Final copy as submitted to *Groundwater* for publication as:
Day-Lewis, F.D., Johnson, C.D., Slater, L.D., Robinson, J.L., Williams, J.H., Boyden, C.L., Werkema, D., and Lane, J.W., 2016, A Fractured Rock Geophysical Toolbox Method Selection Tool: Groundwater. doi:10.1111/gwat.12397

Title: A Fractured Rock Geophysical Toolbox Method Selection Tool

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Conflict of interest: None

Key words: geophysics, hydrogeophysics, fractured rock, field methods, characterization

Article impact statement: A spreadsheet-based software is presented to identify methods for use at fractured-rock sites, based on project goals and site description

Geophysical technologies have the potential to improve site characterization and monitoring in fractured rock, but the appropriate and effective application of geophysics at a particular site strongly depends on project goals (e.g., identifying discrete fractures) and site characteristics (e.g., lithology). No method works at every site or for every goal. New approaches are needed to identify a set of geophysical methods appropriate to specific project goals and site conditions while considering budget constraints. To this end, we present the Excel-based Fractured-Rock Geophysical Toolbox Method Selection Tool (FRGT-MST). We envision the FRGT-MST (1) equipping remediation professionals with a tool to understand what is likely to be realistic and cost effective when contracting geophysical services, and (2) reducing applications of geophysics with unrealistic objectives or where methods are likely to fail.

The FRGT-MST is an Excel-based tool for identification of geophysical methods most likely to be appropriate for project goals and site conditions. The ‘toolbox’ comprises 30 surface, cross-hole, and borehole geophysical methods. Additionally, hydrologic tests appropriate to fractured rock are included. The user enters information in two tables for site parameters and project goals. Based on user entry, a third table is populated with indicators for which methods support specified goals and are feasible at the site. Worksheet appendices provide detailed information on various methods.

Conditional formatting is used throughout the spreadsheet, coded based on rules of thumb and common-sense constraints for experiment design. For example: (1) borehole optical televiewer requires that borehole fluids are not opaque; (2) borehole ground-penetrating radar (GPR) requires that boreholes are open or PVC-cased; and (3) cross-hole methods generally require well aspect ratio (vertical:horizontal imaging area) >1.5 for good resolution. Conditional formatting also indicates which methods support specified project goals.

As distributed, the FRGT-MST spreadsheet reflects application to the U.S. Geological Survey (USGS) research site at the Naval Air Warfare Center, West Trenton, New Jersey. The results of the FRGT-MST analysis correctly indicate that borehole and cross-hole radar methods are unlikely to work at the site, whereas borehole gamma and electromagnetic methods are likely to work and also support project goals. These recommendations are based on relatively simple site geologic information, in addition to the project goals.

We encourage users to examine the spreadsheet’s equations to gain insight into experiment design. We stress that the FRGT-MST is meant to be a simple tool. Like any tool, its capabilities are limited. The results of the FRGT-MST are not the official recommendations of USGS, Rutgers, or EPA. The USGS, Rutgers University, and EPA provide no warranty, expressed or implied, as to the correctness of the furnished software or the suitability for any purpose. The software has been tested, but as with any software, there could be undetected errors. Users who find errors are asked to report them to the first author. The spreadsheet is available from http://water.usgs.gov/ogw/bgas/frgt.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix A. Supporting Information: Explanation and examples from the FRGT-MST spreadsheet

Please note: "Supporting Information" is generally not peer reviewed. Wiley-Blackwell is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing materials) should be directed to the corresponding author.

Acknowledgment

This work was supported by ESTCP grant ER-201118, the U.S. Geological Survey (USGS) Toxic Substances Hydrology Program, USGS Office of Groundwater, and the U.S. Environmental Protection Agency (EPA) through its Office of Research and Development via agreement DW-14-92381701 to the USGS. This software tool has been subjected to USGS and EPA review and approved for publication. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Appendix A. Supporting Information

The FRGT-MST comprises Excel worksheets including (1) an introduction worksheet (**Figure S1**), (2) the FRGT MATRIX worksheet, where users input site and project information and results are generated (**Figure S2**), and (3) 30 worksheet appendices (**Figure S3**), which are hyperlinked from the FGRT MATRIX and provide information on the methods comprising the fractured rock geophysical toolbox. The FRGT-MST spreadsheet can be downloaded from http://water.usgs.gov/ogw/bgas/frgt/.

Figure S1. FRGT INTRODUCTION worksheet which provides background information and instructions for the use of the FRGT-MST.

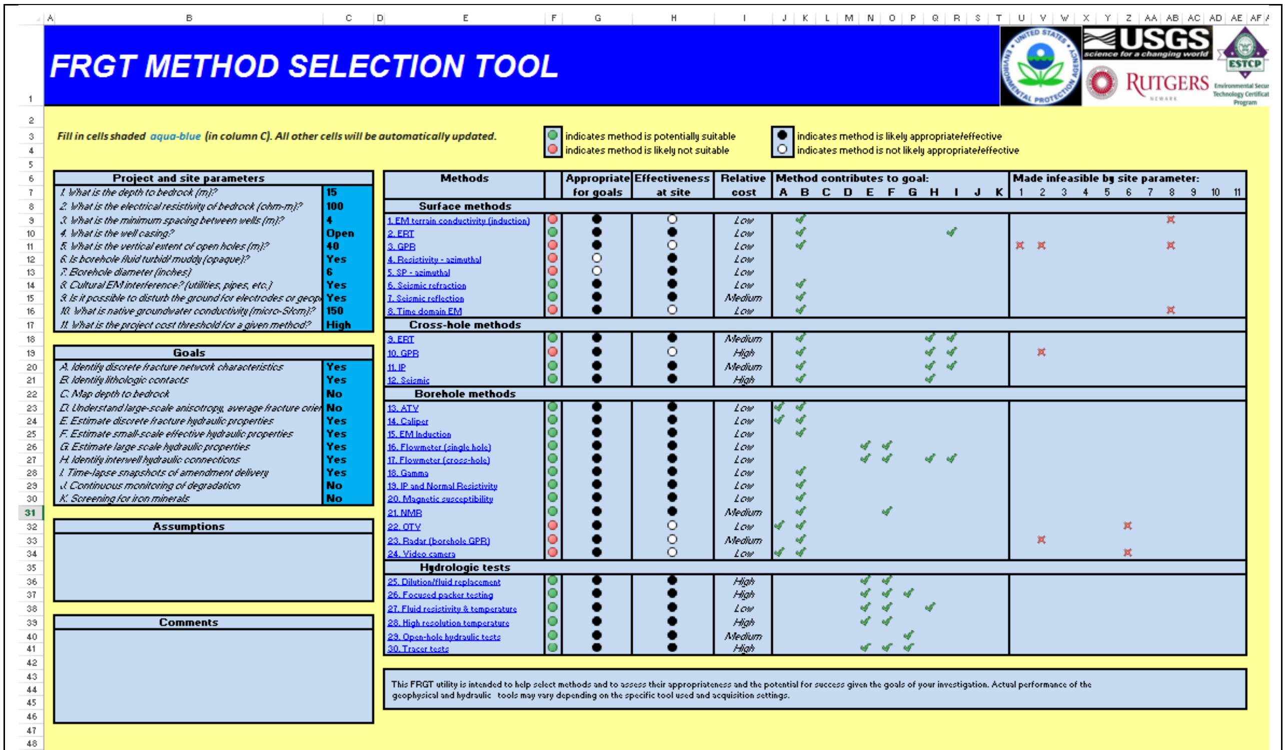

Figure S2. FRGT MATRIX worksheet, where the user enters project/site parameters and goals and the output table is generated showing which methods are likely feasible for the site and appropriate to specified goals. Methods satisfying both feasibility and appropriateness conditions are indicated by 'green lights' in column F, whereas methods that are infeasible or inappropriate are indicated by 'red lights.'

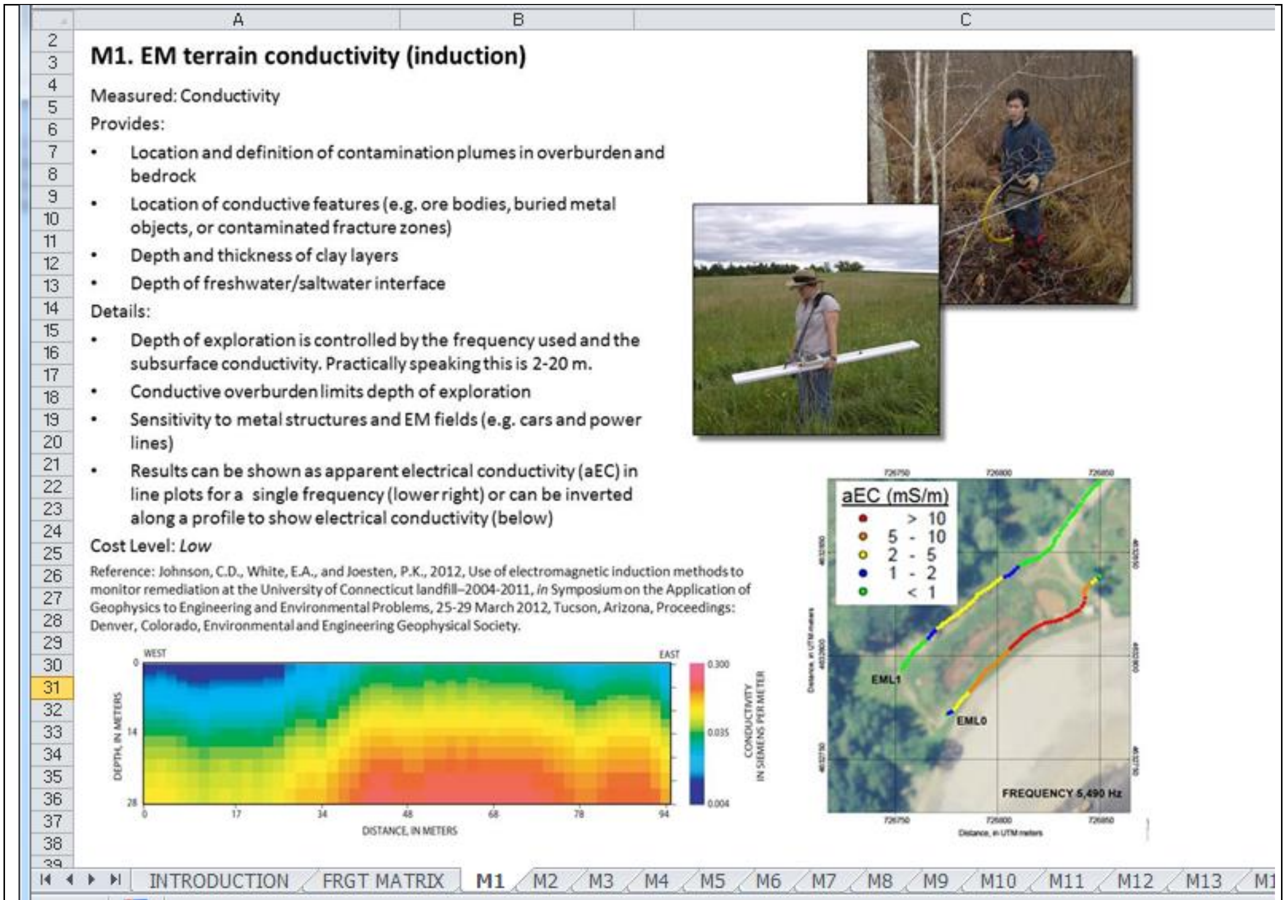

Figure S3. Example FRGT worksheet appendix, M1, providing an overview of surface-based electromagnetic terrain conductivity.