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Updating groundwater table class maps 1:50,000 by statistical methods : an analysis of quality versus cost
Mise à jour des cartes de classes de profondeur de nappes au 1:50 000 par des méthodes statistiques : une analyse coût-qualité

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Introduction

Groundwater table (GT) class maps are used extensively in the Netherlands to estimate land capabilities and diverse land qualities. Also, they are essential to many studies in which water movement is calculated, either to provide boundary conditions for hydrological models or to validate model results.. It is the only source of data describing seasonal dynamics of phreatic water levels with national coverage. The strong impact of man on the Dutch landscape has influenced seasonal dynamics as well, due to activities like land reclamation, drainage, reallotment and levelling. These practices have led to man induced drought in large parts of the Netherlands, and, subsequently, of the aging of the available databases.
Since GT maps are the only full-cover spatial source of information on groundwaterdynamics in The Netherlands, the updating of GT-maps is a priority activity in the Dutch data acquisition programme.

GT class map updating methods

The GT is defined as a typical combination of a range of mean highest groundwater levels and a range of mean lowest groundwater levels. GT is a mappable property at 1:50,000 scale. A number of methods have been developed to update the GT-maps at scale 1:50,000. These methods vary in the degree they use existing data (such as the original maps, elevation data, long-term piezometer monitoring measurements etc.), in the amount of field work required, and thus in the associated cost. All methods have in common that data availability is usually too small to allow for the delineation of new polygons. Mapping GT-class maps is considered too expensive. Therefore updating has been limited to attaching new GT-classes to existing map polygons rather than to draw new polygons. The smallest spatial unit that can be updated is a function of the amount of data available, which may partly be derived from fieldwork. Table 1 classifies the update methods that have been evaluated into the smallest spatial unit (SSU) that can be updated and the type of fieldwork required. Two types of fieldwork are distinghuished: (i) the monitoring of piezometers. In The Netherlands, thousands of these piezometers are monitored for longer timeperiods (5-10 years) in ongoing monitoring programs, and these data are available easily; (ii) taking point measurements of piezometric levels at two characteristic points in time that correspond to the mean highest groundwater level (MHG) in winter and the mean lowest groundwater level (MLG) in summer. These point measurements comprise field work, usually in a great number of locations.

Table 1 Data requirements and Smallest Spatial Unit to be updated for each updating method

Method	**Data requirements**		**SSU**
	Piezometer time series	**Point measurements**	
Piezometer straight	Yes	No	GT-class
Piezometer optimized	Yes	No	GT-class
Stratified random sampling straight	Yes	Yes	GT-class*
Stratified random optimized	Yes	Yes	GT-class*
Polygonwise	Yes	Yes	Polygon
Blockkriging	Yes	Yes	Polygon

* substrata based on regional differences in discharge patterns possible

The simpler and less expensive methods use only piezometer measurements to estimate time trends which are extrapolated to the area using the GT-class on the map as SSU. The more advanced methods used model based (blockkriging) or design based (stratified random sampling) statistics to obtain updated GT-maps. These methods are dependent on point observations because the SSU are smaller (substrata from GT-classes or individual polygons).

A distinction is made between “straight” methods” and “optimized methods”.
“Straight methods” use all available point-values of the MHG and MLG to calculate spatial averages of MHG and MLG for each SSU, and determine the GT-class directly from these values. “Optimized methods” evaluate which GT-class fits the point data best by evaluating an object function MG for each possible GT-class. MG is calculated from:
$MG = 1/n * \sum(G_{MHW}+G_{MLW})$,
Where G_{MHW} and G_{MLW} are quantitative measures of the degree to which point values correspond to the definition for the map polygon they are inside and n is the number of observations at the point scale used to update the SSU. G_{MHW} is calculated by:
(i) $G_{MHW}=0$ if MHW within the class boundaries prescribed by the GT
(ii) $G_{MHW}=Abs((MHW-NCB)/NCB)$ if MHW is outside the class boundaries prescribed by the GT;
with NCB is the nearest classboundary (in cm) of the GT and the MHW is at the point scale. G_{MLW} is calculated similarly as G_{MHW}.

We have explored these methods in one area of 10,000 ha, and have extrapolated the results to areas of 50,000 and 75,000 ha. In the 10,000 ha area we have verified the quality and cost. The quality of each method was quantified by the MG in a number of independent test point randomly located in the area. The costs were quantified for each method by counting labour days for the complete updating process. Furthermore, the marginal costs were assessed by calculating the costs per unit of quality increase.
The extrapolation was done by keeping the sampling density per SSU constant, and counting

the number of SSU in the larger areas in case of the piezometer methods. In case of the more advanced methods, geostatistical methods were used to determine sampling densities in the larger areas which corresponded to equal sampling errors or interpolation errors as in the 10,000 ha area.

Results and discussion

The quality and costs of the updating methods for different areas is given in Table 2.

Table 2 Costs, Quality and marginal costs for each update method

Method	**10,000 ha**			**50,000 ha**	**75,000 ha**
	Cost (kDfl)	**Quality (cm/cm)**	**MarginalCost (kDfl)**	**MarginalCost (kDfl)**	**Marginal Cost (kDfl)**
Piezometer straight	22	0.22	460	123	20
Piezometer optimized	22	0.22	405	120	20
Stratified random sampling straight	59	0.18	634	359	65
Stratified random optimized	61	0.12	404	313	69
Polygonwise	66	0.20	971	881	240
Blockkriging	67	0.16	582	731	233

The quality to cost ratios of the piezometer methods were more favourable than the other methods. However, the best quality that can be reached is rather poor. The stratified random sampling methods are the most promising, since they combine a good quality of the map resulting from the update with favourable marginal costs at larger areas. Polygonwise or blockkriging methods are both expensive and the polygonwise method did not perform too well too, probably because sampling densities were still too low.

Powerful future applications of model based variants are foreseen because of the emergence of highly detailed digital elevation models. These DEM can be used as auxiliary information, because in the Netherlands surface altitude relative to the sea level usually show a strong correlation to groundwater levels. Currently, methods to use a DEM with a density of 1 observation per 625 m^2 are in development.

References

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