Kansas Geological Survey

Detection of the Saltwater Interface in the Great Bend Prairie Aquifer, South-Central Kansas Using Focused Induction Conductivity Logging

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INTRODUCTION

Natural dissolution of bedded salt occurs at shallow depths in many parts of the eastern Permian Basin of the southwestern U.S.A. (Johnson, 1981; Gustavson, Finley, and McGillis, 1980; Hargadine, Balsters, and Luehring, 1979; Walters, 1978). The resulting brines move laterally and vertically under hydrostatic pressure into overlying alluvial aquifers creating a saltwater interface with fresher waters above. Detection and regional geohydrologic characterization of this interface is critical in the management of groundwater in such areas (Buddemeier, Sophocleous, and Whittemore, 1992). The variable conductive properties of the water types can be exploited to locate an interface between them. This report describes results from experiments using a focused induction conductivity logging instrument to detect the interface in monitoring wells located in the Great Bend Prairie Aquifer of the Groundwater Management District No. 5.

METHODS

Two fully-screened wells and two sets of three partially-screened monitoring wells, located in northern Stafford County (Fig. 1), were selected for testing. These eight wells were logged in July 1992 using a Robertson Geologging, Ltd. focused induction sonde with digital interface data recording (see Appendix I for specifications). This instrument is designed to be most sensitive to formation conductivity at a radial distance of approximately 40 cm. Therefore, this instrument should be unaffected by the nature of the borehole fluid in these plastic cased wells. A schematic representation of the logging process is shown in Figure 2.

Initial duplicate logging runs in the same well revealed a baseline drift in conductivity of between 50 to 100 millisiemens per meter (mS/m). This drift is suspected to have been caused by temperature variations of the sonde. This offset was virtually eliminated by allowing the sonde to equilibrate with the well temperature in the bore hole before external calibration and downhole measurements.

For comparison, the location of the interface in the two fully-screened wells was also determined at the same time by measuring the depth profile of the borehole fluid conductivity.

RESULTS

The resulting conductivity logs are shown with vertical lithologic and natural gamma ray logs recorded when the wells were completed in Figures 3A to C. When necessary, the plots were normalized in order to remove between-hole variations in baseline. This process offset (less than 15 mS/m) the least varying conductivity region in all records to the value of the record in the same region with the lowest, yet still continuously positive profile. Plots of the comparable borehole fluid conductivity measurements in the fully-screened wells are shown in Figures 4A and B.

DISCUSSION

The general increase and abrupt rise in conductivity with depth indicates the presence of a saltwater interface within the alluvial aquifer. All of the partially-screened monitoring wells that penetrate the interface showed very reproducible patterns. Conductivity measurements were unaffected by the location of the 5-foot long screened interval in the upper and lower alluvial or bedrock monitoring wells and by the borehole fluid conductivity variations.

Similar conductivity profiles were obtained for the fully-screened Figger well (Figs. 3A and 4A) using both the focused induction sonde and the borehole fluid conductivity measurements. The fully-screened Sittner well induction profile (Fig. 3B) agrees well with the monitoring well profiles at depth, but not near the surface. Sophocleous and Perkins (1992) observed rapid and extensive changes in the borehole interface in this well. This suggests that the actual interface is partially confined and not free to respond to the pressure changes that affected the fully-screened well. We attribute the shallower conductivity anomalies to well-induced interface movement in the immediate vicinity of the bore hole.

Clay lenses, within the alluvial aquifer, can act to confine the salt water and can also contribute to variations in the background conductivity response detected by the induction method. For example, these effects are indicated just above the interface at Monitoring Site 16 (Fig. 3C). The effect of clay without salt water is seen in the first 15 ft. of the Figger well record (Fig. 3A). Therefore, the observed conductivity is an integration of both the hydrologic and lithologic conductivities. Together with the natural gamma logs, the conductivity logs may also be used to analyze these and other important stratigraphic heterogeneities present in the Great Bend Prairie Aquifer. These measurements together may also prove useful in the hydrostratigraphic characterization of the different Permian bedrock lithologies, encountered in the deep wells, that subcrop beneath and are hydraulically connected to the alluvial aquifer.

CONCLUSION

This method is very successful in the detection of the saltwater interface in these wells. This type of instrument can be used to locate the saltwater interface in the other wells of the monitoring well network and any other suitably completed well in the Great Bend Prairie Aquifer. This will allow regional mapping of the interface as well as local monitoring of seasonal effects such as the potential upconing of the interface in the vicinity of high capacity pumping wells.

ACKNOWLEDGEMENTS

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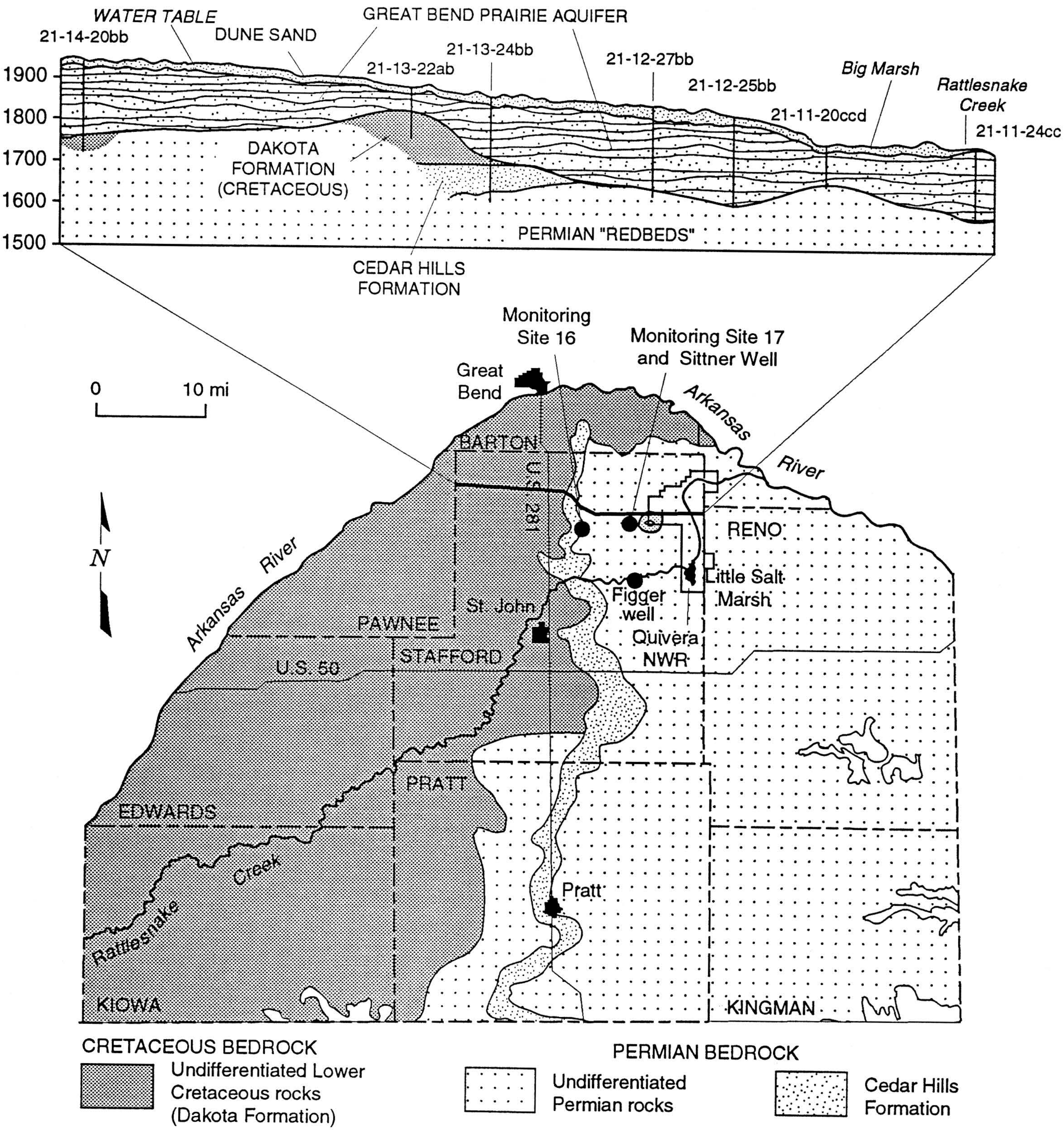


Figure 1. A. Location of test sites on a map of the bedrock beneath the Great Bend Prairie Aquifer , showing the areas in which the Permian formation has the potential to contribute salt water to the overlying aquifer. B. Vertical section from west to east across the region, showing the relation of the alluvial Great Bend Prairie Aquifer to the underlying Dakota and Permian formations.

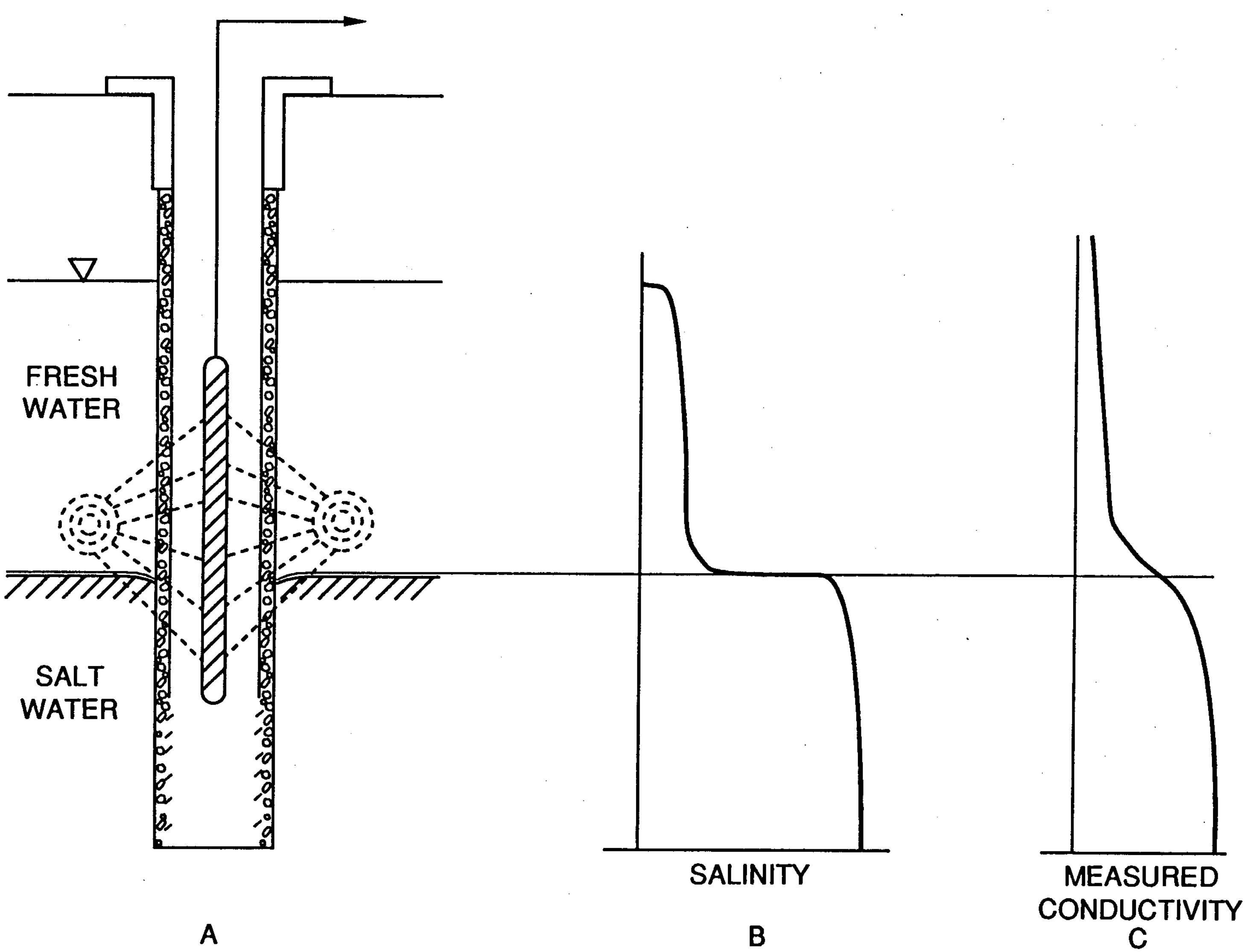


Figure 2. Schematic representation of focussed induction logging. A: the tool is designed to be sensitive to the response of the aquifer to electromagnetic fields at a distance outside of borehole disturbances. If a homogeneous aquifer contains a salt-water interface as shown in B, then the logging process will produce a record that looks likes C.

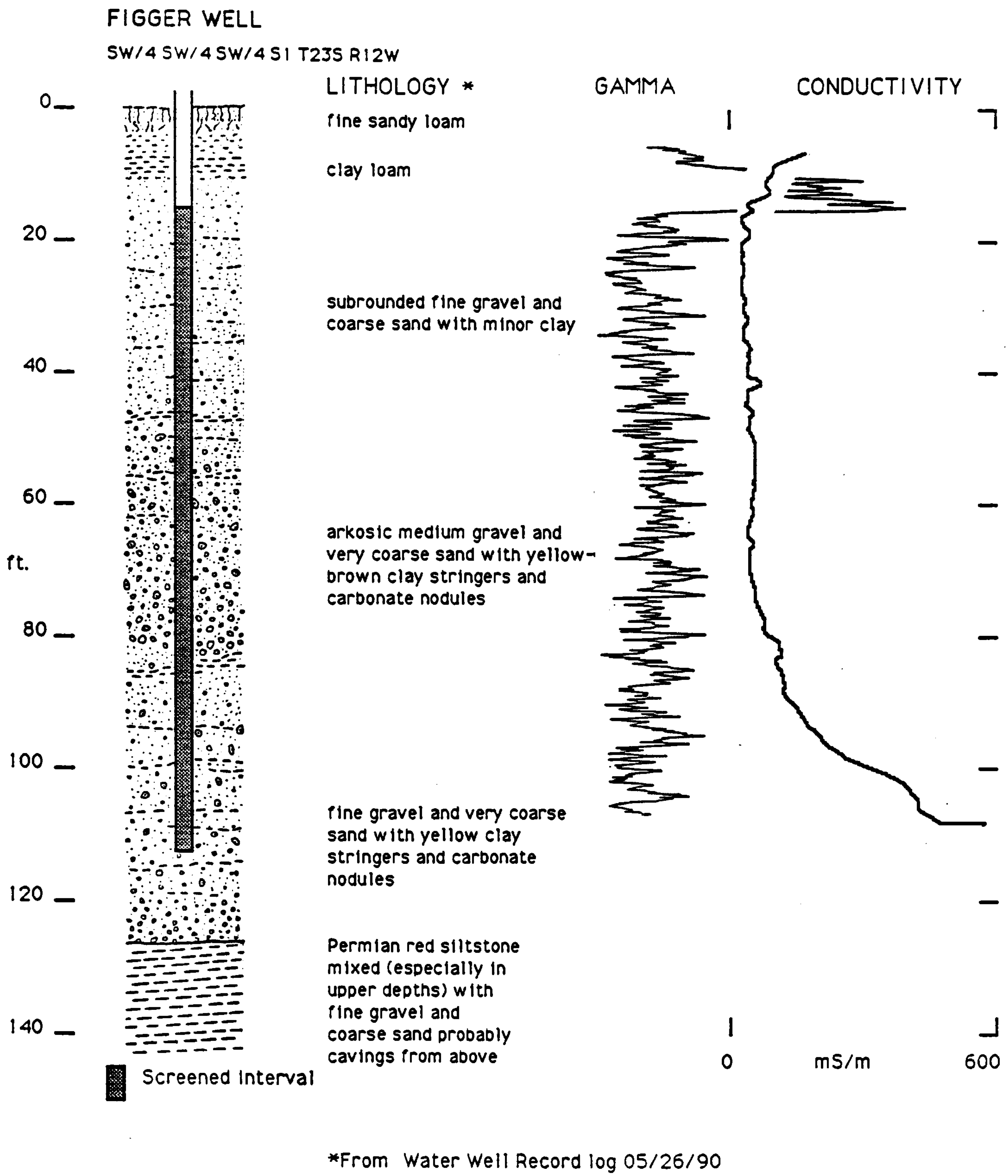


FIGURE 3A. Lithologic, gamma ray, and conductivity logs for the Figger well.

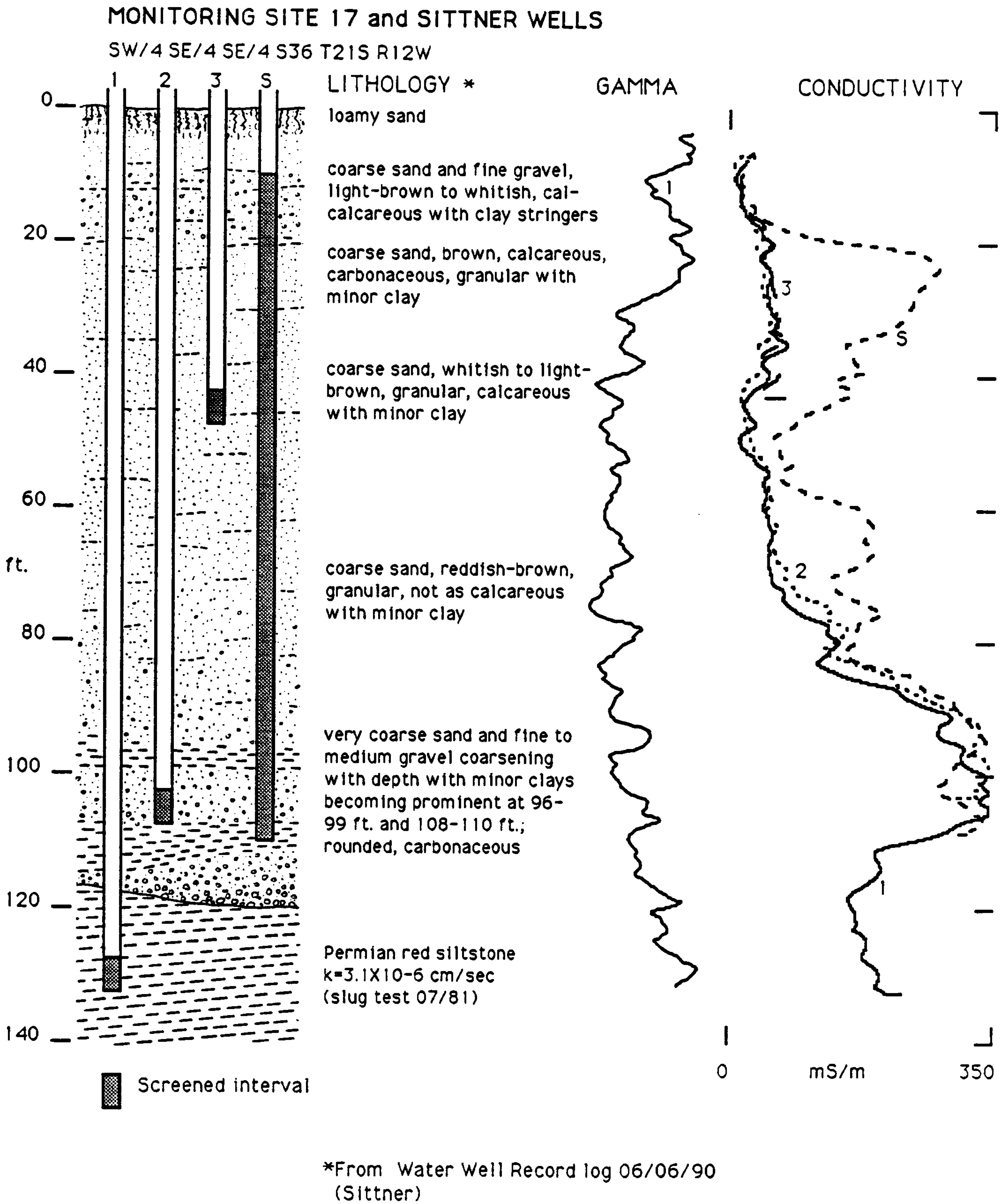


FIGURE 3B. Lithologic, gamma ray, and conductivity logs for the Monitoring Site 17 and Sittner wells.

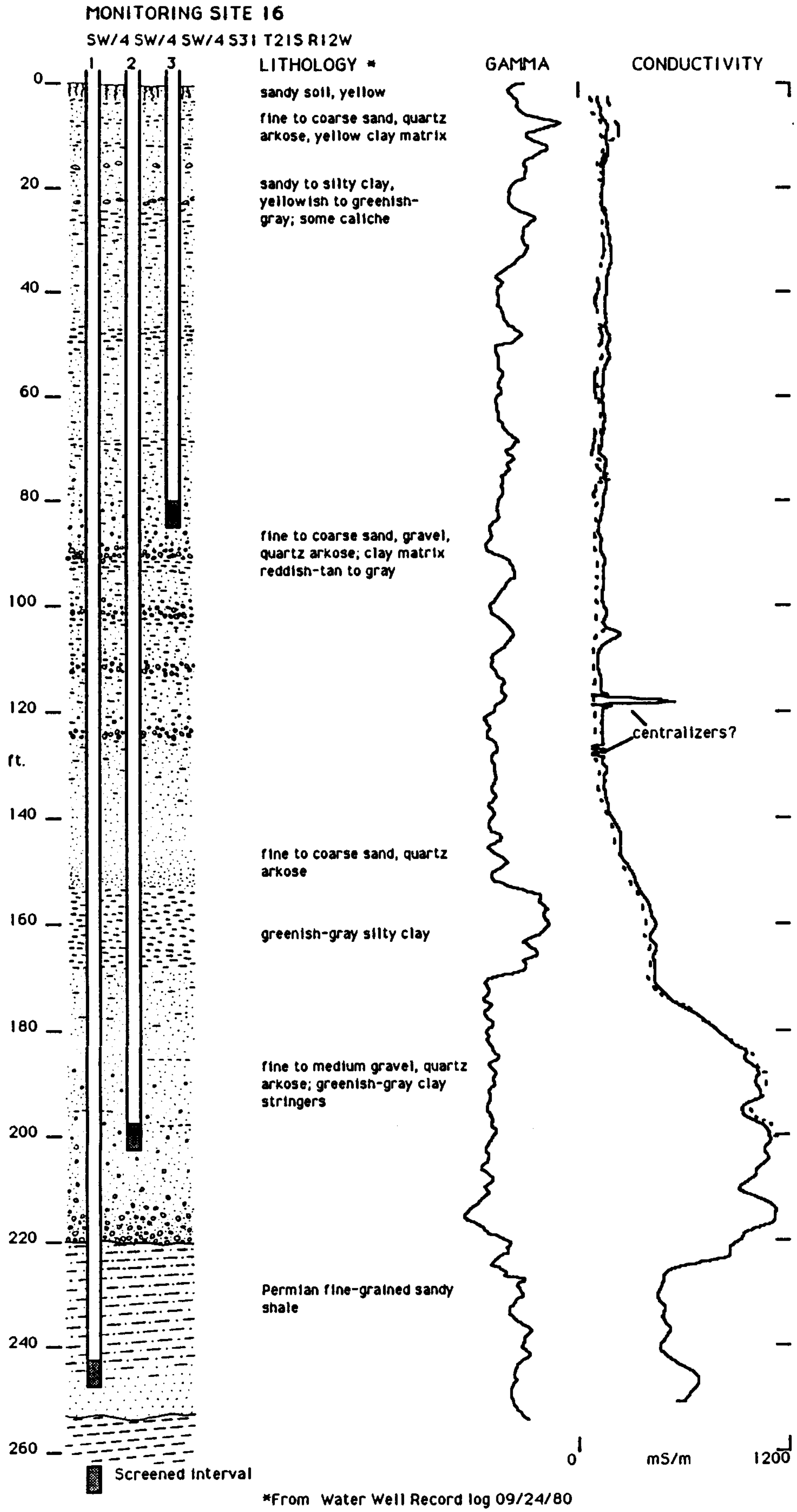


FIGURE 3C. Lithologic, gamma ray, and conductivity logs for the Monitoring Site 16 wells.

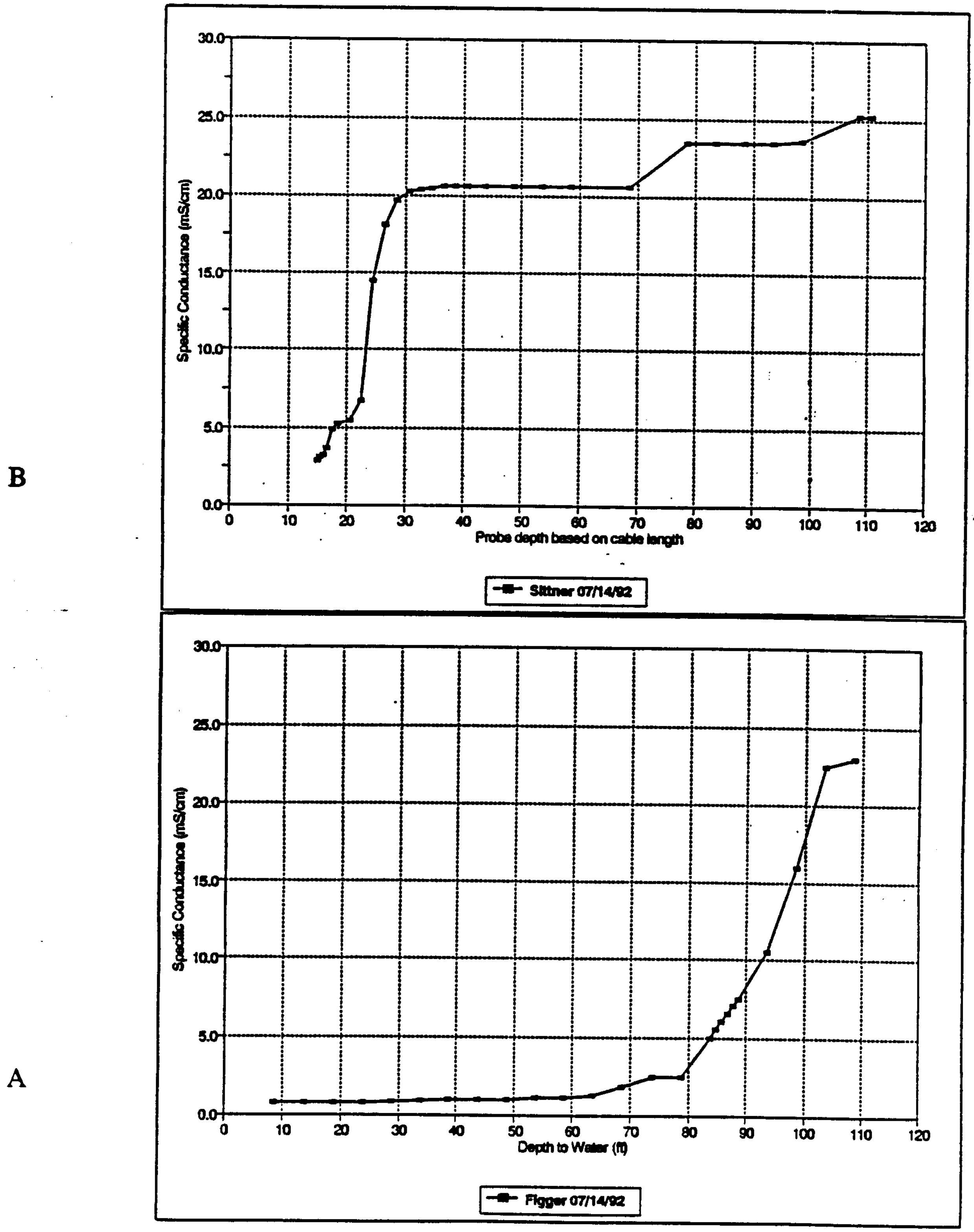


Figure 4. Borehole fluid conductivity profiles for the Figger (A) and Sittner (B) wells.

APPENDIX I.

Focussed Induction Sonde

ROBERTSON
GEOLOGGING
LIMITED

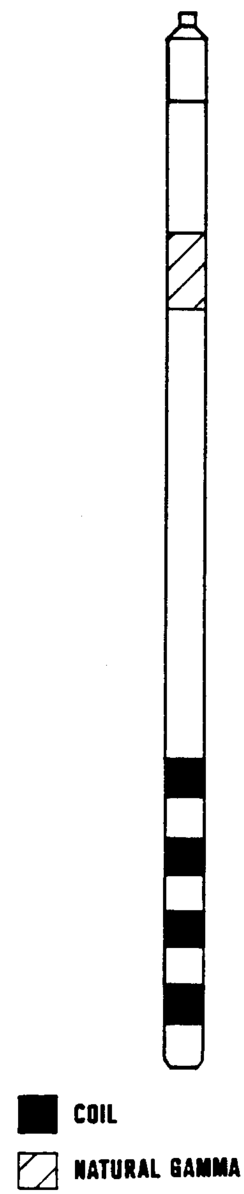
SALES No. 8002 18 basic sonde
8002 18/G with natural gamma

The focussed induction probe produces accurate formation conductivity logs even in dry or plastic-cased boreholes. It is available either as a single-function sonde or combined with natural gamma for correlation purposes.

The probe coil spacing is optimised to achieve high vertical resolution and a deep radius of investigation. Additional focussing coils ensure minimal borehole influence when logging in conductive fluid filled holes.

The long term stability of the probe is excellent, allowing its use for environmental monitoring applications. Calibration rings are available to allow field checks on the measurement accuracy.

All electronics are contained within the downhole probe. This communicates with the surface system using the standard RG digital transmission format. Both monocable and four conductor tool versions are available, compatible with all RG Portalog or RG5000 systems without the need for additional surface modules.



Applications:

- Conductivity measurements in dry or plastic cased boreholes
- Indication of permeable zones and porosity
- Determination of formation water quality
- Groundwater contamination studies
- Long term well monitoring
- Ore identification and quality
- Hydrocarbon detection
- Correlation

FOCUSSED INDUCTION SONDE

SALES No. 8002 18 **basic sonde**
8002 18/G **with natural gamma**

SPECIFICATIONS

Diameter	43mm
Length	2·2m
Weight	9 kg
Max. Temperature	70° Degrees C
Max. Pressure	2200 psi
Power supply	80 VDC nominal
Communications	RG digital format: asynchronous binary transmission
Cable requirement	4 conductor or monocable
Number of coils	4
Effective coil spacing	40 cms
Frequency	20 kHz
Depth of investigation	40 cms (typical)
Range	10 mS/m – 1·65S/m
Accuracy	±10m S/m
Natural gamma detector	NaI (Tl) scintillation

OPTIONAL ACCESSORIES:

Conductivity calibration ring
Gamma ray calibration jig