vapor extraction or *in situ* bioremediation). Treatability or pilot testing may be needed.

Note 3: Remediation requirements for landfills should be developed in a site-specific manner. This procedure depends on numerous site-specific factors, including landfill waste type, quantity, and age; climate; landfill history and geologic setting; local surface and groundwater use; and regulatory requirements. Establishing these requirements allows the selection of appropriate presumptive remedy components. Requirements may include any of the following:

- *Estimating the amount of water that has percolated through the landfill contents before the remediation begins.* Although these estimates may lack precision, they are valuable for interpreting other data and specifying appropriate presumptive remedy components.
- *Minimizing infiltration of water into the landfill contents.* Minimizing infiltration is required at nearly all landfills. However, the specification of an acceptable infiltration rate as a requirement for a landfill should consider that all conventional and accepted landfill covers leak. In semiarid regions, a relatively small annual infiltration rate may be an appropriate requirement. In contrast, a greater infiltration rate may be acceptable in cold, humid regions. The infiltration rate allowed should also depend on the nature and quantities of soluble and leachable contaminants in the waste, the underlying geology and hydrogeology, groundwater use, and site history. It may be impossible to set a single allowable infiltration rate for a landfill. However, acceptable values for this rate must be defined to enable selection of an appropriate cover. Defining these values allows consideration of potentially suitable alternative covers, as well as conventional covers.
- *Controlling gas emissions.* New landfills and other landfills producing relatively large amounts of gas clearly require gas control. Barrier-type covers (e.g., RCRA Subtitle D covers) almost always require gas control to prevent the accumulation of hazardous gas. Most Air Force landfills are old and exhibit low and decreasing gas production rates. Vegetative covers (e.g., ET covers) placed on these landfills will

typically allow the harmless emission of the gas to the atmosphere. Gas control requirements will also be governed by factors such as climate, geology, hydrogeology, landfill reuse plans, and use of the land around the landfill.

- *Controlling erosion.* A landfill cover should include a layer of vegetation on arable soil of adequate depth; such a layer readily meets erosion control requirements. In contrast, accepted conventional covers (e.g., RCRA Subtitle D covers) may sometimes not provide sufficient erosion control because the soil layer is constructed over the compacted zone and is too shallow to support adequate root growth.
- *Other requirements.* Site-specific requirements may also include (1) promoting and controlling drainage off the landfill, (2) collecting, removing, treating, and/or disposing of leachate, (3) preventing surface water run-on, (4) protecting barrier-type covers from freeze/thaw effects, animal intrusion, and/or root intrusion, (5) preventing direct human contact with the waste, (6) preventing the scattering of waste by wind or water, (7) restricting access to the site, (8) minimizing odors, (9) removing wastes in contact with groundwater, and (10) other site-specific requirements.

Note 4: Combinations of methods should be used, as appropriate for the site, to protect human health and the environment. Each component of the presumptive remedy selected should be designed to be an integral component of the overall presumptive remedy and to be compatible with the likely overall final remedy (the presumptive remedy in combination with other specific remedial and removal actions). Innovative technologies should be considered when they meet the remediation requirements. Other components of the presumptive remedy are often combined with actions such as alternative water supplies for a complete remedy. The final remedy—the presumptive remedy in combination with other remedial or removal actions—must be shown to address all complete exposure pathways and COCs for potential human and ecological receptors.

4.2 Figure 2: Landfill Characterization

Note 5: Little source investigation should be needed unless available information indicates the need to investigate known or suspected hotspots or the landfill is small (as a rule of thumb, less than about 100,000 cubic yards [cy]) and either (1) there are unacceptable risks to potential human or ecological receptors or (2) excavation or treatment of landfill contents is a practicable option.

Note 6: CSMs are developed and refined as fully as possible, based on the information available, for both human health and the environment to (1) identify COCs, their hazardous properties, and their concentrations in specific media at the landfill, (2) reveal whether any critical additional information is required to support the decision to remediate, (3) identify the pathways that the presumptive remedy can address, and (4) identify areas beyond the landfill requiring further study. The generic human health CSM provided in Highlight 2 *of Presumptive Remedy for CERCLA Municipal Landfill Sites* (Office of Solid Waste and

Emergency Response [OSWER] Directive 9355.0-49FS, September 1993) should be used as a point of departure.

Note 7: Obtaining the required data may involve sampling groundwater from existing wells, leachate from nearby seeps, surface soils at leachate seeps or areas of stains or stressed vegetation, landfill gas in soil or ambient air, or surface water and sediment from nearby wetlands.

4.3 Figure 3: Presumptive Remedy Decision

Note 8: The reference to 100,000 cy (about 4 acres, 15 feet deep, or 2 acres, 30 feet deep) should be interpreted as a rule of thumb, not as a rigid threshold value.

Note 9: Reasonably anticipated land uses or preferred future reuses on and around the landfill should be considered.

Note 10: The practicality of excavation followed by consolidation or disposal of the excavated wastes depends on site-specific factors, including hydrogeology, volume of contents, safety, and costs of excavation and consolidation or disposal. Evaluating excavation requires balancing lower operation and maintenance costs and unrestricted land use against initial high-capital construction costs and risks associated with excavation and consolidation or disposal.

Note 11: The presumptive remedy may be the most appropriate remedy even though the landfill contents do not meet the municipal-landfill–type definition. For example, the presumptive remedy is appropriate if site investigation or attempted treatment may cause greater risks than leaving the waste in place. Conversely, site-specific conditions may indicate that the presumptive remedy is less suitable than other options. For example, the presumptive remedy is not a likely option if a high water table characterizes the site, especially if substantial quantities of leachable waste lie below the water table. Similarly, the presumptive remedy is not a likely option if an adjacent sensitive environment is threatened by contaminants that can leach from the landfill.

4.4 Figure 4: Municipal-Typed Wastes Criteria

Note 12: The presumptive remedy allows excavation and on-site consolidation, treatment, or off-site disposal of occasional hotspots that contain hazardous wastes. The hotspots may contain industrial hazardous wastes and/or high-hazard military-specific wastes.

Note 13: A reasonable effort should be made to determine whether military-specific wastes are known or believed to be present in the landfill. Military-specific wastes include high-hazard wastes (e.g., munitions, chemical warfare agents and training kits, artillery, small arms, bombs, demolition charges, pyrotechnics, propellants, smoke grenades) and low-hazard wastes (e.g., low-level radioactive materials, decontamination kits, munitions hardware). In comparison, wastes that are common to municipal and military landfills include household

wastes (e.g., refuse, garbage, yard wastes, debris), commercial wastes (e.g., refuse, garbage, hospital wastes, grease, construction debris), sludge, and—to a lesser extent—industrial wastes (e.g., asbestos, batteries, hospital wastes, industrial solid wastes, process wastes pesticides, transformer oils, paints and paint thinner, other solvents).

Note 14: If military-specific wastes are known or believed to be present, then the available information should be used to determine the likely nature (high-hazard or low-hazard), amount, and location(s) of these wastes in the landfill. Specialists in military wastes (e.g., Air Force Civil Engineering Support Agency) should be consulted to determine whether the military-specific wastes found are low-hazard or high-hazard. Low-hazard military-specific wastes (e.g., decontamination kits and munitions hardware) are generally no more hazardous than some industrial wastes found in municipal landfills. High-hazard military-specific wastes are extremely hazardous, and may possess unique safety, risk, and toxicity characteristics. Caution is warranted if historical records or sampling data indicate high-hazard wastes may have been disposed of. Uncertainties about the presence, absence, nature, or locations of military-specific wastes in the landfill should be evaluated based on best professional judgment and site-specific risk management considerations.

Note 15: Wastes meeting this criterion generally include low-hazard military wastes. Some high-hazard wastes can also present low risk depending on the location, volume, and concentrations. Determining whether the wastes of a landfill containing high-hazard or low-hazard military-specific waste meets the definition of municipal-landfill–type wastes depends on both the heterogeneity and the volume of the military-specific wastes in the landfill.

Note 16: Landfills with contents meeting the definition of municipal-landfill–type wastes contain lesser quantities of hazardous wastes (industrial- or military-specific) than other wastes. Military facilities with relatively high levels of industrial activity (e.g., weapons fabrication or testing, major aircraft or equipment repair) typically have higher proportions and wider distributions of industrial (i.e., potentially hazardous) wastes and are less likely to meet the definition of municipal-landfill–type wastes.

4.5 Figure 5: Hotspot Decisions

Note 17: Principal Threat Wastes are source materials that are (1) highly toxic or highly mobile, (2) generally cannot be reliably contained, and (3) could present substantial threat to human health or the environment if released (e.g., liquids in drums, lagoons, or tanks; free product non-aqueous phase liquids [NAPLs]; surface soil with high concentrations of volatiles or dust-associated COCs; highly toxic, non-liquid wastes in buried drums or tanks or in soil at high concentrations). See: *Guide to Principal Threat and Low Level Threat Wastes*, U.S. Environmental Protection Agency, November 1991 (Superfund Publication No. 9380.3-06FS).

Note 18: Either on-site consolidation of hotspot(s) wastes under the landfill cover or off-site disposal of the hotspot(s) waste may follow excavation. Excavation and on-site consolidation

are usually performed to relocate materials from the hotspot(s) at outlying areas of the landfill into more central areas of the landfill contents, thus minimizing the cover size needed.

Note 19: As a rule of thumb, hotspots less than about 100,000 cy (about 4 acres, 15 feet deep, or 2 acres, 30 feet deep) may be small enough, depending on other factors. In addition to the size of the hotspot, a decision to excavate or treat the hotspot will generally depend on the results of any additional investigation performed to further characterize the nature of the hotspot and on an economic analysis of the remedial alternatives. Thus, 100,000 cy should not be taken as a rigid threshold.

Note 20: Hotspots should be treated as unique sites within a landfill. Any additional sampling efforts should be focused on further characterizing the known or suspected hotspot(s). Geophysical and soil-gas surveys facilitate delineation of hotspots. Confirmation is typically achieved by excavating test pits or drilling soil borings. Collecting soil samples enables determination of hotspot waste characteristics, such as target analyte list (TAL) metals, target contaminant list (TCL) organics, RCRA waste characteristics (e.g., toxicity characteristic leachate procedure [TCLP]), total British thermal unit (Btu) content, and bulk weight.

4.6 Figure 6: Presumptive Remedy Focused Feasibility Study

Note 21: It is important for all stakeholders to understand the differences between presumptive remedy and usual cleanup processes, as well as the benefits of the presumptive remedy process. The decision to use the presumptive remedy can apply to one landfill or can be part of base-wide strategy, depending on nature of wastes, landfill size, land reuse potential, public acceptance, and other factors.

Note 22: Under current rules, the remediation of landfills must meet all ARARs unless waivers are obtained. Possible ARARs that must be considered generally include (1) closure requirements of RCRA Subtitle D or Subtitle C, if appropriate, (2) more stringent state closure requirements, and (3) federal or state requirements for landfill gas emissions. The intimate association among the CERCLA, RCRA, and state regulations can pose an impediment to the selection and installation of innovative technologies, including cost-effective alternative landfill covers. This is because both RCRA and state regulations tend to be prescriptive. EPA, state regulatory agencies, and the Department of Defense (DoD) are fully aware of the conflicts that may arise to impede the use of innovative technologies. These agencies have expended considerable effort to define and support the important role that innovative technologies can play in the nation's remediation programs. The following EPA publications and statements discuss and support the use of innovative technologies:

- U.S. Environmental Protection Agency, OSWER Policy Directive 9380.0-25, April 29, 1996, *Promotion of Innovative Technologies in Waste Management Programs*.
- Letter, EPA Administrator, August 19, 1994, *EPA Policy for Innovative Environmental Technologies at Federal Facilities*.

- U.S. Environmental Protection Agency, Office of Reinvention, *Joint EPA/State Agreement to Pursue Regulatory Innovation*–Draft; Federal Register, October 29, 1997, pages 56182-56189.

For additional information, see *Landfill Covers for Use on Air Force Installations*, AFCEE, February 1999.

Note 23: The presumptive remedy may not fully address potential exposure pathways in which contaminant migration extends outside the landfill (e.g., leachate discharge or surface water run-off contaminating surface water, sediments, or wetlands). It may also fail to address contaminated groundwater migrating away from the landfill. These issues may require additional RI/FS or EE/CA and risk assessments to determine whether action is warranted or required beyond the landfill and, if so, the appropriate action.

4.7 Figure 7: Presumptive Remedy Component Selection

No notes appear on this figure.

4.8 Figure 8: New Cover Decisions

Note 24: Specific parameters of interest include the following:

- Soil permeability, grain size, Atterberg limits, and erosion rates
- Frost depth and storm event that would create potential for substantial erosion
- Permeability of the layer underlying landfill, depth to groundwater, thickness of waste below the water table, and groundwater flow through the waste
- Existing cover thickness, area, slope, stability, evidence of freeze-thaw protection, soil characteristics, and ability to (1) reduce surface gas emissions, odors, oxygen intrusion, and surface water infiltration, (2) provide erosion control, and (3) improve site aesthetics.

4.9 Figure 9: Landfill Cover Type

Note 25: Simply enhancing the existing cover may be appropriate, especially in the following situations:

- On all or part of an old landfill through which past surface water or groundwater infiltration has been substantial, making the leachability of the remaining wastes relatively low
- In arid climates, when the primary objective is to control erosion and prevent direct contact
- In regions of more evapotranspiration than rainfall
- On stabilized or solidified wastes

- As an interim cover when, for example, settlement has not yet stabilized
- On a landfill that contains mostly construction debris

However, existing cover material may require processing to make it suitable for use as a cover, and slope stability should be evaluated. Under these circumstances, designing an ET cover or other alternative cover may be a more desirable alternative.

Note 26: Implementing alternative covers may involve regrading existing fill to create proper slope lengths and gradients to remove surface water run-off, revegetating existing fill to stabilize soil surface and promote evapotranspiration, and/or designing a cover to reduce infiltration by incorporating sufficient field storage capacity and an adequate grass cover (e.g., the ET cover).

Note 27: Single-barrier covers (e.g., natural or processed clays, or flexible membrane liners [FMLs]) are low-permeability barriers (e.g., 10^{-7} cm/sec) that may include other layers (e.g., drainage, bedding, vegetative layers) to protect the integrity of the barrier. Moisture control may be difficult with a single-barrier clay cover in dry, windy climates. Examples of situations in which a single-barrier cover is probably adequate include when infiltration is not the primary concern, when volume of contaminant mass is small, when a region is characterized by low annual precipitation, or when groundwater is not used as drinking water.

Note 28: Double-barrier covers (FMLs over compacted clay) provide maximal reduction of infiltration. They must be overlain with drainage and vegetative/protective layers, and they usually require a gas-control layer. Normally, they are used for landfills with RCRA-listed wastes, wastes similar to RCRA-listed wastes, or RCRA-characteristic wastes, depending on site characteristics, potential receptors, and state requirements.

4.10 Figure 10: Landfill Gas Decisions

Note 29: Specific parameters of interest include (1) landfill soil permeability, moisture content, geologic strata, pH, depth to bedrock, and depth to groundwater, and (2) landfill gas composition, moisture content, quantity, and temperature. The composition, quantity, and generation rates of landfill gases depend on factors such as (1) refuse composition, quantity, placement, age, and moisture content, and (2) landfill depth and amount of oxygen present. Gases to be expected include carbon dioxide (CO_2), methane, trace thiols, and sometimes hydrogen sulfide (H_2S). Volatile organic compounds (VOCs) may also be found in landfill gases.

Note 30: Active gas collection systems generally include gas extraction wells, gas collection headers, and vacuum blowers or compressors. In municipal landfills, treatment commonly involves ground flares or methane gas recovery systems.

4.11 Figure 11: Groundwater Control Decisions

Note 31: Groundwater control may include extraction wells and subsurface drains or treatment walls (e.g., iron filing walls). Extraction wells may be used with downgradient slurry walls. Treatment may include on-site chemical (e.g., metals precipitation, pH adjustment), biological (e.g., use of aerobic or anaerobic microorganisms), or physical (e.g., adsorption, air stripping, sedimentation, sand filtration) treatments. Off-site treatment may use publicly owned treatment works (POTW) or a RCRA treatment, storage, and disposal facility (TSDF). Groundwater extracted as part of the presumptive remedy may need to meet discharge limits or other appropriate standards.

Note 32: An upgradient impermeable perimeter trench-type barrier (e.g., soil-bentonite slurry walls) may be used, in combination with extraction wells and surface cover, to reduce the amount of water contacting the landfill contents. A downgradient treatment (e.g., iron filings wall) may control contaminant migration.

4.12 Figure 12: Leachate Collection and Treatment Decisions

Note 33: Leachate collection and treatment may not be possible at Air Force landfills because these landfills typically do not have bottom liners. If it is possible, then the specific parameters of interest include (1) precipitation and evapotranspiration, (2) thickness, depth, and types of wastes, (3) leachate head levels, moisture, decomposition, TCL organics, TAL metals, biological oxygen demand (BOD), chemical oxygen demand (COD), pH, total dissolved solids (TDS), total suspended solids (TSS), phosphorus, nitrogen, and oil and grease, (4) elevation of underlying natural soil layer, and (5) aquifer class, water levels, flow rates, and chemistry.

Note 34: Common leachate collection options include subsurface drains (e.g., gravel-filled trenches with tile or perforated pipe at the landfill perimeter) and vertical extraction wells (e.g., vertical wells in the wastes, screened in a permeable water-bearing zone). Leachate treatment options include on-site chemical (e.g., metals precipitation, pH adjustment), biological (e.g., use of aerobic or anaerobic microorganisms), or physical (e.g., adsorption, air stripping, sedimentation, sand filtration) treatments. Off-site treatment may use POTW or a RCRA TSDF. Leachate extracted as part of the presumptive remedy is required to meet discharge limits or other appropriate standards.

4.13 Figure 13: Institutional Control Decisions

Note 35: Effectiveness of restrictive covenants depends on interpretation and enforcement of state and local laws. Most covenants are subject to changes in political jurisdiction, legal interpretation, and level of enforcement. Aquifer use and other restrictions are only voluntary. Some states do not allow deed restrictions. Where available and likely to be effective, the restrictive covenant should serve to protect the cover by limiting subsurface development (excavation), excessive vehicular traffic (including off-road vehicles and dirt

bikes), and groundwater use. Additional deed restrictions may be required to ensure effective implementation of the other technologies selected.

Note 36: Fencing may be necessary to limit access, depending on the location and nature of the potential risks and local land use restrictions. Fencing options can range from gates alone that restrict vehicular traffic to barbed wire on top of a fence around the landfill to deter trespassing. Effectiveness of such fencing depends on maintenance and monitoring.

Note 37: Signs may be posted to make clear to potential trespassers that there may be a health threat associated with trespassing. Effectiveness of posting signs depends on maintenance and monitoring.

4.14 Figure 14: Conventional Remediation Decisions

Note 38: Removal assessments should be performed any time the information obtained indicates that removal may be needed to protect human health or the environment. Removal actions include security fencing or other access-limiting actions, alternate water supplies, relocation of individuals, excavation of contaminated materials, installation of controls on contaminant migration, and other actions likely to be consistent with the final remedy. In contrast, remedial actions include all actions, consistent with permanent remedy, taken instead of or in addition to removal actions. New data obtained through the RI/FS should be reevaluated continually to determine whether a removal action may be appropriate.

Note 39: Interim or early remedial actions can be initiated before completing the RI/FS and selecting the final remedy if findings indicate unacceptable risks and an opportunity to reduce these risks quickly. Interim or early actions should be selected to constitute part or all of the final remedy.

4.15 Figure 15: Removal Action Decisions

Note 40: Bulk storage containers include drums, barrels, and tanks. Critical gaps and deficiencies should be identified in the information available to support the decision process for the landfill and all other areas potentially contaminated by the landfill contents.

Glossary

Conceptual site model (CSM) A coherent and concise depiction of a waste disposal site prepared by consolidating and integrating the current facts, assumptions, and concepts relevant to the site, and presented typically through a combination of narrative, maps, geological cross sections, flow charts and/or tabular formats, to show the relationships among COCs at the source area and potential exposures at likely receptor contact points.

Complete Pathway Pathway that allows migration of a COC actually or potentially released from a source area to a likely receptor contact point.

Presumptive Remedy Preferred remedy or set of remedies that are presumptively considered to be the most appropriate for addressing a specific type of site, based on historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation for the site type.

Principal Threat Waste A source material that is (1) highly toxic and/or highly mobile, (2) generally cannot be reliably contained, and (3) could present substantial threat to human health or the environment if released (e.g., liquids in drums, lagoons, or tanks; free product non-aqueous phase liquids over or under groundwater; surface soil with high concentrations of volatiles or dust-associated COCs; highly toxic, non-liquid wastes in buried drums or tanks or in soil at high concentrations).

Receptor Human or ecological organism, ecosystem, critical habitat, sensitive environment, or other living entity and environmental resource that may be adversely affected by exposure to a COC.

Receptor contact point Location at which a potential receptor may be present and may engage in an activity that can result in exposure to a medium that is actually or potentially contaminated by COCs released from a source area.

Remedial actions Actions taken to remediate a site, following an RI/FS process, instead of, or in addition to, removal actions that might be taken.

Removal actions Security fencing or other access-limiting actions, alternate water supplies, relocation of individuals, excavation of contaminated materials, installation of controls on contaminant migration, and other actions taken—following an EE/CA process—to prevent exposures of potential receptors to COCs from a source area.

Source Area Area in which the landfill contents are present and from which contaminants have been released in the past, are presently being released, or might be released in the future to migrate to likely receptor contact points at the landfill, near the landfill, or at some distance from the landfill.

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List of Acronyms

ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criterion
BOD	Biological Oxygen Demand
Btu	British thermal unit
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CO_2	Carbon dioxide
COC	Contaminant of Concern
COD	Chemical Oxygen Demand
CSM	Conceptual Site Model
cy	cubic yard
DoD	Department of Defense
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
FFS	Focused Feasibility Study
FS	Feasibility Study
FML	Flexible Membrane Liner
H_2S	Hydrogen sulfide
LDR	Land Disposal Restriction
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NAPL	Non-Aqueous Phase Liquid
OSWER	Office of Solid Waste and Emergency Response
POTW	Publicly Owned Treatment Works
PREECA	Presumptive Remedy Engineering Evaluation/Cost Analysis
PRG	Preliminary Remediation Goal
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action
RI	Remedial Investigation
TAL	Target Analyte List
TCL	Target Contaminant List
TCLP	Toxicity Characteristic Leachate Procedure
TDS	Total Dissolved Solids
TSDF	Treatment, Storage, and Disposal Facility
TSS	Total Suspended Solids
VOC	Volatile Organic Compound