NGU Report 93.029

Investigations of salt groundwater at
Akvaforsk Research Institute,
Sunndalsøra, Norway.

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RAPPORT

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Sammendrag:

The Geological Survey of Norway (NGU) have assessed the possibilities for use of saline groundwater in fish-farming and research, through a research project at the aquaculture research institute AKVAFORSK at Sunndalsøra. From the data collected during the study, the following conclusions can be drawn:

-Salt groundwater appears to have a high and stable mineralogical (inorganic chemical) quality, which is well suited to use in aquaculture. Its stable temperature is another positive factor.
-The general bacterial content of saline groundwater appears significantly lower than in open seawater.
-A high content of organic material can be a general problem in young delta sediments. It leads to reducing conditions and undesirable water quality, particularly as regards hydrogen sulphide, which is very toxic for fish. Further research should focus on glaciofluvial sediments (with low organic content) lying in hydraulic contact with seawater.
-With large, localised abstractions of saline groundwater, it can be a problem to maintain the required high salinity level, due to "freshwater intrusion". This will occur particularly where rivers or fresh groundwater reserves drain towards, or into, the saline aquifer. Separation (e.g. two-level) pumping may be a possible solution to this problem.

Emneord: Hydrogeologi	Salt grunnvann	Grunnvannskvalitet
Deltaavsetning	Fagrapport	

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1 WATER QUALITY PROBLEMS IN AQUACULTURE

Fish farming has enjoyed an explosive biological, technical and economic development in Norway during the past 20 years. Access to large quantities of water of high chemical, physical and bacteriological quality is the most basic requirement for successful aquaculture.

Unfortunately, a range of problems resulting from infectious diseases, parasites, toxic algae and anthropogenic contamination threaten the aquaculture industry's existence and possibilities for further growth. The majority of these problems are spread in watercourses, fjords or the sea by aquatic currents or through infected fish.

At land-based fish farms, which exploit surface water sources, extensive disinfection (ozone or UV) of both salt and fresh water is typically required. "Open" fish farms in Norwegian fjords often require extensive dosing with medicines. At this latter type of fish farm, such problems have underlined the need to develop closed systems, with the possibility of monitoring the quality of both influent and effluent water.

Many of these problems are caused by organisms which are unable to survive in the groundwater environment. The use of both salt and fresh groundwater will therefore yield clear advantages for future aquaculture. One example of this is the NLVF (Norwegian Agricultural Reseach Council) funded resarch institute AKVAFORSK at Sunndalsøra. This institute has been described by an international group of experts as "a significant fishfarming research centre of international status" (NLVF,1992). AKVAFORSK exploits considerable quantities of infection-free fresh groundwater, a decisive factor for its success in fishbreeding research and roe production.

Use of groundwater gives other advantages in aquaculture. Stable water quality and a consistent, high, year-round temperature (6-7° in South Norway) give stable operative parameters and a high growth rate. Exploitation of groundwater's energy potential by use of heat pumps gives added possibilities for increased growth rates.

It is against this background that the Geological Survey of Norway (NGU), in cooperation with the University of Bergen (UiB), have commenced their reserach project at AKVAFORSK at Sunndalsøra, Møre og Romsdal county, in Mid-Norway (Follestad, 1991).

2 DESCRIPTION OF THE LOCALITY

Sunndalsøra lies at the inner end of Sunndalsfjord, 200 km south-west of Trondheim (Fig. 1). The village is built on the surface of a delta at the mouths of the Rivers Driva and Litledalselva (Follestad, 1987). The fish-farming research establishment AKVAFORSK lies at the mouth of Litledalselva (Fig. 2), and it is in this area that the opportunities for abstraction of salt groundwater have been investigated (Soldal, 1990, Soldal et al., 1992, Soldal et al. 1993, Volden, 1991). Two boreholes have been drilled to 21 m depth, and test-pumped for a period of one year. During test-pumping, water quantity and quality have been monitored using automatic loggers (Storrø, 1992). In addition, water samples have been manually collected for detailed analysis.

3 CHEMICAL DESCRIPTION OF SEAWATER AND SALT GROUNDWATER

AKVAFORSK use fresh groundwater in connection with roe and smolt production (Nielsen, 1989). Despite the fact that Sunndalsfjord and the Rivers Driva and Litledalselva carry piscine infections, the groundwater in the area has shown itself to be of exceptionally good hygienic quality, allowing its use directly in the fish-farms without the need for any treatment. The fresh groundwater has a relatively low ion-concentration (c. 4 meq/l), whereof sodium (1.2 meq/l) and chloride (1.3 meq/l) are dominant (Fig. 4). The fresh groundwater therefore bears the traces of the nearby marine environment.

Seawater from Sunndalsfjord has a composition similar to "standard 35‰ seawater" (i.e. an ionic content of 1200 meq/l, with sodium (470 meq/l) and chloride (540 meq/l) dominating (Fig. 4)).

During test-pumping of salt groundwater (Yield (Q) = 2.8 m^3/min) over a 30-days period, the total ionic content decreased from 1100 to 400 meq/l (Fig. 5). The relative chemical composition of the saline groundwater (Fig. 4) remained nevetheless identical to that of standard seawater. This indicates that heavy pumping of the aquifer leads to a steadily increasing recharge flow of fresh water, diluting the saline groundwater.

During a later pumping test, the yield (Q) was reduced to 1.8 m^3/min (Fig. 5). At this yield it appears that the ionic content stabilises at 800 - 1000 meq/l (25-30 ‰), which is an acceptable salinity for aquaculture.

Drilling has shown that there is a significant organic content in the delta sediments comprising the aquifer at Sunndalsøra. This creates strongly reducing conditions in the salt groundwater

(Eh = -140 to -200 mV) and thus reduction of sulphate to hydrogen sulphide (which occurs at 0.1 - 0.2 mgS/l). The dissolved oxygen content is measured as 0.3 - 1.2 mgO_2/l at 8-9°C. Hydrogen sulphide is toxic for fish even at very low concentrations, but preliminary trials indicate that this problem can be treated adequately by conventional aeration.

Organic material could well be a general problem for the exploitation of saline groundwater from young delta sediments. Glaciofluvial sediments which lie in direct contact with seawater, e.g. subsea marginal moraines, may be free of such problems.

4 BACTERIOLOGICAL CONDITIONS

Investigations have been carried out of the bacterial content of saline groundwater at Sunndalsøra (Storset, 1992). One major problem has been that standard analysis methods for specific detection of piscine bacteria do not exist. Analysis of total *Vibrio* bacterial content has therefore been chosen as an indicator of the possible existence of piscine pathogenic bacteria. Bacteria of the genus *Vibrio* are dominant in the marine environment - in the seawater, the sediments and the fishes' intestinal flora. Within the *Vibrio* genus are found, in addition to the natural, non-pathogenic species, two widespread piscine-pathogenic species *V. anguillarum* (vibriosis) and *V. salmonicida* (Hitra-disease).

Investigative results reveal that *Vibrio* bacteria occur in far lesser numbers in salt groundwater than in seawater (Fig. 6). In Oct.-Nov. 1991, total *Vibrio* organisms in saline groundwater were around 1400 - 4000 per litre. For seawater from Sunndalsfjord the results were around ten times higher. In Jan.-Feb. 1992, the *Vibrio*-total was 40-900 per litre in saline groundwater.

5 ACKNOWLEDGEMENTS

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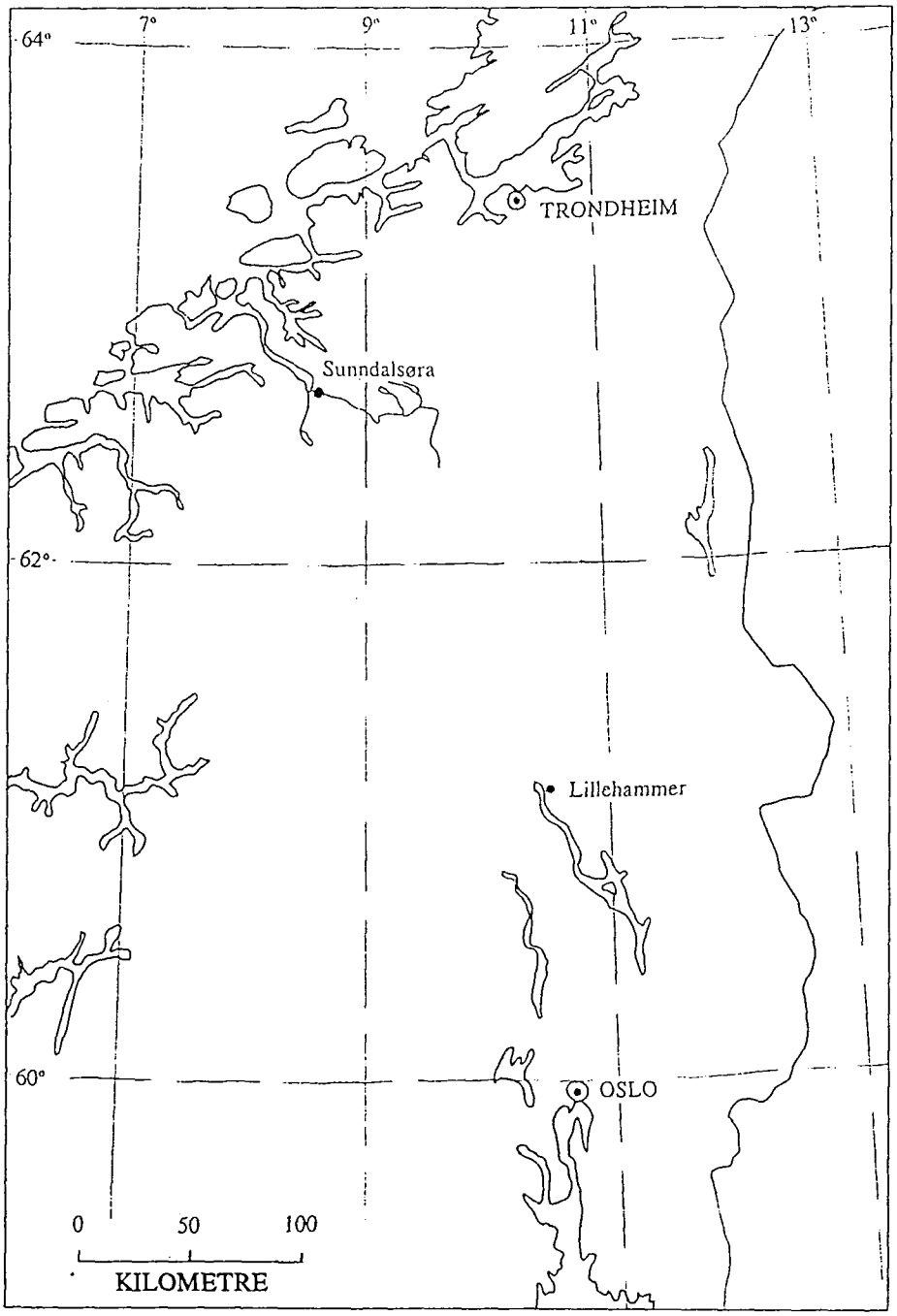


Figure 1: *Summary map.*

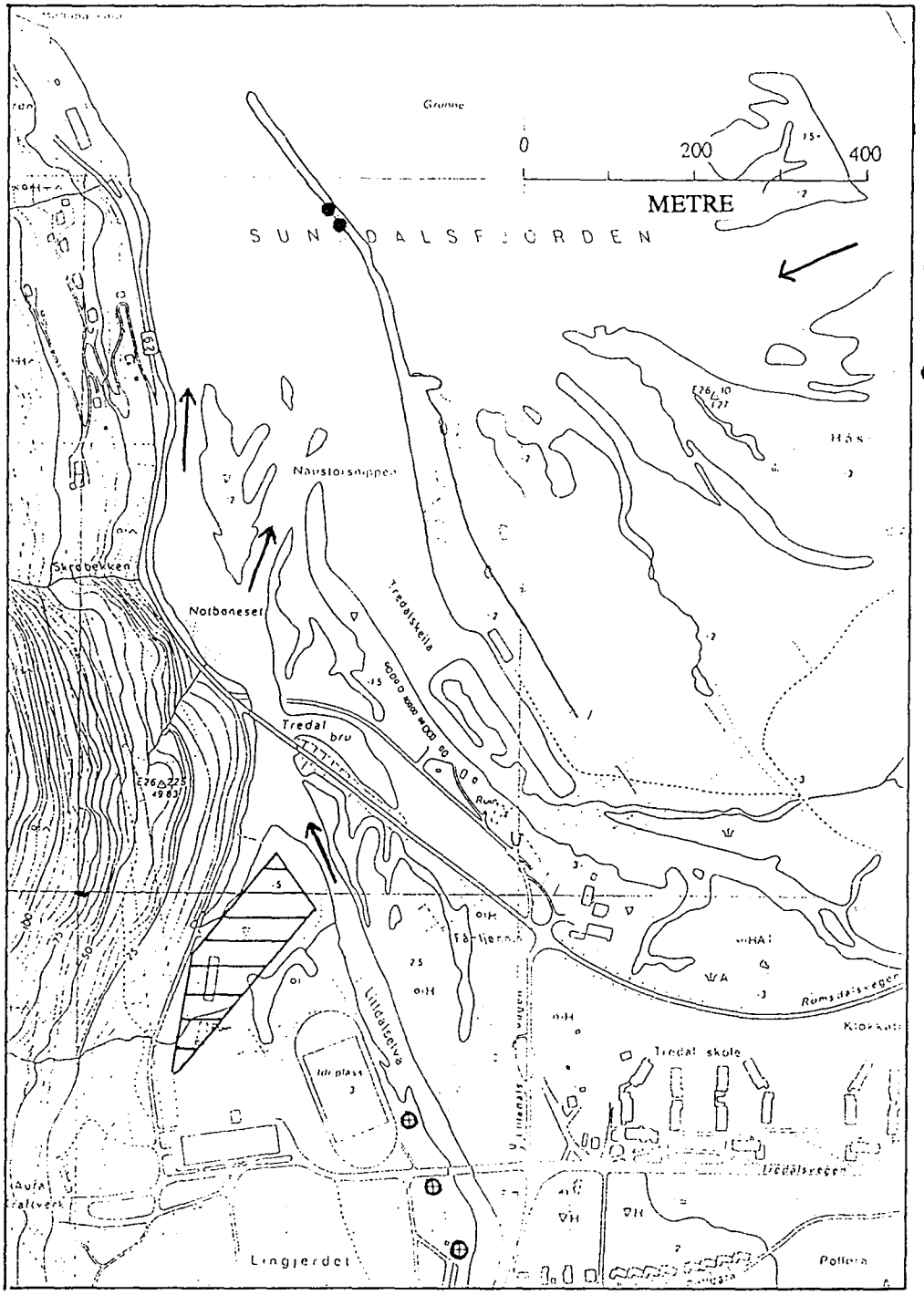


Figure 2: *Detailed map of Sunndalsøra.*

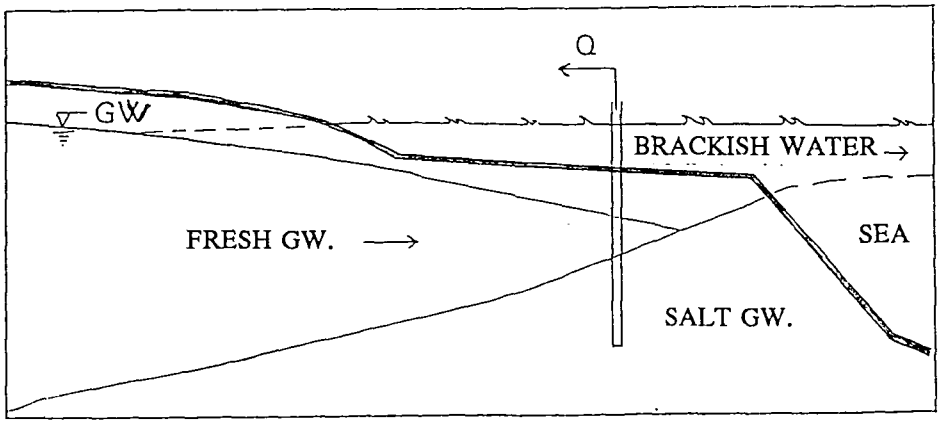


Figure 3: *Sketch of the hydrogeology of a costal aquifer.*

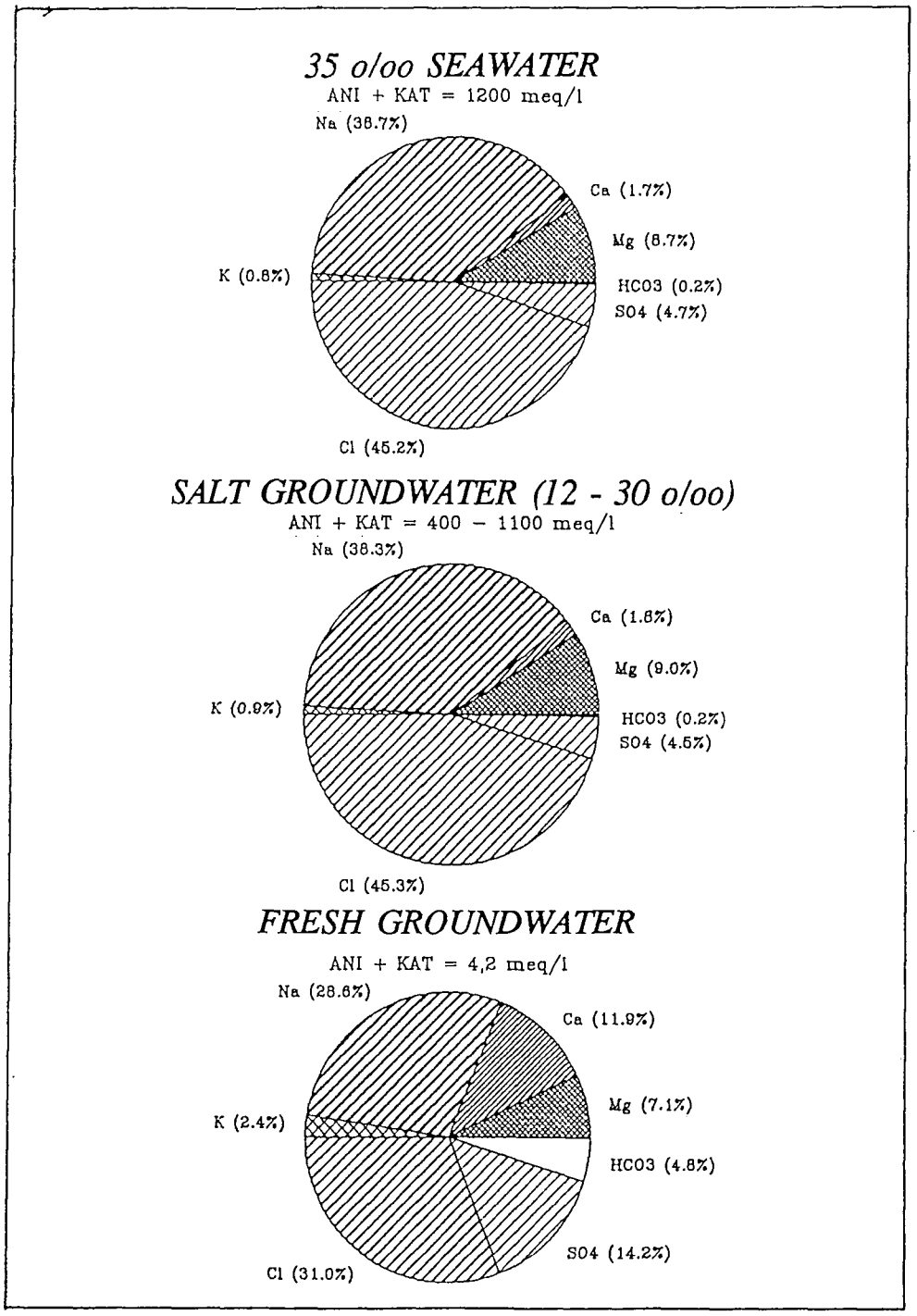


Figure 4: *Chemical composition of various water types at Akvaforsk, Sunndalsøra.*

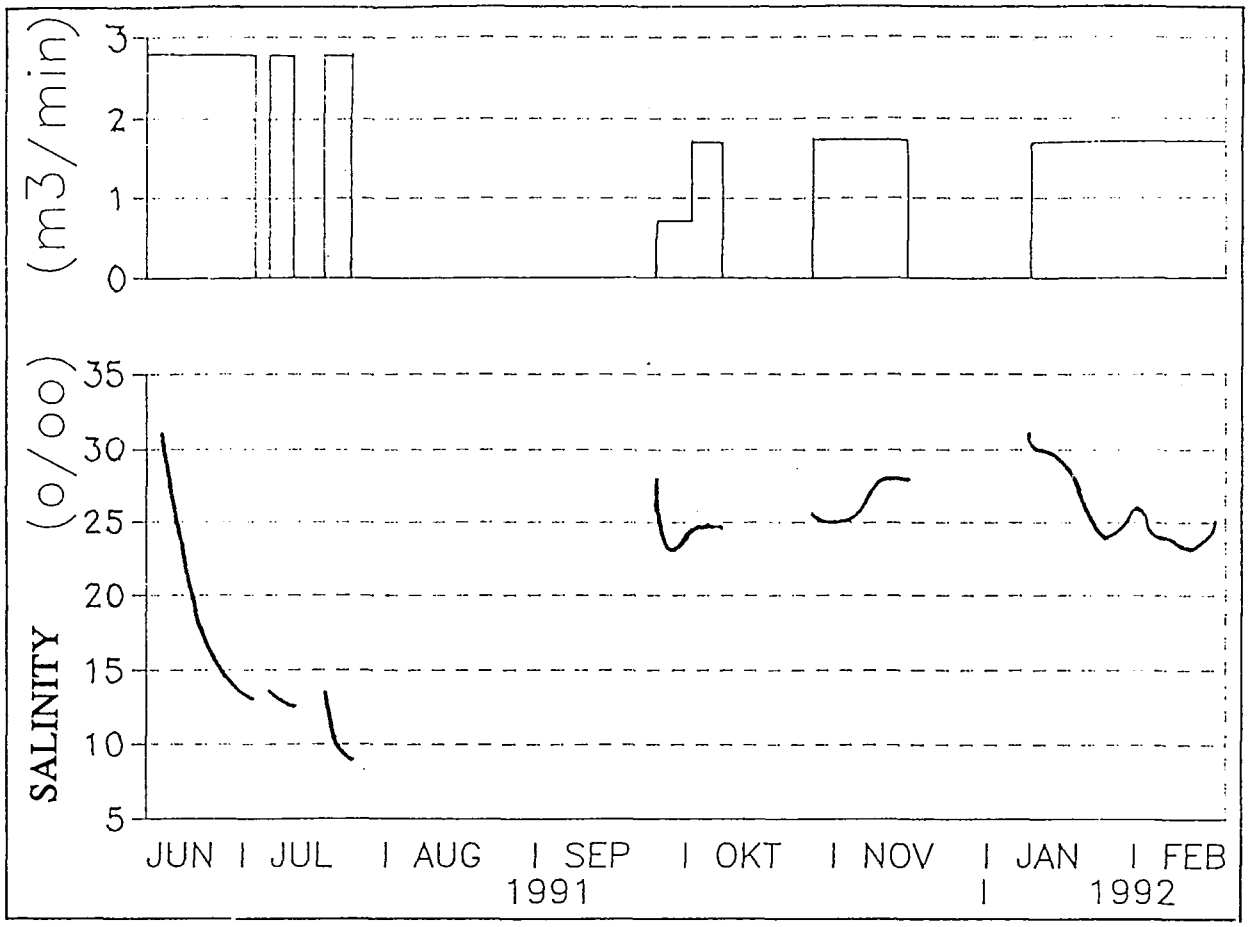
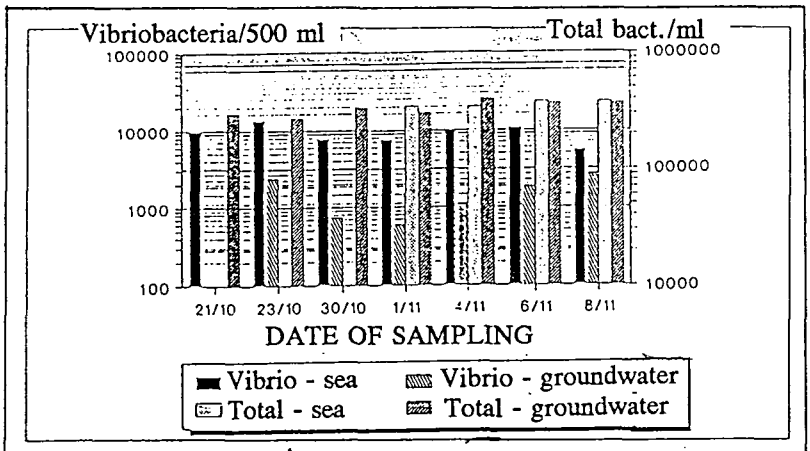
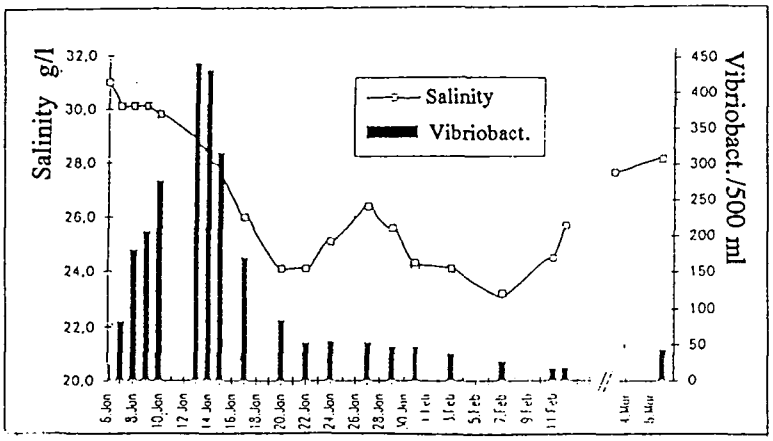


Figure 5: *Development of groundwater salinity during the test pumping.*



Total bacterial count and Vibrio bacteria in salt groundwater and seawater.



Vibrio bacterial count and salinity throughout testpumping period.

Figure 6: *Bacterial count in salt groundwater and seawater.*