ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF SPILL PREVENTION AND RESPONSE

Guidance No. SPAR 2000 -1 January 3, 2000

GUIDANCE ON THE SELECTION OF NATURAL ATTENUATION AS A CLEANUP ALTERNATIVE FOR THE RESTORATION OF SOIL AND GROUND WATER AT CONTAMINATED SITES

PURPOSE:

This guidance is intended to clarify the Department's policy regarding the use of natural attenuation for the cleanup of sites regulated under 18 AAC 75 Article 3.

BACKGROUND:

18 AAC 75.325 establish the administrative processes and standards to determine the necessity for and degree of cleanup required to protect human health, safety, and welfare, and the environment where a hazardous substance is located. This section of the Site Cleanup Rules outline criteria which hazardous substance response actions must meet. 18 AAC 75.360 outlines the elements of a hazardous substance response action, which require department approval prior to implementation. Natural attenuation is one of many remedial options that may effectively, by itself or in combination with other remedies cleanup contaminated soil and groundwater within a reasonable time frame. Natural attenuation is not a no-action remedy, rather it is an alternative means of achieving cleanup objectives that may be appropriate for a limited set of site circumstances where its use will meet the applicable cleanup level. The *GUIDANCE ON THE SELECTION OF NATURAL ATTENUATION AS A CLEANUP ALTERNATIVE FOR THE RESTORATION OF SOIL AND GROUND WATER AT CONTAMINATED SITES* provides background information natural attenuation processes; outlines information which must be collected and considered when evaluating whether natural attenuation is an appropriate remedy at a specific site; and identify elements which should be addressed in a cleanup operations plan.

APPLICABILITY:

This guidance is applicable to staff in the Division of Spill Prevention and Response (SPAR) overseeing the cleanup of contaminated soil in accordance with 18 AAC 78 and 18 AAC 75, Article 3 where cleanup actions include the use of natural attenuation to meet site cleanup requirements.

ACTION:

SPAR staff will refer to this guidance when evaluating and approving cleanup plans which incorporate natural attenuation as a remedy from at sites regulated under 18 AAC 78 and 18 AAC 75, Article 3.

APPROVAL:

________________________________ ____________________
Jim Hayden, Storage Tank Program Manager Date

________________________________ ____________________
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DEPARTMENT OF ENVIRONMENTAL CONSERVATION

GUIDANCE ON THE SELECTION OF NATURAL ATTENUATION AS A CLEANUP ALTERNATIVE FOR THE RESTORATION OF SOIL AND GROUND WATER AT CONTAMINATED SITES

January, 2000

Tony Knowles
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PURPOSE AND OVERVIEW

The Alaska Department of Environmental Conservation (DEC) has developed rules which establish the requirements for determining the necessity for and degree of cleanup required to protect human health, safety and welfare and the environment at contaminated sites under the Contaminated Sites Remediation Program (CSRP). These regulations are found at 18 AAC 75 Article 3. The purpose of this Guidance is to clarify the DEC policy regarding the use of natural attenuation for the cleanup of contaminated soil and groundwater at sites regulated under 18 AAC 75 Article 3.

Natural attenuation is one of many remedial options that may be effective, by itself or in combination with other remedies to clean up contaminated groundwater within a reasonable time frame. Natural attenuation is defined as *the reduction in the concentration and mass of a hazardous substance and its breakdown products, due to naturally occurring physical, chemical and biological processes without human intervention. These processes include, but are not limited to, dispersion, diffusion, sorption and retardation, and degradation processes such as biodegradation and radioactive decay.* DEC does not consider natural attenuation to be a “presumptive” or “default” remedy - it is merely one option that may be evaluated with other viable cleanup remedies. DEC advocates using the most appropriate technology for a given site. DEC does not view natural attenuation to be a “no action” or “walk-away” approach, but rather considers it to be an alternative means of achieving cleanup objectives that may be appropriate for a limited set of site circumstances where its use meets the applicable cleanup levels.

As there are often a variety of methods available for achieving a site’s cleanup objectives, natural attenuation may be evaluated and compared to other viable cleanup alternatives during the site characterization phase. As with any other cleanup alternative, natural attenuation should be selected only where it meets all relevant cleanup selection criteria, where it will be fully protective of human health, safety, welfare and the environment, and where it will meet site cleanup objectives, within a time frame that is reasonable compared to that offered by other cleanup approaches. In the majority of cases where natural attenuation is proposed as a remedy, its use may be appropriate as one component of the total remedy either in conjunction with active remediation or as a follow-up measure. Natural attenuation should be used very cautiously as the sole remedy at contaminated sites.

As with other cleanup alternatives, selection of natural attenuation as a cleanup alternative should be supported by detailed site-specific information that demonstrates the efficacy of this cleanup approach. In addition, the progress of natural attenuation toward a site’s cleanup objectives should be carefully monitored. Where natural attenuation’s ability to meet cleanup objectives is uncertain and based predominantly on predictive analyses, project managers and decision-makers should incorporate contingency measures into the cleanup action.

The scientific understanding of natural attenuation processes continues to evolve rapidly. DEC

recognizes that significant advances have been made in recent years, but there is still a great deal to be learned regarding the mechanisms governing natural attenuation processes and their ability to address different types of contamination problems. Therefore, while DEC believes natural attenuation may be used where circumstances are appropriate, it should be used with caution commensurate with the uncertainties associated with the particular application. Furthermore, largely due to the uncertainty associated with the potential effectiveness of natural attenuation to meet cleanup objectives that are protective of human health, safety, welfare and the environment, source control and performance monitoring are fundamental components of any natural attenuation remedy.

This Guidance is not intended to provide detailed technical guidance on evaluating natural attenuation processes. Several reference sources exist which should be used when evaluating whether natural attenuation processes are occurring at a specific site. These sources include; (1) Wiedemeir, T.H., et al 1995, *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater* and (2) U.S. Environmental Protection Agency, 1998, *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*.

BACKGROUND

The term "natural attenuation," as used in this Guidance, refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific cleanup objectives within a time frame that is reasonable and practicable compared to that offered by other more active methods. The "natural attenuation processes" that are at work in such a cleanup approach include a variety of in-situ physical, chemical, or biological processes. Under favorable conditions, these processes act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These processes include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, or destruction of contaminants. Other terms associated with natural attenuation in the literature include "intrinsic remediation", "intrinsic bioremediation", "passive bioremediation", "natural recovery", and "natural assimilation". While some of these terms are synonymous with "natural attenuation," others refer strictly to biological processes, excluding chemical and physical processes.

Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness depending on the types and concentrations of contaminants present and the physical, chemical, and biological characteristics of the soil and groundwater. Natural attenuation processes may reduce the potential risk posed by site contaminants in three ways:

(1) The contaminant may be converted to a less toxic form through destructive processes such as biodegradation or abiotic transformations;

(2) Potential exposure levels may be reduced by lowering of concentration levels (through destructive processes, or by dilution or dispersion); and

(3) Contaminant mobility and bioavailability may be reduced by sorption to the soil or rock matrix.

Where conditions are favorable, natural attenuation processes may reduce contaminant mass or concentration at sufficiently rapid rates to be integrated into a site's soil or groundwater remedy. Following source control measures, natural attenuation may be sufficiently effective to achieve cleanup objectives at some sites without the aid of other (active) cleanup measures. Typically, however, natural attenuation will be used in conjunction with active cleanup measures. For example, natural attenuation could be employed in lower concentration areas of the dissolved plume and as a follow-up to active remediation in areas of higher concentration. DEC also encourages the consideration of innovative approaches, which may offer greater confidence and reduced cleanup time frames at a modest additional cost.

While natural attenuation is often dubbed "passive" remediation because it occurs without human intervention, its use at a site does **not** preclude the use of "active" remediation or the application of enhancers of biological activity (*e.g.*, electron acceptors, nutrients, and electron donors). However, by definition, a remedy that includes the introduction of an enhancer of any type is no longer considered to be "natural" attenuation. Use of natural attenuation does not imply that activities (and costs) associated with investigating the site or selecting the remedy (*e.g.*, site characterization, risk assessment, comparison of cleanup alternatives and performance monitoring) have been eliminated. These elements of the investigation and cleanup must still be addressed as required under 18 AAC 75 Article 3, regardless of the cleanup approach selected.

<u>Transformation Products</u>

Some natural attenuation processes may result in the creation of transformation products that are more toxic than the parent contaminant (*e.g.*, degradation of trichloroethylene to vinyl chloride). The potential for creation of toxic transformation products is more likely to occur at non-petroleum release sites (*e.g.*, chlorinated solvents or other volatile organic spill sites) and should be evaluated to determine if implementation of a natural attenuation remedy is appropriate and protective in the long term. Additionally, some natural attenuation processes may result in transfer of some contaminants from one medium to another (*e.g.*, from soil to groundwater, from soil to air or surface water, and from groundwater to surface water). Such cross-media transfer is not desirable, and generally not acceptable except under certain site-specific circumstances, and would likely require an evaluation of the potential risk posed by the contaminant(s) once transferred to that medium.

<u>Petroleum-Related Contaminants</u>

Natural attenuation processes, particularly biological degradation, are currently best documented at petroleum fuel spill sites. Under appropriate field conditions, the regulated compounds benzene, toluene, ethyl benzene, and xylene (BTEX) may naturally degrade through microbial activity and ultimately produce non-toxic end products (*e.g.*, carbon dioxide and water). Where microbial activity is sufficiently rapid, the dissolved BTEX contaminant plume may stabilize (*i.e.*, stop expanding), and contaminant concentrations may eventually decrease to levels below regulatory cleanup levels. Following degradation of a dissolved BTEX plume, a residue consisting of heavier petroleum hydrocarbons of relatively low solubility and volatility will typically be left behind in the original source (spill) area. Although this residual contamination may have relatively low potential for further migration, it still may pose a threat to human health, safety, welfare or the environment either from direct contact with soils in the source area or by continuing to slowly leach contaminants to groundwater. For these reasons, monitored natural attenuation alone is generally not sufficient to cleanup even a petroleum release site. Implementation of source control measures in conjunction with natural attenuation is almost always necessary. Other controls (*e.g.*, institutional controls), may also be necessary to ensure protection of human health, safety, welfare and the environment. Furthermore, while BTEX contaminants tend to biodegrade with relative ease, other chemicals (*e.g.*, methyl tertiary-butyl ether [MTBE]) that are more resistant to biological or other degradation processes may also be present in petroleum fuels. In general, natural attenuation is not appropriate as a sole cleanup option at sites where non-degradable and nonattenuated contaminants are present at levels that pose an unacceptable risk to human health, safety, welfare or the environment.

<u>Chlorinated Solvents</u>

Chlorinated solvents, such as trichloroethene (TCE), represent another class of common contaminants that may also biodegrade under certain environmental conditions. Recent research has identified some of the mechanisms responsible for degrading these solvents, furthering the development of methods for estimating biodegradation rates of these chlorinated compounds. However, the hydrologic and geochemical conditions favoring significant biodegradation of chlorinated solvents may not often occur. For example; reductive dechlorination is a destructive degradation process that requires both electron donors (the chlorinated solvent itself) and electron acceptors (such as iron (II)). Oftentimes, geochemical conditions do not favor the presence of electron acceptors. Because of the nature and the distribution of the chlorinated solvents, natural attenuation may not be effective as a cleanup option. If source areas are not adequately addressed through removal or containment measures, source materials can continue to contaminate groundwater for decades or even centuries. Cleanup of solvent spills is also complicated by the fact that a typical spill includes multiple contaminants, including some that are essentially non-degradable. Extremely long dissolved solvent plumes have been documented that may be due to the existence of subsurface conditions that are not conducive to natural attenuation.

<u>Inorganics</u>

Natural attenuation may, under certain conditions (*e.g.*, through sorption or oxidation-reduction reactions), effectively reduce the dissolved concentrations and/or toxic forms of inorganic contaminants in groundwater and soil. Both metals and non-metals (including radionuclides) may be attenuated by sorption reactions such as precipitation, adsorption on the surfaces of soil minerals, absorption into the matrix of soil minerals, or partitioning into organic matter. Oxidation-reduction (redox) reactions can transform the valence states of some inorganic contaminants to less soluble and thus less mobile forms (*e.g.*, hexavalent uranium to tetravalent uranium) and/or to less toxic forms (*e.g.*, hexavalent chromium to trivalent chromium). Sorption and redox reactions are the dominant mechanisms responsible for the reduction of mobility, toxicity, or bioavailability of inorganic contaminants. It is necessary to know what specific mechanism (type of sorption or redox reaction) is responsible for the attenuation of inorganics because some mechanisms are more desirable than others. For example, precipitation reactions and absorption into a soil's solid structure (*e.g.*, cesium into specific clay minerals) are generally stable, whereas surface adsorption (*e.g.*, uranium on iron-oxide minerals) and organic partitioning (complexation reactions) are more reversible. Complexation of metals with carrier (chelating) agents (*e.g.*, trivalent chromium with EDTA) may increase their concentrations in water and thus enhance their mobility. Changes in a contaminant's concentration, pH, redox potential, and chemical speciation may reduce a contaminant's stability at a site and release it into the environment. Determining the existence and demonstrating the irreversibility of these mechanisms are key components of a sufficiently protective natural attenuation remedy.

In addition to sorption and redox reactions, radionuclides exhibit radioactive decay and, for some, a parent-daughter radioactive decay series. For example, the dominant attenuating mechanism of tritium (a radioactive isotopic form of hydrogen with a short half-life) is radioactive decay rather than sorption. Although tritium does not generate radioactive daughter products, those generated by some radionuclides (*e.g.*, Am-241 and Np-237 from Pu-241) may be more toxic, have longer half-lives, and/or be more mobile than the parent in the decay series. It is critical that the near surface or surface soil pathways be carefully evaluated and eliminated as potential sources of radiation exposure.

Inorganic contaminants persist in the subsurface because, except for radioactive decay, they are not degraded by the other natural attenuation processes. Often, however, they may exist in forms that are less mobile, not bioavailable, and/or non-toxic. Therefore, natural attenuation of inorganic contaminants is most applicable to sites where immobilization or radioactive decay is demonstrated to be in effect and the process/mechanism is irreversible.

<u>Advantages and Disadvantages of Natural Attenuation</u>

Natural attenuation has several potential advantages and disadvantages, and its use should be carefully considered during site characterization and evaluation of cleanup alternatives. **Potential advantages** of natural attenuation include:

- As with any *in situ* process, generation of lesser volume of remediation wastes, reduced potential for cross-media transfer of contaminants commonly associated with *ex situ* treatment, and reduced risk of human exposure to contaminated media;

- Less intrusion as few surface structures are required;

- Potential for application to all or part of a given site, depending on site conditions and cleanup objectives;

- Use in conjunction with, or as a follow-up to, other (active) remedial measures; and

- Lower overall remediation costs than those associated with active remediation.

The **potential disadvantages** of monitored natural attenuation include:

- May not meet the requirement of 18 AAC 75.325(f)(C) as longer time frames may be required to achieve remediation objectives, compared to active remediation;

- Site characterization may be more complex and costly;

- Toxicity of transformation products may exceed that of the parent compound;

- Long term monitoring will generally be necessary;

- Institutional controls may be necessary to ensure long term protectiveness;

- Potential exists for continued contamination migration, and/or cross-media transfer of contaminants;

- Hydrologic and geochemical conditions amenable to natural attenuation are likely to change over time and could result in renewed mobility of previously stabilized contaminants, adversely impacting remedial effectiveness; and

- More extensive education and outreach efforts may be required in

order to gain public acceptance of monitored natural attenuation.

IMPLEMENTATION

Recent advances in the scientific understanding of the processes contributing to natural attenuation have resulted in a heightened interest in this approach as a potential means of achieving soil and groundwater cleanup objectives. However, complete reliance on natural attenuation is appropriate only in a limited set of circumstances at contaminated sites. The sections which follow provide some guidance regarding the appropriate use of natural attenuation. Topics addressed include site characterization; the types of sites where natural attenuation may be appropriate; reasonable cleanup time frames; the importance of source control; performance monitoring; and contingency remedies where natural attenuation will be employed.

Demonstrating the Efficacy of Natural Attenuation through Site Characterization

Decisions to employ natural attenuation as a cleanup remedy or remedy component should be thoroughly and adequately supported with site-specific characterization data and analysis. In general, the level of site characterization necessary to support a comprehensive evaluation of natural attenuation is more detailed than that needed to support active remediation. Site characterizations for natural attenuation generally warrant a quantitative understanding of source mass; groundwater flow; contaminant phase distribution and partitioning between soil, groundwater, and soil gas; rates of biological and non-biological transformation; and an understanding of how all of these factors are likely to vary with time. This information is generally necessary since contaminant behavior is governed by dynamic processes that must be well understood before natural attenuation can be appropriately applied at a site. Demonstrating the efficacy of this cleanup approach likely will require analytical or numerical simulation of complex attenuation processes. Such analyses, which are critical to demonstrate natural attenuation's ability to meet remedial action objectives, generally require a detailed conceptual site model as a foundation.

Site characterization should include collecting data to define the nature and distribution of contamination sources, the movement of contamination, and the vertical and lateral extent of the groundwater plume and its potential impacts on receptors. However, where natural attenuation will be considered as a cleanup approach, certain aspects of site characterization may require more detail or additional elements. For example, to assess the contributions of sorption, dilution, and dispersion to natural attenuation of contaminated groundwater, a very detailed understanding of aquifer hydraulics, recharge and discharge areas and volumes, and chemical properties is required. Where biodegradation will be assessed, characterization also should include evaluation of the nutrients and electron donors and acceptors present in the groundwater, the concentrations of co-metabolites and metabolic by-products, and perhaps specific analyses to identify the microbial populations present. The findings of these, and any other analyses pertinent to

characterizing natural attenuation processes, should be incorporated into the contaminant fate and transport conceptual model developed for the site.

Natural attenuation may not be appropriate as a cleanup option at many sites for technological or economic reasons. For example, in some complex geologic systems, technological limitations may preclude adequate monitoring of a natural attenuation remedy to ensure with a high degree of certainty that potential human or ecological receptors will not be impacted. This situation typically occurs in many structured, and/or fractured rock aquifers where groundwater moves preferentially through discrete channels (*e.g.* foliations, fractures, joints). The direction of groundwater flow through such heterogeneous materials can not be predicted directly from the hydraulic gradient, and existing techniques may not be capable of identifying the channels that carry contaminated groundwater through the subsurface. Although in some situations it may be technically feasible to monitor the progress of natural attenuation, the cost of site characterization and long-term monitoring required for the implementation of natural attenuation is high compared to the cost of other cleanup alternatives. Under such circumstances, natural attenuation would not necessarily be the low-cost alternative.

A related consideration for site characterization is how other cleanup activities at the site could affect natural attenuation. For example, the capping of contaminated soil could alter both the type of contaminants leached to groundwater, as well as their rate of transport and degradation. Therefore, the impacts of any ongoing or proposed cleanup actions should be factored into the analysis of natural attenuation's effectiveness. When considering source containment/treatment together with natural attenuation of chlorinated solvents, the potential for cutting off sources of organic carbon (which are critical to biodegradation of the solvents) should be carefully evaluated.

Once the site characterization data have been collected and a conceptual model developed, the next step is to evaluate the efficacy of natural attenuation as a remedial approach. Three types of site-specific information or "evidence" should be used in such an evaluation:

(1) Historical groundwater and soil chemistry data that demonstrates a clear and meaningful trend of decreasing contaminant mass and concentration over time at appropriate monitoring or sampling points. (In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood.);

(2) Hydrogeologic and geochemical data that can be used to demonstrate the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required cleanup levels. For

example, characterization data may be used to quantify the rates of contaminant sorption, dilution, or volatilization, or to demonstrate and quantify the rates of biological degradation processes occurring at the site;

(3) Data from field or microcosm studies (conducted in or with actual contaminated site media) which directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only).

Sites Where Monitored Natural Attenuation May Be Appropriate

In determining whether natural attenuation is an appropriate remedy for soil or groundwater at a given site, the project manager should consider the following:

- Whether the contaminants present in soil or groundwater can be effectively remediated by natural attenuation processes;

- Whether the resulting transformation products present a greater risk than do the parent contaminants;

- The nature and distribution of sources of contamination and whether these sources have been or can be adequately controlled;

- Whether the plume is relatively stable or is still migrating and the potential for environmental conditions to change over time;

- The impact of existing and proposed active cleanup measures upon the natural attenuation component of the remedy;

- Whether drinking water supplies, other groundwaters, surface waters, ecosystems, sediments, air, or other environmental resources could be adversely impacted as a consequence of selecting natural attenuation as the cleanup option;

- Whether the estimated time frame of cleanup is reasonable (see below) compared to time frames required for other more active methods (including the anticipated effectiveness of various cleanup approaches on different portions of the contaminated soil and/or groundwater);

- Current and projected demand for the affected aquifer over the time period that the remedy will remain in effect (including the availability of other water supplies and the loss of availability of other groundwater resources due to contamination from other sources);

- Whether reliable site-specific vehicles for implementing institutional controls (*i.e.*, deed restrictions) are available, and if the applicable institutional controls are binding and enforceable; and

- Whether the natural attenuation remedy is in compliance with DEC regulations at 18 AAC 75 Article 3.

For example, evaluation of a given site may determine that, once the source area and higher concentration portions of the plume are effectively contained or remediated, lower concentration portions of the plume could achieve cleanup levels within a few decades through natural attenuation. Also, natural attenuation would more likely be appropriate if the plume is not expanding, nor threatening downgradient wells or surface water bodies, and where ample potable water supplies are available. The remedy for this site could include source control, a pump-and-treat system to mitigate only the highly-contaminated plume areas, and natural attenuation in the lower concentration portions of the plume. In combination, these methods would maximize groundwater restored to beneficial use in a time frame consistent with future demand on the aquifer, while utilizing natural attenuation processes to reduce the reliance on active remediation methods (and reduce cost).

Of the above factors, the most important considerations regarding the suitability of natural attenuation as a remedy include whether the groundwater contaminant plume is growing, stable, or shrinking, and any risks posed to human and environmental receptors by the contamination. Natural attenuation should not be used where such an approach would result in significant contaminant migration or unacceptable impacts to receptors. Therefore, sites where the contaminant plumes are no longer increasing in size, or are shrinking in size, would be the most appropriate candidates for natural attenuation remedies.

Reasonableness of Remediation Time Frame

The longer remediation time frames typically associated with natural attenuation should be compatible with site-specific land and groundwater use scenarios. Remediation time frames generally should be estimated for all cleanup alternatives being analyzed, including natural attenuation. Decisions regarding the “reasonableness” of the remediation time frame for any given cleanup alternative should then be evaluated on a site-specific basis. While it is expected

that natural attenuation may require somewhat longer to achieve cleanup objectives than would active remediation, the overall remediation time frame for a remedy which relies in whole or in part on natural attenuation should not be excessive compared to the other remedies considered. Furthermore, subsurface conditions and plume stability can change over the extended time frames that are necessary for natural attenuation.

Defining a reasonable time frame is a complex and site-specific decision. Factors that should be considered when evaluating the length of time appropriate for remediation include:

- Classification of the affected resource (*e.g.*, drinking water source, agricultural water source) and value (*e.g.*, cultural, subsistence, ecological) of the resource;

- Relative time frame in which the affected portions of the aquifer might be needed for future water supply (including the availability of alternate supplies);

- Uncertainties regarding the mass of contaminants in the subsurface and predictive analyses (*e.g.*, remediation time frame, timing of future demand, and travel time for contaminants to reach points of exposure appropriate for the site);

- Reliability of monitoring and of institutional controls over long time periods;

- Public acceptance of the extended time for cleanup; and

- Provisions by the responsible person for monitoring and performance evaluation over the period required for cleanup.

Thus, project managers should consider a number of factors when evaluating reasonable time frames for natural attenuation at a given site. These factors, on the whole, should enable DEC to determine whether a natural attenuation remedy (including institutional controls where applicable) will fully protect potential human and ecological receptors, and whether the site cleanup objectives and the time needed to meet them are consistent with the regulatory expectation that contaminated groundwaters will meet cleanup levels within a reasonable time frame. When these conditions cannot be met using natural attenuation, a cleanup alternative that does meet these expectations should be selected instead.

<u>Cleanup of Contamination Sources and Highly Contaminated Areas</u>

The need for active cleanup of contamination sources and other highly contaminated areas should

be evaluated as part of the cleanup decision process at all sites, particularly where natural attenuation is under consideration as the remedy or as a remedy component. Active cleanup measures include removal, treatment, or containment measures (*e.g.*, physical or hydraulic control of areas of the plume in which NAPLs are present in the subsurface).

Contaminant sources which are not adequately addressed complicate the long-term cleanup effort. For example, following free product recovery, residual contamination from a petroleum fuel spill may continue to leach significant quantities of contaminants into the groundwater. Such a lingering source can unacceptably extend the time necessary to reach cleanup objectives. This leaching can occur even while contaminants are being naturally attenuated in other parts of the plume. If the rate of attenuation is lower than the rate of replenishment of contaminants to the groundwater, the plume can continue to expand and threaten downgradient receptors. Active cleanup of source areas is the most effective means of ensuring the timely attainment of cleanup objectives. DEC, therefore, expects that active cleanup of source areas will be conducted at most sites to the maximum extent practicable.

<u>Performance Monitoring</u>

Performance monitoring to evaluate remedy effectiveness and to ensure protection of human health, safety, welfare and the environment is a critical element of all cleanup actions. Performance monitoring is of even greater importance for natural attenuation than for other types of remedies due to the longer remediation time frames, potential for ongoing contaminant migration, and other uncertainties associated with using natural attenuation.

The monitoring program developed for each site should specify the location, frequency, and type of samples and measurements necessary to evaluate remedy performance as well as define the anticipated performance objectives of the remedy. In addition, all monitoring programs should be designed to accomplish the following:

- Demonstrate that natural attenuation is occurring according to objectives and expectations specified in the monitoring work plan;

- Demonstrate that geochemical conditions are conducive to natural attenuation processes (*e.g.* dissolved oxygen and/or nitrogen content is sufficient to allow biodegradation to occur);

- Identify any potentially toxic transformation products resulting from natural attenuation processes;

- Determine if a plume is expanding (either downgradient, laterally or vertically);

- Ensure no impact to downgradient receptors;

- Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy;

- Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors;

- Detect changes in environmental conditions (*e.g.*, hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of any of the natural attenuation processes; and

- Verify attainment of cleanup levels.

Performance monitoring should continue as long as contamination remains above approved cleanup levels. Typically, monitoring is continued for a specified period (*e.g.*, one to three years) after cleanup levels have been achieved to ensure that concentration levels are stable and remain below cleanup levels. The mechanisms for maintaining the monitoring program should be clearly established in the cleanup decision or other site documents, as appropriate.

A long-term monitoring plan must be submitted to DEC as part of any proposed natural attenuation remedy. Further information on the types of data useful for monitoring natural attenuation performance can be found in several publications referenced at the end of this guidance.

<u>Contingency Remedies</u>

A contingency remedy is a cleanup technology or approach specified in the site cleanup decision document that functions as a backup" remedy in the event that the "selected" remedy fails to perform as anticipated. A contingency remedy may specify a technology (or technologies) that is (are) different from the selected remedy, or it may simply call for modification and enhancement of the selected technology, if needed. Contingency remedies should generally be flexible, allowing for the incorporation of new information about site risks and technologies.

Contingency remedies should be employed where natural attenuation is not proven for the specific site application, where there is significant uncertainty regarding the nature and extent of contamination at the time the natural attenuation remedy is selected, or where there is uncertainty regarding whether natural attenuation will perform as anticipated.

It is also recommended that one or more criteria ("triggers") be established, as appropriate, in the cleanup decision document that will signal unacceptable performance of natural attenuation as the selected cleanup alternative and indicate when to implement contingency measures. Such

criteria might include the following:

- Contaminant concentrations in soil or groundwater at specified locations exhibit an increasing trend;

- Near-source wells exhibit large concentration increases indicative of a new or renewed release;

- Contaminants are identified in sentry/sentinel wells located outside of the original plume boundary, indicating renewed contaminant migration;

- Contaminant concentrations are not decreasing at a sufficiently rapid rate to meet the approved cleanup levels; and

- Changes in land and/or groundwater use will adversely affect the protectiveness of the natural attenuation remedy.

In establishing triggers or contingency remedies, however, care is needed to ensure that sampling variability or seasonal fluctuations do not set off a trigger inappropriately. For example, an anomalous spike in dissolved concentration(s) at a well(s), which may set off a trigger, might not be a true indication of a change in trend.

Decision Documentation

A site where natural attenuation is selected as a remedy would receive a No Further Remedial Action Planned letter. Long Term Monitoring (LTM) and Institutional Control (IC) would be required. The LTM and IC actions are described in the CSRP Database Guidance Manual. Site Closure would only occur when the cleanup levels for groundwater established under 18 AAC 75.345 are met. The CSRP decision framework and documents are described in the CSRP Guidance on Decision Documentation Under The Site Cleanup Rules (18 AAC 75.325-18 AAC 75.390), July 1999.

SUMMARY

Natural attenuation should be selected only where it will be fully protective of human health, safety, welfare and the environment. DEC does not view natural attenuation to be a “no action” remedy, but rather considers it to be a means of addressing contamination under a limited set of site circumstances where its use meets the applicable regulatory requirements. Natural attenuation is not a “presumptive” or “default” cleanup alternative, but rather should be evaluated and compared to other viable cleanup alternatives during the study phases leading to the selection of a cleanup remedy. The decision to implement natural attenuation should include a

comprehensive site characterization, risk assessment where appropriate, and measures to control sources of contamination. Also, natural attenuation should not be used where such an approach would result in significant contaminant migration or unacceptable impacts to receptors and other environmental resources. In addition, the progress of natural attenuation towards a site's cleanup objectives should be carefully monitored and compared with expectations to ensure that it will meet site cleanup objectives within a time frame that is reasonable compared to time frames associated with other alternatives. Where natural attenuation's ability to meet these expectations is uncertain and based predominantly on predictive analyses, decision-makers should incorporate contingency measures into the remedy.

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