## Case of the persistent sink-hole

Ted was an ardent hiker and overjoyed to be offered a job as an apprentice operator at a new powerplant being built in the mountain range near his home. Water from an upstream storage dam was to be channeled into a sidehill canal built across a mountain scree slope to an intake after which it would drop 340 meters in a tunnel to the powerhouse. Shortly after commissioning, the sidehill canal washed out with damage limited to some erosion of the stream bed below the canal. However the repair required several months, and with no plant to operate, Ted spent his time observing the repair work.

Failure of the canal was attributed to an inadequate seal between the clay blanket lining the canal and a rock nose which crossed the canal at invert level. In the repair, the blanket thickness was increased and also the overlap with the rock. Ted joined the survey crew and took a keen interest in the work, particularly the placement of the clay blanket. His interest was noted by the geotechnical engineer, who realized that it would be useful to have a plant operator with some knowledge of the repair, to keep an eye on the performance of the canal. Ted was given a short course on canal inspection and in particular, was instructed to look out for "sink holes" in the blanket - small holes of less than about one centimeter in diameter where water could be observed flowing down and out through the blanket. If left unrepaired, the sinkholes could gradually increase in size and precipitate another washout.

The repairs were completed and the plant resumed operation. Once a month, Ted would walk up and down the two kilometer long canal looking for sinkholes. However, he soon realized that detection of any sinkholes from the bank was difficult if not impossible. The problem was solved by building a box with a glass bottom, through which the canal foundation could be observed from a small rowboat. When sinkholes were found, he noted their location and then dumped a mixture of fine sand and clay onto the hole until flow ceased. Over the years, he kept records and knew where sinkholes were most likely to occur. About every five years, a geotechnical engineer would return to inspect the canal and discuss the continuing "sinkhole sealing" with Ted. Over time, the inspection method improved to an outboard powered aluminum boat with a meter square glass viewing window in the bottom, a plastic roof and side screens to reduce glare and improve visibility through the glass, bins for sand and clay fill, and a canvas trunk on an aluminum guide pole to precisely place material on the sinkhole.

Since the canal could not be inspected in winter due to an ice cover, the spring inspection was most important, precisely the time when numerous underground springs would appear on the scree slope below the canal. For this reason, attempts to monitor leakage from the canal proved ineffective, due to the high porosity if the scree and the volume of melt water flowing below the canal from snow above the canal. Ted's work kept the canal operational for over thirty years until he retired. Unfortunately, his retirement coincided with a change in plant operations, with many of the operators being replaced by automatic remote controls and a roving repair crew responsible for several plants in the river basin. The new crew was not as dedicated as Ted, not having witnessed the consequences of a washout, and hence not fully realizing the importance of early sinkhole detection and repair. Some two years after Ted retired, the canal again washed out. This time, the repairs were much more extensive, included an enlargement of the canal section to reduce flow velocity, two filter zones under the clay blanket and a fine sand cover to reduce erosion. Canal inspection was improved with semi-annual underwater traverses by qualified geotechnical frogmen, during which flow velocity is reduced, allowing the frogmen to drift slowly down the canal with the current, in addition to the monthly glass bottomed boat inspections.

**Lessons Learned.**

Many powerplants have some idiosyncrasy which is known to the initial operators, such as leakage which requires continuous monitoring or limitations on operating at certain turbine gate openings under certain heads. Often these limitations and their consequences are not passed on to new operators when there is a change in staff or ownership. The new operators, unaware of the plant peculiarity, may disregard the operating limitations with disastrous results. It is the responsibility of the plant owners to ensure that knowledge of any plant idiosyncrasies are passed on to new operating staff.