

Preferred Boreholes

for

Use with

*FLUTe* Flexible Liners

**Preferred Boreholes for FLUTe Liners**

FLUTe systems have been installed in many HQ (3.78”) and PQ (4.85”) core holes. However, those are not optimum boreholes for several reasons:

1. Core holes are ~3x the cost of air rotary holes.
2. It is easier to install FLUTe systems in 6” holes than 4” holes (see below).
3. Core hole drilling produces more cross connection of contaminants than air rotary drilling:
   1. Drilling fluids are recirculated in core drilling, not in air rotary.
   2. The holes are left open overnight during the long time needed to core a hole (e.g., 3 days for a 150 ft hole)
4. FLUTe methods provide better results in boreholes with less cross connection.
5. Core holes tend to clog fractures with cuttings more than air rotary drilling and therefore may require more aggressive well development to clear the fractures. (see below for details).

The above generalizations fit the FLUTe experience. It is difficult to find explicit published measurements to support the generalizations, but transmissivity profiles in both kinds of holes and recent measurements with FACT methods lend support to the concepts. The recirculation of drilling fluids is not the best method to avoid cross connection if the drilling fluids become contaminated while drilling through contaminated formations. Nor is it considered good practice to leave boreholes open overnight for several nights during the drilling operation if one is to avoid the spread of contamination such as DNAPL.

Given the cost difference and the cross contamination differences, why is core drilling so common? The obvious answer is the desire to look at the core for geologic information or to analyze the core for contamination. Looking at the core is said to help in identifying open fractures and to identify NAPL. However, there is a large body of experience that the fractures in the core may have been developed in the coring process or fractured intervals lost in the highly altered intervals of weak rock and poor core recovery. Observing the fractures does not determine the relative conductivity/transmissivity of the fractured interval. Nor does absence of NAPL in the fractures in core prove the fractures were not full of NAPL in-situ. Frequent NAPL FLUTe measurements in core-holes have provided graphic evidence of DNAPL (e.g., TCE) in fractures that were not seen to contain DNAPL in the core.

Analysis of the core near fractures does sometimes show evidence of contaminants in the matrix. However, the absence of detectable contaminants in the matrix is not proof that there is no contamination in the fracture water flow (D. Goode, et al. 2014)

**Is the core drilling process really three times as expensive as air rotary?**

Ask your driller for the cost of the two methods for a 150 ft hole with HQ core and using 6” air rotary. Include mobilization costs, and overnight housing costs. The total cost is probably more than 3X air rotary drilling.

**The difference in drilling fluid effects**

Why is the drilling fluid recirculated? It reduces the water requirements and the IDW that would be produced by continually supplying clean water to flush the cuttings to the surface and to clear and cool the bit. Only if circulation is lost and the water is not returned to the surface, is new water added to the system during core drilling. The pressure of the core drilling fluids in the narrow annular space outside the drill pipe is necessarily higher than the head in the formation in order to drive the fluid and cuttings to the surface. There is an expected loss of the drill fluids and cuttings to the formation, unless the fractures are already sealed by the cuttings.

In contrast, the air rotary procedure generally uses air to carry the cuttings to the surface. If drilling below the water table, water in the formation is drawn into the borehole much like air lift pumping and that water is carried to the surface with the cuttings. Sometimes, that can produce a very large volume of contaminated water that must be treated. However, that water flow is carried to the surface in a relatively large annular space compared to the core water flow. The driving pressure in the borehole is often less than the head in the formation and only rarely is there a loss of circulation of cuttings to the surface. Such a loss of circulation must flow into the formation. But the lower pressure in the borehole tends to cause a general inflow condition of water into the borehole rather than out of the borehole. This is called an “underbalance drilling condition” preferred for minimal mud cake (Robert J. Sterrett). The cuttings are therefore not driven into the fractures as is the case with core drilling’s fluid pressure in the borehole.

The comments about the superiority of air rotary drilling also applies to hammer bit drilling with air drilling.

**Effects of core drilling on other aspects of flexible liner use**

**Installation**

The installation of a flexible liner is much easier in a 6 inch hole than in a 4 inch hole (e.g., HQ core hole). The drag of the liner in the hole is less, the pressure required to evert the liner is less and so it is less likely therefore to require an extension of the surface casing to install a flexible liner in a 6 inch hole. It is noteworthy that the price of the 6 inch liner systems are the same as for 4 inch systems for both blank FLUTe liners and Water FLUTe liners.

The quality of transmissivity profiling data is better for larger boreholes due to reduced drag of the liner on the borehole wall and the larger towing force available with a larger diameter borehole.

**The number of sampling intervals**

For the Water FLUTe system, or the Shallow Water FLUTe multi-level systems, more than twice as many sampling intervals can be installed in a 6 inch hole than a 4 inch hole and even more in an 8 inch hole. The simple reason is the difference in the borehole cross section.

This limitation on the number of sampling intervals extends to other MLS systems. The hole size also affects the difficulty of reliable emplacement of the traditional backfill materials around a casing.

**The effects of cross connection**

The FLUTe FACT system ([www.flut.com](http://www.flut.com)) wicks contamination from the pore space of the formation and from fractures. Cross connection in the borehole can provide a contamination of the borehole wall material and of the fracture water that will provide at least a background level of contamination in the activated carbon felt that can make it less sensitive to the contamination gained in the 2 week exposure of the carbon to the fracture and pore water contamination. Whereas the FACT system has been shown to be effective in detection of the contamination in the pore space as seen in core, it is not prudent to allow cross connection to occur for any significant time. The overnight open hole common for core drilling and the recirculation of the drilling fluids is not good for any measurement of contaminant distribution. The effect of the recirculation of contaminated drilling fluids on the core can be significant for high levels of contamination or for more porous and permeable core unless the outer portion of the core is sufficiently removed.

**What can be done to reduce the disadvantages of not obtaining core?**

Coring of a few boreholes can be useful to obtain the geologic structure. If those boreholes are not the primary source of contaminant distribution information, the cross connection is less significant. Geophysical measurements can be done in those boreholes for the geologic information available and to correlate the geophysical measurements with the core observations. In other boreholes not cored, the geophysical measurements such as ATV and OTV can detect fracture orientation, geologic formation color differences, and other characteristics related to the geologic structure and bedding orientation that replaces the information not available from fewer core holes.

As noted in Sterling, et al, cross connection can taint the subsequent water samples obtained from cross connected holes so that use of the core holes is reduced if cross connection is allowed. In that respect, the contaminant distribution in water samples obtained from boreholes with less cross connection is more useful. It is also noteworthy that the measurements of contamination in core of the matrix is not relevant to the current contamination existent in fractures. D. Goode, et al has noted that shallow fractures which probably contained the initial DNAPL at the NAWC site in New Jersey were apparently subsequently flushed of the DNAPL by surface infiltration and currently contained relatively low levels of DNAPL while the matrix near those fractures contained relatively higher levels of DNAPL. The matrix contamination is more relevant to the remediation process and the “rebound” observed after a remediation procedure. In light of that information, the current contamination in fracture water is of good use as a tracer of ground water flow and contaminant transport, or flux, than is the distribution of the matrix contamination. To the extent that cross connection disrupts the normal contaminant migration, it reduces the value of fracture flow samples as a measure of the natural flux of contamination.

**Arguments in favor of core drilling**

It has been said that the cored borehole wall is better for sealing of the borehole with packers. However, the flexible liner conforms to the borehole wall so well as to provide a sufficient seal of the borehole (see the videos of the interior of liners on the web site [www.flut.com](http://www.flut.com) and in the paper by J. A. Cherry, et al 2007). Bypass of the packer in the formation can be more important than the packer seal against the borehole wall.

Another objection voiced is that ATV and OTV logs cannot be done satisfactorily in air rotary drilled boreholes. However, there are many examples of excellent ATV and OTV logs in FLUTe files as provided by customers for comparison to FLUTe transmissivity profiles.

**Conclusion**

Air rotary drilling is the preferred form of drilling for use of FLUTe flexible liner methods for the reasons:

1. Rapid method of drilling at much lower cost
2. Provides less cross connection of contamination during the drilling process
3. Produces less clogging of fractures with cuttings
4. Provides larger diameter boreholes than core holes
   1. For easier installation of flexible liners
   2. For more sampling intervals of the Water FLUTe multi-level systems
   3. Reduces liner drag influence on transmissivity profiling measurements.

**References**

Cherry, J. A., Parker, B. L. and C. Keller, “A new depth-discrete multilevel monitoring approach for fractured rock,” **Ground Water Monitoring and Remediation**, vol. 27, no. 2, pp. 57-70, 2007.

Keller, C. E., J. A. Cherry, B. L. Parker, “New Method for Continuous Transmissivity Profiling in Fractured Rock,”, **Groundwater, 52(3), 352-367,** 2014.

Goode, D. J., T. E. Imbrigiotta, P. J. Lacombe, “High-resolution delineation of chlorinated volatile organic compounds in a dipping fractured mudstone: Depth-and strata-dependent spatial variability from rock-core sampling,” **Journal of Contaminant Hydrology**, vol. 171 (2014) 1-11.

Sterling, S.N., B.L. Parker, J.A. Cherry, J.H. Williams, J.W. Lane Jr., and F.P. Haeni. 2005. Vertical cross contamination of trichloroethylene in a borehole in fractured sandstone. **Ground Water** 43, no. 4: 557-573.

Sterrett, R. J., editor , **Ground Water and Wells**, Third edition, 2007