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GROUNDWATER DISCHARGE EVALUATION FOR IMPACT ASSESSMENT OF NATURE DEVELOPMENT PROJECTS

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Introduction

Due to the present pressure on environmental planning it is becoming more and more necessary to actively develop nature. One of the main presumptions for ecological valuable development is a favourable hydrological gradient with discharge of groundwater of oligotrophic quality. The presented model for hydrological system analysis for potential nature areas has as most important result *natural* groundwater discharge. The model uses uniform, average effective precipitation and does therefor take not into account the present landuse. The groundwater discharges diffuse over a topographical low area rather than concentrated in or along the drainagesystem because no local drainagesystem is included in the model. The model indicates therefor conceptually the groundwater discharge potential of a landscape both in area and quantity.

Hydrological systemmodelling methodology

To analyse a hydrological system of a nature area it is necessary to have a physical-mathematical description of the groundwater levels, flowvelocities and -directions. The groundwater flow for a single layer can be described as follow:

$$\frac{\partial}{\partial x}\left[T\frac{\partial h}{\partial x}\right]+\frac{\partial}{\partial y}\left[T\frac{\partial h}{\partial y}\right]+N-Q_{pu}=Q$$

x, y : x and y co-ordinates [L]
T : transmissivity of the aquifer $[L^2T^{-1}]$
h : level of the watertable [L]
N : effective precipitation $[LT^{-1}]$
Q_{pu} : pumped amount of water $[L^3T^{-1}L^{-2}]$
Q : groundwater discharge to wetland, drainage or riversystem $[L^3T^{-1}L^{-2}]$

Known information in this equation is:

- The transmissivity; which is used in stead of the product of the hydraulic conductivity and the varying thickness of the *waterbearing* part of the aquifer. This results in a small approximation.
- The effective precipitation; that part of the precipitation that effectively contributes to the groundwater recharge (precipitation minus evapotranspiration).
- Pumped quantity of groundwater; which has only a value there where groundwater pumping takes place.

The model calculates:

- The groundwater levels in the study area; a maximum limit is imposed equal to the topography minus the thickness of the unsaturated zone.
- The groundwater discharge to the wetlands or drainagesystem; calculated from the groundwater levels as discharging groundwater on places where it reaches the maximum level.

Infiltration areas occur where the groundwater level is below the maximum limit. It follows that a groundwater discharge area is defined as *an area where the groundwater level is close to the ground level and where there is an upward groundwater flow.* A mixed area is an area where the groundwater level is close to the groundlevel and where there is a downward groundwater flow smaller than the effective precipitation. The remainder of the effective precipitation becomes surface runoff. An infiltration area is an area where all the effective precipitation infiltrates and the groundwater recharges. By analyses of the relative presence of groundwater discharge and infiltration areas in a certain landscape an insight is obtained in the dependency of the landscape on the regional groundwater system.

Flowpathes and -times within the groundwater system can be calculated by way of the phreatic groundwater levels. Flowpathes run from infiltration to discharge areas and will therefor indicate the size and place of the recharge areas. The flowtimes indicate the time that passes from the moment of infiltration till groundwater discharge. Indirectly the flowpathes and -times also indicate the sensitivity of a groundwater discharge area to pollution or drying out.

<u>Application case Terkleppebeek-Molenbeek (zone 410)</u>

The area on which the model has been applied is the catchment Terkleppebeek-Molenbeek (zone 410), in the province of East-Flanders. The catchment is a tributary catchment of the Dender basin.

Since the topography serves as a reference level (i.e., maximum groundwater level) in the calculation of the groundwater discharge areas an accurate Digital Terrain Model (DTM) is crucial. The digitized contour levels of the 1:10000 topographic maps have been interpolated in the GIS-GRASS by a spline interpolation algorithm (Mitášová en Mitáš, 1993). In this way a DTM was created with a resolution of 10 time's 10m.

The geology of the area has been described by De Breuck et al. (1987) and especially Honnay en Louis (1966). In the catchment the unconfined aquifer is situated in loamy depositions of the Quaternary and partially in the fine sands of the Formation of Egem and sands of Ypres (Formation of Tielt). The lower boundary of this aquifer is formed by the Formation of Kortrijk (Clay of Ypres). In order to determine the depth of this layer 101 drillings of 5m and deeper, which reach the Formation of Kortrijk, have been analysed. By interpolating the depth of this unconfined aquifer the thickness was estimated to vary between 2-30m, with an average of 11.6m. For the hydraulic conductivity a regional uniform value 1m/day has been assumed based on the fine-sandy character of the unconfined aquifer. The effective precipitation has been based on a 21 year runoff series on the Molenbeek. The average effective precipitation for the catchment derived from this series was 0.68mm/day.

The groundwatermodel is solved for the 800 times 1800 (is 1440000) cells of 10 time's 10m by means of a finite difference technique, Gauss-Seidel iteration with red-black ordering (Hackbusch, 1985). This results in a symmetric calculation with a high convergence. The model calculates the groundwater levels with a maximum error of 10^{-4} on the groundwater levels.

Results of hydrological systemmodelling

The calculated groundwater levels in the catchment range from 9.6 to 121.5m. In figure 1 the results of the groundwater discharge calculation are shown. The quantity of the discharge is divided in two categories: low discharge, 0.68-2mm/day and high discharge, 2- ±10mm/day.

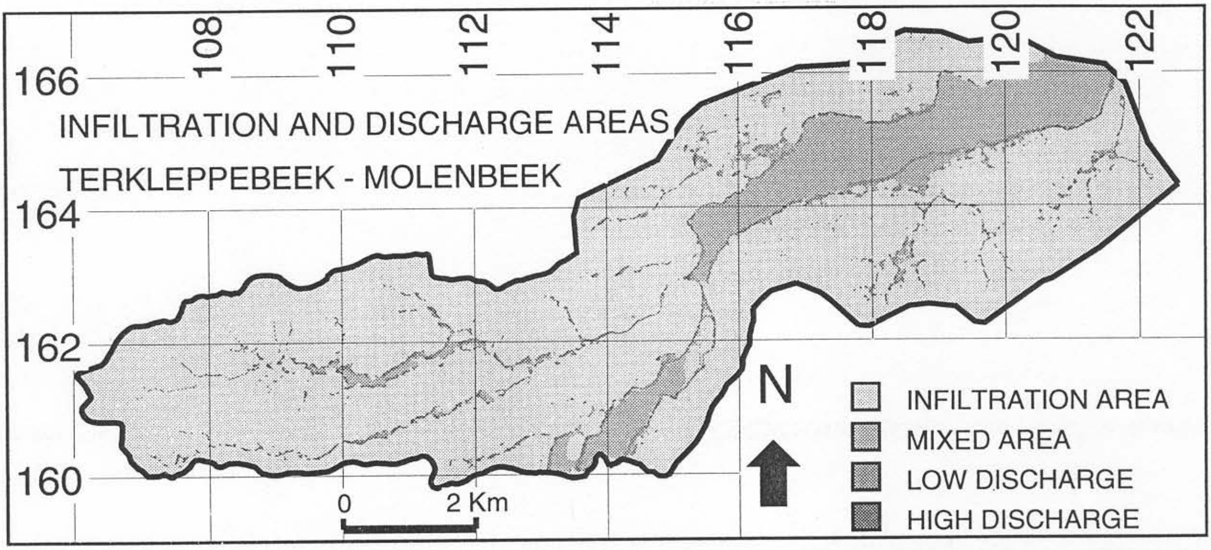

Figure 1: Calculated natural groundwater discharge and infiltration areas in zone 410

The minimum level of 0.68mm/day corresponds to the definition that the discharge has to be bigger than the groundwater recharge or effective precipitation. The mixed zones, which have an infiltration smaller than the effective precipitation, are also indicated in figure 1. From the results it appears that 89.0% of the area consists of infiltration area, 2.8% are mixed areas and 8.2% are groundwater discharge areas. The ratio of infiltration-groundwater discharge area is 10.9 for the whole zone and 16.5 for the Terkleppe-Binche-Molenbeek. It appears that the groundwater discharge in the Molenbeek takes place concentrated in the lowest parts of the valley. In the Dender valley the surface area of the groundwater discharge is bigger due to the less pronounced topography compared to the Molenbeek catchment. Typical is that the discharge takes place at the foot of the valley. This is especially clear in the middle reach of the Molenbeek, Binchebeek and the Dender. In the valley itself are often mixed zones (groundwater table at ground surface); here a major part of the effective precipitation runs off superficially. It appears that low groundwater discharge takes place diffuse. In those areas groundwater levels are shallow. Middle high groundwater discharge areas have a surface area that extends outside the river zone. For the development of groundwater dependent nature reserves those are the areas with most potential (e.g., middle reach of Terkleppe-Molenbeek). The high groundwater discharge zones are in general located adjacently to the river and take as such care for the baseflow of the river.

Figure 2 shows the results of the groundwater flowline calculations with zones of equal flowtimes to the discharge areas. For every infiltration point the 3 dimensional flowpath is known. On base of this data the exact infiltration area can be determined for every individual discharge or nature area.

The quantity as well as the quality of discharging groundwater is determined by the area of the infiltration and the change in quality along the flowpath. Ecological objectives for groundwater discharge areas require good to excellent quality of the groundwater and as natural as possible recharge and flow towards the discharge areas, i.e., as little as possible human influence. A protection zone of 0-5 years will therefor often be necessary.

Nature development projects do in general not require an environmental impact assessment study. However the here presented approach can be used to assess areas most appropriate for nature development and is as such a tool to optimize the impact of an environmental policy. Additionally is the approach very suitable for application in environmental impact assessment studies to calculate a *natural* reference situation of the regional groundwater system. It can therefor be used to determine deviations from the natural flow situation of the groundwater system due to planned abstraction, reduction of infiltration area, pollution of waste disposal sites, industries or agriculture.

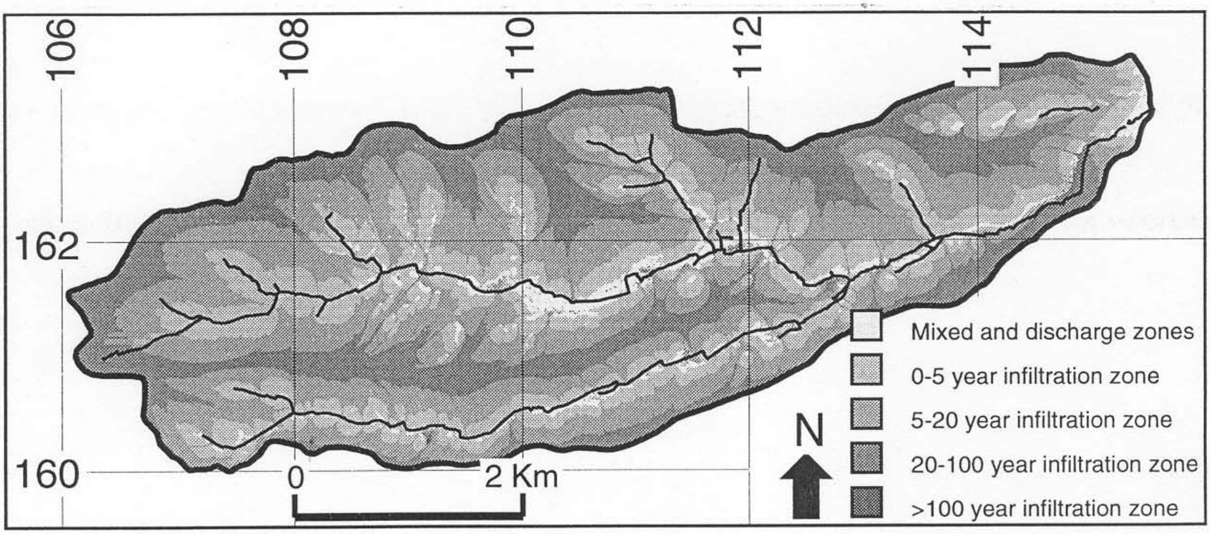

Figure 2: Calculated groundwater flowtimes to groundwater discharge areas of Terkleppe-Molenbeek

Literature

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