NMR Logging: A tool for quantifying effective porosity and hydraulic conductivity within the Murray Darling Basin of Australia

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Within Australia, and the world, understanding groundwater resources and their management are growing in importance to society. As groundwater resources are stressed by climatic changes and continued development, a complex juxtaposition of economic and environmental agendas promote conflict. To minimize these conflicts, new tools and techniques need to be applied to support knowledge-based decisions and management. The most critical and challenging measurements in characterizing aquifers include effective porosity and hydraulic conductivity. Typically, values for effective porosity and hydraulic conductivity are derived by lithological comparisons with published data; direct measurements of hydraulic conductivity acquired by a few constant head aquifer tests or slug tests; and expensive and time consuming laboratory measurements of cores which can be biased by sampling and the difficulty of making measurements on unconsolidated materials. Aquifer tests are considered to be the best method to gather information on hydraulic conductivity but are rare because of cost and difficult logistics. Also they are unique in design and interpretation from site to site. Nuclear Magnetic Resonance (NMR) can provide a direct measurement of the presence of water in the pore space of aquifer materials. Detection and direct measurement is possible due to the nuclear magnetization of the hydrogen (protons) in the water. These measurements are the basis of the familiar MRI (magnetic resonance imaging) in medical applications. NMR is also widely used in logging applications within the petroleum industry. Within the Murray Darling drainage NMR data were acquired in 26 boreholes. Effective porosity values were derived directly from the NMR data, and hydraulic conductivity values were calculated using empirical relationships calibrated and verified with laboratory permeameter and aquifer tests (figure 1). NMR provided measurements of the effective porosity and hydraulic conductivity at a resolution not possible using traditional methods. Unlike aquifer tests, NMR logs are not unique in design and are applied in similar fashion from borehole to borehole providing a standard way of measuring hydraulic properties. When the hydraulic properties from the NMR are integrated with hydrogeological interpretations of airborne electromagnetic data large areas of the Murray Darling Basin can be characterised. This provides a much more robust method for conceptualizing groundwater models then simply using previously published site specific data for assigning effective porosity and hydraulic conductivity interpolated across geographic areas. Borehole NMR provides superior, rapid measurements of the complexities of aquifers within the Murray Darling Basin when compared with the traditional methods.

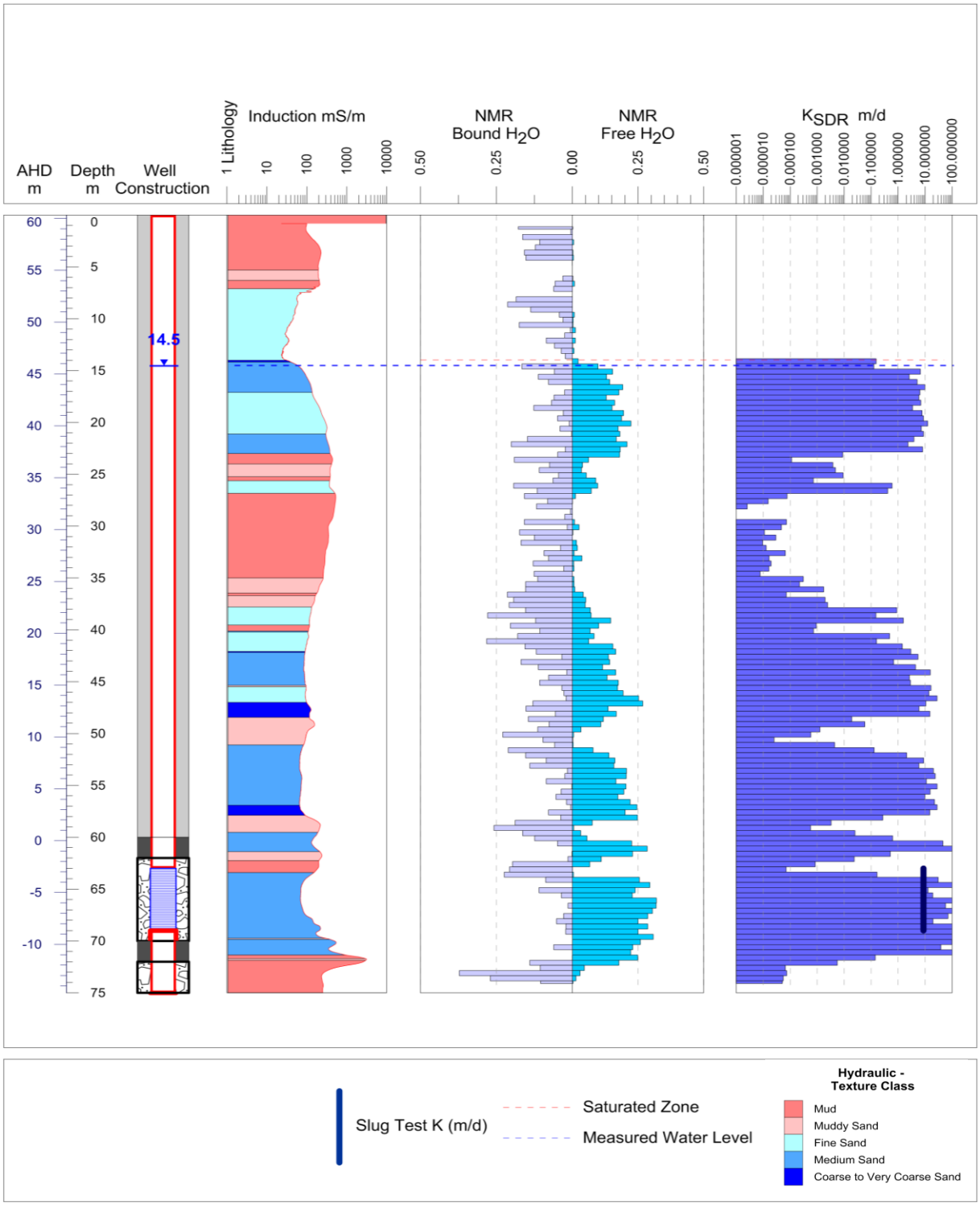

Figure 1. Example log from the Murray Darling Basin including (from right to left) well construction, borehole induction with hydraulic texture class, NMR bound-water, NMR free-water (effective porosity) and the hydraulic conductivity, slug test hydraulic conductivity, saturated zone, and water table indicated by dashed line.