Corrective Action Design Report (CADR) Guidance

for Leaking Underground Storage Tanks (LUST) Sites
Using Risk-Based Corrective Action (RBCA)

Iowa Department of Natural Resources
Underground Storage Tank Section
Wallace State Office Building
502 East Ninth Street
Des Moines, IA 50319-0034
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General Information

The primary objectives of corrective action in response to a high risk classification are both short-term and long-term. The short-term goal is to eliminate or reduce the risk of exposure at actual receptors which have been or are imminently threatened with exposure above target levels. The long-term goal is to prevent exposure to actual receptors which are not currently impacted or are not imminently threatened with exposure. To achieve these objectives, concentrations of applicable chemicals of concern must be reduced by active remediation to levels below the site-specific target level (SSTL) line at all points between the source(s) and the point(s) of exposure as well as to undertake such interim corrective action as necessary to eliminate or prevent exposure until concentrations below the SSTL line are achieved. If it is shown that concentrations at all applicable points have been reduced to below the SSTL line, the secondary objective is to establish that the field data can be reasonably relied upon to predict future conditions at points of exposure rather than reliance on the modeled data. Field data are considered reliable when monitoring indicates concentrations within the contaminant plume are steady or declining. Institutional controls and technological controls may be used to sever pathways or control the risk of receptor impacts. For the soil vapor and soil to plastic water line pathways, these objectives are achieved by active remediation of soil contamination to below the target level at the point(s) of exposure or other designated point(s) of compliance using the same measurement methods for receptor evaluation under subrules 135.10(7) and 135.10(9). For a site classified as high risk or reclassified as high risk for the soil leaching to groundwater ingestion pathway, these objectives are achieved by active remediation of soil contamination to reduce the soil concentration to below the site-specific target level at the source.

The following document provides the guidance for preparing the Corrective Action Design Report (CADR) for sites classified as high risk. The CADR contains the technical information specific to the treatment system chosen to remediate the site and a monitoring proposal designed to determine the effectiveness of the system and detect contamination movement. A checklist has been provided which outlines the minimum requirements for CADR submittal. If more than one technology will be implemented at the site, all the information from all applicable technologies must be provided. If a section of the CADR does not appear to be applicable to the corrective action proposed, provide justification in the appropriate section of the CADR.

The information contained in this document was obtained from the Environmental Protection Agency's (EPA) *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*. More information regarding the remediation techniques discussed in this document may be obtained from EPA's RCRA/Superfund Hotline. The Hotline is open Monday through Friday from 8:30 a.m. to 7:30 p.m. EST. The toll-free number is 800/424-9346; for the hearing impaired, the number is TDD 800/553-7672.

The CADR must be submitted in the format required by Iowa Department of Natural Resources (IDNR). The guidance documents for Tier 1 and Tier 2 should be consulted for acceptable sampling and assessment procedures. The CADR must be prepared by an Iowa certified groundwater professional. Reports must be signed by the responsible party as well as by an Iowa certified groundwater professional. It is the responsibility of the tank owner or operator to ensure that the groundwater professional prepares a report appropriate for the conditions at the site. All groundwater and soil data obtained during the preparation of the CADR must be collected by or under the supervision of an Iowa certified groundwater professional.

Underground Storage Tank (UST) owners and operators eligible to receive state funds to cover site investigation and corrective action expenses must submit the CADR preparation budget (and the Tier 1 and/or Tier 2 budgets, if not completed) prior to initiating work for the site to GAB Robins, PO Box 3837, 2600 72nd Street, Suite A, Des Moines, IA 50322, 515/276-8046. Failure to receive budget approval from GAB Robins prior to starting work for the site may result in a loss of state benefit eligibility.

Copies of administrative rules referenced in this document may be obtained from IDNR Records Center by calling 515/242-5818. This document references various Chapters of 567 IAC (Iowa Administrative Code)(455B).

Report submittal

Unless a Tier 3 assessment is to be conducted, a CADR must be submitted to the department within 120 days of the date the IDNR approves or is deemed to approve a Tier 2 Site Cleanup Report which indicated a high risk classification (unless a different deadline is set by the department). Every CADR should contain the following sections, at a minimum:

[ ] Completed CADR cover page (found at the end of this document)
[ ] Completed CADR checklist (found at the end of this document)
[ ] I. Executive summary
[ ] II. Comparison of two corrective action alternatives
[ ] III. Justification for selected corrective action
[ ] IV. Timetable and critical performance benchmarks
[ ] V. System design
[ ] VI. Pilot test
[ ] VII. Operation and maintenance plan
[ ] VIII. Start-up period plan
[ ] IX. Groundwater summary corrective action map from the Tier 2 report
[ ] X. Soil summary corrective action map from the Tier 2 report
[ ] XI. Groundwater flow direction maps (current and historic)
[ ] XII. Monitoring plan
[ ] XIII. Waste management disposal plan
[ ] XIV. Security / System protection
[ ] Appendix A: Permits
[ ] Appendix B: Justification
[ ] Appendix C: Boring logs / well construction diagrams (Only those which have not been previously submitted to the IDNR.)
[ ] Appendix D: Laboratory analytical reports (Only those which have not been previously submitted to the IDNR.)

Note: All maps and diagrams must contain a legend explaining all symbols used on the map or in the figure. When a groundwater flow map is required, please also include copies of historic groundwater flow maps.

Send one copy of the completed CADR to the Iowa Department of Natural Resources, LUST Coordinator, Wallace Building, Des Moines, IA 50319-0034 and, if the state UST Fund is being used, send one copy to GAB Robins, PO Box 3837, 2600 72nd Street, Suite A, Des Moines, IA 50322.

Review process

A submitted CADR is considered to be complete if it contains all the information and data required by the department's administrative rules and guidance. The report is considered accurate if the information and data are reasonably reliable based first on the standards in Chapter 135 and this guidance, and second, on generally accepted industry standards. Unless the report proposes to classify the site as no action required, the department must approve the report within 60 days for purposes of completeness or disapprove the report upon a finding of incompleteness, inaccuracy or noncompliance with Chapter 135. If no decision is made within this 60-day period, the report is deemed to be approved for purposes of completeness. The department will review each CADR which proposes to classify a site as no action required to determine whether the data and information are complete and accurate, the data and information comply with department rules and guidance and the site classification proposal is reasonably supported by the data and information.

Reclassification

Any site or pathway which is classified as high risk may be reclassified to low risk if in the course of corrective action the criteria for low risk classification are established. Remediation systems must be turned off, and conditions allowed to stabilize before monitoring can be considered as justification for a no action required classification. Any site or pathway which is classified as low risk may be reclassified to high risk if in the course of monitoring the conditions for high risk classification are established. Sites subject to department-approved institutional or technological controls are classified as no action required if all other criteria for no action required classification are satisfied.

Site Monitoring Reports

Site Monitoring Reports (SMRs) must be submitted semi-annually after the second and fourth quarters for remediation monitoring and at least annually for all other types of monitoring. Remediation monitoring may include groundwater sampling, influent/effluent sampling, etc. Checklists are provided in the SMR Guidance document listing the requirements for every type of monitoring.

Report Preparation

Cover page

Fully complete the cover page of the CADR report including signatures of the responsible party and certified groundwater professional. The street address is sufficient for site identification purposes. If a rural route, box number or street without a house number is used, then a legal description must be provided using the township, range, and ¼, ¼, ¼, ¼ section. Check all boxes of technologies proposed to be implemented at the site. The blank boxes may be used if the technology proposed is not listed in the table.

CADR checklist

Fully complete the CADR checklist by checking the boxes for those items included in the CADR.

I. Executive summary

This section should be no longer than one or two pages and briefly summarize the following:

<u>Recommended corrective action</u>: Describe the type(s) of corrective action proposed for the site.

<u>Receptors to be addressed</u>: List all receptors which must be addressed and include the site-specific target levels (SSTL) and chemicals of concern which exceed the SSTL lines for the receptors.

<u>Estimated costs</u>: Provide an estimate of how much it will cost to install, operate and maintain the proposed system.

Installation & start-up ______________
Annual operation and maintenance costs ______________
Total monitoring costs ______________
TOTAL estimated cost ______________

<u>Estimated operation time:</u> Estimate the operation time, expressed in years, for proposed system to reach the SSTL at the site.

II. Comparison of two corrective action alternatives

Two principally applicable corrective actions: The CADR must identify at least two principally applicable corrective action options designed to meet the objectives in 135.12(3).

Estimated operation time: Estimate the operation time, expressed in years, for each alternative system to reach the SSTL at the site.

Estimated costs: Provide an estimate of how much it will cost to install, operate and maintain each alternate system. Provide the same type of information, in the same format, as in the "Estimated costs" section of the Executive Summary.

III. Justification for selected corrective action

Cost comparison: The CADR must contain an analysis of the proposed corrective action's cost effectiveness in relation to other options.

Documentation: Provide supporting documentation consistent with industry standards that the technology is effective to accomplish site-specific objectives.

IV. Timetable and critical performance benchmarks

An outline of the projected timetable and critical performance benchmarks must be provided. If, at any time during the operation of the system, the timetable deadlines won't be met, provide prior justification to the department with a firm date by which they will be met.

V. System design

Provide a detailed narrative description and proposed design of the engineering strategy and system(s), including:

- complete design criteria such as expected contaminant concentrations; total contaminant volumes; projected flow rates and volumes; temperatures, pressures, etc., under varying conditions (seasonal and project phases); methods for all on-site collection, treatment, storage, and disposal;
- alarm and safety features to respond to malfunctions, potential overflows, etc.;
- type and location of utility services needed for the system; and
- general layout and process flow diagrams depicting the location of all collection, treatment, storage, and disposal activities.
- Checklists to be used for system design have been included in the soil vapor extraction (SVE), biomounding, bioremediation, and air sparging with SVE sections of this document.

VI. Pilot test

A pilot test should be performed before the submittal of the CADR. The information gathered during the test must be included to show the effectiveness of the proposed system. Pilot test checklists are provided for the soil vapor extraction (SVE) and air sparging with SVE sections. If a pilot test is not conducted, justification must be provided to ensure the remediation system chosen for the site will be successful.

VII. Operation and maintenance plan

An operation and maintenance (O & M) plan should outline the equipment operational parameters, specifications and operational tasks, monitoring, corrective actions, record-keeping techniques, health and safety measures, and reporting method and schedule. Designers or other responsible persons should begin to draft the plan when the CADR is prepared, and it should be updated to reflect changes outlined in the detailed plans, specifications and the construction documentation report. The plan should be updated during the operation of the system to reflect any changes in normal operation, and any failure of a corrective action described in the plan.

VIII. Start-up period plan

After the system is installed, it may be necessary to specify a start-up period to acclimate the system and make any adjustments that are needed to ensure optimal operation. Complete treatment may not occur during this period, but effluent discharge limits must be met during the period. (It may be necessary to store effluent during the start-up period and re-treat and discharge it later.) Start-up periods are usually necessary for some chemical treatment systems and for most biological methods. Air strippers and carbon systems probably will only need minor adjustments, so a start-up period may not be necessary.

IX. Groundwater summary corrective action map(s) from Tier 2 Site Cleanup Report

Provide a copy of the map(s) from the Tier 2 Site Cleanup Report and indicate the areas required to be cleaned up and the contaminant levels which must be achieved at the site.

X. Soil summary corrective action map(s) from Tier 2 Site Cleanup Report

Provide a copy of the map(s) from the Tier 2 Site Cleanup Report and indicate the areas required to be cleaned up and the contaminant levels which must be achieved at the site.

XI. Groundwater flow direction maps

Provide current and historical groundwater flow maps for the site. Groundwater elevations must be measured on the same date to provide for accurate groundwater flow contouring.

XII. Monitoring plan

Provide a monitoring plan which outlines all sampling points and parameters which are required to be monitored for annual monitoring and remediation monitoring. Monitoring results should be submitted using the appropriate sections of the Site Monitoring Report (SMR). Annual sampling should be conducted during the third calendar quarter with the SMR due by October 30th. Remediation monitoring is required to be **conducted** at least quarterly with SMRs submitted semi-annually (after the second and fourth quarters). The initial SMR submitted after a remediation system has been started should include a construction documentation section, an initial progress summary, monitoring plan from the Tier 2 Site Cleanup Report and a best management practices section. SMRs submitted for the fourth calendar quarter of each year should also include any high risk interim monitoring (conducted in the third calendar quarter) which is required in addition to the remediation monitoring.

<u>Bedrock monitoring</u>: When monitoring at non-granular bedrock sites, all groundwater monitoring wells at the site must be sampled. When monitoring at granular bedrock sites, a transition well and a sentry well for each applicable receptor must be sampled. Bedrock monitoring is required at least annually.

<u>High risk interim</u>: Interim monitoring begins once a Tier 2 site cleanup report is submitted and continues until the site is classified as no action required. Groundwater samples must be taken from a source well, a transition well and a guard well. Interim monitoring is required at least annually.

High risk remediation: Remediation monitoring is performed during the operation of an **active** remediation system. The certified groundwater professional must provide a specific monitoring plan and schedule (at least quarterly monitoring) for the site in the CADR. Remediation monitoring may include groundwater sampling, influent/effluent sampling, etc. Remediation monitoring is required to be **conducted** at least quarterly with SMRs submitted semi-annually (after the second and fourth quarters). The initial SMR submitted after a remediation system has been started should include a construction documentation section, an initial progress summary, monitoring plan from the Tier 2 Site Cleanup Report and a best management practices section. SMRs submitted for the fourth calendar quarter of each year should also include any high risk interim monitoring (conducted in the third calendar quarter) which is required in addition to the remediation monitoring.

Construction documentation: After the treatment system is constructed, the as-built plans should be presented in the construction documentation section. This should be submitted to the IDNR as part of the **initial** Site Monitoring Report. Include the following:

- As-built plans
- Description of the installation
- Certification that the design and construction was in accordance with the plans and specifications listed in the CADR with a description of any deviations
- Results of any testing or monitoring conducted as part of the construction/testing of the system

Progress summary: A progress summary detailing all corrective action activities must be submitted to the IDNR at least semi-annually during the operation of an active remediation system. The summary should be submitted as part of the SMR and provide a general discussion of recent activities, all monitoring data for the reporting period, and show the progress to date toward attainment of the cleanup goals established in the CADR. The progress summary should include the following items:

1) Operation summary
   - A summary of system operations during the reporting period including documentation of the volume of contaminants recovered, volumes disposed of or recycled, and any equipment problems, down time, repairs, modifications made to the system, and replacements; (The IDNR must be informed within 24 hours of system shut-down.)
2) Effectiveness
   - A discussion of the efficiency and effectiveness of the corrective action strategy to date and any recommendations for modification of the existing system, or if it is determined the system will not work at this site, provide a proposal to replace existing system with an alternate technology(ies).
   - Copies of all laboratory data for soil, soil vapor and groundwater sampling conducted during the reporting period, including Chain of Custody forms and any pertinent QC/QA information;
   - Graphs that include data through the life of the project are very useful to evaluate trends. An example is a graph indicating total contaminant removal with time on the X axis and cumulative contaminant removal on the Y axis;
3) Other information
   - Any other pertinent information or data.

XIII. Waste management disposal plan

Provide a plan for disposal of the different forms of waste produced by the remediation system. Include estimated volumes of soil, process water, sludge and free product.

Wastewater discharges to storm sewers: The following are treatment system effluent limitations for storm sewer discharges. The discharge limitations are only applicable to systems treating water contaminated as a result of a gasoline release.

Benzene	5 parts per billion (ppb)
Total benzene, toluene, ethylbenzene & xylenes (BTEX)	100 ppb
pH	6 minimum - 9 maximum

To obtain approval for a discharge to a storm sewer for a gasoline related release, provide:

1) A map showing discharge points of the treatment system into the storm sewer and the storm sewer's discharge point into the receiving stream.
2) Documentation indicating the treatment system is sufficiently designed to assure the effluent is within the limitations for benzene and total BTEX.
3) A letter or other form of certification from the entity owning the sewer approving the use of the sewer as a discharge point.

Wastewater discharges to sanitary sewers: The following are treatment system effluent limitations for sanitary sewer discharges. The discharge limitations are only applicable to systems treating water contaminated as a result of a gasoline release.

Benzene	50 parts per billion (ppb)
Total benzene, toluene, ethylbenzene & xylenes (BTEX)	750 ppb
pH	6 minimum - 9 maximum

To obtain approval for a discharge to a sanitary sewer of a gasoline related release, provide:

1) Documentation indicating the treatment system is sufficiently designed to assure the effluent is within the limitations for benzene and total BTEX.
2) A letter or other form of certification from the entity owning the sewer approving the use of the sewer as a discharge point.

Sanitary and storm sewer discharge limitations have not been established for systems treating water contaminated with petroleum products other than gasoline. At present, the discharge limitations are determined on a case-by-case basis. The IDNR must have the following information to establish a discharge limit:

1) If a surface discharge is being considered, a map showing the discharge point of the treatment system into the storm sewer and the storm sewer's discharge point into the receiving stream.
2) Expected effluent levels of benzene, toluene, ethylbenzene and xylenes from the treatment system.
3) A letter or other form of certification from the entity owning the sewer approving the use of the sewer as a discharge point.
4) Maximum design flow for the proposed treatment system.

Some larger communities manage their own sanitary sewer programs. These communities have the authority to establish sanitary discharge limitations different from those discussed above. In those situations, you must provide:

1) Discharge limitations established by the community.
2) Documentation that the treatment system is sufficiently designed to prevent the effluent from exceeding the discharge limitations.
3) A letter or other form of certification from the entity owning the sewer approving the discharge use.

XIV. Security / system protection

Describe the type of security system to be placed at the site to protect against vandalism and inclement weather. Lock all structures housing parts of the remediation system. All monitoring and recovery wells must have locking caps. The keys for the wells and structures housing the remediation system should remain at the site. If this is impossible, provide a name, address and daytime phone number of a contact person who will hold the keys.

Soil remediation

The following section describes some criteria for evaluating different methods to remediate soil.

Soil Vapor Extraction (SVE)
Bioventing
Biomounding
Thermal Desorption
Land Farming
Excavation (off-site treatment)

Soil Vapor Extraction

Soil vapor extraction (SVE), also known as soil venting or vacuum extraction, is an in situ technique for removing contaminants from unsaturated soils. This technology creates a negative pressure gradient resulting in movement of vapors to the extraction wells. The extraction wells bring the contaminants to the surface, where they can be collected, treated (when necessary) and safely discharged.

SVE is most effective in coarse-grained soils such as sand and gravel. SVE is generally more successful when applied to the lighter (more volatile) petroleum products such as gasoline. Diesel fuel, heating oils, and kerosene, which are less volatile than gasoline, are not readily treated by SVE but may be suitable for removal by bioventing. SVE generally requires a minimum 5-foot-thick unsaturated zone of soil. SVE can be used in conjunction with air sparging, groundwater pumping or bioremediation systems. This technique is able to treat large volumes of soil effectively and with minimal disruption to business operation. It also can remove contamination from near or under fixed structures.

Advantages:
- Effectively treats large volumes (>1,000 cubic yards) of soil.
- Removes contamination near or under fixed structures.
- Causes minimal disruption to business operations.
- Removes volatile contaminants from the zone of water table fluctuation.
- Readily available equipment; easy installation.
- Short treatment times under optimal conditions.
- Easily combined with other technologies.

Limitations:
- Effectiveness limited in heterogeneous soils or soils with high clay or organic content.
- Airflow may not contact all parts of soil.
- May require air discharge permits.
- May require costly treatment for atmospheric discharge of extracted vapors.
- Concentration reductions greater than 90% are difficult to achieve.
- Only treats unsaturated-zone soils; other methods may also be needed to treat saturated-zone soils and groundwater.

System components & information:
- Vertical or horizontal extraction wells
- Well orientation, placement and construction details
- Manifold piping
- Trenches
- Vacuum blower or pump selection
- Vacuum pretreatment design
- Injection and passive inlet wells
- Instrumentation and control design
- Aboveground vapor treatment equipment (optional)
- Surface seals (optional)
- Groundwater treatment systems (optional)
- Vapor treatment systems (optional)

Waste stream treatment: Vapor treatment options (if needed):

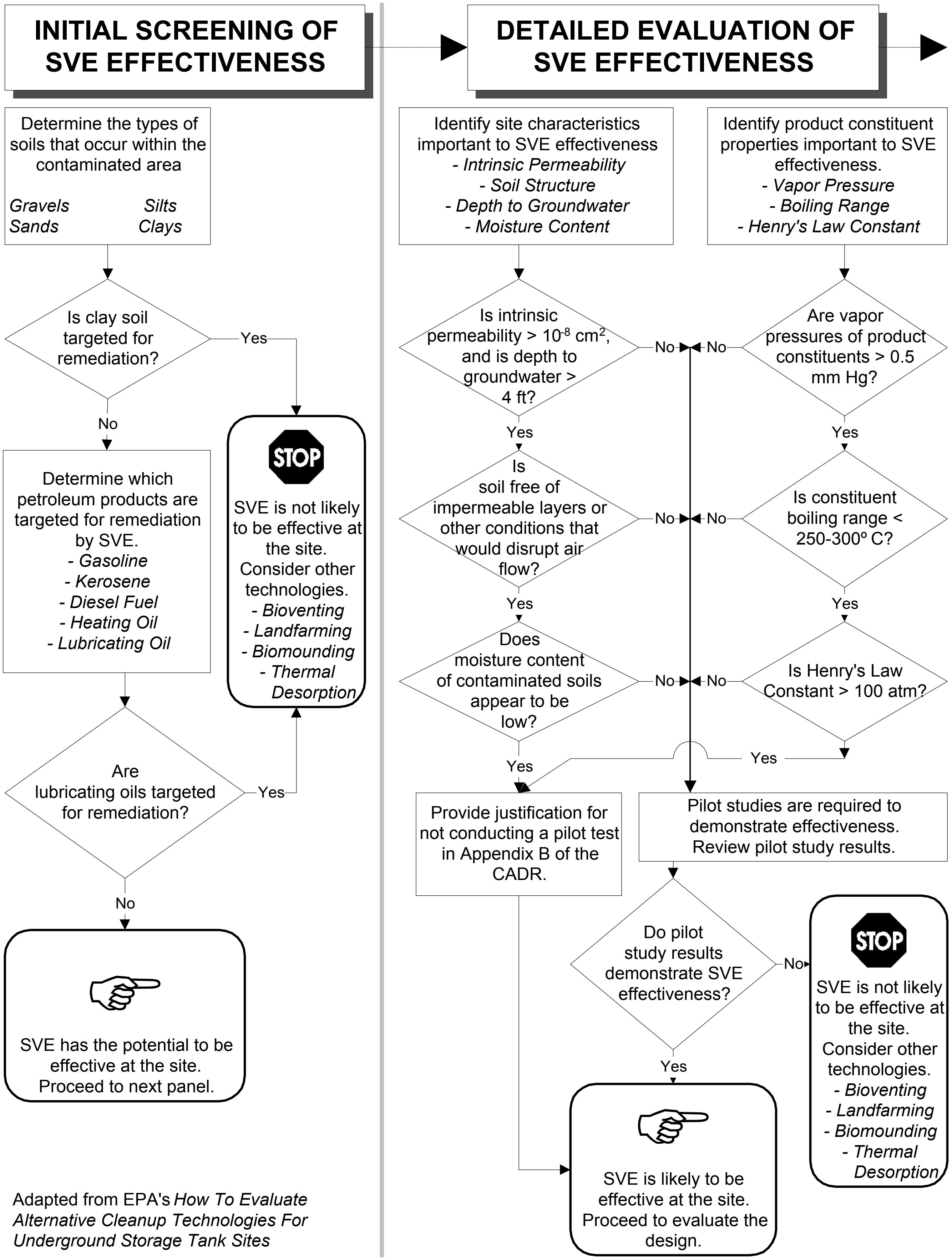
- Vapor phase biofilter
- Granulated activated carbon
- Internal combustion engine
- Catalytic oxidation unit
- Thermal incinerator

Recommended monitoring and control equipment		
Monitoring equipment	**Location in system**	**Example of equipment**
Flow meter	◊ At each well head ◊ Manifold to blower ◊ Blower discharge	◊ Pitot tube ◊ In-line rotameter ◊ Orifice plate ◊ Venturi or flow tube
Vacuum gauge	◊ At each well head or manifold branch ◊ Before and after filters upstream of blower ◊ Before and after vapor treatment	◊ Manometer ◊ Magnehelic gauge ◊ Vacuum gauge
Vapor temperature sensor	◊ Manifold to blower ◊ Blower discharge (prior to vapor treatment)	◊ Bi-metal dial-type thermometer
Sampling port	◊ At each well head or manifold branch ◊ Manifold to blower ◊ Blower discharge	◊ Hose barb ◊ Septa fitting
Vapor sample collection equipment (used through a sampling port) - lab analysis or PID would be acceptable	◊ At each well head or manifold branch ◊ Manifold to blower ◊ Blower discharge	◊ Tedlar bags ◊ Sorbent tubes ◊ Sorbent canisters ◊ Polypropylene tubing for direct GC injection
Control equipment		
Flow control valves	◊ At each well head or manifold branch ◊ Dilution or bleed valve at manifold to blower	◊ Ball valve ◊ Gate/globe valve ◊ Butterfly valve

Required parameters to monitor for system performance:

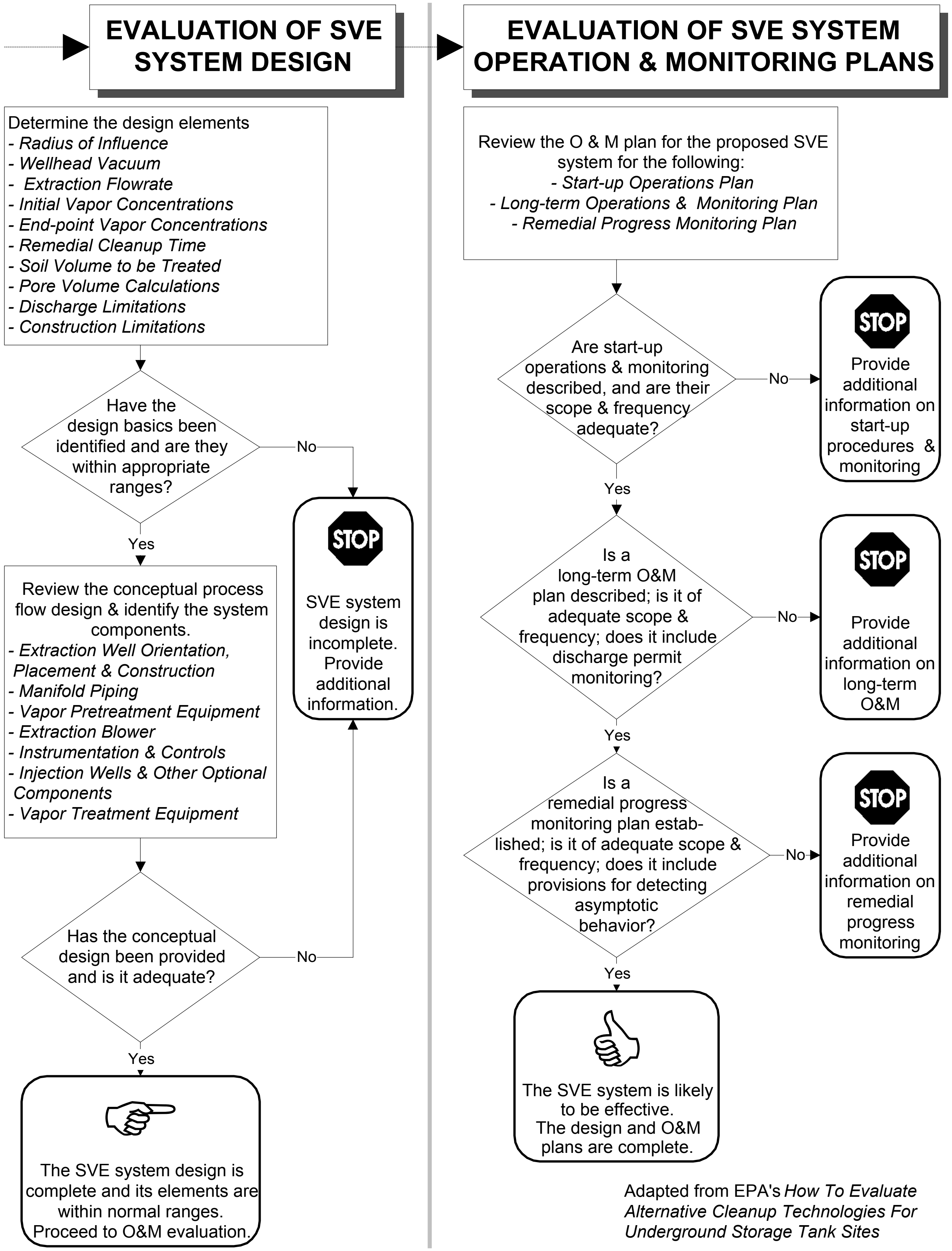
- Vapor concentration at each SVE extraction point, vapor peizometer, system manifold, and discharge stack (using PID/FID)
- Vacuum pressure at each SVE extraction point, vapor peizometer, and system manifold
- Air flow measurement (standard cubic feet per minute - scfm) at each SVE extraction point, and system manifold
- Static water level measurements in each monitoring well and SVE recovery well. (Compare the static water level with the elevation of the vapor extraction screen or point)
- BTEX and dissolved oxygen in the groundwater at selected monitoring wells
- Volatile organic hydrocarbon concentration: total air flow rate for the system and volatile organic hydrocarbon concentration for the system (laboratory analyzed samples)

SVE Evaluation Process Flow Chart (1 of 2)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

SVE Evaluation Process Flow Chart (2 of 2)



EVALUATION OF SVE SYSTEM DESIGN

Determine the design elements
- *Radius of Influence*
- *Wellhead Vacuum*
- *Extraction Flowrate*
- *Initial Vapor Concentrations*
- *End-point Vapor Concentrations*
- *Remedial Cleanup Time*
- *Soil Volume to be Treated*
- *Pore Volume Calculations*
- *Discharge Limitations*
- *Construction Limitations*

Have the design basics been identified and are they within appropriate ranges?

Review the conceptual process flow design & identify the system components.
- *Extraction Well Orientation, Placement & Construction*
- *Manifold Piping*
- *Vapor Pretreatment Equipment*
- *Extraction Blower*
- *Instrumentation & Controls*
- *Injection Wells & Other Optional Components*
- *Vapor Treatment Equipment*

Has the conceptual design been provided and is it adequate?

SVE system design is incomplete. Provide additional information.

The SVE system design is complete and its elements are within normal ranges. Proceed to O&M evaluation.

EVALUATION OF SVE SYSTEM OPERATION & MONITORING PLANS

Review the O & M plan for the proposed SVE system for the following:
- *Start-up Operations Plan*
- *Long-term Operations & Monitoring Plan*
- *Remedial Progress Monitoring Plan*

Are start-up operations & monitoring described, and are their scope & frequency adequate?

Provide additional information on start-up procedures & monitoring

Is a long-term O&M plan described; is it of adequate scope & frequency; does it include discharge permit monitoring?

Provide additional information on long-term O&M

Is a remedial progress monitoring plan established; is it of adequate scope & frequency; does it include provisions for detecting asymptotic behavior?

Provide additional information on remedial progress monitoring

The SVE system is likely to be effective. The design and O&M plans are complete.

Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Can SVE be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that may require closer scrutiny. If the answer to several questions is no, additional information may be required to determine if SVE will accomplish the clean-up goals at the site. (Technical factors may be found in Appendix B.)

1. Factors that contribute to permeability of soil

Yes	No	
☐	☐	Is the hydraulic conductivity greater than 0.44 m/d?
☐	☐	Is the intrinsic permeability greater than 10^{-8} cm^2 ?
☐	☐	Is the depth to groundwater greater than 4 feet? If no, this parameter alone may not negate the use of SVE. However, provisions for use of a surface seal, construction of horizontal wells or for lowering the water table must be incorporated into the CADR.
☐	☐	Are site soils generally dry?

2. Factors that contribute to constituent volatility

Yes	No	
☐	☐	Is the contaminant vapor pressure greater than 0.5 mm Hg?
☐	☐	If the contaminant vapor pressure is not greater 0.5 mm Hg, is some type of enhancement (e.g., heated air injection) proposed to increase volatility?
☐	☐	Are the boiling points of the contaminant constituents less than 250°C?
☐	☐	Is the Henry's law constant for the contaminant greater than 100 atm?

3. Evaluation of the SVE system design

Yes	No	
☐	☐	Does the radius of influence (ROI) for the proposed extraction wells fall in the range of 5-100 feet?
☐	☐	Has the ROI been calculated for each soil type at the site?
☐	☐	Examine the extraction flow rate. Will these flow rates achieve cleanup in the time allotted for remediation in the CADR?
☐	☐	Is the type of proposed well (horizontal or vertical) appropriate for the site conditions present?
☐	☐	Is the proposed well density appropriate, given the total area to be cleaned up and the radius of influence of each well?
☐	☐	Do the proposed well screen intervals match soil conditions at the site?
☐	☐	Is the blower selected appropriate for the desired vacuum conditions?

4. Optional SVE components

Yes	No	
☐	☐	Are air injection or passive inlet wells proposed?
☐	☐	Is the proposed air injection/inlet well design appropriate for this site?
☐	☐	Are surface seals proposed?
☐	☐	Are the sealing materials proposed appropriate for this site?
☐	☐	Will groundwater depression be necessary?
☐	☐	If groundwater depression is necessary, are the pumping wells correctly spaced?
☐	☐	Is a vapor treatment system required?
☐	☐	If a vapor treatment system is required, is the proposed system appropriate for the contaminant concentration at this site?

Initial screening of SVE effectiveness:

- Permeability of the petroleum-contaminated soil.
- Volatility of the petroleum constituents.
- Soil moisture content.

Rationale for the design:

- Design radius of influence.
- Well head vacuum.
- Vapor extraction flow rate.
- Initial constituent vapor concentrations.
- Required final constituent concentrations.
- Soil volume to be treated.
- Pore volume calculations.
- Discharge limitations and monitoring requirements.
- Site construction limitations.

Pilot test

A pilot test is a small-scale, short-duration test of a basic SVE system to obtain data required to design an effective large-scale SVE-based remediation system. To be successful, the pilot test must provide accurate and reliable data to (1) identify sustainable airflow rates, (2) anticipate contaminant composition and removal rates, (3) determine airflow patterns in the subsurface, and (4) estimate the number of vapor extraction wells that will be required to capture volatile constituents from the target areas of contamination.

SVE pilot testing is an integral step in the process leading to proper SVE system design. The list below presents activities that should be considered during the planning and performance of a pilot test. Once a pilot test is complete, all data required to adequately design the full-scale SVE system should be available.

Pilot test checklist

A. Description: Provide a description of the pilot study and conditions at the time the pilot study was conducted:

[ ] 1. Date(s) of the test

[ ] 2. Last rainfall event

[ ] 3. Ambient air temperature

[ ] 4. Barometric pressure and pressure trends (e.g., climbing, falling or steady).

[ ] 5. Any other pertinent field observations

[ ] B. Duration: Justification for the length of time the pilot study was conducted.

[ ] C. Monitoring well construction justification: If existing monitoring wells were used, explain how the installed screen slot size and filter pack are appropriate for soil venting. Provide construction diagrams (on IDNR form 542-1392) for air extraction wells in Appendix C.

[ ] D. Measures to prevent upwelling: Describe any measures taken to prevent a significant upwelling of the water table during the pilot study. Discuss the treatment or discharge of contaminated groundwater if any. Provide copies of discharge approvals in Appendix A.

[ ] E. Pilot study blower system. Specify the type and capacity of blower used. The use of an explosion proof blower and switches is recommended for the pilot study. The blower should be equipped with a discharge stack, muffler (silencer) on the exhaust and a dilution or bleed valve on the blower inlet.

F. Sampling:

[ ] 1. Provide a list of the sample collection equipment or instruments used during the pilot test.

[ ] 2. Discuss the ability of the instruments or equipment to accurately measure VOCs (volatile organic compounds).

[ ] 3. Describe sampling methods and procedures.

[ ] 4. Justify the sampling frequency used during the pilot test.

[ ] 5. Discuss measured hydrocarbon and dissolved oxygen levels.

[ ] 6. Discuss tracer gas tests, if performed.

[ ] G. Method for measuring vacuum: Describe the method (e.g., air extraction wells, water wells, soil gas probes) for measuring the vacuum in the soil at varying distances from the air extraction wells. Provide the depths these measurements were made. Due to the vertical pressure gradients under active venting, it is important to use vacuum monitoring points that are equal in depth or as close as possible.

H. Test data:

[ ] 1. Flow rate (standard cubic feet per minute),
[ ] 2. vacuum (inches of water column - to two digits of accuracy),
[ ] 3. static water level (feet above sea level [ASL] tied to a geodetic datum) in the well prior to test,
[ ] 4. static water level (ASL) in well after test,
[ ] 5. time test started, and
[ ] 6. time vacuum measurements were taken.

[ ] I. Static water level: Static water level measurements (if a well was measured more than once, list each measurement chronologically).

J. Figures:

[ ] 1. Schematic of the pilot study venting system showing the location of air flow meters, vacuum gauges and thermometers.
[ ] 2. Site map with the following illustrated:
[ ] a. Location of all past and present USTs & lines with the type of substances stored in the USTs.
[ ] b. Location of air extraction wells and vacuum measuring points.
[ ] c. Paved areas, buildings and structures that may act as a surface seal or an infiltration barrier.
[ ] d. Buried utility trenches that may act as zones of higher permeability.
[ ] e. Any other pertinent site features that may affect a permanent soil venting system.
[ ] 3. Groundwater contour map of the site for the day the pilot study was conducted. Use an arrow to show the direction of groundwater flow.

[ ] K. Groundwater elevation changes: Discuss groundwater elevation changes resulting from air extraction/injection.

[ ] L. Radius of influence: Discuss how the radius of influence was calculated for each well.

[ ] M. Analytical data: Copies of all laboratory analytical data in Appendix D. Quantify results in mass per unit volume (milligrams per cubic meter of contaminated air).

[ ] N. Pilot test conclusions. Clearly state all assumptions. Show all calculations. Provide detailed justification for responses.

[ ] 1. What contaminant vapor concentrations are likely to be obtained?
[ ] 2. Under ideal vapor flow conditions, is the concentration great enough to yield acceptable removal rates?
[ ] 3. What range of vapor flow rates can be realistically achieved?
[ ] 4. Will the contaminant concentrations and realistic vapor flow rates produce acceptable removal rates?
[ ] 5. What residual concentrations, if any, will be left in the soil and/or groundwater? How do these residuals compare with target levels? Provide an estimation of the time it will take to achieve target levels.
[ ] 6. What vapor composition and concentration changes will occur with time?

[ ] O. Modeling. If a model is used to justify SVE, identify the model and vendor names, describe all input variables, and provide a copy of the output data.

SVE system design checklist

[ ] A. Overview of system design: Provide a system schematic and discuss the system design.

[ ] B. Geologic conditions: Provide a brief discussion of the geologic conditions at the site.

[ ] C. Well construction: Provide construction logs of wells used for air extraction. Explain how it was determined the screen slot size and filter pack are appropriate for soil venting if existing monitoring wells are used for air extraction. Discuss the logic for determining well screen placement.

D. Manifold system: Provide details of the manifold system:

- [ ] 1. Piping type
- [ ] 2. Piping diameter
- [ ] 3. Description of instrumentation for measuring flow
- [ ] 4. Description of instrumentation for measuring vacuum

[ ] E. Air flow rate calculations: Provide calculations for predicting total air flow rate.

F. Blower system: Provide details of the blower system:

- [ ] 1. Anticipated air flow rate
- [ ] 2. Anticipated vacuum levels
- [ ] 3. Blower type
- [ ] 4. Blower size

[ ] G. Justification to prevent explosions: Provide assurances that explosion proof vacuum pump, vacuum gauges and condensation traps are provided for in the design of the treatment system.

[ ] H. Disposal of contaminated water: Discuss the method for disposal of incidental collected water. Provide copies of discharge approvals.

[ ] I. Well spacing and radius of influence: Discuss the method used to determine well spacing and radius of influence. Show calculations. If an air flow model is used, include the results of the model and any assumptions the model uses. Identify the model and vendor names.

J. SVE system maps: Scaled site maps with the following illustrated:

- [ ] 1. Location of venting wells with area of influence indicated.
- [ ] 2. Monitoring locations to determine venting effectiveness.

[ ] K. VOC testing: Discuss the methods and instrumentation used for testing for total VOCs. Provide in the discussion the anticipated levels of analytical precision and evaluate any factors that could bias sample results.

Operation and monitoring plan

Start-up operations: The start-up phase should include 7 to 10 days of manifold valve adjustments. These adjustments should optimize contaminant mass removal by concentrating vacuum pressure on the extraction wells that are producing vapors with higher contaminant concentrations, thereby balancing flow and optimizing contaminant mass removal. Flow measurements, vacuum readings, and vapor concentrations should be recorded daily from each extraction well, from the manifold and from the effluent stack.

[ ] A. Describe the monitoring program conducted to evaluate system startup and to determine the effectiveness of the treatment system and progress of site remediation.

- Recommendations:
  - Daily for the first 3 days of operation
  - Weekly for the next 3 weeks
  - Monthly thereafter
- Recommended parameters:
  - Flow rate (standard cubic feet/minute) at each well
  - Total flow rate (standard cubic feet/minute)
  - Vacuum at each well (inches of water)

[ ] B. Describe the groundwater elevation monitoring conducted to determine if significant upwelling is occurring.

Long-term operations: Long-term monitoring should consist of flow-balancing, flow and pressure measurements and vapor concentration readings. Measurements should take place at bi-weekly to monthly intervals for the duration of the system operational period. Provide justification if measurements will be obtained less frequently. The table below provides a brief synopsis of system monitoring recommendations.

Recommended system monitoring requirements

Phase	Monitoring frequency	What to monitor	Where to monitor
Start-up (7-10 days)	Daily	◊ Flow ◊ Vacuum ◊ Vapor Concentrations	◊ Extraction vents ◊ Manifold ◊ Effluent stack
Remedial (on-going)	Biweekly to monthly (at least quarterly)	◊ Flow ◊ Vacuum ◊ Vapor concentrations	◊ Extraction vents ◊ Manifold ◊ Effluent stack

Bioventing

Bioventing is a technique for removing biodegradable contaminants from unsaturated soils. Soils in the capillary fringe and saturated zone are not affected. The technique injects air/oxygen into contaminated soil. The air/oxygen stimulates the aerobic biodegradation of the organic contaminants in the soil. Air/oxygen is delivered at a low rate to encourage biodegradation rather than volatilization.

Bioventing is most effective in coarse-grained soils such as sand and gravel. All aerobically biodegradable constituents can be treated by bioventing. In particular, bioventing has proven to be very effective in remediating releases of petroleum products including gasoline, jet fuels, kerosene, and diesel fuel. Bioventing is most often used at sites with mid-weight petroleum products (i.e., diesel fuel and jet fuel), because lighter products (i.e., gasoline) tend to volatilize readily and can be removed more rapidly using SVE. Bioventing requires a minimum 5-foot-thick unsaturated zone. This technique can be used in conjunction with air sparging or groundwater pumping systems. This technique is able to treat large volumes of soil effectively with minimal disruption to business operations. It also can remove contamination from near or under fixed structures. Bioventing also reduces the need for aboveground treatment because it degrades contaminants in place.

Advantages:

- Degrades semi-volatile organic compounds (SVOCs) and nonvolatile organic compounds
- Effectively treats large volumes (>1,000 cubic yards) of soil
- Causes minimal disruption to business operations
- Degrades contaminants near or under fixed structures
- Degrades volatile organic compounds (VOCs) in place, which reduces air emissions and subsequent need for treatment
- Uses readily available equipment; easy to install
- Requires short treatment times under optimal conditions
- Easily combinable with other technologies (e.g., air sparging, groundwater extraction)
- May not require costly off gas treatment

Limitations:

- Targets only biodegradable constituents
- Is a relatively slow process when conditions are not optimal
- Requires sufficient nutrients, moisture, active indigenous microbial population, and pH of 6-8 to degrade contaminants
- Effectiveness limited in heterogeneous soils
- High constituent concentrations may initially be toxic to microorganisms
- Not applicable for certain site conditions (e.g., low soil permeabilities, high clay content, insufficient delineation of subsurface conditions)
- Cannot always achieve very low cleanup standards
- Permits generally required for nutrient injection wells (if used). Permits for air injection may also be required.

System components & information:

- Vertical or horizontal extraction wells
- Well orientation, placement and construction details
- Piping design, trenches
- Vacuum blower or pump selection
- Injection and passive inlet wells
- Vapor pretreatment design
- Instrumentation and control design
- Vapor treatment system selection and nutrient delivery equipment (optional)

Factors to consider for well placement / number of wells:

- In areas of high contaminant concentrations, closer well spacing is desired to increase air/oxygen flow and accelerate contaminant degradation rates.
- Wells may be spaced slightly further apart if a surface seal installation is planned or if one already exists. A surface seal increases the radius of influence by forcing air to be drawn from a greater distance by preventing short-circuiting from the land surface. However, passive vent wells or air injection wells may be required to supplement the flow of air in the subsurface.
- In stratified or structured soils, well spacing may be irregular. Wells screened in zones of lower intrinsic permeability must be spaced closer together than wells screened in zones of higher intrinsic permeability.

Waste stream treatment: Vapor treatment options (might be needed for high concentrations of contaminants):

- Vapor phase biofilter
- Granulated activated carbon
- Internal combustion engine
- Catalytic oxidation unit
- Thermal incinerator

Required parameters to monitor for system performance:

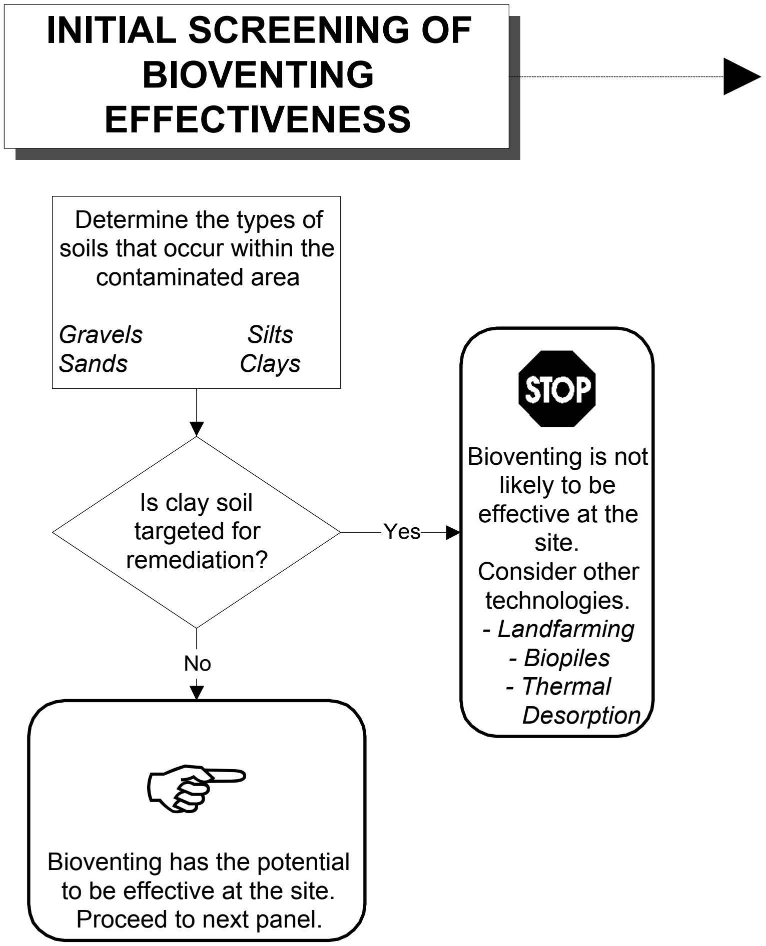
- Vapor concentration at each SVE extraction point, vapor peizometer, system manifold, and discharge stack (using PID/FID)
- Vacuum pressure at each SVE extraction point, vapor peizometer, and system manifold
- Air flow measurement (standard cubic feet per minute - scfm) at each SVE extraction point, and system manifold
- Static water level measurements in each monitoring well and SVE recovery well. (Compare the static water level with the elevation of the vapor extraction screen or point)
- BTEX and dissolved oxygen in the groundwater at selected monitoring wells
- Volatile organic hydrocarbon concentration: total air flow rate for the system and volatile organic hydrocarbon concentration for the system (laboratory analyzed samples)

Recommended monitoring equipment		
Instrument	**Location in system**	**Example of equipment**
Flow meter	◊ At each well head ◊ Manifold to blower ◊ Blower discharge ◊ Nutrient manifold	◊ Pitot tube ◊ In-line rotameter ◊ Orifice plate ◊ Turbine wheel ◊ Venturi or flow tube
Vacuum/pressure gauge	◊ At each well head or manifold branch ◊ Before and after filters before blower ◊ Before and after vapor treatment	◊ Manometer ◊ Magnehelic gauge ◊ Vacuum gauge
Vapor temperature sensor	◊ Manifold to blower ◊ Blower discharge (prior to vapor treatment)	◊ Bi-metal dial-type thermometer
Flow control valves	◊ At each well head or manifold branch ◊ Dilution or bleed valve at manifold to blower	◊ Ball valve ◊ Gate valve ◊ Dilution/ambient air bleed valve
Sampling port	◊ At each well head or manifold branch ◊ Manifold to blower ◊ Blower discharge	◊ Hose barb ◊ Septa fitting
Vapor sample collection equipment (used through a sampling port) - lab analysis or PID would be acceptable	◊ At each well head or manifold branch ◊ Manifold to blower ◊ Blower discharge	◊ Tedlar bags ◊ Sorbent tubes ◊ Sorbent canisters ◊ Polypropylene tubing for direct GC injection
Control equipment		
Flow control valves	◊ At each well head or manifold branch ◊ Dilution or bleed valve at manifold to blower	◊ Ball valve ◊ Gate/globe valve ◊ Butterfly valve

<u>Initial screening of bioventing effectiveness</u>:

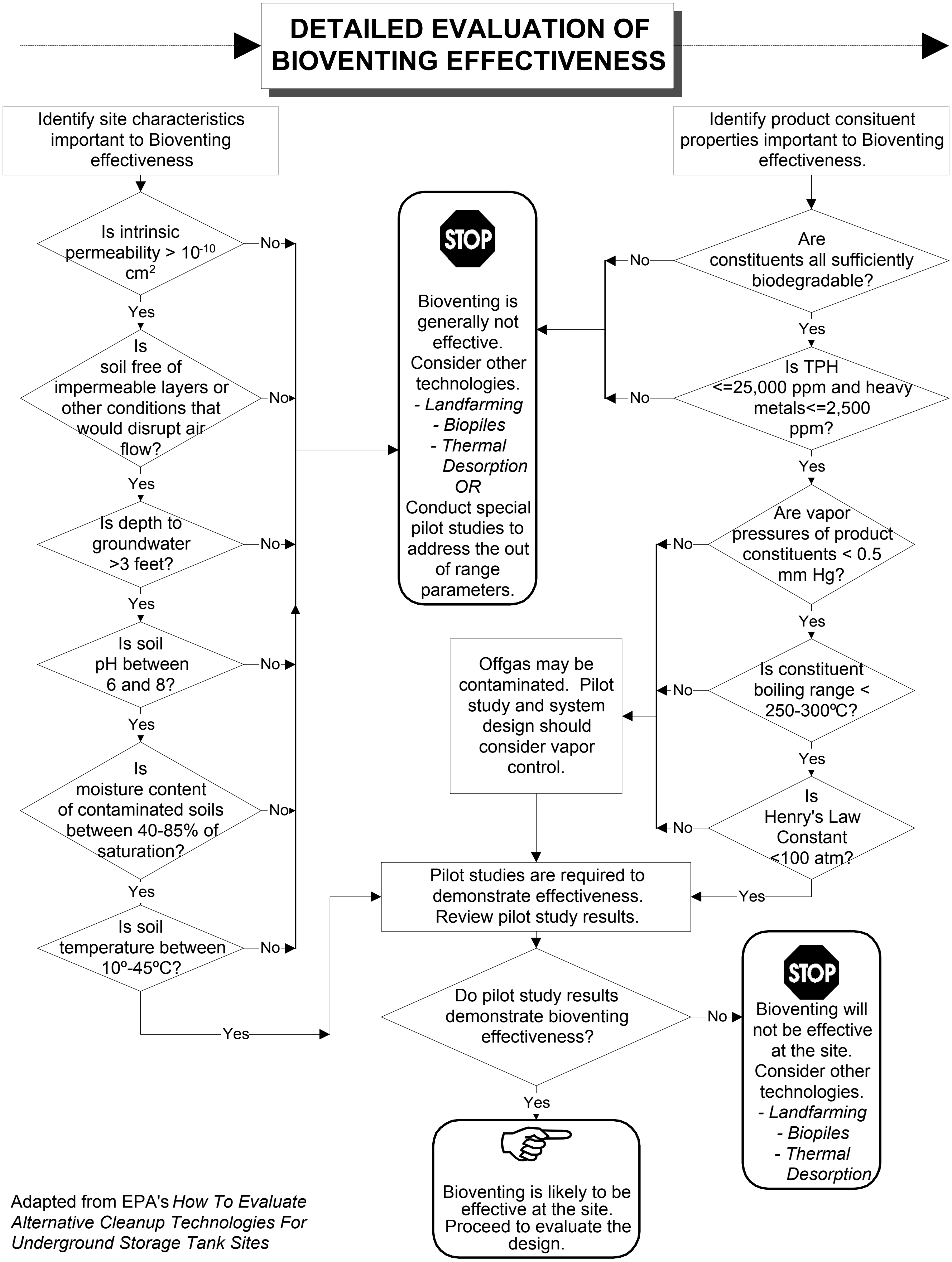
- Permeability of the petroleum-contaminated soils.
- Biodegradability of the petroleum constituents.

Bioventing Evaluation Process Flow Chart (1 of 3)



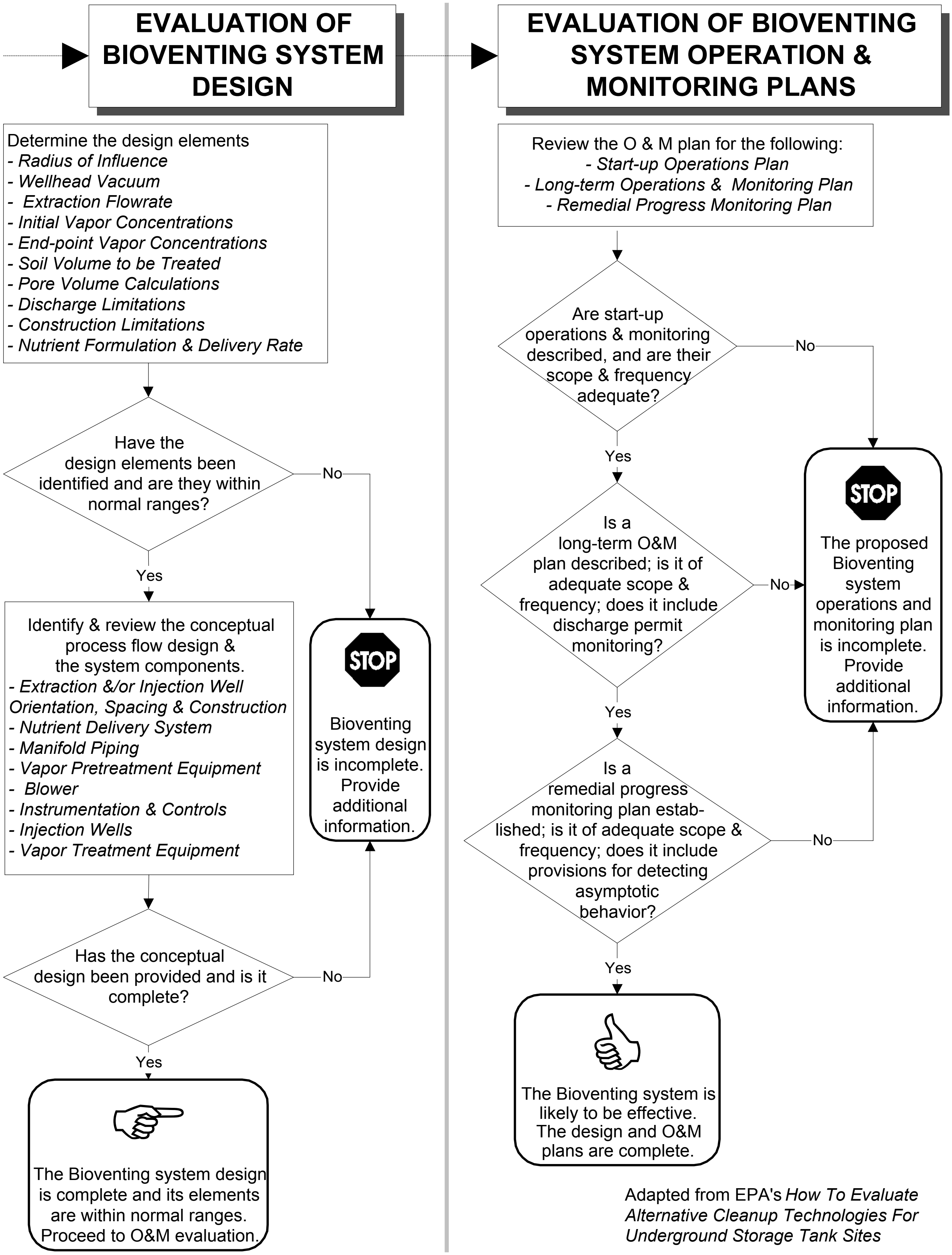
Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Bioventing Evaluation Process Flow Chart (2 of 3)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Bioventing Evaluation Process Flow Chart (3 of 3)



EVALUATION OF BIOVENTING SYSTEM DESIGN

Determine the design elements
- *Radius of Influence*
- *Wellhead Vacuum*
- *Extraction Flowrate*
- *Initial Vapor Concentrations*
- *End-point Vapor Concentrations*
- *Soil Volume to be Treated*
- *Pore Volume Calculations*
- *Discharge Limitations*
- *Construction Limitations*
- *Nutrient Formulation & Delivery Rate*

Have the design elements been identified and are they within normal ranges?

Identify & review the conceptual process flow design & the system components.
- *Extraction &/or Injection Well Orientation, Spacing & Construction*
- *Nutrient Delivery System*
- *Manifold Piping*
- *Vapor Pretreatment Equipment*
- *Blower*
- *Instrumentation & Controls*
- *Injection Wells*
- *Vapor Treatment Equipment*

Has the conceptual design been provided and is it complete?

Bioventing system design is incomplete. Provide additional information.

The Bioventing system design is complete and its elements are within normal ranges. Proceed to O&M evaluation.

EVALUATION OF BIOVENTING SYSTEM OPERATION & MONITORING PLANS

Review the O & M plan for the following:
- *Start-up Operations Plan*
- *Long-term Operations & Monitoring Plan*
- *Remedial Progress Monitoring Plan*

Are start-up operations & monitoring described, and are their scope & frequency adequate?

Is a long-term O&M plan described; is it of adequate scope & frequency; does it include discharge permit monitoring?

Is a remedial progress monitoring plan established; is it of adequate scope & frequency; does it include provisions for detecting asymptotic behavior?

The proposed Bioventing system operations and monitoring plan is incomplete. Provide additional information.

The Bioventing system is likely to be effective. The design and O&M plans are complete.

Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Can bioventing be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that require closer scrutiny. If the answer to several questions is no, additional information may be required to determine if bioventing will accomplish the clean-up goals at the site. (Technical factors may be found in Appendix B.)

1. Site characteristics

Yes	No	
☐	☐	Is the soil intrinsic permeability greater than 10^{-10} cm^2 ?
☐	☐	Is the soil free of impermeable layers or other conditions that would disrupt air flow?
☐	☐	Is soil pH between 6 and 8?
☐	☐	Is the moisture content of soil in the contaminated area between 40% to 85% of saturation?
☐	☐	Is soil temperature between 10°C and 45°C during the proposed operational period of the treatment system?
☐	☐	Is the carbon:nitrogen:phosphorus ratio between 100:10:5 and 100:1:0.5?
☐	☐	Is the depth to groundwater >3 feet? This parameter alone may not negate the use of bioventing. However, provisions for the construction of horizontal wells or trenches or for lowering the water table should be incorporated into the CADR.

2. Constituent characteristics

Yes	No	
☐	☐	Are all constituents sufficiently biodegradable?
☐	☐	Is the concentration of total petroleum hydrocarbon ≤ 25,000 ppm & heavy metals ≤ 2,500 ppm?
☐	☐	If there are constituents with vapor pressures greater than 0.5 mm Hg, boiling ranges above 250°C, or Henry's law constants less than 100 atm/mole fraction, has the CADR addressed the potential environmental impact of the volatilized constituents?

3. Evaluation of the bioventing system design

Yes	No	
☐	☐	Will the air flow rates achieve cleanup in the time allotted for remediation in the CADR?
☐	☐	Does the radius of influence (ROI) for the proposed extraction or injection wells fall in the range of 5-100 feet?
☐	☐	Has the ROI been calculated for each soil type at the site?
☐	☐	Is the type of well proposed (horizontal or vertical) appropriate for the site conditions present?
☐	☐	Is the proposed well density appropriate, given the total area to be cleaned up and the radius of influence of each well?
☐	☐	Do the proposed well screen intervals match soil conditions at the site?
☐	☐	Are air injection wells proposed?
☐	☐	Is the proposed air injection well design appropriate for this site?
☐	☐	Is the blower selected appropriate for the desired vacuum conditions?

4. Optional bioventing components

Yes	No	
☐	☐	If nutrient delivery systems are needed, are designs for those systems provided?
☐	☐	Are surface seals proposed?
☐	☐	Are the proposed sealing materials appropriate for this site?
☐	☐	Will groundwater depression be necessary?
☐	☐	If groundwater depression is necessary, are the pumping wells correctly spaced?
☐	☐	Is a vapor treatment system required?
☐	☐	If a vapor treatment system is required, is the proposed system appropriate for the contaminant concentration at this site?

Pilot tests

In general, remedial approaches which rely on biological processes should be subject to field pilot tests to verify and quantify the potential effectiveness of the approach and provide data necessary to design the system. For bioventing, these studies may range in scope and complexity from a simple soil column test to field respirometry tests and soil vapor extraction (or injection) pilot studies. The scope of pilot testing or laboratory studies should be commensurate with the size of the area to be remediated, the reduction in constituent concentration required, and the results of the initial effectiveness screening. A list and description of commonly used laboratory and pilot-scale tests is provided below:

Soil vapor extraction and injection treatability tests: Soil vapor extraction and injection treatability tests are generally used to determine the radius of influence that an extraction well or injection well can exert in the surrounding soils, the optimum vapor flow rate and pressure (or vacuum) that should be applied to the wells, and the concentration of petroleum constituents in the induced air stream. The test most often includes short-term vapor extraction or air injection from a single well while measuring the pressure effect in monitoring wells or probes spaced at increasing distances from the extraction well or the injection well. The test can assist in determining the spacing, number and type of wells needed for the full-scale system. It is usually not economically attractive to perform this test for sites with areas smaller than 5,000 cubic yards of in situ contaminated soil or for sites with soil permeabilities greater than 10^{-8} cm^2.

Respirometry studies: Respirometry studies are generally used to determine the oxygen transport capacity of the site soils and to estimate the biodegradation rates under field conditions. The test includes short-term injection of an oxygen/inert gas mixture into a well that has been screened in the contaminated soil horizon. Carbon dioxide, inert gas (typically helium), and oxygen concentrations are measured in the injection well and surrounding wells periodically for about 1 to 5 days. The measurements are then compared to baseline concentrations of the gases prior to injection. Increases in carbon dioxide and decreases in oxygen concentrations are indications of biological metabolism of constituents; the inert gas concentration provides the baseline for these calculations. Temperature of the extracted vapor may also be monitored to serve as an additional indicator of biological activities. Field respirometry studies are usually only needed for sites with large areas of contamination, perhaps greater than 100,000 cubic yards of in situ soils requiring remediation; at sites where soil permeability is less than 10^{-8} cm^2; or when reductions of more than 80 percent of the constituents that have vapor pressures less than 0.5 mm Hg are required.

Laboratory biodegradation studies: Laboratory biodegradation studies can be used to estimate the rate of oxygen delivery and to determine if the addition of inorganic nutrients is necessary. However, laboratory studies cannot duplicate field conditions, and field tests are more reliable. There are two kinds of laboratory studies: slurry studies and column studies. Slurry studies, which are more common and less costly, involve the preparation of numerous “soil microcosms” consisting of small samples of site soils mixed into a slurry with site groundwater. The microcosms are divided into several groups which may include control groups that are “poisoned” to destroy any bacteria, non-nutrified test groups that have been provided oxygen but not nutrients, and nutrified test groups which are supplied both oxygen and nutrients. Microcosms from each group are analyzed periodically (usually weekly) for at test period duration (usually 4 to 12 weeks) for bacterial population counts and constituent concentrations. Results of slurry studies should be considered as representing optimal conditions because slurry microcosms do not consider the effects of limited oxygen delivery or soil heterogeneity. Column studies are set up in a similar way using columns of site soils and may provide more realistic expectations of bioventing performance.

Rationale for the design:

- Design radius of influence
- Well head pressure
- Induced vapor flow rate
- Initial constituent vapor concentrations
- Required final constituent concentrations
- Soil volume to be treated
- Pore volume calculations
- Discharge limitations and monitoring requirements
- Site construction limitations
- Nutrient formulation and delivery rate

Operation and monitoring plan

Start-up operations: The start-up phase should include 7 to 10 days of manifold valve adjustments. These adjustments should balance flow to optimize carbon dioxide production and oxygen uptake rate while, to the extent possible, minimizing volatilization by concentrating pressure (or vacuum) on the wells that are in areas of higher contaminant concentrations. To accomplish this, flow measurements, pressure or vacuum readings, carbon dioxide concentrations, oxygen concentrations, and VOC concentrations should be recorded daily from each extraction well, from the manifold, and from the effluent stack. Nutrient delivery (if needed) should not be performed until after start-up operations are complete. If nutrient addition is necessary, an EPA Underground Injection Control (UIC) Permit is required (or a letter from EPA indicating the system does not require a UIC permit).

Long-term operations: Long-term monitoring should consist of flow-balancing, flow and pressure measurements, carbon dioxide measurements, oxygen measurements and VOC concentration readings. Measurements should take place at weekly or bi-weekly intervals for the duration of the system operational period. Nutrient addition, if necessary, should occur periodically rather than continuously. Some literature suggests that nutrient solutions be injected into wells or trenches or applied to the surface at monthly or quarterly intervals. The table below provides a brief synopsis of system monitoring recommendations.

Recommended system monitoring requirements

Phase	Monitoring frequency	What to monitor	Where to monitor
Start-up (7-10 days)	At least daily	◊ Flow ◊ Vacuum readings ◊ VOCs ◊ Carbon dioxide ◊ Oxygen	◊ Extraction vents ◊ Manifold ◊ Effluent stack
Remedial (on-going)	Weekly to bi-weekly (at least quarterly)	◊ Flow ◊ Vacuum ◊ VOCs ◊ Carbon dioxide ◊ Oxygen	◊ Extraction vents ◊ Manifold ◊ Effluent stack

Biomounding

Biomounds (also known as biopiles, biocells, and compost piles) are used to reduce concentrations of petroleum constituents in excavated soils through the use of biodegradation. This technology involves heaping contaminated soils into mounds (or “cells”) and stimulating aerobic microbial activity within the soils through the aeration and/or addition of minerals, nutrients, bulking agents and moisture. The enhanced microbial activity results in degradation of adsorbed petroleum-product constituents through microbial respiration. Biomounds are similar to land farms in that they are above-ground, engineered systems that use oxygen, generally from air, to stimulate the growth and reproduction of aerobic bacteria which, in turn, degrade the petroleum constituents adsorbed to soil. While land farms are aerated by tilling or plowing, biomounds are aerated most often by forcing injected air or by extracting air through slotted or perforated piping placed throughout the mound.

Biomounds, like land farms, have proven effective in reducing concentrations of nearly all the constituents of petroleum products typically found at underground storage tank sites. Lighter (more volatile) petroleum products (e.g., gasoline) tend to be removed by evaporation during the aeration process (i.e., air injection, air extraction, or pile turning) and, to a lesser extent, degraded by microbial respiration. Depending upon regulations for air emissions of volatile organic compounds (VOCs), control of the VOC emissions may be needed. Control involves capturing the vapors before they are emitted to the atmosphere, passing them through an appropriate treatment process, and then venting them to the atmosphere. The mid-range hydrocarbon products (e.g., diesel fuel, kerosene) contain lower percentages of lighter constituents than gasoline. Biodegradation of these petroleum products is more significant than evaporation. Heavier (non-volatile) petroleum products (e.g., heating oil, lubricating oils) do not evaporate during biomound aeration; the dominant mechanism that breaks down these petroleum products is biodegradation. However, higher molecular weight petroleum constituents such as those found in heating and lubricating oils, and, to a lesser extent, in diesel fuel and kerosene, require a longer period of time to degrade than gasoline constituents.

Advantages:

- Degrades semi-volatile organic compounds (SVOCs) and nonvolatile organic compounds
- Requires low maintenance
- Enhances control and management of aeration, moisture, nutrients, and soil texture
- Can use treated soil as backfill
- Relatively simple to design and implement
- Short treatment times under optimal conditions
- Requires less land area than land farms
- Can be designed as a closed system; vapor emissions can be controlled
- Can be engineered to be potentially effective for any combination of site conditions and petroleum products.

Limitations:

- Targets only biodegradable constituents
- Must excavate soil and remove debris
- Requires sufficient nutrients, moisture, active indigenous microbial population, and pH of 6-8 to degrade contaminants
- Concentration reductions >95% and constituent concentrations <0.1 ppm are very difficult to achieve
- May not be effective for high constituent concentrations (>50,000 ppm total petroleum hydrocarbons)
- Presence of significant heavy metal concentrations (>2,500 ppm) may inhibit microbial growth.
- Volatile constituents tend to evaporate rather than biodegrade during treatment
- Requires a large land area for treatment, although less than landfarming
- Vapor generation during aeration may require treatment prior to discharge
- May require a bottom liner if leaching from the biomound is a concern

System components & information:

- Plastic liner
- Gravel and slotted pipe to provide air to mound
- Nutrients (optional)
- Bulking agents
- Blower
- Soil vapor sampling probes
- Irrigation system / plastic cover / vapor treatment equipment (optional)

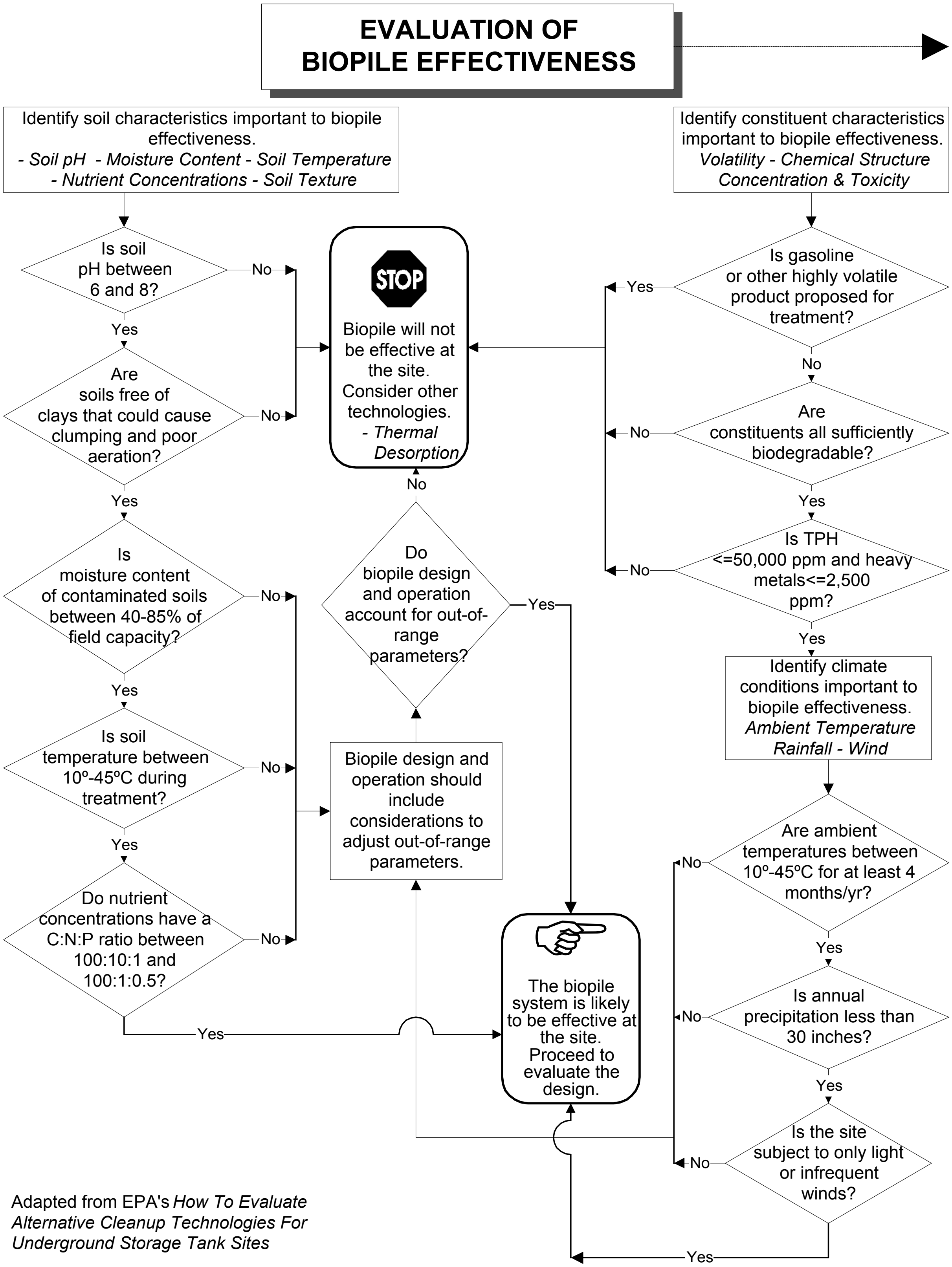
Waste stream treatment:
- Vapor treatment options (may be needed for high concentrations of contaminants):
    - Granulated activated carbon
    - Internal combustion engine
    - Catalytic oxidation unit
    - Thermal incinerator

Recommended parameters used to evaluate the effectiveness of biomound systems		
Soil characteristics	**Constituent characteristics**	**Climatic conditions**
◊ Soil pH ◊ Moisture content ◊ Soil temperature ◊ Nutrient concentrations ◊ Soil texture	◊ Volatility ◊ Chemical structure ◊ Concentration and toxicity	◊ Ambient temperature ◊ Rainfall ◊ Wind

Required parameters to monitor for system performance:
- Vapor concentration at the air extraction vents
- BTEX from water collected within the bermed area

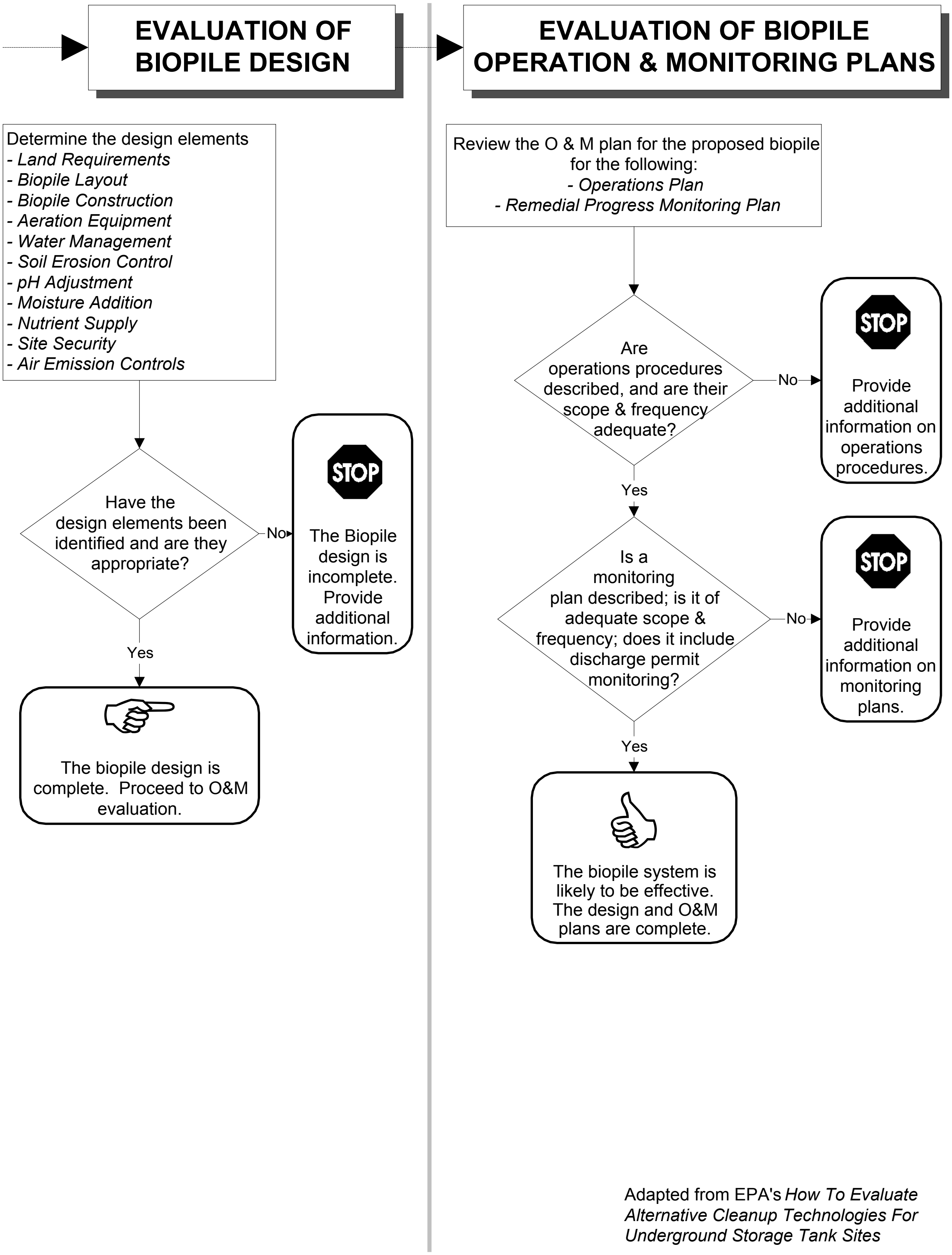
System design:
Once you have verified that biomounds have the potential to be effective, you can evaluate the design of the biomound system. The CADR should include conceptual engineering design and a discussion of the rationale. Detailed engineering design documents should be included. Include the following in the discussion of the design:
[ ] Land requirements
[ ] Biomound layout
[ ] Biomound construction
[ ] Aeration equipment
[ ] Water management
[ ] Leachate development and control
[ ] Leachate run-off and control
[ ] Soil erosion
[ ] pH adjustment, moisture and bulking agent addition, and nutrient supply
[ ] Site security
[ ] Air emission controls

Biopile Evaluation Process Flow Chart (1 of 2)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Biopile Evaluation Process Flow Chart (2 of 2)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Can biomounds be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that require closer scrutiny. If the answer to several questions is no and biotreatability studies demonstrate marginal to ineffective results, additional information will be required to determine if biomounds will accomplish the clean-up goals at the site. (Technical factors may be found in Appendix B.)

1. Soil characteristics that contribute to biomound effectiveness

Yes	No	
☐	☐	Is the soil pH between 6 and 8?
☐	☐	Is the soil moisture between 40% and 85%?
☐	☐	Is the soil temperature between 10°C and 45°C?
☐	☐	Is the carbon:nitrogen:phosphorus ratio between 100:10:1 and 100:1:0.5?
☐	☐	Does the soil divide easily and tend not to clump together?

2. Constituent characteristics that contribute to biomound effectiveness

Yes	No	
☐	☐	Are products to be treated primarily kerosene or heavier (i.e., not gasoline), or will air emissions be monitored and, if necessary, controlled?
☐	☐	Are total petroleum constituents ≤ 50,000 ppm and total heavy metals ≤ 2,500 ppm?
☐	☐	Are most of the constituents readily degradable?

3. Climatic conditions that contribute to biomound effectiveness

Yes	No	
☐	☐	Is the rainfall less than 30 inches during the biomound season?
☐	☐	Is the site subject to only light or infrequent winds?

4. Evaluation of biomound design

Yes	No	
☐	☐	Is sufficient land available considering the biomound depth and additional space for berms and access?
☐	☐	Is run-on and run-off controlled?
☐	☐	Are erosion control measures specified?
☐	☐	Are the frequency of application and composition of nutrients and pH adjustment materials specified?
☐	☐	Is moisture addition needed?
☐	☐	Are other sub-optimal natural site conditions addressed in the biomound design (e.g., low temperatures, poor soil texture, and excessive rainfall)?
☐	☐	Is the site secured?
☐	☐	Are air emissions estimated and will air emissions monitoring be conducted?
☐	☐	Are provisions included for air emissions controls, if needed?

5. Operation and monitoring plans

Yes	No	
☐	☐	Are frequencies of aeration, nutrient addition, and moisture addition provided in the operation plan?
☐	☐	Is monitoring for constituent reduction and biodegradation conditions proposed?
☐	☐	Are air, soil, and surface run-off water sampling (if applicable) proposed to ensure compliance with appropriate permits?
☐	☐	Are the proposed number of samples to be collected, sampling locations, and collection methods in accordance with regulations?
☐	☐	Is quarterly (or more frequent) monitoring for soil pH, moisture content, nutrient content, and constituent concentrations proposed?

Operation and monitoring plan

Start-up operations: It is important to ascertain that system operation and monitoring plans have been developed for the biomound operation. Regular monitoring is necessary to ensure optimization of biodegradation rates, to track constituent concentration reductions, and to monitor vapor emissions, migration of constituents into soils beneath the biomound (if unlined), and groundwater quality. If appropriate, ensure that monitoring to determine compliance with stormwater discharge or air quality permits is also proposed.

Long-term operations: The plan for operating the biomound system described in the CADR should include the anticipated frequency of aeration, nutrient addition, and moisture addition. The plan should be flexible and modified based on the results of regular monitoring of the biomound soils. The plan should also account for seasonal variations in ambient temperature and rainfall. In general, aeration, moisture and nutrient applications should be more frequent in the warmer, drier months. If the biomound is covered with impervious sheeting (e.g., plastic or geofabric / geotextile), the condition of the cover must be checked periodically to ensure that it remains in place and that it is free of rips, tears, or other holes. Provision should be made for replacement of the cover if its condition deteriorates to the point where it is no longer effective. The table below provides a brief synopsis of system monitoring recommendations.

Recommended system monitoring requirements

Medium to be monitored	Purpose	Sampling frequency	Parameters to be analyzed
Soil in the biomound	Determine constituent degradation and biodegradation conditions	Monthly to quarterly during the operation	Constituent concentrations, pH, ammonia, moisture content, phosphorous, other rate limiting conditions
Air extracted or collected from the biomound	Determine constituent degradation and biodegradation conditions	Weekly during the first 3 months then monthly or quarterly	CO_2, O_2, CH_4, H_2S, VOCs
Ambient air - see Appendix A	Site personnel and population health hazards	Twice during the first 2 weeks of operation, quarterly thereafter or to meet air quality requirements	Volatile constituents, particulates
Run-off water	Soluble or suspended constituents	As required for NPDES permit	As specified for NPDES permit; also hazardous organics
Soil beneath the biomound	Migration of constituents	Quarterly or twice per biomound season	Hazardous constituents
Groundwater downgradient of biomound	Migration of soluble constituents	Once per biomound season (annually)	Hazardous, soluble constituents

Low Temperature Thermal Desorption

Low temperature thermal desorption (LTTD) is a technique for removing contaminants from large volumes (> 1,000 cubic yards) of soil. The technique heats contaminated soil to relatively low temperatures (200-1,000°F). The heat causes contaminants to vaporize so they can be treated with air emissions treatment systems. (Linn and Polk Counties may require air emissions permits.)

On-site thermal treatment is most effective on soil that contains high levels of hydrocarbons. It requires less time than bioremediation or soil vapor extraction (SVE). On-site thermal treatment can be implemented rapidly and works quickly at a relatively low cost.

Advantages:
- Rapid to implement
- Minimizes long-term liability
- Can reuse some types of soil for backfill

Limitations:
- Expensive for soil with high moisture or clay content
- May require air discharge permits

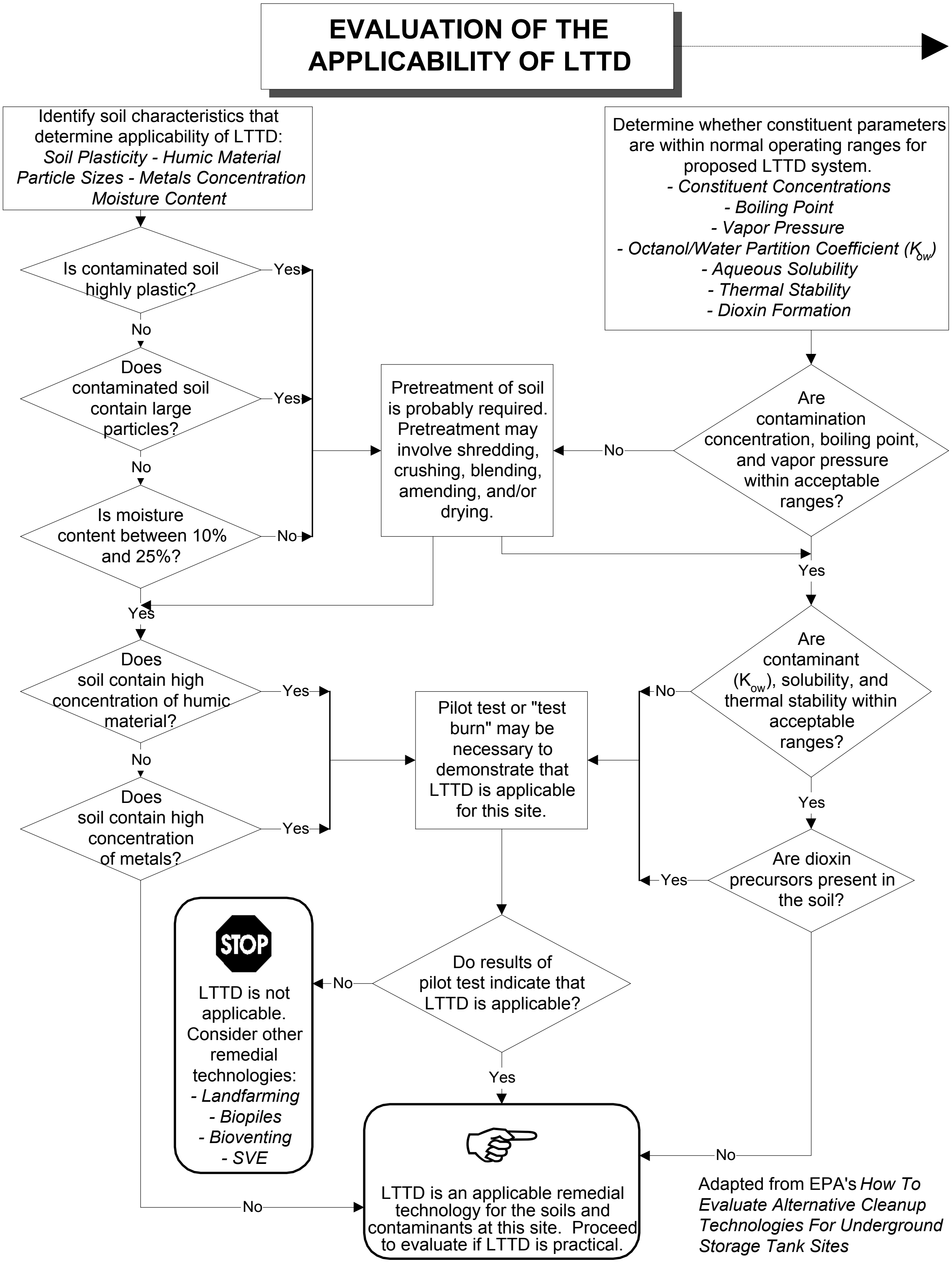
System components & information:
- Excavation equipment
- Sorting and sizing equipment
- Rotary kiln
- Off-gas treatment equipment

Waste stream treatment:
- Air emissions equipment (See Appendix A - Linn and Polk Counties may require air emissions permits.)

Required parameters to monitor for system performance (mobile unit):
- Vapor concentration (benzene and toluene using NIOSH 1501) at effluent stack
- Any required EPA or IDNR Air Quality Section permits

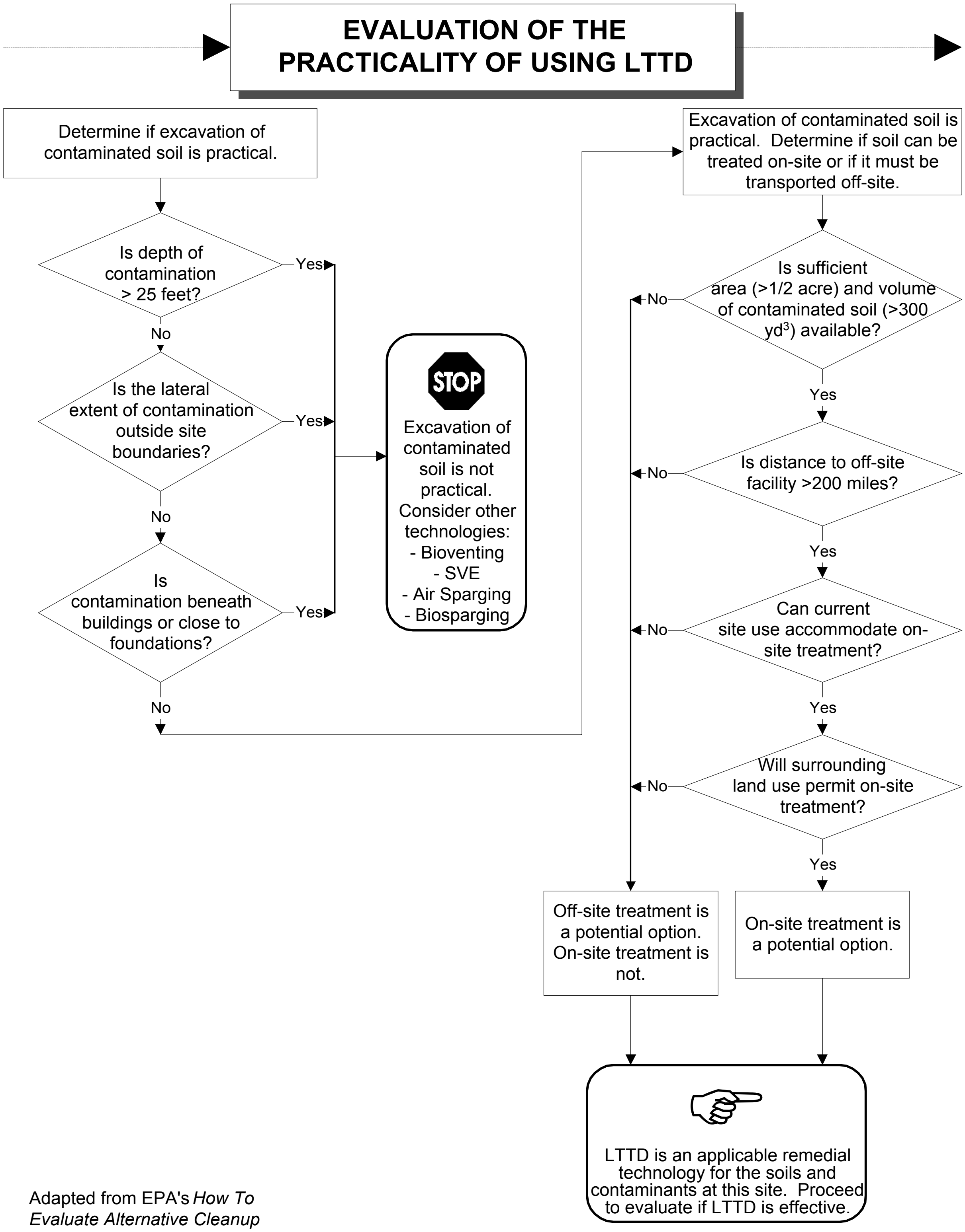
State and local permits which may be required:
- Air emissions (See Appendix A - Linn & Polk Counties)
- Solid wastes
- Water districts
- Health department
- Fire marshal
- Building inspector
- Contractor’s license

Low-Temperature Thermal Desorption Process Flow Chart (1 of 3)



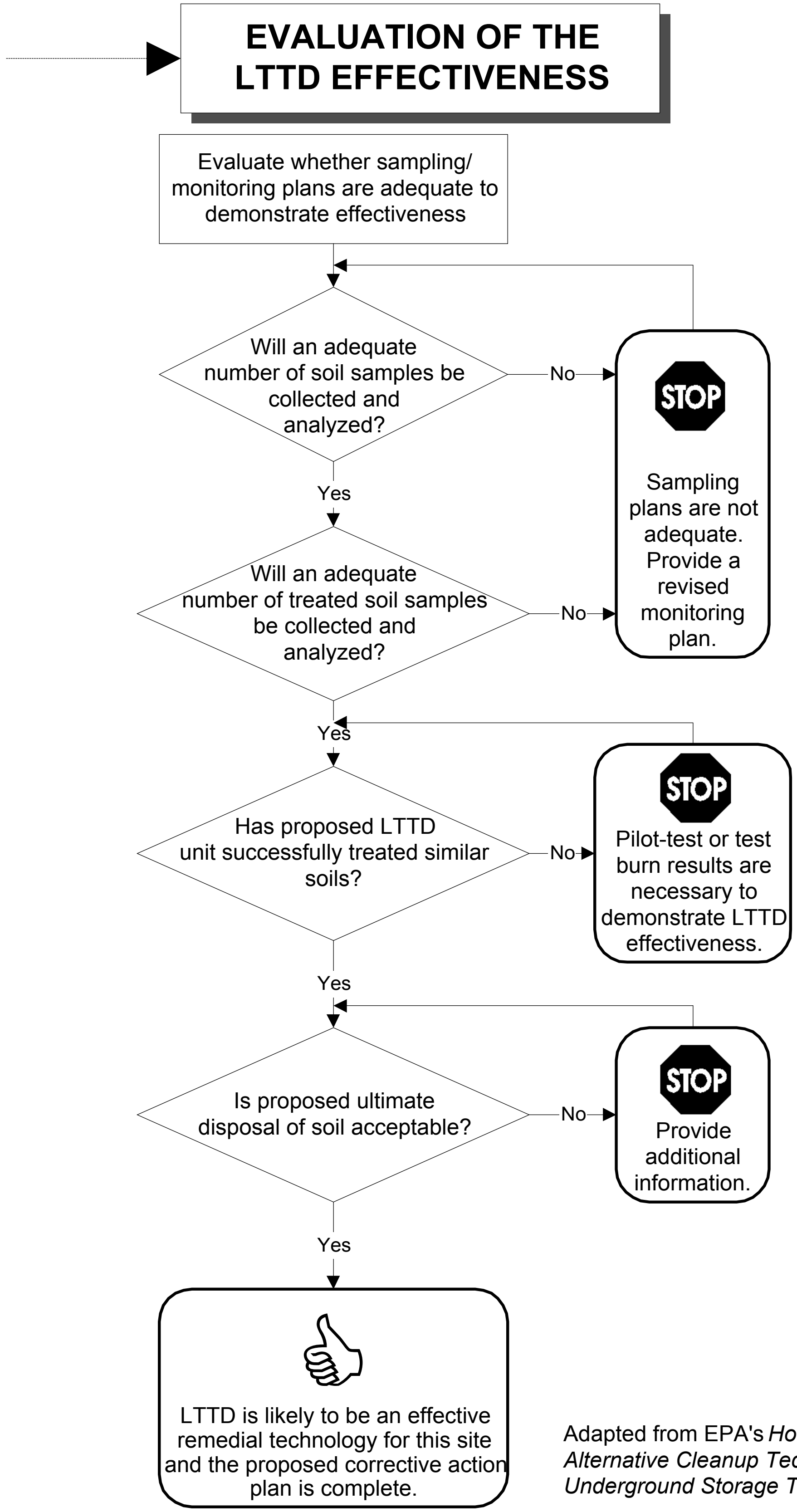
Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Low-Temperature Thermal Desorption Process Flow Chart (2 of 3)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Low-Temperature Thermal Desorption Process Flow Chart (3 of 3)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Can LTTD be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that require closer evaluation. As you go through the CADR answer the following questions. (Technical factors may be found in Appendix B.)

1. Evaluation of LTTD effectiveness

Yes	No	
☐	☐	Do soils have high plasticity?
☐	☐	Do soils contain large rocks or debris?
☐	☐	Is the moisture content > 35%?
☐	☐	Is the TPH concentration > 2% by weight?
☐	☐	Are hydrocarbons highly volatile?

If the answer to any of the above questions is yes, then the soils require pretreatment.

Yes	No	
☐	☐	Do the soils have a high concentration of humic material?
☐	☐	Do the soils have a high concentration of heavy metals?
☐	☐	Are contaminant K_{ow}s relatively high?
☐	☐	Are dioxin precursors present in the soils?

If the answer to any of the above questions is yes, then a pilot test or "test burn" should be conducted to demonstrate that LTTD is an applicable remedial technology.

Yes	No	
☐	☐	Do the results of the pilot test indicate that LTTD is applicable?

2. Constituent characteristics

Yes	No	
☐	☐	Is the depth of contaminated soil 25 feet or less below the ground surface?
☐	☐	Is contaminated soil contained within the site boundaries?
☐	☐	Is there no contamination beneath buildings or near building foundations?

If the answer to any of the above questions is no, then excavation of the soil is not practicable; therefore, LTTD is not practicable. Consider an in situ remedial technology instead.

Yes	No	
☐	☐	Is sufficient land area available for operation of equipment and temporary storage (staging) of contaminated soil and treated soil?
☐	☐	Is the distance to an off-site facility prohibitively far?
☐	☐	Will surrounding land use permit operation of an on-site system in the neighborhood?

If the answer to any of the above questions is no, then excavated soils must be transported to an off-site facility for treatment.

3. Evaluation of the effectiveness of using LTTD

Yes	No	
☐	☐	Will an adequate number of in situ soil samples be collected and analyzed?
☐	☐	Will an adequate number of treated soil samples be collected and analyzed?
☐	☐	Has the proposed desorption unit successfully treated similar soils with similar contaminant concentration levels?
☐	☐	Is the proposed ultimate disposal of the soil (e.g., return to excavation, transport to landfill for cover, etc.) acceptable?

If the answer to any of the above questions is no, then additional information is necessary to evaluate whether LTTD is likely to be an effective remedial technology.

Land Farming

Land farming is a technique for removing biodegradable contaminants from excavated soil. The excavated soil and added nutrients are spread over a lined treatment area. The area is periodically tilled to facilitate the natural release of volatile organic compounds (VOCs) and the biodegradation of contaminants.

Land farming is effective on many soil types and a variety of contaminants. It is also easy and inexpensive to design, operate and maintain. Prior to land applying contaminated soil, the notification form 542-1384, must be completed and sent with a legible contour map of the application area to the Iowa Department of Natural Resources (form may be obtained by calling 515/242-6492). The authority to regulate land application of petroleum contaminated soils is contained in subrule 567-121.3(2) of the Iowa Administrative Code (IAC).

Local authorities may also regulate soil, air and groundwater contaminants within their jurisdiction. It is advisable to contact the local county/city engineer's office, the local zoning board, and board of health prior to land applying petroleum contaminated soils.

To complete form 542-1384, information must be obtained from various sources. These sources may include:

County Engineer
County Zoning Office
DNR, Geological Survey Bureau (319/335-1575)
County Office of the Farm Services Agency
NRCS Office (formerly SCS)
County Health Department or Sanitarian

<u>Advantages</u>:

- Simple and inexpensive to design, operate, and maintain
- Effective on many soil types with a variety of contaminants

<u>Limitations</u>:

- Targets only biodegradable constituents
- Requires substantial space

<u>System components & information</u>:

- Nutrients (fertilizer)
- Lined treatment cell with berms around the perimeter (optional)
- Tilling equipment
- Lime (needed for low pH)
- Irrigation equipment (optional)

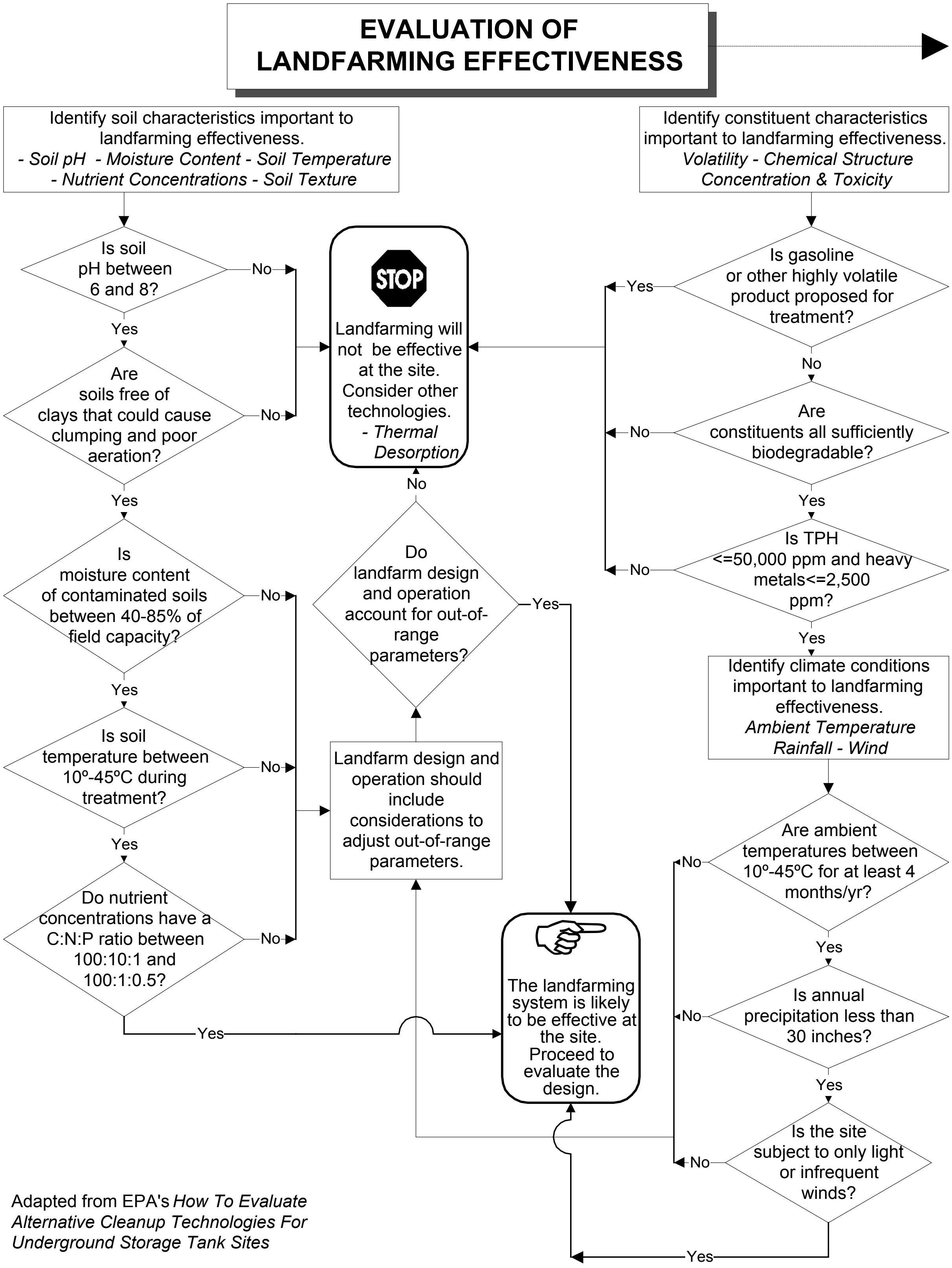
<u>Waste stream treatment</u>:

- May need to treat or dispose of collected rainwater or leachate

<u>Recommended parameters to be monitored for system performance</u>:

- Soil contaminant concentration
- Soil pH, moisture, and nutrients
- Leachate analysis (optional)

Landfarming Evaluation Process Flow Chart (1 of 2)



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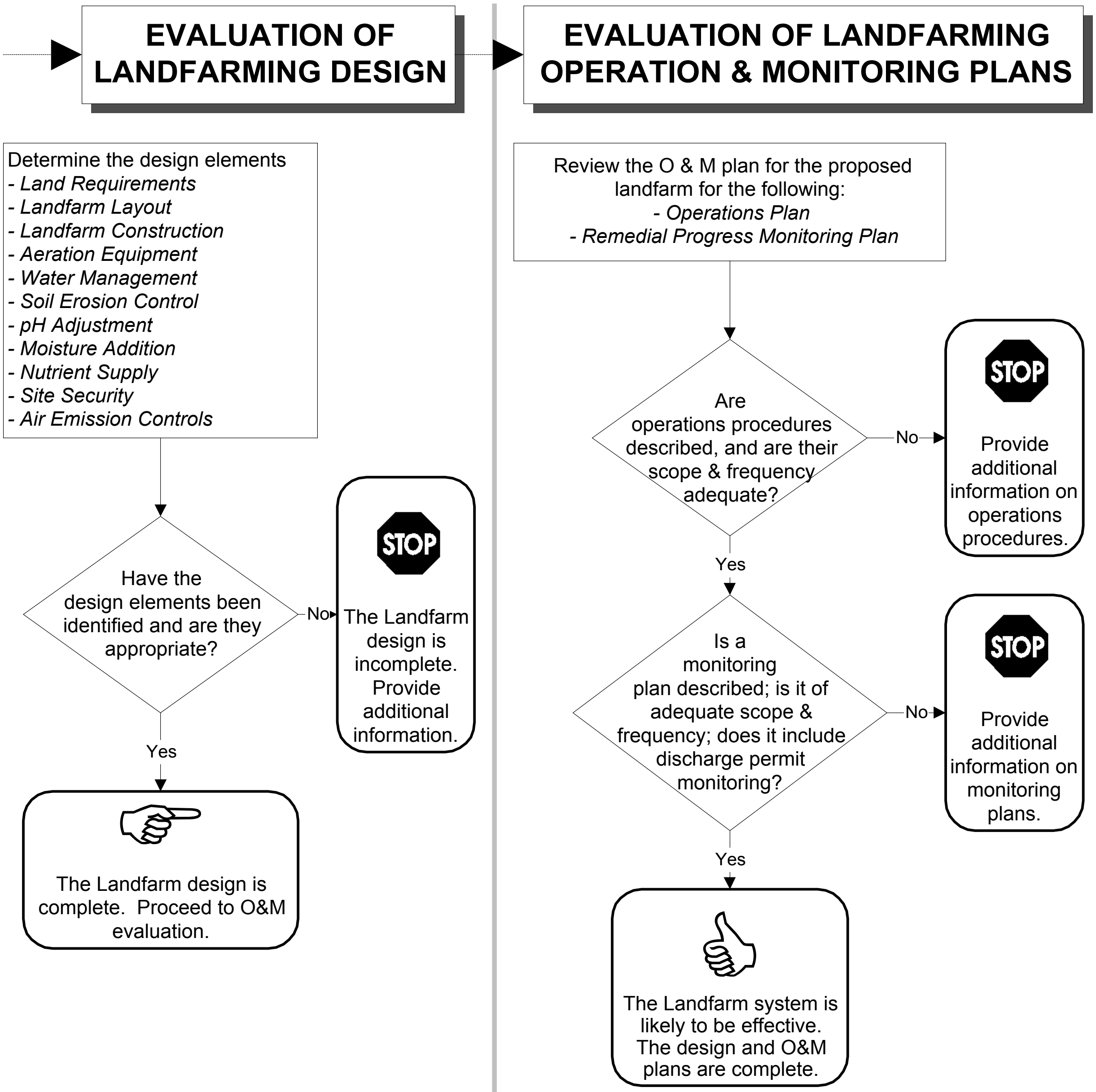
Landfarming Evaluation Process Flow Chart (2 of 2)



EVALUATION OF LANDFARMING DESIGN

Determine the design elements
- *Land Requirements*
- *Landfarm Layout*
- *Landfarm Construction*
- *Aeration Equipment*
- *Water Management*
- *Soil Erosion Control*
- *pH Adjustment*
- *Moisture Addition*
- *Nutrient Supply*
- *Site Security*
- *Air Emission Controls*

Have the design elements been identified and are they appropriate?

The Landfarm design is incomplete. Provide additional information.

The Landfarm design is complete. Proceed to O&M evaluation.

EVALUATION OF LANDFARMING OPERATION & MONITORING PLANS

Review the O & M plan for the proposed landfarm for the following:
- *Operations Plan*
- *Remedial Progress Monitoring Plan*

Are operations procedures described, and are their scope & frequency adequate?

Provide additional information on operations procedures.

Is a monitoring plan described; is it of adequate scope & frequency; does it include discharge permit monitoring?

Provide additional information on monitoring plans.

The Landfarm system is likely to be effective. The design and O&M plans are complete.

Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Can landfarming be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that require closer scrutiny. As you go through the CADR answer the following questions. If the answer to several questions is no and biotreatability studies demonstrate marginal to ineffective results, provide additional information to determine if landfarming will accomplish cleanup goals at the site.

1. Site Characteristics that contribute to landfarming effectiveness

Yes	**No**	
[ ]	[ ]	Is the soil pH between 6 and 8?
[ ]	[ ]	Is the soil moisture content of soil between 40% to 85% of saturation?
[ ]	[ ]	Is soil temperature between 10°C and 45°C?
[ ]	[ ]	Is the carbon:nitrogen:phosphorus ratio between 100:10:1 and 100:1:0.5?
[ ]	[ ]	Does the soil divide easily and tend not to clump together?

2. Constituent characteristics that contribute to landfarming effectiveness

Yes	**No**	
[ ]	[ ]	Are products to be treated primarily kerosene or heavier (i.e., not gasoline), or will air emissions be monitored and, if necessary, controlled?
[ ]	[ ]	Are most of the constituents readily degradable?
[ ]	[ ]	Are total petroleum constituents ≤ 50,000 ppm and total heavy metals ≤ 2,500 ppm?

3. Climatic conditions that contribute to landfarming effectiveness

Yes	**No**	
[ ]	[ ]	Is the rainfall less than 30 inches during the landfarming season?
[ ]	[ ]	Are high winds unlikely?

4. Evaluation of land farm design

Yes	**No**	
[ ]	[ ]	Is sufficient land available considering the land farm depth and additional space for berms & access?
[ ]	[ ]	Are run-on and runoff controlled?
[ ]	[ ]	Are erosion control measures specified?
[ ]	[ ]	Are the frequency of application and composition of nutrients & pH adjustment materials specified?
[ ]	[ ]	Is moisture addition needed?
[ ]	[ ]	Are other sub-optimal natural site conditions addressed in the land farm design?
[ ]	[ ]	Is the site secured?
[ ]	[ ]	Are air emissions estimated and will air emissions monitoring be conducted?
[ ]	[ ]	Are provisions included for air emissions controls, if needed?

5. Operation and monitoring plans

Yes	**No**	
[ ]	[ ]	Is monitoring for stormwater discharge or air quality permits (if applicable) proposed?
[ ]	[ ]	Does the operation plan include the anticipated frequency of aeration, nutrient & moisture addition?
[ ]	[ ]	Does the monitoring plan propose measuring constituent reduction & biodegradation conditions in the land farm soils?
[ ]	[ ]	Are air, soil and surface runoff water sampling (if applicable) proposed to ensure compliance with appropriate permits?
[ ]	[ ]	Are the proposed numbers of samples to be collected, sampling locations, and collected methods in accordance with IDNR regulations?
[ ]	[ ]	Is monitoring for soil pH, moisture content, nutrient content, & constituent concentrations proposed?

Excavation and Off-site Treatment

Excavation and off-site treatment is a method for removing contaminants from small volumes (<1,000 cubic yards) of soil that cannot be treated effectively on site. Contaminated soil is excavated and then treated. (The Tier 1 and Tier 2 Guidance documents provide department requirements for soil excavation.) Typical treatment facilities include:

- Low temperature thermal desorption facilities
- Asphalt plants
- Incinerators

This technique can be used with many different kinds of soils and contaminants. It offers the benefit of actually destroying contaminants rather than simply moving them from one location or medium to another. Before hauling contaminated soil to any of these facilities, determine if the facility has all applicable permits required by local, state or federal laws.

Advantages:

- Easy and rapid to implement
- Destroys contaminants
- Can reuse some types of soil for backfill
- Effective on soils with varying concentrations and constituents

Limitations:

- Expensive for large volumes of soil with low contaminant concentrations, high moisture or clay content
- Transportation costs can be high

System components & information:

- System components can include:
    - Excavation equipment
    - Trucking equipment
    - Equipment for sorting and sizing
    - Rotary dryer or kiln
    - Thermal screw
    - Off-gas treatment equipment

Waste stream treatment:

- Air emissions equipment (See Appendix A - Linn and Polk Counties)

Recommended parameters to monitor for system performance:

- Contaminant concentrations in pre- and post-treatment soil

Groundwater Remediation

The following section describes some criteria for evaluating different methods to remediate groundwater.

Air Sparging with Soil Vapor Extraction (SVE)
Bioremediation
Biosparging
Vacuum Enhanced Pump and Treat
Pump and Treat
Air Stripper Treatment
Carbon Adsorption
Aeration Treatment

Air Sparging With Soil Vapor Extraction

Air sparging with soil vapor extraction (SVE) is a technique for removing dissolved volatile contaminants from groundwater. The technique injects air into the saturated zone. The air forms bubbles which rise into the unsaturated zone, carrying trapped and dissolved contaminants. Extraction wells in the unsaturated zone capture sparged air. If necessary, the air can then be treated by using a variety of vapor treatment options. This technique is most effective in homogeneous, permeable aquifers. Performance data for this technique are limited. Air sparging with SVE is a rapid remediation technique which can reduce contamination levels in as little as six months under optimal conditions. It is also able to quickly remove volatile organic compounds (VOCs) from below the groundwater table. **The department does NOT recommend air sparging without soil vapor extraction.**

Advantages:
- Rapidly reduces VOCs from below the groundwater table
- Can enhance and accelerate effectiveness of soil vapor extraction and downgradient pumping

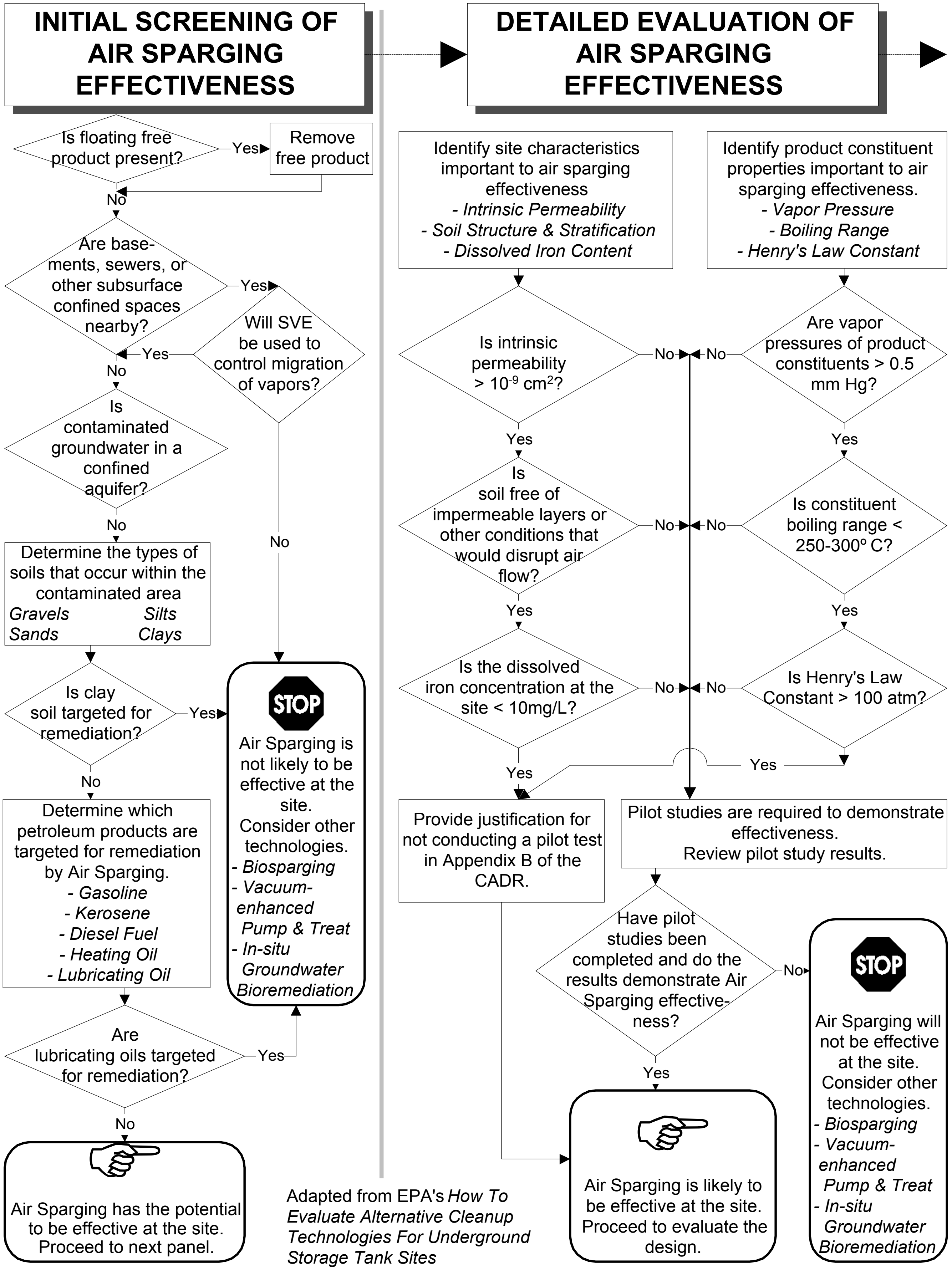
Limitations:
- Removes primarily volatile constituents
- Effectiveness is limited in low permeability or heterogeneous media
- Difficult to control air distribution in groundwater
- Can promote vapor and plume migration
- Limited performance data are available; contaminant levels may rebound over time
- **Potential movement of toxic or explosive vapors into inhabited structures**

System components & information:
- Vertical or horizontal extraction and injection wells
- Trenches
- Availability of 240 volt or 3-phase electrical power
- Vacuum pump, compressor, or blower
- Aboveground vapor treatment equipment (optional)

Waste stream treatment:
- Vapor treatment options (if needed):
    - Vapor phase biofilter
    - Granulated activated carbon
    - Internal combustion engine
    - Catalytic oxidation unit
    - Thermal incinerator

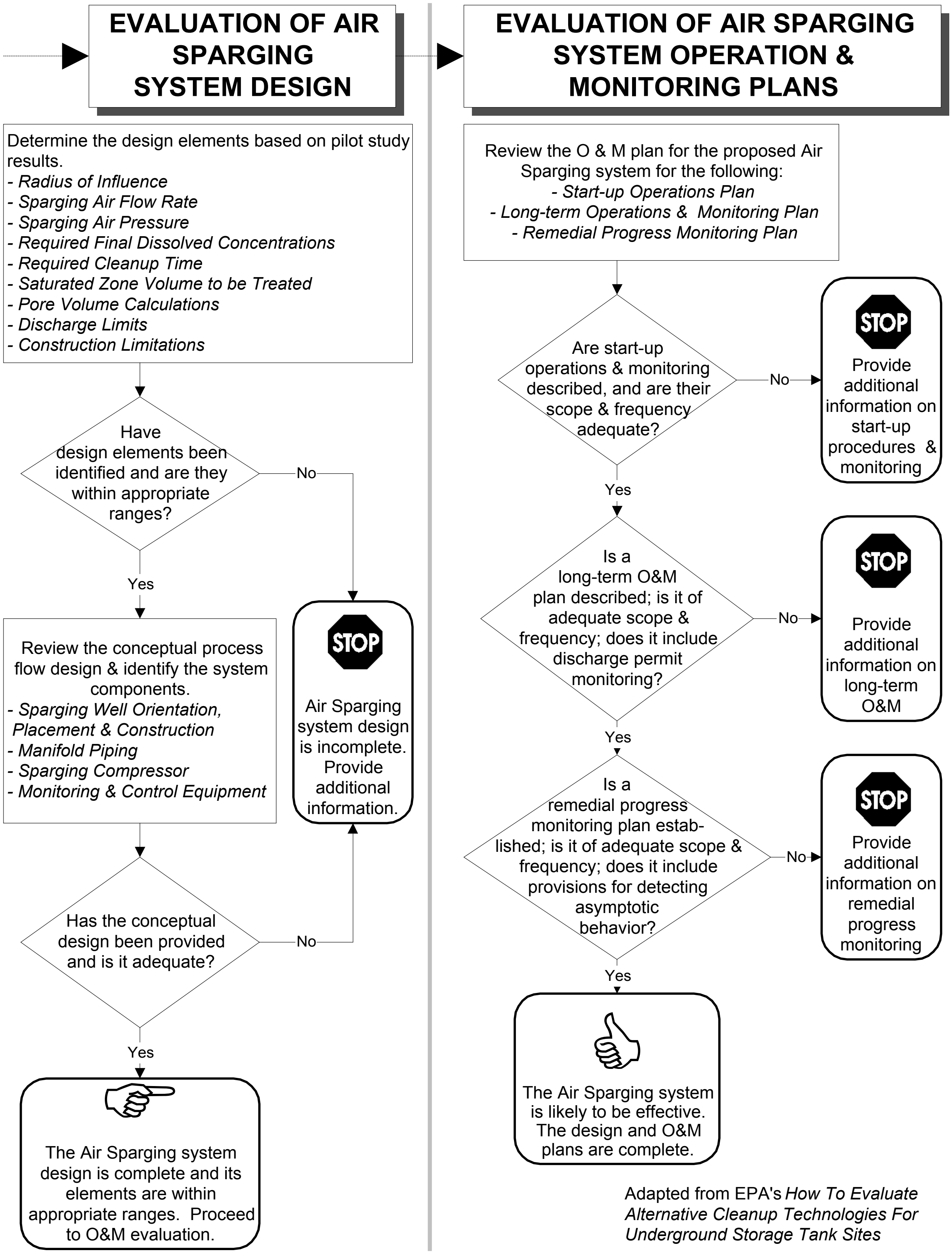
Required parameters to monitor for system performance:
- Vapor concentration at each SVE extraction point, vapor peizometer, system manifold, and discharge stack (using PID/FID)
- Vacuum pressure at each SVE extraction point, vapor peizometer, and system manifold
- Air flow measurement (standard cubic feet per minute - scfm) at each SVE extraction point, system manifold, and discharge stack
- Air flow rate (feet per minute) and well pressure (pounds per square inch - psi) into each air-sparge well head
- Static water level measurements in each monitoring well and SVE recovery well. (Compare the static water level with the elevation of the vapor extraction screen or point and compare the static water levels with sparge point elevations and screen elevations in monitoring wells.)
- BTEX and dissolved oxygen in the groundwater at selected monitoring wells
- Pressure and flow rate at injection points

Air Sparging Evaluation Process Flow Chart (1 of 2)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Air Sparging Evaluation Process Flow Chart (2 of 2)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Required parameters to monitor for system performance continued:

- Volatile organic hydrocarbon concentration: total air flow rate for the system and volatile organic hydrocarbon concentration for the system (laboratory analyzed samples)
- Total air flow rate of the system (scfm) and total system pressure (psi)
- A system of pressure monitoring points to insure maintenance of radius of influence. Measure the pressure at those points
- PID/FID and % LEL readings in any nearby storm/sanitary sewers, basements, confined spaces, etc.

Can air sparging be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that require closer scrutiny. As you go through the CADR answer the following questions. If the answer to several questions is no, additional information may be required to determine if air sparging will accomplish the clean-up goals at the site.

1. Factors that contribute to the vapor / dissolved phase partitioning of the constituents

Yes	No	
[ ]	[ ]	Is the Henry's law constant greater than 100 atm?
[ ]	[ ]	Are the boiling points of the contaminant constituents less than 300°C?
[ ]	[ ]	Is the contaminant vapor pressure greater than 0.5 mm Hg?

2. Factors that contribute to permeability of soil

Yes	No	
[ ]	[ ]	Is the intrinsic permeability greater than 10^{-9} cm^2?
[ ]	[ ]	Is the soil free of impermeable layers or other conditions that would disrupt air flow?
[ ]	[ ]	Is the dissolved iron concentration at the site < 10 mg/L?

3. Evaluation of the air sparging system design

Yes	No	
[ ]	[ ]	Does the radius of influence (ROI) for the proposed air sparging wells fall in the range of 5' to 100'?
[ ]	[ ]	Has the ROI been calculated for each soil type at the site?
[ ]	[ ]	Examine the sparging air flow rate. Will these flow rates provide sufficient vapor / dissolved phase partitioning of constituents to achieve cleanup in the time allotted for remediation in the CADR?
[ ]	[ ]	Examine the sparging air pressure. Will the proposed pressure be sufficient to overcome the hydraulic head and capillary forces?
[ ]	[ ]	Is the number and placement of wells appropriate, given the total area to be cleaned up and the ROI of each well?
[ ]	[ ]	Do the proposed well screen intervals account for contaminant plume location at the site?
[ ]	[ ]	Is the proposed well configuration appropriate for the site conditions present?
[ ]	[ ]	Is the air compressor selected appropriate for the desired sparge pressure?

4. Operation and monitoring plans

Yes	No	
[ ]	[ ]	Does the CADR propose starting up the SVE system prior to starting the air sparging system?
[ ]	[ ]	Are manifold valving adjustments proposed during the first 7 to 10 days of operation?
[ ]	[ ]	Is monitoring for sparge pressure and flows, vacuum readings (for SVE), groundwater depth, vapor concentrations, dissolved oxygen levels, carbon dioxide levels, and pH proposed for the first 7 to 10 days of operation?
[ ]	[ ]	Is weekly to biweekly monitoring of groundwater pH and levels of contaminants, carbon dioxide, and dissolved oxygen proposed following startup?
[ ]	[ ]	Is weekly to biweekly monitoring of the effluent stack for levels of contaminants, oxygen, and carbon dioxide proposed following startup?

Pilot test

Field pilot studies are necessary to adequately design and evaluate any air sparging system. However, pilot tests should not be conducted if free product is known to exist at the site. If uncontrolled, vapors could migrate into confined spaces, sewers, or buildings. The air sparge well used for pilot testing is generally located in an area of moderate constituent concentrations. Testing the system in areas of extremely low constituent concentrations may not provide sufficient data. In addition, because sparging can induce migration of constituents, pilot tests are generally not conducted in areas of extremely high constituent concentrations. The air sparging pilot study should include an SVE pilot study when SVE is included in the design of the air sparging system.

Pilot studies for air sparging often include SVE pilot testing to determine if SVE can be used to effectively control the vapor plume. Pilot studies, therefore, should include the installation of a single sparge point, several vapor extraction points, and soil gas monitoring points to evaluate vapor generation rates and to define the vapor plume. Existing groundwater monitoring wells (normally not fewer than three to five wells around the plume) that have been screened above the saturated zone and through the dissolved phase plume can be used to monitor both dissolved and vapor phase migration, to monitor for changes in dissolved oxygen, and to measure changes in the depth to the static water level. Additional vapor probes should be used to further define the vapor plume and identify any preferential migration pathways.

When SVE is to be used in the air sparging system, the first portion of the test should be conducted using vapor extraction only and evaluated as described in the Soil Vapor Extraction chapter in this guidance document without the air sparging system being operated. This portion of the pilot test will establish the baseline vapor extraction levels, the extent of the non-sparged vapor plume, the SVE well radius of influence, and the intrinsic permeability of the unsaturated zone. The air sparging portion of the test should be conducted with the sparging point operating at variable sparge pressures (e.g., 5 pounds per square inch-gauge [psig], 10 psig, etc.) and at different depths (e.g., 5 feet, 10 feet below the dissolved phase plume). It is essential that vapor equilibrium be obtained prior to changing the sparge rate or depth. When no change in vapor emission rates from baseline occurs, the air sparging system may not be controlling the sparge vapor plume, possibly due to soil heterogeneity. Assess the potential for this problem by reviewing the site's soil lithology, typically documented on soil boring logs. During this test, the hydraulic gradient and VOC concentrations in soil vapors extracted from monitoring wells must be monitored until equilibrium is reached.

The final portion of the pilot test is the concurrent operation of the SVE pilot system and air sparging system. This portion of the test will determine the optimum SVE system (i.e., number and orientation of wells) that will capture the sparged VOCs for various sparging rates. In addition, this portion of the test requires monitoring of VOC emissions, sparging pressure and flow rates, SVE vacuum and flow rates, monitoring well vapor concentrations, and dissolved constituent concentrations.

NOTE: The soil venting system should extract at least four times the volume of air injected by the air sparging system, unless other means are used to demonstrate that all injected air is captured and there is no vapor migration. The soil venting system's influence should cover the entire area influenced by the air sparging wells to assure all emissions are captured and quantified. If any structures are located near the sparging wells, gas probes should be used to assess subsurface pressure and vapor. The table below presents a summary of the pilot test data objectives.

Recommended pilot test data objectives

Data requirement	Source
SVE test portion	
SVE radius of influence (ROI)	Monitoring point pressure gauges
Well head and monitoring point vacuum	Well head pressure gauge
Initial contaminant vapor concentrations	SVE exhaust flame ionization detector (FID) readings (or other suitable detection device)
Initial hydraulic gradient	Water level tape at monitoring wells or pressure transducers and data logger
Air sparging test portion	
Air sparging ROI	Monitoring point pressure gauge
Sparging rate	Compressor discharge flow gauge
Sparging vapor concentrations	Monitoring well and vapor point FID readings (or other suitable detection device)
Hydraulic gradient influence	Water level tape at monitoring wells or pressure transducers and data logger
Dissolved oxygen and carbon dioxide	Dissolved oxygen and carbon dioxide probes at monitoring wells
Combined test	
Sparging / SVE capture rates	Pressure / flow gauges
Constituent vapor concentrations	Blower discharge and monitoring points

Pilot test checklist

[ ] A. Hydrogeological conditions: Provide a general discussion describing the hydrogeological conditions at the site.

[ ] B. Field procedures: Provide a complete discussion of the field procedures used for the pilot test.

[ ] C. Well construction: Provide boring logs and construction details for the air sparge wells on IDNR forms.

[ ] D. Air flow rates: Provide a discussion of the air flow rates injected and extracted during the test and show how the contaminant concentrations in the soil venting system (if installed) changed with differing air injection rates. Also include the ratio of extracted to injected air flow rates.

[ ] E. Radius of influence: If a radius of influence was estimated, discuss how the estimate was determined and provide a discussion of the field test data that were used to make the estimate.

[ ] F. Vapor control: Discuss how air vapors will be adequately controlled to prevent entry into surrounding buildings and enclosed spaces.

[ ] G. Geologic limitations: Discuss the potential for geologic conditions to limit the efficient operation of the air sparging system.

[ ] H. Groundwater or biologic limitations: Discuss the potential for groundwater quality or biologic activity to limit the efficient operation of the air sparging system.

[ ] I. System design: Discuss system design (i.e., well placement and spacing, number of wells, pressure and air flow requirements for the compressor, etc.). Discuss how the system will handle groundwater level fluctuations.

J. Figures: Provide the following figures and maps:

[ ] 1. A graph indicating the pressure and air flow characteristics of the air sparge well(s) tested.

[ ] 2. If upwelling in monitoring wells is measured, include a graph indicating upwelling (y axis) versus time (x axis).

[ ] 3. Geologic cross section.

[ ] 4. Scaled site map with the following illustrated:

[ ] a. Locations of existing sparge wells.

[ ] b. Locations of existing air extraction wells if venting system is installed.

[ ] c. Groundwater contour map for the day of the pilot test.

[ ] d. Iso-concentration map with groundwater dissolved oxygen concentrations.

K. Tables:

[ ] 1. Water level elevations in monitoring wells and dates of measurement.

[ ] 2. Field data, including the time of readings, air flow rates, injected air temperature, and injected air pressure.
[ ] L. Analytical data: Provide copies of all analytical data in Appendix D.

Air sparging with SVE system design checklist

[ ] A. Description: Provide a general description of the system.
[ ] B. Schematic: Schematic of the sparge system.
[ ] C. Calculations: Calculations for determining sparge well placement.
[ ] D. Well placement: Describe the reasoning used to establish well spacing and pattern.
[ ] E. Groundwater flow changes: Discuss the anticipated changes in the groundwater flow patterns that may be caused by the operation of the treatment system and the ways the system design will limit or prevent the migration of contaminants outside the radius of influence.
[ ] F. Well construction: Provide sparge well construction design.
G. Manifold system: Provide a description of the manifold system. Include the following:
[ ] 1. Pipe material.
[ ] 2. Pipe diameter.
[ ] 3. Location of valves.
[ ] 4. Description of instrumentation for measuring air flow rate, vacuum and temperature.
H. Air compressor specifications: Provide a description of the air compressor specifications. Include the following:
[ ] 1. Type.
[ ] 2. Total anticipated air flow rate.
[ ] 3. Anticipated pressure levels.
[ ] I. Extracted air:Injected air: Discuss the ratio of extracted air to injected air.
J. Air sparging with SVE maps: Scaled site map with the following illustrated.
[ ] 1. Location of existing and proposed sparge wells with area of influence indicated.
[ ] 2. Manifold location.
[ ] 3. Location of air compressor and other equipment.
[ ] 4. Scaled site map indicating the proposed monitoring locations to determine sparging effectiveness.
[ ] 5. Other pertinent site features.
[ ] K. VOC testing: Discuss the methods and instrumentation used for testing for total VOCs. Provide in the discussion the anticipated levels of analytical precision and evaluate any factors that could bias sample results.
[ ] L. Dissolved oxygen: Methodology for measuring groundwater dissolved oxygen.

Operation and monitoring plan

The system operation and monitoring plans should include both system startup and long-term operations. Operations and monitoring are necessary to ensure optimal system performance and to track the rate of contaminant mass removal.

Start-up operations: The start-up phase should begin with only the SVE portion of the system as described earlier. After the SVE system is adjusted, the air sparging system should be started. Startup operations should include 7 to 10 days of manifold valve adjustments to balance injection rates and optimize mass flow rates. Injection and extraction rates, pressures, depth to groundwater, hydraulic gradient, and VOC levels should be recorded hourly during initial startup until the flow is stabilized. Injection rates should then be monitored daily. Vapor concentration should also be monitored in any nearby utility lines, basements, or other subsurface confined spaces. Other monitoring of the system should be done in accordance with SVE requirements from the SVE section of this document.

[ ] A. Description of the monitoring program conducted to evaluate system startup and to determine the effectiveness of the treatment system and progress of site remediation.
[ ] B. Description of the groundwater elevation monitoring conducted to determine if significant upwelling is occurring. Address changes in static water levels caused by other factors and how this will be handled.

Long-term operations: Long-term monitoring should consist of contaminant level measurements (in the groundwater, vapor wells, and blower exhaust), flow-balancing (including flow and pressure measurements), and vapor concentration readings.

Samples collected during sparging operations may give readings which show lower concentrations of dissolved contaminants than those found in the surrounding aquifer. These readings could lead to the erroneous conclusion that remediation is occurring throughout the aquifer. Therefore, contaminant concentrations should be determined shortly following system shutdown, when the subsurface environment has reached equilibrium.

System monitoring recommendations

Phase	**Monitoring frequency**	**What to monitor**	**Where to monitor**
Start-up (7-10 days)	Daily	◊ Sparge pressure ◊ Flow ◊ Vacuum readings (SVE) ◊ Vapor Concentrations (SVE)	◊ Air sparging well head ◊ Sparge and extraction wells ◊ Manifold ◊ Effluent stack
Remedial (on-going)	Biweekly to monthly	◊ Flow (SVE) ◊ Vacuum readings (SVE) ◊ Sparge pressure ◊ Vapor concentrations (SVE)	◊ Extraction vents ◊ Manifold ◊ Air sparging well head ◊ Effluent stack
	Quarterly to annually	◊ Dissolved constituent concentrations	◊ Groundwater monitoring wells

Bioremediation

In situ bioremediation is a technique for removing biodegradable contaminants from groundwater. The technique relies on microorganisms and supplemental oxygen and nutrients to break down petroleum products in the groundwater.

In situ bioremediation offers the advantage of being able to treat the contamination in place, without the need for pumping or the subsequent treatment of pumped groundwater. The technique is most effective in permeable aquifers.

Advantages:
- Degrades contaminants in place
- Achieves lower concentration levels than pump and treat

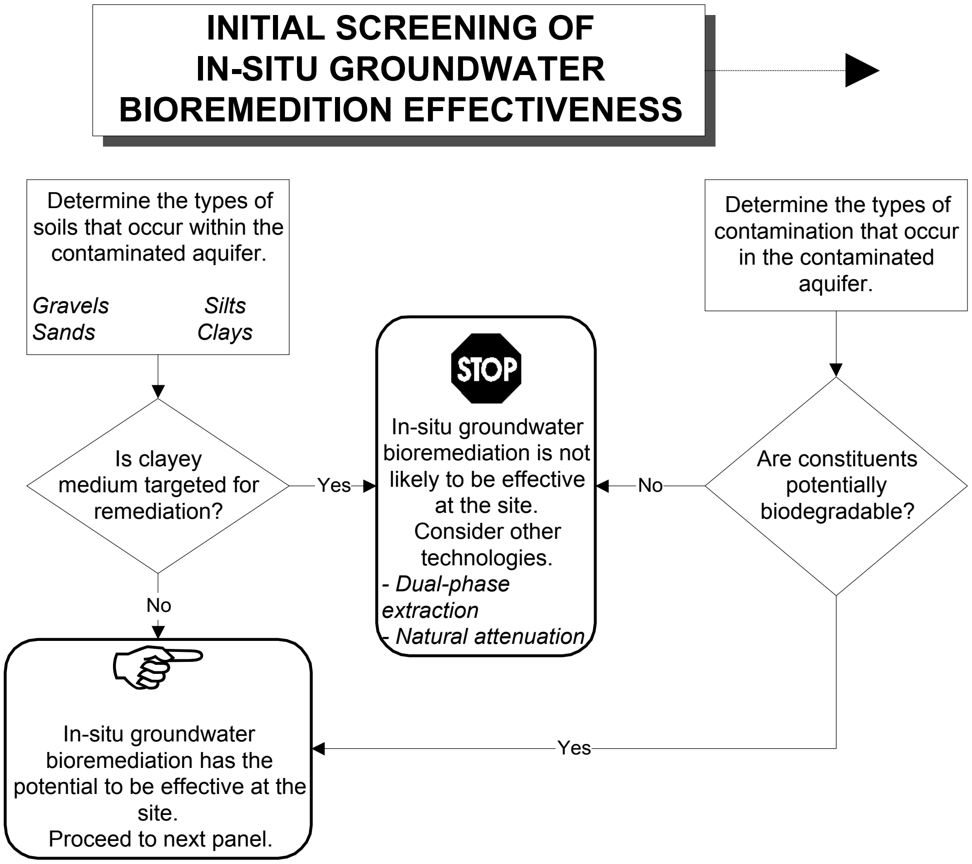
Limitations:
- Effectiveness is limited in low permeability or heterogeneous media
- Ability to transport nutrients and oxygen might be hindered by soil and groundwater mineral content or pH
- Targets only biodegradable constituents

System components & information:
- Groundwater containment system
- Oxygen delivery equipment
- Nutrient delivery equipment (optional)
- Injection trenches / wells
- Recovery wells or trenches
- Pumps
- Monitoring points

Waste stream treatment:
- Recirculated groundwater treatment options:
    - Air stripping
    - Granulated activated carbon
    - Bioreactors

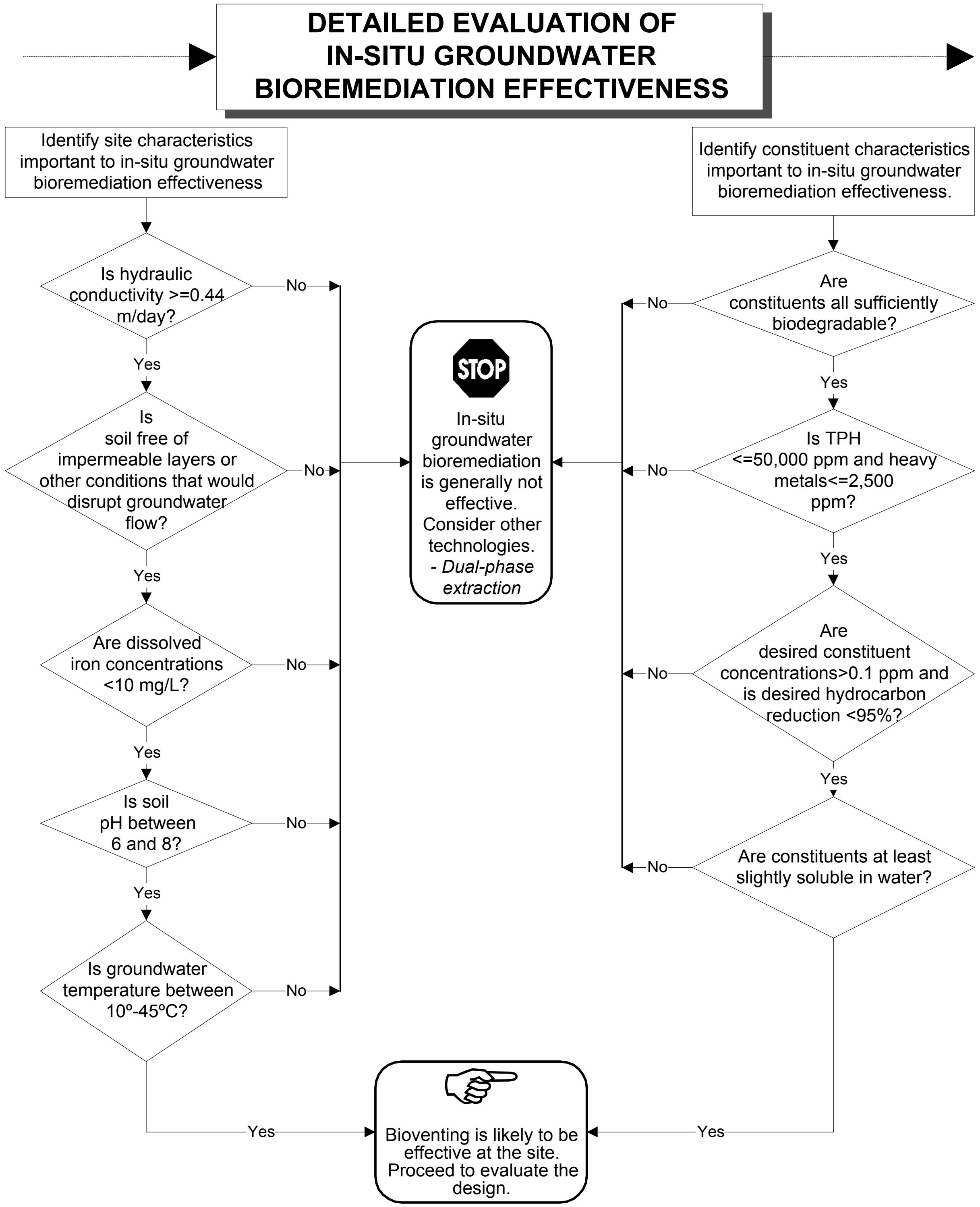
Required parameters to monitor for system performance:
- Without injection
    - static water level measurements
    - BTEX in groundwater
    - dissolved oxygen in groundwater
    - carbon dioxide in groundwater
- With injection
    - static water level measurements
    - BTEX in groundwater
    - dissolved oxygen in groundwater
    - carbon dioxide in groundwater
    - parameters required by the EPA

In-situ Groundwater Bioremediation Evaluation Process Flow Chart (1 of 3)



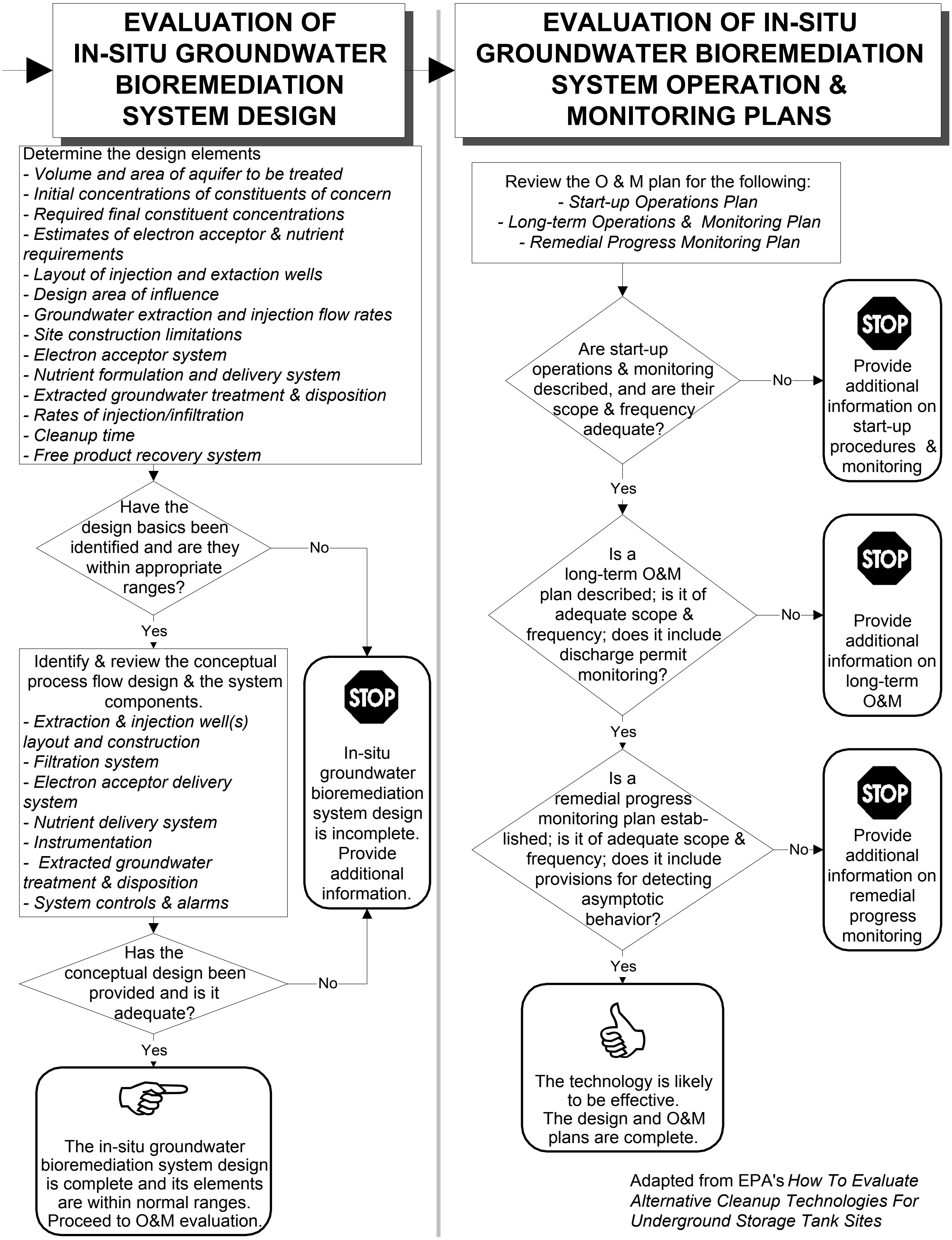
Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

In-situ Groundwater Bioremediation Evaluation Process Flow Chart (2 of 3)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

In-situ Groundwater Bioremediation Evaluation Process Flow Chart (3 of 3)



EVALUATION OF IN-SITU GROUNDWATER BIOREMEDIATION SYSTEM DESIGN

Determine the design elements
- *Volume and area of aquifer to be treated*
- *Initial concentrations of constituents of concern*
- *Required final constituent concentrations*
- *Estimates of electron acceptor & nutrient requirements*
- *Layout of injection and extaction wells*
- *Design area of influence*
- *Groundwater extraction and injection flow rates*
- *Site construction limitations*
- *Electron acceptor system*
- *Nutrient formulation and delivery system*
- *Extracted groundwater treatment & disposition*
- *Rates of injection/infiltration*
- *Cleanup time*
- *Free product recovery system*

Have the design basics been identified and are they within appropriate ranges?

Identify & review the conceptual process flow design & the system components.
- *Extraction & injection well(s) layout and construction*
- *Filtration system*
- *Electron acceptor delivery system*
- *Nutrient delivery system*
- *Instrumentation*
- *Extracted groundwater treatment & disposition*
- *System controls & alarms*

Has the conceptual design been provided and is it adequate?

STOP In-situ groundwater bioremediation system design is incomplete. Provide additional information.

The in-situ groundwater bioremediation system design is complete and its elements are within normal ranges. Proceed to O&M evaluation.

EVALUATION OF IN-SITU GROUNDWATER BIOREMEDIATION SYSTEM OPERATION & MONITORING PLANS

Review the O & M plan for the following:
- *Start-up Operations Plan*
- *Long-term Operations & Monitoring Plan*
- *Remedial Progress Monitoring Plan*

Are start-up operations & monitoring described, and are their scope & frequency adequate?

STOP Provide additional information on start-up procedures & monitoring

Is a long-term O&M plan described; is it of adequate scope & frequency; does it include discharge permit monitoring?

STOP Provide additional information on long-term O&M

Is a remedial progress monitoring plan established; is it of adequate scope & frequency; does it include provisions for detecting asymptotic behavior?

STOP Provide additional information on remedial progress monitoring

The technology is likely to be effective. The design and O&M plans are complete.

Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Can bioremediation be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that require closer scrutiny. As you go through the CADR answer the following questions. If the answer to several questions is no, additional information may be required to determine if bioremediation will accomplish the clean-up goals at the site. (Technical factors may be found in Appendix B.)

1. Site characteristics

Yes	No	
[ ]	[ ]	Is the aquifer hydraulic conductivity greater than 10^{-4} cm/sec ?
[ ]	[ ]	Have impermeable layers or other conditions that would disrupt groundwater flow been considered in the design of the remediation system?
[ ]	[ ]	Has the groundwater mineral content been quantified and taken into consideration?
[ ]	[ ]	Is soil pH between 6 and 8?
[ ]	[ ]	Are dissolved iron concentrations < 10 mg/L?
[ ]	[ ]	Is soil temperature between 10°C and 45°C?
[ ]	[ ]	Is the carbon:nitrogen:phosphorus ratio between 100:10:1 and 100:1:0.5?

2. Constituent characteristics

Yes	No	
[ ]	[ ]	Have all constituents of concern been identified?
[ ]	[ ]	Are constituents all sufficiently biodegradable?
[ ]	[ ]	Is the concentration of total petroleum hydrocarbon ≤ 50,000 ppm and heavy metals ≤ 7,000 ppm?
[ ]	[ ]	Are desired constituent concentrations > 0.1 ppm and is the desired hydrocarbon reduction < 95%?
[ ]	[ ]	Are the constituents present soluble in groundwater?

3. Evaluation of the air sparging system design

Yes	No	
[ ]	[ ]	Has treatability testing been performed?
[ ]	[ ]	Has groundwater modeling been used to calculate aquifer conditions over time?
[ ]	[ ]	If not, has some other method been used to calculate cleanup times?
[ ]	[ ]	Will the processing rates achieve cleanup in the time allotted for remediation in the CADR?
[ ]	[ ]	Have remediation rates been established for the project?
[ ]	[ ]	Has the area of influence for the proposed extraction or injection wells been determined?
[ ]	[ ]	Is the proposed well placement appropriate, given the total area to be cleaned up and the area of influence of each injection / extraction well system?
[ ]	[ ]	Has the amount of the contaminant to be remediated been determined?
[ ]	[ ]	Has the quantity and type of electron acceptors required for the remediation been determined?
[ ]	[ ]	If an electron acceptor system will be needed, is a design for that system provided?
[ ]	[ ]	Will aboveground treatment of groundwater be required?
[ ]	[ ]	Has the quantity of nutrients required for remediation, if needed, been determined?
[ ]	[ ]	If nutrient delivery systems will be needed, are designs for those systems provided?
[ ]	[ ]	Have groundwater extraction rates been determined?
[ ]	[ ]	Is a system control / alarm system included in the design?
[ ]	[ ]	Is a free product recovery system needed?

4. Operation and monitoring plans

Yes	No	
[ ]	[ ]	Is hydraulic balancing proposed as the first activity in startup?
[ ]	[ ]	Is routine system operation and monitoring proposed?
[ ]	[ ]	Is subsurface soil and groundwater sampling proposed for tracking constituent reduction and biodegradation conditions?
[ ]	[ ]	Is a schedule for tracking constituent reduction proposed?
[ ]	[ ]	Is nutrient addition (if necessary) proposed to be controlled on a periodic rather than continuous basis?

System design:

[ ] Evaluation of the suitability of the soils at the site for bioremediation.
[ ] List of nutrients being introduced (biostimulation) to enhance the existing biodegradation process and description of the introduction process, if applicable.
[ ] Evaluation of effectiveness of measures being implemented to control biofouling of the injection or recirculation system.
[ ] Identification of the water quality parameters which have the potential to interfere with the removal of the target compounds or cause fouling or corrosion of the treatment system. Discuss the measures that will be taken to alleviate these problems.
[ ] Description of the measures taken and monitoring which will be conducted to ensure hydraulic control of the contamination plume.
[ ] Description of the system operation.
[ ] Detailed schematic of treatment system.
[ ] Construction specifications for the treatment system and appurtenances (i.e., wells, galleries, etc.)
[ ] Scaled site maps showing location of the treatment system, injection wells, galleries or trenches, extraction and monitoring wells, contamination plume, treatment process area of influence and area of hydraulic control.
[ ] Discussion of potential for the production of toxic breakdown products.
[ ] Description of the saturated and unsaturated zones and treatment system monitoring program to be conducted to determine the effectiveness of the bioremediation process. Relate the monitoring results to mass balance equations and determine the effectiveness of the treatment process. Include in the discussion such factors as frequency, locations, parameters and water level measurements.

Infiltration gallery systems:

- Results of field percolation tests and evaluations of the significance of the results in terms of the site's suitability for the treatment process.
- Description of any modeling or field testing conducted to determine the gallery's effect on contamination plume migration.

Above ground bioreactors:

- Statement of whether the treatment process is an aerobic or anaerobic biological process. If anaerobic, describe the fate of methane produced during operation of the system.
- Evaluation of the potential for sludge production; include production rates and disposal methods.

Permits:

Provide a copy of the EPA underground injection control (UIC) permit or letter from EPA indicating the system does not require an UIC permit in Appendix A. (Required for groundwater injection systems only.)

Bioventing Combined With Low Flow Air Sparging (Biosparging)

Bioventing combined with low flow air sparging (biosparging) stimulates the aerobic biodegradation of organic contaminants in groundwater by delivering oxygen to the unsatuarated and saturated zones. The oxygen is delivered at a slow rate to encourage biodegradation rather than volatilization.

Biosparging degrades volatile organic compounds (VOCs) in place, reducing the need for subsequent vapor treatment and the costs of remediation. This technique is most effective in permeable aquifers.

Advantages:
- Degrades VOCs in place
- Reduces air emissions and subsequent need for vapor treatment

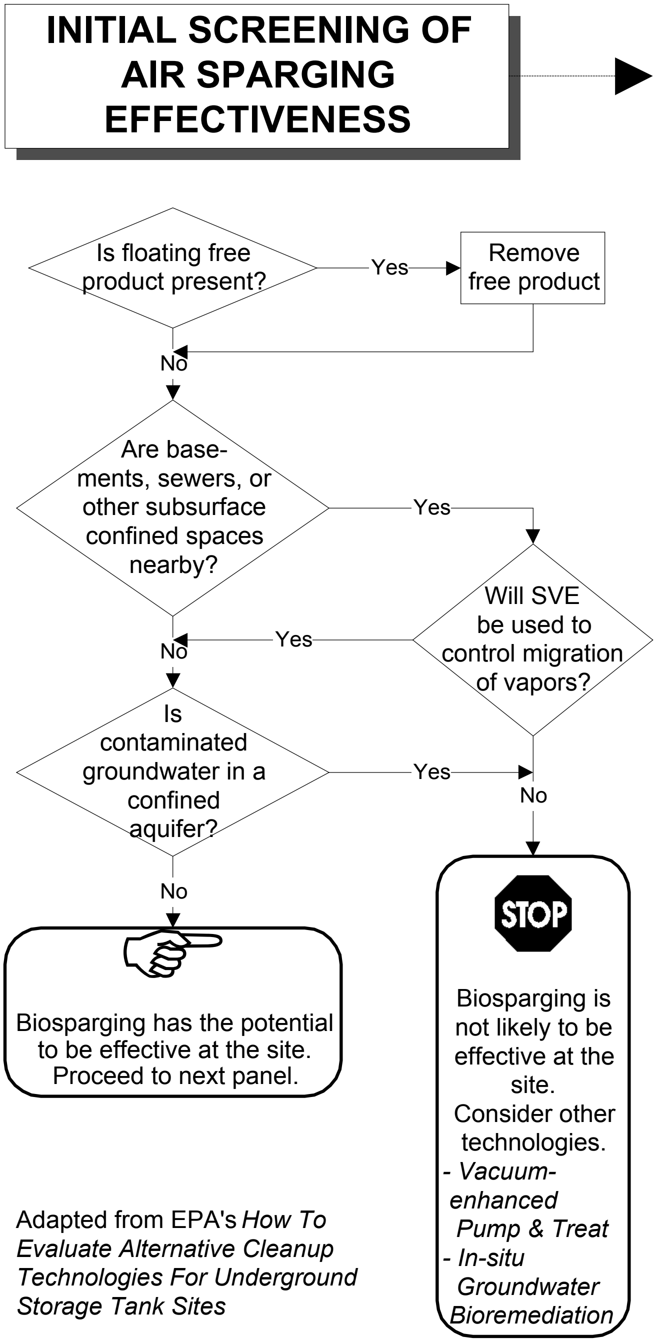
Limitations:
- Effectiveness is limited in low permeability or heterogeneous media
- Difficult to control air distribution in groundwater
- Limited performance data available

System components & information:
- Vertical or horizontal extraction and injection wells
- Vacuum pump, compressor, or blower
- Above ground vapor treatment (optional)

Waste stream treatment:
- Vapor treatment options (may be needed for high concentrations of contaminants):
    - Vapor phase biofilters
    - Granulated activated carbon
    - Internal combustion engine
    - Catalytic oxidation unit
    - Thermal incinerator

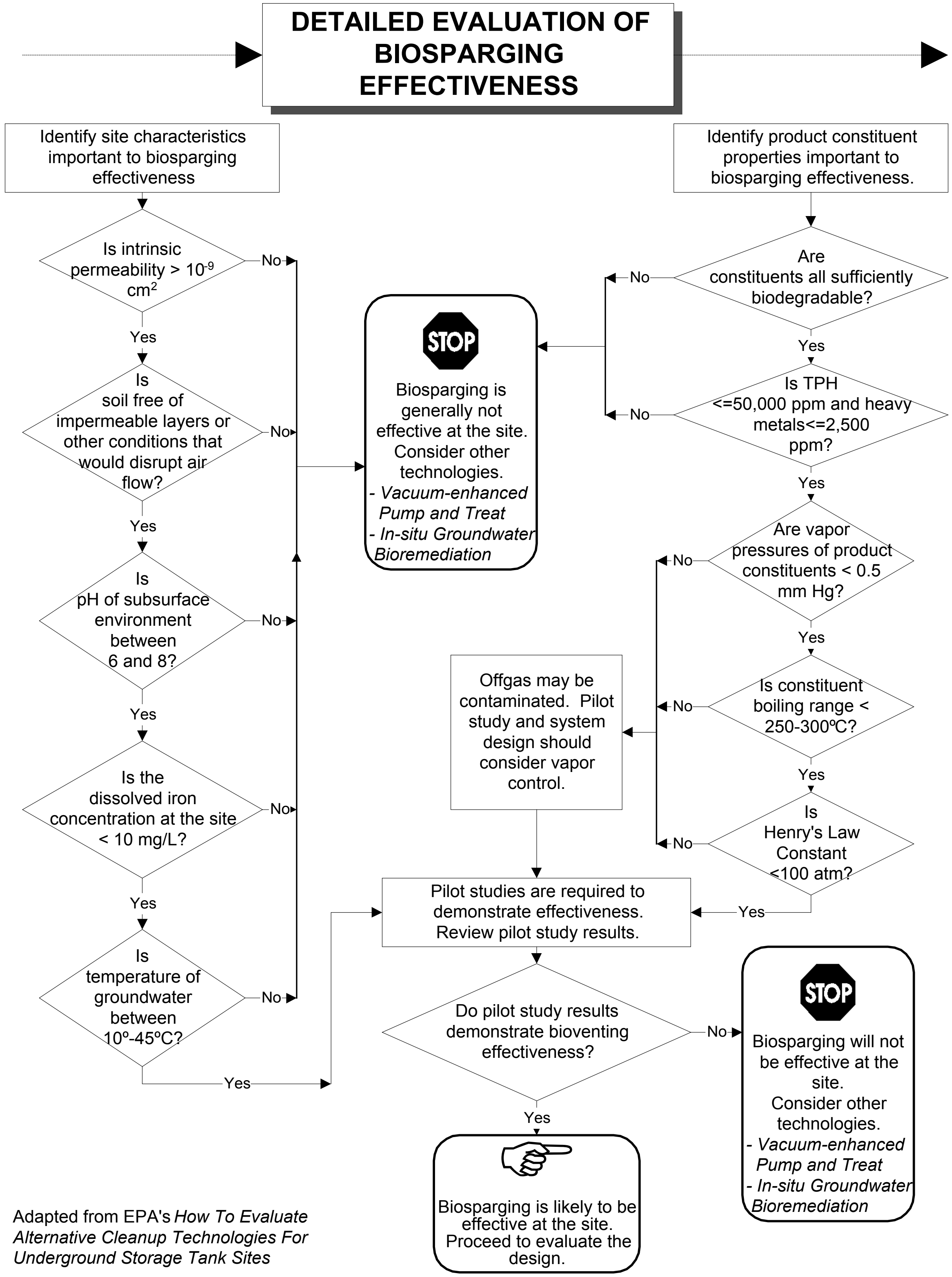
Required parameters to monitor for system performance:
- flow rate (positive pressure) into each air-sparge well head
- static water level measurements
- BTEX in groundwater
- PID/FID and % LEL readings in any nearby storm/sanitary sewers, basements, confined spaces, etc.

Biosparging Evaluation Process Flow Chart (1 of 3)



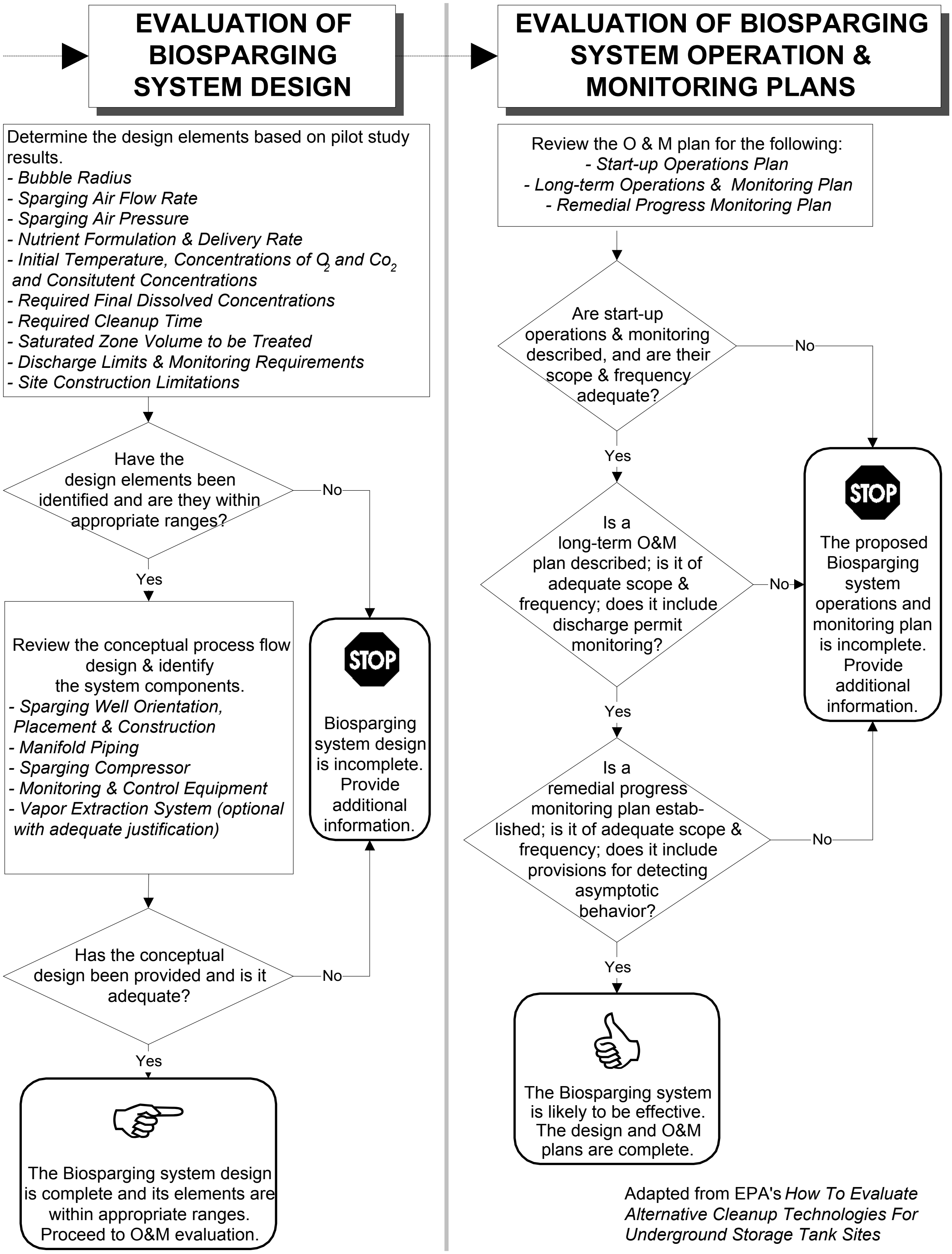
Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Biosparging Evaluation Process Flow Chart (2 of 3)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Biosparging Evaluation Process Flow Chart (3 of 3)



Adapted from EPA's *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites*

Can biosparging be used at this site?

This checklist can help evaluate the completeness of the CADR and identify areas that require closer scrutiny. As you go through the CADR, answer the following questions. If the answer to several questions is no, additional information may be required to determine if biosparging will accomplish the clean-up goals at the site. (Technical factors may be found in Appendix B.)

1. Site factors

Yes	No	
[ ]	[ ]	Is the aquifer clear of floating free product?
[ ]	[ ]	Is the soil intrinsic permeability greater than 10^{-9} cm^2 ?
[ ]	[ ]	Is the soil free of impermeable layers or other conditions that would disrupt air flow?
[ ]	[ ]	Is soil pH between 6 and 8?
[ ]	[ ]	Is soil temperature between 10°C and 45°C during the proposed treatment season?
[ ]	[ ]	Is the carbon:nitrogen:phosphorus ratio between 100:10:1 and 100:1:0.5?
[ ]	[ ]	Is the dissolved iron concentration at the site < 10 mg/L?
[ ]	[ ]	Is vapor migration of constituents controlled?
[ ]	[ ]	Is the depth to groundwater >3 feet? This parameter alone may not negate the use of bioventing. However, provisions for the construction of horizontal wells or trenches or for lowering the water table should be incorporated into the CADR.

2. Constituent characteristics

Yes	No	
[ ]	[ ]	Are all constituents sufficiently biodegradable?
[ ]	[ ]	Is the concentration of Total Petroleum Hydrocarbons ≤ 50,000 ppm & heavy metals ≤ 2,500 ppm?
[ ]	[ ]	Are the constituent vapor pressures less than 0.5 mm Hg?
[ ]	[ ]	Are the Henry's law constants for the constituents present lower than 100 atm?

3. Evaluation of the biosparging system design

Yes	No	
[ ]	[ ]	Examine the sparging air pressure. Will the proposed pressure be sufficient to overcome the hydraulic head and capillary forces?
[ ]	[ ]	Is the proposed well density appropriate, given the total area to be cleaned up and the radius of influence of each well?
[ ]	[ ]	Do the proposed well screen intervals account for contaminant plume location at the site?
[ ]	[ ]	Is the proposed well configuration appropriate for the site conditions present?
[ ]	[ ]	Is the air compressor selected appropriate for the desired sparge pressure?
[ ]	[ ]	If nutrient addition is needed, are nutrient formulation and delivery rates appropriate for the site, based on laboratory or field studies?
[ ]	[ ]	Have background concentrations of oxygen and CO_2 (measured in pilot test) been taken into account in establishing operating requirements?

4. Operation and monitoring plans

Yes	No	
[ ]	[ ]	Are manifold valving adjustments proposed during the first 7 to 10 days of operation?
[ ]	[ ]	Are hourly recordings of injection and extraction rates, pressures, depth to groundwater, hydraulic gradient, and VOC levels proposed during the first 7 to 10 days of operation?
[ ]	[ ]	Is daily monitoring of injection rates proposed during the first 7 to 10 days of operation?
[ ]	[ ]	Are biweekly to monthly measurements of contaminant levels in groundwater, vapor wells, and blower exhausts proposed?
[ ]	[ ]	Are biweekly to monthly measurements of vapor concentration proposed?

Vacuum Enhanced Pump and Treat

Vacuum enhanced pump and treat is a technique that uses a surface-mounted vacuum pump to remove contaminated soil vapors and groundwater simultaneously. The pumped water and soil vapors can then be treated with a number of techniques. Vacuum enhanced pump and treat is most effective when used in aquifers with medium to low permeability (silts and clays). This method offers pumping rates that are 3 to 10 times greater than conventional pump and treat rates. Increased pumping rates result in decreased remediation time.

Advantages:
- Controls contaminant plume migration and reduces plume concentrations
- Increases recovery pumping rate, thus reducing remediation times
- Effective in aquifers with low permeability
- Can remove residuals from dewatered aquifer soils

Limitations
- Can require treatment of vapors from vacuum pump
- Generates larger volume of water for treatment in a shorter time than conventional pump and treat
- Requires control of water table fluctuation to minimize smearing contaminants
- High iron content/hardness can affect water treatment

System components & information:
- Vertical or horizontal extraction wells
- Trenches
- Vacuum blower or pump
- Water pumps
- Aboveground air/water treatment systems

Waste stream treatment
- Vapor treatment options:
  - Vapor phase biofilters
  - Granulated activated carbon
  - Internal combustion engine
  - Catalytic oxidation unit
  - Thermal incinerator
- Water treatment options:
  - Air stripping, granulated activated carbon, bioreactors

Required parameters to monitor for system performance:
- Vapor concentration at each SVE extraction point, vapor peizometer, system manifold, and discharge stack (using PID/FID)
- Vacuum pressure at each SVE extraction point, vapor peizometer, and system manifold
- Air flow measurement (standard cubic feet per minute - scfm) at each SVE extraction point, system manifold, and discharge stack
- Pumping rate - compare with the design pumping rate
- Draw down in recovery wells - compare with the design draw down
- Static water level measurements in each monitoring well and SVE recovery well. (Compare the static water level with the elevation of the vapor extraction screen or point)
- BTEX and dissolved oxygen in the groundwater at selected monitoring wells, influent & effluent
- Volatile organic hydrocarbon concentration: total air flow rate for the system and volatile organic hydrocarbon concentration for the system (laboratory analyzed samples)

Pump and Treat

Pump and treat is a technique that brings contaminated groundwater above the ground through the use of extraction wells. Generally, the water is then treated using one of three processes: granulative activated carbon, air stripping, or bioremediation. Pump and treat is most effective in permeable aquifers. It also can be used with in situ soil vapor extraction to enhance removal of volatile contaminants from the zone of water table fluctuation.

A limitation of pump and treat is the excessive length of time required to achieve complete remediation (sometimes several years for an ideal site). In addition, this method is subject to fluctuations of the water table that can smear contaminants and complicate cleanups.

Advantages:
- Controls contaminant plume migration and reduces plume concentration

Limitations:
- Not very effective in aquifers with low permeability
- Can require expensive and lengthy long-term pumping and treating
- High iron content / hardness can affect water treatment
- Requires control of water table fluctuations to minimize smearing contaminants
- Might require off-site discharge permits

System components & information:
- Vertical or horizontal extraction wells
- Trenches
- Water pumps
- Above ground water handling and/or treatment systems

Waste stream treatment:
- Waste stream treatment options:
    - Air stripping
    - Granulated activated carbon
    - Bioreactors

Required parameters to monitor for system performance:
- static water levels measurements
- BTEX in groundwater
- BTEX, dissolved oxygen and pH in system influent and effluent
- Pumping rate - compare with the design pumping rate
- Draw down in recovery wells - compare with the design draw down

Innovative or Alternative Treatment Technologies

The use of institutional and technological controls, plugging drinking and non-drinking water wells, soil excavation and replacement / relocation of plastic water lines are discussed in detail in the Tier 2 guidance document. A CADR for a technology proposed for the site which has not been discussed in this CADR guidance document should contain adequate information describing the system, design, monitoring parameters, etc.

Air stripper treatment - Provide a report discussing the following, at a minimum:

[ ] A. Description: Description of the system operation.
[ ] B. Schematic: Detailed schematic of the treatment system.
[ ] C. Water quality: Identification of the water quality parameters that have the potential to interfere with the removal of the target compounds or cause fouling, biofouling or corrosion of the treatment system. Describe the measures that will be taken to alleviate these problems.
[ ] D. Air stripper treatment maps: Scaled site maps showing location of the treatment system, recovery and monitoring wells, contamination plume, area of hydraulic control and pertinent site features.
[ ] E. Free product: Description and schematic of the water product separator, product recovery system and warning system to detect high product levels in the product recovery tank if free product is present or has the potential to be present at the site.
[ ] F. Assumptions and calculations: Design assumptions and calculations used to size the tower height and diameter, packing height, and flow rate.
[ ] G. Treatment specifications: Specifications for treatment system and appurtenances (i.e., monitoring wells, recovery wells, packing material, etc.).
[ ] H. Start-up monitoring plan: Description of the monitoring program that will be conducted during the initial start-up of the system. The program must be designed to prevent the release of effluent exceeding discharge limitations and to detect any variability in treatment efficiencies.
[ ] I. Remediation monitoring plan: Description of the monitoring program to be conducted to determine the effectiveness of the treatment unit and the status of site remediation. Include in the discussion such factors as frequency, locations, analytical parameters, and water level measurements in monitoring and recovery wells.

Carbon adsorption - Provide a report discussing the following, at a minimum:

[ ] A. Description: Description of the system operation.
[ ] B. Schematic: Detailed schematic of the treatment system.
[ ] C. Water quality: Identification of the water quality parameters that have the potential to interfere with the removal of the target compounds or cause fouling, biofouling or corrosion of the treatment system. Describe the measures that will be taken to alleviate these problems.
[ ] D. Carbon adsorption treatment maps: Scaled site maps showing location of the treatment system, recovery and monitoring wells, contamination plume, area of hydraulic control and pertinent site features.
[ ] E. Free product: Description and schematic of the water product separator, product recovery system and warning system to detect high product levels in the product recovery tank if free product is present or has the potential to be present at the site.
[ ] F. Carbon units: Methods and evaluation of the design assumptions used to size the carbon units, determine carbon usage, contact time, breakthrough of contaminant into the waste stream effluent, necessity of treatment units in series, pressure gauges, pressure release valves and type of filtering device prior to the carbon units.
[ ] G. Remediation monitoring plan: Description of the monitoring program conducted to determine the effectiveness of the treatment unit and the status of site remediation. Include such factors as monitoring frequency, locations, parameters, measures to prevent or detect contaminant breakthrough and water level measurements. If isotherm data from pilot studies were not used to estimate the carbon capacity required and the sampling frequency, explain why.
[ ] H. Carbon disposal / replacement: Description of carbon disposal and replacement procedures.

Aeration treatment technology - Provide a report discussing the following, at a minimum:

[ ] A. Description: Description of the system operation.

[ ] B. Schematic: Detailed schematic of the treatment system.

[ ] C. Water quality: Identification of the water quality parameters that have the potential to interfere with the removal of the target compounds or cause fouling, biofouling or corrosion of the treatment system. Describe the measures that will be taken to alleviate these problems.

[ ] D. Aeration treatment technology maps: Scaled site maps showing location of the treatment system, recovery and monitoring wells, contamination plume, area of hydraulic control and pertinent site features.

[ ] E. Free product: Description and schematic of the water product separator, product recovery system and warning system to detect high product levels in the product recovery tank if free product is present or has the potential to be present at the site.

[ ] F. Assumptions and calculations: Design assumptions and calculations used to size aeration tanks, determine residence time, and air and influent groundwater flow rates.

[ ] G. Treatment specifications: Construction specifications for the treatment system and appurtenances (i.e., monitoring wells, recovery wells, aeration tank, air injection system, diffusers, etc.).

[ ] H. Start-up monitoring plan: Description of the monitoring program to be conducted during initial start-up of the system. The program must be designed to prevent the release of effluent exceeding discharge limitations and to detect any variabilities in treatment efficiencies.

[ ] I. Remediation monitoring plan: Description of the monitoring program to be conducted to determine the effectiveness of the treatment unit and the status of site remediation. Include in the discussion such factors as frequency, locations, analytical parameters, and water level measurements in monitoring and recovery wells.

Appendix A

Permits

Permitting of groundwater injection systems: Groundwater professionals considering the reinjection of treatment system effluent as part of a treatment process must contact the U.S. Environmental Protection Agency (EPA), Kansas City, KS (913/551-7413) to determine if the process will require an Underground Injection Control Permit. Submittals proposing a reinjection process must contain copies of correspondence indicating the process does not require a permit or a copy of a permit issued by the EPA, Kansas City Office.

Permitting of groundwater use: A groundwater use permit is required when groundwater withdrawal exceeds 25,000 gallons in a 24-hour period. An application for this permit can be obtained by contacting the Water Supply Section at 515/281-6681.

Air discharge permits: Currently, no air discharge permits are required in Iowa for LUST remediation systems, except in Polk and Linn Counties.

Polk County contact for air discharge requirements:
Gary Young
Polk County Public Works Department
Air Quality Division
1530 NE 58th Avenue
Des Moines, IA 50313-1296
515/286-3372

Linn County contact for air discharge requirements:
Greg Slager
Air Quality Division, Linn County Health Department
501 13th Street NW
Cedar Rapids, IA 52405
319/398-3551

Appendix B

Technical Factors

Data regarding vapor pressures, boiling point ranges, Henry's law constants, solubilities, etc. can be found in the CRC Handbook of Chemistry and Physics as well as in the Tier 2 Site Cleanup Report Guidance appendices.

Intrinsic permeability

The measure of intrinsic permeability is one of the most important indicators of whether certain treatment technologies will be successful at a site. Intrinsic permeability is a measure of the ability of soils to transmit fluids (liquid or gas). Intrinsic permeability ranges over 12 orders of magnitude (from 10^{-16} to 10^{-3} cm^2) for the wide variety of earth materials, although a more limited range applies for common soil types (10^{-13} to 10^{-5} cm^2). Intrinsic permeability is best determined from field tests, but can be estimated within one or two orders of magnitude from soil boring logs and laboratory tests. Coarse-grained soils (e.g., sands) have greater intrinsic permeability than fine-grained soils (e.g., clays or silts). Note that the ability of a soil to transmit air is reduced by the presence of soil water, which can block the soil pores and reduce air flow. This is especially notable in fine-grained soils, which tend to retain water.

Intrinsic permeability can be determined in the field by conducting permeability tests or in the laboratory using soil core samples from the site. Procedures for these tests are described by the EPA (U.S. Environmental Protection Agency. *Guide for Conducting Treatability Studies Under CERCLA: Aerobic Biodegradation Remedy Screening*. Washington, DC: Office of Emergency and Remedial Response. EPA/540/2-91/013A, 1991). At sites where the soils in the saturated zone are similar to those in the unsaturated zone, hydraulic conductivity of the soils may be used to estimate the permeability of the soils. Hydraulic conductivity is a measure of the ability of soils to transmit water. Hydraulic conductivity can be determined from aquifer tests, including slug tests and pumping tests. You can convert hydraulic conductivity to intrinsic permeability using the following equation:

$$k = K (\mu / \rho g)$$

where: k = intrinsic permeability (cm^2)
K = hydraulic conductivity (cm/sec)
μ = water viscosity (g/cm x sec)
ρ = water density (g/cm^3)
g = accelerator due to gravity (cm/sec^2)

At 20°C: $\mu / \rho g = 1.02 \times 10^{-5}$ cm/sec
To convert k from cm^2 to darcy, multiply by 10^8
To convert K in m/d to k in cm^2, multiply by 1.33×10^{-8}
To convert k in cm^2 to K in m/day, multiply by 7.52×10^7

Pore volume calculations

Pore volume is the total volume of pore space in a given volume of rock or sediment. Pore volume usually relates to the volume of air or water that must be moved through contaminated material in order to flush the contaminants. Pore volume calculations are used along with extraction flow rate to determine the pore volume exchange rate and, therefore, oxygen delivery rate. The exchange rate is calculated by dividing the soil pore space within the treatment zone by the design vapor extraction rate. The pore space within the treatment zone is calculated by multiplying the soil porosity by the volume of soil to be treated. Some literature suggests that one pore volume of soil vapor should be extracted at least weekly for effective remedial progress.

You can calculate the time required to exchange one pore volume of soil vapor using the following equation:

$$E = \frac{\varepsilon V}{Q}$$

where: E = pore volume exchange time (hr)
ε = soil porosity (m^3 vapor/m^3 soil)
V = volume of soil to be treated (m^3 soil)
Q = total vapor extraction flowrate (m^3 vapor/hr)

$$E = \frac{(\text{m}^3 \text{ vapor} / \text{m}^3 \text{ soil}) \bullet (\text{m}^3 \text{ soil})}{(\text{m}^3 \text{ vapor} / \text{hr})} = \text{hr}$$

Corrective Action Design Report for Leaking Underground Storage Tank Sites
Iowa Department of Natural Resources

SITE IDENTIFICATION

LUST No.

UST Registration No.

Site Name:

Site Address:

City:

RESPONSIBLE PARTY IDENTIFICATION

Name:

Street:

City:

State:

Zip Code:

The treatment technologies to be used at the site. ***Check all that apply.***

[ ] Soil Vapor Extraction (SVE)
[ ] Bioventing
[ ] Biomounding
[ ] Thermal Desorption
[ ] Land Farming
[ ] Excavation (off-site treatment
[ ]
[ ]
[ ]
[ ]
[ ] Air Sparging with SVE
[ ] Bioremediation
[ ] Biosparging
[ ] Vacuum Enhanced P & T
[ ] Pump & Treat (P & T)
[ ] Air Stripper Treatment
[ ] Carbon Adsorption
[ ] Aeration Treatment
[ ]
[ ]

I, _______________________________________, groundwater professional number ___________, am familiar with all applicable requirements of Iowa Code section 455B.474 and all rules and procedures adopted thereunder including, but not limited to, the Iowa Department of Natural Resources' guidance and specifications for corrective action design reports. Based on my knowledge of those documents and the information I have prepared and reviewed regarding this site, UST registration number ______________, LUST number ______________, I certify that this document is complete and accurate as provided in 135.12(9) and meets the applicable requirements of the corrective action design report, and that the recommended corrective action can reasonably be expected to meet its stated objectives.

Print: Name/Address/Phone Number of Iowa Certified Groundwater Professional

____ Signature: _______________________________________

____

____ Date: ____

____

I certify that I have reviewed this document, appendices and attachments for submittal to the Iowa Department of Natural Resources.

____ ____

Print Name of Responsible Party | Signature - Responsible Party | Date

Official IDNR Use Only

Date Received:		Comment Letter Date:	
Reviewer:		Approved:	Y / N

CADR checklist

[ ] Completed CADR cover page
[ ] Completed CADR checklist
[ ] I. Executive summary
[ ] II. Comparison of two corrective action alternatives
[ ] III. Justification for selected corrective action
[ ] IV. Timetable and critical performance benchmarks
[ ] V. System design
[ ] VI. Pilot test
[ ] VII. Operation and maintenance plan
[ ] VIII. Start-up period plan
[ ] IX. Groundwater summary corrective action map from the Tier 2 report
[ ] X. Soil summary corrective action map from the Tier 2 report
[ ] XI. Groundwater flow direction maps (current and historic)
[ ] XII. Monitoring plan
[ ] XIII. Waste management disposal plan
[ ] XIV. Security / System protection
[ ] Appendix A: Permits
[ ] Appendix B: Justification
[ ] Appendix C: Boring logs / well construction diagrams (Only those which have not been previously submitted to the IDNR.)
[ ] Appendix D: Laboratory analytical reports (Only those which have not been previously submitted to the IDNR.)