Ground Penetration Radar Survey at Yallah’s Lower Basin, St. Thomas May 28-29., and June 01.-03. 2004

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University of the West Indies,
Mona Campus, Kingston, June 2004
Acknowledgements

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Introduction
The field work described herein was carried out as part of the project entitled ‘Modelling Groundwater Flow in the Alluvial Aquifer of the Lower Yallahs Basin, St. Thomas’. A Ground Penetrating Radar (GPR) survey was performed at the Lower Yallah’s Basin during May 27-28 and June 1-3, 2004. This report primarily presents the data obtained during the field work and does not include any interpretation of data. Raw GPR data are attached as an appendix and is available for downloading at: http://folk.uio.no/nilsotto/PUBL/Yallah_2004_GPR_survey.tar.gz until Nov. 2004.

Coastal Alluvial deposits are important resources around the world. At Lower Yallah’s Basin obvious interests are agriculture, gravel mining, and tourist industry. The potential value of this resource depends, however, to a large extent on the availability of fresh water. Balancing of interests may consequently burn down to a question of water management.

According to previous studies (Baptiste, 1996) the main recharge of the aquifer is through seepage of water from Yallahs River. Baptiste (1996) estimated a sustained flow into the aquifer at 45·10^3 m^3/day. Furthermore, it was estimated that in order to prevent hazardous intrusion of salt water from the Caribbean Sea, the recharge of the aquifer should not be lower than 12·10^3 m^3/day (based on an aquifer thickness of 1,316 m). Safe yield was consequently estimated to be 11·10^3 m^3/day. The estimate of safe yield assumes, however, that maximum pumping rate from any location within the aquifer does not exceed 5·10^3 m^3/day.

The objectives of the present survey were spatial estimation of:
(1) depth to groundwater table
(2) depth to the fresh-salt water diffusion zone; and
(3) sedimentological structures within the alluvium.

Ground Penetrating Radar
The physical principle of the Ground Penetrating Radar (GPR) is well-known and details are available in textbooks (e.g. Sharma, 1997). The high frequency Electro-Magnetic (EM) signal that is transmitted through the ground is sensitive to changes in the relative dielectric conductivity (Table I). Contrasts in the dielectric properties in natural soils are usually related to the degree of water saturation. Where changes in the water content take place (as for example the interface between the unsaturated and saturated zones) reflection in the GPR-signal will occur. However, registration of the GPR-reflections also depends on the transmission of the EM waves. The critical factor for transmission is the electrical conductivity of the subsurface. High electrical conductivity dampens the signals. It is possible to improve the depth of penetration by using EM-waves of lower frequencies (or longer wavelengths). However, lower frequencies also result in lower resolution. Two different frequencies were used in the present survey i.e., 200 MHz and...
50 MHz. Given an average velocity (v) of 125 m/ms, signals with frequencies (f) of 200 MHz and 50 MHz, have wavelengths (w) of 0.625 m and 2.5 m respectively (w=v/f). Theoretical value of vertical resolution is \( w/4 \), but in practice (due to noise and scattering) the vertical resolution varies between 0.5 and 1.0 m. GPR data can be used for a number of purposes such as infiltration studies (Kowalski et al. 2001) or as input for geostatistical analysis (Langsholt et al., 1998).

<table>
<thead>
<tr>
<th>Medium</th>
<th>( \varepsilon_r )</th>
<th>Velocity [m/ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>Fresh water</td>
<td>81</td>
<td>33</td>
</tr>
<tr>
<td>Limestone</td>
<td>7-6</td>
<td>75-113</td>
</tr>
<tr>
<td>Granite</td>
<td>5-7</td>
<td>113-134</td>
</tr>
<tr>
<td>Schist</td>
<td>5-15</td>
<td>77-134</td>
</tr>
<tr>
<td>Concrete</td>
<td>4-10</td>
<td>95-150</td>
</tr>
<tr>
<td>Clay</td>
<td>4-16</td>
<td>74-150</td>
</tr>
<tr>
<td>Silt</td>
<td>9-23</td>
<td>63-100</td>
</tr>
<tr>
<td>Sand</td>
<td>4-30</td>
<td>55-150</td>
</tr>
<tr>
<td>Moraine/Till</td>
<td>9.25</td>
<td>60-100</td>
</tr>
<tr>
<td>Ice</td>
<td>3-4</td>
<td>150-173</td>
</tr>
<tr>
<td>Permafrost</td>
<td>4-8</td>
<td>106-150</td>
</tr>
</tbody>
</table>

Table 1. Relative dielectric constant (\( \varepsilon_r \)) also called relative permittivity, and propagation velocities for different media (Malå Geoscience, 2001)

**Ground Penetrating Survey at Lower Yallah’s Basin**

The survey carried over a 5-day period (May 27-28 and June 1-3, 2004) was concentrated on the western part of the Aquifer at Albion. Three short profiles were also sampled in the main riverbed of Yallah’s river (Fig. 1). Two different types of sampling were carried out: “zero-offset” sampling and “move-out” sampling. Separation distance between receiver and transmitter antenna for the zero-offset profiles were 1 m for both 200- and 50 MHz antennas. The move-out configuration (Fig. 2) was performed only with the 200 MHz antennas due to a serious malfunction in the 50 MHz antennas after May 28. Move-out sampling improves the quality of information and facilitates more accurate signal processing (Fisher et al., 1992a,b; Vasco et al., 1997). Only plot of raw data is included in this field report. Location of GPR-profiles and groundwater wells are given in Fig. 1 and in the Appendix.
Figure 1. Location of groundwater wells (magenta) and Ground Penetrating Radar (GPR) profiles. NOTE: The GPR profiles and the wells are in consistent coordinates, but the topography is not. For example the was the long GPR profile at the lower left corner terminated at the sea-shore.

Figure 2. Move-out configuration. For each GPR-shot, the receiving antenna was kept at the same location while the transmitting antenna was moved from 1 m, 3 m, 5 m ... etc. to 30 m from the receiving antenna. After one shot point, the receiving antenna was moved one 1 m forward, and the same procedure was repeated.
References:
Baptiste, J., Hydrogeological study of the lower Yallah’s Basin, St. Thomas, Jamaica, W.I., Ph.D thesis (monograph), University of the West Indies, Department of Geology, faculty of Natural Resources, Campus: Mona, 1996
Fisher, E., McMechan, G.A., Annan, A.P., Acquisition and processing of wide-aperture ground-penetrating radar data, Geophysics, 57 (3) 495-504, 1992a
Fisher, E., McMechan, G.A., Annan, A.P., Cosway, S.W., Examples of reverse-time migration of single-channel, ground-penetrating radar profiles, Geophysics 57 (4) 577-586, 1992b
Appendix

A) Plot of raw Ground Penetrating Radar data

B) Geophysical Survey, Yallahs, St. Thomas, Geographical Positions and Field Notes
A) Plot of raw Ground Penetrating Radar data
### B) Geophysical Survey, Yallahs, St. Thomas, Geographical Positions and Field Notes

**Day 1 – May 27, 2004**

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Coordinates</th>
<th>Depth to Water (ft)</th>
<th>Elevation of Measurement Point (above sea level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>London Piece Well</td>
<td>18 329570 E, 1979102 N</td>
<td>20.97</td>
<td>64 top of casing</td>
</tr>
<tr>
<td>Norris</td>
<td>18 332454 E, 1981500 N</td>
<td>118.19</td>
<td>102 m top of pipe</td>
</tr>
<tr>
<td>Yallahs</td>
<td>18 333585 E, 1977184 N</td>
<td>16.32</td>
<td>19m top of casing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profile 1 North-South 200 mHz</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (metres)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>18 330366E, 1977803N</td>
</tr>
<tr>
<td>50</td>
<td>18 330330E, 1977768N</td>
</tr>
<tr>
<td>100</td>
<td>18 330296E, 1977737N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profile 2 West-East 200 mHz</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (metres)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>18 330320E, 1977785N</td>
</tr>
<tr>
<td>50</td>
<td>18 330340E, 1977736N</td>
</tr>
<tr>
<td>100</td>
<td>18 330375E, 1977695N</td>
</tr>
</tbody>
</table>

**Crosspoint – 18 330375E, 1977695N**

<table>
<thead>
<tr>
<th>Profile 3 West-East 50 mHz</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (metres)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>18 330325E, 1977772N</td>
</tr>
<tr>
<td>50</td>
<td>18 330345E, 1977732N</td>
</tr>
<tr>
<td>100</td>
<td>18 330377E, 1977694N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Profile 4 North-South 50 mHz</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (metres)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>18 330331E, 1977770N</td>
</tr>
<tr>
<td>100</td>
<td>18 330297E, 1977730N</td>
</tr>
</tbody>
</table>
Day 2 – May 28, 2004

Profile 1  Parallel to Coast

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 329409E, 1976922N</td>
</tr>
<tr>
<td>50</td>
<td>18 329367E 1976951N</td>
</tr>
<tr>
<td>100</td>
<td>18 329324E, 1976978N</td>
</tr>
</tbody>
</table>

Profile 2  Perpendicular to Coast

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 329363E, 1976948N</td>
</tr>
<tr>
<td>50</td>
<td>18 329399E, 1976982N</td>
</tr>
<tr>
<td>100</td>
<td>18 329432E, 1977016N</td>
</tr>
<tr>
<td>150</td>
<td>18 329472E, 1977047N</td>
</tr>
<tr>
<td>250</td>
<td>18 329529E, 1977133N</td>
</tr>
<tr>
<td>284</td>
<td>18 329557E, 1977116N</td>
</tr>
<tr>
<td>800</td>
<td>18 329926E, 1977479N</td>
</tr>
</tbody>
</table>

Crosspoint – 18 329367E, 1976951N

Note:
- Land starts to slope at 11 metres from coastline and flattens at 18 metres.
- Equipment boxes were at 33 metres.
- Asphalt starts at 94 metres.
- Transect turned parallel to sea at 250 metres and then turned perpendicular at 284 metres.
- Stopped for lunch at 800 metres.
### Day 3 – June 1, 2004

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Coordinates</th>
<th>Depth to water (ft. below groundlevel)</th>
<th>Elevation above sea level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yallahs non-pumping well at quarry</td>
<td>18 330510E 1977569N</td>
<td>46.21</td>
<td>22 metres</td>
</tr>
<tr>
<td>Pumping well at quarry</td>
<td>18 330535E 1977583N</td>
<td>No measurement point and splashing water.</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
- Nearby well pumping approximately 23.80 metres away.
- Bucket bail test was performed with a five gallon (18.9 litres) bucket. Times taken were 1.83s, 1.91s, 1.30s, 1.48s, 1.34s, 1.57s, 1.73s, and 1.43s.

#### Profile 1  From pumping well to observation well

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330535E, 1977583</td>
</tr>
<tr>
<td>End</td>
<td>18 330521E, 1977569N</td>
</tr>
</tbody>
</table>

**Note:**
- Measurements were taken at 0.5 metre interval.
- There was a pipe at 9 metres.
- There was a light wire at 10 metres.
- There was the steel gate for the well house at 20 metres.

#### Profile 2  From observation well to fence at quarry

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330528E, 1977569N</td>
</tr>
<tr>
<td>50</td>
<td>18 330488E, 1977598N</td>
</tr>
<tr>
<td>63</td>
<td>18 330488E, 1977597N</td>
</tr>
</tbody>
</table>

**Note:**
- Crosspoint is at 10 metres.
- Water at surface at 26.5 metres, 34-36 metres and 38-40 metres.
- There was metal across the road at 56 metres.
- Profile turned at 63 metres (crosspoint with profile 3).

#### Profile 3

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330484E, 1977606N</td>
</tr>
<tr>
<td>50</td>
<td>18 330459E, 1977572N</td>
</tr>
</tbody>
</table>
### Profile 4

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330468E, 1977596N</td>
</tr>
<tr>
<td>50</td>
<td>18 330433E, 1977624N</td>
</tr>
<tr>
<td>100</td>
<td>18 330391E, 1977655N</td>
</tr>
</tbody>
</table>

**Note:** Canal at 5 metres.

### Profile 5

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330374E, 1977626N</td>
</tr>
<tr>
<td>50</td>
<td>18 330397E, 1977670N</td>
</tr>
</tbody>
</table>

### Profile 6

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330397E, 1977670N</td>
</tr>
<tr>
<td>50</td>
<td>18 330368E, 1977710N</td>
</tr>
<tr>
<td>100</td>
<td>18 330332E, 1977750N</td>
</tr>
<tr>
<td>150</td>
<td>18 330318E, 1977795N</td>
</tr>
<tr>
<td>200</td>
<td>18 330303E, 1977843N</td>
</tr>
<tr>
<td>220</td>
<td>18 330298E, 1977861N</td>
</tr>
</tbody>
</table>

**Note:**
- Profile 6 is perpendicular to Profile 5.
- Asphalt starts at 135 metres

### Profile 7

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330308E, 1977864N</td>
</tr>
<tr>
<td>50</td>
<td>18 330260E, 1977848N</td>
</tr>
<tr>
<td>100</td>
<td>18 330212E, 1977838N</td>
</tr>
<tr>
<td>150</td>
<td>18 330163E, 1977838N</td>
</tr>
</tbody>
</table>

**Note:** Profile 7 crosses with Profile 6 at 11 metres.

### Profile 8

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330195E, 1977842N</td>
</tr>
<tr>
<td>50</td>
<td>18 330196E, 1977794N</td>
</tr>
<tr>
<td>100</td>
<td>18 330192E, 1977744N</td>
</tr>
</tbody>
</table>

**Note:** Profile 7 crosses Profile 8 at 5 metres.
### Profile 9

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330192E, 1977744N</td>
</tr>
<tr>
<td>50</td>
<td>18 330150E, 1977714N</td>
</tr>
<tr>
<td>100</td>
<td>18 330119E, 1977680N</td>
</tr>
<tr>
<td>150</td>
<td>18 330083E, 1977641N</td>
</tr>
<tr>
<td>200</td>
<td>18 330046E, 1977607N</td>
</tr>
<tr>
<td>250</td>
<td>18 330011E, 1977573N</td>
</tr>
</tbody>
</table>

**Note:** A truck was parked at 150 metres.

---

### Day 4 – June 2, 2004

#### Profile 1

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330011E, 1977573N</td>
</tr>
<tr>
<td>50</td>
<td>18 329977E, 1977535N</td>
</tr>
<tr>
<td>100</td>
<td>18 329939E, 1977503N</td>
</tr>
<tr>
<td>150</td>
<td>18 329895E, 1977468N</td>
</tr>
<tr>
<td>200</td>
<td>18 329865E, 1977433N</td>
</tr>
<tr>
<td>250</td>
<td>18 329831E, 1977400N</td>
</tr>
<tr>
<td>300</td>
<td>18 329797E, 1977364N</td>
</tr>
<tr>
<td>350</td>
<td>18 329761E, 1977327N</td>
</tr>
<tr>
<td>400</td>
<td>18 329727E, 1977296N</td>
</tr>
<tr>
<td>450</td>
<td>18 329688E, 1977258N</td>
</tr>
<tr>
<td>500</td>
<td>18 329653E, 1977223N</td>
</tr>
<tr>
<td>550</td>
<td>18 329617E, 1977188N</td>
</tr>
<tr>
<td>600</td>
<td>18 329579E, 1977156N</td>
</tr>
<tr>
<td>642</td>
<td>18 329553E, 1977127N</td>
</tr>
</tbody>
</table>

**Note:**
- Profile 2 crosses Profile 1 at 640 metres – 18329552E, 1977122N.
- Profile 1 crosses Profile 2 at 15 metres.

#### Profile 2

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 329564E, 1977115N</td>
</tr>
<tr>
<td>50</td>
<td>18 329524E, 1977142N</td>
</tr>
</tbody>
</table>

**Note:**
- Profile 3 crosses Profile 2 at 43 metres. Profile 2 crosses Profile 3 at 8 metres.
- Crosspoint – 18 329532E, 1977136N.
Profile 3

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 329535E, 1977139N</td>
</tr>
<tr>
<td>50</td>
<td>18 329507E, 1977099N</td>
</tr>
<tr>
<td>100</td>
<td>18 329476E, 1977063N</td>
</tr>
<tr>
<td>150</td>
<td>18 329444E, 1977030N</td>
</tr>
<tr>
<td>200</td>
<td>18 329408E, 1976990N</td>
</tr>
<tr>
<td>250</td>
<td>18 329371E, 1976957N</td>
</tr>
<tr>
<td>292</td>
<td>18 329376E, 1976959N</td>
</tr>
<tr>
<td>311 (end)</td>
<td>18 329363E, 1976946N</td>
</tr>
</tbody>
</table>

Note:
- Pipe crosses road at 60 metres and 149.3 metres.
- Asphalt starts at 387 metres.
- Slopes downwards at 292 metres and slope ends at 300 metres.
- Coordinates at 292 metres are 18 329376E, 1976959N at approximately 11 metres above sea level.
- Profile 3 crosses profile on Day 1 at 305 metres.

Profile 4

Move out after lunch.

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 329381E, 1976965N</td>
</tr>
</tbody>
</table>

Day 5 – June 3, 2004

Profile 1

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
<th>Elevation (metres a.m.s.l.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 329400E, 1976986N</td>
<td>15</td>
</tr>
<tr>
<td>35</td>
<td>18 329423E, 1977013N</td>
<td>12</td>
</tr>
</tbody>
</table>

Note:
- Continued where the profile from the previous day had ended.
- Gravel and bad road started at 41 metres.

Profile 2

Perpendicular to Coast

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 329429E, 1977012N</td>
</tr>
<tr>
<td>50</td>
<td>18 329399E, 1977049N</td>
</tr>
</tbody>
</table>
Profile 3  On ridge at Yallahs river

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
<th>Elevation (metres a.m.s.l.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18 330960E, 1977477N</td>
<td>33</td>
</tr>
<tr>
<td>50</td>
<td>18 330953E, 1977431N</td>
<td>26</td>
</tr>
</tbody>
</table>

Note:
- Elevation at 40 metres is 24 metres a.m.s.l.

Profile 4  In river bed running west to east

<table>
<thead>
<tr>
<th>Distance (metres)</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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Profile 5  North-South towards sea

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<th>Distance (metres)</th>
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