02.17 New Groundwater Formation (Edition 2007)

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) maps.

Knowledge of the level of new groundwater formation is particularly important for long-term and sustainable use of groundwater resources, and also in order to enable an 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 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 (SenStadt 2007, current as of 2005) constitute the essential basis for the calculation of new groundwater formation rates broken down by section. 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 totals
Eta =	long-term mean actual evapo-transpiration
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 totals
Eta =	long-term actual mean evapo-transpiration
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 this 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). Moreover, 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. 1 shows the areas distinguished for the determination of new groundwater formation rates according to open or covered aquifers.

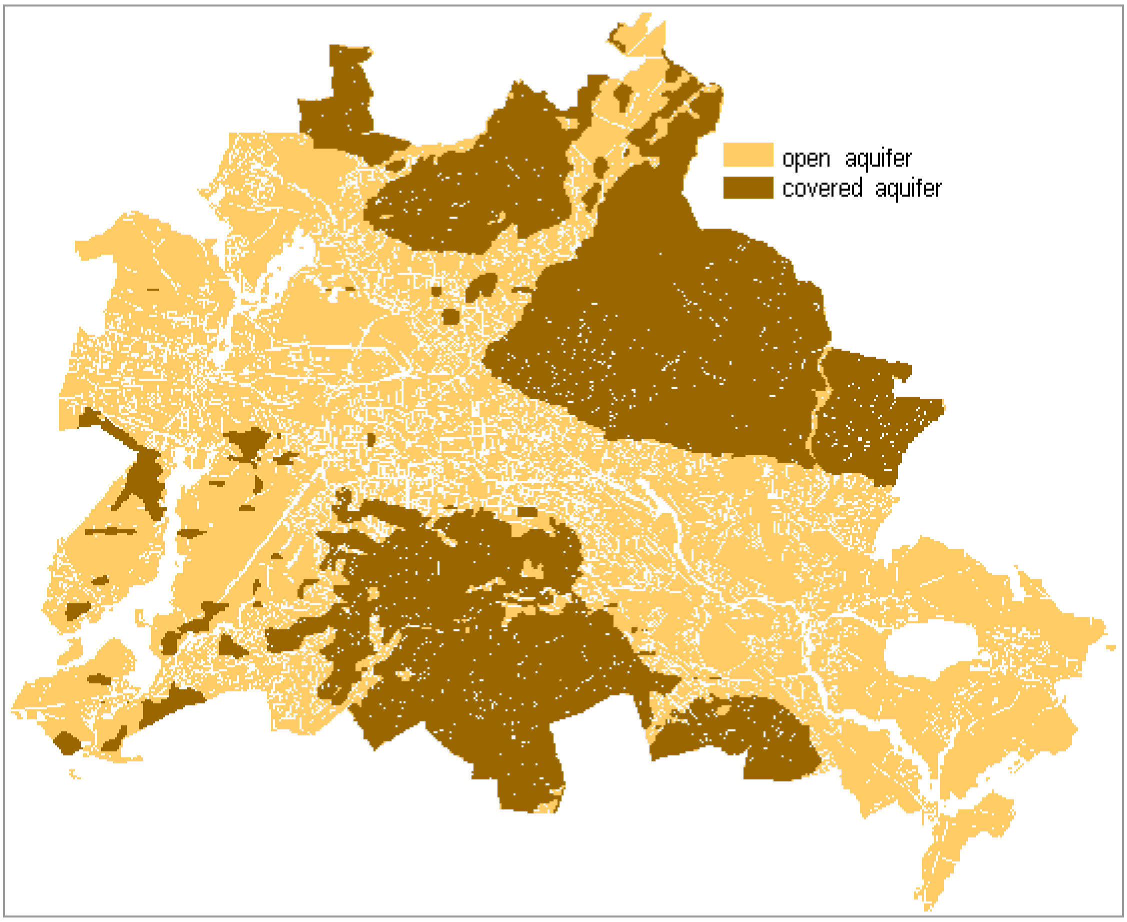

Fig. 1: Areas with covered and open aquifers

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 isolated 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 sq. km) exceeds that with covered aquifers (335 sq. km).

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 imperviousness, 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 those covered catchment areas which show very high surface runoff due to strong imperviousness. 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, so that 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 segments 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 segments 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 section, the percolation water rate of every single block segment was reduced by the reduction factor RDF for the catchment area, e.g., for Tegel Creek, by 76%.

Catchment Area Segment	Average total runoff formation R (mm/year) 4)	Average percolation water formation Ri (mm/year) 4)	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 Ditch	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
4) The calculation was carried out in 2003 on the basis of the water balance quanta, which were ascertained from data on land use, impervious covering and the sewage system from 1990 (cf. 02.13 (Edition 1999). With regard to the depth to the groundwater table, the calculation was based on information current as of May 2002. The calculation was carried out using ABIMO 2.

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

For the current edition of the map, the reduction factors ascertained in this manner in 2003 on the basis of the water balance quanta from Map 02.13 (Edition 1999, but recalculated with depth to groundwater as of May 2002) were adopted and applied to the updated percolation-water rates (as of 2005).

Map Description

In the areas with open aquifers, new groundwater formation rates correspond to the percolation rates shown 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) above 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 to 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 4.6% of the percolation water rate, but for only 18.1% 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	0.51	0.37
0-50	2.67	4.04
50-100	4.61	18.10
100-150	30.35	38.12
150-200	32.63	19.76
200-250	16.18	10.83
250-300	6.40	4.30
300-400	5.36	3.62
>400	1.29	0.85

Tab. 2: Section shares of percolation water and new groundwater formation rates (without bodies of water)

The totals for the area of the State of Berlin can be derived from the new groundwater formation rates, 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)	258	177	149
Absolute value in cu.m/year	216.7 million	149 million	125.6 million
Absolute value in l/s* sq. km	8.2	5.6	4.7

Remarks:
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.

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 imperviousness**. This means that the stated values for new groundwater formation give mean values covering pervious and impervious areas of the block sections including the surrounding traffic areas represented. Since the imperviousness and the different availability of sewers affect the water balance considerably, the stated values are not transferable to the pervious areas of the respective sections.

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