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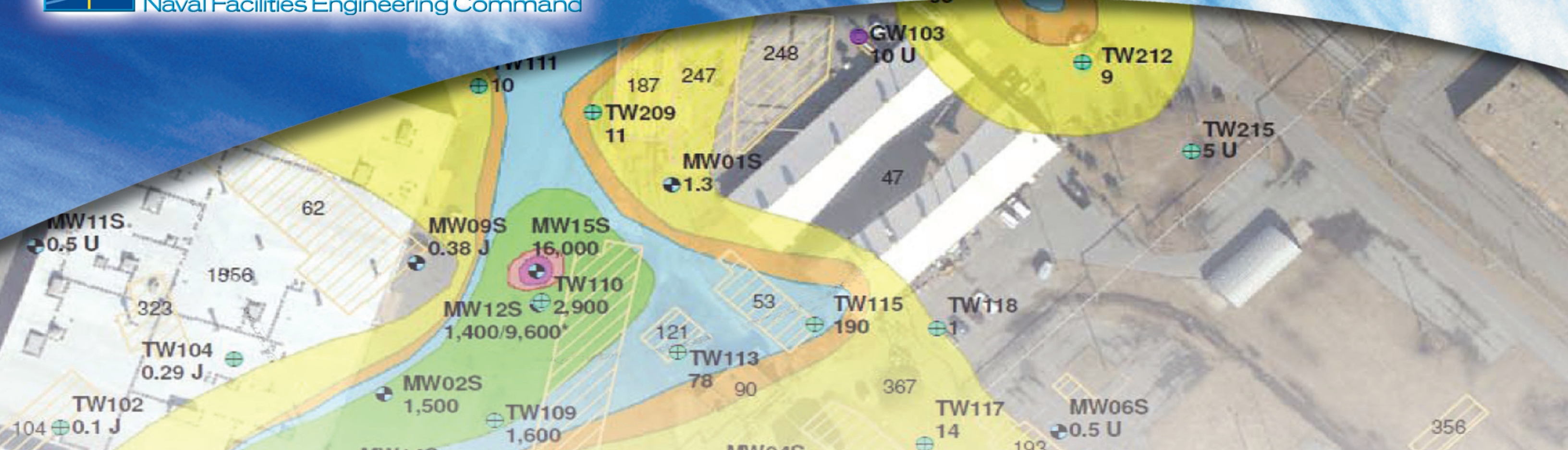

ENVIRONMENTAL RESTORATION

Transitioning from Conventional to Passive Sampling for Groundwater

Objective

The objective of this fact sheet is to provide an overall framework that can be used to assist remedial project managers (RPMs) in designing a transition plan from conventional to passive sampling. It is recommended to use the following step-wise approach: conducting a desktop review; establishing data quality objectives (DQOs); designing and implementing a comparative study; and evaluating the data using statistics and defined acceptance criteria.

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Background

Innovation in groundwater sampling has led to the development of passive sampling techniques that provide unique, cost-saving and sustainable opportunities. In general, passive samplers are deployed, allowed to equilibrate, and retrieved without purging. The three types of passive samplers are: 1) grab samplers, which provide instantaneous samples; 2) diffusion-based samplers, which achieve chemical equilibrium with ambient water through diffusion; and 3) sorption-based samplers, which rely on diffusion and sorption of target analytes onto a sample module. The key advantages and limitations of passive sampling are provided in Table 1.

There are inherent differences in conventional and passive methods. Conventional methods actively pull water from the formation, while passive samplers sample water that enters the well borehole through ambient flow. It is important to demonstrate the equivalence of the methods if RPMs wish to replace conventional sampling with passive sampling.

Desktop Review of Conceptual Site Model and Sampling Strategies

A transition plan should include a desktop review of the conceptual site model (CSM) and sampling strategies. A review of the CSM should include an understanding of site physical and chemical conditions including site lithology, hydrogeology, and contaminant distribution. More information on CSM development can be found in NAVFAC (2010). The current sampling and analysis plan needs to be reviewed for information regarding monitoring well location,

Table 1. Passive Sampler Advantages and Limitations

Advantages	Limitations
• Reduced costs by 50%-80% • Little to no purge water • Little to no decontamination of sampling equipment • Units are often disposable • Minimal field equipment required • Recovery can be rapid for certain sampler types • Useful for vertical profiling	• Limited analytes for diffusion and diffusion/sorption-based samplers • Ambient water movement required • Vertical flow increases uncertainty • Wells with large screens require multiple samplers • Multiple site visits may be required

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analytical requirements, and project DQOs. Well construction details also need to be reviewed during this process. Regulators and other stakeholders should approve of and be involved in the development of the transition plan. In addition, transitioning to passive sampling should be carefully considered in context of the site conditions, especially when a site is very close to meeting closure standards. Changing sampling methods at this time could limit the potential cost-savings of using passive sampling and could prolong site monitoring if the passive results are inconsistent with historical data.

Establishing Data Quality Objectives

Understanding the potential effect of passive sampling on project DQOs is an important first step in developing the passive sampling transition process. DQOs are stated quantity and quality requirements that data must meet in order to be usable for project goals and decisions. DQOs are important in a transition plan for two reasons: (1) original DQOs must be maintained (or properly modified) and (2) DQOs must be established to evaluate the equivalency of passive and conventional sampling.

Table 2 provides considerations for designing DQOs for transition plans following the seven-step process outlined by the U.S. Environmental Protection Agency (EPA) (2006). Most of the steps are similar in all transition plans; however, input decisions, study boundaries, and decision rules can vary between sites and types of passive samplers.

Table 2. Generic Transition Plan DQOs

- **State the Problem:** Transitioning to passive sampling
- **Identify Decisions:** Are passive samples representative? Is passive sampling an adequate substitute for conventional sampling methods?
- **Identify Input Decisions:** Information needed to solve decision questions (i.e., comparative chemical data sets gathered using conventional and passive sampling methods).
- **Define Study Boundaries:** What wells will be sampled at what times? How many samplers will be used?
- **Develop Decision Rules:** What criteria will constitute a successful representative sample?
- **Specify Tolerance of Error Limits:** What are the consequences of making an incorrect decision?
- **Optimize Sampling Design:** Review CSM to ensure a representative number of passive sampling locations are selected to understand potential sampling variables.

Designing and Implementing a Comparative Study

Comparative studies are an effective way to test if passive samplers are providing equivalent samples. Studies can either be concurrent or can evaluate data collected during separate sampling events. Several concurrent transition plans are summarized in Table 3. During a concurrent study, samples are collected from the same monitoring wells using both passive and then conventional sampling methods shortly afterward (Note: it is important to sample using passive methods first).

Table 3. Concurrent Study Methods and Results

Citation	Sample Methods	# of Paired Samples	Result
Parsons, 2005	Grab/LF	20	EQ
EPA, 2008	Grab/LF	13-26	EQ except LL TCE
GeoLogic, 2009	Grab/LF	50	EQ
Church, 2001	Diff/LF	20	EQ
Vroblesky and Peters, 2001	Diff/LF	15	Generally EQ
Tunks et al., 2001	Diff/LF & 3V	9	EQ
Vroblesky et al., 2001	Diff/3V	14	EQ

Data gathered during separate events can also be used to determine equivalence; however, the aspects of these separate data sets must be carefully evaluated to ensure comparisons are appropriate. Data set evaluations should consider: project DQOs, contaminant concentrations, if the site is undergoing active treatment, seasonal variability, and analytical methods. If the data are comparable, the use of separate events can save time and money. However, this practice is likely limited and no documented case studies were noted in the literature.

The number of monitoring wells selected for inclusion in the comparative study should be representative of site conditions, including variations in water depth, chemical concentration, and groundwater elevation. Typically, a greater number of wells are included in the comparative study for heterogeneous sites (i.e., with varying geologic/hydrologic conditions between locations) compared to homogeneous sites. Results are compared using statistical and/or non-statistical methods and are considered equivalent if they are within pre-established acceptance criteria (see next section). Transition plan design can vary widely according to passive sampler type and/or site conditions.

While the transition plan and comparative analysis do require an initial investment (analytical costs can be double or more and equipment and labor costs need to be considered), a passive sampling event typically costs between 50% and 80% less than a traditional sampling event. These cost savings are realized through decreased sampling time (which is minimized even further if samplers for a subsequent monitoring event are emplaced during a sampler collection event) and the reduced need to handle and dispose of investigation derived waste. Cost savings and the potential return on investment should be evaluated as part of the transition plan.

Evaluation Methods and Acceptance Criteria

Acceptance criteria are pre-determined limits that measure the equivalence of the passive sampling method compared to the current conventional sampling method. Evaluation methods can be non-statistical (e.g., 1:1 graphical comparisons) or statistical, and are generally best when they are based upon a defensible method with rigorous acceptance criteria.

Table 4 provides descriptions of various statistical analyses that can be used. The most common method used for comparison in the studies outlined in Table 3 was relative percent difference (RPD) with acceptance criteria of ±10%. This relatively simple method allows for rapid assessment with a minimal amount of data and statistical expertise. However, a more rigorous statistical approach may be warranted based upon the nature and type of data to be collected. A statistician should be consulted regarding the applicability and advantages or limitations of a given statistical test under consideration.

Table 4. Statistical Tests

Test	Sample Type	Distribution	Description
Paired T-Test	Paired	Normal	Tests if average of the differences is approximately zero.
Two One-Sided Test (TOST)	Paired	Non-para.	Two part procedure designed to: 1) demonstrate that the intercept of the regression line equals zero and 2) demonstrate that the slope equals one. TOST controls the probability of a false positive.
Wilcoxin Sign Ranked	Paired	Non-para. (symmetric)	Tests if median of the differences is approximately zero.
Fisher Sign	Paired	Non-para.	Tests if median of the differences is approximately zero.
Two-Sample T-Test	Non-paired	Normal	Determines if the averages of two sample populations are significantly different.
Mann-Whitney Rank Sum	Non-paired	Non-para.	Determines if the medians of two sample populations are significantly different.

References

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