

02.05 Vulnerability of Groundwater to Pollution (Edition 1993)

Overview

Groundwater is a resource necessary for human life.

A relatively tense situation was shown by the report on the Situation and Development of Public Drinking Supplies in the State of Berlin and the cities and communities of the State of Brandenburg in the surrounding areas of Berlin (AG Wasser 1991). The maximum amount of groundwater theoretically available to **West Berlin is already being used**. Berlin groundwater comes from natural groundwater formation, from bank-filtered water supplies, and from groundwater recharge programs. The only **groundwater reserve** is in **East Berlin**, formed by the difference between stocks used in 1990 and the maximum theoretically available stocks (=appraised groundwater supplies). Berlin will use up this amount almost completely by 2010, according to prognoses of the largest possible population growth to 4 million (cf. Tab. 1).

Groundwater Volume	East Berlin 1)	West Berlin (mio. m ³ /a)	Total Berlin
required 2010 2)	148.3	215.2	363.5
required 2000 2)	131.7	199.7	331.4
existing, maximum	223.2	176.0	399.2
consumed, 1990	153.1	176.0	329.1
reserve, 1990	70.1	0.0	70.1

1) including waterworks Stolpe
2) calculation base: consumption of 240 l per inhabitant and day

Tab. 1: Groundwater Volume and Use (AG Wasser 1991)

That means any further contamination of groundwater will prevent supplying the population with sufficient amounts of good quality drinking water.

The protection of groundwater should be given great importance. The first requirement is protection of soils from contamination, because soluble pollutants will be transported by rainwater infiltration and percolation into groundwater.

The vulnerability of groundwater to pollution depends on a range of factors:

- geological-lithological - formation of infiltration and percolation zones
- morphological - surface form
- geo-chemical - binding conditions of soil
- composition of pollutants
- physical - adhesive and cohesive forces in soils
- hydrogeological - surface and subterranean flows
- flow direction and speed

The first groundwater aquifer is protected to varying degrees from contaminants by a geologic mantle of surface strata (natural protective effect). Cohesive soils are capable of absorbing a certain amount of pollutants by incorporating metals into their layer lattice of argillaceous minerals. These complexly bound

pollutants in soils pose a relatively low danger to groundwater, but pollutants which are not bound can percolate (seep) into the groundwater.

A decomposition of pollutants in soil can occur by microbiological processes, but decomposition is substance-specific, and dependent on the nature, temperature, and oxygen content of the soil. But this self-purification, as well as the filtering effect, are relatively insignificant. Every further contamination presents a danger for the first groundwater aquifer. Sand and gravel without cohesive components bind only very small amounts of pollutants, and hardly protect groundwater. A "certain" protection is afforded only by a greater thickness (> 10 m), which prolongs percolation time.

Of importance for the **temporal and spatial distribution** of pollutants or groundwater are:

- overland flow and flow direction
- rate of infiltration and percolation and
- the horizontal flow velocity in the aquifer.

Overland flow occurs when

- the infiltration zone is composed of argillaceous material such as clay, silt and/or boulder marl
- the surface has a gradient (slope)
- precipitation water exceeds the rate of infiltration.

Pollutants deposited in argillaceous soil cannot infiltrate so quickly, but pollutants can be transported by rainwater into hollows with a sandy undersoil, and are also a great danger for the first groundwater aquifer.

The **percolation rate** or the **water depth per unit of time** is one of the critical criteria for groundwater vulnerability to pollution. This vulnerability derives primarily from the geologic structure of the mantle covering the groundwater (permeability, porosity) and its thickness (flow and percolation routes). An increase in argillaceous material is related to a decrease of the permeability co-efficient and thus the percolation rate. Greater depth increases the time needed for percolation.

The lithological (rock) structure of the groundwater aquifer and the groundwater flow gradient determine the **horizontal flow rate** and thus the temporal and spatial dispersion of pollutants within groundwater. A groundwater aquifer is not a homogeneous structure. Fine sand, coarse sand, or silt can alternate. For this reason a horizontal coefficient of permeability must be included to calculate flow velocity.

It is very difficult in practice to include every important influence on the vulnerability of groundwater to pollution into a model. Only the most important **morphological and geological factors** can be considered in preparing models and maps. No consideration can be given to the influences of **physical-chemical characteristics** of pollutants, or their interactions with the geological environment (such as geo-chemical coherence behavior).

The most important morphological and geological factors are considered to be:

- a terrain form line model (as a form line map, particularly for the evaluation of direction, velocity and volume of overland flow)
- a model of geological structures and the thickness of the mantle covering the first groundwater aquifer (as a differentiated map of vertical permeability coefficient)
- a model of groundwater dynamics (as a map of groundwater flow directions and velocities).

Initial attempts for preparing a hydrogeological model for Berlin are being developed by the Arbeitsgruppe Landesgeologie der Senatsverwaltung für Stadtentwicklung und Umweltschutz (Work Group for State Geology of the Berlin Department of Urban Development and Environmental Protection).

A detailed evaluation of the vulnerability of groundwater to pollution was not possible, due to the previously mentioned geological and morphological factors. A range of necessary statistical bases were either not available or their precision did not meet requirements.

Statistical Base

The statistical base for West Berlin was given by the Map of Groundwater Vulnerability to Pollution (scale 1:50,000) in the first edition of the Environmental Atlas (SenStadtUm 1985) and the Map of Depth to Groundwater (from the surface) in West Berlin (scale 1:50,000) of the present edition of the Environmental Atlas (SenStadtUm 1992). Both maps are based on data from 1983. Data for groundwater depths from the surface in the Spandau forest were gathered in 1987.

The statistical base for East Berlin included the Map of Threats to Groundwater from the Hydrogeologic Cartography of the GDR (scale 1:50,000) (ZGI 1984). Data from the 60's and 70's were used in this map.

Areas previously used by the GDR as border security strips around West Berlin appear in white on the maps. Data for these border security strips were bore samples from the Archiv des Landesamtes für Geowissenschaften und Rohstoffe Brandenburg (Archives of the Brandenburg State Office for Geo-Sciences and Raw Materials), and from the Archive der Senatsverwaltung für Stadtentwicklung und Umweltschutz Berlin (Berlin Department of Urban Development and Environmental Protection), as well as hydrogeological reports from the Archiv der Bundesanstalt für Geowissenschaften und Rohstoffe, Aussenstelle Berlin (Archives of the Federal Office for Geo-Sciences and Raw Materials, Berlin Office).

Methodology

The available statistical bases allow only limited conclusions to be drawn regarding groundwater vulnerability to pollution based on **percolation rate**. This rate is determined mainly by the **geologic structure** of the mantle (permeability, porosity) and its **thickness** (percolation routes, depth).

The evaluation of total Berlin groundwater vulnerability to pollution required parallels to be drawn between the Map of West Berlin Groundwater Vulnerability to Pollution and the East Berlin Map of Threats to Groundwater.

These two maps are based on different classifications for vulnerability of groundwater to pollution. They cannot be directly transferred or exchanged. Different attributes are used to describe the geologic structure of the mantle over the first groundwater aquifer. There are a range of problems in drawing parallels between the basic classifications, and this can be attempted only with certain limitations (cf. Tab. 2).

Tab. 2: Classification of Geologic Structure of Mantles in the Map Bases of West and East Berlin	
West Berlin Map of Vulnerability to Pollution	East Berlin Map of Threats to Groundwater
sand and pebble	unconsolidated stone with < 20% argillaceous material
sand and pebble with interstratified boulder clay and marl	unconsolidated stone with 20 - 80% argillaceous material
sand and pebble with alternating strata of boulder clay and marl	unconsolidated stone with > 80% argillaceous material
boulder clay and marl	unconsolidated stone with > 80% argillaceous material
peat and organic soils	half-bog material
The term unconsolidated stone includes sand and pebble strata as well as argillaceous strata or materials of clay, silt and marl; the percentual proportion of clay, silt, or marl in the total mantle or unconsolidated stone layer is summarized under the proportion of argillaceous material (< 20%, 20 - 80%, > 80%).	

Tab. 2: Classification of Geologic Structure of Mantles in the Map Bases of West and East Berlin

The lack of opportunity to examine the geological bore samples made it impossible to differentiate the 3 classes of vulnerability to pollution used in the East Berlin map. It was also impossible to transpose the different systems used for the mantle. The East Berlin map typifies a mantle of unconsolidated stone with 20 - 80% of argillaceous material. The West Berlin map gives 2 typifications: a sand and pebble mantle with

interstratified or with alternating strata of boulder clay and boulder marl. The map for all Berlin used the mantle classification and the 3-stage evaluation of vulnerability to pollution method of the GDR Hydrogeological Cartography.

The two mantle types used in West Berlin (sand and pebble mantle with interstratified or with alternating strata of boulder clay and boulder marl) were considered equivalent to the mantle type used in East Berlin (mantle of unconsolidated stone with 20 - 80% of argillaceous material). It is questionable if this may be correct in every case, or if the portion of argillaceous material might sometimes be under 20 or over 80%.

Preference was also given to the method used by the Hydrogeologic Cartography for reasons of content. The West Berlin map describes the cohesiveness of the mantle only qualitatively (interstratified or alternating strata). The East Berlin map describes the proportion of argillaceous material quantitatively. This proportion of total mantle thickness is the most important criterium for the evaluation of vulnerability to pollution based on percolation velocity. This velocity is determined by the strata with the lowest permeability. The GDR Hydrogeological Cartography mantle classification method is the more suitable approach for a later differentiation of the 3 classes of vulnerability to pollution. The mantle classification of unconsolidated stone with a 20-80% proportion of argillaceous material is more suitable because of its wide range in registering the proportion of argillaceous material. This range could be further subdivided, based on more precise strata analyses of bore samples. Much finer increments of the evaluation matrix are possible.

The further differentiation of the endangerment classifications is based on **depth to groundwater from the surface**.

The **West Berlin** vulnerability to pollution map did not depict the depths to groundwater from the surface necessary for evaluation in its classifications. The Groundwater Depths (from the surface) Map was used as an aid. This map was based on uniform measurements of groundwater table contours made in May, 1983 (depth was calculated from terrain contours and groundwater table contours). The data for Spandau forest were gathered in 1987.

A discrepancy between the Map for Vulnerability to Pollution and the Map of Groundwater Depths occurred in the 0 - 5 m category. A 5 m depth line was used in West Berlin at that time for the evaluation of the vulnerability to pollution, but the 4 m depth line was portrayed in the Map of Depths. For West Berlin then, the 4 m line must be read as the 5 meter line.

Depths to groundwater from the surface given in the **East Berlin** Map of Threats to Groundwater were also calculated from terrain contours and groundwater table contours. But measurements were not made at the same time of groundwater table contours at bore sites. The measurement values of groundwater level used in the preparation of this map were taken from hydrogeological reports made in the 60's and 70's.

Neither the development of new water plants after 1980 nor the changes in amounts of existing water suppliers were considered. These would cause changes in groundwater flow patterns, especially groundwater tables.

Discrepancies in depths to groundwater from surface are mainly due to these differences in the statistical base. These discrepancies appear between West Berlin and surrounding areas (especially visible between Spandau and Hennigsdorf to Staaken), and in areas used as security borders around West Berlin.

It should be generally noted that depth to groundwater from the surface is a continually changing value, determined mainly by precipitation and evaporation. Depths are less each spring than they are in the fall, even in years of high precipitation. The variations in depth to groundwater from the surface influence the changing limits of various areas of vulnerability to pollution, but are of less importance for precision.

The East Berlin Map of Threats to Groundwater surveyed areas of half-bog formations only incompletely. The preparation of the map included here did not correct this deficiency.

Figure 1 is a schematic portrayal of a few example combinations of the geological structure of the mantle and depth to groundwater from the surface. They were classified into high, medium, and low categories of vulnerability to pollution.

ground moraine: rock pulverized and abraded by the glacier. The glacial till consists of a heterogeneous mix of clay, silt (rock flour) and sand (boulder marl, boulder clay) and unpulverized blocks of rock (boulders in the marl mass).

end or terminal moraine: formed by rough, often large rock material (plucking of bedrock) transported in front of the glacier. A balance of new ice from the accumulation zone into the ablation (loss) zone over a longer period of time (glacier equilibrium) results in great deposits of blocks of Nordic type rock, often very large, but also of gravel and sand, and some clay.

outwash plain: glacier meltwater washes gravelly, rough and middle-sandy material out of the end moraine into the

glacial valley: outflow area of meltwater.

Between the 3 great glacial advances there were several phases of advance-and-retreat. There were 3 such phases in the Weichselian period: the Brandenburg, Frankfurt, and Pomeranian phases. These phases also followed the dynamics described above. There was an overlapping of several glacial dynamic periods, with each period building its respective formations.

The splitting of the glacier into several glacial streams, each with its own dynamic, had the effect of even more overlapping glacial formations. In areas of smaller glacial landforms, it is often difficult to assign the origin of specific landforms to specific glaciers.

Ground moraine landforms are even more strongly subdivided. One result of meltwater are lakes of various forms, another result is various depositional formations of rock carried by ice (glacial drift). The outflow of meltwater in glacial crevices created deep, narrow channel lakes, such as the Grunewald chain of lakes or the Havel chain of lakes. The eroding action of tongues of ice from inland-ice sheets often created the wide and deep, stretched out tongue-basin lakes. Melting 'dead-ice masses', (ice-blocks cut off from the main mass) created non-flowing, water-filled hollows, sinks and sloughs. Ice meltwater washout from the ground moraine carried sand, gravel and blocks to form eskers (from ice crevices and tunnels) and kames (stratified drift sand and gravel deposits in detrial hills), as well as drumlins (elliptical hills with a clay core of boulder marl).

Geology and Vulnerability to Pollution of the Geomorphic Unit Berlin

Barnim flat upland

The Barnim boulder marl flat upland was created during the Brandenburg phase of the Weichselian ice-age. The southern border of this ground moraine runs approximately from Frohnau over Hermsdorf, Pankow, Humboldthain, Lichtenberg (train station), Rüdersdorf and Herzfelde. The Barnim slopes to the south, to the glacial valley (Urstromtal). Boulder marl is on the surface or near-surface. Upland area sand covers it at a few locations, but is not a groundwater aquifer. North of Buch, Karow, Schönerlinde and Hobrechtsfelde, the upland area is covered by washout sand of the Frankfurt phase. Saalian and Weichselian ice-age boulder marl often form compact jams. They are sometimes separated only by a thin sand strata. The main groundwater aquifer is protected in the north by a boulder marl mantle approximately 30 - 40 cm thick, and in the south by a boulder marl mantle approximately 10 - 30 cm thick. The mantle is especially thick in Buch - approximately 50 m. In the area of Hohenschönhausen, Falkenberg, Malchow and Schwanebeck, this main aquifer tapers off northwest towards Panketal. In Weissensee, Pankow and Wedding it splits through interstratified boulder marl into several groundwater aquifers.

A **low** vulnerability of groundwater to pollution predominates in the Barnim flat upland, at least in view of the mantle strata type (boulder marl >10 m). Pollutants reach the groundwater in the northern upland later than in the southern, because of the greater thickness of the boulder marl.

But the groundwater of this upland area is not completely protected from the entry of contaminants. Channel systems created by meltwater, such as the Wuhle and the Neuenhagen Fliess, break through the protective boulder marl layer and enable the penetration of contaminants. Contaminants can be distributed over long distances because of the groundwater flow and stream conditions (in deeper aquifers also).

The **Wuhle** is much more endangered, because it is an meltwater channel, and because both natural given conditions, as well as the manner of use at these areas have high degrees of threat. The Wuhle is of sand

with a depth to groundwater from the surface of less than 5 m. Sand and boulder marl alternate between Biesdorf-Nord and Eiche. The depth to groundwater from the direct Wuhle to the surrounding boulder marl increases (from <5 m to >10 m). The mantle overlaying the groundwater thus shows a **high to medium** vulnerability to pollution. Nevertheless, domestic waste, debris and building rubble was dumped along the Wuhle for many years (Ahrensfelder and Kienberg dump, debris from Biesdorf). The exact composition of this waste is unknown. Pollutants were and will be dissolved by precipitation and carried into the Wuhle. The insufficiently purified waste water from the Falkenberg sewage water treatment plant, the scrap-yards bordering on the Wuhle, as well as the 'wild' waste dumping present an enormous concentration of pollutants. The Wuhle, which begins north of Ahrensfelde, carries this large concentration of pollution into other highly-vulnerable areas through its connection with the Spree in the Pleistocene watercourse.

The natural conditions of the **Neuenhagen Mühlenfliess** (sand in the valley with a depth to groundwater of 0 - 5 m) also allow the entry of pollutants, whether through percolation or through the surface runoff of contaminated water.

Sewage farm operations in broad areas of the Barnim area (north of Falkenberg and Marzahn to Wartenberg and Malchow) until 1960 (and the continuing use in some cases) caused soils to accumulate high concentrations of heavy metals, nutrients and organic pollutants. The factors responsible for this accumulation in soils, besides the large pollutant concentration in discharged effluents, are the large buffer capacities and the high content of organic substances as well as the Redox/pH conditions (especially from the alkaline character of the treated sewage waters and the large content of dead organic substances). Long-term acid precipitation in discontinued sewage farms caused the redox-potential and pH values in these areas to drop. The exceeding of certain thresholds caused previously bound heavy metals to mobilize. Precipitation or the formation of layer water (existing in sandy boulder marl) could thus discharge pollutants into areas sensitive to pollution. Surface water and groundwater flow towards the southwest in the direction of the glacial watercourse (Urstomtal). The entry and dispersion of contaminant-bearing precipitation and layer water into groundwater aquifers are conditioned by lesser depths to groundwater and a mantle of sand or sand and argillaceous soils in alternate strata (which predominate south of the Malchow lake, not far from the previously used sewage farms), as well as the location of this area in the flow direction.

Local sand windows (which surely have not all been mapped), or portions of very sandy boulder marl above greater thickness', or the tearing of boulder marl areas of low thickness by construction activity, all enable entry of pollutants into the flow and stream cycle of groundwater (and not just the upper groundwater aquifer).

An entirely different danger to groundwater, not anthropogenic but rather geogenic, is present everywhere that **thin irregularities or absences in rupelton clay** exist (formed in the Tertiary Epoch). These irregularities or absences were formed by insufficient deposits or erosion caused by ice. Clay sometimes separates low-mineralized water and highly-mineralized waters. Thin irregularities or absences (such as in Schwanebeck) can allow high-mineralized water to climb from below the rupelton clay up into the near-surface area. This possibility exists mainly in areas where inversions of the natural flow regime occur, often in areas worked by wells which supply drinking water preparation facilities.

The examples presented here should make it clear that even a boulder marl flat upland is not completely protected against entry of contaminants.

Panketal

Panketal lies between Barnim and West Barnim. The western border is formed by Wilhelmsruh, Rosenthal, Niederschönhausen, Buchholz, Lindenhof, the east surface-rail station Pankow, Heinersdorf, Blankenburg, and Karow. Panketal was created by meltwater during the last ice-age. Fine sand was predominately deposited here. The Panketal has a **high** vulnerability for groundwater pollution.

West Barnim

West Barnim is the continuation of the Barnim on the northwest side of the Panketal. It is bordered in the west by the Havel lowlands and in the south by the Berlin glacial valley. The map presents only the southern portion.

Subterranean levels are composed of Saalian and Weichselian age boulder marl. The Saalian boulder marl is often split by thin layers of sand. But it only comes to the surface between Blankenfelde and Rosenthal, by Buchholz, around Mühlenbeck, Schönfliess, Stolpe village, and north of Schönerlinde in the form of small and somewhat larger islands. These areas have a **low** degree of groundwater vulnerability to pollution (depth to groundwater > 10m).

There are depots of surface sand from the Weichselian age between the boulder marl islands. These depots are especially large in the Schildow-Blankenfelde-Arkenberge area. These sands sometimes have argillaceous layers in more than 20% proportions of total thickness. They are rated as having a **medium** level of groundwater vulnerability to pollution (depth to groundwater 0 - 10 m).

The outwash plain formations of the Frankfurt phase east of Schönerlinde are overlaid by a ground moraine. Because of the small depths to groundwater from the surface and the coarse grain structures, this area has a **high** degree of groundwater vulnerability to pollution.

The strongly disturbed subsurface in the southern portion of West Barnim hinders the formation of a groundwater aquifer of larger extent. A higher strata of tertiary sediments in the area of Frohnau-Hermsdorf-Buchholz-Schönerlinde, for example, fall steeply towards the east.

Berlin Pleistocene watercourse

The north border of the Pleistocene watercourse runs from the east along Rüdersdorf, Woltersdorf, Hoppegarten, and Lichtenberg, and bends at the Friedrichshain district towards the northwest, following Pankow, Hermsdorf and Frohnau. The southern border runs approximately from east to west over Schulzendorf, Schönefeld, Altglienicke, Rudow, Buckow, Britz, Schöneberg and Wilmersdorf to south of the point where the Spree flows into the Havel.

The (Warsaw) Berlin Pleistocene watercourse was created as a glacial valley during the Saalian ice age. During the Weichselian ice age it functioned as the outflow valley for meltwater of the Frankfurt phase. It has a slight gradient from southeast to northwest. The deepest location in the glacial valley is Rohrbeck, 30 m above sea level.

Assmann (1957) described the structure of the glacial valley as a five-fold rhythmic deposition of fine sands with local interstratifications of fine clay, medium sands, coarse sands to pebbles, and gravel that could contain drift boulders. The latter are often remainders of washed-out Saalian age ground moraines, which often go over into thin layers of boulder marl, and then lead to a splitting up of the 40 - 55 m thick uncovered groundwater aquifer into several different levels. Sometimes only a few boulder marl lenses are stratified in the main groundwater aquifer, for example in the uppermost layers of valley sand by Charlottenburg (here are remains of the Weichselian age ground moraine).

Remainders of end moraines on the surface form the Müggelberge, the Gosener Berge and the Höhen south of New Zittau. These are composed mainly of sand bearing traces of compression. Channel-like valleys, some of them with lakes, cross the Urstromtal glacial valley in a north-south direction, especially in the Köpenick-Erkner area. Elsterian ice age layers of strongly varying thickness appear in the Urstromtal Pleistocene watercourse. They are composed of often changing, sometimes pulverized tertiary sediments. They are not as suitable for supplying water as the sands formed by the Saalian and Weichselian ice ages.

Dunes were formed at the end of the last ice age by blow-outs of fine-grained components from end moraines and especially from valley and Barnim area sands. These were distributed in the Urstromtal glacial valley between Köpenick and Erkner, in the Spandau forest, as well as at Hennigsdorf and at Falkensee. They are up to 15 m thick.

The very slight gradient of the Urstromtal glacial valley (Spree 0.1%) and the high groundwater level facilitated the formation of Holocene peat and half-bog soils. Hollows without outlets, channels and river pools can be filled with these deposits also.

The Urstromtal Pleistocene watercourse, on the whole, has a **very high** degree of groundwater vulnerability to pollution because of its geological structure. Boulder marl only appears occasionally in thin-layered lenses and thus offers no protection at all against contamination. In spite of this vulnerability, countless industrial operations which impair groundwater and soil quality are located precisely in this sensitive zone. Pollutant

entries of dissolved heavy metals accumulated in surface waters from the Barnim upland can occur. The extremely slight gradient and the low flow velocity mean that a concentration of pollutants in the Pleistocene watercourse area as well as in sediments and in surface waters cannot be ruled out.

Teltow flat upland

The Teltow is a flat undulating ground moraine formation south to southwest of the Berlin Urstromtal or the Dahme-Spree Bogen. Its southern borders are the Nuthe and Notte lowlands. The western border is the Berlin and Potsdam Havel area.

The Teltow can be divided into three areas in regard to groundwater vulnerability to pollution:

- northwest portion with Grunewald,
- southeast portion between Britz, Mariendorf, Buckow, Lichtenrade and Osdorf and
- southern portion between Osdorf, Lichtenrade and the Nuthe Notte lowlands.

Northwest portion with Grunewald

The direct northwest edge along the Havel shore consists of kame formations (Havelberge). These stretch south from Ruhleben in a length of about 2.5 km to the north of Schwanenwerder, but become narrower. The eastern border is formed by the lakes of Teufelsee-Pechsee-Barsee-Rinne (lake channel). This ice age formation is primarily of layered sands with individual interstratified layers of pebble and boulders. Sands with less than a 20% proportion of argillaceous material (clays, silt, brown coal) dominate. This area is classified as having a **medium** groundwater vulnerability to pollution only because depths to groundwater are more than 10 m. The direct shore area of the Havel has a **higher** vulnerability of groundwater to pollution because the depths to groundwater are smaller. The well galleries of the Tiefwerder and Beelitzhof waterworks are located in an area without a natural protective layer.

Outflow meltwater from the edge of the ice created the Teufelsee-Pechsee-Barsee lake channel and were later marked by melting 'dead' ice blocks. Hollows with no outflow exist here today.

The flat undulating portion of the Teltow runs to the southeast (east Grunewald), and reaches southward to south of the Teltow canal. It is formed of 10 - 15 m thick fluvioglacial sands which have covering sands 1 - 2 m thick. Occasional boulders and local boulder marl lenses are relicts of a ground moraine which overlaid the fluvioglacial sands. The ground moraine was washed out by meltwater from a glacier tongue (Brandenburg glacier) in the area of the Nauener Platte and the Havel.

This area also has a **medium** degree of groundwater vulnerability to pollution, because the covering mantle is composed of sands with a thickness of more than 10 m.

Southeast portion between Britz, Mariendorf, Lichtenrade and Osdorf

This portion is the core of the ground moraine flat upland and is formed mainly of boulder marl. It is occasionally covered by a thin layer of upland sands, but they are less than 20% of the mantle thickness. The boulder marl is usually more than 10 m thick, often more than 20 m thick, and thus gives the area a **low** measure of groundwater vulnerability to pollution.

Southern portion between Lichtenrade, Osdorf and the Nuthe-Notte lowlands

The uniform boulder marl mantle in the northern portion is broken up beginning at the Nuthe lowlands by flat, narrow transverse valleys into single islands of boulder marl. This area thus offers many opportunities for the seepage of polluted water. The valleys often contain flat bog peat or sand deposits. This area also has many local sand windows, areas of alternating deposits of sand and argillaceous strata, as well as thin layers of boulder marl islands (< 5 m thick). These have a **high to medium** vulnerability to pollution.

The main groundwater aquifer is formed by Saalian ice age sands. A damming mantle of Weichselian boulder marl overlays it, in direct connection with Saalian boulder marl in some localities. This mantle is often split by

sands deposited between, so that individual sand strata can be hydraulically connected. Only a few areas have confined groundwater for this reason.

Bäketal

The Bäketal, which sometimes follows the Teltow canal, cut the northern boulder marl areas of the Teltow from west to east or southwest to northeast. It was formed by meltwater of the last ice age. It is composed almost only of sands and organic sediments and has a **high** vulnerability to pollution. A hydraulic connection with the main groundwater aquifer is questionable.

Nauen Platte

The Nauen Platte is bordered in the north by the Havelland Luch, in the south by the Brandenburg Potsdam Havel area, and in the east by the Havel. Only its eastern portion is portrayed in the map.

The Nauen Platte originated, like the Teltow and Barnim flat uplands previously mentioned, during the Brandenburg phase of the Weichselian age. It is mainly composed of Saalian and Weichselian ground moraines. These flat-to-undulating, mostly closed-off ground moraine areas are sometimes overlaid by end moraine formations. The central portion of the Platte is composed of clay-to-silt boulder marl. The west and east edges, on the other hand, mainly of sandy boulder marl. The east edge of the Nauen Platte reaches Berlin at Gatow, Kladow and Grossglienicke. The upland sands here are more than 10 m thick, mostly close to and sometimes reaching the surface. The sands have boulder marl only at a few places, such as Seeburg, in the Gatow Heide, and at Karolinenhöhe.

There are favorable groundwater conditions on the Nauen Platte. The aquifers are not very disturbed. They are often split by boulder marl lenses only at the west and south edges. The main groundwater aquifer is a covered aquifer of fluvio-glacial Saalian sands with large horizontal distribution. It lies 20 - 40 m under terrain protected by a boulder marl covering, especially in the central part. The partial absence of boulder marl at the eastern edge of the Nauen Platte facilitates the entry of pollutants into groundwater. Water collecting in the higher level sands west of the Havel is also poorly protected against the entry of contaminants. This area can be assigned a **medium** vulnerability to pollution only because the higher level sands are more than 10 m thick.

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