02.17 New Groundwater Formation (Edition 2003)

Overview

The term new groundwater formation as used here refers to the process by which groundwater is formed from the percolation of precipitation water. The amount of new groundwater formation differs from the amount of percolation water formation. It is reduced, by comparison with the percolation water rate, by the proportion of interflow, i.e., that portion of the runoff that flows into the receiving streams from the near-surface layers of soil. For these reasons, a **new groundwater formation** map, Map **02.17**, has been drafted in addition to the percolation (Map 02.13.2) and the total runoff (Map 02.13.3).

Knowledge of the level of new groundwater formation is particularly important for long-term and sustainability use of groundwater resources and furthermore for the estimate of the potential danger of immission of pollutants from the non-saturated zone to the groundwater. The amount of new groundwater formation shown in Map 02.17 as the new groundwater formation rate (mm/year) by block section, is an important initial parameter for the derivation of the dwell time of the percolation water in the groundwater overburden (Map 02.16).

Statistical Base

The runoff formation and percolation rates in Maps 02.13.3 and 02.13.2, respectively, of the Environmental Atlas constitute the essential basis for the calculation of new groundwater formation rates, broken down by block section. Initially, the runoff and percolation rates on the above maps were recalculated on the basis of the current depth to groundwater (Map 02.07, 2003 of the Environmental Atlas), but with retention of the other initial parameters. Only in areas with shallow depth to groundwater has this recalculation resulted in minor modification of the runoff and percolation rates, respectively. A detailed description of the data bases for these maps can be found in the general text for Map 02.13. In addition, data on runoff measurements to receiving stream as well as data from the literature were used for the calculation.

Methodology

The amount of new groundwater formation was calculated from the percolation rates according to the methodology suggested by Glugla (Glugla & Fürtig, 1997, Glugla & Müller, 1997, Glugla & Eyrich, 1993, Glugla & König, 1989, Glugla et al., 1999). According to Glugla (see above), for **open aquifers**, such as the glacial spillways and outwashes of northern Germany, the new groundwater formation corresponds to the percolation water formation; there, the following applies:

$$GWNB = Ri = P - Eta - Row$$

where

GWNB = new groundwater formation

Ri = percolation water formation

P = long-term mean annual precipitation sums

Eta = long-term mean actual evapotranspiration

Row = long-term mean surface runoff

However, in areas with covered aquifers, e.g. the ground moraines with glacial till or loam, only a part of the percolation water formation reaches the groundwater. In these areas, a part of the percolation water is carried away as near-surface interflow into bodies of water (receiving streams). Surface runoff and interflow together constitute the mean runoff MQ to the receiving streams. In areas with **covered aquifers**, the new groundwater formation can therefore be derived from the difference between the

calculated total runoff formation (R = P - Eta) and the actual runoff MQ to the receiving streams which drain the area. In these areas, the following applies:

GWNB = Ri - Rzw

GWNB = P – Eta – Row - Rzw

GWNB = P – Eta – MQ

> where
>
> GWNB =   new groundwater formation
>
> Ri =   percolation water formation
>
> P =   long-term mean annual precipitation sums
>
> Eta =   long-term mean actual evapotranspiration
>
> Row =   long-term mean surface runoff
>
> Rzw =   long-term mean interflow
>
> MQ =   mean runoff to the receiving streams (= Row + Rzw)

Data on mean runoff to receiving streams in the catchment areas and their segments are an important basis for the calculation of new groundwater formation in areas with covered aquifers. These data are, however, only partially available. The data situation for the application of the method for the area of the State of Berlin must be considered difficult. Nevertheless, the method suggested by Glugla permits altogether plausible new groundwater formation rates to be calculated from the runoff and percolation water formation data.

For the determination of new groundwater formation rates, areas with covered and open aquifers were first distinguished, for only for the areas with covered aquifers does the new groundwater formation differ from the percolation water formation. The areas with covered aquifers were essentially derived from the Digital Map for the Characterization of Overburden, according to WRRL (SenStadt, 2002). Furthermore, all mapped areas with confined groundwater (p. Map 02.07) which extend beyond the areas of the above-mentioned map represented as "groundwater overburden" were certified as covered. Fig. 5 shows the areas distinguished for the determination of new groundwater formation rates according to open or covered aquifers.
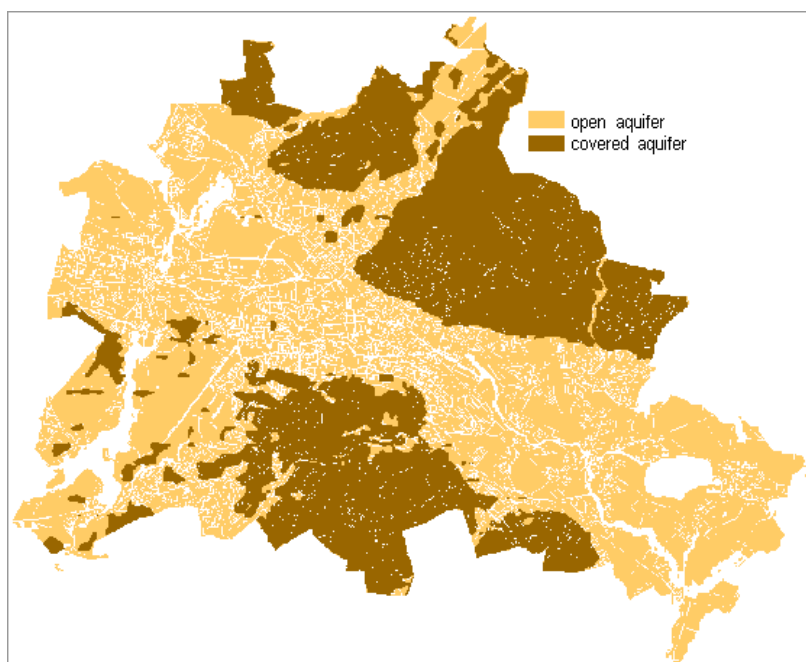
Fig. 1: Areas with covered and open aquifers

The contiguous, covered areas certified here are essentially the Barnim and Teltow ground moraines. The Warsaw-Berlin glacial spillway and the larger valley lowlands of the Barnim, particularly the Panke

valley, are essentially areas with open aquifers, except for single islands with cohesive substrata. Large contiguous areas with open aquifers are also present in the area of the plateau sands of the Teltow plateau and the Nauen plate. In terms of the area of the State of Berlin, the area with open groundwater (518 km²) outweighs that with covered aquifers (335 km²).

In another processing stage (SenStadt Data Base, 2003), the catchment areas of the receiving streams were delimited in those areas with covered aquifers. To the extent available, runoff measurements from watermark gauges at the receiving streams were assigned to these catchment areas. From the long-term mean runoff MQ and the size of the catchment associated with it, the average annual influx (sum of surface and interflow runoff) into the respective receiving stream was ascertained. The problems here were on the one hand the frequently insufficient data (e.g. for the Teltow plateau), and on the other, the fact that measured runoffs are characterized by influx from sewage plants and pipelines, and by the often very high degree of sealing, and thus only partially reflect natural runoff behavior. For these reasons the runoffs measured to receiving stream generally permit statements of only limited accuracy.

Due to this very heterogeneous database, three cases had to be distinguished (cf. Table 1) for the runoff data to the receiving streams:

- Case 1: there are runoff values measured at watermark gauges;

- Case 2: no data are available from measurements; hence, additional data were evaluated from the literature (Glugla & Müller, 1997);

- Case 3: neither measured runoff data nor references from the literature were available. In Case 3, an assumable mean runoff was assessed for the covered catchment areas which show very high surface runoff due to strong sealing. An interflow of 80 mm/year was accepted in these areas. The mean runoff was calculated from the sum of the assumed interflow and the surface runoff according to Map 02.13.1 of the Environmental Atlas for block sections within a catchment area.

Values for Cases 2 and 3 in Table 1 therefore merely show benchmark values.

On the basis of the method of Glugla (Glugla & Fürtig, 1997, Glugla & Eyrich, 1993), the share of the runoff formation of each of the delimited catchment areas which was led off as surface and lateral or interflow runoff into the receiving stream and therefore did not contribute to new groundwater formation was calculated using this database. Moreover, there is the fundamental problem that parts of the catchment areas runoff to the receiving stream are outside the area of the state of Berlin and no appropriately detailed runoff data from these areas were available for the process. However, since the geological and climatic relationships of the catchment areas observed do not differ fundamentally inside and outside the state boundary of Berlin, the available runoff data from Berlin have also been taken as representative for the shares of the catchment areas outside Berlin. A reduction factor for the calculation of new groundwater formation from the percolation water formation was then derived for every catchment area from the relationship of runoff and percolation water, respectively, and the sum of surface and interflow runoff (see Tab. 1).

The calculation process will be explained briefly here by way of the example of the Tegel Creek catchment area: The calculated average total runoff formation R in this catchment area is 229 mm/yr. (section-weighted mean of the total runoff from precipitation for all block sections in this catchment area, according to Map 02.13.3 of the Environmental Atlas). The average percolation water formation Ri (section-weighted mean of the percolation from precipitation of all block sections in this catchment area according to Map 02.13.2 of the Environmental Atlas) is 192 mm/year. Surface runoff is thus 229 mm/yr. - 192 mm/yr. = 37 mm/yr. However, Tegel Creek, which drains this catchment area, shows a real mean runoff MQ of 183 mm/yr. This mean runoff MQ includes the surface runoff (37 mm/yr.) and the interflow (183 mm/yr. - 37 mm/yr. = 146 mm/yr.). The average new groundwater formation is calculated from the difference between the average total runoff formation R (229 mm/yr.) and the mean runoff MQ (183 mm/yr.). It is 46 mm/yr. in this area, i.e. it is reduced by 76 % compared with the percolation water rate; hence, only 24 % of the percolation water quantity is effective in new groundwater formation. Thus, the new groundwater formation is very substantially lower than the average percolation water formation in this area.

This reduction of the percolation water rate for the determination of new groundwater formation was carried out analogously for the other catchment areas (reduction factor "RDF referenced to Ri" in Table 1 for the exemplary area of Tegel Creek = 76 %). For the calculation of new groundwater formation rates broken down by block section, the percolation water rate of every single block section

was reduced by the reduction factor RDF for the catchment area, i.e. for the example of Tegel Creek, by 76 %.

Catchment Area Segment	Average total runoff formation R (mm/year)	Average percolation water formation Ri (mm/year)	Runoff MQ of the catchment area (mm/year)	New GW formation (R – MQ) (mm/year)	RDF as % of Ri
Tegel Creek	229	192	183[2]	46	76
Laake	228	221	80[1]	148	33
Panke	220	191	113[1]	107	44
Kindel Creek	201	196	100[2]	101	48
Neuenhagen Creek	248	238	100[2]	148	38
Wuhle	260	196	100[2]	160	18
Nordgraben	229	196	100[2]	129	41
Selchow	233	219	100[2]	133	39
Spree	339	181	238[3]	101	44
MHG	327	176	231[3]	96	45
Fürstenbrunnen Ditch	367	179	268[3]	99	45
Teltow Canal	286	182	184[3]	102	44
Grunewald Lakes	254	202	132[3]	122	40
City Moat	250	180	150[3]	100	44
Others	234	190	100[2]	134	29

[1] Run-off MQ according to level measurement,
[2] Run-off MQ according to literature,
[3] Run-off MQ value

Tab. 1: Runoff data, percolation water and new groundwater formation amounts, and reduction factors RDF in the catchment area segments of Berlin

Map Description

In the areas with open aquifers, new groundwater formation rates correspond to the percolation rates represented in Map 02.13.2. The new groundwater formation rates shown in the map are lower than the percolation water rates in the areas with covered aquifers, depending on the conditions and the reduction factors ascertained. In the areas with covered aquifers, a reduction of at least 18 % (Wuhle) and at most 76 % (Tegel Creek) over the percolation water rates occurs; in most areas with covered aquifers, the new groundwater formation rate is approx. 40 % - 50 % below the percolation water rate.

The area shares of the different percolation water rates according to Map 02.13.2 and the derived new groundwater formation rates (Map 02.17) are shown in Tab. 2. The category with 100-150 mm/yr. predominates. Due to the reduction in the covered areas, a shift from higher too lower values occurs in the new groundwater formation values, as compared with the percolation water rate, which is primarily evident in the mean values. Thus, the section shares of the category 50 - 100 mm account for 5.68 % of the percolation water rate, but for only 18.37 % the new groundwater formation rate. On the other hand, the section shares for percolation water rates of the categories above 150 mm are consistently greater than for new groundwater formation rates.

Category [mm/year]	Section shares of percolation water rate [%]	Section shares of new groundwater formation [%]
<0	0,37	0,37
0-50	2,85	4,26
50-100	5,68	18,37
100-150	31,03	37,19

150-200	28,63	18,63
200-250	14,63	10,10
250-300	8,60	5,57
300-400	3,93	2,67
>400	4,55	2,83

Tab. 2: Section shares of percolation water and new groundwater formation rates

From the new groundwater formation rates, the totals for the area of the State of Berlin can be derived, with consideration for section sizes. In Tab. 3, these values have been juxtaposed to the corresponding values for total runoff formation and percolation water formation:

	Total runoff formation	Percolation water formation	New groundwater formation
Section-weighted mean average value (mm/year)	241	181	152
Absolute value in m³/year	205,7 Mio	154,3 Mio	129,9 Mio
Absolute value in l/s*km²	7,6	5,7	4,8

Remarks:
1. All values exclusive of bodies of water. Shore filtrate shares (which e.g. are discharged in the Berlin waterworks from the Havel and Spree) are not taken into account in percolation water formation or new groundwater formation.
2. Information on total runoff and percolation water formation diverge from data in Tab. 3, map 02.13. This is due on the one hand to the fact that in Tab. 3 of map 02.13 section-weighted mean values were formed, and on the other hand the depth to groundwater of May 2002 was used for the calculation, which to some extent affects the values.

Tab. 3: Water balance and new groundwater formation in Berlin

It has to be taken into account that the calculations for percolation water rates were carried out with **consideration for sealing**. This means that the stated values for new groundwater formation give mean values covering sealed and unsealed areas of the block sections represented. Since the sealing and the different availability of sewers affect the water balance considerably, the stated values are not transferable to the unsealed areas of the respective sections. For this reason a calculation assuming completely unsealed conditions was also carried out, for the sake of further-reaching planning purposes. These data are also available at the Senate Department, but have not been published in the Environmental Atlas.

Literature

[1] **Ad-hoc-Arbeitsgruppe Boden der Geologischen Landesämter und der Bundesanstalt für Geowissenschaften und Rohstoffe der Bundesrepublik Deutschland 1994:** Bodenkundliche Kartieranleitung, 4. Auflage.

[2] **DIN 19732 1997:**
Bestimmung des standörtlichen Verlagerungspotentials von nichtadsorbierbaren Stoffen. DIN Deutsches Institut Datengrundlagen für Normung e.V.; Beuth Verlag Berlin.

[3] **EU 2000:**
Richtlinie 2000/60/EG des Europäischen Parlaments und des Rates zur Schaffung eines Ordnungsrahmens für Maßnahmen der Gemeinschaft im Bereich der Wasserpolitik (Wasserrahmenrichtlinie) vom 22.12.2000, Luxemburg.

[4] **Glugla, G., König, B. 1989:**
Der mikrorechnergestützte Arbeitsplatz Grundwasserdargebot. Wasserwirtschaft-Wassertechnik, 39 (8): S. 178 – 181, Berlin.

[5] **Glugla, G., Eyrich, A. 1993:**
Ergebnisse und Erfahrungen bei der Anwendung des BAGROV-GLUGLA-Verfahrens zur Berechnung von Grundwasserhaushalt und Grundwasserneubildung im Lockergestein Norddeutschlands. Kolloquium Hydrogeologie 10/93 Erfurt, 22 - 26**.**

[6] **Glugla, G., Fürtig, G. 1997:**
Abflußbildung in urbanen Gebieten. Schriftenreihe Hydrologie/Wasserwirtschaft 14, Ruhr-Universität Bochum, S.140-160.

[7] **Glugla, G., Müller, E. 1997:**
Grundwasserneubildung als Komponente der Abflussbildung. in: C. Leibundgut & S. Demuth (Hrsg.): Grundwasserneubildung. Freiburger Schriften zur Hydrologie. Band 5, S. 23 -35.

[8] **Glugla, G., Goedecke, M., Wessolek, G., Fürtig, G. 1999:**
Langjährige Abflußbildung und Wasserhaushalt im urbanen Gebiet Berlin. Wasserwirtschaft, in Vorbereitung.

[9] **Heinkele, T., Voigt, H.-J., Jahnke, C., Hannappel, S., Donath, E. 2002:**
Charakterisierung der Empfindlichkeit von Grundwasservorkommen. UBA-FB 000251.

[10] **Limberg, A., Thierbach, J. 1997:**
Gliederung der Grundwasserleiter in Berlin, Brandenburgische Geowiss. Beiträge. 4, 2, S. 21-26, Kleinmachnow.

[11] **Voigt, H.J., Heinkele, T., Jahnke, C., Hannappel, S., Thomas, L. 2003:**
Erstellung von Karten zur Schutzfunktion der Grundwasserüberdeckung für das Land Berlin ; im Auftrag der Senatsverwaltung für Stadtentwicklung, Cottbus September 2003 unveröffentlicht.

[12] **Voigt, H.J., Heinkele, T., Jahnke, C., Wolter, R. 2003:**
Characterisation of Groundwater Vulnerability - a Methodological Suggestion to Fulfill the Requirements of the Water Framework Directive of the European Union. Zur Publikation eingereicht bei: Geofisica international.

Maps

[13] **LGRB & SenStadt (Landesamt für Geologie und Rohstoffe Brandenburg in Zusammenarbeit mit Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin) 1995:**
Geologische Übersichtskarte von Berlin und Umgebung 1:100.000 GÜK 100.

[14] **SenStadtUm (Senatsverwaltung für Stadtentwicklung und Umweltschutz) (Hrsg.) 1993:**
Umweltatlas Berlin, aktualisierte und erweiterte Ausgabe, Karte 02.05
Verschmutzungsempfindlichkeit des Grundwassers, 1 : 50 000, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/
umwelt/umweltatlas/i205.htm

[15] **SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 1998:**
Umweltatlas Berlin, 02.07 Flurabstand des Grundwassers, 1:50 000, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/
umwelt/umweltatlas/i207.htm

[16] **SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 1998:**
Umweltatlas Berlin, aktualisierte und erweiterte Ausgabe, Karte 01.01 Bodengesellschaften,
1:50 000, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/
umwelt/umweltatlas/i101.htm

[17] **SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2002:**
Umweltatlas Berlin, Karte 01.06.1 Bodenarten, 1:50 000, Berlin.
Internet:
http://www.stadtentwicklung.berlin.de/
umwelt/umweltatlas/i106.htm

[18] **SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2002:**
Geologischer Atlas von Berlin.

[19] **SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2002:**
Karte zur Charakterisierung der Deckschichten nach WRRL
(digitale Karte im arcview- shape-Format)

[20] **SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2003:**
Flächen der oberflächlichen Einzugsgebiete im Stadtgebiet Berlin, digitale Karten arcview-
shape-Format ."Obere_havel_sol", "Untere_havel_sol", "Spree_berlin", "Dahme_sol".

[21] **SenStadt (Senatsverwaltung für Stadtentwicklung Berlin) (Hrsg.) 2003:**
Umweltatlas Berlin, erweiterte und aktualisierte Ausgabe, Karte 02.07 Flurabstand des
Grundwassers, 1:50 000, Berlin.
Internet:
http:// www.sensut.berlin.de/
umwelt/umweltatlas/ia207.htm