Please fill in the name of the event you are preparing this manuscript for.	2020 International Petroleum Technology Conference
Please fill in your 5-digit IPTC manuscript number.	IPTC-20144
Please fill in your manuscript title.	Surface-to-Borehole Electromagnetics: A Novel Approach to 3D Waterflood Monitoring

Please fill in your author name(s) and company affiliation.

Given Name	Surname	Company
Daniele	Colombo	Saudi Aramco
Gary	McNeice	Saudi Aramco

Abstract

Objectives/Scope: Monitoring the waterflood recovery process is a difficult task for seismic-based methods. The changes in velocity/density due to water-oil substitution are often too small when compared to the errors involved in repeating the measurements. We developed a novel technique based on surface-to-borehole controlled-source electromagnetics (CSEM), which exploits the large contrast in resistivity between injected water and oil to derive 3D resistivity distributions (proportional to saturations) in the reservoir. Surface-to-borehole CSEM responses using surface electric transmitters and borehole EM receivers were first modeled using a black-oil simulator for a carbonate reservoir. Results indicated the detectability of waterfront changes in the electric field over two and five-year time-lapse scenarios. The next phase consisted of engineering a surface-to-borehole acquisition system comprising the development of a powerful, custom-made electric transmitter (2000V/500A) and borehole electric and magnetic field sensors. The surface-to-borehole 3D CSEM technology was tested in the same well used for the modeling study.

Methods, Procedures, Process: Data acquisition was carried with 144 permanent surface electrodes that were drilled in a radial configuration around a vertical observation well. The current electrodes were designed in an L pattern to form 48 inline (radial) and 48 cross-line (tangential) bipoles at a nominal range of 500m to 3,000m from the vertical observation well. The wireline sensor array comprising two vertical electric and two vertical magnetic field sensors recorded the EM signal transmitted from the surface in 20 positions spaced 5m apart in the reservoir. Surface measurements of transient EM (TEM), CSEM and MT were taken together with the borehole acquisition to characterize the overburden and the shallow subsurface. The acquired dataset was processed to increase the signal/noise content of the data as well as to correct for casing effects and surface distortions. The 3D inversion of the data provides a snapshot of the resistivity distribution that is consistent with the expected position of the waterfront in the reservoir.

Results, Observations, Conclusions: The analysis of the surface-to-borehole CSEM data suggests that this new technology may become an important tool for analyzing waterflood evolution in the interwell

space. This technology is expected to enhance reservoir management and history matching.

Novel/Additive Information: