GroundMetrics is a full-service survey and monitoring company and the world leader in land-based resistivity & electromagnetic sensor systems.

But that’s only part of the story. By processing GroundMetrics’ survey data through GroundMetrics’ DSEMI-3D inversion software, we produce full-field resistivity maps and 3D models that provide an enhanced view to help your engineers and geoscientists make better drill and field development decisions. Add in the expertise of GroundMetrics’ geoscientists and engineers plus the knowledge of your engineering and G&G team that have experience with the specific field at hand and you get the most reliable joint interpretation possible.
Prior to contacting GroundMetrics, the customer was producing oil from an upthrown reservoir characterized as low-resistivity pay (4 - 5 ohm-m) with current water cuts from 88 - 98%.

Five wells were drilled in the upthrown fault block; four of these wells (4, 6, 7, and 11) produced oil and one (12) was a dry hole. Well 6 produced for seven years, at which point it was converted to an injector due to low oil production and high water cut.

The geology of the upthrown reservoir was developed using formation tops of wells 4, 6, 7 and 11 and seismic where no well control existed. Seismic (Image C) showed a southwest to northeast orientation where the oil-water contact was lower to the west. Well 12 was drilled to test the geology of the upthrown fault block extending to the south, but encountered the downthrown side of the fault contrary to what seismic showed. Well 12 was dry.

Wells 1, 3, and 9 were drilled in the downthrown fault block to test a deeper structure and formation. Wells 3 and 9 were dry holes and Well 1 was a gas well which produced from a deeper formation than the target reservoir. Well 1 is no longer producing and was used as the source well for the resistivity survey.

Wells 4, 6, 7, and 11 all produced oil from the upthrown fault block. Well 4 has the highest cumulative production at 115 MBO EUR (ACTIVE). Well 6 produced 87 MBO and was subsequently converted to an injection well. Well 7 produced 53 MBO and due to casing problems and low oil price was plugged and abandoned (P&A). Well 11 was drilled as a replacement to Well 7 and has produced 14 MBO.

Image B is a plan view of the reservoir in the upthrown fault block showing estimated locations of the trapping fault and oil-water contact. Image B is based on the seismic interpretation represented in Image C.

Image A is a satellite image showing well locations and GroundMetrics eQube™ sensor positions. The specific location of the field is currently confidential.

Well 1 was used as the source well as it was close to the fault and also near Wells, 4, 6, 7, and 11, which produced oil from the upthrown reservoir and near Well 12.
GroundMetrics’ geoscientists and engineers worked with the operator to design the survey to acquire data over the dry holes, producers, and predicted fault line to help achieve the goals of the survey. The planned survey area covered approximately half a square mile (one square kilometer).

Once the survey was designed, the GroundMetrics’ survey crew deployed to the site to conduct the land survey and collect resistivity data. The crew consisted of survey technicians charged with placing and moving survey equipment, a data observer who monitored and assured the quality of the data, a source operator, and a field operations manager who oversaw all operations.

Survey equipment consisted of proprietary eQube™ sensors, Eos™ data recorders and cables positioned strategically throughout the survey site. In addition a small truck containing TCS-30™ source and monitoring equipment and a few additional vehicles were on site throughout the survey.

Acquisition took place over a two-week time period, and over 2100 channels of data were collected. Time-in-field scales with size of crew and varies based on survey design; the aforementioned acquisition timeline met GroundMetrics best practice of a two-week or less survey window. Additionally the site-specific Health, Safety and Environment (HSE) procedure was executed to plan and included daily HSE briefings for all crew.

Once successfully acquired, data were then processed using the GroundMetrics’ DSEMI-3D Inversion software.
The GroundMetrics' DSEMI-3D inversion was completely unconstrained and blind. The team running the inversion did not know which wells were dry or producing and did not know water cuts of the producing wells to ensure an unbiased inversion.

The DSEMI-3D inversion found the reservoir layer as provided in Image D. The curved red lines on both sides of the fault represent the anticline structure as provided by formation tops. The GroundMetrics' DSEMI-3D inversion was completely unconstrained and blind. The team running the inversion did not know which wells were dry or producing and did not know water cuts of the producing wells to ensure an unbiased inversion.

**RESULTS & INTERPRETATION**

The results of the GroundMetrics’ DSEMI-3D inversion agree with well data and well production. They also provide an additional geological model which validates GroundMetrics’ technology.

Well 4 produced the most oil in the upthrown reservoir and is the best well in the field. Well 11 is the structurally highest. The reservoir top is structurally lower in Wells 4 and 6 (southwest) and Well 7 (northeast). It is three feet (one meter) lower in Well 4, 40 feet (12 meters) lower in Well 6 and 10 feet (three meters) lower in Well 7. This would suggest an anticline feature in the upthrown side with an upward slope from Well 6 to Well 4 to the “high” in Well 11 and a downward slope to Well 7.

A similar condition exists on the downthrown side of the fault. The source well (Well 1) is the structurally highest. The reservoir top is structurally lower to the source well (Well 1) in both Well 3 (southwest) and a well (not pictured) to the northeast. It is 60 feet (18 meters) lower in Well 3 and 15 feet (five meters) lower in another well to the northeast. This would also suggest an anticline in the downthrown side with an upward slope from Well 3 to a “high” in the source well (Well 1) and a downward slope to the northeast well (not pictured). The anticline structure is supported on both sides of the fault.

The inversion (and well data) suggest a faulted anticline with the primary axis of the anticline oriented in an east to west direction thereby providing insight into a new geological model. This anticline would have been present at the time of fault generation.

The “blue” areas within Image D represent conductive zones and are therefore believed to represent water. The blue areas to the south and north of the anticline would support why Well 3, 9, and 12 (to the south) were dry, why Well 6 produced only 31 MBO and why Well 7 (to the north) produced 53 MBO. This interpretation fulfills the first primary goal of explaining why the dry holes didn’t encounter pay in the reservoir as well as providing valuable technology ground truth. With this explanation, it was also determined that no additional infill locations exist, thus fulfilling the second primary goal of the project.

Additionally, the inversion image clearly delineates the location of the resistivity change (indicating an oil-water boundary) represented by the change from dark blue to lighter green and yellow. This is helpful in demonstrating the ability to assist with fluid monitoring for IOR/EOR (as listed in the first additional goal). The well log data further validates the higher resistivity shown by the GroundMetrics’ survey and inversion.

**SUMMARY**

Based on this Full-Field Resistivity Survey and resulting DSEMI-3D inversion study, GroundMetrics’ is able to conclude the following:

1. Resistivity contrast in the reservoir layer is consistent with the known facts. The producing zone is now at a high water cut.
2. No additional infill locations were identified.
3. The inversion was validated from formation tops and resistivity logs at the wells.
4. The inversion found the reservoir without constraining the model, showing the GroundMetrics’ results were not skewed.
5. Had the survey been conducted before drilling Well 12, the customer would have saved hundreds of thousands of dollars in associated drilling and evaluation costs.

**VALUE OF GROUNDMETRICS’ FULL-FIELD RESISTIVITY SURVEYS**

In a typical reservoir model, the fluid data from well logs, production history and ratios (oil/water, water cut, etc.) are only known at the wells. The values assigned to the reservoir between and beyond wells is an extrapolation of the known well data.

With GroundMetrics’ Full-Field Resistivity data, the region between and beyond the well is measured. This means we have a self-consistent image of the entire reservoir. By self-consistent, the entire reservoir is included at once when determining the resistivity values in one specific region.

Further, well logs provide data at different points in time, whereas a GroundMetrics’ Full-Field Resistivity Survey images the reservoir as a whole in real time. GroundMetrics’ method provides, for the first time, a complete and current map of reservoir fluids between and beyond the wells.