# Appendix F. Geophysical Testing of Boreholes

## F.1—Borehole Flow Meter Test

Borehole geophysical information was collected in the City of Mosier number 3 well (454033121230101) to identify the depth of permeable productive zones, quantify the contribution from these zones, estimate vertical flow in the borehole between permeable zones, and evaluate the integrity of the well seal and loss of water from the borehole, if any. At the well, groundwater is under pressure and naturally flows from the well unless the well is capped, or shut in. Based on drillers' reports and analysis of cuttings, the well penetrates Pomona basalt, the Selah interbed, Priest Rapids basalt, and enters the top of the Frenchman Springs basalt. Within the Pomona basalt, a potentially permeable zone, identified as broken basalt on the driller report, occurs at a depth of 86 ft (fig. F1). A sedimentary interbed from a depth of 230 to 270 ft separates the Pomona basalt from the underlying Priest Rapids basalt. Based on the driller's description of cracked or broken (fractured) basalt, potentially permeable zones occur at depths of 285, 310, and 368 ft in the Priest Rapids, at 390 and 398 ft at the top of the Frenchman Springs. Although fractured zones of basalt typically are associated with enlargements of the borehole diameter, the borehole caliper log shows little variation in borehole diameter below 275 ft in depth (fig. F1).

Steel casing, with hydraulic seals, extends from land surface to 275 ft in depth, which is designed to isolate the Pomona basalt and the sedimentary interbed from the well. Below a depth of 275 ft, the well is an open borehole, which allows water to enter and leave the borehole to the Priest Rapids and Frenchman Springs basalt and associated interbed.

Imagery of borehole conditions from a video camera confirmed the depths of potentially permeable zones identified as cracked or broken basalt in the drillers' reports. The video images also indicated upward flow of water in the borehole at the base of the casing under shut-in conditions suggesting that water is flowing outside the casing.

Measurements of vertical flow in the borehole with a flowmeter (fig. F1) indicate maximum upward flow at the base of the casing and an abrupt decline in flow in the cased area of the well under shut-in and flowing conditions. The difference in flow below the casing and in the casing is the groundwater flowing upward outside of the casing between the borehole and the casing. Productive permeable zones, characterized by increases in vertical flow in the borehole from 375 to 400 ft in depth and from 300 to 325 ft in depth, represent intervals where groundwater flows from the basalt aquifer system to the borehole. The increase in flow in the borehole is greater from 375 to 400 ft in depth than from 300 to 325 ft in depth, indicating that the deeper interval contributes more water to the borehole.

Fluid temperature and resistivity logs provide information on changes of fluid properties with depth. These changes can be associated with changes in flow into or out of the borehole. Changes in fluid properties at 375 and 310 ft in depth correspond to productive zones in the flowmeter log where water enters the borehole.

Under shut-in conditions, there is no vertical flow in the cased area of the well. Under flowing conditions, water was measured flowing from the well at 55 gal/min. By calibrating the response of the flowmeter to this measured flow, flow in the borehole and flow from the borehole to the annular space can be estimated. Under shut-in conditions, 70 gal/min of upward flow is measured immediately below the casing at 275 ft in depth. Because there is no measured flow in the casing, all of the 70 gal/min of flow exits the borehole at the bottom of the casing. Under flowing conditions, upward flow is 190 gal/min immediately below the casing and 55 gal/min in the casing. The difference between these measurements (135 gal/min) is the net flow leaking outside the cased area of the well. This approach probably represents estimates of maximum flow in the uncased borehole and exiting the borehole.

## F.2—Temperature Probe Screening Tool

A miniature pressure and temperature probe was tested as a tool for pre-screening potentially commingling wells for future geophysical logging. Geothermal gradients in the proximal Hood Basin are typically 1–2 °C per 100 ft (Grady, 1983), and it was assumed that wells with no commingling would have similar thermal gradients in the well water. If there is significant commingling, then isothermal zones will occur in the region of flow through the borehole.

The City of Mosier number 3 well (454033121230101) exhibits this behavior with temperature varying in zones of groundwater flow contribution to intra-borehole flow, and with relatively constant temperature in zones of constant borehole flow (fig. F1). Even though borehole flow measurements are zero in the well casing during shut-in conditions, flow continues outside the casing, and the isothermal signature persists between approximately 100 and 300 ft. This is the result of thermal conduction into the stagnant water in the well casing from outside the casing where intra-borehole flow was occurring. The temperature log indicates that near 90 ft depth, up-borehole flow is exiting the system, possibly through the "broken grey basalt" recorded on the well construction report between 86 and 87 ft.

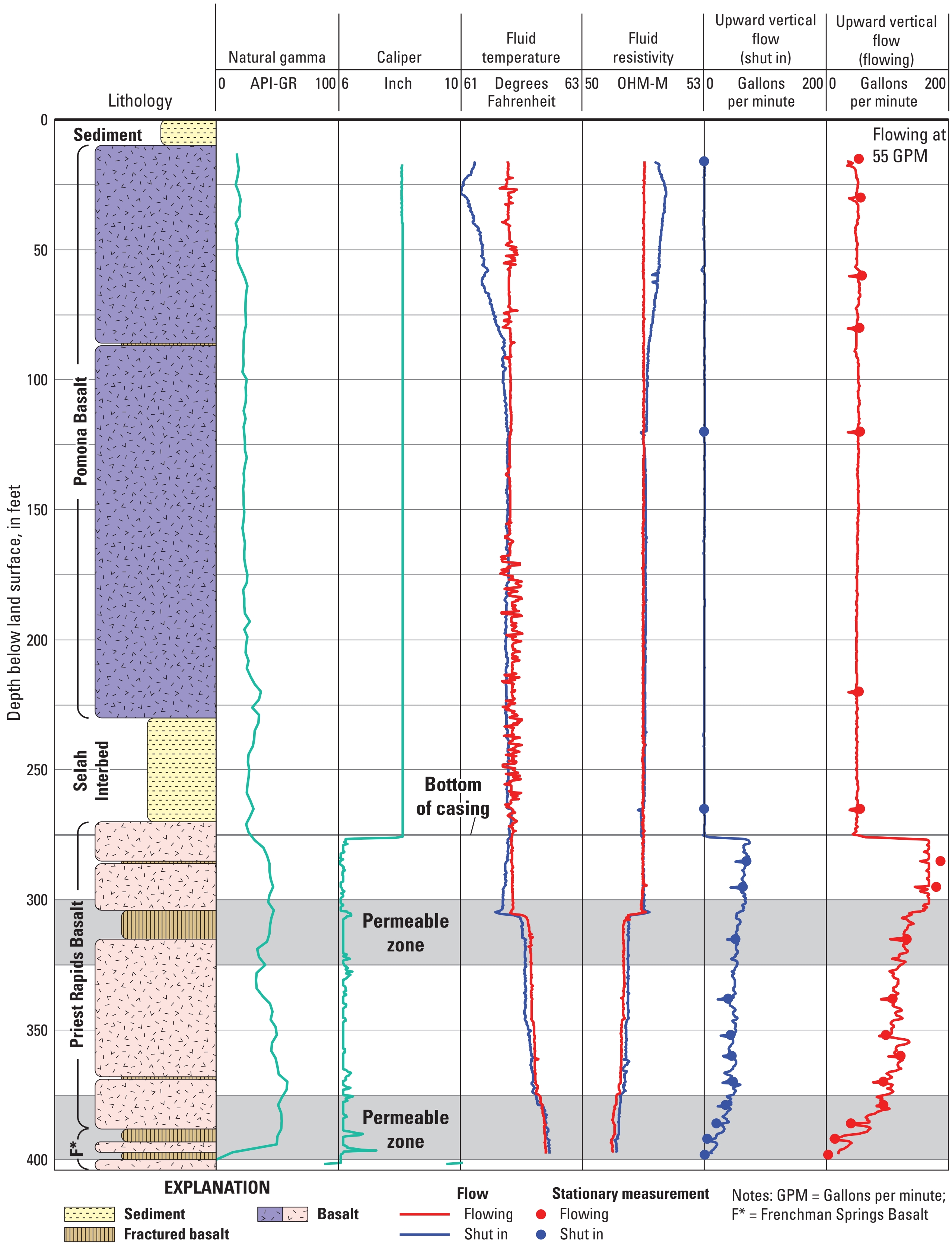


**Figure F1.** Results of borehole geophysical logging.

The pressure and temperature probe tested as a screening tool was a Data Storage Tag micro Temperature and Depth (DST micro TD) purchased from Star-Oddi. This device is self contained and measures 8.3 mm by 25.4 mm. The device has a rated maximum depth of 150 m with a resolution of 12 cm. The rated temperature range was -1 to +40 °C with a resolution of 0.032 °C. The probe was attached to a water level probe and lowered into wells past pumps and pump linkages if possible.

The probe was tested on seven wells considered to have a relatively high potential to commingle. Results were mixed with the probe hanging up in three of the wells, although some useful data were collected on one of these wells before getting stuck. The temperature signature indicated potential commingling in four wells, indicating the screening tool is viable for use as a rapid screening tool for wells with sufficient clearance to allow lowering the probe.