



APPLIED GEOPHYSICS TO CREATE INSIGHT AND REDUCE UNCERTAINTIES

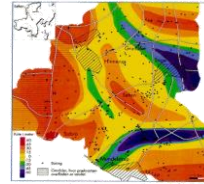
TIME DOMAIN ELECTROMAGNETICS (TDEM)

MAX HALKJÆR
HYDRO-GEOPHYSICIST



APPLIED GEOPHYSICS
20171204

WE NEEDED MORE DATA TO REDUCE UNCERTAINTIES AND TO REPLENISH AND SUSTAINABLY MANAGE AQUIFERS



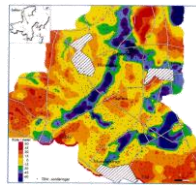
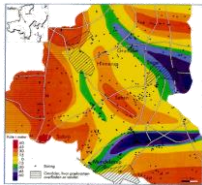
Thomsen et al. 2004

Data

- Information from 518 wells

APPLIED GEOPHYSICS
20171204

WE NEEDED MORE DATA TO REDUCE UNCERTAINTIES AND TO REPLENISH AND SUSTAINABLY MANAGE AQUIFERS



Thomsen et al. 2004

Data

- Information from 518 wells

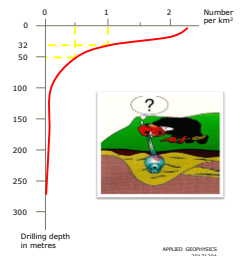
Data

- Information from 518 wells
- And 1400 TDEM soundings

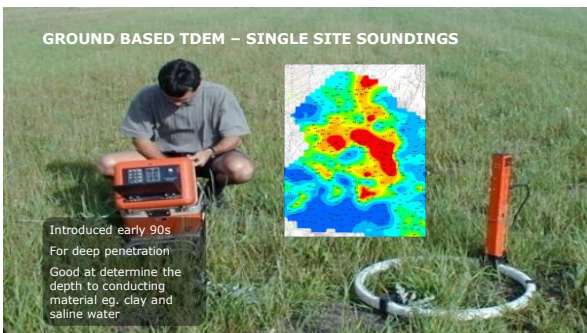
APPLIED GEOPHYSICS
20171204

SHALLOW AND TOO FEW WELLS

- Drill depth versus frequency in Aarhus County
- Results:
 - Total of 2.5 drillings per km²
 - < 32 m: 1 drilling per 1 km²
 - < 50 m: 1 drilling per 2 km²
 - < 100m: 1 drilling per 15 km²
- Conclusion: we don't know enough



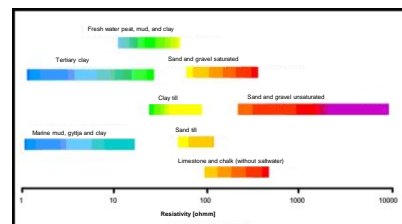
APPLIED GEOPHYSICS
20171204



GROUND BASED TDEM – SINGLE SITE SOUNDINGS

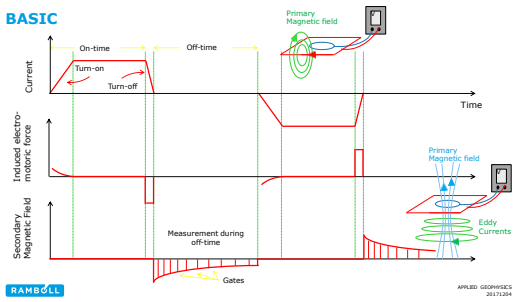
Introduced early 90s
For deep penetration
Good at determine the depth to conducting material eg. clay and saline water

CORRELATION - RESISTIVITY – HYDROGEOLOGY



APPLIED GEOPHYSICS
20171204

BASIC



AQUIFER STORAGE AND RECOVERY MIDDLE EAST

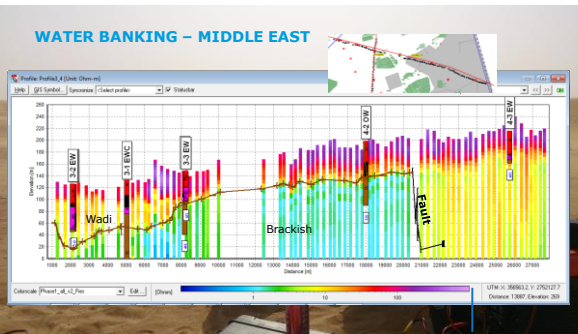


Challenge
 Aquifer Storage and Recovery (ASR)
 Determine water banking capacity of natural aquifers.

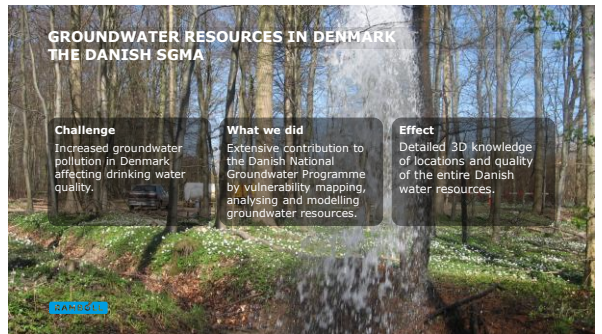
What we did
 Geophysical study 800 TEM soundings
 3D geological interpretation

Effect
 Established basis for creating natural water storage saving large amounts on alternative concrete structures.

WATER BANKING – MIDDLE EAST



GROUNDWATER RESOURCES IN DENMARK THE DANISH SGMA



Challenge
 Increased groundwater pollution in Denmark affecting drinking water quality.

What we did
 Extensive contribution to the Danish National Groundwater Programme by vulnerability mapping, analysing and modelling groundwater resources.

Effect
 Detailed 3D knowledge of locations and quality of the entire Danish water resources.

AIRBORNE GEOPHYSICS SKYTEM

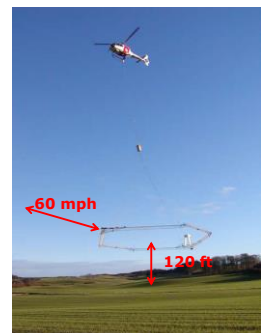
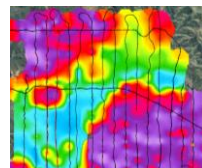
- Developed specifically for groundwater
- High production rate
- Cost efficient
- High vertical and lateral resolution
- No need to access the ground



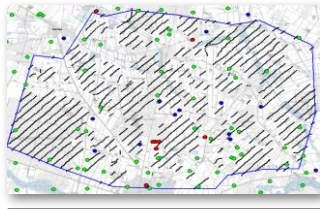
RAMBOLL

SURVEY SPECIFICATIONS

- Speed
- Height
- Line spacing
- Only possible in rural areas



Western Denmark – SkyTEM

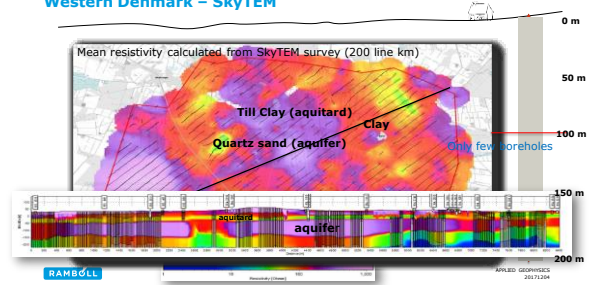


- Boreholes [drilling depth]**
- 0 – 30 m
 - 30 – 100 m
 - > 100 m
 - SkyTEM, 200 line km

RAMBOLL

APPLIED GEOPHYSICS 20171204

Western Denmark – SkyTEM



RAMBOLL

APPLIED GEOPHYSICS 20171204

MONTEREY BAY, CALIFORNIA

Challenge

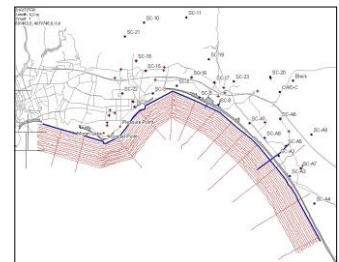
Increased the knowledge of the salt – fresh water interaction in a coastal environment

Effect

An understanding of the fresh-saltwater interaction

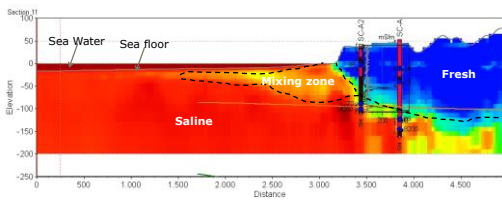
What we did

320 line km of near shore SkyTEM survey with a 100m line spacing
Hydrogeological interpretation



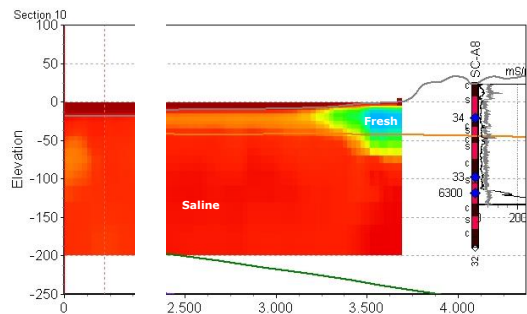
RAMBOLL

MONTEREY BAY, CALIFORNIA

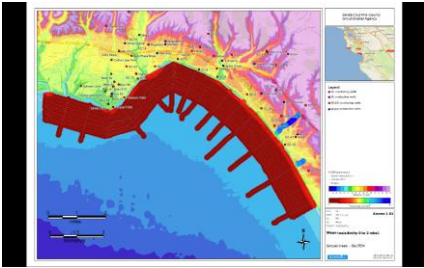


RAMBOLL

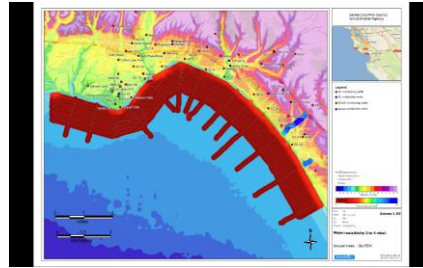
APPLIED GEOPHYSICS 20171204



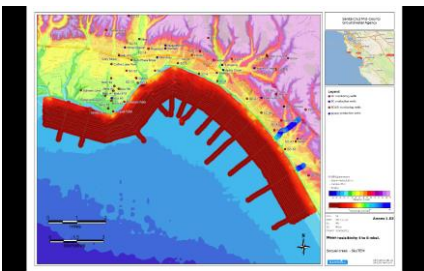
0 TO 2 METER BELOW SEA LEVEL



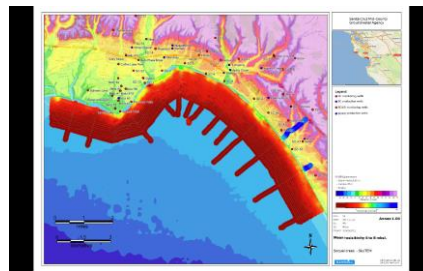
2 TO 4 METER BELOW SEA LEVEL



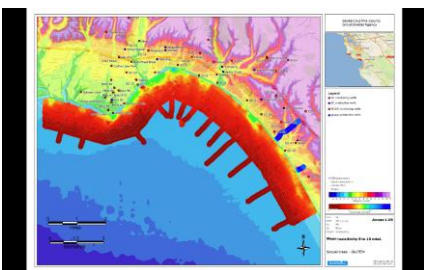
4 TO 6 METER BELOW SEA LEVEL



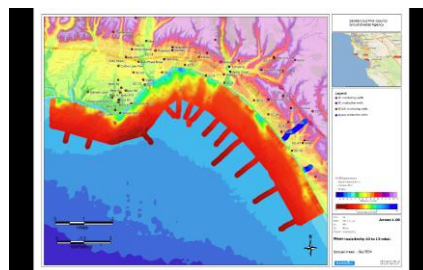
6 TO 8 METER BELOW SEA LEVEL



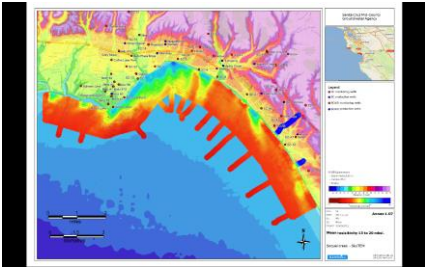
8 TO 10 METER BELOW SEA LEVEL



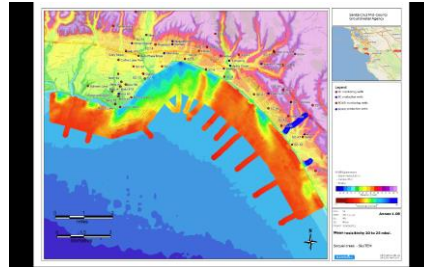
10 TO 15 METER BELOW SEA LEVEL



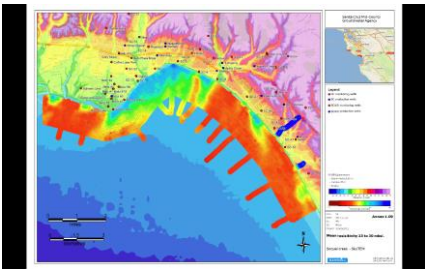
15 TO 20 METER BELOW SEA LEVEL



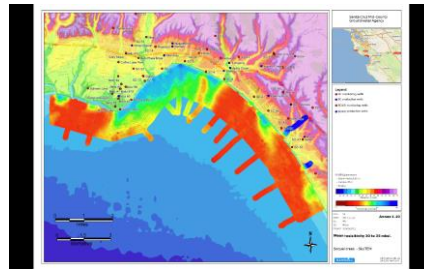
20 TO 25 METER BELOW SEA LEVEL



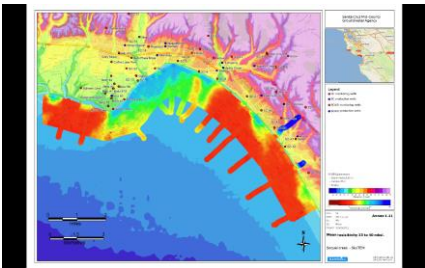
25 TO 30 METER BELOW SEA LEVEL



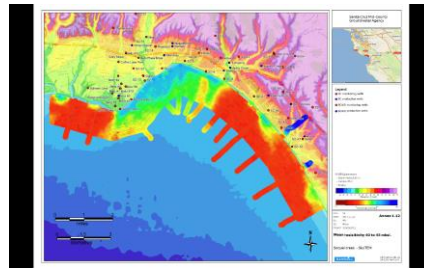
30 TO 35 METER BELOW SEA LEVEL



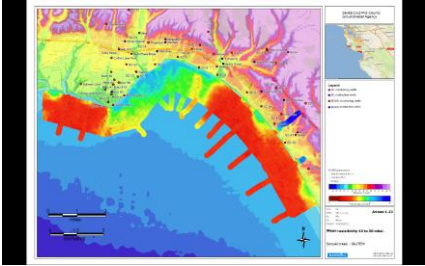
35 TO 40 METER BELOW SEA LEVEL



40 TO 45 METER BELOW SEA LEVEL

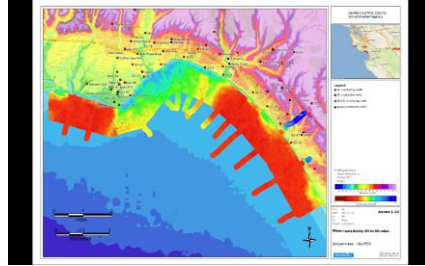


45 TO 50 METER BELOW SEA LEVEL



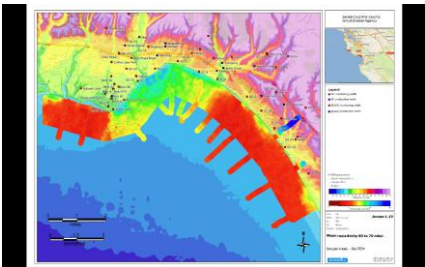
APPLIED GEOPHYSICS
20171204

50 TO 60 METER BELOW SEA LEVEL



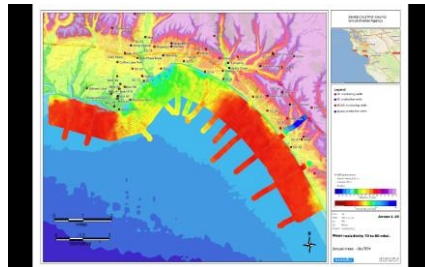
APPLIED GEOPHYSICS
20171204

60 TO 70 METER BELOW SEA LEVEL



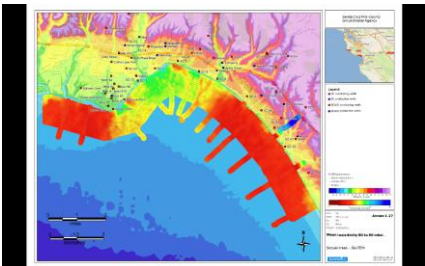
APPLIED GEOPHYSICS
20171204

70 TO 80 METER BELOW SEA LEVEL



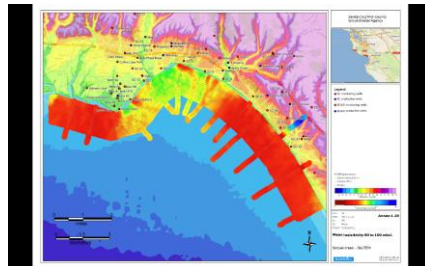
APPLIED GEOPHYSICS
20171204

80 TO 90 METER BELOW SEA LEVEL



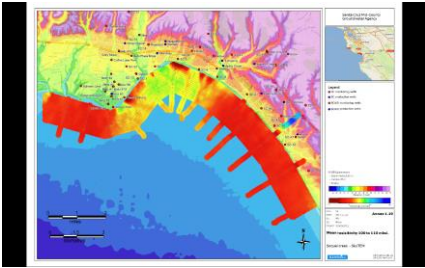
APPLIED GEOPHYSICS
20171204

90 TO 100 METER BELOW SEA LEVEL



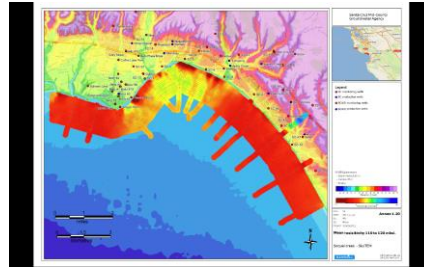
APPLIED GEOPHYSICS
20171204

100 TO 110 METER BELOW SEA LEVEL



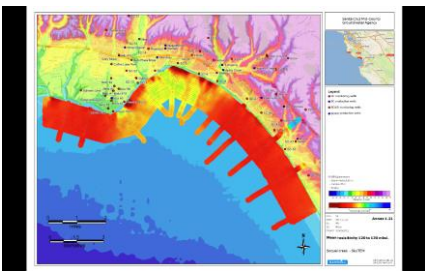
APPLIED GEOPHYSICS
20171204

110 TO 120 METER BELOW SEA LEVEL



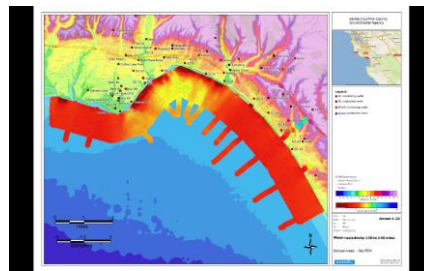
APPLIED GEOPHYSICS
20171204

120 TO 130 METER BELOW SEA LEVEL



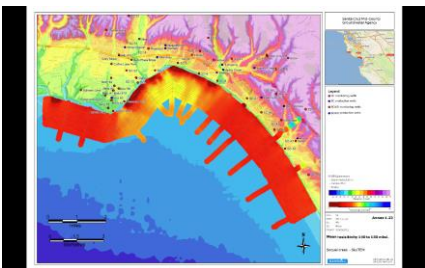
APPLIED GEOPHYSICS
20171204

130 TO 140 METER BELOW SEA LEVEL



APPLIED GEOPHYSICS
20171204

140 TO 150 METER BELOW SEA LEVEL



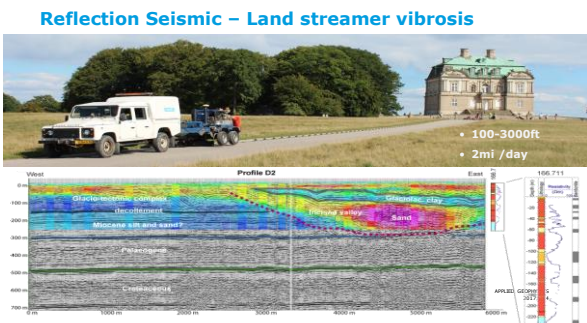
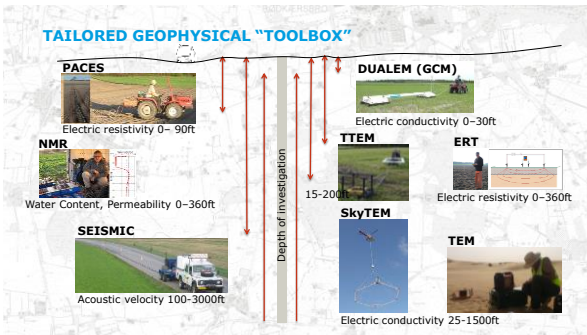
APPLIED GEOPHYSICS
20171204

**LIMITATIONS
MAN-MADE INSTALLATIONS**

Noise
Galvanic – LR circuit
Fences, wire vineyards, irrigation pipes
Capacitive – LCR circuit
Cables
Require a distance of 300-600ft

Galvanic

Capacitive



KEY TAKE AWAYS

- Select the right geophysical tool and understand the benefits and the limitation
- Dense measurements
- Use information from boreholes to validate and to constrain the geophysical inversion
- Aim for high quality systems - resistivity contrasts less than a factor of 2 can be essential
- Geophysics is inexpensive !

THANKS

Max Halkjaer
Hydrogeologist
Market Manager Water Resources & Supply
maxh@ramboll.com
+45 5161 2960
<https://dk.linkedin.com/in/maxhalkjaer>
<https://twitter.com/MaxHalkjaer>

RAMBOLL | RAMBOLL.COM/WATER