02.07 Depth to Groundwater (Edition 1998)

Overview

Groundwater levels in a metropolitan area like Berlin are subject not only to natural factors such as precipitation, evaporation and subterranean outflows, but are also strongly influenced by such human factors as development, sealing of surface, dewatering plants, withdrawals and returns.

The main factors of **withdrawal** include the groundwater demands of public water suppliers, private water production, and the lowering of groundwater levels at construction sites (cf. Map 02.11). **Groundwater recharge** is accomplished by precipitation, shore filtration, artificial recharge with surface water and returns of groundwater at construction sites.

In Berlin, there are two groundwater layers. The deeper layer carries salt water and is separated from upper groundwater layer by an 80 m thick layer of clay. The upper layer carries fresh water and has an average thickness of 150 m. It is the source of drinking (potable) and process (non-potable) water supply in Berlin. It consists of a variable combination of permeable and binding loose sediments. Sand and gravel (permeable soils) combine to form the groundwater aquifer, while the clay, silt and mud (binding soils) constitute a groundwater obstructing layer.

The upper surface of the groundwater is dependent on the (usually low grade) gradient of groundwater and the terrain morphology (cf. Fig. 1). The **depth to groundwater** is defined by calculating the perpendicular distance between the upper edge of the surface, and the upper surface of the groundwater. When the groundwater aquifer is covered by relatively impermeable, binding soil layers (groundwater obstructing layer), the groundwater is unable to rise enough to reach the height of its hydrostatic pressure. It is under these conditions that the groundwater level becomes confined. Only by drilling through the obstructing layer, is the groundwater able to rise on a level with the groundwater pressure area (Fig. 1).

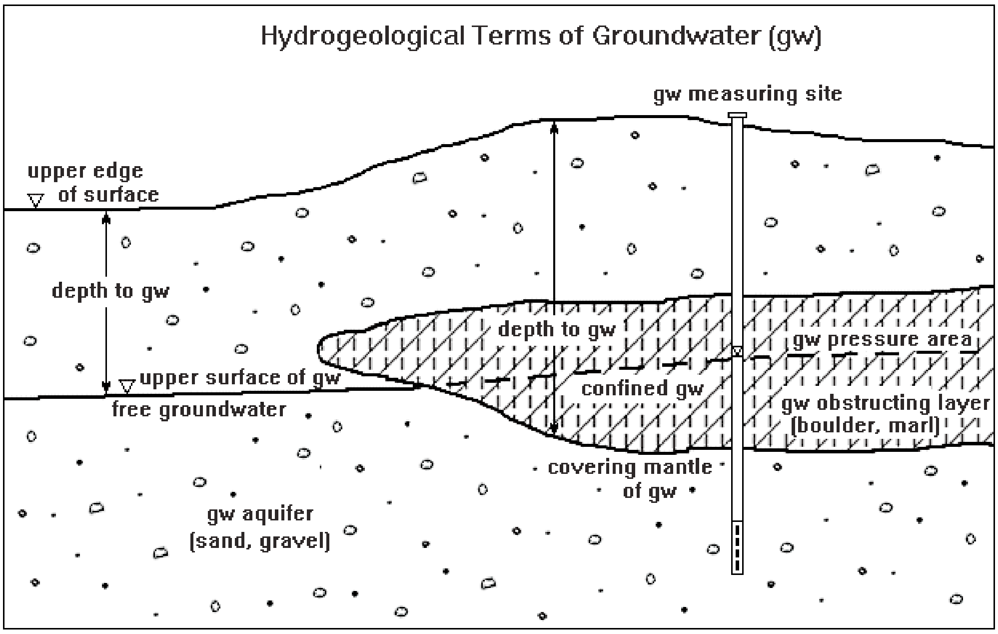

Fig. 1: Depth to Groundwater Shown at Two Different Stages: Free and Confined

The Map of Depth to Groundwater gives an overview of the spatial distribution of areas with the same depth classifications. Areas with a lower depth to groundwater (to about 4 m) are of particular importance. **Pollution of soils** can quickly lead to deterioration of groundwater in these areas, depending on the nature of the mantle (permeable or non-permeable) above the groundwater. The Map of Depth to Groundwater serves as a basic foundation for the preparation of the Map of

Groundwater Vulnerability to Pollution. The spatial overlaying of groundwater depth onto geological characteristics of the covering mantle enables groundwater vulnerability to pollution to be differentiated (cf. Map 02.05).

Knowledge of groundwater depths enables an estimatione of groundwater influence on **vegetation**. The influence of groundwater on vegetation depends on the root depths of plants and, according to soil type, the capillary climbing capacity of groundwater. The threshold depth at which groundwater can be used by trees is given at 4 m for general Berlin conditions. Vegetation in wetlands depends mostly on groundwater and requires a depth to groundwater of less than 50 cm.

Groundwater level in the city is subject to diverse **man-made influences**. The first lowering of the groundwater level and the destruction of wetlands in the Berlin area, was the dewatering of swampy areas like the Hopfenbruch in Wilmersdorf in the 18th century. The 19th and 20th centuries saw the dewatering of other areas by the construction of canals. The groundwater level was further lowered by the increasing demand for drinking and process water, and by restrictions on groundwater recharge caused by surface sealing.

Up until the end of the 19th century, the mean groundwater level in Berlin was subject only to the yearly fluctuation in precipitation. The period between 1890 and the end of the Second World War was marked by rapid urban growth, the construction of rail networks (Alexanderplatz), and by major reconstruction projects. Because of the construction, the groundwater level in the inner city was dramatically lowered, resulting in the 8 m drop of the groundwater level. With the breakdown of the public water supply at the end of the war, the depth of groundwater was able to restore itself to naturally levels (Fig. 2).

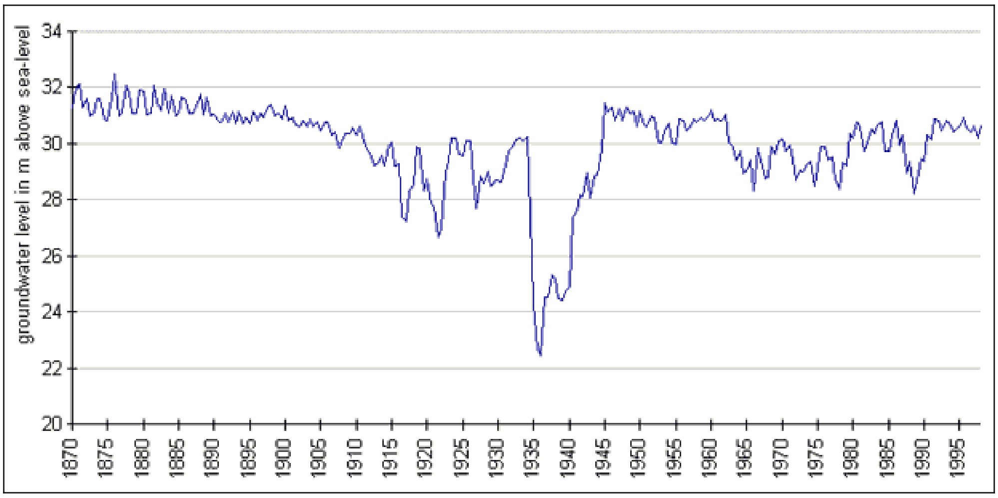

Fig. 2: Fluctuation of Groundwater Levels at Measuring Site 5140 in Mitte (Charlottenstrasse) since 1870

In the following period, from the beginning of the 50's to the beginning of the 80's, the groundwater level **sank** continually and over large areas because of increasing withdrawals. This trend was particularly noticeable in water production areas (waterwork facilities). This lowering was caused by the general rise in water consumption by private households, and by construction (the rebuilding of the heavily destroyed city, subway construction, and massive construction projects). The expansion of water production facilities in West Berlin waterworks was completed by the beginning of the 70's. The enlargement of the Friedrichshagen Waterwork in East Berlin began in the mid-70's to supply water to the new residential areas in Hellersdorf, Marzahn and Hohenschönhausen.

A slight **rise** of groundwater levels has occured in West Berlin since the end of the 70's.

A range of reasons can be given for this rise: smaller withdrawals from private wells; smaller withdrawals at construction sites (smaller construction volume and enforcement of groundwater returns); smaller withdrawal volumes of public waterworks; and, not least, effective man-made **groundwater recharging** (cf. Map 02.11).

Following the political changes in 1989 (fall of the Berlin Wall), the level of water consumption in the eastern boroughs of Berlin was drastically reduced, and the production at the waterworks in those areas fell an estimated 50 %. This resulted in the rise of the groundwater level throughout the city, east and west. Those areas nearest to waterworks recorded level increases as high as 3 m. The Berlin

Pleistocene Watercourse, which covers half the area of the city, anyway has a very low depth to groundwater of only a few meters. Many of the cellars in some areas were not constructed according to code, therefore the sudden increase in groundwater caused major damage from flooding. In two areas, the damage was so extensive that it was necessary to implement groundwater regulatory measures. In Rudow within the catchment area of the Johannisthal Waterwork the groundwater level was lowered by a well gallery. Near the Kaulsdorf Waterwork, it is planed to regulate the groundwater by lowering the lake level in the Kaulsdorfer Seen (lakes).

Permanent, wide and deep **cones of depression** have formed in water catchment areas around waterwork extraction wells. The considerable differences seen among the groundwater levels are directly related to variations in extraction demands at the waterworks. Riemeistersee (see=lake) and Nikolassee were dried out by water withdrawals of the Beelitzhof Waterwork at the beginning of this century. The groundwater level at Schlachtensee fell by 2 m, and at Krumme Lanke by 1 m. Water from the Havel has been pumped into the Grunewaldseen (inversion of natural flow) to balance this loss since 1913. The wetlands of Hundekehlefenn, Langes Luch and Riemeisterfenn, as well as the shore areas of the lakes were saved by this measure.

The cones of depression around well galleries at the Havel Lake have effects deep into the Grunewald (forest). The groundwater level at Postfenn sank 3.5 m between 1954 and 1974, and at Pechsee in Grunewald about 4.5 m between 1955 and 1975. Well gallery withdrawals at banks of the Havel cause severe drying of root soils of plants in the direct vicinity of the Havel.

About 90 % of the wetlands around the Müggelsee in southeast Berlin are threatened (Krumme Laake, Müggelheim, Teufelsseemoor, Neue Wiesen/Kuhgraben, Mostpfuhl, Thyrn, the lower course of Fredersdorfer Fliess).

Some wetland areas were flooded and given seepages of surface water to moderate negative effects caused by lowering of groundwater levels. These were the West Berlin nature reserves Grosser Rohrpfuhl and Teufelsbruch in the Spandau Forest, and Barssee in Grunewald; in East Berlin, Krumme Lake in Grünau and Schildow in Pankow.

Large-area lowering of groundwater levels occured in the Spandau Forest also, caused by the higher withdrawals by the Spandau Waterwork since the 70’s. A groundwater recharge plant, operated since 1983, percolates purified Havel water in an attempt to gradually raise groundwater levels. The groundwater level in the Spandau Forest was raised an average of 0.5 - 2.5 m by May, 1987. Groundwater recharge in this area has been restricted again because water appeared in cellars of near-by residential areas. The simultaneously rising withdrawal amounts of the Spandau Waterwork lowered the groundwater level again since 1990. In the following period, the groundwater level rose once more, due to the further reduction of withdrawal amounts.

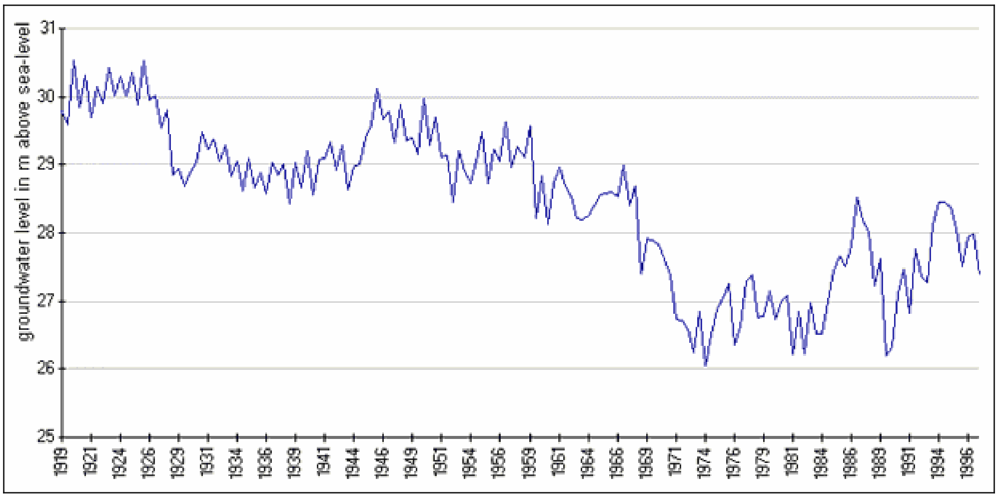

Fig. 3: Fluctuation of Groundwater Levels at Measuring Site 1516 in Spandau Forest

Statistical Base

The depths to groundwater are calculated from the difference between surface heights and the height of the groundwater level above sea-level. The calculations of groundwater levels are based on data taken from approximately 1,500 groundwater measuring sites. The data was collected in May 1995, in cooperation with the State Water Utiliy of the Berlin Department of Urban Development, Environmental Protection and Technology, and the Brandenburg State Environmental Agency. For areas with confined groundwater, selected geological drillings of the Drilling Archive were used. The terrain elevations were taken from the Terrain Elevations Model in the Environmental Information System (UIS). The statistical base and methodology used for this model are described in the text accompanying Map 01.08.

Methodology

To find out the groundwater depths at first a model of the height of groundwater level above sea-level was calculated from data collected at the groundwater measuring sites (using the methods described in the text accompanying Map 02.12 - Groundwater Levels). The depth to groundwater for areas with a confined groundwater is defined as the distance between the lower edge of the covering mantle (or the upper edge of the groundwater aquifer) and the surface. Measurements taken from the geological drillings are used to establish values for the depth of confined groundwater areas. From the Barnim flat upland approximately 100 drillings were considered. From the Teltow flat upland nearly 40 drillings were considered. Through this process of measuring and sampling, one has a model of the upper surface of the groundwater (hydro-contour lines - lines of the same groundwater level). Interpolation of data was made with the program SICAD-SCOP (GIS software).

Then a Difference Model was calculated with SICAD-SCOP using the **Model of the Upper Surface of Groundwater** and the **Terrain Elevations Model** (model of the altitude of ground about sea-level) of the Environmental Information System (UIS). The width of the grid was 100 m. Depths to groundwater are divided into seven depth classifications portrayed as a map of different heigth levels to groundwater. The first results revealed regional inadequacies of the Terrain Elevations Model, so it became necessary to carry out the calculations several times to insure accuracy. The obvious mistakes were corrected in the Terrain Elevations Model and the Groundwater Depth Model was repeated. In order to differentiate depths to groundwater in the range of up to 4 m, which are important for vegetation, an irregular division of classification was chosen.

For smaller areas it would be possible to obtain more exact results using smaller widths of grid to interpolate the data, provided that the density of data of the Terrain Elevations Model is included. Value limits used for classification of depths to groundwater also can be chosen arbitrarily.

The exactness of the data collected for the Groundwater Depth Model is directly dependent on the quality of the Terrain Elevations Model. Therefore, any miscalculations in the Terrain Elevations Model also apply to the Groundwater Depth Model.

The following points should be considered, to avoid false interpretations:

- Narrow strips at the edge of surface waters, which have some connection to groundwater, are not portrayable in the chosen scale
- Because of the state of the data, the Terrain Elevations Model will show some inaccuracies. This relates on the one hand to areas in the outlying districts (forests and agricultural areas) with not enough points of elevation and on the other hand to areas that were not yet developed at the time when the measurements were taken. Because of anthropogenic landfills, some of the map showing depressions with a low depth to groundwater no longer exist.
- Areas of confined groundwater existing under thick relatively impermeable, obstructive boulder marl layer can usually be assumed to have depths to groundwater of more than 10 m. The lower edge of the groundwater obstructing layer is assumed to be the upper surface of the groundwater. Sandy interstratifications in these boulder marl layer, within which near-surface perched groundwater can also appear, are narrowly limited spatially, and their sites can hardly be localized, and cannot be portrayed.
- Upper surface of the groundwater is subject to strong variations in areas near wells, depending upon withdrawal amounts. Depths to groundwater of more than 10 m can occur here. These areas cannot be portrayed by these scales either.
- It is to be noted that not all wet areas potentially valuable for the protection of biotopes and species can be read in the Map of Depth to Groundwater (depth less than 1.0 m). This includes areas that have no connection to groundwater and are moistened by flooding programms or periodic natural flooding (such as the Tiefwerder Meadows).

Map Description

The Teltow and Barnim flat uplands are usually characterized by depths to groundwater greater than 10 m. Confined groundwater often occurs here. Groundwater here was not reachable for vegetation previously either.

Current depths to groundwater in the deeper-lying areas of the Warsaw-Berlin Pleistocene Watercourse are often less than 4 m. Exceptions include the areas near well galleries, and the highpoints of the Müggelberge and Gosener Berge (hills), which are a morphological island in the glacial valley. Groundwater only appears here in depths of greater than 10 m (some more than 40 m). Groundwater levels in the pleistocene watercourse were generally higher previously. The lowering of groundwater by public waterwork withdrawals has strongly influenced local conditions for vegetation (cf. Map 02.11).

Low depths to groundwater are found along the glacial meltwater channel which runs from the Barnim into the pleistocene watercourse. These valley sections, in which the Tegeler Fliess and the Mühlenfliess, as well as the Panke and the Wuhle (creeks) flow today, sometimes stretch deeply into the Barnim. The depth to groundwater in this area is usually under 2 m, and some localized depths of < 1.0 m can be found. The Tegeler Fliess, important because of its relatively large area, has very low depths to groundwater. Withdrawals made from the Tegel Waterwork are noticeable here, too.

Low depths to groundwater are also found in the Spreetal (valley) between Dämeritzsee and Seddinsee (Gosen Meadows).

The dimensions of the groundwater rise in Berlin since 1989 are clearly shown on the Figure 4. Here the rise of groundwater levels from November 1989 to November 1995 is illustrated. Groundwater rise of > 0.5 m can be found in broad areas of the pleitocene watercourse, which anyway has low depths to groundwater. The rise of groundwater especially in the closer catchment areas of waterworks is very significant. Due to the decreasing levels of withdrawals in these areas, the groundwater levels have risen between 1 m and 3 m. The results of the groundwater rise in the flat upland areas are not so important because there the depths to groundwater are generally higher. In those areas of the Teltow flat upland, where confined groundwater occurs, the depicted rise of groundwater refers only to the groundwater pressure area. Depths to groundwater in such areas remain unchanged.

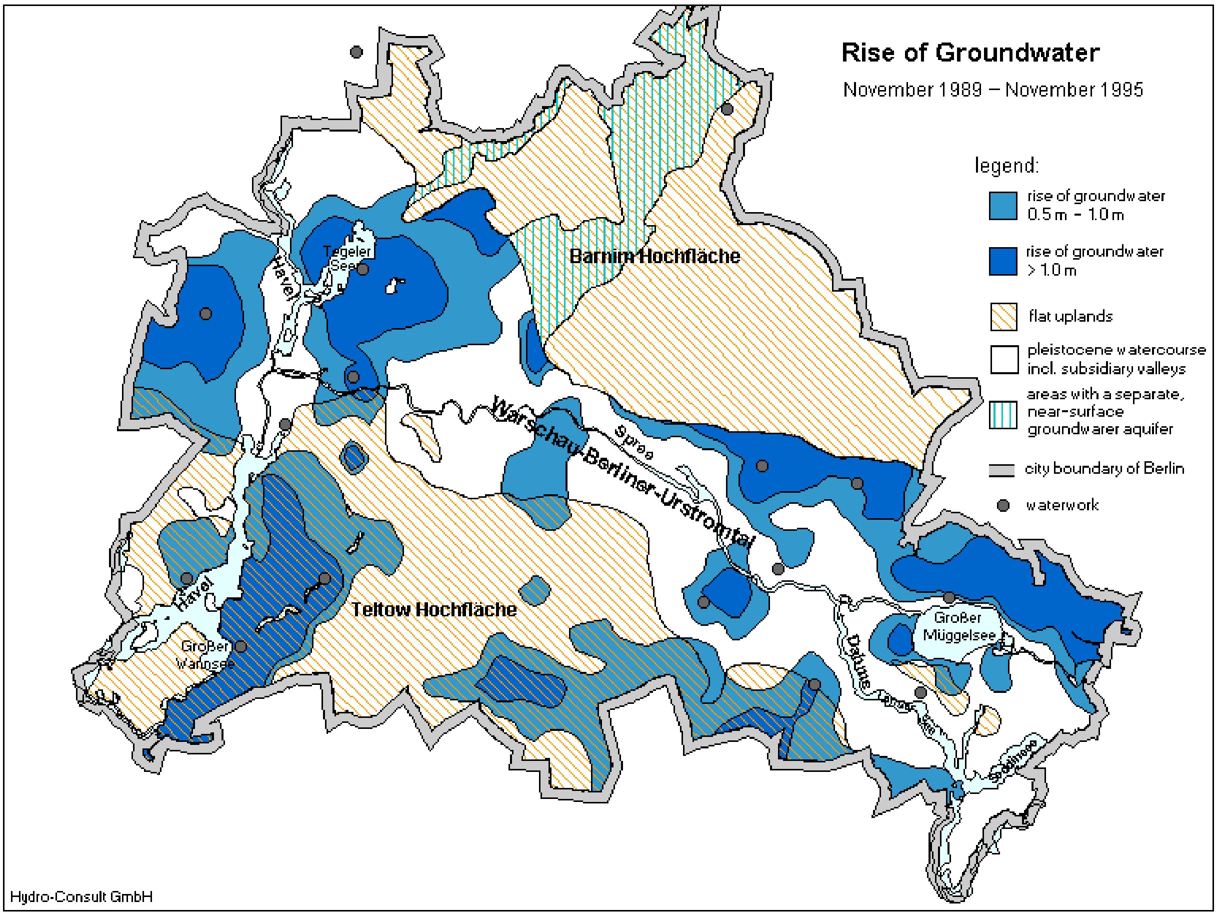

Fig. 4: Groundwater Rise from November 1989 to November 1995

The rise of groundwater in observation wells of measuring sites is portrayed (in areas of confined groundwater that means the rise of the groundwater pressure area and not of the real upper surface of groundwater). The rise of the Barnim flat upland cannot be portrayed due to the low data density.

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