# Assessment of groundwater quality in the coastal regions of Aceh Province, North Sumatra, after the tsumani, 26 December 2004

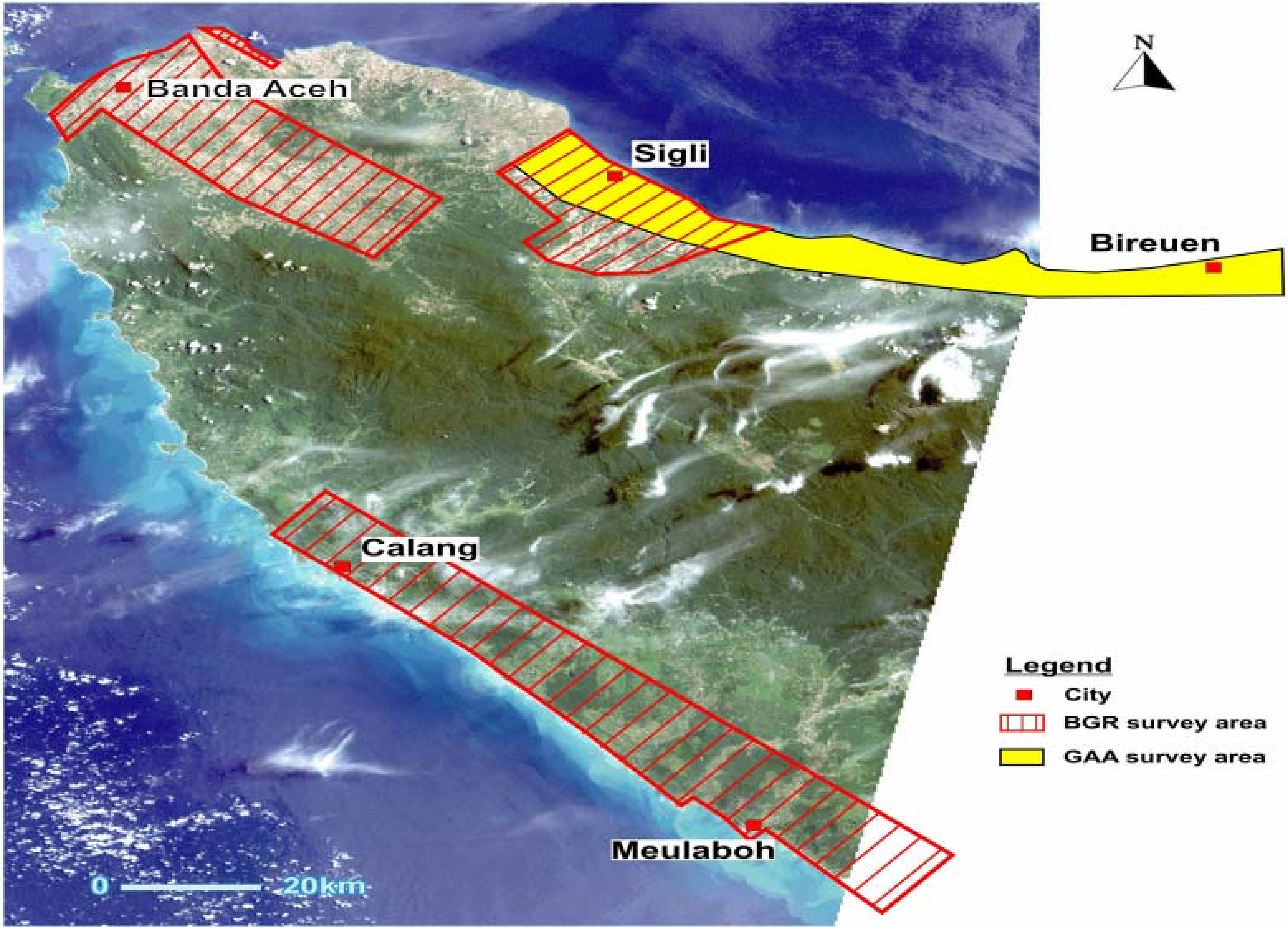
D. Ploethner, H. Klinge & J. Boehme

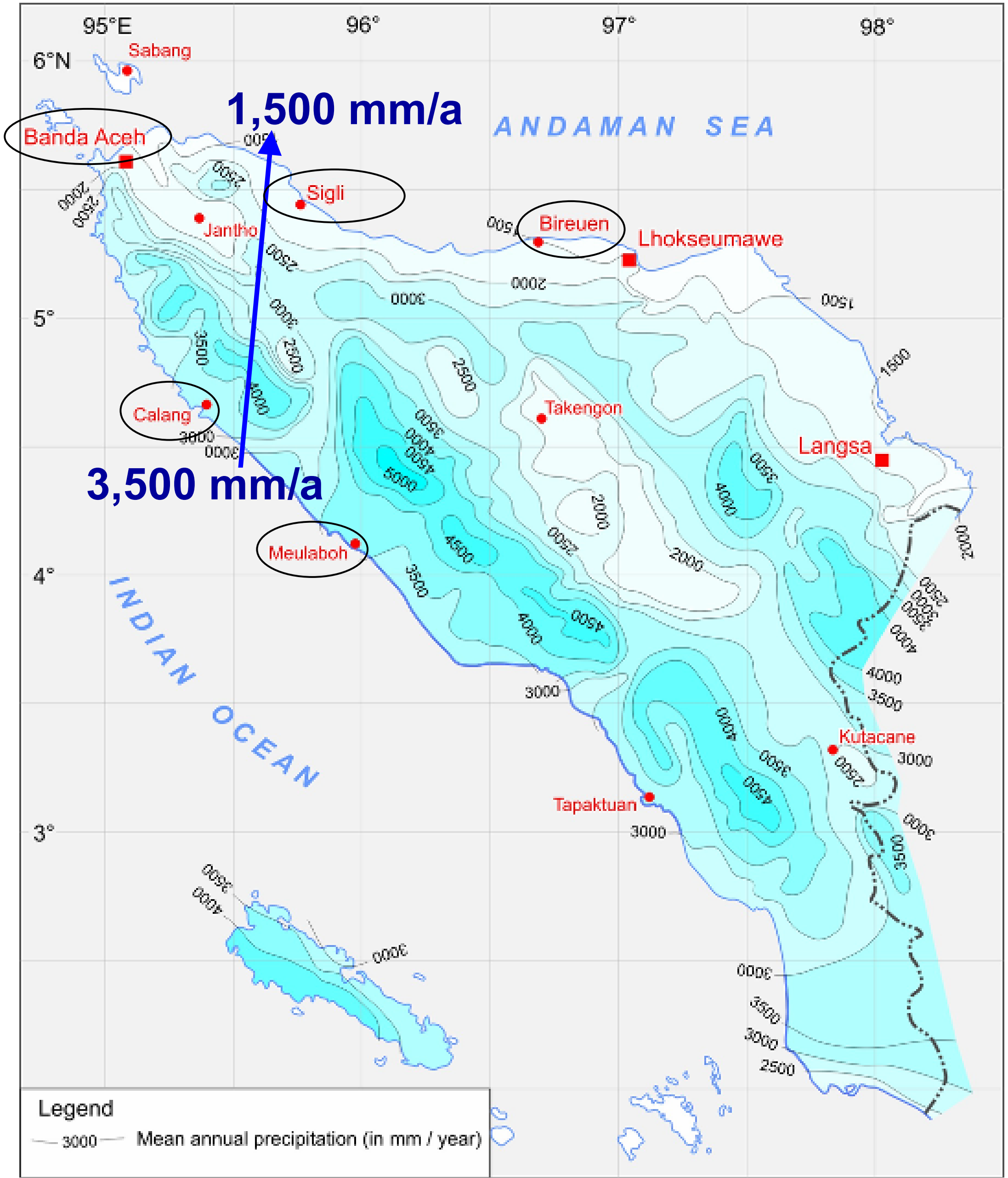
# BGR‘s main activities in the water sector

1. Hydrogeological reconnaissance surveys in combination with airborne geophysics (2005)
2. Advisory services to national and international rescue organisations and NGOs (2005-2006)
3. Collection, storage, and evaluation of borehole and water quality data (2005-2009)
4. On-the-job-training & capacity buildung of the Geological Survey (2005-2009)

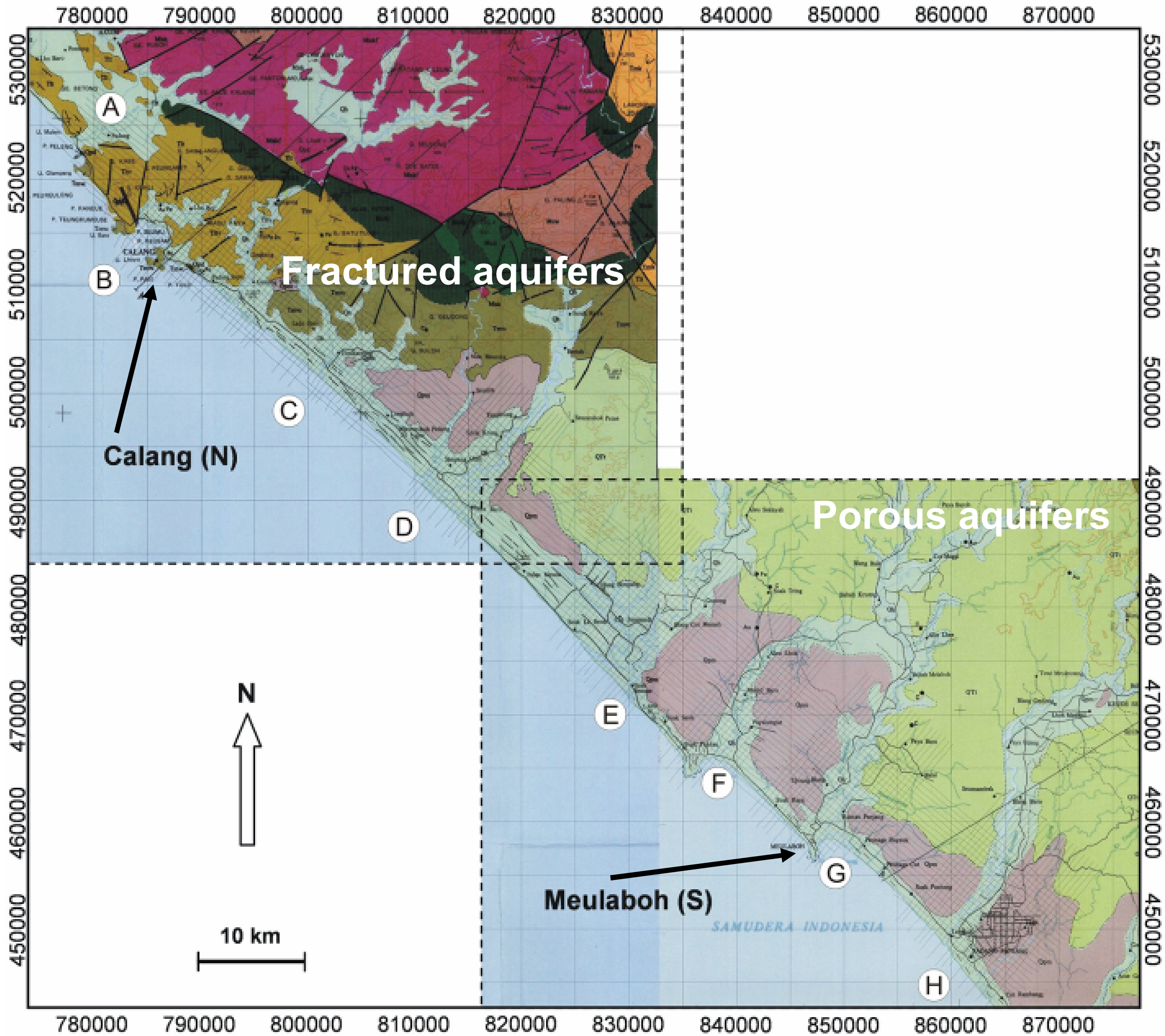
# Management of Georisks NAD

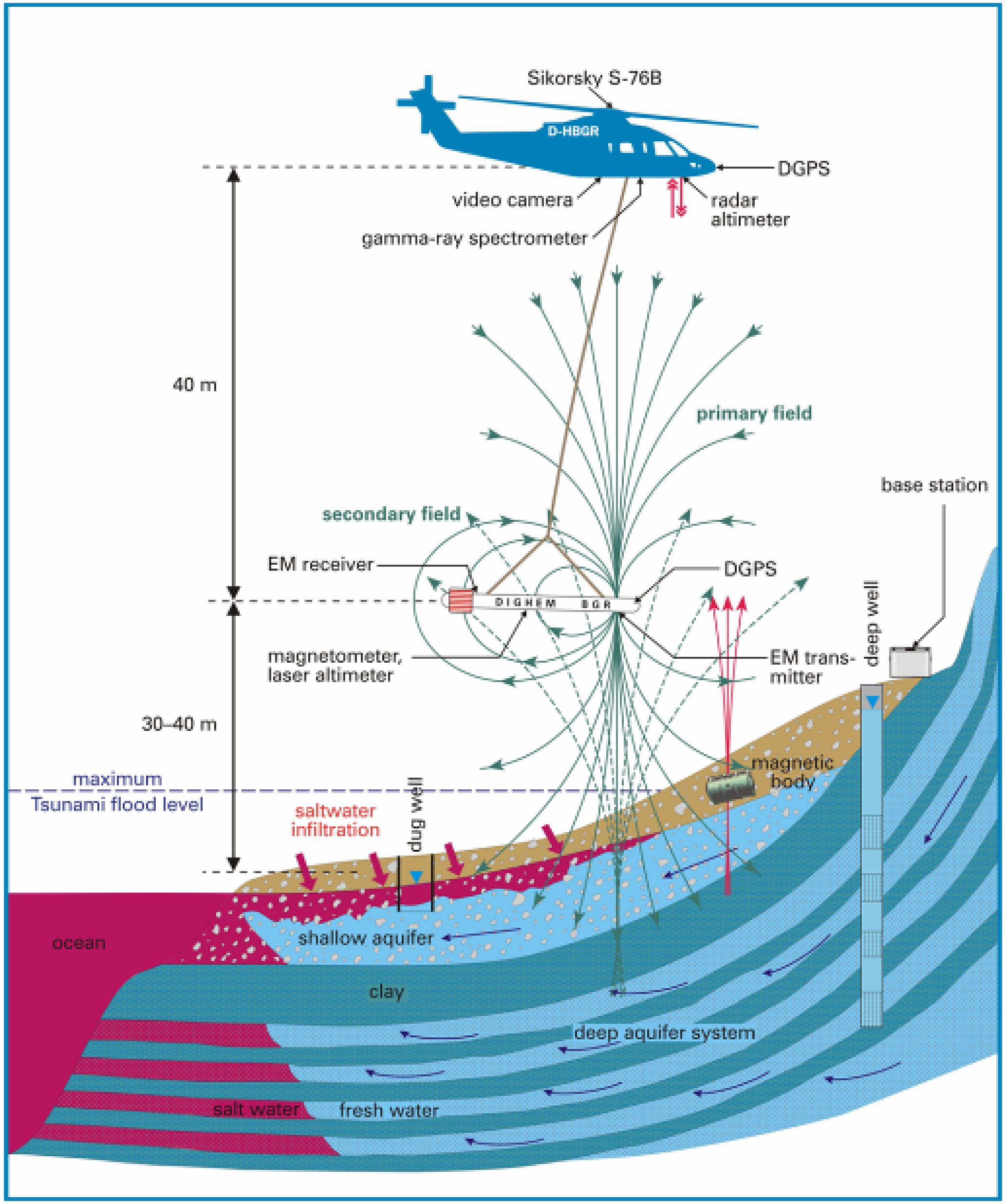
## MANGEONAD





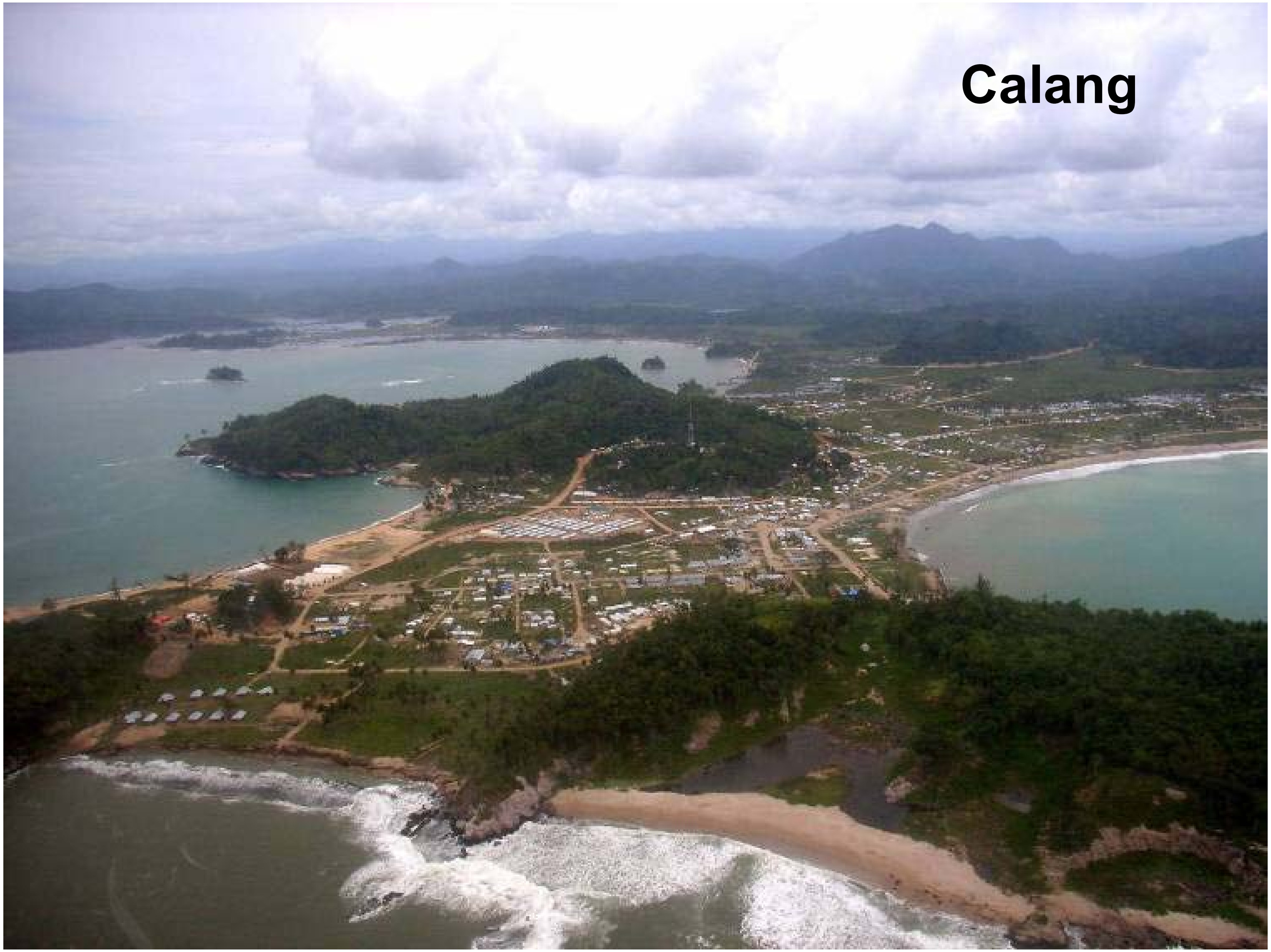

# Mean Annual Precipitation (IWACO 1993)

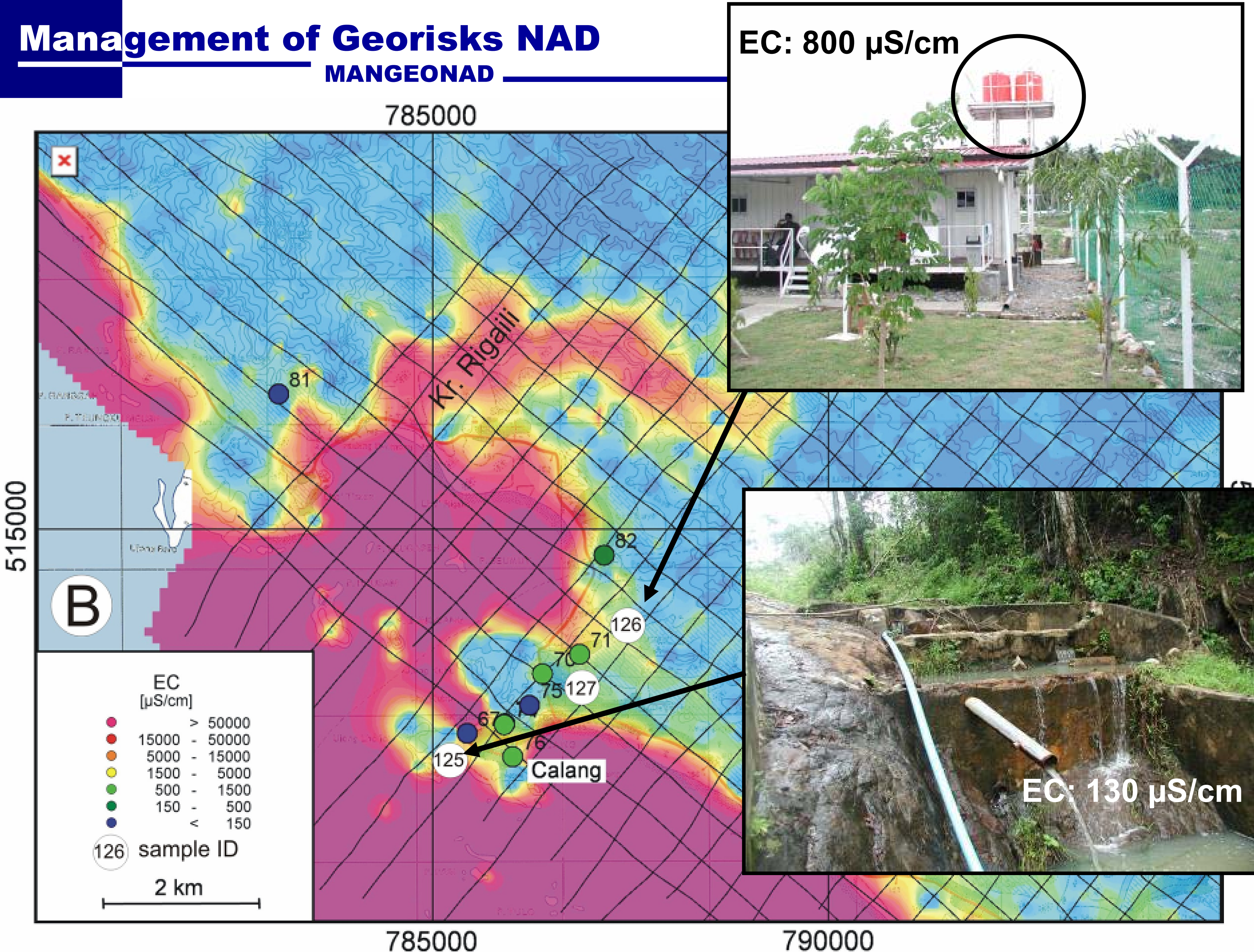

780000
790000
800000
810000
820000
830000
840000
850000
860000
870000
530000
520000
510000
500000
490000
480000
470000
460000
450000
A
B
C
D
E
F
G
H
Fractured aquifers
Porous aquifers
Calang (N)
Meulaboh (S)
N
10 km
SAMUDERA INDONESIA

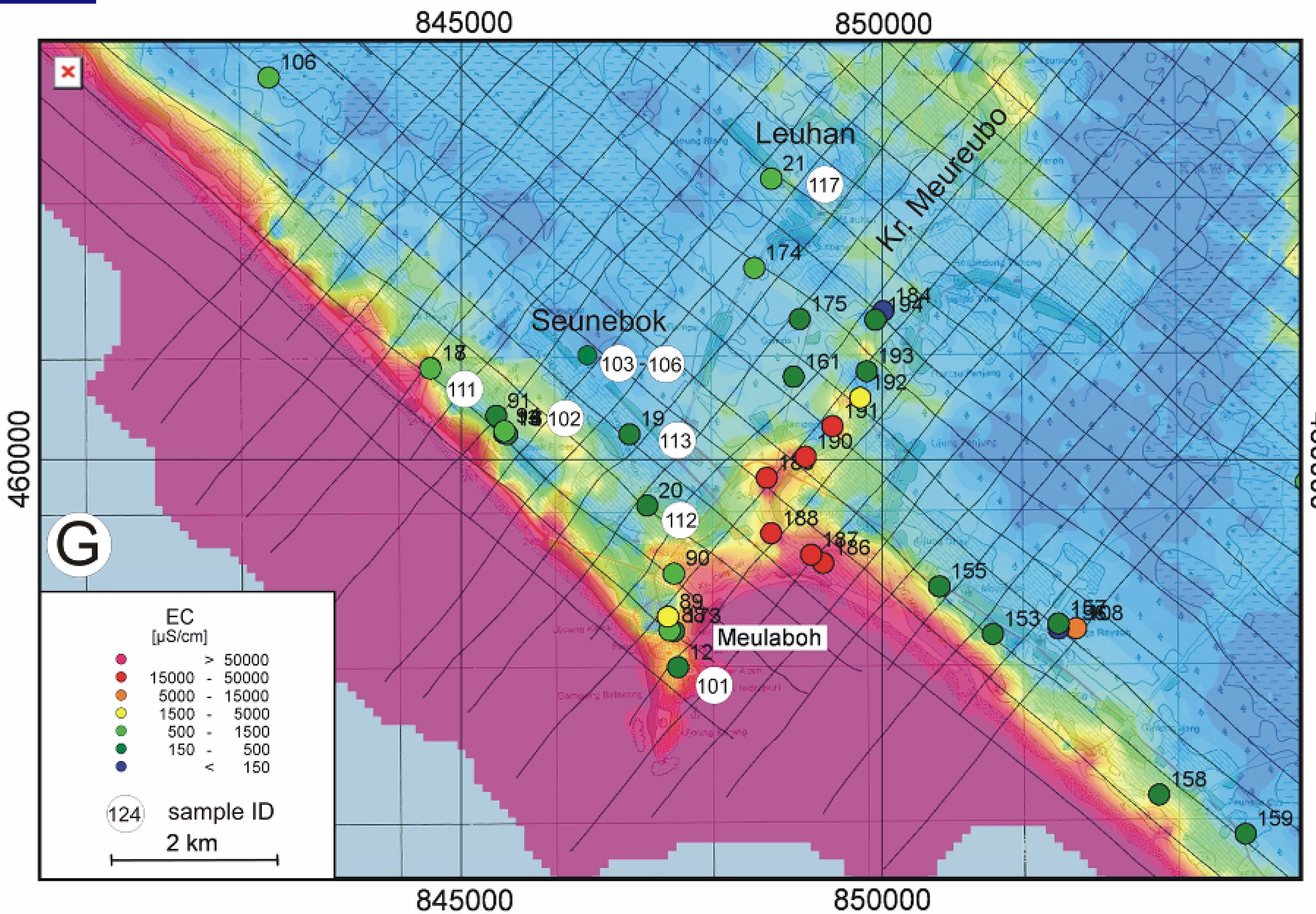



## Airborne Geophysical System

## Coastal Multi-layer Aquifer System / Saltwater Infiltration


Calang

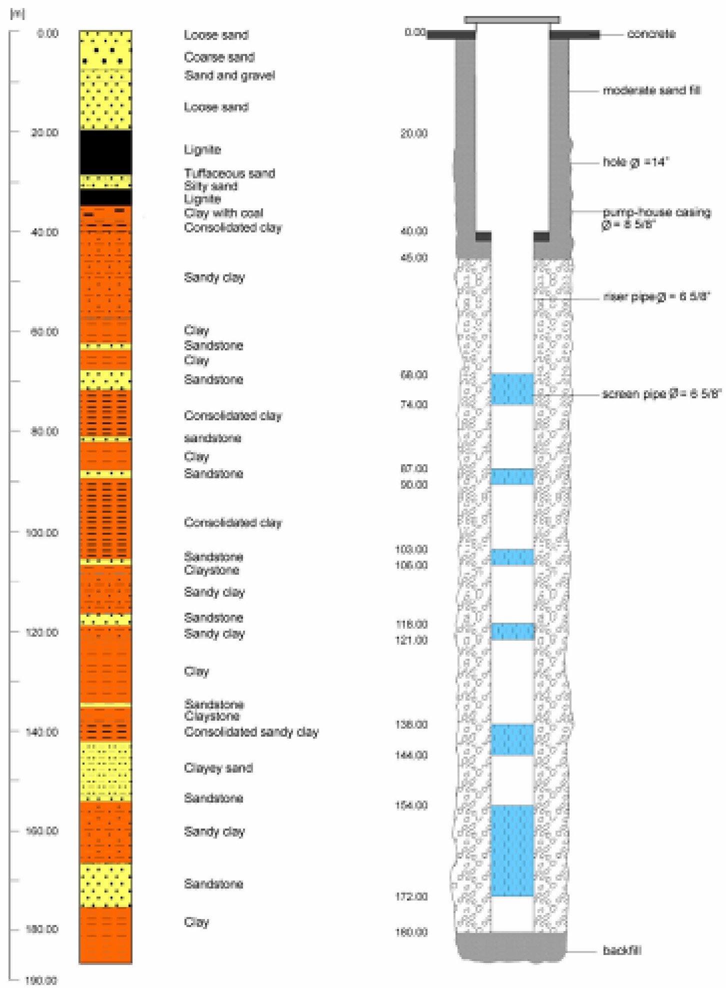

785000
785000
790000
515000
Kr. Rigaili
B
81
82
126
71
70
75
127
67
76
125
Calang
EC
[µS/cm]
> 50000
15000 - 50000
5000 - 15000
1500 - 5000
500 - 1500
150 - 500
< 150
126 sample ID
2 km
EC: 800 µS/cm
EC: 130 µS/cm


845000
850000
460000
Leuhan
Kr. Meureubo
Seunebok
Meulaboh
G
EC
[µS/cm]
> 50000
15000 - 50000
5000 - 15000
1500 - 5000
500 - 1500
150 - 500
< 150
124 sample ID
2 km

**Dug well: Traditional source of drinking water supply**
**May-June 1993: EC range from 50 to 500 µS/cm (IWACO 1993)**

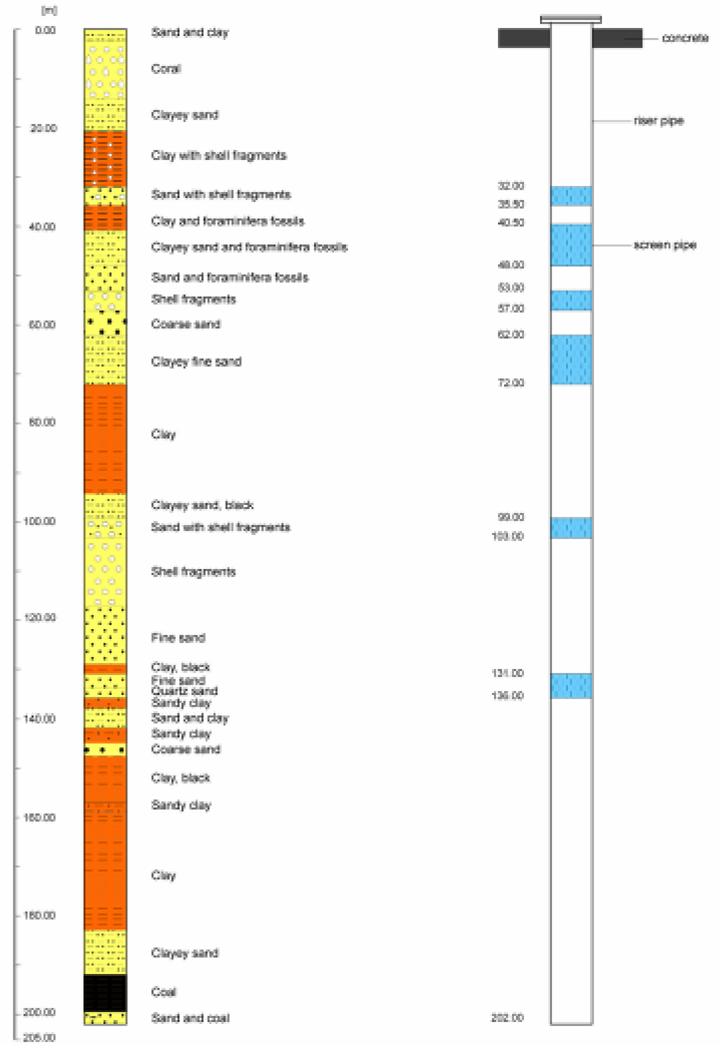
**Mid-February 2005: >3,000 µS/cm up to 2-3 km inland (Planète Urgénce 2005)**

## LITHOLOGIC LOG AND WELL DESIGN
## WW-III, KAMPUNG GAMPA, MEULABOH




Source : DHV Consulting Engineer, Medan

## LITHOLOGIC LOG AND WELL DESIGN
## WW-A, BINA MARGA/PUBLIC WORKS OFFICE, MEULABOH
## (WELL COMPLETED IN 1924)

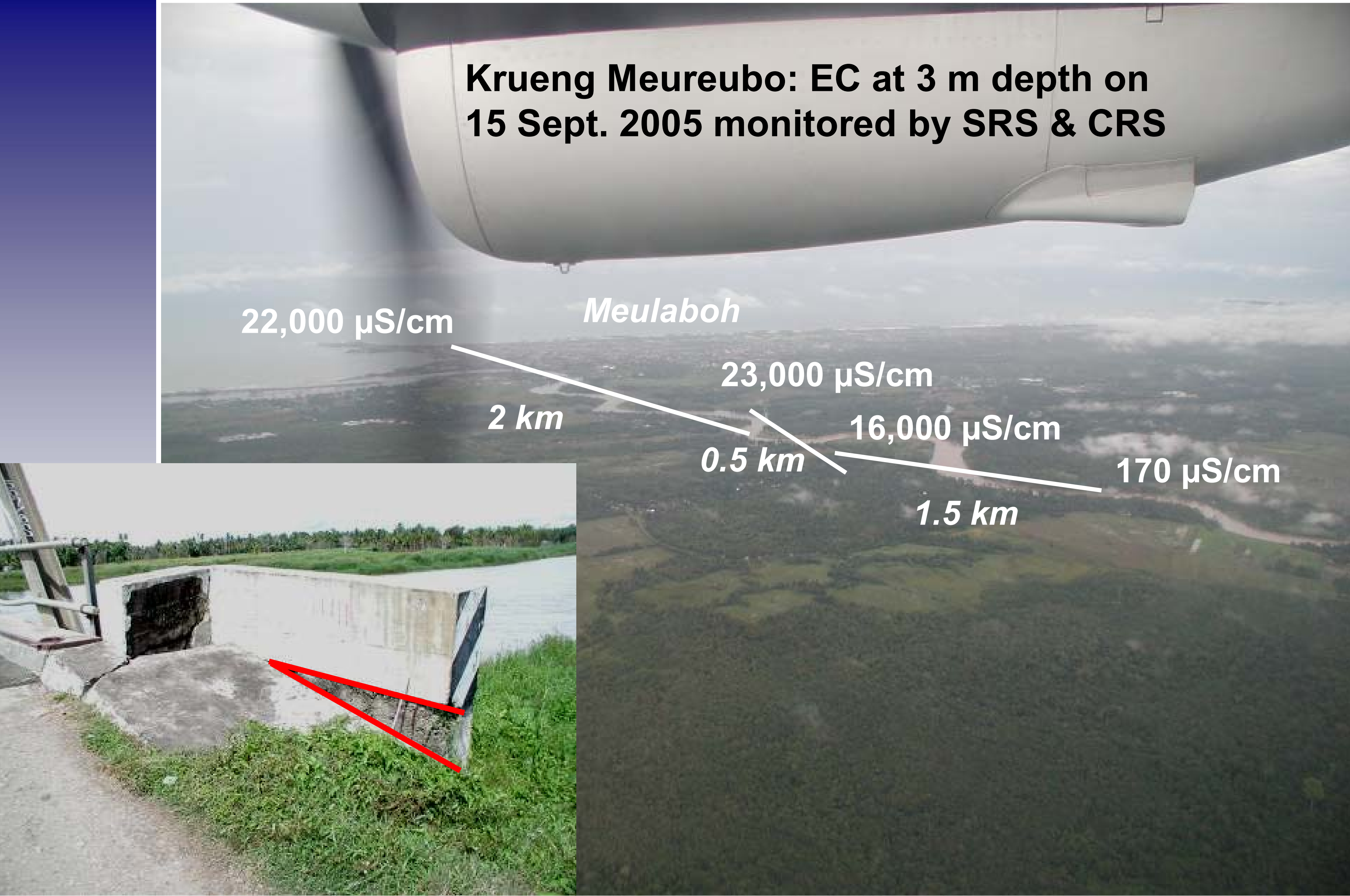


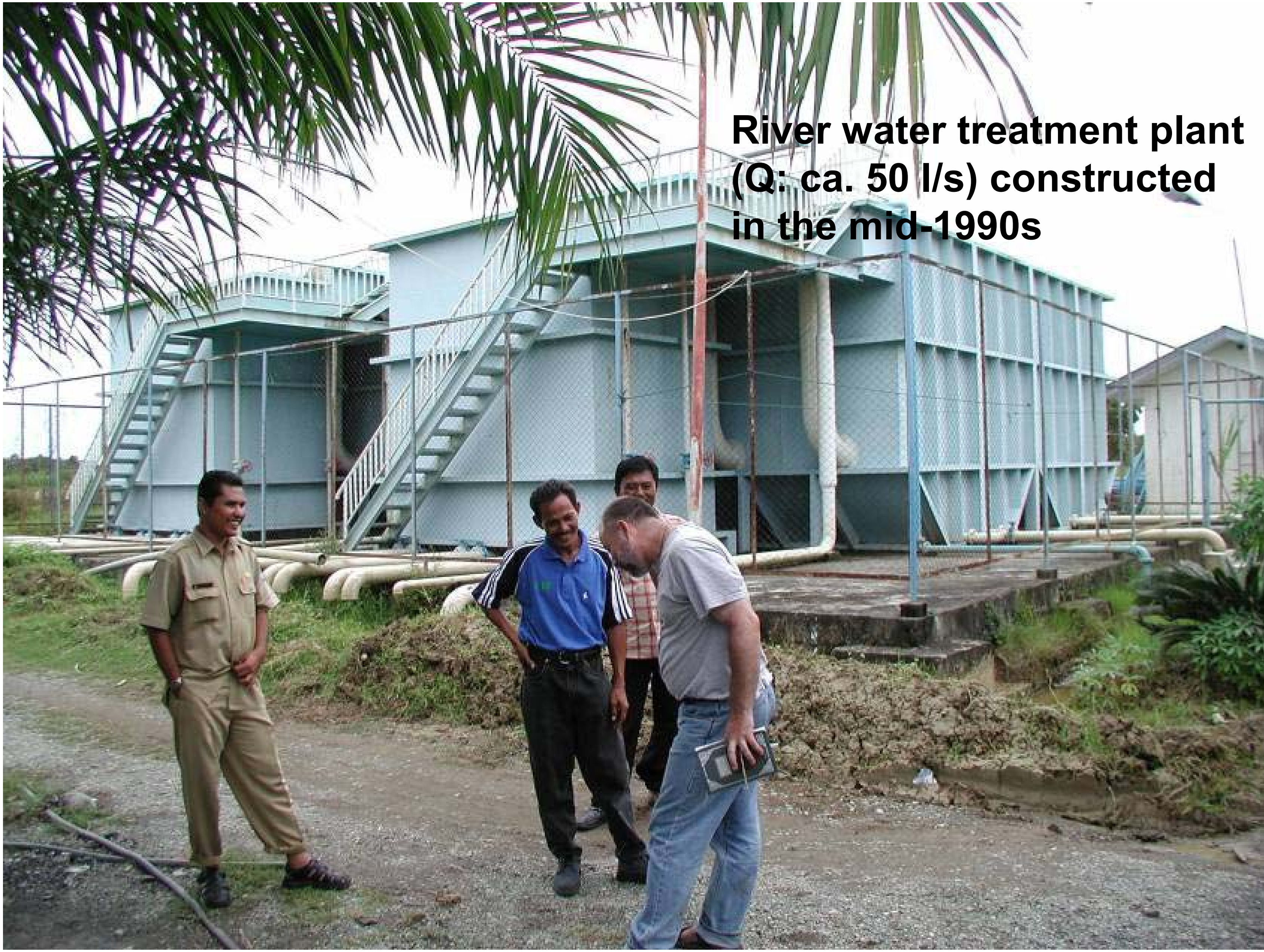

Source : Directorate of Geological & Mining Area Environment

**Five deep wells (Q: 25 l/s) constructed in 1982**

**Iron removal treatment constructed in 1987 / abandoned in the early 1990s; iron concentration was reduced with 20% only**

## Krueng Meureubo: EC at 3 m depth on 15 Sept. 2005 monitored by SRS & CRS





River water treatment plant (Q: ca. 50 l/s) constructed in the mid-1990s

17-36 m

**As: 340 µg/l**

Fe: 2.2 mg/l
$NH_4$: 1.7 mg/l
$NO_2$: 7.6 mg/l
Mn: 1.3 mg/l

?-90 m

**As: <1 µg/l**

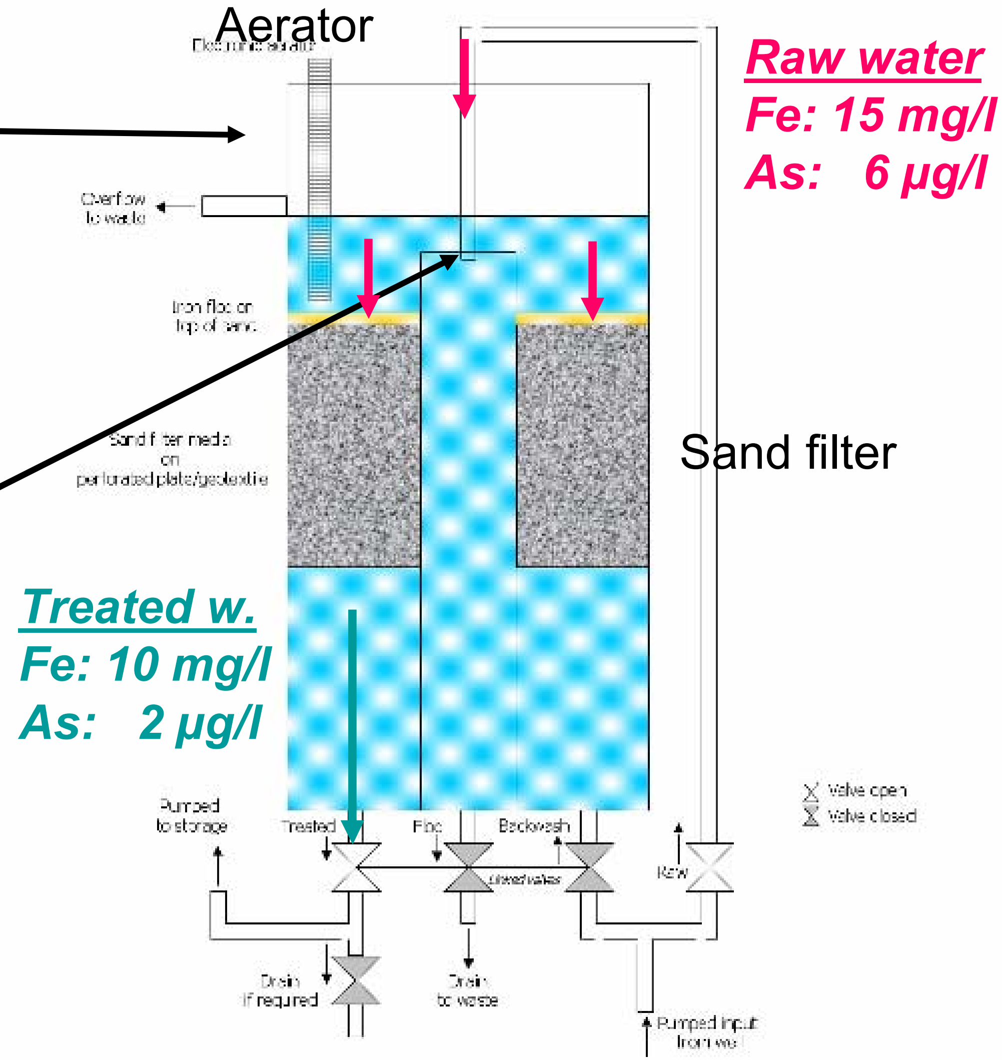
Fe: 1.0 mg/l
$NH_4$: 0.3 mg/l
$NO_2$: <0.01 mg/l
Mn: 0.3 mg/l

68-172 m

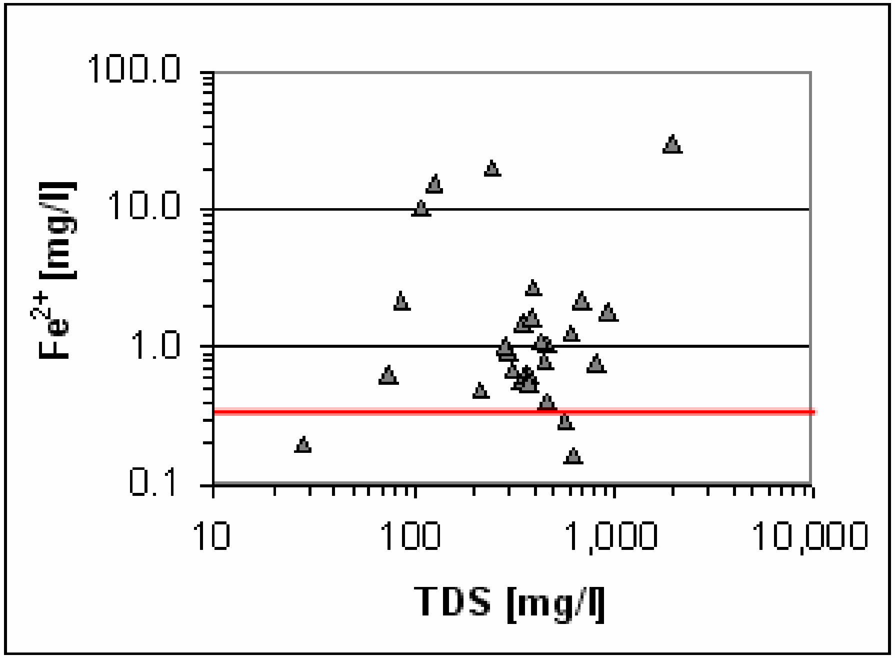
**As: <1 µg/l**

Fe: 0.3 mg/l
$NH_4$: 1.3 mg/l
$NO_2$: 0.01 mg/l
Mn: 0.1 mg/l

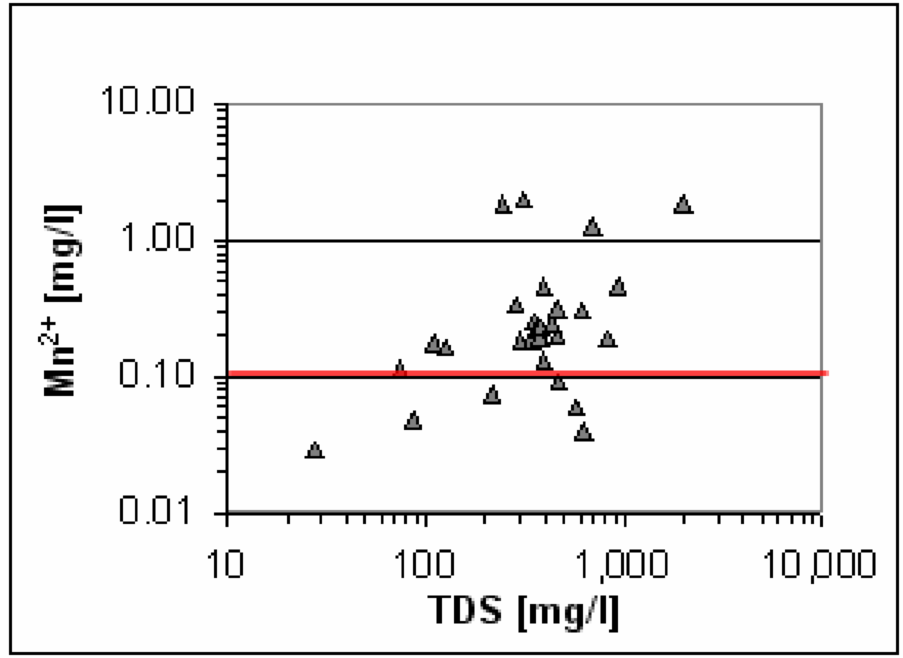
# Iron removal filter “Ferro Filter”



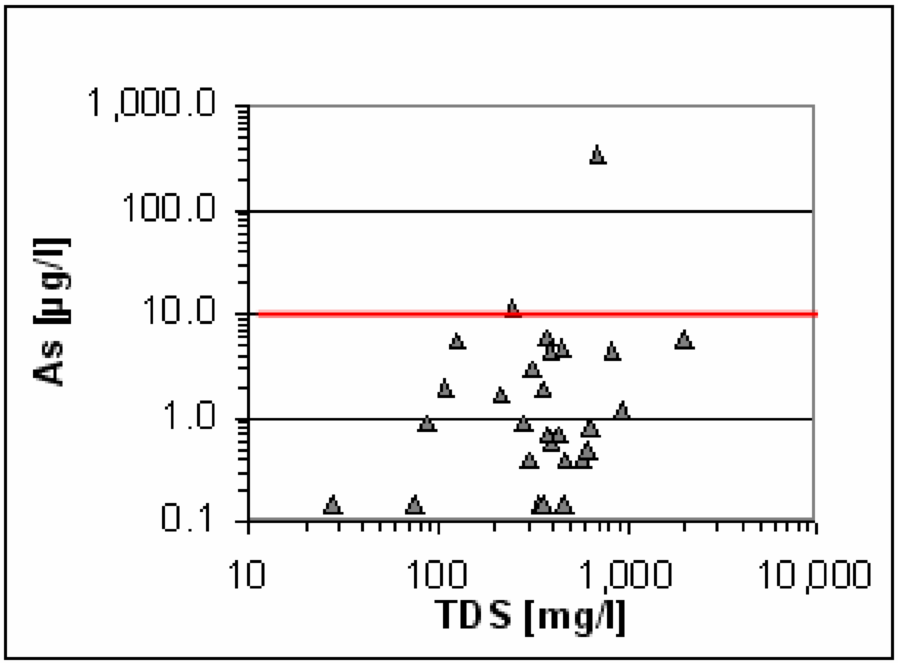

*(Note: Measured just after backwash!)*



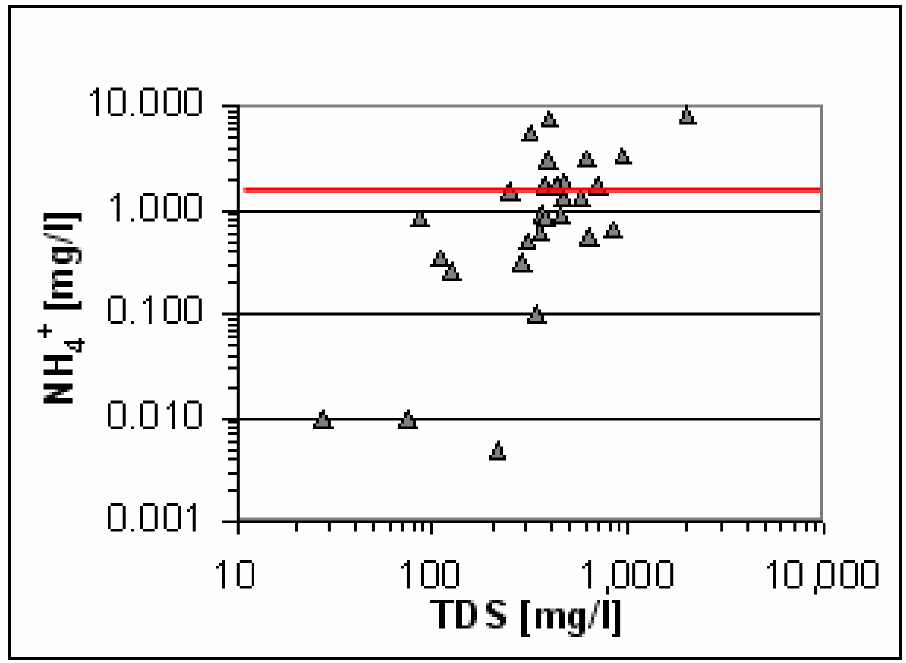
100.0
10.0
1.0
0.1
Fe2+ [mg/l]
10
100
1,000
10,000
TDS [mg/l]

10.00
1.00
0.10
0.01
Mn2+ [mg/l]
10
100
1,000
10,000
TDS [mg/l]

1,000.0
100.0
10.0
1.0
0.1
As [µg/l]
10
100
1,000
10,000
TDS [mg/l]

10.000
1.000
0.100
0.010
0.001
NH4+ [mg/l]
10
100
1,000
10,000
TDS [mg/l]

# Meulaboh - Calang

Groundwater is mostly fresh, but elevated concentrations of some selected inorganic constituents give rise to concern such as:

| *Parameter* | *Limit* | *Elevated range* | *Percentage* |
|---|---|---|---|
| **Arsenic [µg/l]** | **10** | **11 to 340** | **10%** |
| **Nitrate [mg/l]** | **50** | **Nil** | **Nil** |
| **Nitrite [mg/l]** | **3** | **4 to 11** | **15%** |
| **Ammonium [mg/l]** | **1.5** | **1.5 to 8** | **40%** |
| **Iron [mg/l]** | **0.3** | **0.3 to 30** | **90%** |
| **Manganese [mg/l]** | **0.1** | **0.1 to 2** | **80%** |

# Hydro-geochemical features (I)

**Cation exchange** takes place during artesian flow through abundant clayey aquitards: → **Na and $HCO_3$ are the predominant ions**

Decomposition of organic matter (e.g., peat, lignite) causes the frequent **depletion of dissolved oxygen** in groundwater (as low as 0.1 mg/l $O_2$)

Microbial **nitrate reduction** with coeval oxidation of organic matter generates the final products nitrogen (N) and carbon dioxide ($CO_2$). **Bacterial reduction** may also proceed to the final product ammonium ($NH_4$):
→up to **80 mg/l $CO_2$**,
→ up to **8 mg/l $NH_4$**, up to **20 mg/l $NO_2$**, → **$NO_3$<<10 mg/l**

# Hydro-geochemical features (II)

Under anoxic conditions iron, manganese and arsenic are dissolved and mobile: → **up to 30 mg/l Fe**, → **up to 2 mg/ Mn**, elevated concentrations of **arsenic range from 10 to 50 µg/l** (UNICEF data) with one hot spot at 340 µg/l As

Elevated arsenic concentrations appear to correlate with sandy clay horizons which partly contain peat and lignite up to a depth of approx. 60 m bgl

Sulfate decomposition by oxidation of organic carbon leads to $H_2S$ and low $SO_4$ concentrations: → **$SO_4$ <<20 mg/l**

$CO_2$ is a final product of nitrate and sulfate reduction. In calcareous aquifers the released $CO_2$ reacts with calcite and forms bicarbonate:
→ **up to 600 mg/l $HCO_3$**, however, Ca is generally below 70 mg/l

# Conclusions:

- Seawater has been intruding into some rivers further upstream than prior to the tsunami most likely due to land subsidence
- Many dug wells are still producing brackish groundwater within the flooded areas
- Small diameter emergency wells recently jetted or drilled up to 100 m deep generally tap fresh groundwater
- Elevated concentrations of iron, manganese and ammonium are the major limiting water quality factors; arsenic and nitrite may be above the drinking water limits in 10-15% of the wells

# Recommendations:

- Place well screens at depths below 60 m bgl to avoid elevated concentrations of arsenic in groundwater
- Tests should be carried out whether locally manufactured iron removal devices could also be used for elimination of manganese, ammonium and arsenic

# ***Thank you for your attention*!**