Actionable Science for Communities

Measuring Contaminant Mass Flux and Groundwater Velocity in a Fractured Rock Aquifer Using Passive Flux Meters – SHC 3.61.2

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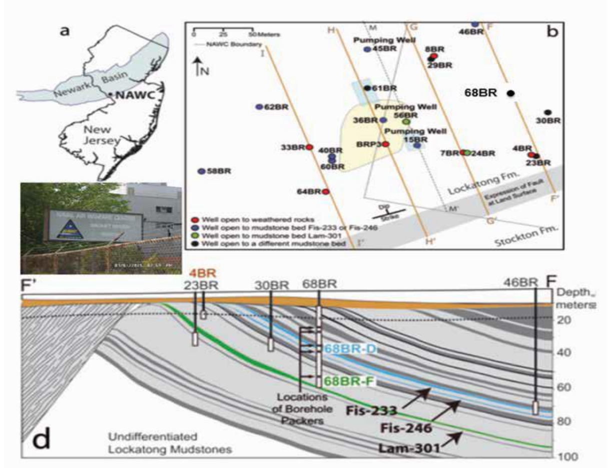
Purpose/Utility of Research

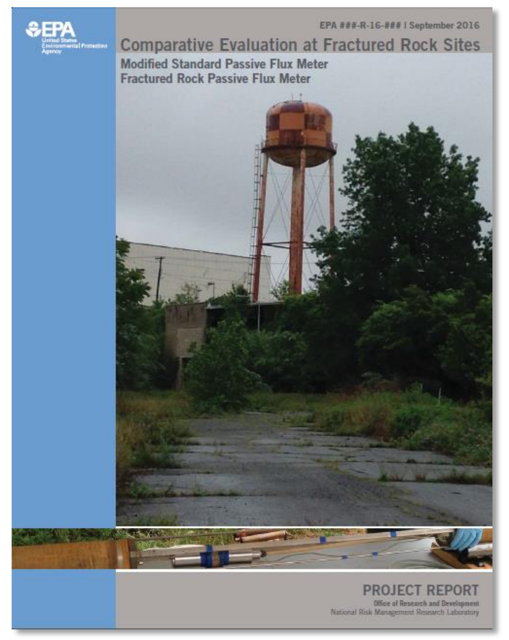
Proper site characterization is critical in developing accurate conceptual site models and in achieving restoration at all contaminated sites. Contaminated fractured rock sites pose a special challenge given the high cost of site investigations and a lack of understanding of the processes that control fate and transport in these complex environments. Available investigative methods cannot directly measure groundwater flow velocity and contaminant mass flux in fractured bedrock units, two parameters that are important in understanding the behavior of contaminants in the subsurface, assessing risk, and designing a successful remediation approach. This project researched the ability of a tool under development, the fractured rock passive flux meter (FRPFM), in measuring groundwater flow velocity and mass flux in a fractured bedrock setting and compared the results to currently available technology.

Application & Translation



The study was conducted in the contaminated sedimentary rock aquifer underlying the USGS Naval Air Warfare Center (NAWC) Research Site, in West Trenton, New Jersey.

The EPA document (under review) ***Comparative Evaluation at Fractured Rock Sites, Modified Standard Passive Flux Meter, Fractured Rock Passive Flux Meter*** summarizes the results of the study.



Highlights

- The study was designed to assess the ability of an experimental tool – a fractured rock passive flux meter (FRPFM) - to measure groundwater specific discharge and mass flux in a fractured bedrock setting, and compare and contrast the results with results obtained using investigative methods typically deployed at Superfund sites to characterize fractured bedrock hydrogeology.
- The FRPFM offers a unique combination of capabilities in a closed borehole, thereby reducing the chances of vertical borehole flow and cross contamination that can occur during open borehole tests.
- The tool can locate active or flowing fractures, identify individual fracture orientation (strike, dip, and dip azimuth), and determine cumulative groundwater flux and flow direction.

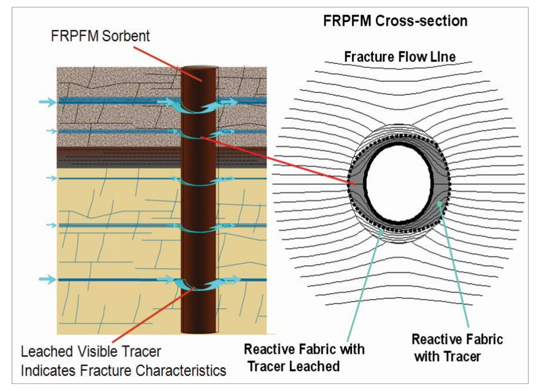


Figure 1. A profile view of an unscreened borehole containing an FRPFM

Figure 1 illustrates an idealized profile view of an FRPFM intercepting fractures and matrix fluid flow over a given borehole depth. **Figure 2** represents a horizontal cross-sectional view of the same FRPFM in a borehole. Both figures show that the device is composed of an impermeable inflatable core, and a permeable reactive sorbent layer (or fabric) sandwiched between the core and the inner surface of the borehole. The sorbent is a permeable fabric derived from activated carbon, ion exchange resin, or other relevant sorbents. Once inserted, the device is inflated causing it to conform to the shape of the borehole. Exposing the FRPFM to flowing groundwater for a specified duration gradually elutes tracer from the sorbent layer and produces a residual distribution of tracers.

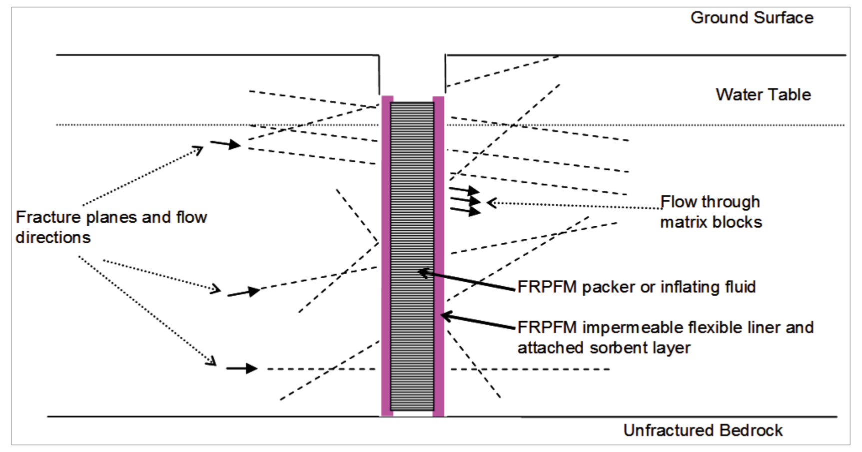


Figure 2. Horizontal cross-section of an FRPFM in a borehole.

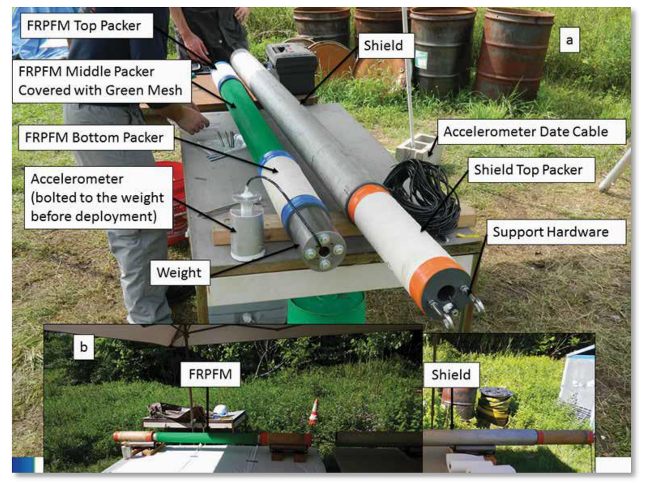


Figure 3. FRPFM Components

Figure 4. FRPFM Retrieval and Sampling
a) Shield and FRPFM at the surface. **b)** FRPFM removed from the shield. **c)** Felt and fabric pulled back up into position before removing them from the FRPFM. **d)** Felt laid out after removal from the FRPFM, note the tears in the felt. **e)** Measuring the felt prior to cutting into strips for sample collection. **f)** Cutting felt into strips and placing them into sample containers.

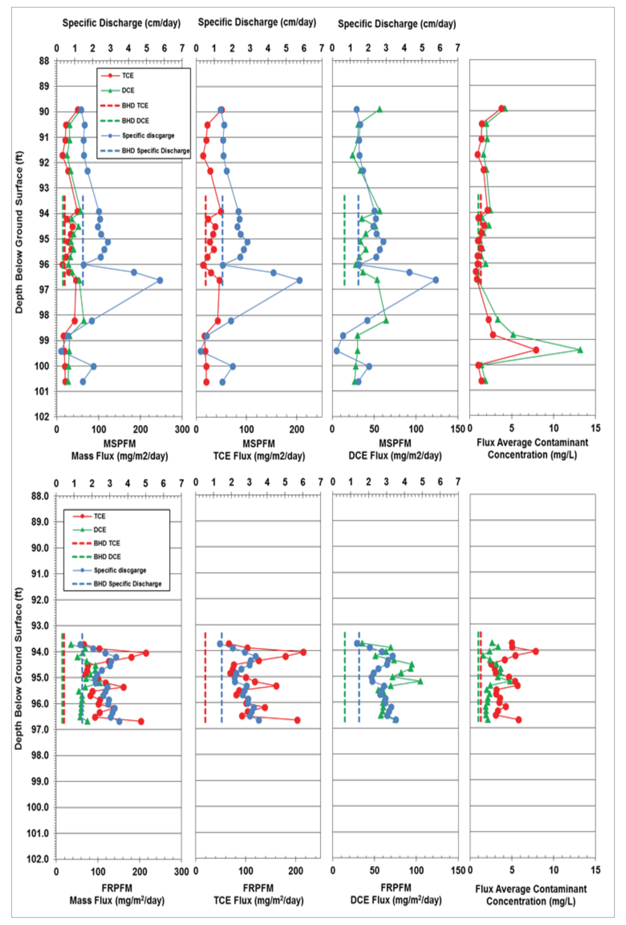


Figure 6. Comparison of FRPFM results with those of a borehole dilution test (BHD) and a modified version of a commercially available passive flux meter (MSPFM).

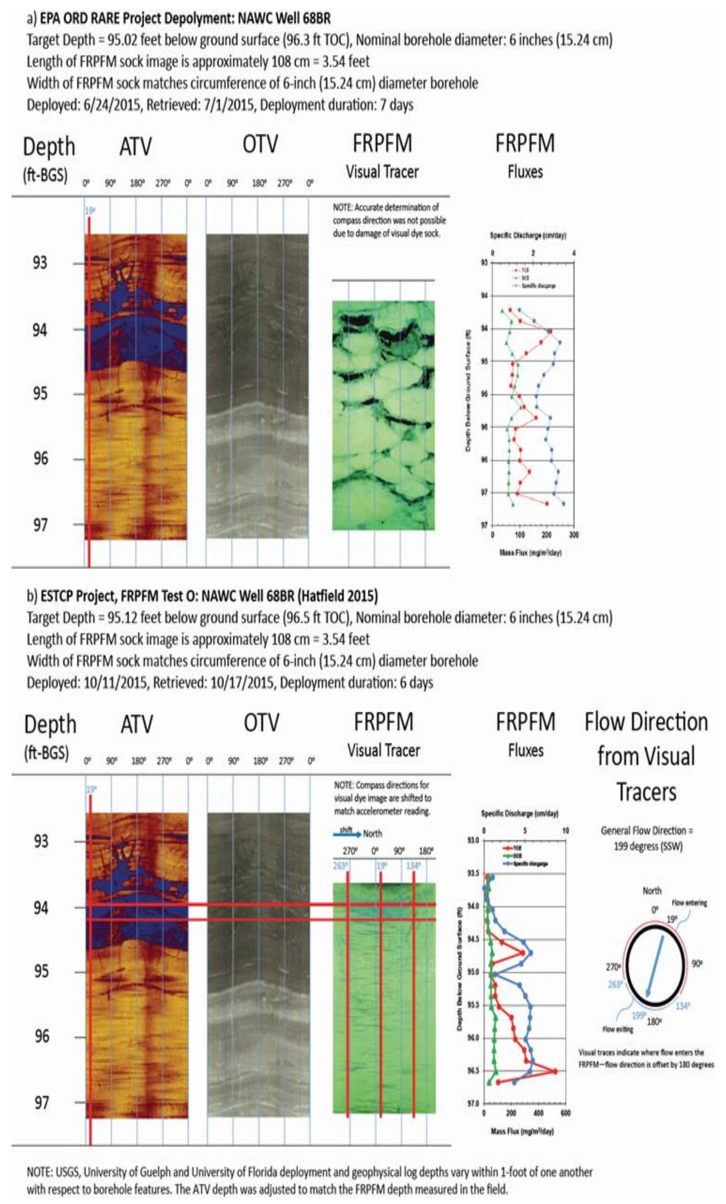


Figure 5. Visual inspection of the FRPFM gives estimates of the number of active flowing fracture locations and individual fracture orientations.

Intended End Users

This research addresses a Region 2 science and research priority - *develop cost-effective investigation and remediation techniques for contamination in fractured rock*. This work is applicable to a wider universe of sites given the large number of contaminated rock sites that exist in the rest of the U.S. The project was funded by EPA ORD's Regional Applied Research Effort (RARE) Program. RARE projects address a wide array of environmental science issues critical to ORD's regional partners.

Lessons Learned

- In practice it was difficult to determine if the FRPFM was fully retrieved into the shield before it was removed from the well. As shown in Figure 4a and 2-8b, a rock fragment was dislodged during deflation of the core and wedged between the FRPFM and shield, which caused the fabric sleeve and felt to be dragged down and bunch up at the bottom of the middle packer as the FRPFM was raised into the shield. Both the fabric and felt were torn in places due to contact with the rock fragment and borehole wall.
- The University of Florida analyzed the fabric sleeve from the FRPFM at their facility to try to gather data from it to determine fracture frequency, to identify flowing fractures, and to determine groundwater flow direction. UF reported that because the fabric sock was damaged during retrieval it was not possible to evaluate fracture frequency, flow, or flow direction.
- The FRPFM, compared to the other methods, was the most complex method to prepare, deploy, retrieve, and sample. The FRPFM, as presently configured, is not practical to use widely at this time.
- Further development of the FRPFM is needed. Adapting it to a flexible liner technology to simplify deployment and retrieval is suggested.