Milingimbi
Geophysical Salinity Assessment

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1.0 Introduction

Milingimbi is an island located 450 kilometres east of Darwin on the northern coastline of the Arnhem Land Aboriginal Reserve within the Northern Territory.

During the field season of 1990 Milingimbi was surveyed using geophysical techniques to assess salinity problems which were identified by the Groundwater Evaluation Section of Water Resources, Power and Water Authority.

Two surveys were carried out, the first 25th May - 2nd June 1990 and the second 29th October - 3rd November 1990. These periods approximate to the beginning and end of the 'dry season' in the tropics.

The first survey involved a total field period of 4 days during which 3 Vertical Electric Soundings (VES) and 15 line kilometres of em34-3 were completed. The second survey involved 3 VES, 3 Sirotem soundings, 13.7 line kilometres of em34-3 and 8 kilometres of em31.
2.0 Geology

The geology is covered by the Milingimbi 1:250 000 Geological Series map sheet and explanatory notes.

Briefly, the regional geology involves the Wessel Group, an Upper-Protorezoic unit, consisting of sedimentary sequences. The Wessel Group consists of the Railwalla Shale overlain by the Marchinbar Sandstone which in turn is overlain by the Elcho Island formation.

Milingimbi consists mainly of the Elcho Island formation overlain by Cretaceous sands with Cainozoic laterization, a schematic cross section and the relevant lithologies are shown in figure 2.
3.0 Instrumentation and Techniques

3.1 Resistivity instrumentation

The resistivity instrumentation used consists of a d.c. to d.c. converter employing a single saturable transformer inverter design. The unit is battery powered and capable of supplying 300 watts of d.c. power. The voltage is selectable, at 100 volt steps, up to 1500 volts.

The receiver unit comprises a Fluke, Model 8060A. The instrument is a 4-1/2 digit, high impedance, digital voltmeter with a facility to offset spurious voltages. On the 200 millivolt range it has a resolution of 0.01 millivolt and accuracy of +/-0.04%.

3.2 Electromagnetic instrumentation

Electromagnetic instruments used on the present survey comprised the Sirotem MkIISE, Geonics em34-3 and em31. The Geonics instruments are commercial inductive terrain conductivity meters.

The em34-3 employs a dual coil system in either horizontal or vertical coplanar mode with three coil separation and frequency combinations. These operating parameters have been chosen to ensure the systems operation at low induction numbers where an apparent ground conductivity is definable from the quadrature response. Apparent conductivities in the range 0 - 3 to 300 millimhos/meter are read directly from the meter.

The em31 operates similarly to the em34-3 in either horizontal or vertical mode with a fixed spacing of 3.66m. It operates at a frequency of 9.8kHz. Apparent conductivities are measured directly from the meter in the ranges 0 - 3 to 1000 millimhos/meter.

The Sirotem MkIISE is a commercially available transient electromagnetic instrument with an early time option. This instrument records across 32 channels out to a maximum delay time of 165 milliseconds. The instrument is able to resolve one nanovolt per amp. It has a high degree of ambient noise rejection capability due to its ability to stack up to 2048 separate readings to obtain the output average.
This is performed simultaneously over all channels so that the background noise is common to all channels at the time of measurement.

All traverses were either along existing roads or surveyed using a compass. The location of traverses are shown in figures 3 and 4. Access to the north of the island during May was restricted due to Aboriginal ceremonies.

During the orientation phase of the field program a sample of vertical electric soundings (VES) were completed throughout the area.

All VES were conducted with the Schlumberger configuration of electrodes. The VES were used to a maximum AB/2 of 500m, while the half potential electrode separation (MN/2) was moved from 0.5m to 10.0m with one intermediate step. AB/MN was kept greater than 5. The frequency of sampling was greater than 6 points per decade.

The Siroten soundings were carried out over the centre of the VES during the second field survey. This involved a square, 50m side, receiving loop located in the centre with an external transmitting loop 3m from each side.
4.0 Results

The Schlumberger sounding data seem relatively unchanged between the first and second surveys. Generally, sounding data is of very good quality.

The joint sounding data was inverted using the program Grendl which was developed by K. McAllister and A. Raiche. The resulting geoelectric sections can be seen in figures 5, 6 and 7.

VES 1 and 2 were located close to RN9257 and RN21332 respectively. The lithologies described, in the drillers log, approximate closely to the geoelectric sections obtained after the joint inversion of sounding data.

The em34-3 data is of good quality and the repeatability of data extremely good. This was despite regional, and sometimes local, thunderstorm activity at the time of the second survey.

Horizontal and Vertical coplanar loop configurations were used with a coil separation of 40m. Em34-3 horizontal coil data contours are presented in figures 8 and 9. The vertical coil data contours are shown in figures 10 and 11.

The data clearly shows high salinity along the outer extremities of the borefield. Over the relatively short period of time between surveys the conductivities have changed little. Conductivities do appear to have changed slightly in the western region of the survey area particularly in the vertical coil data. The vertical coil data is more representative of the shallow aquifer system under investigation.

The degree of control offered by monitoring is limited. Conductivities were measured in April and November, 1990, and are tabulated below.
Bore Conductivity (uS/cm)

17/04/90  12/11/90

RN9257   365    293
RN9258   196    206
RN21382  79     71

The EM31 data reflects the surficial layer conductivities and has a depth investigation considerably shallower than the aquifer systems under investigation. EM31, horizontal coil, conductivity contours are presented in figure 12.

Clearly, conductivities have changed very little within the borefield between surveys and this is reflected in the EM34-3 data. Unfortunately, the relatively unchanged conductivities imply no firm conclusion can be drawn from the data set indicating either intrusion from the coast or upconing from a lower saline aquifer system. Though intrusion from the coast is least likely only further field studies can discount it entirely.
5.0 Recommendations

The em34-3 data collection should continue after a good "wet season" to examine the relative change in conductivities with a considerable amount of recharge into the aquifer systems as occurred during the good "wet season" of 1990/91. Alternatively, with continued monitoring of the borefield, a significant change in conductivities can be investigated further using the em34-3.

Sirotem, with an early time option, profiling should be carried out along one or two profiles of em34-3 data to build a better picture of the geoelectric section in terms of conductivities. This data would yield considerably more with which future Sirotem data could be correlated.

The em34-3 is a rapid reconnaissance tool which produces data representing the bulk of discrete conductivities to a particular depth. The Sirotem will provide voltage measurements at each delay time which are normalized to an apparent conductivity so as to provide a crude indication of the subsurface conductivity structure. The Sirotem is better suited to defining either upconning or small changes in conductivities along an arbitrary boundary. If the em34-3 can better define areas of interest those areas should then, providing field conditions permit, be profiled with the Sirotem.
SCHEMATIC PROFILE OF THE GROUNDWATER SYSTEM

Fig 2
Millingimbi, May 1990

Location of EM34/3 lines

Fig 3
Millingimbi, Joint Sounding at VES1, 31/10/90

SIROTEM

--- field data
--- model fit

FINAL MODEL AFTER INVERSION:
Resistivity  Thickness
542.18      2.97
169.72      2.84
880.53      18.82
55.39       48.78
2.54        32.73
24.38

EFF. PAR. = 9.83
STD. ERROR = 9.06 %
APR. ERROR = 9.62 %

Fig 5
Milingimbi, Joint Sounding at VES2, 31/10/90

SIROTEM

FINAL MODEL AFTER INVERSION:
Resistivity                Thickness
535.90                    2.26
234.44                    3.50
1369.42                   19.78
64.20                     52.35
2.15                      29.55
7.30

EFF. PAR. = 9.95
STD. ERROR = 8.07 %
APR. ERROR = 8.96 %

Fig 6
Milingimbi, Joint Sounding at VES3, 31/10/90

FINAL MODEL AFTER INVERSION:

Resistivity  Thickness
455.17      2.46
89.84       17.57
15.85       37.81
1.25        94.81
8349.55

Eff. PAR. = 8.00
STD. ERROR = 8.64 %
APR. ERROR = 9.28 %

Fig 7
Millingtum, May 1990

Contour of conductivity in milihmho/meter, measured with a Geonics EM34/3 instrument with a spacing of 40m in the horizontal coplanar mode.

Fig 8
Fig 9.

Contour of conductivity in millimhos/meter. Measured with a Geonics EM34/3 instrument with a spacing of 40m in the horizontal coplanar mode.
Contour of conductivity in millimho/meter. Measured with a Geonics EM34/3 instrument with a spacing of 40m in the vertical coplanar mode.

Fig 10
Fig 11

Contour of conductivity in millimho/meter. Measured with a Geonics EM34/3 instrument with a spacing of 40m in the vertical coplanar mode.
Contours of conductivity in millimho/meter
Measured with a Geonics EM31.

Fig 12