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ScienceDirect
Engineering Geology 91 (2007) 72 – 77
ENGINEERING GEOLOGY
www.elsevier.com/locate/enggeo

On the spreading mechanism of shallow groundwater in the Hinterland of the Dutch Dune hill area

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Accepted 11 December 2006
Available online 20 January 2007

Abstract

The low lying Western part of the Netherlands is protected from the sea by a 5 km wide stretch of dunes rising to some 50 m of height. The fresh water pocket in the dunes overlies saline groundwater and a brackish transition zone. There was during a century an extraction of fresh groundwater for drinking water, supported by artificial infiltration. This has been stopped some 30 years ago. The consequent wetting of the valuable farm area (flower cultures) behind the dunes is stronger and more extensive than could be expected from mere replenishment of the fresh water zones in the dunes. It is shown in this paper that the lateral shear flows in the brackish and saline groundwater area have displaced (and are displacing) the interfaces vertically downward. The effect of more fresh and less saline groundwater in an arbitrary groundwater column is an (extra) rise of the groundwater head of the upper fresh water part. The described slow process will continue for decades until a new equilibrium has been established. In the mean time the inner dune farm area will have to cope with a surprisingly strong and extensive water level rise.

Keywords: Dunes; Fresh; Brackish; Saline Groundwater; Replenishment; Extraction

1. Introduction

Along the west-coast of the Netherlands the dunes are protecting the low lying area against flooding by the sea. Underneath the dunes fresh groundwater (fresh water pocket) can be found above a layer of brackish water (transition zone). Saline water is present underneath the brackish water. Some 150 years ago rather high fresh groundwater levels could be found in the dune area. Due to extraction of water from the dunes by drainage and deep wells the groundwater tables lowered causing problems of desiccation.

From the point of view of ecology, a restoration of higher groundwater tables was achieved by reducing the extractions. However, next to the dune area lies an agricultural area. For a number of years the groundwater levels and the leakage in this area are too high.

It is suggested that shutting down groundwater extractions together with a number of other causes, such as high precipitation during a number of years and the excavation of the dunes at the inner side over a width of about 2 km are the cause of too high groundwater tables causing damage to the farmer's crops. As this is the area where the production of flowers and flower bulbs is of high economical value the damage is of great concern.

The basic question is what is causing the high groundwater tables in the farmland where the flowers are growing.

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doi:10.1016/j.enggeo.2006.12.014

In this paper a brief historical overview will be given with respect to groundwater hydrology from the midst of the nineteenth century up to now.

2. The historical hydrological situation

Until the middle of the nineteenth century hardly any groundwater was being withdrawn from the dune area. In those days the dune area was much wider than nowadays because excavation had not yet taken place. In the present situation the dunes have a width of 3 to 4 km, in the old days the width was 5 to 6 km. The dunes were an infiltration area where the natural groundwater levels were significantly higher than they are now. In this situation with high groundwater tables due to the natural groundwater recharge a geohydrological situation existed with fresh, brackish and saline groundwater. Fresh water was overlying a transition zone of about 5 to 10 m where the chloride content was increasing with depth from about 50 mg/l up to 16,000 mg/l. Underneath the brackish water was the saline water.

This geohydrological system was in a situation of dynamic equilibrium and is described extensively in literature on the basis of physical laws (Bear, 1972, 1979).

3. The geohydrological situation from the midst nineteenth to the midst of the twentieth century

Since the second half of the nineteenth century groundwater was extracted on behalf of drinking water production in the dune area by means of canals and drains. This caused a lowering of groundwater levels and a decreasing replenishment to the fresh water pocket leading to a decreasing shear flow along the fresh/saline interface. When the shear flow decreases the processes of dispersion and diffusion will lead to thickening of the transition zone combined with upward motion of the underlying saline water.

During these geohydrological changes the excavations of the landside dune area took place together with a number of measures to manage the groundwater levels in the area. It is important to realize that these measures were taken within the hydrological boundaries realized by the groundwater extraction and the fresh/saline water situation of that particular moment. It is obvious to presume that the level of excavation was chosen in accordance with the present situation of water management and the groundwater levels at that particular moment. Later on some additional excavations took place at several locations because of too deep groundwater levels caused by increasing extractions of groundwater.

Of course one was looking for the optimal situation from an agricultural point of view and in order to achieve this, the level of excavation followed the drawdown of the groundwater level.

Hence, in the middle of the twentieth century a hydrological system was present in which the extraction of groundwater, the division of fresh/saline groundwater, the water management and the groundwater levels enabled a sound practical and economical management by the farmers.

4. The situation from the mid-twentieth century onwards

It was recognized that the ongoing extraction of (too) much fresh groundwater out of the dune area sooner or later would lead to an unacceptable situation with respect to the increase of the transition zone and the upcoming of the saline water.

Earlier plans to infiltrate pretreated river water were executed. During a few decades a continuous extraction of deep groundwater took place. However more and more one became aware that this continuous extraction of deep groundwater was not favorable for an increase or at least the maintenance of the fresh water pocket. At the end of the seventies of the last century the extraction of deep groundwater was heavily reduced and became nearly zero soon afterwards.

It is obvious that the aim of this reduction in extraction was a recovery of the original thickness of the fresh water pocket and a reduction of the increased brackish water transition zone. Nowadays there is a balance between the artificial recharge and the recovery of water resulting in higher groundwater levels in the dune area. The maintenance of a higher level in some of the drainage canals has caused a higher groundwater level in the surrounding area as well.

However up to this moment the reduction of the extractions of deep groundwater that took place about 20 years ago has had only little effect on the recovery of the thickness of the fresh water pocket. Instead, the increased natural recharge has resulted in a horizontal extension of the fresh water pocket.

5. Causes of the high groundwater tables in the agricultural area adjacent to the dunes

The high humidity of agricultural land is caused by elevated groundwater levels and/or increased leakage. In cases like these it is obvious to analyze the effects of the decreasing extractions. The changes in groundwater heads caused by the decreasing extractions are on local or regional