# Assessment Tool for Closure of Low-Threat Chlorinated Solvent Sites

Prepared by:

**Groundwater Committee, a staff committee of the California Regional Water Quality Control Board San Francisco Bay Region**

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# Executive Summary

The Groundwater Committee, a staff committee of the San Francisco Bay Regional Water Quality Control Board (S.F. Bay Water Board) embarked on a project to develop criteria for evaluating if and when chlorinated solvent sites that pose little threat to human and ecological health, water quality, and beneficial uses but do not yet meet cleanup standards at all locations, could be closed. This process is referred to as "low-threat closure."

Low-threat closure is based on the understanding that cleanup standards can be met under natural conditions within a reasonable timeframe, once adequate source control and plume remediation are complete and considering site-specific conditions, the future land use, and the likelihood of and timeframe for actual beneficial use of the affected water resources. Nonetheless, it can be difficult to close chlorinated solvent sites due to concerns about pollutant toxicity, recalcitrance, and mobility, and the uncertainty associated with site characterization and remediation.

This document summarizes nine narrative criteria for site closure, which are presented below in Table ES-1 and, with more detail, in an attachment to this document. The narrative criteria describe the conditions under which closure is warranted for low-threat sites. The criteria are grouped into three categories to show how they relate to the overall site assessment and cleanup process. Group 1 addresses conceptual site model development, including source and plume delineation, site characterization, receptor identification, exposure pathway evaluation, risk assessment, and establishing cleanup standards. Group 2 emphasizes mitigation of risks to human and ecological receptors and threats to water resources. Group 3 addresses the need for source control and evaluation of potential adverse affects to future beneficial uses from residual pollutants.

The narrative criteria are consistent with existing Water Board policy. They build upon existing guidance for low-risk closure of fuel-impacted sites and a number of site-specific decisions to issue low-threat closures at solvent-impacted sites. Although the criteria are intended for chlorinated solvent sites, they may be applicable to other contaminated sites on a case-by-case basis. This document is a site-management tool to supplement the closure decision-making process and is not intended to establish new policy or regulation. Ultimate decisions regarding site closure will remain dependent on site-specific conditions and factors.

## *Table ES-1 Recommended Closure Criteria[1] for Low-Threat Chlorinated Solvent Sites*

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|---|
| **1. Develop a complete Conceptual Site Model (CSM)**<br>***1a) Pollutant sources are identified and evaluated***<br>***1b) The site is adequately characterized***<br>***1c) Exposure pathways, receptors, and potential risks, threats, and other environmental concerns are identified and assessed*** |
| **2. Control sources and mitigate risks and threats**<br>***2a) Pollutant sources are remediated to the extent feasible***<br>***2b) Unacceptable risks to human health, ecological health, and sensitive receptors, considering current and future land and water uses, are mitigated***<br>***2c) Unacceptable threats to groundwater and surface water resources, considering existing and potential beneficial uses, are mitigated*** |
| **3. Demonstrate that residual pollution in all media will not adversely affect present and anticipated land and water uses**<br>***3a) Groundwater plumes are decreasing***<br>***3b) Cleanup standards can be met within a reasonable timeframe***<br>***3c) Risk management measures are appropriate, documented, and do not require future Water Board oversight*** |

***1 Closure criteria are intended to facilitate the decision-making process and not circumvent best professional judgment.***

# Introduction

Cleaning up groundwater pollution sites can be difficult for several reasons. S.F Bay Water Board policy essentially defines all groundwater in the region as a potential source of drinking water. Water quality objectives (narrative objectives and numerical limits for the reasonable protection of water quality) for drinking water are often set at low, part-per-billion concentrations, which is the case for many chlorinated solvents. Site cleanups are supposed to attain background concentrations of all pollutants and, failing that, at least restore all beneficial uses of groundwater. Despite many years of advances in groundwater cleanup technology, it is often technically and/or economically infeasible to attain low pollutant concentrations in groundwater. As a result, many sites accomplish significant reductions in groundwater pollutant concentrations, but fail to meet prescribed groundwater cleanup standards. In this case, the site is not ready for a conventional closure action, yet the “next steps” in the cleanup lifecycle may not be obvious.

The S.F. Bay Water Board has several options for addressing this issue.

- Require additional investigation and cleanup. Sometimes, the selection of a different remedial technology can result in additional reductions in groundwater pollution levels. We have seen this action succeed at a number of our older cleanup sites, where groundwater “pump and treat” was used initially, followed by various in-situ methods, such as enhanced biodegradation.

- Approve the “monitored natural attenuation” remedy. This cleanup approach is based on evidence of natural biodegradation at most fuel-impacted sites and some solvent-impacted sites. This approach requires ongoing monitoring to demonstrate continued natural attenuation at a site.

- Establish a “containment zone.” This regulatory option is established by State Water Board policy, and is best suited for sites with recalcitrant pollutants that are unlikely to degrade or attenuate over time. This action requires ongoing monitoring to demonstrate the pollution does not migrate. “Containment zone” sites are expected to remain open indefinitely.

- Issue a low-threat closure. This option involves closing the site before beneficial uses of groundwater are fully restored. This action only makes sense if a conclusion is reached that cleanup standards can be met under natural conditions within a reasonable timeframe, following completion of cleanup and monitoring. In that sense, it can be thought of as a next step following either of the first two bullets above (additional cleanup or monitored natural attenuation).

This document provides a detailed discussion of the latter option, low-threat closure, with a focus on chlorinated solvent sites, and builds on a 1996 S.F. Bay Water Board staff document pertaining to fuel-impacted sites, "*Supplemental Instructions to State Board December 8, 1995, Interim Guidance on Required Cleanup at Low Risk Fuel Sites.*" Although this document is intended for chlorinated solvent sites, it may be applicable to other polluted sites, on a case-by-case basis.

This document and the nine criteria in it can help establish goals and objectives throughout the investigation and cleanup process. Water Board staff recommend considering the criteria early in that process and using them to develop any request for low-threat site closure.

# Recommended Closure Criteria

This section describes nine narrative criteria for low-threat site closure (*see Table ES-1* and *Attachment A*). The nine criteria describe the conditions under which site closure is warranted for sites that pose little threat to human and ecological health, water quality, and beneficial uses, but do not yet meet cleanup standards at all locations.

The criteria are grouped into three categories to show how they relate to the overall site assessment and cleanup process. Group 1 addresses conceptual site model development, including source and plume delineation, site characterization, receptor identification, and exposure pathway evaluation. Group 2 emphasizes the need for source control and mitigation of risks to human and ecological receptors and threats to water resources. Group 3 addresses evaluation of potential adverse affects to future beneficial uses from residual pollutants.

## *1 Develop a complete Conceptual Site Model (CSM)*

Developing a CSM is a standard part of the cleanup process. The CSM represents site conditions and explains where pollutants are in the environment and the potential threats that these pollutants pose to human and ecological health, water resources, and the environment. The CSM is used to assess risks and threats to human and ecological receptors and water resources. The CSM is typically conveyed through written descriptions and is supported by maps, hydrogeologic cross-sections, tables, diagrams and other illustrations.

Developing a comprehensive CSM is a dynamic process that starts early in the investigation phase and continues to be updated and refined as additional information is obtained. Critical elements of the CSM include describing:

- Sources of pollution
- Pollutant distribution within the environment (i.e., nature and extent)
- Hydrogeologic conditions and framework
- Actual and potential migration pathways
- Actual and potential exposure pathways and receptors

Site closure requests presented in a complete and technically-defensible CSM will increase the confidence of S.F. Bay Water Board staff in making site closure decisions. ***Criteria 1a through 1c*** are intended to verify CSM completeness.

### *1a) Pollutant sources are identified and evaluated*

Pollutant sources consist of the primary leak source, e.g., a tank, sump, pipeline, or other vessel, and secondary sources, which include the pollutants released to the environment that sustain groundwater or vapor plumes. Secondary sources typically comprise the "source zone" because they can migrate laterally and vertically depending on various chemical and hydrogeological factors. Source zones include separate-phase products, such as Light or Dense Non-Aqueous Phase Liquids (LNAPLs / DNAPLs), and residual pollutants entrained within or sorbed to soil or sediment.

Source zone characterization and delineation is critical to successful cleanup because the nature and extent of the source zone affects pollutant concentrations and plume longevity. Incomplete source evaluation can significantly increase the monitoring and closure timeframe. Source zone characterization should start with a review of historic records and business practices to develop the most effective investigation strategy. For chlorinated solvents, vertical delineation is critical due to the propensity for DNAPLs to sink through groundwater aquifers and threaten deeper sources of drinking water. Characterization efforts that employ an "outside-in", approach (starting at the distal ends of the plume and working inward toward the source) and that use standard precautionary methods and technologies are recommended to minimize the potential for cross-contamination. For more information, see ***high-resolution methods for source evaluation and site characterization***.

Relying on soil data alone to characterize and delineate chlorinated solvent source zones is not recommended. This is due to soil heterogeneity that can lead to a wide variation of soil concentrations over short distances. Furthermore, it may be that residual chlorinated solvent pollution trapped within the vadose zone is minimal and belies an underlying saturated zone problem or a vapor plume.

### *1b) The site is adequately characterized*

Assessing the occurrence and distribution of chlorinated solvents (including DNAPL) is inherently difficult due to their physical and chemical properties and complex hydrogeologic conditions. Site characterization work should be designed to minimize uncertainty and maximize accuracy to 1) effectively characterize pollutant distribution and migration pathways in all media, including soil, soil-gas, and groundwater, and 2) identify potential migration pathways to allow for appropriate decision-making pertaining to risk, monitoring and remediation.

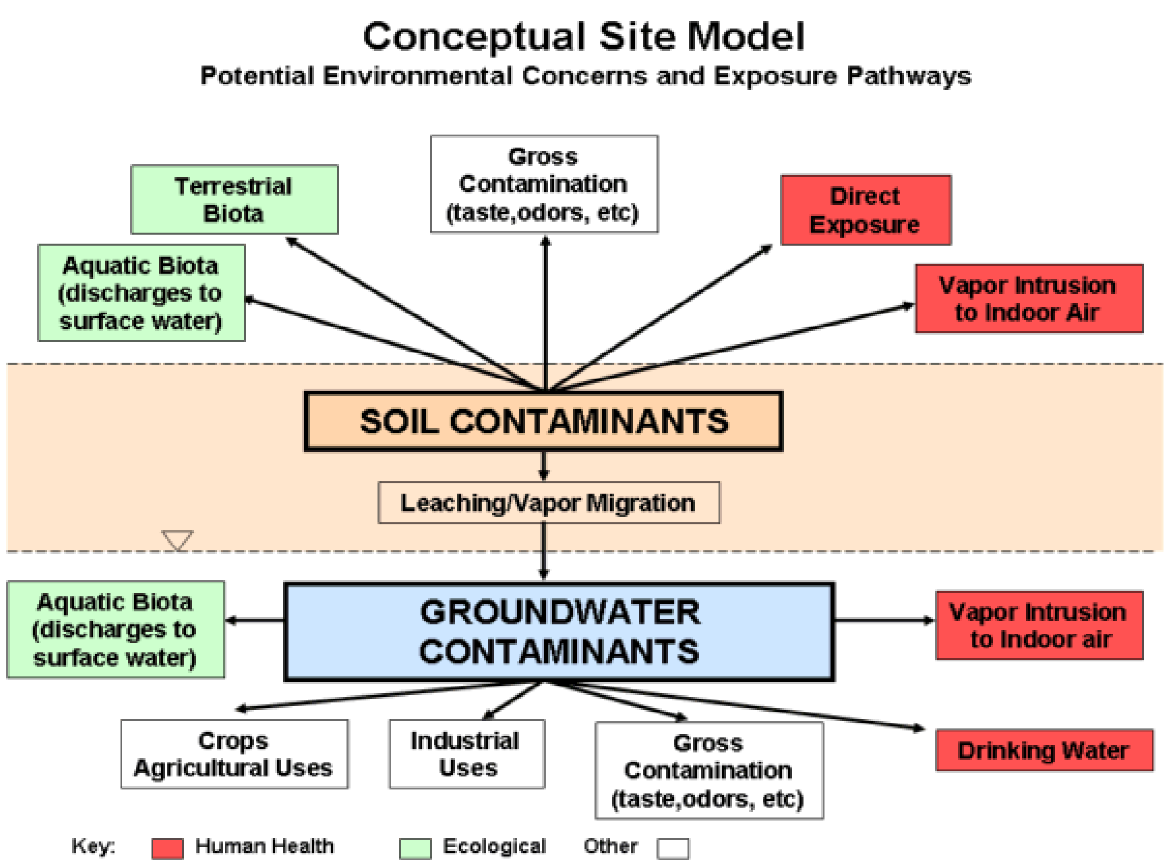
Adequate site characterization provides the basis for effective remedy selection and design. All data should be presented, including data collected by other consultants. Incomplete site characterization may undermine regulatory confidence and result in ineffective cleanup and costly additional investigation and remediation efforts.

Site characterization often requires several iterations of subsurface investigation. Conventional investigation methods, such as interval soil coring/sampling and loosely-spaced or long-screened monitoring wells, may not provide an adequate assessment of pollutant distribution. This is particularly true for DNAPL and vapor intrusion sources and for preferential migration pathways, including natural permeable "channels" or man-made conduits. State-of-the-art and higher-resolution methods for multi-level groundwater sampling, soil-gas sampling, continuous logging, and continuous pollutant detection should be considered to reduce uncertainty. For more information, see ***high-resolution methods for source evaluation and site characterization***.

Site characterization should also consider the nature of the industry or business that caused the release in order to adequately profile the pollutants of concern. This is particularly important with chlorinated solvents because their sources may associated with other pollutants, such as perchlorate, NDMA, or 1,4-Dioxane. The expected fate of these associated pollutants should be accounted for. For example, highly soluble and hydrophilic compounds such as perchlorate and 1,4-dioxane are more likely to concentrate in fine-grained silts and clays near the point of release than in the more transmissive zones. Interpretations of contaminant distribution from monitoring points completed in sand units may understate the residual contaminate mass as a result.

### *1c) Exposure pathways, receptors, and potential risks, threats, and other environmental concerns are identified and assessed*

Actual and potential pathways that may result in risks or threats to human and ecological health, water resources, and the environment should be identified and assessed based on current <u>and</u> reasonably anticipated land and water uses. This should include the source property and all potentially-impacted properties nearby. Common pathways and receptors that should be addressed are illustrated in the following figure.



Sensitive receptors, such as residences, day-care centers, hospitals, and schools, should be identified. Migration pathways and risks associated with indoor air exposure should be adequately evaluated for current and future occupants at the source property and other affected properties. Pollutant migration in groundwater to deeper zones/aquifers (due to vertical hydraulic gradients, gravity-driven flow, and/or vertical conduits) should be addressed.

Surveys for nearby water resource receptors are a standard part of the pathway-receptor evaluation and should include:

- Surface water bodies (e.g., wetlands, streams, lakes, bays)
- Groundwater (e.g., shallow water-bearing zones, deep aquifers)
- Water-supply wells (e.g., domestic, municipal, agricultural, industrial supply)
- Vertical conduits (e.g., abandoned/ineffectively sealed wells)
- Aquifer recharge facilities (e.g., recharge ponds, aquifer injection wells)

The areal extent of the survey should be based on knowledge of current and predicted future plume size and movement (plume length could range from hundreds to thousands of feet) and should be discussed with S.F. Bay Water Board staff. A door-to-door survey may be necessary to locate any private wells, groundwater sumps, and basements in the vicinity. The survey should also consider the potential for changes in site conditions that may be caused by future groundwater recharge or pumping.

Existing and potential beneficial uses of water, as identified in the S.F. Bay Water Board's Basin Plan should also be considered. A weight-of-evidence approach may be helpful when comparing site-specific conditions and pollutant behavior (nature and extent, migration pathways and potential, and degradation rates) with the location and nature of nearby existing beneficial uses. In the case of potential future beneficial uses, the likelihood and timeframe for such use should also be considered.

Tools such as screening levels can help identify potential risk/threat/nuisance concerns for many of the above pathways. Examples of screening levels include:

- S.F. Bay Water Board's Environmental Screening Levels (ESLs) available at www.waterboards.ca.gov/sanfranciscobay/esl.shtml.
- Cal/EPA's California Human Health Screening Levels (CHHSLs) available at www.calepa.ca.gov/brownfields/sb32.htm.
- USEPA's Regional Screening Levels, formerly Preliminary Remediation Goals (PRGs), available at www.epa.gov/region09/superfund/prg.

Screening-level risk assessments can expedite the process and help identify potential exposure pathways for further evaluation. Site-specific risk assessment may be necessary or desirable to refine risks to human or ecological receptors, particularly when screening levels are not applicable or sufficient.

# *2 Control sources and mitigate risks and threats*

Source control and risk/threat mitigation are standard parts of the cleanup process that follow CSM development and risk/threat assessment (*see criteria 1a-1c*). In this context, source control means action taken to permanently reduce, remove, or contain the source. However, a site where a source-control remedy requires long-term monitoring or maintenance is probably not a low-threat site and probably not eligible for low-threat site closure. Source control requires an understanding of what and where the sources are followed by remediation to the extent feasible. Likewise, risk/threat mitigation requires an understanding of what the risks/threats are followed by corrective action to remediate pollutants and/or eliminate exposure pathways. Pollutant distribution, migration/exposure pathways, and assessment of risks and threats provide the basis for developing appropriate corrective actions for adequate source control and risk/threat mitigation. ***Criteria 2a through 2c*** are a check on these elements.

## *2a) Pollutant sources are remediated to the extent feasible*

Source remediation is a fundamental component of site closure decisions. Pollutant sources must be remediated to the maximum extent practicable considering several factors, including 1) the level of risk or threat, 2) the application of the best available technologies, and 3) the technical and economic feasibility of remedial alternatives.

Source remediation should address both primary and secondary sources. Primary sources are mitigated by eliminating the potential for further or on-going releases, which may involve closure or removal of a physical structure (e.g., tank, sump, or pipeline) or making operational/procedural improvements. Secondary sources are remediated through technologies, such as excavation, vapor extraction, in-situ bioremediation, etc.

Technical feasibility generally refers to the ability to achieve remedial objectives using existing remedial technologies, methods, and strategies, without regard to cost. It often requires field-scale application of a technology to demonstrate. Economic feasibility refers to the relationship of cost to benefit gained (i.e., cost-benefit evaluation) based on using all technically feasible methods. Although only partial source reduction may be feasible, success with respect to site closure will ultimately be based on the down-gradient plume behavior, risk and threat evaluations, and the likelihood that cleanup standards can be achieved in a reasonable timeframe.

Source reduction efforts should be evaluated and demonstrated using data collected from monitoring programs specifically designed to measure 1) remedy performance during implementation, and 2) remedy effectiveness, including post-remediation verification, for a period that accounts for pre- and post-treatment conditions and pollutant rebound. For further information, see ***monitoring timeframes***.

### *2b) Unacceptable risks to human health, ecological health, and sensitive receptors, considering current and future land and water uses, are mitigated*

Demonstrating that unacceptable risks to human and ecological health are mitigated requires that those corrective actions deemed necessary and appropriate based on assessment of risks to human and ecological receptors have been implemented and are effective. Confirmation sampling, monitoring data, and/or implementation of risk management measures typically provide the information needed to demonstrate effective risk mitigation. If risk management measures such as engineering and land use controls are utilized, documents such as engineering completion reports, construction certification, land use covenants, and deed restrictions are necessary to document their implementation.

### *2c) Unacceptable threats to groundwater and surface water resources, considering existing and potential beneficial uses, are mitigated*

Demonstrating that unacceptable threats to water resources are mitigated requires that those corrective actions deemed necessary and appropriate based on evaluation of threats to water resources have been implemented and are effective. As with risk mitigation, adequate confirmation sampling, monitoring data, and/or implementation of risk management measures are necessary to demonstrate this.

## *3 Demonstrate that residual pollution in all media will not adversely affect present and anticipated land and water uses*

***Criteria 1a through 2c*** are part of the standard site assessment and cleanup process. However, ***Criteria 3a through 3c*** apply specifically when residual pollution in any medium (e.g. soil, soil gas, indoor air, groundwater, or surface water) remains in-place above cleanup standards.

### *3a) Groundwater plumes are decreasing*

A groundwater plume is decreasing when pollutant concentrations within the plume are declining over time and the plume's "footprint" is shrinking or remaining stable. A decreasing plume, once active remediation has been stopped and long-term equilibrium re-established, is the best indicator of effective source remediation and plume attenuation. It also provides an important basis for evaluating the cleanup timeframe. In most cases, plume decrease is necessary for low-threat chlorinated solvent site closure. However, under certain limited circumstances, a stable plume may be sufficient. For example, when the potential for adverse affects to beneficial uses is considered low based on site-specific factors <u>and</u> pollutants are sequestered in low-permeability soils or, plume size, concentration, or mass is limited.

Demonstrating plume decrease requires evaluating three factors: 1) spatial and temporal trends for all pollutants of concern, including parent and breakdown products, 2) natural attenuation rates, and 3) credible evidence of biodegradation. For 3), this evidence should include concentration trends for important biogeochemical indicators, which could include electron acceptors, metabolic end-products, redox potential, and pH. It may also require evidence of microbial populations capable of fully converting pollutants to acceptable end points.

Evidence for all three factors is necessary because, after site closure, natural attenuation processes are relied upon to achieve cleanup standards before beneficial use of the affected resource is needed. An effective monitoring network and strategy is critical to provide the necessary spatial and time-series data for pollutants, breakdown products, and biogeochemical "indicator" compounds to clearly demonstrate plume decrease and natural attenuation trends. For more information, see ***demonstrating plume stability and decrease*** and ***monitoring timeframes***.

If a site does not meet this criterion, then the site should remain open. Additional monitoring and/or cleanup may be necessary to demonstrate that this criterion is met.

### *3b) Cleanup standards can be met in a reasonable timeframe*

Cleanup standards are site-specific levels that are protective of beneficial uses of water, protective of existing and likely future land uses, and in compliance with S.F. Bay Water Board policies such as the non-degradation policy.

Evaluating if cleanup standards can be met in a reasonable timeframe is essentially a three-step problem. It consists of: 1) evaluating the estimated timeframe to achieve cleanup standards throughout the affected area (i.e., the cleanup timeframe), 2) evaluating the likelihood and timeframe for beneficial use of the affected and nearby resources (i.e., the beneficial use timeframe), and 3) evaluating the potential for residual pollution to adversely affect future beneficial uses. The purpose is to compare the estimated cleanup and beneficial use timeframes and evaluate if residual pollution at that time is likely to adversely affect the beneficial use.

Estimating timeframes is a site-specific determination. The estimated cleanup timeframe should be based on observed/measured plume trends where possible (for further information, see ***demonstrating plume stability and decrease***. Statistical methods, such as regression analysis, are helpful to evaluate and extrapolate the cleanup timeframe if it is not readily apparent. For stable plumes that are not decreasing, it may be difficult to estimate a cleanup timeframe. This may indicate that a persistent source remains, that little biological degradation is occurring, and/or that groundwater is essentially stagnant. Under certain limited circumstances a stable but not decreasing plume may be acceptable for low-threat closure, if based on all other factors, there is low potential for future beneficial use, or low potential for adverse affects to future beneficial use.

Evaluating the likelihood and timeframe for future beneficial use should include review of relevant reports and databases and discussions with groundwater management and/or water-supply agencies or purveyors. For further information, see ***evaluating future groundwater use***.

The potential for adverse effects depends on several factors, including the potential for residual pollutants to significantly affect water quality at a future well or other receptor. This requires evaluating the likely proximity to future receptors, hydraulic connection, pollutant mobility, pollutant attenuation, and many other factors that comprise the CSM. In most cases it is reasonable to assume that pollutants in shallow groundwater could adversely affect a deeper well. However, in some cases it may not be, for example, when 1) pollutants are sequestered in low-permeability zones and their mobility is diffusion-limited, 2) plume size, concentration, or mass is limited, and 3) there is little hydraulic communication between shallow and deeper groundwater zones.

Reasonable cleanup timeframes could range from a few years to decades, depending on hydrogeologic conditions, the CSM, the anticipated beneficial use timeframe, and regulatory confidence in the estimates. Reasonable cleanup timeframes may be longer when:

- Groundwater is shallow, perched, or otherwise isolated
- There are no abandoned wells and other vertical conduits in proximity to the site
- There is no current beneficial groundwater use and the potential for future use in proximity to the site is low
- There are well construction practices, local zoning practices, land-use restrictions, etc., that would tend to limit or preclude future beneficial use of the affected water resource

Conversely, deeper groundwater impacts, lack of a competent aquitard, existence of vertical conduits, or groundwater pumping scenarios may require cleanup in a shorter timeframe.

In previous appeals decisions (decisions made upon appeal of Regional Water Board orders or actions), the State Water Board, when determining a reasonable cleanup timeframe, has considered all relevant factors including, but not limited to, existing and anticipated beneficial uses. If, for example, it will take 50 years to meet the requisite level of water quality, that may be a reasonable timeframe if neither existing nor anticipated beneficial uses would be impacted during that time.

If a site does not meet this criterion, then the site should remain open. Additional monitoring and/or cleanup may be necessary to demonstrate that this criterion is met.

### *3c) Risk management measures are appropriate, documented, and do not require further Water Board oversight*

Risk management measures are often needed at sites where residual pollution (i.e., above cleanup standards) poses potentially unacceptable risks or threats based on current or anticipated land or water uses. Risk management measures include *engineering controls* (such as vapor barriers, subslab venting, soil capping, and fencing) and *institutional controls* (such as deed restrictions, land-use covenants, and soil management plans). Deed restrictions are required prior to closure of some cleanup sites when the property is not suitable for unrestricted use and restrictions are necessary to protect public health, safety, or the environment (see Water Code section 13307.1(c)). Deed restrictions are generally only applicable to the site property and not to off-site properties that may be affected (see FAQ #6 in the ***Frequently Asked Questions*** attachment). Deed restrictions and land use covenants are tracked in the state's publicly accessible electronic databases:

- Geotracker (www.geotracker.waterboards.ca.gov) for sites overseen by Water Boards
- EnviroStor (www.envirostor.dtsc.ca.gov) for sites overseen by DTSC

Sites with risk management measures may be eligible for low-threat site closure provided that the risk management measure is appropriate for the circumstances, continued oversight by the S.F. Bay Water Board is not required, and the site meets all other closure criteria.

Examples of when risk management measures would be compatible with low-threat site closure include the following:

- Deed restriction to prohibit groundwater use for drinking water, when there is no other risk or threat other than drinking water standards that have not been met;
- Voluntary protective measures, such as vapor barriers for potential soil gas intrusion to indoor air, as long as such measures are not required to prevent an existing, eminent, or likely threat.

On the other hand, the need for risk management measures may mean that a site is not low-threat and is therefore not eligible for low-threat closure. Examples include sites with:

- Containment zones or other required waste-containment remedies
- Engineering controls required to mitigate the spread of, or exposure to residual pollutants
- Institutional controls to prohibit sensitive land uses or restrict soil trenching or excavation (as required by risk management plan and/or deed restriction)

If a site does not meet this criterion, then the site should stay open so that the S.F. Bay Water Board can track and monitor compliance with the risk management measures. It may be appropriate to regulate the site under a more focused directive similar to DTSC's "certificate of completion" with ongoing risk management measures under an "operation and maintenance" plan.

# Applying Selected Criteria

The following subsections provide more detail on applying several of the low-threat closure criteria. This document and the nine criteria in it can help establish goals and objectives throughout the investigation and cleanup process. Water Board staff recommend considering the criteria early and throughout that process. Requests for low-threat site closure should be developed based on the criteria. The figure, *Applying low-threat closure criteria in the cleanup process,* attached to this document helps illustrate application of the criteria.

## *High-resolution methods for source evaluation and site characterization*

S.F. Bay Water Board staff strongly encourages use of state-of-the-art, high-resolution methods, where appropriate, to identify and evaluate sources. High-resolution methods generally reduce uncertainty and increase confidence in conclusions about potential risks and threats, plume behavior, acceptable closure concentrations, and the timeframe to meet groundwater cleanup standards.

High resolution techniques can provide a better understanding of hydrogeologic conditions, migration pathways, and source distribution, which are critical for successful source reduction actions. For example, multi-level groundwater sampling, soil-gas sampling, continuous coring, and continuous pollutant detection methods, can help minimize uncertainty that sources have been identified and removed to the extent feasible.

Furthermore, efforts to evaluate pollutant mass flux and source strength, using multi-level monitoring transects, borehole flow meters, and other means, may provide more confidence in predictions of plume longevity and cleanup timeframe. A better understanding of the relationship between source reduction and plume behavior can lead to development of performance targets and the need for additional source reduction and/or enhanced plume degradation.

### Important considerations for DNAPL

DNAPL migration is gravity-driven along the path of least resistance, which can lead to a tortuous migration pathway making it difficult to locate. DNAPL may reside as small, thin, disconnected, saturated zones or “pools,” or as unsaturated residual product, depending on site hydrogeology and natural or man-made conduits. Higher-resolution, state-of-the-art methods are generally more effective than conventional methods at identifying and delineating DNAPL.

## *Demonstrating plume stability and decrease*

A groundwater plume is stable when pollutant concentrations and the plume's footprint are stable. Plume stability occurs when dissolved-phase pollutants attenuate at a rate equal to their generation. A stable plume shows that pollutant migration in groundwater is under control.

A decreasing plume is diminishing in concentration and its location is not migrating or expanding. This occurs when the attenuation rate of dissolved-phase pollutants exceeds their generation rate from all sources. Sources that are sustaining the dissolved-phase plume may include pollutants sorbed to fine-grained, low-permeability materials located throughout the plume and outside the identified "source zone". A decreasing plume supports natural attenuation as a viable remedial alternative.

For fuel-impacted sites, monitoring for plume stability is a primary low-risk criterion because fuel plumes are typically limited in size and, once stable, generally begin to retreat in a relatively short timeframe under natural conditions. Chlorinated solvent plumes, however, tend to be longer and are less likely to retreat under natural conditions. This is because solvent plumes are more sensitive to source strength and exhibit slower attenuation rates compared to fuel plumes. For the majority of solvent plumes, the natural attenuation rate will not be sufficient to overcome source loading without rigorous source removal and/or plume remediation to directly destroy pollutants and/or enhance natural attenuation rates.

### *Evaluate pollutant concentration trends*

Spatial and temporal trends of pollutant concentrations should be evaluated and presented to demonstrate evidence of plume attenuation. Pollutants of concern include the breakdown products resulting from dechlorination and plume degradation.

Biodegradation of chlorinated solvents results in specific spatial and temporal patterns among parent and daughter pollutants. For example, biodegradation of tetrachloroethylene (PCE) in a predominantly anaerobic environment will ideally result in increasing cis-1,2-dichloroethylene (cis-1,2-DCE) and vinyl chloride (VC) in the near down-gradient portion of the plume, followed by decreasing cis-1,2-DCE and VC concentrations and increasing ethene concentrations at the distal ends of the plume. Although the production of breakdown products is a good indicator that biodegradation is occurring, their dissipation must be verified to demonstrate that biodegradation has not stalled. The presence or absence of such patterns must be evaluated and presented graphically.

Using standard presentation methods summarized below, spatial and temporal trends should be evaluated and presented to demonstrate if the groundwater plume is attenuating sufficiently to warrant site closure. Statistical methods (e.g., regression analysis) should be applied to demonstrate significant decreasing trends if they are not readily apparent from the observed data. Description and justification of statistical methods should be provided.

a) Figures illustrating the current extent of groundwater impacts, in excess of established cleanup standards, using posted pollutant concentrations next to each well or point where measured
b) Figures comparing the current limits of pollution with its extent from prior time periods to illustrate plume stability, no migration, and plume retreat
c) Graphs showing current and historic pollutant concentrations and water levels versus time throughout the plume, including the plume boundaries
d) Graphs showing the current and historic pollutant concentrations versus distance in the direction of groundwater flow

### *Evaluate biogeochemical indicator trends*

Spatial and temporal trends of biogeochemical parameters (e.g., dissolved oxygen, pH, electron acceptors, microbial populations, etc.) provide important evidence to show the potential for biodegradation throughout the plume. Indicator parameters should be evaluated and the meaning of their occurrence and distribution should be explained. Figures and tables should be used to clearly demonstrate the spatial and temporal distribution of indicator parameters.

## *Monitoring timeframes*

### *Natural variability*

Stable plumes often display short-term variability in groundwater concentrations. These effects are due to changes in groundwater flow, degradation rates, sampling procedures, and other factors, which are inherently variable. Quarterly monitoring for at least one hydrologic cycle is the recommended minimum frequency and timeframe to evaluate natural, short-term groundwater variability. If groundwater conditions (e.g., depth, gradient, flow path) are expected to change significantly from year to year due to droughts, adjacent pumping, excess recharge, or other factors, then more frequent and/or additional monitoring may be necessary.

### *Post-remediation rebound*

Pollutant concentrations often display some degree of increase (i.e., rebound) following active remediation methods such as groundwater extraction, in-situ chemical oxidation, or in-situ bioremediation using various injected or emplaced materials. Monitoring is necessary to evaluate these phenomena and determine if site conditions will remain stable or improve overtime.

To fully evaluate post-remediation rebound, monitoring data should compare baseline (pre-treatment) conditions with conditions during implementation of the remedy (e.g., performance monitoring data) and following completion (e.g., verification monitoring data). The objectives of verification monitoring are two-fold 1) demonstrate a return to natural/equilibrium conditions, and 2) demonstrate that concentrations have stabilized and that rebound will not occur.

The timeframe for rebound monitoring may be on the order of months to years depending on site-specific conditions (e.g., timeframe for natural/equilibrium conditions, groundwater velocity, source strength, etc.) and the specific remediation methods used. For example, it may take only a few months for groundwater hydraulics to re-equilibrate after shutting off a groundwater extraction system, while it may take one or two years or more to evaluate rebound following chemical oxidation treatment.

### *MNA to demonstrate plume stability/decrease*

Monitoring must occur over a time period sufficient to demonstrate plume stability or decrease under natural conditions after the effects of post-remediation rebound have been evaluated. This may take up to several years depending on site-specific conditions, including the monitoring data trend analysis, potential threats to beneficial uses, and other uncertainties. If monitoring data do not demonstrate plume stability/decrease, this may indicate that further source/plume remediation and monitoring is necessary.

## *Evaluating future groundwater use*

State Water Board appeals decisions, which are decisions made upon appeal of Regional Water Board orders or actions, provide that the timeframe to meet cleanup standards must be reasonable, and that what is reasonable should be evaluated in the context of the likelihood of, and timeframe for, future groundwater use. Evaluating the cleanup and groundwater use timeframes necessitates the use of best professional judgment based on site-specific data.

Evaluating the potential for future groundwater use should include review of all relevant information, such as: 1) USGS and DWR water resources publications, 2) the S.F. Bay Water Board's beneficial use and groundwater protection evaluations, 3) local groundwater management plans, 4) municipal water supply production and monitoring well locations, 5) domestic water well locations, and 6) local land and water use/supply plans. Additionally, consultation with the water agencies that have responsibility for managing groundwater in the site vicinity is strongly recommended to aid with the evaluation. The goals of the water agency consultation are:

- Confirmation of hydrogeologic interpretations and assumptions
- Confirmation of water use plans or projects (or lack thereof)
- Confirmation of future beneficial use timeframes

### *Beneficial uses for shallow and deep groundwater*

Existing and potential beneficial uses for surface water bodies and groundwater basins are listed in the S.F. Bay Water Board's Basin Plan and must be considered regardless of specific use plans. For water bodies not specifically listed in the Basin Plan, the tributary rule generally applies. This means that upstream water will, at a minimum, have the same beneficial use as the downstream water. For groundwater, this depends on the degree of hydraulic communication between the water-bearing zones.

Beneficial uses assigned to groundwater basins identified in the Basin Plan do not distinguish between shallow groundwater and deeper aquifers. Shallow groundwater is generally assumed to be in hydraulic communication with a deeper aquifer when a substantial, competent aquitard is not identified or when data (i.e., aquifer pumping tests) are not available. Therefore, in such cases, shallow groundwater will typically be assigned the same beneficial uses designated for the groundwater basin.

Additionally, S.F. Bay Water Board Resolution 89-039 and State Water Board Resolution 88-63 provide that all groundwater is presumed to have drinking water beneficial use with certain exceptions. Therefore, shallow groundwater is assumed to have potential drinking water beneficial use unless exception to Resolution 89-039 is demonstrated and the shallow groundwater is not reasonably expected to be in hydraulic communication with a deeper aquifer. In certain instances, the use of a deeper aquifer as a source of drinking water may be considered impractical due to the threat of degradation, such as salt-water intrusion caused by excessive pumping, or pre-existing poor quality.

### *Sensitive or vulnerable groundwater basins*

Some groundwater basins, including recharge areas, may require a higher degree of protection because they are or could become highly used, or because they are considered more sensitive or vulnerable to groundwater quality degradation through individual or cumulative affects. In such areas, low-threat closure of chlorinated solvent sites may be limited and more stringent source and/or plume remediation or demonstration of plume retreat, cleanup timeframe, and residual risk management may be required. This decision would be based on site-specific factors.

The State Water Board's Groundwater Ambient Monitoring and Assessment (GAMA) program has identified "priority" basins in California based primarily on their high groundwater use. Information collected by the GAMA program can provide an indication of overall water quality and potential vulnerability of deep aquifers.More information on the GAMA program can be found at: http://www.waterboards.ca.gov/gama/

S.F. Bay Water Board staff has also conducted groundwater protection and beneficial use evaluations for several groundwater basins in the Region that includes review of basin hydrogeology, groundwater quality, and beneficial uses. S.F. Bay Water Board staff intend to utilize these and other studies/information to help determine if low-threat site closure is an appropriate option in specific sensitive or vulnerable groundwater basins and recharge areas.

# Discussion

This section contains a discussion of supporting Water Board policy, a survey of low-threat closures of solvent sites, and a comparison of fuel- and solvent-impacted sites with respect to low-threat closures.

## *Consistency with Water Board Policy*

Low-threat site closure is consistent with policies and appeals decisions of the State Water Resources Control Board (State Water Board) and the S.F. Bay Water Board. This section contains a summary of the relevant policies and appeals decisions with respect to cleanup, beneficial use, and water resources protection.

### *State Water Board Resolution No. 68-16*

Resolution No. 68-16 was adopted as part of State policy for water quality control and has also been incorporated into all of the State's regional water quality control plans. Resolution No. 68-16 states that:

*Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.*

Resolution No. 68-16 restricts a reduction in the quality of groundwater or surface water even though such a reduction might still allow the protection of beneficial uses associated with the water prior to the quality reduction. The policy goal is to maintain high quality waters. The policy allows changes in water quality only if: (1) it is consistent with maximum benefit to the people of the State, (2) it does not unreasonably affect present and anticipated beneficial uses, and (3) it does not result in water quality less than that prescribed in water quality control plans or policies.

### *State Water Board Resolution No. 88-63*

Resolution No. 88-63 specifies which groundwater and surface waters are considered to be suitable or potentially suitable for the beneficial use of municipal and domestic water supply (MUN). Regional water boards are to ensure that the MUN beneficial use is designated for protection wherever the use is presently being attained and shall make certain that any changes in beneficial use designation is consistent with all applicable regulations adopted by the U.S. Environmental Protection Agency. The policy allows Regional water boards some discretion in making MUN determinations and in de-designating the MUN beneficial use in some water bodies. Specifically, it contains exception criteria for salinity (waters containing over 3,000 mg/l TDS) and sustained yield (groundwater yield less than 200 gal/day).

### *State Water Board Resolution No. 92-49*

Resolution No. 92-49 was adopted by the State Water Board initially in 1992 and revised in 1996. The Resolution contains the policies and procedures pertaining to site investigations as well as cleanup and abatement activities related to all types of discharges. Regional Water Boards can determine cleanup and abatement schedules that are based on factors such as the degree of threat or impact on water quality and beneficial uses and the financial and technical resources available to the discharger. In approving cleanup levels less stringent than background, Resolution No. 92-49 requires that any such cleanup level shall consider criteria and conditions listed in Resolution No. 68-16 and Resolution No. 88-63.

Section III.G of Resolution No. 92-49 restates the three tests in Resolution No. 68-16 for allowing cleanup to end prior to attaining background concentrations. Specifically, Regional Water Boards shall "ensure that dischargers are required to clean up and abate the effects of discharges in a manner that promotes attainment of either background water quality, or the best water quality which is reasonable if background levels of water quality cannot be restored, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible." Any such alternative cleanup level shall: (1) be consistent with the maximum benefit to the people of the state, (2) not unreasonably affect present and anticipated beneficial use of such water, and (3) not result in water quality less than that prescribed in water quality control plans and policies adopted by the State and Regional Water Boards.

This policy introduces the important concept of "substantial likelihood" to achieve cleanup standards within a "reasonable timeframe," considering what is "technologically and economically feasible."

### *State Water Board Appeals Decisions*

State Water Board appeals decisions are based on appeals of Regional Water Board orders. In many cases the appeals were based on determinations by a local agency to not close a site on various grounds. Most appeals decisions provide guidance regarding interpretation of State Water Board policies. Following is a summary of three decisions that provide guidance specifically related to low-threat site closure.

#### Walker (1998)

The State Water Board's Walker decision (WQ 98-04 UST) applies the above policies to a specific leaking underground fuel tank (LUFT) site in Napa County and concludes that the site should be closed, despite the fact that relevant groundwater quality objectives are not met and probably won't be met for hundreds of years.

The Napa site involved petroleum fuel hydrocarbons released from underground fuel tanks. The tanks had been removed, along with contaminated soil in the tank excavation. Post-excavation sampling detected some fuel hydrocarbons in soil and groundwater in the immediate vicinity. Concentrations in several samples exceeded secondary MCLs (taste and odor) but not primary MCLs (human health). The discharger requested site closure but the local oversight agency (Napa County) requested additional investigation.

The State Water Board found that the site qualified as a low-risk site: adequate site investigation, adequate cleanup, no nearby supply wells, residual pollutants pose no threat to human health or safety, and residual pollutants do not adversely affect current or probable future beneficial uses of water.

Furthermore, the State Water Board found that the three tests in Resolution No. 68-16 were met in this case: the level of cleanup is consistent with the maximum benefit to the people of the state and applicable water quality objectives will be met within a reasonable time. On the *"maximum benefit"* test, the State Water Board considered the implications of cleaning up this and all other sites to background and concluded that this would result in a large volume of soil excavation, which would greatly impact already limited landfill space statewide. On the *"reasonable time"* test, the State Water Board referred to section III.A of Resolution 92-49, citing this as the basis for closing a site where requisite levels of water quality have not yet been met, but will be attained within a reasonable period. The decision says that in this case the reasonable period may be several hundred years, given the low likelihood of beneficial use of the onsite shallow groundwater and the conceptual site model (e.g. shallow isolated groundwater, low-permeability soils, lack of nearby wells, potential for continued chemical degradation, etc.).

Complete details can be found at:
http://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/wqo98.shtml

### Texaco (1998)

The State Water Board's Texaco decision (WQ 98-08 UST) applies the above policies to a specific LUFT site in Coachella and concludes that the site should be closed, despite the fact that relevant groundwater quality objectives were not met at the time. The key findings of this decision relate to interpretation of Resolution No. 68-16 and suggest that the statewide consequences of requiring immediate and complete cleanup (e.g., costs, landfill impacts, etc.) can and should be considered.

Complete details can be found at:
http://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/wqo98.shtml

Green and Kelly (2005)

The State Water Board's Green and Kelly decision (WQ 2005-0002-UST) applies the above policies to a specific LUFT site in Eureka and concludes that the site should be closed, despite the fact that relevant groundwater quality objectives were not met at the time. The key findings of this decision relate to interpretation of Resolution No. 92-49. In the decision, State Water Board concluded that the adverse effect on shallow groundwater would be minimal and localized, and there would be no adverse effect on the groundwater in deeper aquifers, given the physical and chemical characteristics of the petroleum constituents, the hydrogeologic characteristics of the site and surrounding land, and the quantity of groundwater and direction of groundwater flow. In addition, the potential for adverse effects to beneficial uses of groundwater is low, given that that nearby, up-gradient water supply wells are not being used and based on evaluation of (1) the current and potential future uses of groundwater in the area; (2) the potential for health risks caused by human exposure; (3) the potential damage to wildlife, crops, vegetation, and physical structures; and (4) the persistence and permanence of potential effects, (i.e., the environmental fate of the remaining, residual hydrocarbons in site soil and groundwater). State Water Board further concluded that a level of water quality less stringent than background is unlikely to have any impact on surface water quality for these same reasons.

Complete details can be found at:
www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/wqo05.shtml

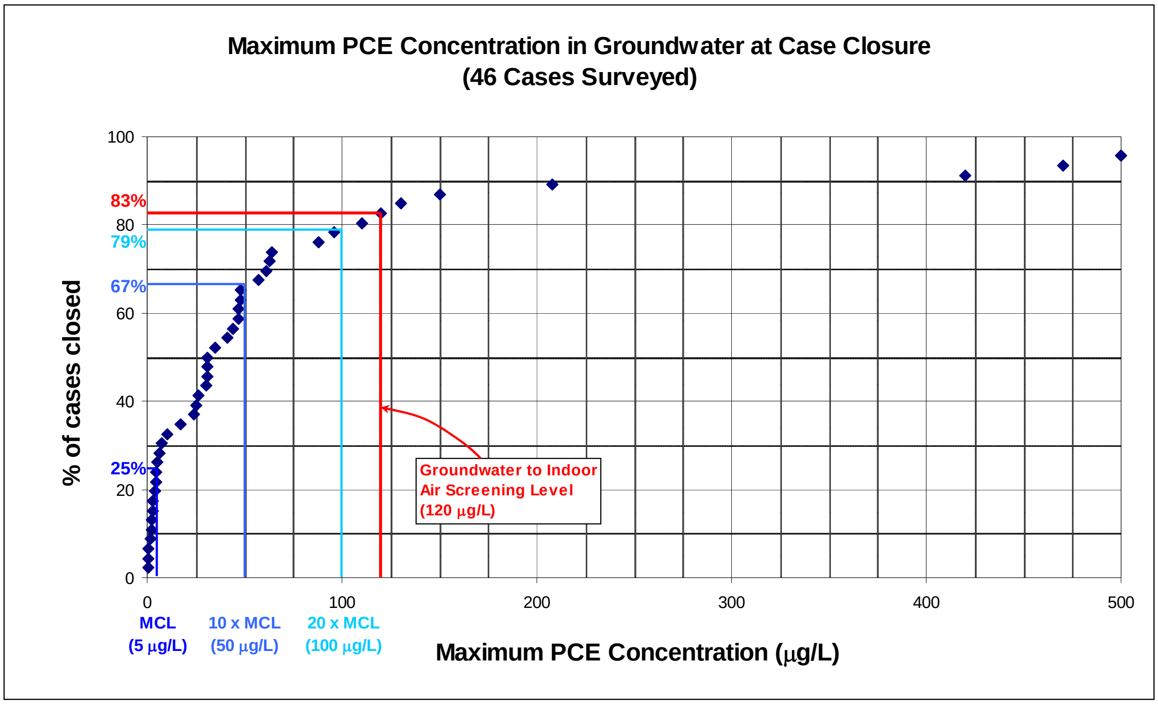
### *State Water Board December 1995 Memorandum*

In a December 8, 1995, memorandum to Regional Water Board Chairpersons, Executive Officers, and Local Oversight Program Agency Directors titled "LLNL Report on Leaking Underground Storage Tank Cleanup," State Water Board Executive Officer Walt Pettit encouraged those agencies to (1) aggressively close low-risk LUFT sites that only affect soil ("soil only cases") and (2) shift from active cleanup to monitor-only at other low-risk LUFT sites. The memorandum cited the findings of the 1995 Lawrence Livermore National Laboratory (LLNL) report "Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks" in support of this recommendation. Although the 1995 memorandum is specific to LUFT sites, it has provided a foundation on which to develop the low-threat closure criteria for chlorinated solvent sites presented in this document.

## *Site closure survey*

In 2007, S.F. Bay Water Board staff surveyed 46 chlorinated solvent sites within the S.F Bay Region that were closed between January 2002 and August 2007. These sites were presumed closed using the S.F. Bay Water Board's January 1996 low-risk fuel site guidance and best professional judgment. The purpose of the survey was to evaluate the extent and implications of low-threat chlorinated solvent site closure within the S.F. Bay Region.

The figure below is a plot of the maximum closure concentration for tetrachloroethylene (PCE) in groundwater for each site. Findings are summarized below.




## Findings:

- 11 of 46 sites (~24%) were closed with maximum PCE concentrations at or below the MCL (5 ug/l)
- 19 sites (~40%) were closed between the MCL and 10 times the MCL (5 to 50 ug/l)
- 25 sites (~54%) were closed between the MCL and 20 times the (5 to 100 ug/l)
- 38 sites (~83%) were closed below the groundwater screening level for potential vapor intrusion concern (residential land use) of 120 µg/l[1]
- The highest maximum PCE closure concentration in groundwater was 750 µg/l

## Discussion:

Site closure decisions were made with the best available information at the time and in some cases may predate the use of vapor intrusion screening levels. Drinking water maximum contaminant levels (MCLs) were presumed to be the cleanup standards for each site, but the actual cleanup standards were not confirmed.

[1] Table E-1A, Screening For Environmental Concerns at Sites with Contaminated Soil and Groundwater, Interim Final, November 2007

For the purpose of this survey, site closures were not evaluated for location, plume size, age, or degree of source evaluation or site characterization. For example, some may:

- Involve sites where no definite source was ever identified
- Represent the remnants of a historic or diffuse source such as a leaky sewer line
- Represent the down-gradient affects from an up-gradient and off-site source
- Reflect a single well with persistent concentrations considered to be a relatively small impact in a low-permeable formation
- Reflect situations where complete source removal and/or plume remediation work were performed

A similar survey was performed for maximum TCE concentrations at site closure. The results (not presented here) were similar to those for PCE. Other chlorinated solvents were evaluated, but there were insufficient data points to perform a useful survey.

Conclusions:

S.F. Bay Water Board staff have approved low-threat site closures for solvent-related sites in the recent past. Residual groundwater pollutant concentrations at the time of low-threat closure were less than 20 times MCL at most sites.

## *Comparison of fuel and solvent sites*

While there are numerous similarities between fuel- and solvent-impacted sites, there are also several important differences. This subsection discusses the differences. It also contrasts the low-threat closure criteria in this document with those in the 1995 document for fuel-impacted sites.

### *Technical comparison*

Fuel- and solvent-impacted sites differ mainly due to differences in chemical properties and toxicity. For example:

- Fuels are susceptible to natural attenuation; solvents are typically recalcitrant
- Fuel plumes often become stable within a few hundred feet of the release site since the degradation rate is usually quicker than the transport rate; solvent plumes typically grow much longer before stabilizing
- Solvents are generally more toxic, with maximum contaminant levels (MCLs) often orders of magnitude lower than fuel-component MCLs (ppm vs. ppb)
- Solvent breakdown products can be more toxic than parent compounds and degradation can “stall,” resulting in the buildup of cis-1,2-DCE or vinyl chloride

- Fuels are typically less dense than water (floating), which generally precludes downward migration; dense solvents often sink to the aquifer bottom increasing the potential for cross-contamination between aquifers and making cleanup longer, more difficult, and more expensive

Empirical studies show that natural attenuation is much more prevalent at fuel-impacted sites compared to solvent-impacted sites. In the mid-1990s, Lawrence Livermore National Laboratory (LLNL) conducted a study of fuel-impacted sites in California, finding evidence of natural attenuation that limited plume length at more than 90% of 271 sites examined in detail. The study led to an October 1995 LLNL report to the State Water Board, "*Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks*."

A 1999 study of approximately 250 solvent plumes nation-wide found much less evidence of natural attenuation ("*Historical Case Analysis of Chlorinated Volatile Organic Compound Plumes*") by a group that included the U.S. Department of Energy and LLNL. This study concluded that the median solvent plume length was about 1,600 feet (as compared to 130 feet for fuel plumes) and that, in general, chlorinated solvent plume length is more sensitive to source strength (i.e., concentration and flow rate) than to natural attenuation. Put another way, natural attenuation alone is not typically sufficient to maintain limited plume length. Thus, source reduction and enhanced attenuation are critical factors in achieving a stable or retreating chlorinated solvent plume.

### *Comparison of low-threat closure criteria*

These technical differences have implications for low-threat closure criteria for fuel- and solvent-impacted sites. In general, we want to see robust, site-specific evidence for natural attenuation at solvent sites. We are also more concerned about long-term risk management at solvent sites, given the longer time typically required for beneficial uses to be fully restored.

Low-threat closure criteria for fuel-impacted sites in this region are found in the January 1996 "Supplemental Instructions to State Water Board December 8, 1995, Interim Guidance on Required Cleanup at Low-Risk Fuel Sites" issued by the S.F. Bay Water Board staff. That document presents criteria that qualitatively define low-risk sites where petroleum hydrocarbon fuels are the only pollutants of concern. The supplemental instructions establish six categories (i.e., criteria) to identify low-risk cases and provide answers to frequently-asked questions (FAQs). One response specifically addresses when to close low-risk LUFT sites:

> "*… Closure of low-risk UST sites would be appropriate as soon as enough data supported the conclusion that the source had been removed, the plume had stabilized, and [intrinsic] bioremediation was expected to achieve water quality objectives in a reasonable time.*"

The following tables compare the low-threat closure criteria for solvent-impacted sites in this document with the 1996 low-risk closure criteria for fuel-impacted sites.

| Low-Threat Closure Criteria for Chlorinated Solvent Sites | Low-Risk Closure Criteria for Fuel Sites |
|---|---|
| **1a – S**ources identified and evaluated<br>**1b –** Site adequately characterized<br>**1c –** Exposure pathways, receptors, risk and threats identified and assessed<br>**2a –** Sources remediate to extent feasible<br>**2b –** Risks to human and ecological health and sensitive receptors mitigated<br>**2c –** Threats to groundwater and surface water beneficial uses mitigated<br>**3a –** Plumes are decreasing<br>**3b –** Cleanup timeframe is reasonable<br>**3c –** Risk management measures are appropriate, documented and require no further oversight | **1 -** Leak stopped; free product and other sources removed/remediated.<br>**2 -** Site adequately characterized.<br>**3 –** Plume is stable<br>**4 -** No impacts to water wells, drinking water aquifers, surface water, or sensitive receptors<br>**5 -** No significant human health risk.<br>**6 -** No significant environmental risk |

| **Comparison of closure criteria for solvent and fuel sites** | | **Comments** |
|---|---|---|
| Solvent Sites | Fuel Sites | |
| **1a** | **1** | Somewhat equivalent. Source evaluation and remediation separated into two criteria for solvent sites |
| **1b** | **2** | Equivalent |
| **1c** | **4** | Somewhat equivalent. Added emphasis on pathway/receptor identification and evaluation for solvent sites |
| **2a** | **1** | Somewhat equivalent. Added emphasis on source remediation to extent feasible for solvent sites |
| **2b** | **5, 6** | Mostly equivalent. Human and ecological health risk assessment/mitigation combined in a single criterion for solvent sites |
| **2c** | **4** | Mostly equivalent. Added emphasis on threats to beneficial uses for solvent sites |
| **3a** | **3** | Mostly equivalent except for added emphasis on decreasing rather than stable plumes for solvent sites |
| **3b** | **3** | Added emphasis on demonstrating a reasonable cleanup timeframe in context of beneficial use timeframe |
| **3c** | **- -** | Added emphasis on risk management measure; not a major concern for fuel sites |

# Attachments

# Closure Criteria "Quick Reference" for Low-Threat Chlorinated Solvent Sites

## 1. Develop a complete Conceptual Site Model (CSM)

***1a) Pollutant sources are identified and evaluated***

- √ ***Leak/spill sources (tanks, sumps, pipelines, etc.) are identified and controlled***
- √ ***The pollutant source zone (sorbed/entrained residual pollutants and free product that sustain groundwater & vapor plumes) is identified and delineated***

***1b) The site is adequately characterized***

- √ ***Site history, hydrology, and hydrogeology are characterized***
- √ ***The nature & extent (lateral and vertical) of pollutants are characterized in soil, groundwater & soil gas, as necessary***

***1c) Exposure pathways, receptors, and potential risks, threats, and other environmental concerns are identified and assessed***

- √ ***Nearby receptors (wetlands, streams, wells, homes, schools, businesses, etc.) are identified***
- √ ***Groundwater & vapor migration/exposure pathways, natural & artificial (storm drains, sewer lines, buried channels, abandoned wells, etc.) are assessed***
- √ ***Reasonably anticipated land and water use scenarios have been considered***
- √ ***Actual and potential risks to receptors and adverse affects to beneficial uses are assessed***

## 2. Control sources and mitigate risks and threats

***2a) Pollutant sources are remediated to the extent feasible***

- √ ***The technical and economic feasibility of source remediation methods/technologies have been evaluated***
- √ ***Feasible source remediation technologies have been implemented***
- √ ***Appropriate source remediation performance monitoring has been conducted***
- √ ***Source mass removal has been documented***
- √ ***The effects of source remediation on groundwater/vapor plume behavior have been evaluated***

***2b) Unacceptable risks to human health, ecological health, and sensitive receptors, considering current and future land and water uses, are mitigated***

- √ ***Necessary & appropriate corrective actions have been implemented***
- √ ***Confirmation sampling, monitoring, and/or risk management measures demonstrate that risks are mitigated***

***2c) Unacceptable threats to groundwater and surface water resources, considering existing and potential beneficial uses, are mitigated***

- √ ***Necessary & appropriate corrective actions have been implemented***
- √ ***Confirmation sampling, monitoring, and/or risk management measures demonstrate that threats are mitigated***

## 3. Demonstrate that residual pollution in all media will not adversely affect present and anticipated land and water uses

***3a) Groundwater plumes are decreasing***

- √ ***Appropriate plume monitoring has confirmed the lateral and vertical extent over time***
- √ ***Spatial and temporal trends for pollutants, including parent and breakdown products, have been evaluated***
- √ ***Spatial and temporal trends for natural attenuation indicators have been evaluated***
- √ ***Evidence of breakdown to acceptable end products is documented***
- √ ***Plume concentrations are decreasing and the plume is not moving or expanding***

***3b) Cleanup standards can be met in a reasonable timeframe***

- √ ***The estimated timeframe to achieve cleanup standards throughout the affected area is evaluated***
- √ ***The anticipated timeframe for beneficial use of the affected and nearby water resources is evaluated***
- √ ***The potential to adversely affect beneficial uses is assessed based on comparison of cleanup and beneficial use timeframes, hydrogeologic conditions, and the CSM***

***3c) Risk management measures are appropriate, documented, and do not require future Water Board oversight***

- √ ***Necessary risk management measures (land use restrictions, engineered vapor barriers, soil management plans, etc.) are implemented and documented***
- √ ***Risk management measures do not require future Water Board oversight***

# Frequently Asked Questions

### *1. What is a source and why is source remediation important?*

Pollutant sources consist of the primary leak source, e.g., a tank, sump, pipeline, or other vessel, and secondary sources, which include the pollutants released to the environment that sustain groundwater or vapor plumes. Secondary sources typically comprise the "source zone" at contaminated sites because they can migrate laterally and vertically depending on various chemical and hydrogeological factors. Source zones include separate-phase products, such as Light or Dense Non-Aqueous Phase Liquids (LNAPLs / DNAPLs), and residual pollutants entrained within or sorbed to soil or sediment.

Source zone remediation is critical because the source zone affects pollutant concentration levels and plume longevity, and may present risks to human health or the environment. Inadequate source remediation can significantly increase the cleanup time frame and the costs associated with additional groundwater or vapor plume remediation and monitoring.

### *2. Does the presence of DNAPL make a site ineligible for low-threat closure?*

In general, the presence of dense non-aqueous phase liquid (DNAPL) at a site will require significant source remediation efforts to remove enough mass to demonstrate a reasonable cleanup timeframe. In many cases, mass removal to the degree necessary for site closure is not feasible. Furthermore, DNAPL sites may pose excess risk or threat to human health and the environment due to the continual partitioning of pollutants from DNAPL to groundwater or vapor. Therefore, it is more likely that DNAPL sites will require long-term remediation and monitoring to demonstrate that risks and threats are controlled and that current and future beneficial uses are not be adversely affected.

### *3. Is soil-gas sampling required prior to low-threat closure?*

Generally, yes. Soil-gas samples are generally used to define both the spatial and temporal distribution of chlorinated VOCs present in the unsaturated (vadose) zone. Soil-gas evaluations are typically a routine component of site characterization, risk assessment, remedial effectiveness, or vapor intrusion studies. Soil-gas evaluation can provide data to improve decisions about current and future indoor air exposure scenarios in existing or future buildings. Prior to site closure, soil-gas sampling will usually be necessary to evaluate potential threats from residual pollution at the site and if engineering and/or institutional controls are necessary based on current or future land uses.

Soil-gas sampling is typically required whenever groundwater screening levels for vapor intrusion are exceeded. Conversely, soil-gas sampling may not be necessary at sites where groundwater screening levels for vapor intrusion are met. Furthermore, soil-gas sampling may not be necessary at open-space sites where redevelopment is not anticipated. Land use restrictions may be needed to ensure that redevelopment to inappropriate uses does not occur without re-evaluation of soil gas and potential vapor intrusion concerns.

### 4. *How is the cleanup timeframe estimated and how do we know if it's reasonable?*

Estimating the cleanup timeframe is a site-specific determination that should be based on observed/measured plume trends where possible. Statistical methods, such as regression analysis, are helpful to evaluate and extrapolate the cleanup timeframe from the data. For chlorinated solvent contaminated sites, the best estimates of cleanup timeframe are based on data trends that indicate that the plume is decreasing and that there is evidence of significant biotransformation occurring.

Evaluating if the cleanup timeframe is reasonable requires consideration of the timeframe for actual future beneficial use of the affected water resource and if pollutants are likely to adversely affect the use at that time. This requires reviewing relevant reports and databases and consulting with groundwater supply managers and purveyors regarding the probably use scenarios for the location in question. It also requires evaluating the likely proximity to future receptors, hydraulic connection, pollutant mobility, pollutant attenuation, and many other factors that comprise the CSM. In most cases it is reasonable to assume that pollutants in shallow groundwater could adversely affect a deeper well. However, in some cases it may not be, for example, when 1) pollutants are sequestered in low-permeability zones and their mobility is diffusion-limited, 2) plume size, concentration, or mass is limited, and 3) there is little hydraulic communication between shallow and deeper groundwater zones.

Reasonable cleanup timeframes could range from a few years to decades, depending on hydrogeologic conditions, the CSM, the anticipated beneficial use timeframe, and regulatory confidence in the estimates. Reasonable cleanup timeframes may be longer when:

- Groundwater is shallow, perched, or otherwise isolated
- There are no abandoned wells and other vertical conduits in proximity to the site
- There is no current beneficial groundwater use and the potential for future use in proximity to the site is low
- There are well construction practices, local zoning practices, land-use restrictions, etc., that would tend to limit or preclude future beneficial use of the affected water resource

Conversely, deeper groundwater impacts, lack of a competent aquitard, existence of vertical conduits, or groundwater pumping scenarios may require cleanup in a shorter timeframe.

### *5. How does technical and/or economic feasibility of remediation affect low-threat closure decisions?*

Technical feasibility generally refers to the ability to achieve remedial objectives using existing remedial technologies, methods, and strategies, without regard to cost. It often requires field-scale application of a technology to demonstrate. Economic feasibility refers to the relationship of cost to benefit gained (i.e., cost-benefit evaluation) based on using all technically feasible methods.

Remediation of sources and plumes to the extent technically and economically feasible is required before site closure can be considered. Although this doesn't mean that each and every cleanup technology must be applied to determine if it is feasible, it does require a detailed feasibility evaluation of technologies that are or have been applied under similar conditions at other sites. It also requires the application (implementation) of appropriate technologies that are considered technically and economically feasible.

### *6. Are there special cases that may not be eligible for low-threat closure?*

Yes, depending on site-specific circumstances and conditions. Below are some examples of special cases that may be difficult or impossible to close under the low-threat criteria:

- Sites with off-site impacts or sensitive land uses: Both situations increase the likelihood that risk management measures will be needed to manage residual pollution and that agency oversight will be needed to assure diligent implementation of those measures. As such, it will be harder for sites in these situations to meet low-threat criterion 3c (risk management measures … do not require future Water Board oversight).
- Sites with co-mingled plumes: Where there are multiple sources of groundwater pollution, there are usually multiple groups of dischargers responsible for investigation and cleanup. In this situation, the low-threat closure criteria would have to be met for all the source properties and the resulting commingled groundwater plume; it would not be enough to meet the criteria at, say, three of four source properties. To the extent that some source properties are lagging behind others, low-threat closure would probably have to wait for the slowest source property.
- Federal Superfund and RCRA sites: Sites that are subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or the Resource Conservation and Recovery Act (RCRA) must comply with similar but separate state and federal requirements. Low-threat closure is done pursuant to state law (the Water Code) but does not necessarily comply with CERCLA or RCRA. USEPA staff would need to be consulted to see if a particular CERCLA or RCRA site is eligible for low-threat closure.

### *7. Are there alternatives if low-threat site closure is not warranted?*

Yes, there are several alternatives:

- Additional site characterization or cleanup: This alternative would be appropriate if the site does not meet low-threat criteria 1b through 2c. Following this additional work, the site can be considered for low-threat closure or one of the other alternatives below.
- Containment zone: This alternative is provided in State Water Board resolution 92-49. It is intended for situations where residual pollution is not expected to degrade or diminish significantly over time (e.g., conservative pollutants such as metals, significant DNAPL sources). It would be appropriate if the site does not meet low-threat criterion 3a (decreasing groundwater plume).
- Monitored natural attenuation (MNA): MNA is a remedial option that may be selected to address groundwater pollution at all or part of a site. It requires regular monitoring to confirm continued biodegradation over time. This alternative would be appropriate if the site does not meet low-threat criterion 3c (cleanup standards can be met in a reasonable timeframe).
- Monitored risk management: This alternative involves Water Board oversight of risk management measure implementation (e.g., site cleanup order requiring regular reports documenting cap maintenance or sub-slab venting system operation). It would be appropriate if the site does not meet low-threat criterion 3d (risk management measures … do not require Water Board oversight).

### *8. Is a deed restriction or other land use control required for low-threat closure?*

The answer depends on whether the site closure action is subject to a 2002 state law concerning deed restrictions (Water Code section 13307.1(c)). The law only applies to sites subject to section 13304 cleanup orders where the release is from a non-UST source. For these sites, the law requires a deed restriction at the time of site closure if both of the following criteria are met: 1) the site is not suitable for unrestricted use; and 2) a land use restriction is necessary for the protection of public health, safety, or the environment. If a site is suitable for unrestricted use, then a deed restriction is unnecessary. Therefore, the second criterion is usually decisive. Whether a land use restriction is necessary for the protection of public health, safety, or the environment is a site-specific determination, based on whether the proposed risk management measures and other existing administrative controls are sufficient to address the threat of residual pollution and if their voluntary implementation is reliable. For example, a deed restriction would typically be required if the site were unsuitable for residential or other sensitive land uses due to the residual pollution on the site. However, a deed restriction may not be required if residential or other sensitive land uses are acceptable but shallow groundwater use is not and the likelihood of shallow well installation is small (e.g., due to local ordinances, low yield, or other site-specific factors).

In practice, the S.F. Bay Water Board usually requires deed restrictions at solvent-impacted sites, even if they're not required by law. The same thought process as described above would apply when determining if a deed restriction is necessary. As a general rule, a deed restriction is appropriate if digging or sensitive land uses are restricted due to residual contamination. A deed restriction may not be needed if shallow supply wells are the only concern.

### *9. How can the public participate in low-threat closure decisions?*

The S.F. Bay Water Board recognizes that effective communication is essential to elicit public comments and to discuss the consequences of closing a chlorinated solvent site. It is standard practice to inform the public of key findings and decisions throughout the investigation and cleanup process through Fact Sheets. Prior to formalizing a site closure decision, surrounding property owners and residents within an appropriate distance of the site will be notified of a minimum 30-day public comment period. The Fact Sheet will also be posted on the S.F. Bay Water Board's website. If the groundwater plume extends off-site and beyond the public right-of-way, all property owners and residents affected, or potentially affected, will be notified. S.F. Bay Water Board staff may also participate in community or public meetings to discuss the pending low-threat closure decision.

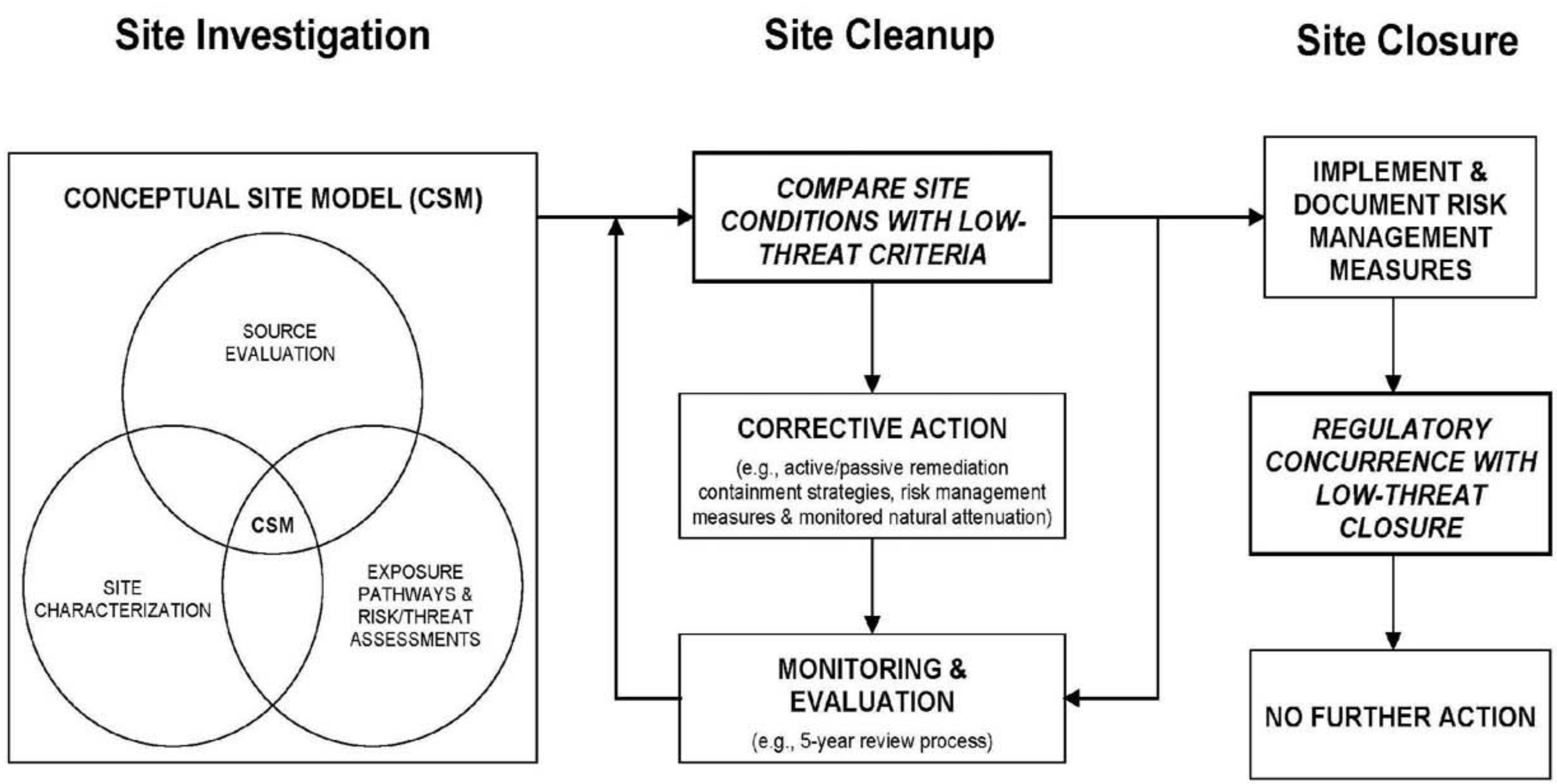
### *10. How does low-threat closure compare to the DTSC's "certificate of completion" or the USEPA's "technical impracticability" waiver?*

S.F. Bay Water Board staff typically approve site closure (regular or low-threat) by issuing a "no further action" (NFA) letter. The S.F. Bay Water Board uses the terms "closure" and "no further action" synonymously. Although S.F. Bay Water Board site closure may be approved with or without land use restrictions (or other risk management measures) no further action is required and no further regulatory oversight is intended.

DTSC issues a certificate of completion rather than a closure letter. A certificate of completion signifies the end of active cleanup. If ongoing monitoring or risk management is needed, then DTSC would require it through an operation and maintenance plan. DTSC's certificate of completion without an operations and maintenance plan is analogous to S.F. Bay Water Board site closure.

USEPA issues technical impracticability (TI) waivers at federal Superfund sites where it finds that it's technically impracticable to meet all relevant cleanup standards, such as MCLs in groundwater. Active remediation may still be needed to mitigate unacceptable risks and to prevent pollution migration. Monitoring is required until relevant cleanup standards are met. Therefore, EPA's TI waiver is not the same as low-threat closure because 1) monitoring is required until cleanup standards are met throughout the affected area, and 2) TI waivers could be approved for sites that are not necessarily considered low-threat. USEPA's TI waivers are more analogous to the State Water Board containment zones.

# Applying Low-Threat Closure Criteria in the Cleanup Process




The CSM is developed to understand site conditions, including the source zone, and potential threats to human health, water resources, and the environment. It is important to revisit and update the CSM throughout the cleanup process. Low-threat closure criteria address important requirements for the CSM.

Low-threat closure criteria can help determine if/when corrective action and/or additional monitoring is needed, based on the site-specific CSM.

Site closure (i.e., no further action) is approved when closure criteria are satisfied. This includes documenting all necessary risk management measures, such as deed restrictions, landuse convenants, etc.