Introduction and Use of the Borehole Camera in Mining-Related Investigations

U.S. Office of Surface Mining Reclamation and Enforcement
1/16/2013

Background: One of the more valuable tools used in mining-related hydrologic investigations can be a borehole camera. It can dispel to some degree the old adage that you cannot see under the ground. This instrument permits viewing and video recording of boreholes, domestic wells, mine shafts, open sink holes and other vertically accessible subsurface avenues.

There are numerous makes and models of commercially-available borehole cameras on the market. This document will primarily cover the use of these instruments based on a Marks GeoVISION™ camera. However, this is for reference only and in no way constitutes an endorsement of this product by the Office of Surface Mining.

Camera Specifics: By and large these cameras are portable and operate from either a 12 volt DC connection to an automotive battery and/or by common 110 volt AC household supply. The images can be recorded by an integral digital (DVD) system or 8 mm videotape. Additionally, the camera can output to an external DVD or VHS recorder and/or an auxiliary TV. Most systems have a depth readout that displays on the viewer and is recorded or there may be a separate depth indicator. Some systems also come equipped with depth-marked cable. Most systems also have sound recording capabilities. Manual and power winding mechanisms are available. The latter is recommended.

Most borehole cameras will fit into as little as 2-inch inside diameter casing. Depending on the attachments, or lack thereof, these cameras may fit into a smaller diameter hole or require a larger diameter bore. It is critical that there is enough clearance between the camera and the borehole sides. Offsets and substantial bends in the borehole can impede access or cause the camera to become stuck. To preclude these potential problems, it is recommended the borehole interior diameter be ¾ to 1 inch larger than the camera diameter. The support cable usually has integral electrical wiring for the camera and lighting. The units are waterproof and generally have enough cable to be lowered at least 1000 feet. You need to consult the manufacturer to determine if the camera is gas permissible and will not trigger an ignition or explosion in a methane-rich or other flammable gas rich environment.

There are various accessories that may come with the camera, can be purchased separately or can be easily adapted by the user to increase the information that can be obtained using a borehole camera. These include but are not limited to:

- Auxiliary lights to improve viewing in large open spaces. Borehole cameras come with their own light source, but auxiliary lights can be used to augment viewing. Additional lights are frequently needed in mine shafts, sink holes and other large openings. A separate light source can be used to view mine workings between two access points (e.g., boreholes). Lowering the camera down one hole and the light in the other, will often allow the mined area in between to be seen. Some cameras can be outfitted with low-light level lenses to aid viewing.
- Compass to determine the direction of viewing and points of interest.
- Side-viewing mirrors or an articulating lens to allow for better lateral viewing. This function is especially useful for viewing mine voids and fractures within the well bore.
- Range finders can determine distances within voids. It is not always easy to determine distances underground by just looking through the camera. Additionally, an automatic range finder coupled to a data logger or computer can gather data to allow the creation of a 3-dimentional model of the void using commercially-available software.
- Neutral buoyancy tape may allow notation of vertical or horizontal water flow within the borehole. The tape is attached in such a way that it can be viewed by the camera.

- Attach various instruments to the camera to couple what is being viewed to real time water quality readings. For example: creating a specific conductance and/or temperature profile along with the borehole video can allow determination water-bearing fractures from "dead" non-water-bearing ones.
- Ruler or other type of scaled instrument can aid in determining the size of features (e.g., fracture apertures, casing splits, or void sizes) in a borehole.

Potential Uses: Mining-related hydrologic investigations include problems dealing with well dewatering (partial or complete), well contamination, and loss of well or casing integrity. Some of the information that can be obtained by using a borehole camera include but are not limited to:

- **Lithologic or Stratigraphic Logging**: While the borehole camera is less than ideal for detailed lithologic logging, it can allow a moderate level of lithology determination. Sandstones, shales, and coals can usually be differentiated. Separation of shales and siltstones are at times possible. Conglomeritic zones, nodules, coal spars, and concretions can be easily observed within units with contrasting color. Lithologic determinations work best with a color camera setup.
- **Fracture Logging**: The location, orientation, rough width (aperture size), and condition (open, plugged, or stained) of fractures can be viewed and recorded. The frequency of fractures within lithologic units, with changes in depth, topographic location, and well location with respect to geologic structure, mines, and other salient features are all of interest. With the specific equipment, fracture strike and dip can be estimated. Using an integral ruled gauge, the fracture aperture can usually be determined. The degree to which a fracture is filled is important as to whether it can contribute ground water, the type of fill material or precipitate may be indicative of the water quality yielded by that fracture, or if bacterial plugging has occurred.
- **Well Bore and Casing Integrity**: The camera can be employed to observe the general condition of the well bore in terms of off-sets, zones of sloughing, precipitate buildups, sediment accumulation at the bottom, or blockages. The cracks or holes in the casing, casing deterioration, leaking joints, and casing buckling can be documented. If the pump is left in place, the condition of the pump, piping and/or wiring can be determined as well.
- **Ground Water Information**: A multitude of information concerning the ground water can be ascertained with the borehole camera.
    - If no electric water level meter is available, the location of the standing water level can be determined generally within a foot.
    - The color and clarity of the water can be assessed.
    - The camera will show location, color, consistency, and quantity of the precipitates.
    - Vertical (up or down) flow direction and ground water inflow points can often be observed in wells. Changes in water color or clarity are commonly indicative of zones of inflowing water. If this color continues below a certain point, this indicates a downward flow. If the discolored water stops at a certain level this may indicate inflow back into an aquifer or another significant source of inflowing water. The neutral buoyancy tape will also help in determining flow direction and relative velocity.
    - Gas bubbles (e.g., methane, hydrogen sulfide, carbon dioxide) in the well water can be observed as well as the location of the influxzone.
    - Historic water levels can often be determined. The location of historic water levels can be ascertained with the presence of substantial staining of the casing or well bore well above or below present water levels. If the water is chemically aggressive, the historic water level can also be determined by an upper limit of heavy corrosion of steel casing.
- **Impacts of Mining**: Impacts from mine subsidence can be observed with borehole camera. This is especially true if the holes are viewed before and after an event. Mining-related observations include unnaturally widened and newly-created fractures, ruptured, sheared, or pinched casing, and rubblized or caved zones above subsided sections. The mining-induced fractures are frequently at angles

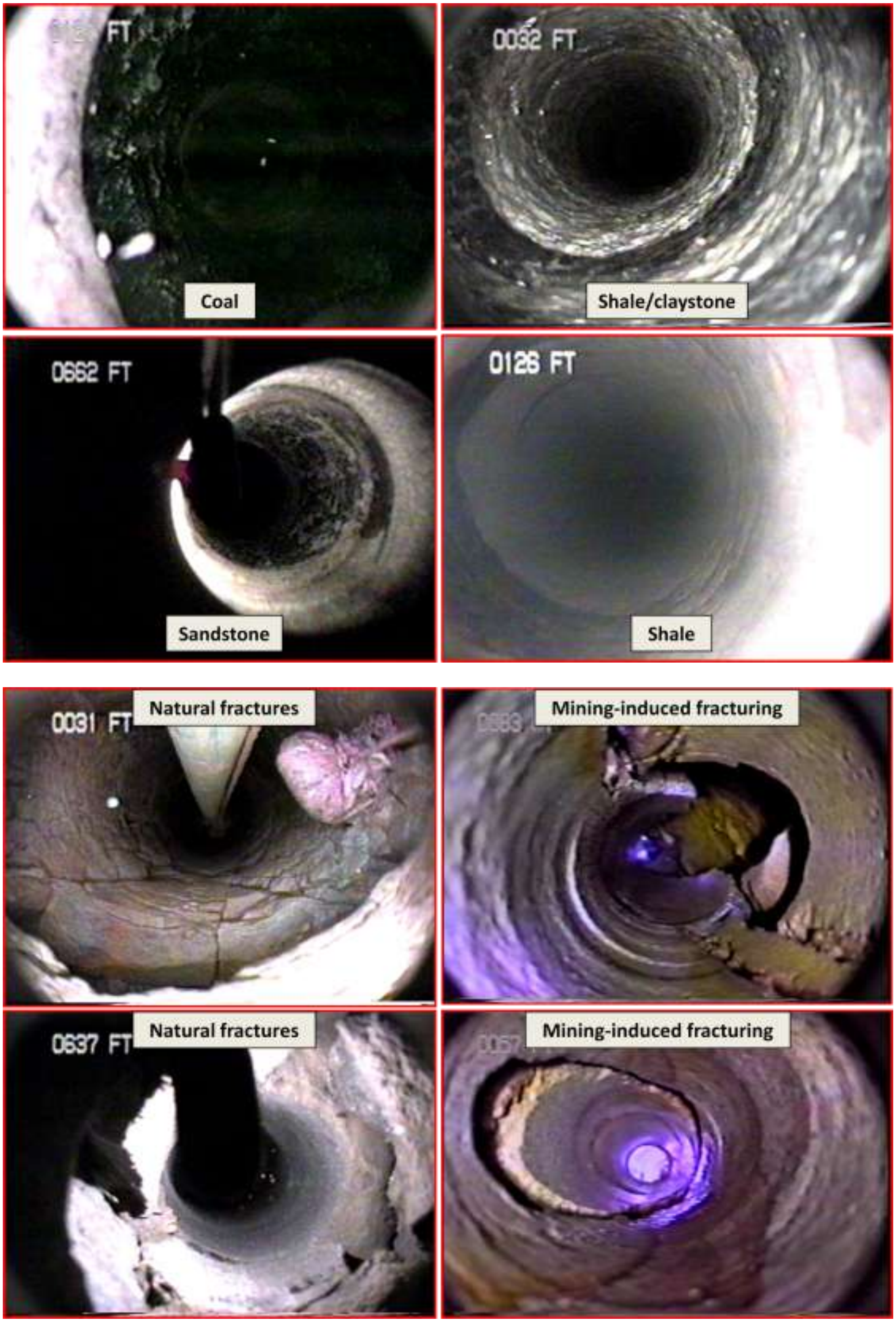
oblique to horizontal and vertical. The fracture surface is commonly rougher and more irregular than fractures derived from natural forces.
- **Condition of Mine Workings**: Boreholes, sinkholes and shafts into abandoned mines workings can yield valuable information on the condition. The degree of subsidence, roof sag, pillar or rib spalling, pillar punching, in-mine water conditions and other features can be observed using the camera. If two or more access points exist within sight of each other, the workings between those points can often be viewed using auxiliary lighting.

The following are a few tips based on use of the camera during investigative work.
- In domestic water wells, it is recommended to have the pump, piping and wiring removed from the bore prior to viewing with the borehole camera. It is easy for the camera to get caught between the wire and the piping, on spacers (or torque arrestors) or at other confined points. If you run the camera down the hole with the pump in place, be prepared to pull everything out if the camera gets stuck. Additionally, if the pump starts up while the camera is in the well bore, it can create substantial electrical interference.
- The water in the bore can become cloudy when the pump is first removed. This is caused by sloughing of materials off the side of the well bore and disturbance of the sediment at the bottom of the well. So, it is recommended that the pump be removed at least a day prior to using the camera to allow for the water to clarify.
- At times it is useful to couple the camera use with pumping down the well. It is recommended that you use a small diameter portable pump in this operation. As the water level is drawn down, the camera can follow it. Water-bearing fractures become clearly apparent when conducting this operation. The pump can be used to remove cloudiness and draw in clearer fresh water for better visibility.
- If the portion of the hole ahead of the camera looks unsafe for the camera, it probably is. Only continue to advance the camera, if the information that you will obtain is more valuable than the camera itself, which is very rarely the case.
- Be very cautious with wells or other environments that can contain elevated concentrations methane or other flammable gases. If you are unsure, check with an explosive gases meter prior to introducing the camera.
- If you putting your camera into a domestic water well, it is highly recommended that you disinfect it prior to use. You do not want to drag (introduce) any bacteria or other organisms into someone's well that you picked up at another site. It is recommended to have a pump-up type garden sprayer on hand with which to apply a mixture of water and chlorine bleach (sodium hypochlorite – 5.25 to 6.16% solution). Mix 1.5 cups (12 ounces) of bleach with 1 gallon of water to make a disinfecting solution.

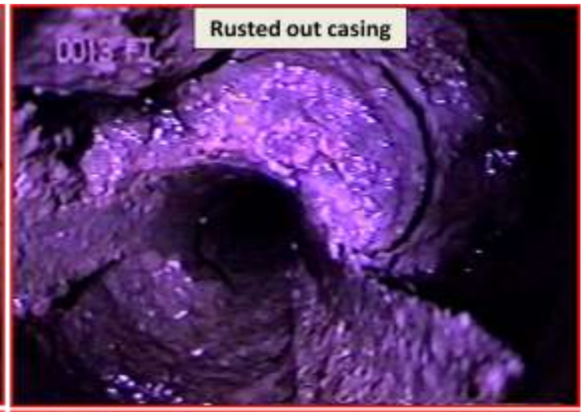
If additional information is required, contact any of the hydrologists at the Appalachian Regional Office or you can consult the following references:

The Borehole Camera: An Investigative Geophysical Tool Applied to Engineering, Environmental, and Mining Challenges, L. M. Gochioco, C. Magill, and F. Marks, The Leading Edge, Society of Exploration Geophysicists, pp. 474-477.

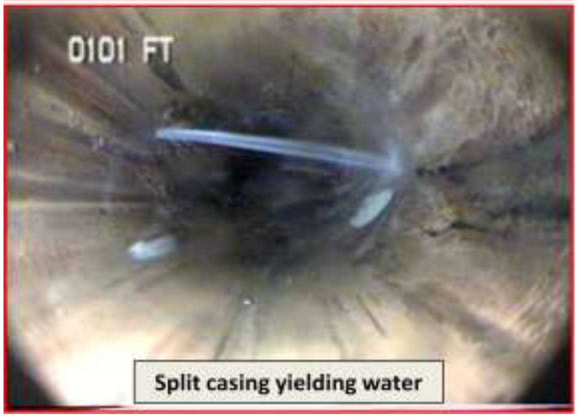
Uses of the Borehole Camera in Hydrologic Investigations Related to Coal Mining, J.W. Hawkins and R.S. Evans, Proceedings of the 21st Meeting of American Society of Mining and Reclamation, Morgantown, WV, 2004, pp. 847-859.


Coal
0032 FT
Shale/claystone
0662 FT
Sandstone
0126 FT
Shale
0031 FT
Natural fractures
Mining-induced fracturing
0637 FT
Natural fractures
Mining-induced fracturing

Corroded casing showing historic the water level



Rusted out casing

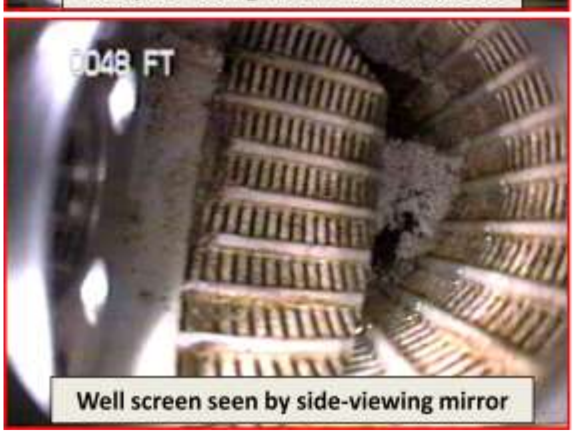


Split casing yielding water

Cracked casing seen by side-viewing mirror

Collapsed casing from mine subsidence

Broken casing from mine subsidence



Well screen seen by side-viewing mirror

Methane gas bubbles

Neutral buoyancy tape showing artesian flow

Ground-water inflow from fractures

Aquatic biota living in the water column

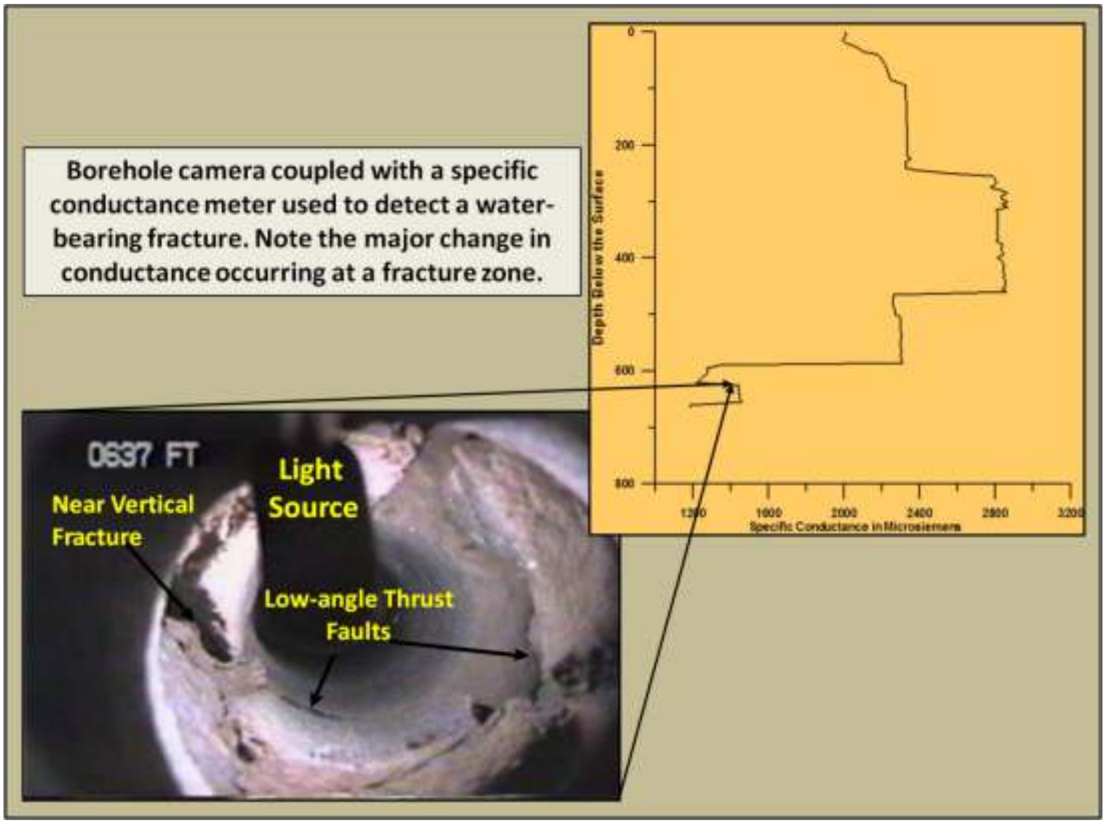
Bacterial slime coating well bore

Mine entry with standing support post

Support post holds up mine roof


Open mine entry with intact roof rock


Roof bolt hanging in open mine entry



Borehole camera coupled with a specific conductance meter used to detect a water-bearing fracture. Note the major change in conductance occurring at a fracture zone.