Final

# Design Guidance for Application of Permeable Reactive Barriers for Groundwater Remediation

Prepared for

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# Executive Summary

## A. Objective

The Air Force Research Laboratory (AFRL) at Tyndall Air Force Base (AFB), FL contracted Battelle in Columbus, OH to prepare a design guidance document for the application of permeable barriers. The first version of this document was issued in February 1997, after being widely reviewed by several members of the Remedial Technologies Development Forum's (RTDF's) Permeable Barriers Working Group (PBWG) and the Interstate Technology and Regulatory Cooperation's (ITRC's) Permeable Barriers Subgroup. The current document is an effort to update the previous design guidance after reviewing the performance of previously installed permeable reactive barriers (PRBs) and evaluating the design and construction of newer PRB applications, such as the one at Dover AFB. The United States Department of Defense's (DoD's) Strategic Environmental Research and Development Program (SERDP) provided the funds for this project.

The objective of this document is to guide site managers, contractors, and state and federal regulators through the process of:

(a) Determining the technical and economic suitability of a PRB for a given site, and
(b) Designing, constructing, and monitoring the PRB.

Unlike conventional ex situ technologies, such as pump-and-treat (P&T) systems, in situ technologies are more dependent on site-specific parameters. Therefore, this document does not purport to replace the scientific judgment of the site hydrologist or site engineer. Instead, this document highlights various chemical, biological, and hydrologic issues that affect the application of PRBs to various sites and the options available for resolving these issues.

## B. Background

At many sites, groundwater remediation is proving to be a much more difficult and persistent problem than originally thought. One of the more common and difficult groundwater problems prevalent at DoD sites and other government and industrial properties is the presence of chlorinated solvent-contaminated soil and groundwater. Chlorinated solvents or chlorinated volatile organic compounds (CVOCs), such as trichloroethylene (TCE) and perchloroethylene (PCE), were commonly used at these sites and properties for aircraft maintenance, dry cleaning, electronics manufacturing, metal finishing, and other operations. These solvents have entered the ground through leaks, spills, or past disposal practices, and there may be more than 600 such sites at Air Force bases across the country. The United States Environmental Protection Agency (U.S. EPA) estimates that there are 5,000 DoD, United States Department of Energy (DOE), and Superfund sites contaminated with chlorinated solvents.

Because chlorinated solvents often tend to persist in soil and groundwater for several years or decades, their remediation is usually a technically and economically challenging undertaking. The conventional method for addressing groundwater contamination at most sites has been P&T

systems, which extract groundwater from the aquifer, treat it above ground, and discharge it to a sewer or back to the environment. The energy and labor inputs required to keep these systems operational for many years is a severe economic burden for site owners. PRBs are an innovative technology that offer a passive alternative to conventional P&T systems for addressing long-term groundwater contamination problems. Although PRBs initially were applied to treat CVOC plumes, they also have been applied to treat or capture other contaminants, such as hexavalent chromium and uranium.

**C. Scope**

The overall methodology for the application of a PRB at a given site is discussed in this document and involves the following steps:

- Preliminary assessment
- Site characterization
- Reactive media selection
- Treatability testing
- Modeling and engineering design
- Selection of a suitable construction method
- Monitoring plan preparation
- Economic evaluation.

The guidance in this document is organized in accordance with these design steps.

**D. Conclusions**

The preliminary assessment is conducted to evaluate the technical and economic suitability of a given site for PRB application. Once a site is determined to be suitable, additional design steps are initiated as shown above. For common contaminants, such as TCE, that are to be treated with common reactive media, namely iron, it may be possible, if regulators agree, to forego treatability testing in favor of published contaminant half-lives and a design that includes appropriate safety factors.

At several existing sites, PRB construction generally has involved installation of reactive media in an excavated space. Excavation using backhoes, continuous trenchers, augers, or caissons is a conventional way of ensuring that the desired thickness and continuity of the reactive cell is achieved. The increasing use of a biodegradable slurry, instead of sheet piles or cross-bracing, to stabilize the excavation has increased the convenience and safety of installing the reactive media in the ground. However, these excavation methods have varying depth limitations (generally between 30 to 50 ft below ground surface). Innovative installation methods, such as jetting, hydraulic fracturing, vibrating beam, deep soil mixing, and the use of mandrels, have been tested at some sites and offer potentially lower-cost alternatives for installing reactive media at greater depths. As published data from various field sites become available on the ability of these techniques to install the reactive media at the desired thickness and continuity, it is likely that deeper aquifers can be accessed in a cost-effective manner.

Ensuring and verifying hydraulic performance are the main design and monitoring challenges during application of PRBs. Aquifer heterogeneities, plume heterogeneities, and seasonal fluctuations in flow are the factors that make the design and monitoring of a PRB's hydraulic performance difficult. Groundwater flow bypass and/or inadequate residence time in the reactive medium have been the main causes of the inability to meet treatment targets reported at some sites. Adequate site characterization, simulation of multiple flow scenarios, and incorporation of adequate safety factors during design are the main ways of achieving satisfactory hydraulic performance.

The economics of a PRB application depend largely on the useful life (longevity) of the reactive media, especially when treating plumes that are expected to persist for several years or decades. Most current geochemical evaluation techniques (e.g., groundwater monitoring, reactive medium coring, and geochemical modeling) have not been able to predict the life of common reactive media, and empirical evidence is lacking given the relatively short history of PRB applications. In the absence of reliable longevity predictions, this document suggests that multiple longevity scenarios be evaluated to place long-term PRB application costs (and benefits) in the context of varying life expectancies of the reactive medium.