2. Study site

2.1 Geographical, geological and climate conditions

2.1.1 Geographical and geological conditions

Berlin is the capital and the largest city of Germany. It is located in the Northern German Lowlands, in the middle of the Havel and Spree river systems which are part of the river Elbe basin. In present time, the city has a population of 3,4 million inhabitants and covers an area of 892 km^2, of which 59 km^2 consists of various sizes of rivers, riverine lakes and ponds (BERLINER STATISTIK, 2006). The elevation of the city varies between 32 m a.s.l. (at Wannsee) and 115 m a.s.l. (at Müggelberge).

Berlin's landscape is characterized by Quaternary glacial deposits, slow-flowing lowland rivers with their Holocen flood plains and shallow riverine lakes. The region was formed by three glacial periods: the Elsters, Saale and Weichsel glacial (Figure 2.1). The deeper subsurface strata series are being covered by thick Tertiary and Quaternary overburden (KALLENBACH, 1995). Glacial erosion and drainage during the ice melt formed the rivers Dahme, Spree and Havel, and their riverine lakes: Lake Tegel, Lake Wannsee and Lake Müggelsee. Three aquifers of the city are formed in Pleistocene glacial sediments. They are separated from each other by thick layers of boulder clay or till that act as aquitards (KNAPPE, 2005).

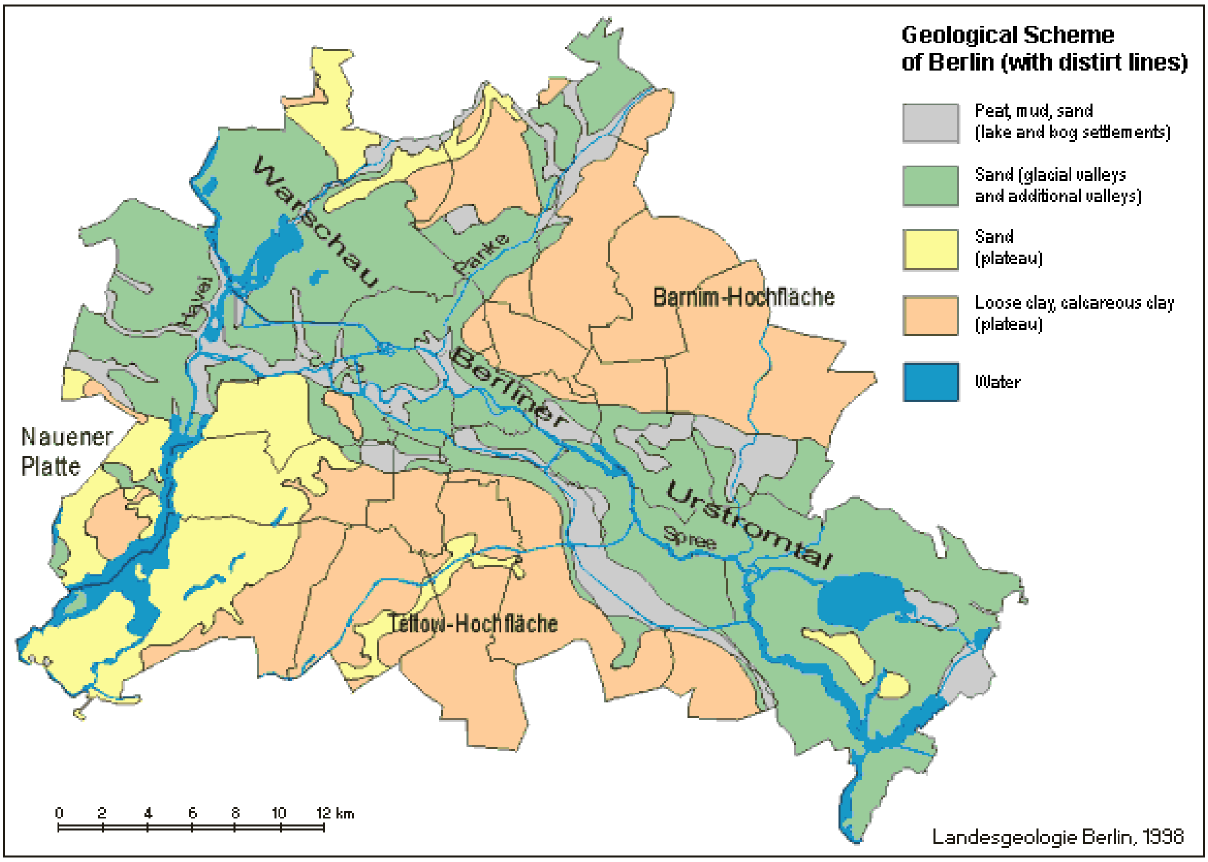

Figure 2.1: Berlin Geological Scheme *(SENSTADTUM, 1999)*

The wide and shallow Berlin – Warsaw Urstromtal separates the moraine plateaus of Teltow in the south, Barnim in the north and Nauen to the west. The Berlin Urstromtal was developed as a part of the Berlin-Warsaw Urstromtal at the end of the last glacial maximum, during the Weichsel Ice Age approximately 10,000 years ago. The city center lies along the river Spree in the Berlin-Warsaw Urstromtal running from east to west, formed by water flowing from melting water of the inland ice sheets (SUKOPP, 1990, 1995). Typical soils of are formed depended on the substratum and vary between luvisols, cambisols and podsols where ground watertable is low and gleys close to the water bodies. However, most soil in the town area and at sewage farms are anthropogenic (rubble soils) (ALAILY et al., 1995).

2.1.2 Climate

Berlin has a temperate/mesothermal climate (Cfb) according to the Köppen climate classification system (ARTHUR, 1984). The mean annual precipitation is 589 mm (average for the period of 1961-1990). The highest precipitations occurs in June, August (65 to 71 mm). The drought months occur in October, Feburary and March with 36 to 38 mm (Figure 2.2).

The mean annual temperature for Berlin-Dahlem (a location within Steglitz-Zehlendorf) is 9.4°C. The warmest months are June, July, and August, with mean temperatures of 16.6 to 17.9°C (period of 1961-1990). The coldest are January, February and December, with mean temperatures of −0.5 to + 1.1°C (period of 1961-1990). Berlin's built-up area creates a microclimate, with heat stored by the city's buildings. Temperature can be 4°C higher in the inner city than in the suburban areas (BERLINER STATISTIK, 2006).

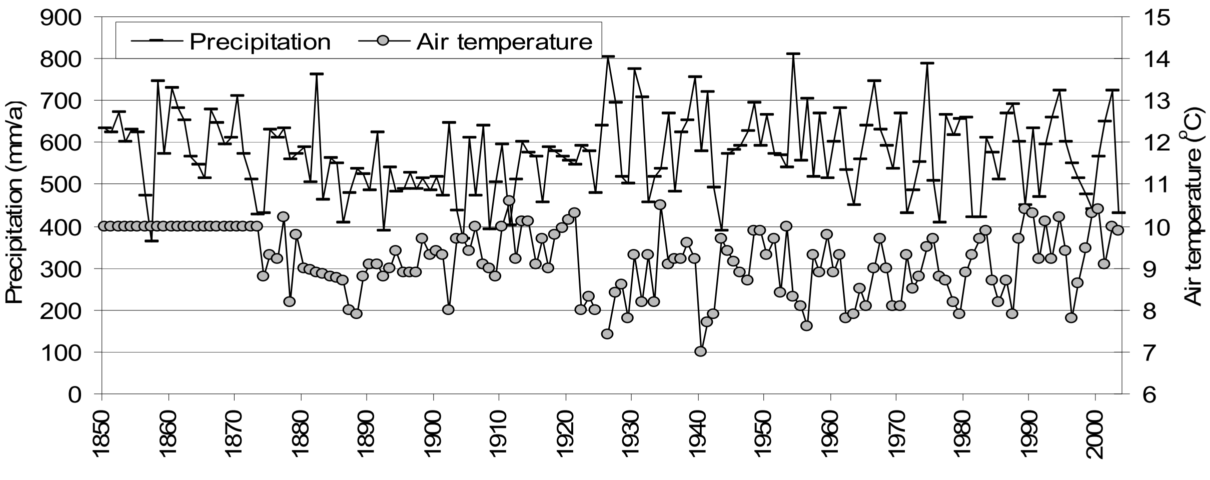

Figure 2.2: Annual air temperature and precipitation in Berlin over the last 150 years *(Source: BERLINER STATISTIK, 1874-2003)*

2.2 The surface water system

2.2.1 The water bodies of Berlin

About 6.7 % of the total area of Berlin are surface waters with approximately 197 kilometers of waterways and more than 100 lakes. Berlin's surface water system is composed of three major flows: the Spree, the Havel and the Dahme and some smaller running waters like

Tegeler Fließ, Nordgraben, Panke and Erpe (Figure 2.3). Next to this, an extended canal system with Tetowkanal and Landwehrkanal as the most famous exists over the last 100 years. The canal and small flow system serves predominantly as receiving streams for the sewage purification plant and sewage farm ditches located around the Berlin city vicinity. The river Spree is the major feeding water. The navigable rivers Spree, Havel and Dahme flow in an overall length of 89 kilometers through the city. Eight artificially created channels with an overall length of 66 kilometers interlace the city with the rivers and numerous navigable lakes.

Additionally, as a typical lowland river with very low slope of the relief (<0.1%), the Spree and the Havel in Berlin have many riverin lakes (e.g lake Tegelersee, Müggelsee, Wannsee). Berlin has some 60 lakes which are smaller than one hectare and more than 500 natural very small water bodies. All Berlin lakes together have an area of 2,265 hectares (Table 2.1). Average depth of Berlin lakes is 4.24 m. Surface water bodies have a volume of 227.8 million m^3 in total (SenStadtUm, 2002).

Table 2.1: The water bodies of Berlin *(Berliner Statistik, 2006)*

Natural flow	Length (km)	Canal	Length (km)	Lake	Area (ha)
Spree	45.1	Teltowkanal	29.1	Great Müggelsee	743.3
Havel	27.1	Landwehrkanal	11.8	Tegelersee	384.3
Panke	17.6	Hohenzollernkanal	7.9	Langer	290.3
Dahme	16.4	Neuköllner-Schiffahrtskanal	4.0	Great Wannsee	273.2
Wuhle	15.7	Berlin – Spandauer Schiffahrskanal	3.9	Seddinsee	258.0
Nordgraben	11.7	Britzerkanal	3.4	Zeuthenersee	228.4
Tegeler Fließ	11.2	Westhafenkanal	3.1	Jungfernsee	124.2

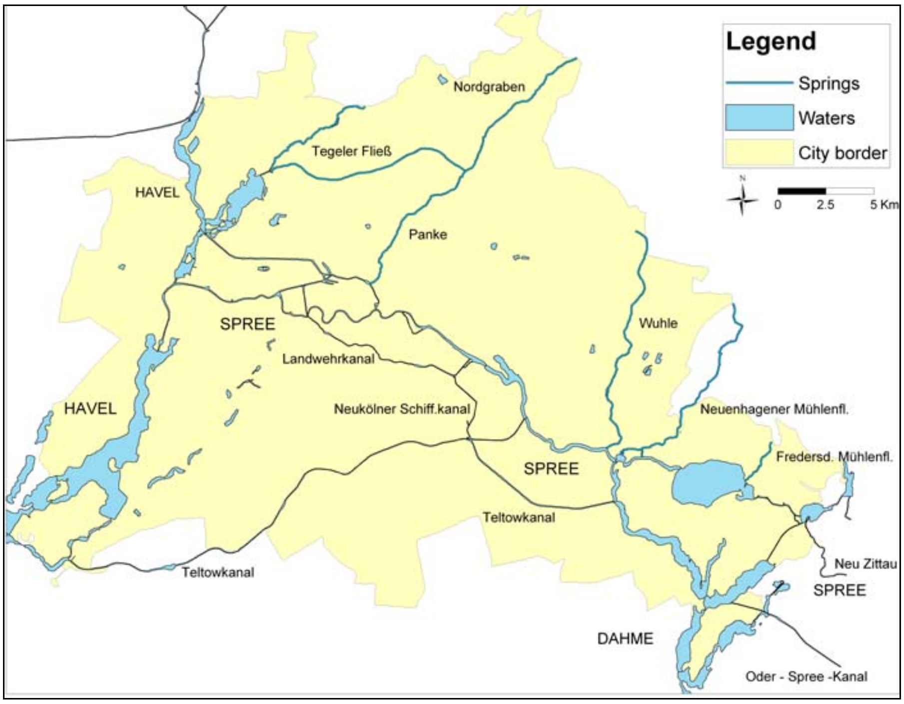

Figure 2.3: The surface water system of Berlin *(SenStadtUm, 1999)*

2.2.2 The river Havel

The river Havel is one of the longest tributary of the Elbe River – the 12th largest river systems in Europa. It rises in Mecklenburg-Western Pomerania, flows through Brandenburg, Berlin and enters the Elbe in Saxonia-Anhalt (Figure 2.4). The river overcomes only 40.6 meters difference at height, from 66 m a.s.l. at its spring to 22 m a.s.l. at the confluence with the Elbe. Although, the direct distance of the spring to the mouth is only 69 kilometers, it is the longest tributary (325 km) of the Elbe (LANDESUMWELTAMT BRANDENBURG, 1995). The catchment area of the Havel is prevailly characterized by artificial drained wetlands. Only in the south of the catchment there are higher uprisings in Fläming.

The Havel channel, a glacial channel system, runs from north to south, cutting across the Teltow plain south of the Spree delta. The wide, basin-like features in the lower parth of the Havel were caused by exaration during the Brandenburg stage about 20 ka BP, which stopped south of Berlin. The area of Berlin valley forms broadly and nearly plain valley surface, which is towered only by some risings as remainders of the hall-cold-temporal relief. Some gutter-like valleys, in which many lakes are embedded, cross it in north - south direction. In the lowland area, valley sand as well as older glacial sand formed an uncovered groundwater structure with very different thickness (SUKOPP, 1995). In the area of Potsdam, the Havel changes its course to the west up to the lake Plauersee. It crosses the landscape area of the Mittelbrandenburg plates and lowland. Here, almost all glacial elements are represented: ground moraine, end moraine, outwash plain and sand valley surfaces. The geological structure almost takes part of young Pleistocene deposits exclusively, like till sand and loams, glacial fluvial sand and gravel, dune sand and Holocene humose formations (PACHUR & WÜNNEMAN, 1995).

The Havel catchment covers an area of 23,480 km^2, with relative low population density (234 inh./km^2) (Figure 2.5). The dominant landuse is agriculture (48.5%) and forest (37.3%). Urban area composes of 7.7% total area (Table 2.2). According to administrative boundaries of the Havel catchment, Berlin has the highest population density of 3790 inh./km^2 and Mecklenburg–Strelitz district in the Upper Havel sub-catchment has the lowest population density of 41-42 inh./km^2 (Figure 2.5).

Table 2.2: Land use in the Havel catchment *(Source: BEHRENDT, 1999, 2004)*

Catchment	Catchment area (km^2)	Population (inh./km^2)	Portions of the main land uses (%)				
			Urban area	Agricultural use	Farm land	Forest	Water
Spree - Upstream Cottbus	2,269	140	10.8	38.7	32.5	40.9	2.9
Spree - Upstream Neu Zittau	6,401	114	9.2	38.4	28.3	45.7	2.1
Dahme at Neue Mühle	1,362	76	4.3	33.4	28.1	57.3	4.2
Spree at Sophienwerder Berlin	9,930	330	10.5	44.9	37.8	37.1	2.1
Upper Havel	3,110	64	4.2	37.0	28.7	51.7	5.1
Havel	23,480	234	7.7	48.5	38.5	37.3	2.5

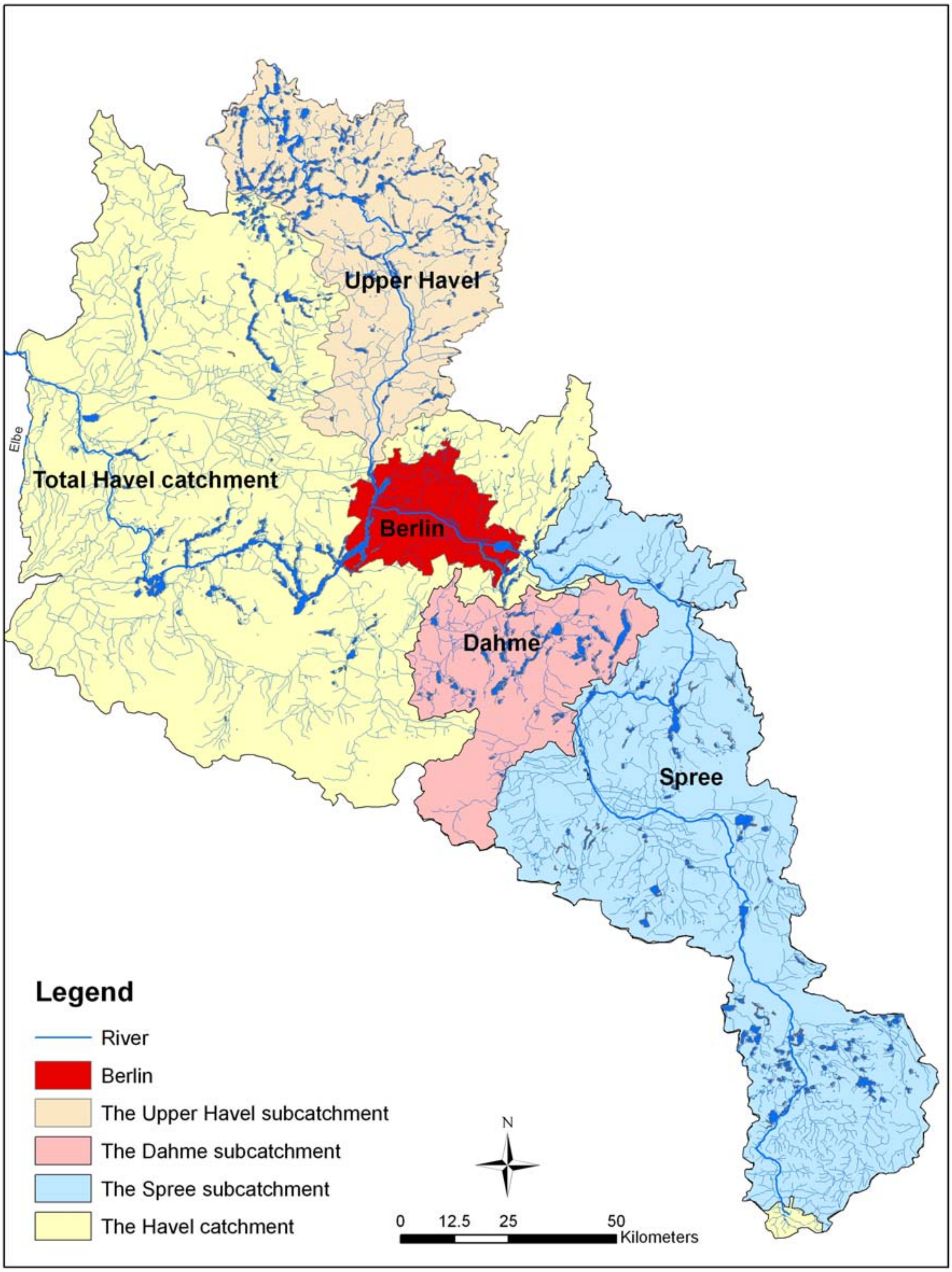

Figure 2.4: The Havel catchment and subcatchments
(Source: IGB Database)

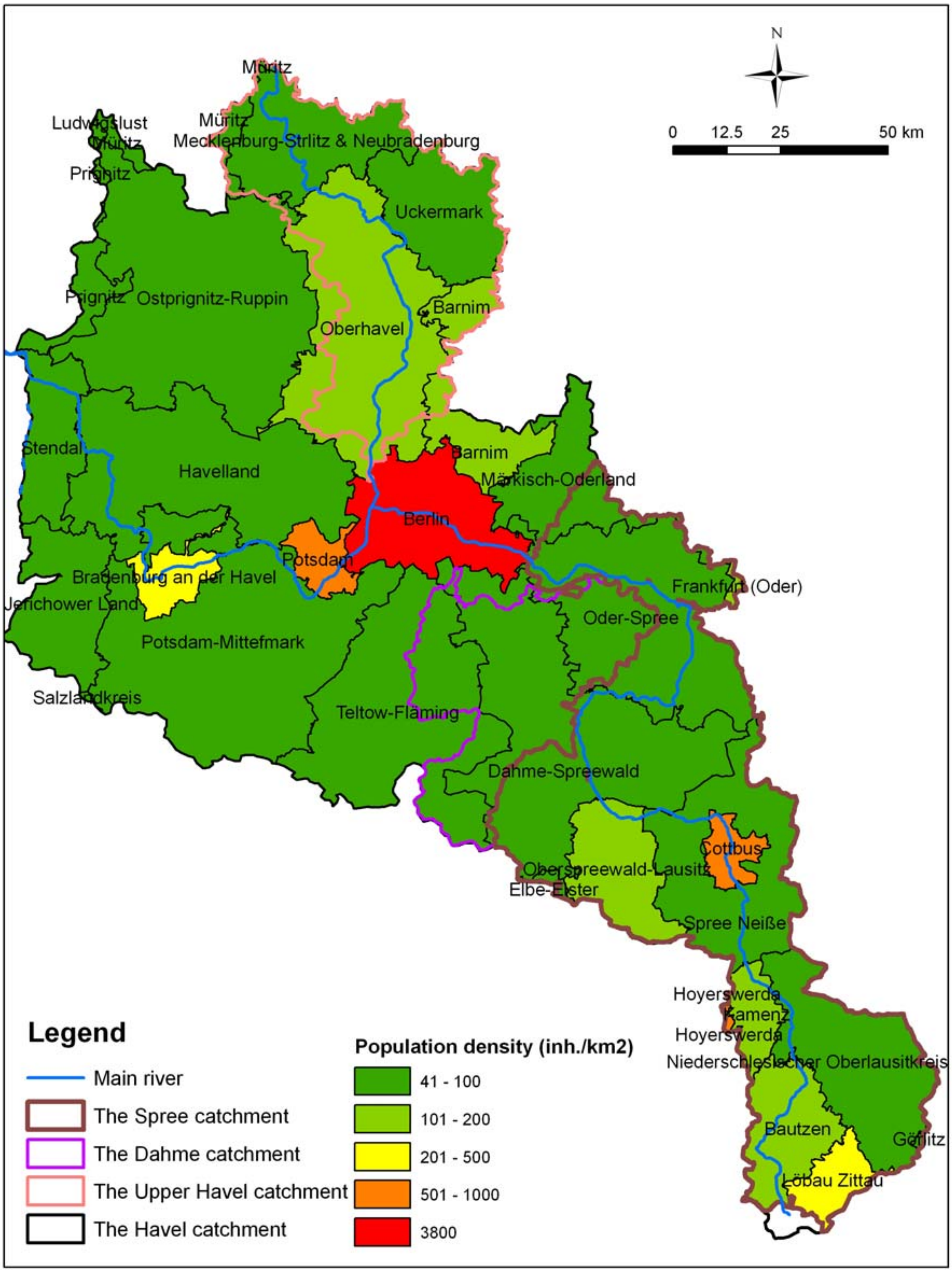

Figure 2.5: Population density within administrative boundaries of the Havel catchment
(Source: Statistik Berlin-Brandenburg; Saxony; Saxony-Anhalt; Mecklenburg-Vorpommern, 2006; IGB Database)

2.2.3 The river Spree

The river Spree is the largest tributary of the river Havel, which discharges at the delta more than twice as much water than the Havel (36 m³/s of the Spree at Sophienwerder in comparison to 15 m³/s of the Havel at Spandau) and in addition also in the length exceeds (380km). The Spree flows through the Federal States Saxonia, Brandenburg and Berlin. The spring is located in the Lausitzer mountains close to the border of the Czech Republic. Major parts of the Spree catchment spread over Pleistocene and Holocene deposits. Only in the headwater area, the Spree catchment drains the Paleozoic rocks of the Lausitzer granite massifs and some sediment formation of greywacke and shale (DRIESCHER, 2002). The Spree flows 46 km inside Berlin. Because of its very small downward gradient, flow velocity is slow. Along the entire distance numerous inflowing waters occur (Westhafenkanal, Berlin-Spandauer- Schifffahrtskanal, Landwehrkanal, Charlottenburger connection channel). The river banks are typically urban shaped, industrial plants, large living and office-complexes and parking lots alternate. The bank edges are predominantly sealed. Numerous inland ports and pass channels are characteristic for the inner city areas (BALDOWSKI et al., 2000). The hydrological situation of the Spree is characterized by a small runoff and intensive anthropogenic impacts, including reservoirs, the brown coal open mining in the Lusatian mining district, the old cultural landscape Spreewald and the channelized surface water system in Berlin (KADEN, 2002). Since 1991, the successive closures of the brown coal open mining in the catchment area of the river Spree have resulted in a decreasing water flux of the river. The overall inflow water from the river Spree to Berlin has dropped from 32 m^3/s in the years 1980–1990 to 21 m^3/s in the period of 1991-2000 (SENSTADTUM, 1997; KNAPPE, 2005) (Figure 2.7).

The catchment area of the Spree river covers 9,930 km^2 with an average population density of 330 inh./km^2 for the total catchment (Figures 2.5, 2.7). The agricultural use comprise of around 40% of total area, except in the Dahme sub-catchment (33.4%). Farm land area portion in total area varies from 28.1% in the Dahme to 32.5% in catchment upstream Cottbus. Forest covers approximately 40-57% of total area in the Spree catchment (Table 2.2). The urban area covers 10% of total catchment area.

2.2.4 The river Dahme

The Dahme is an approx. 120 km long tributary of the Spree, flowing in southeast Berlin. It originates from the Dahme land and flows in northern direction through Märkisch Buchholz and Königs Wusterhausen and enters the Spree in Berlin Köpenick. In Golssen, the river reaches the Baruther Urstromtal. Starting from Märkisch Buchholz, the Dahme transforms from the small flow into a broad channel, navigable, due to the Dahme Umflutkanal supplied by the Spree. The Dahme catchment covers an area of 1,360 km^2, with very low average population density (76 inh./km^2 compared to the density 114 inh./km^2 of the Spree upstream

Berlin) (Table 2.2, Figure 2.5). In the Spree catchment, the Dahme tributary has highest portions of forest area (57.3%) and surface water (4.2%) and the lowest portions of urban area (4.3%) and agricultural land use (33.4%). Figure 2.8 shows the discharges of the river Dahme in the period of 1953-2003.

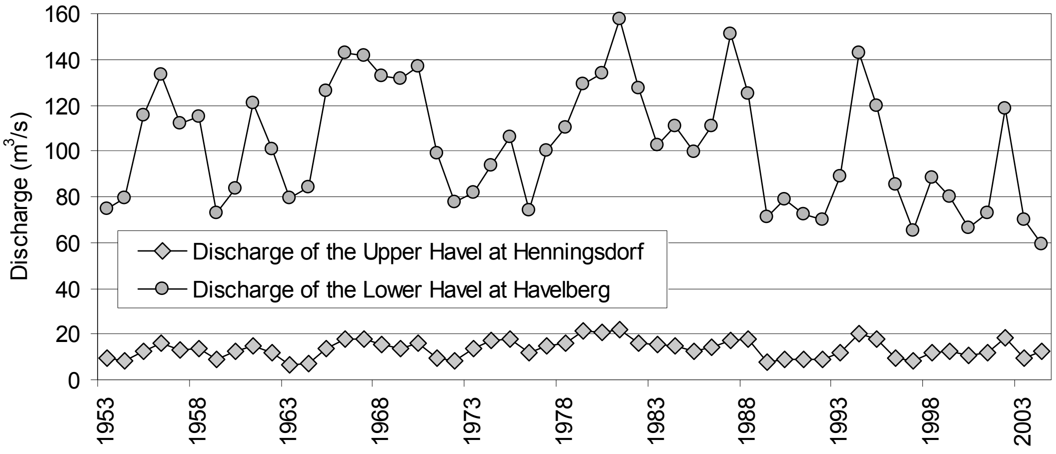

Figure 2.6: The Havel's discharge at Hennigsdorf and Havelberg in the period of 1953-2003
(Source: DEUTSCHES GEWAESSERKUNDLICHES JAHRBUCH, 1953-2003)

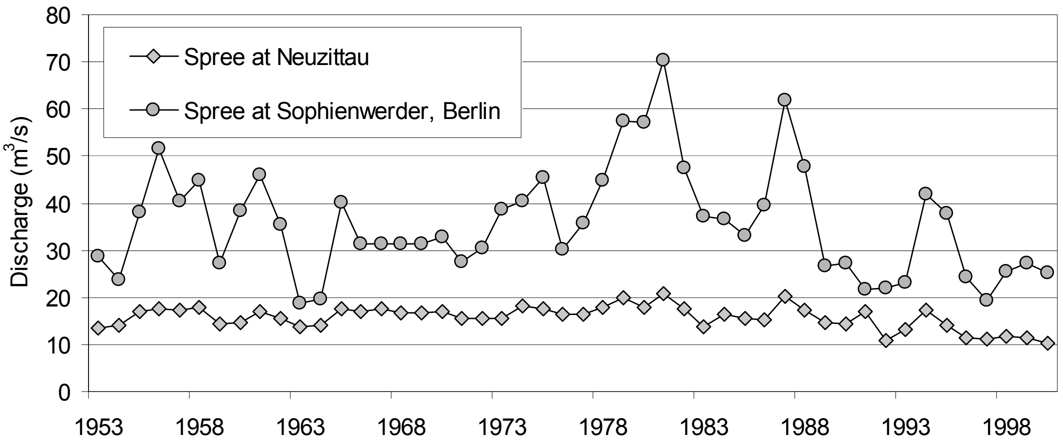

Figure 2.7: The Spree's discharge at Neuzittau and Sophienwerder in the period of 1953-2003
(Source: DEUTSCHES GEWAESSERKUNDLICHES JAHRBUCH, 1953-2003 and calculation)

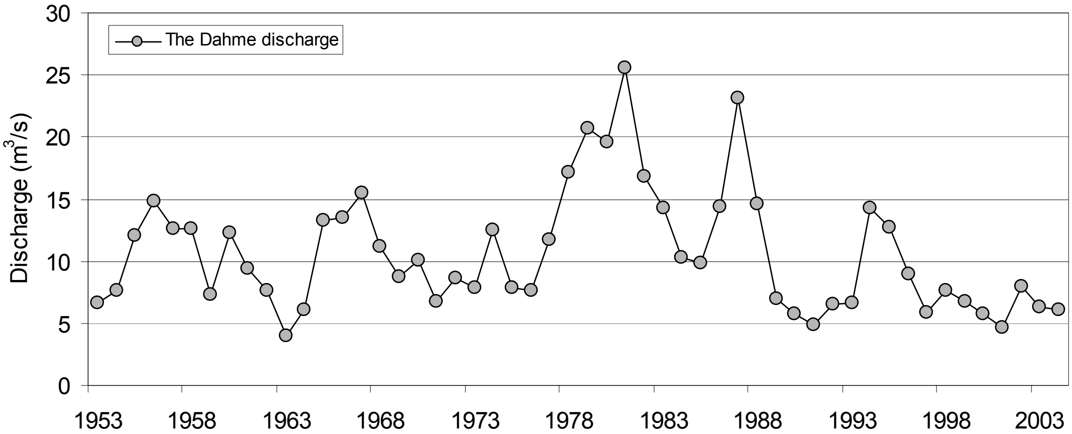

Figure 2.8: The Dahme's discharge at Neue Mühle in the period of 1953-2003
(Source: DEUTSCHES GEWAESSERKUNDLICHES JAHRBUCH, 1953-2003)

2.3 Development of the population and urban infrastructure of Berlin in the last 150 years

2.3.1 Urban and impvervious area development

The Greater Berlin Act (passed on 27 April 1920 by the Prussia parliament) established Greater Berlin, including the Old Berlin city (*Alt-Berlin*); 7 other adivining towns (Charlottenburg, Köpenick, Lichtenberg, Neukölln, Schöneberg, Spandau and Wilmersdorf); and 59 rural communities as well as 27 forest estates from the surrounding districts of Niederbarnim, Osthavelland and Teltow (BADER, 1981; BERLINER STATISTIK, 1924) (Figure 2.9).

Berlin is 770 years old. It was the capital of the Kingdom of Prussia (1701-1871), the German Empire (1871-1918), the Weimar Republic (1919-1932) and the Third Reich (1933-1945). After the Second World War, Berlin was divided since 1947, but strictly from 1961 until 1989 by the Berlin Wall (SCHLÖR, 2006). After reunification in 1990, Berlin became the capital of the Federal Republic of Germany.

In the period of 1850-1891, the major part of the built-up area in Greater Berlin located in the Old Berlin city. Since 1891, the increasing built-up area occurred mostly in the extension part of Greater Berlin (satellite cities and towns) (Figure 2.11).

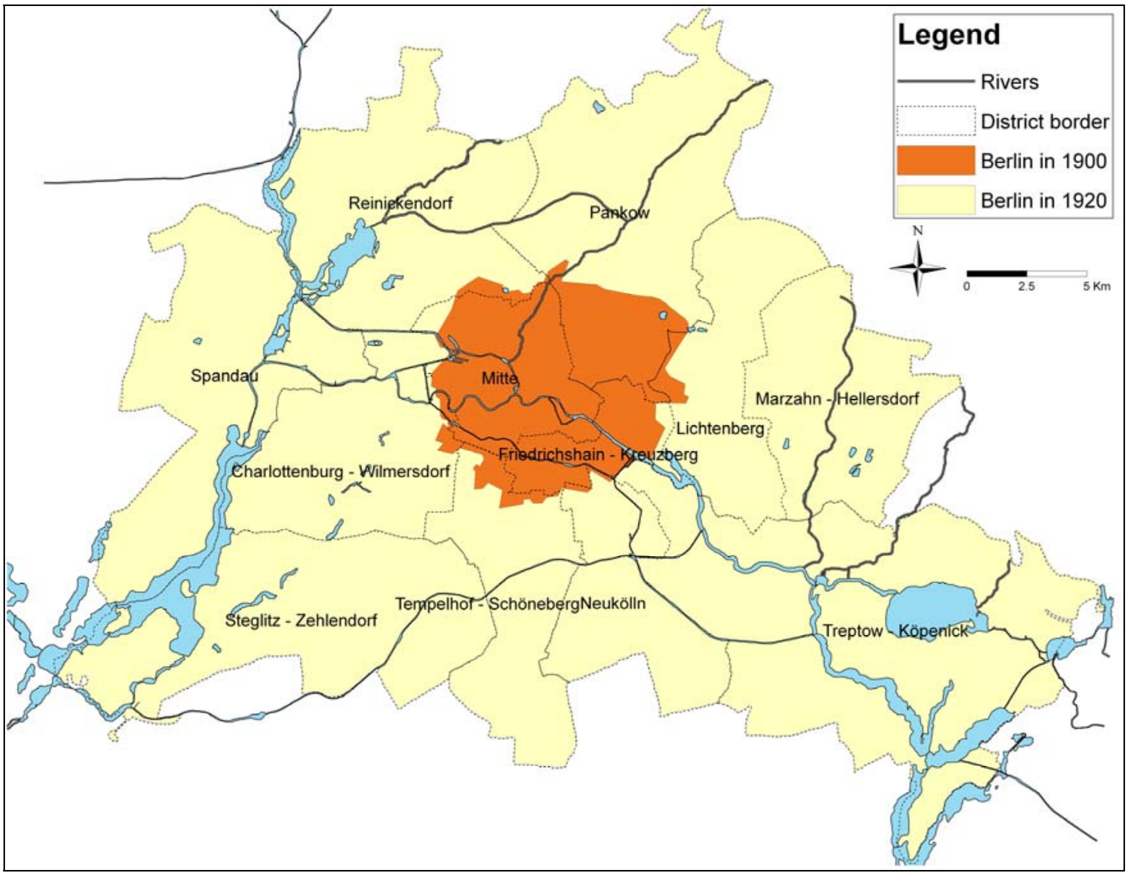

Figure 2.9: The Old Berlin city and Greater Berlin in 1920 *(BERLINER STATISTIK, 1924)*

The impervious area of Berlin has continuously increased since 1850 (Figure 2.10). It increased from 1117 ha in 1850 to 13,028 ha in 1920 when Greater Berlin had been established. At the end of the Second World War, Berlin has approximately 20,000 ha of impervious/paved area. The total impervious area was decreasing in the period of 1943-1948, because approximately 20% of all buildings had been totally destroyed and another 50% were in severely damaged conditions.

In West Berlin, the massive destructions of the Second World War were quickly eliminated by large-scale building activities during the 1950ies and 1960ies as a result of economic aid as part of the reconstruction program (Marschall Plan). During the 1970ies, construction policy in West Berlin concentrated on the revival of the inner city. East Berlin lacked economic support and the same time was burdened by reparations. The reconstruction of East Berlin began on a large scale only after construction of the Wall in 1961 with a focus on the recreation of the center of the city on areas wiped out and cleared as the result of the war. The housing program in East Berlin was proclaimed as the main focus of the social program since the 1970ies due to the shortage of living space (SENSTADTUM, 2007).

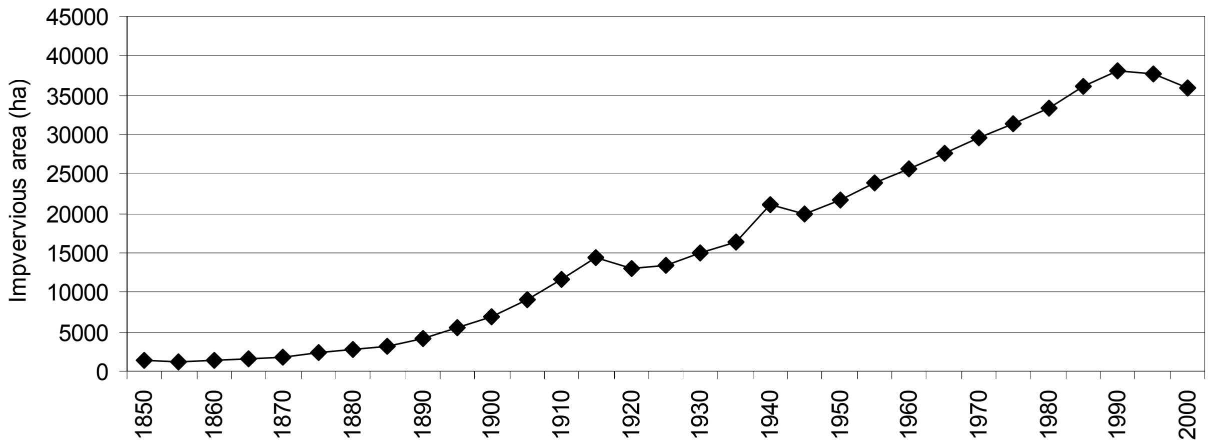

Figure 2.10: The development of the impervious area in Greater Berlin, 1850-2003 *(STASTISHES JAHRBUCH BERLIN; 1873-20041)*

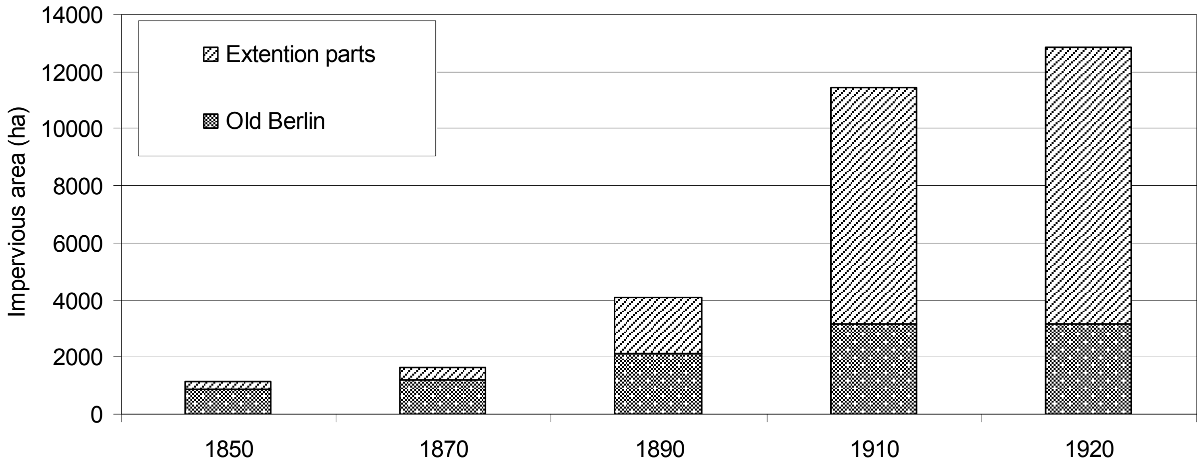

Figure 2.11: Contribution of the Old Berlin city and the extension parts to the total impervious area of Greater Berlin *(BERLINER STATISTIK, 1924)*

The impervious area has continuosly increased until reunification in 1990. Approximately 60 % of all reconstructions in the period of 1990-2005 were erected as small supplements of the existing structure. From 1993 to 1997 new suburbs in the outskirts were erected as well as numerous big projects in the inner city area, like the Potsdam place or the government constructions. Since 1997, the housing construction is retrograde due to the reduction of finance support (BWB, 1996; SENSTADTUM, 2007).

2.3.2 Population development

Berlin is the largest city in Germany. The Industrial Revolution transformed Berlin during the 19th century, the city's economy and population expanded rapidly, and it became the main rail hub and economic center of the country (Figure 2.12). Additional suburbs soon developed and increased the area and population of Berlin. The inner city boroughs of Mitte, Tiergarten, Wedding, Prenzlauer Berg, Friedrichshain and Kreuzberg reached their greatest population density in 1910 with 327 inh./ha. Today, the population density of these boroughs has dropped to 100 inh./ha, one-third of the peak value (Figure 2.14). Population in the inner city area continuously decreased its portion in total population of Greater Berlin over the last 150 years from 89% in 1850 to 36% in 1945 and almost 20% today (Figure 2.13) (STASTISHES JAHRBUCH DER STADT BERLIN, 1878-1943; BERLIN IN ZAHLEN, 1927-1951; STASTISHES JAHRBUCH BERLIN <West>, 1952-1990; STATISTICHES JAHRBUCH DER HAUPTSTADT DER DEUTSCHEN DEMOKRATISCHEN REPUBLK, 1961-1983; STASTISHES JAHRBUCH BERLIN, 1991-2006).

In contrast, the population in the outer boroughs continuously rose, except for a drop in 1945. In Greater Berlin scale, the population density has continuously increased from 5 inh./ha in 1850 to the historical maximum 51 inh./ha in 1942. In 1945 the population droped down to 31.6 inh./ha as a result of the city destruction in the Second World War (Figure 2.13, Appendix 11.5). After reunification in 1990, population density in Berlin has slightly decreased, from 38.6 inh./ha in 1990 to 38 inh./ha in 2003 (STASTISHES JAHRBUCH BERLIN, 1991-2006).

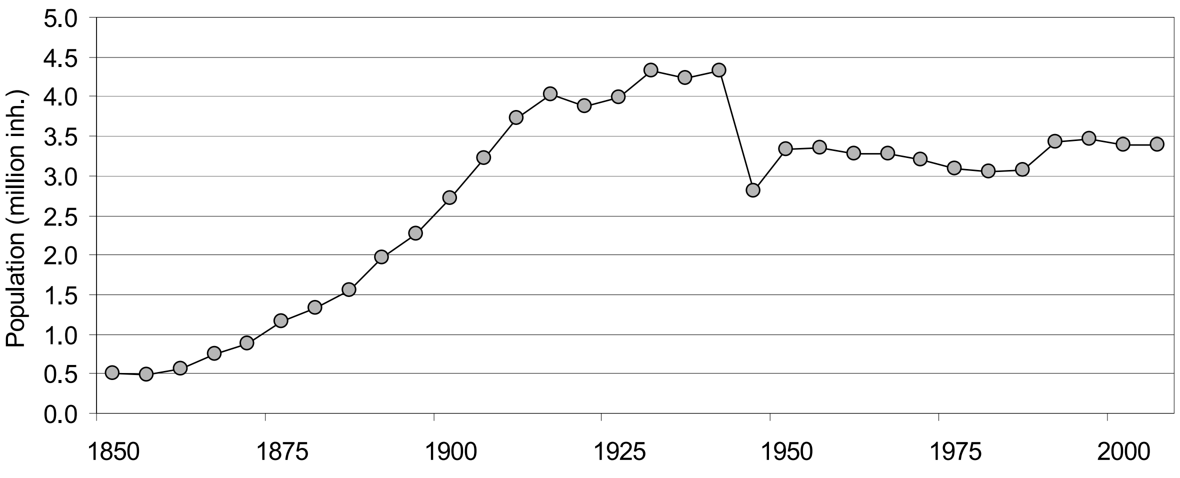

Figure 2.12: Population development of Greater Berlin (entire city) over the last 150 years *(Source: STASTISHES JAHRBUCH BERLIN; 1873-2001)*

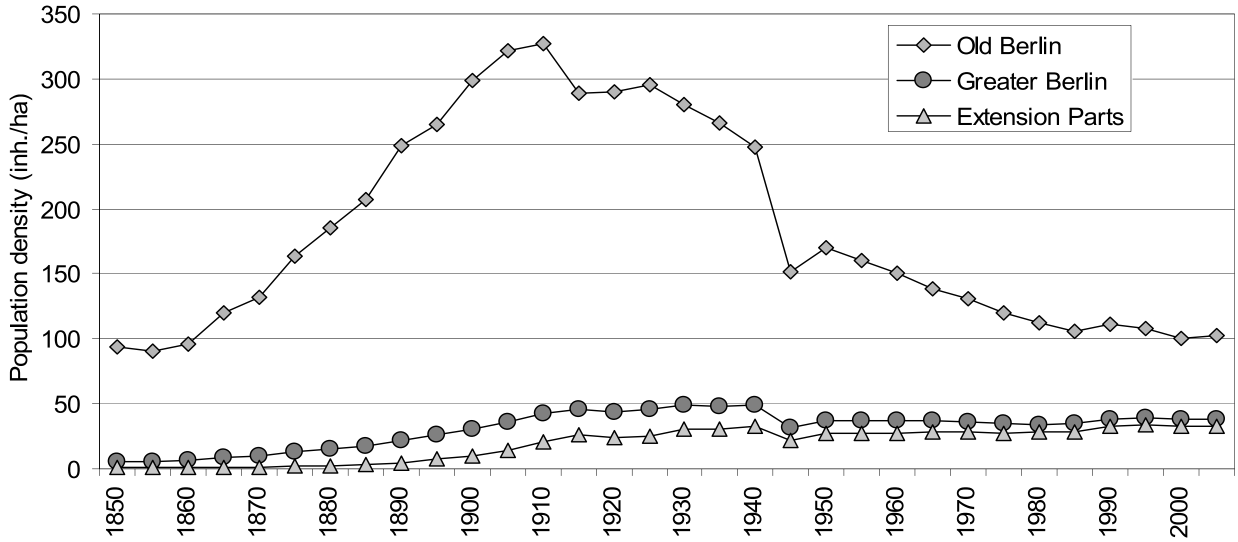

Figure 2.13: Development of population density in Berlin over the last 150 years
(Source: STASTISHES JAHRBUCH BERLIN; 1873-2001; BERLIN DIGITAL ENVIRONMENTAL ATLAS, 2004)

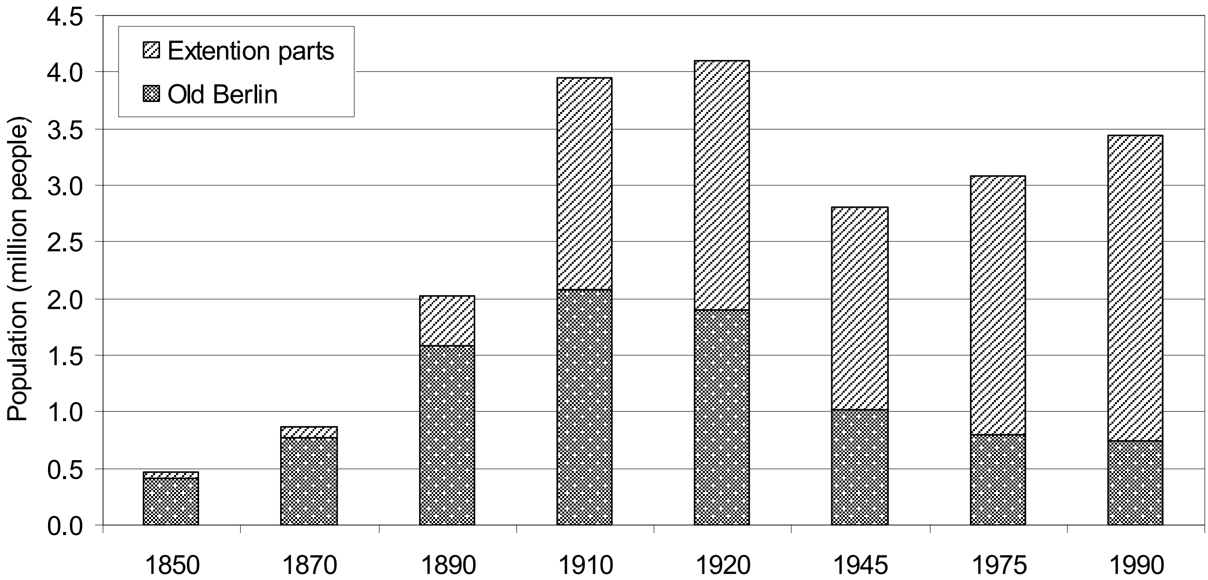

Figure 2.14: Contribution of the Old Berlin city and the extension parts to the total population of Greater Berlin in the period of 1850-1990
(Source: STASTISHES JAHRBUCH BERLIN, 1873-1991)

2.4 The development of water supply, waste water collection and treatment system

2.4.1 The development of water supply

Today, the Berlin water production is a semi-closed recycling on groundwater abstracted within the city boundaries. Berlin is located in a relatively dry area of Germany (average 572 mm annual precipitation over the last 150 years), but having a favorable hydro-geological situation in the Berlin-Warsaw Glacial Valley formed during the last ice age. The underground consists of sand and gravel up to a depth of 150 m with embedded boulder clay and clay seams. These water bearing layers contain freshwater. Beneath these layers is a contiguous layers of clay (sandy marls), around 100 m thick, separating the “freshwater stratum” from the deeper underlying “saltwater stratum” (KALLENBACH, 1995; BWB, 2000). The inhabitants of the Old Berlin city could easily and free of charge tap on the extensive groundwater aquifers underlying the city via private and public wells. In 1800, Berlin had 5500 private and public wells, or two wells for three houses and one well for 30 inhabitants (LANZ, 2005). Before the first house was attached to the central water supply in 1856, Berlin had 9000 private and 900 public wells which supplied 442,000 inhabitants (MOHAJERI, 2005). After long time of on-road and on-yard disposal of waste water and open toilet in back-yard, the groundwater was heavily polluted (Table 2.4). This contamination resulted in the spread of Cholera. Therefore, a central water supply system was necessary to safeguard Berlin’s inhabitants.

In July 1856, the central water supply system started in Berlin in the Plant Stralauer Tor with a capacity of 16.000 m^3/d (just for 314 houses). The capacity of the system increased to 16 million m^3/a in 1875 for 8749 houses and 943,000 inhabitants. The supplied water volume in 1900 totaled 54.8 million m^3, and reached the volume of 100 million m^3 in 1921 and 330 million m^3 in 1949 (Figure 2.15). The development of Berlin’s water setor in the period of 1852-2002 are summerized in Table 2.3 (BÄRTHEL, 2003; MOHAJERI, 2005).

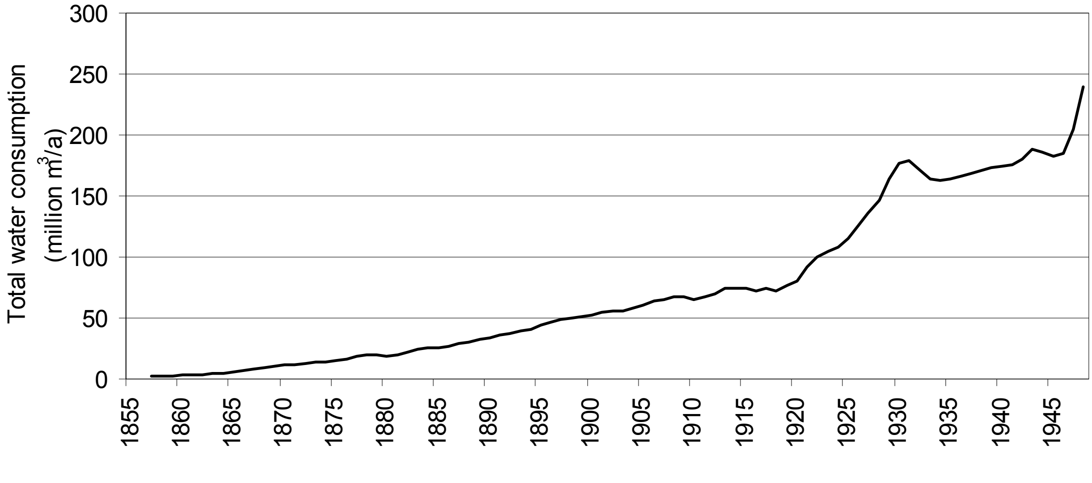

Figure 2.15: Development of water supply volume in Berlin, 1857-1950
(Source: GERICKE, 1956)

Table 2.3: The development of Berlin's water sector, 1852- 2002

1852	Contract drawn up and agreed between Berlin's Polizeipräsident (police superintendent) and the British engineers Fox and Crampton to supply the city of Berlin with running water for drinking and street cleaning, fire fiting
1853	Berlin Waterworks Company founded in London
1856	Berlin Waterworks Company's first waterworks facility takes up operations
1873	The city of Berlin acquires (municipalises) the Berlin Waterworks Company. A Municipal Committee on Construction is formed for Berlin's sewer system
1876	Berlin's first sewage farm takes up its operations
1878	Charlottenburger Wasserwerke AG founded. Official takeover of wastewater treatment plants
1920	The birth of modern Berlin: Greater Berlin is established by merging eight cities, 59 communities and 27 districts
1923	Reorganisation of municipal drainage facilities
1924	Berliner Städtische Wasserwerke AG founded as a public utility
1937	The public limited company "Berliner Städtische Wasserwerke" becomes an owner-operated municipal enterprise
1945	Merger of Berliner Städtische Wasserwerke and Charlottenburger Wasserwerke AG to form Berliner Wasserwerke, a public utility
1949	Division of the city of Berlin, organisational separation of Berlin's municipal water supply and sanitation
1951	Berlin municipal sanitation and Berlin waterworks in Berlin (East) combined to form Groß-Berliner Wasser- und Entwässerungswerke (Greater Berlin Water and Wastewater Treatment Plants)
1961	Construction of Berlin Wall, and severing of water supply pipes from East to West Berlin
1962	Organisational, yet not operational merger of Berlin sewerage with the Berlin waterworks in Berlin (West)
1964	Formation of VEB Wasserversorgung und Abwasserbehandlung Berlin in Berlin (East) for the provision of water supply and sewerage services (VEB = Volkseigener Betrieb, i.e. people owned company, the main legal form of companies in the Democratic Republic of Germany)
1988	Operational merger of the Berlin waterworks and Berlin wastewater treatment plants to form Berliner Wasser-Betriebe in Berlin (West)
1990	East and West Berlin are reunified, East Berlin magistrate commissions West Berlin Wasserbetriebe to run water and waste water services in East Berlin.
1992	Merger of Berliner Wasser-Betriebe (West) and VEB Wasserversorgung and Abwasserbehandlung Berlin (East) to become Berliner Wasserbetriebe.
1994	Conversion of Berliner Wasserbetriebe into an Anstalt des öffentlichen Rechts AöR, a public-law corporation
1999	Part-privatization of Berliner Wasserbetriebe. 50.1 per cent of the shares remain in the possession of Land Berlin, 49.9 held by a consortium consisting of the French corporation Vivendi, the multi-utility company RWE and the insurance company Allianz (10 per cent)
2002	Allianz sells its shares to Vivendi and RWE who now each hold 24.95 per cent of Berlinwasser

(Sources: LANZ, 2005; MOHAJERI , 2005; HERBKE, 2006)

Table 2.4: Water quality in the central supply system and wells of Berlin in 1856

Parameter	Berlin tap water (26.03.1856)	Berlin wells	London New River	Hamburg
Water hardness	7 3/4°	45	20	
Solid components (mg/l)	157	1000	230	190
Organic components (mg/l)	40	150	29	74

(Source: MOHAJERI, 2005)

Today's water supply

Most recently, Berlin's inhabitants use an average of 119 litres of water daily. An average 565,000 m^3 of drinking water is daily supplied to domestic and industrial/commercial sectors via 7800 km of drinking water mains and water supply pipes beneath Berlin's roads (BWB, 2000). Table 2.5 shows water use development in Berlin in the period of 1986-2000.

The drinking water promotion historically grew almost within the Berlin city boundaries. Berlin is thereby one of the few European capitals, whose water supply comes nearly completely from the groundwater and bank filtration supplies inside the city area. Within the city area, the rivers and lakes are intensively used for different purposes, e.g. recreation, fishing, waterways and, most important, for the drinking water extraction via lake bank filtration. The water extracted from the wells is of drinking water quality and needs no further treatment except aeration before it is distributed to the city water supply. This is caused by the clogging of the sediments which results in good filter quality and long travel times to the generally deep-seated production wells. Since 1991, the drinking water has been exclusively supplied by groundwater bank filtration through over 700 wells between 30 m and 70 m depth (KNAPPE, 2005).

In general, in Berlin groundwater replenishments are 56% of bank filtrate, 30% of natural water discharge and 14% of groundwater replenishment. Bank filtration in Berlin has long tradition (since 1850s) and today 75 % (220 million m^3 per year) of drinking water originates from bank filtration (FRITZ, 2003).

Table 2.5: Water use development in Berlin in the period of 1986-2000

Year	Berlin (mill.m^3/year)	East Berlin (mill.m^3/year)	West Berlin (mill.m^3/year)	Year	Berlin (mill.m^3/year)	East Berlin (mill.m^3/year)	West Berlin (mill.m^3/year)
1986	353	169	184	1993	261	98	160
1987	346	172	174	1994	261	99	162
1988	356	174	182	1995	250	94	156
1989	366	178	188	1996	240	91	149
1990	331	148	183	1997	239	89	150
1991	298	118	180	1998	226	85	141
1992	287	105	182	1999	224		
				2000	222		

(Source: BWB, 2001)

2.4.2 The development of waste water collection system

2.4.2.1 Waste water problem of Berlin in the middle of the 19th century

In the early 19th century in Berlin the household waste water primarily shifted in the yard pits. It was only rarely used for agricultural purpose and was mainly directly disposed into the water courses (the Spree) by „night chair buckets - Nachtstuhl-Eimer " or by „night bucket women" –Nachteimer Frauen every evening after 11 PM. The remaining domestic waste water and the rain water discharged over gutter system (Rinnstein) into the nearest public receiving streams. The gutters were open ditches between the sidewalks and the roadway with sole and walls which usually consisted of irregular small round stones. Normally, these gutters had a dimension of 0.5 m width and 0.6 m in depth. They developed parallel to the development of the roads and were not subject to systematic planning. Starting from 1842 the pit emptying into public waters was forbidden, the night buckets should be disposed now exclusively into the domestic seeping pits. The pit emptying represented particularly during the warm season an intolerable smelling nuisance (Figure 2.16) (BÄRTHEL, 2003; MOHAJERI, 2005).

As a result of the rapid expansion of the city surface and the growth rate of the Berlin population, the human excrement could not be taken by the agricultural farms and market gardens any longer. Therefore, the excrements were disposed illegally at vacant places at the edge of the city. The normal domestic waste water was derived by wooden gutters into the road gutters. These wooden gutters mostly lay in the gate passages of the houses and were covered with boards and flowed at the road-lateral edge of the sidewalk into the gutters. Apart from the derivative of domestic and partially also small commercial waste water, the gutter also served the disposal of the rain water. During storm events, waste materials of all kinds were washed into the gutters (including horse dung, market wastes, leaves as well as sand and stone) (BÄRTHEL, 2003; SENSTADTUM, 2004; MOHAJERI, 2005).

Figure 2.16: Backyard with toilet and pump from near surface groundwater in a Berlin's house, 1850ies
(Source: MUSEUM IM WASSERWERK BERLIN, 1996)

Due to the solid compounds as well as the small downward gradient of the gutter, inundation situation occurred and, on the other hand, on hot days this system posed an intolerable smell. In order to be able to ensure the discharge of the waste water, the gutter had to be built more deeply and more broadly (up to 1m deep), however, this improvement limited the usable surface of the roads, impaired the traffic and endangered pedestrians. With the bad smells ascending from the gutter the obvious acceptance was connected that these could be harmful for the public health.

Starting from 1856, the water company at the Stralauer Tor promoted water from the river Spree. From the 1860ies water closets were increasingly installed, whose waste water was led frequently into the gutters already overloaded. Obviously, the gutter system just move the pollution source to another place – purring into the inner city waters, again causing serious problems. Another reason for this situation is the very small flow velocity of the rivers, particularly in the summer months. The introduction of large quantities of waste water in the inner city Spree damaged the city appearance, imposed an intolerable nuisance, and threaded the public health. Therefore Berlin city started to implement a modern sewage disposal systems already established in other cities (BÄRTHEL, 2003; MOHAJERI, 2005).

2.4.2.2 The Hobrecht plan

The first plan for the improvement of the hygienic conditions was the CRELLE's Plan (1842), which arranged Berlin into eleven drainage zones. Each zone had an introduction point and waste water purred directly into the Spree within the inner city area (Figure 2.17). After the WIEBE design in 1861 Berlin had only one drainage zone with a single introduction point, where waste water purred into the Spree outside of the city (Figure 2.18). But this plan was rejected by the city council. A delegation studied waste water treatment systems in Hamburg, Paris and London (Table 2.6). In 1867, a new delegation was formed, led by Rudolf Virchow for investigation on relative problems to drains and waste water removal. One year later (1868), Hobrecht's general report on a new sewer system was delivered to the city council, it was officially accepted in 1873 (Figure 2.19). The Hobrecht's plan was the trigger for the complete change of hygienic and water-economical conditions in Berlin. It arranged Berlin into twelve drainage zones without any introduction into the river Spree except emergency discharge in consequence of heavy rain. The implementation of the Hobrecht's plan was realized by the installation of the combined sewerage system and construction pressure pipes from the center to the sewage farms in the vicinity of Berlin (Osdorf).

Table 2.6: Sewer construction in German cities

City	Construction year	Population in 1900
Hamburg	1842	650,000
Franfurt	1867	285,000
Berlin (old)	1873	1,750,000
Breslau	1877	425,000
München	1881	500,000

(Source: SEEGER, 1999)

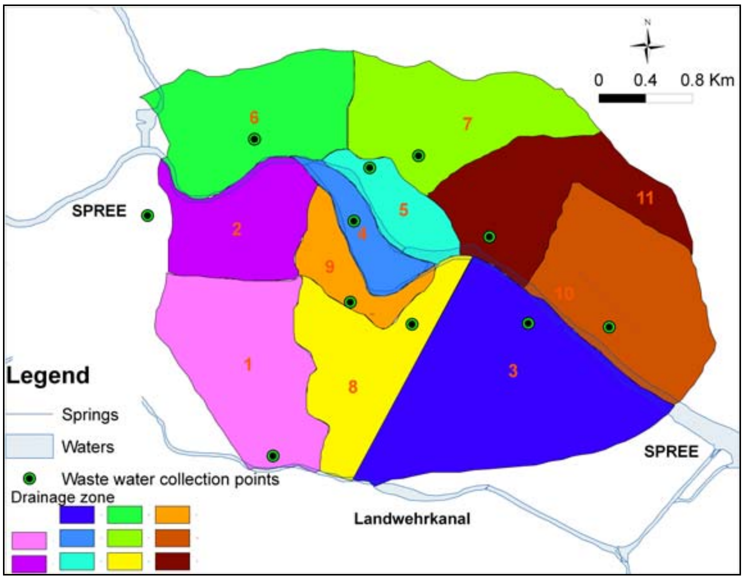

Figure 2.17: The CRELLE Plan for Berlin drainage system in 1842 with 11 drainage zones and 11 introduction points within the inner city *(Source: BÄRTHEL, 2003)*

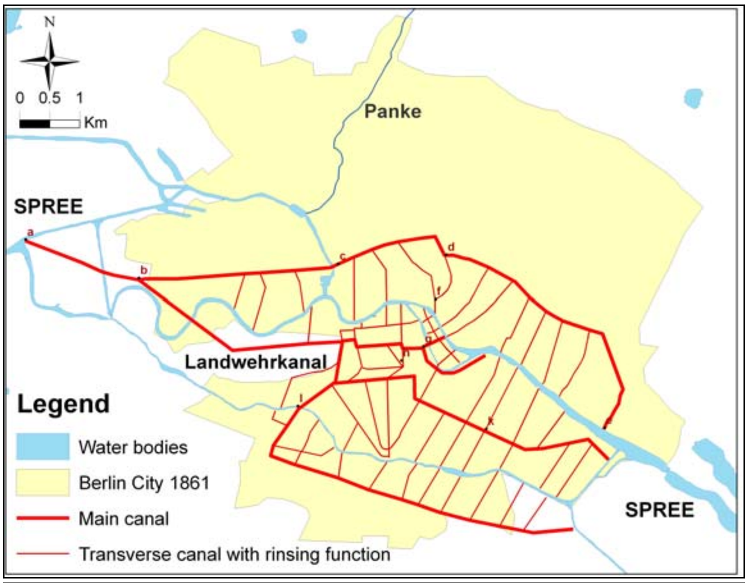

Figure 2.18: The WIEBE Plan for Berlin drainage system in 1861 with only one drainage zone and a single introduction point into the Spree out side the city *(Source: BÄRTHEL, 2003)*

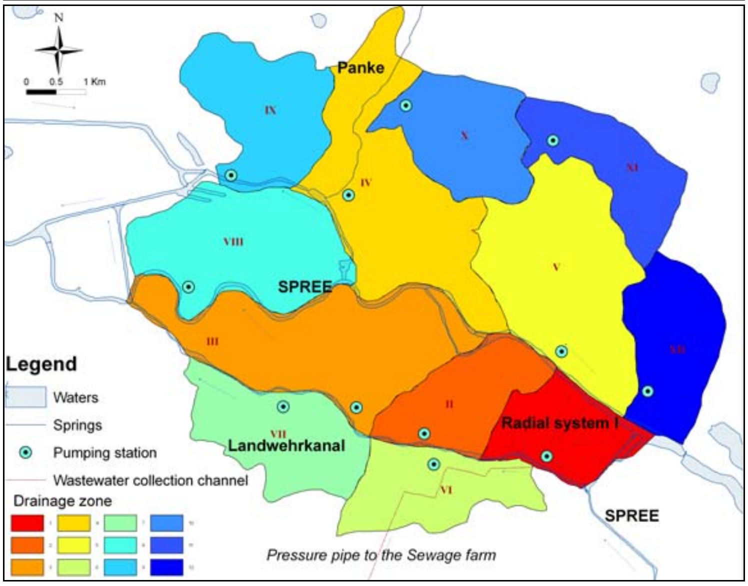

Figure 2.19: The HOBRECHT Plan for Berlin waste water collection and treatment in 1871 with 12 drainage zones (radial systems), pressure pipes and the sewage farms without any introduction into the Spree *(Source: BÄRTHEL, 2003)*

2.4.2.3 The drainage system of Berlin

In 1873 Berlin's combined sewer canal system was built after a design by James Hobrecht. In the beginning of the 20th century this system capacity and efficiency was no longer appropriate for the new urban areas. Since then the new urban areas of Greater Berlin were sewered by the separate sewage system (Appendix 11.3). Drainage areas are oriented towards river courses and shipping canals and they also follow different altitudes (SENSTADTUM, 2004).

Aprroximately three quarters of the sewerage-equiped city area of Berlin is drained by separate sewers. The remaining quarter of the inner city area and a part of surrounding cities has combined sewers. The inner city districts of Wedding, Tiergarten, Mitte, Prenzlauer Berg, Friedrichshain, Kreuzberg, Schoeneberg, parts of Neukölln, and of Wilmersdorf, Westend as well as the Spandauer Altstadt are serviced by the combined sewer system (Figures 2.20-2.24, Table 2.9, 2.10).

The outlying districts of Reinickendorf, Pankow, Weissensee, Hohenschönhausen, Marzahn, Hellersdorf, Lichtenberg, Köpenick, Neukölln, Tempelhof, Steglitz, Zehlendorf, Spandau as well as parts of Wilmersdorf and Charlottenburg are connected to the separate sewer system (BWB, 1999).

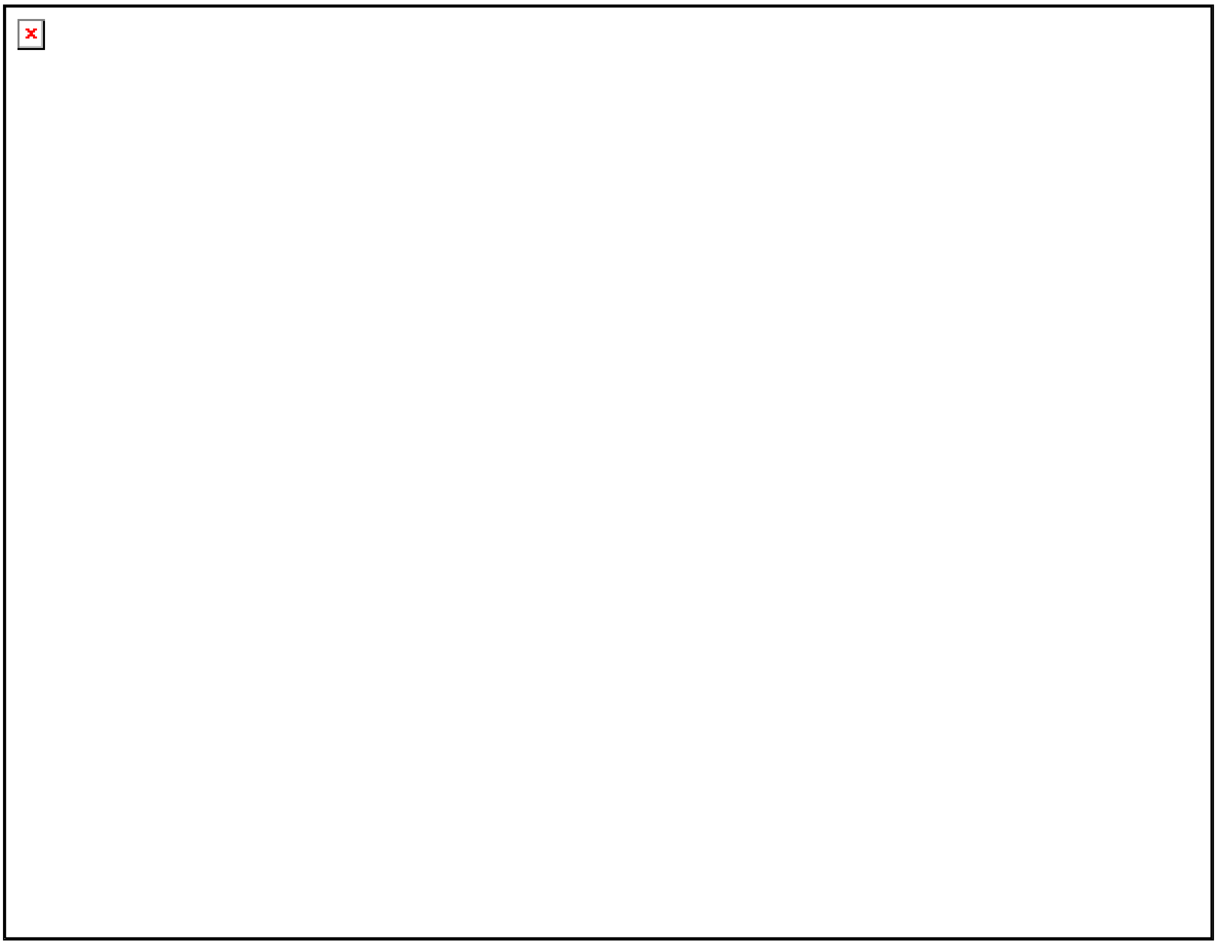

Figure 2.20: Waste water collection and treatment system of Berlin *(BWB, 1999)*

In the fist half of the 20th century, predominantly in the suburban area of Greater Berlin houseblocks were connected to the sewer system. In the period of 1925-1938, the number of houseblock connected to sewer system in the inner city area only increased 4.7 %, while in the extension areas of Greater Berlin this number increased up to 80% (Figure 2.23) (BERLIN IN ZAHLEN, 1925-1940).

In 1920, Berlin sewer system was 2978 km of length, including 305 km of pipeline, 70 pumping stations and 18 sewage farms with an area of 9497 ha. Through this system, 40397 houseblocks with 1.85 million inhabitants were serviced. The sewered area of Old Berlin totaled 6040 ha in 1920 and occupied 91.8% of the inner city area (MOHAJERI, 2005). In 1926, the population connected to the combined sewer and separate sewer system of Greater Berlin totaled 3,924,000 (STASTISHES JAHRBUCH BERLIN, 1928). 63 % of the total area in the combined sewer services attached to drainage system, and only 16% of the total area in the separate sewer services connected to the rain water and waste water sewer systems (HAHN, 1928) (Table 2.10).

The sewer net rose from 1414 km in 1950 to 5169 km in 1990, at the same time the connected houseblocks increased from 66,820 to 133,000. In 1990, 65,150 inhabitants in East Berlin (5% population) lacked connection to sewer system, especially in the quarters Weißensee, Hellersdorf and Köpenick (BÄRTHEL, 2003). In 2000, about 96 % of the population in the eastern and 99 % of the people in the western parts of Berlin were connected to the sewerage network (SENSTADTUM, 2004; FRANZKE, 2004). In 2001, Berlin has 531 storm overflows, nine storm overflow basins and one reservoir channel. The overflow frequency depends on the events of heavy rain days and the retention capacity of the individual pumping catchment areas, it varies between 1 and > 30 times a year.

At present, the sewerage network is operated by the Berliner Wasserbetriebe (Berlin Water Works). The sewerage totals 4,100 km of waste water drains, 1,894 km of combined water drains, 3,166 km of rain water drains and 68 km of special drains. Through 145 pumping plants and a more than 1,120 km long waste water pressure pipe net, waste water will be pumped to six WWTPs for treatment (BWB, 2006). In 2005, 227 millions m^3 of waste water from Berlin and the surrounding countryside (from private households, trade, industry, public institutions as well as rain water) were treated (in compare to 251 millions m^3 in 2003) (BWB, 2006; SENSTADTUM, 2004).

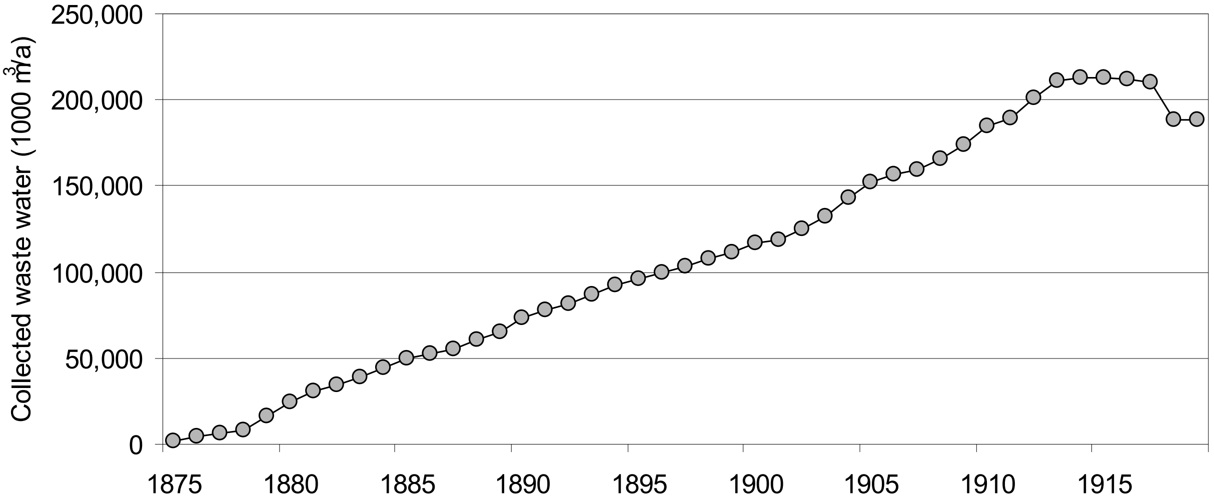

Figure 2.21: Collected waste water of Greater Berlin in the period of 1875-1920

(Source: STASTISHES JAHRBUCH BERLIN, 1873-1921)

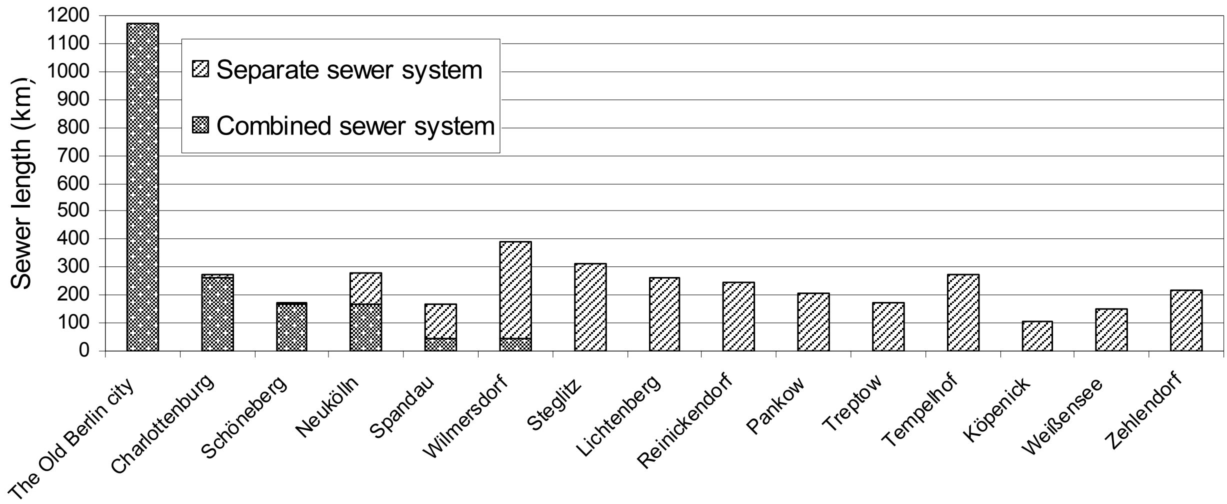

Figure 2.22: The waste water collection system of Greater Berlin in 1927
(Source: HAHN, 1928)

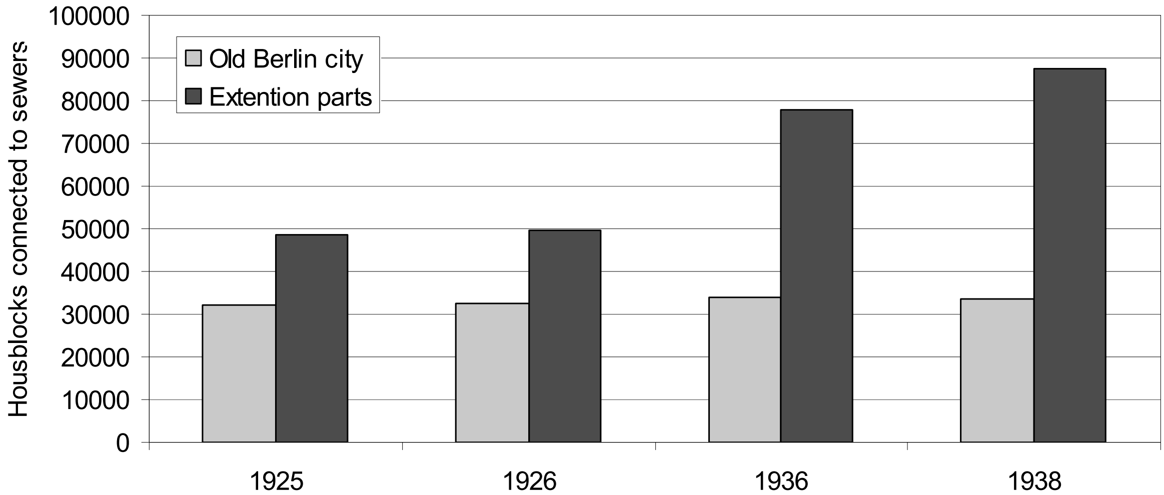

Figure 2.23: Development of connected houseblocks to the sewer system of Greater Berlin, 1925-1938
(Source: BERLIN IN ZAHLEN, 1925-1940)

The combined sewer system

The combined sewer system is mostly located in the old quarter of Berlin and satellite cities: completely in Neukölln, Schönerberg, Borisgwalde, Friedenau, Spandau-Citadel and partly in Charlottenburg, Spandau, Wilmersdorf, Lichtenberg-Friedrichshain (Figure 2.19, Appendix 11.1).

In this system, drainage and waste water from households, commercial and industrial centers, plots of land and the road system are collected by one sewer (Figure 2.25). The waste water flows by utilising a gradient system to the pumping stations. Waste water is first collected in sedimentation basins made of concrete or earth. Water flows through the tank while most sediment settles to the bottom. Immersion panels hold back floating matter (Figure 2.24) (ANONYMOUS, 1896; BÄRTHEL, 2003). Sediments settling in the sedimentation basin are regularly evacuated and dewatered at special sludge drying areas. Dewatered sludge was used as a soil conditioner for agriculture and horticulture in early years. The combined sewer system underlies approximately 100 km^2 of the built-up city area with a total length of 1.900 km (BROOKS, 1905).

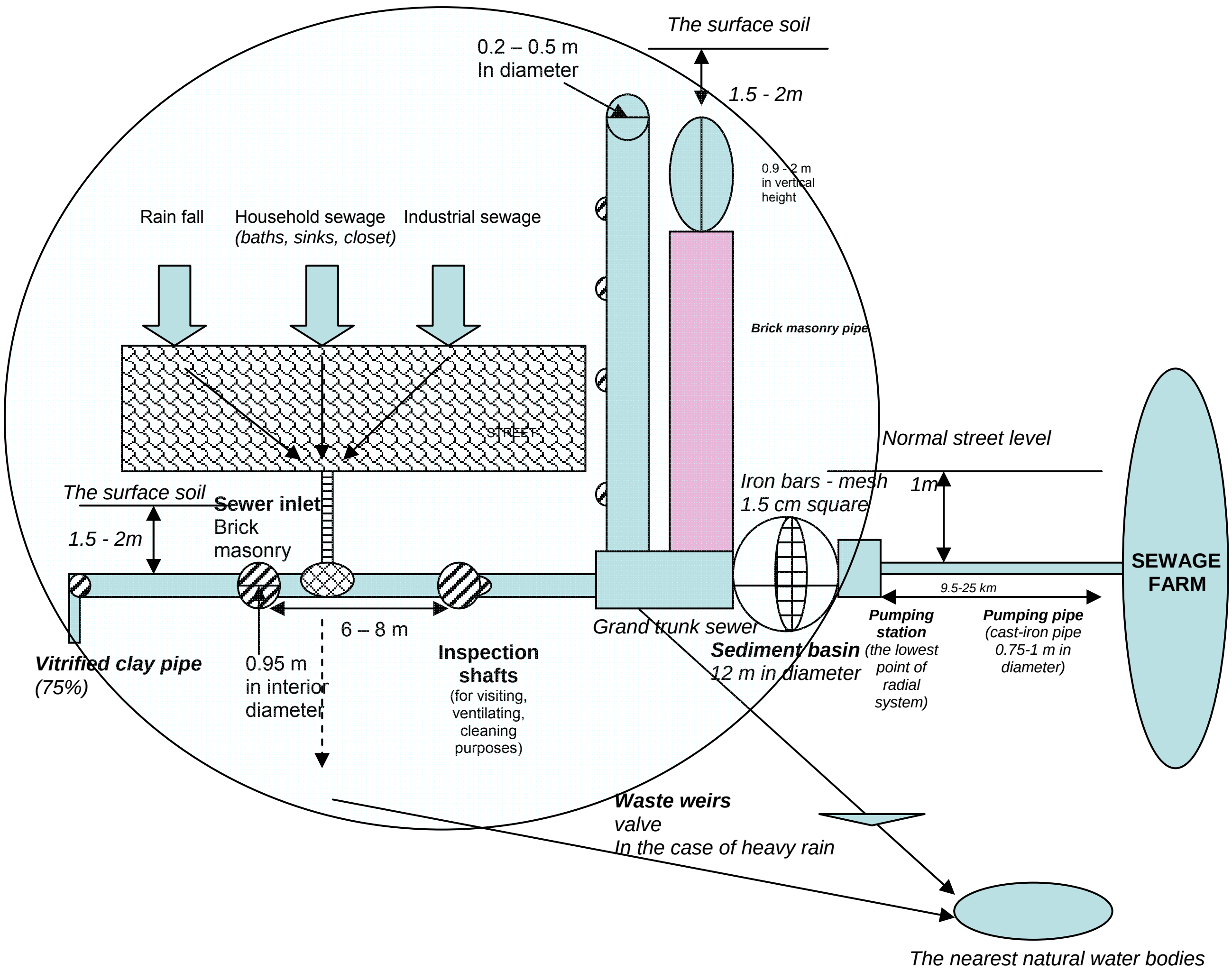

Figure 2.24: Drainage system in one radial system in the Old Berlin city
(Source: ANONYMOUS, 1896)

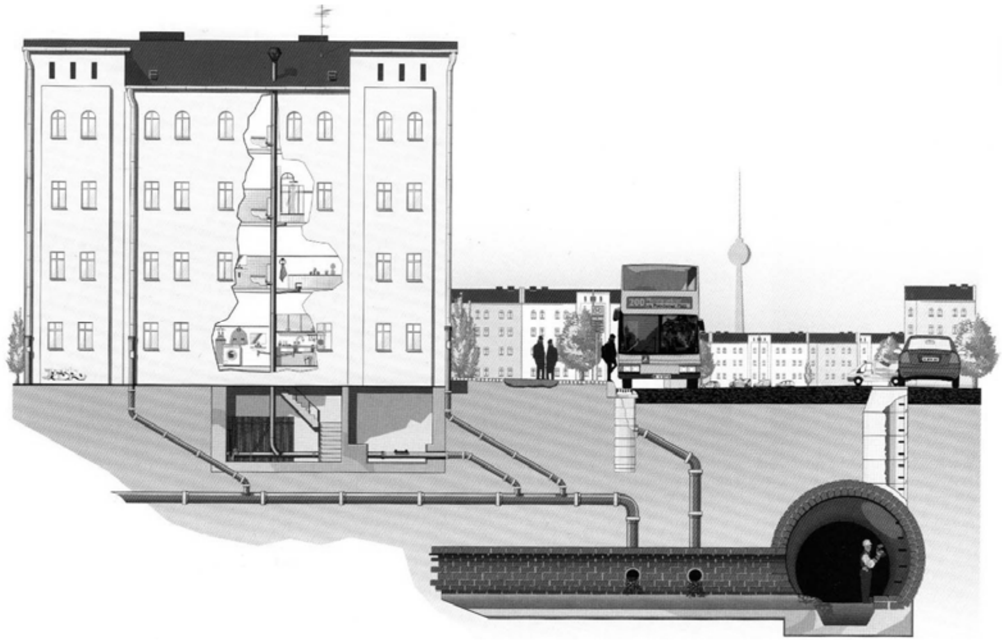

Figure 2.25: The combined sewer system in Berlin *(BWB, 2000)*

The capacity of the combined sewer system is limited to 2 or 3 times of dry weather discharge. Therefore, in case of heavier rainfalls, the capacity of the system was over loaded and the exceeding water is discharged into storm overflow basin or surface water bodies. To reduce the load by combined sewers, in some areas of the north of the city motorway, rain water sewers were built which discharge into the rain overflow drains of the combined sewerage system. Sewage continues to pass through these combined sewers. From 1956, together with the decision on the construction of 2 new purification plants, rainwater basins also have been constructed in West Berlin. In this rainwater basin (around 1500 m^3 in volume and nearby 7 important pumping plants), rain water is restrained and after rain event it will be re-introduced into pump plants. When the rain volume is over capacity of rainwater basins, these basins serve as sediment tank (BÄRTHEL, 2003; SENSTADTUM, 2004).

Most pumping stations are equipped with emergency discharges. In situations of technological malfunction, combined sewage is discharged into outlet ditches. 74 emergency discharges can be counted, 35 of them discharge into the river Spree, 13 into the river Havel, and 18 into the Teltowkanal. 5 discharge into standing surface water bodies and the remaining three emergency discharges take waters via waste water drains to other pumping stations. Emergency discharge operations also heavily fluctuate over the years. The average annual quantity involved totales 20,000 m³. Retention basins were built in the immediate vicinity of large pumping stations and at the most important sites of the combined sewer system. They cope with excess quantities of combined sewage during brief periods of high-intensity rainfalls. Sludge and suspended solid particles will be deposited in these retention basins (SENSTADTUM, 2004).

The separate sewer system

The separate sewerage system is predominatly installed in the new development areas of Greater Berlin (Figure 2.19, Appendices 11.1, 11.3). In a system of separated drains waste water and rain water are collected. The main sewers discharge domestic, trade and industrial waste water to the pumping stations and then pumped to the sewage farms and WWTPs via pressurised pipes (Figure 2.26).

Rain water sewers collect precipitation from paved/impervious surfaces (streets, rooftops, yards). They also collect cooling water from the power plants as well as water from drainage ditches and then directly discharge into the nearest surface waters. At the begining, the separate sewers were an advantage. Due to the increase of deposition, traffic etc. the rain water was more and more polluted, contributing to an increasing pollution of the river system. Waste water in this system is heavy contaminated by dust, air pollutants, rubbed-off road surface and tire particles, leaked oil, leaves, animal faeces, road grit in winter. To clean these quantities, rain water basins and retention soil filters operate at the main discharge points (SENSTADTUM, 2004; FRANZKE, 2005).

The cooling water use

The cooling water withdrawals of 14 thermoelectric power plants and other industries in Berlin are larger than the inflow water volume from the Upper Havel, the Spree and the Dahme (GROSCH, 2000). On average, water coming from these plants will be warmed up around 3^{o}C. In the period of 1977 – 1989, the cooling water withdrawal of seven thermoelectric power plants in the West Berlin totaled around 1,122 million m^3 each year and the Teltowkanal received 47% of this (SENSTADTUM, 1988). In 1992 for example, the Teltowkanal received 435 million m^3 heated water or 36.4% of the total cooling waters of the city (SENSTADTUM, 1992).

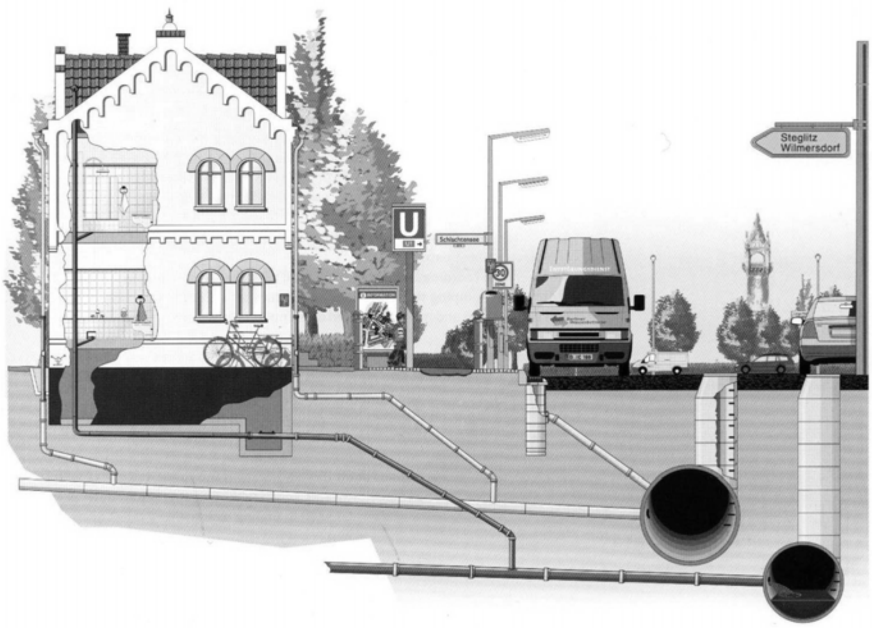

Figure 2.26: The separate sewer system in Berlin *(BWB, 2000)*

2.4.3 The development of waste water treatment system

2.4.3.1 The sewage farms

In the period of 1876-1985, sewage effluents in Berlin's urban area were conducted from the pumping stations through pressure pipelines to sewage farms located outside the city (Figure 2.27). Some sewage farms were additionally supplied by direct pipelines. After sewage water has passed through the sedimentation basin, e.g. has been mechanically cleaned, it flows through gravity feeders to the terraces. The sewage farm trench system was also regularly cleaned, whereby removed sediments are usually deposited directly alongside the trench.

The basic construction of a sewage field was the following: Terraces were constructed horizontally or sloping, depending on the surface. They were about 0.25 ha in size, and surrounded by embankments. There occured three methods of sewage farm treatment: 1. Horizontal terraces are flooded by surrounding distribution ditches, 2. Slope terraces, sewage water overflows the upper bank and irrigates the sloped terrace and 3. Bed terraces with ditch irrigation were also initially used. Waste water flowed through bed terraces in connected parallel furrows, about one meter apart (Figure 2.28) (SENSTADTUM, 2001).

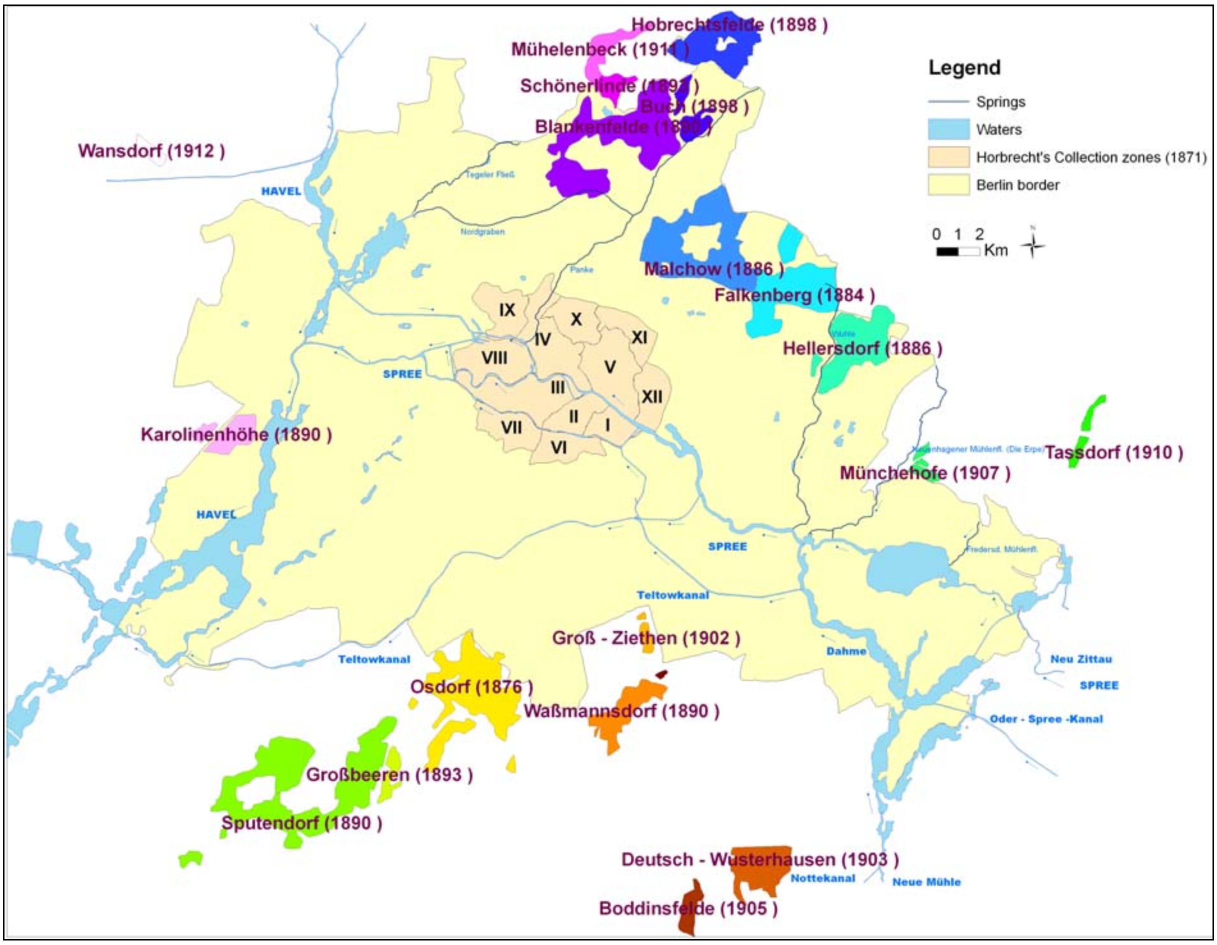

Figure 2.27: Location of Berlin sewage farms – the first waste water treatment facilities implemented in the late 19th century
(Source: SENSTADTUM, 2001; BÄRTHEL, 2003)

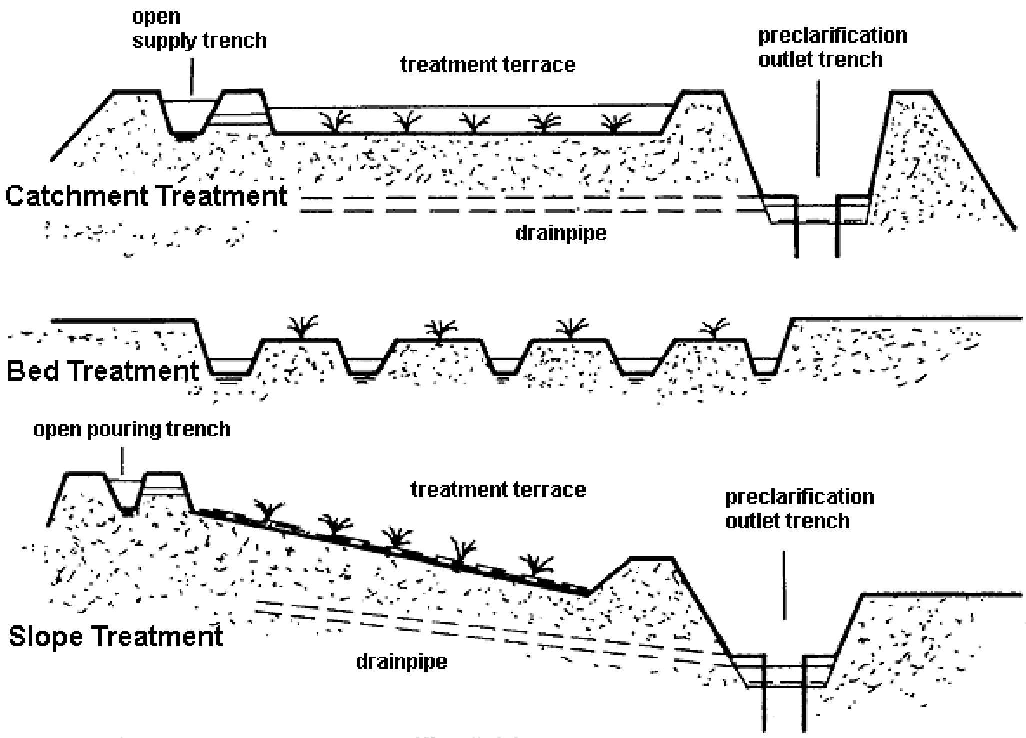

Figure 2.28: Schematic illustration of types of sewage farms
(according to ERHARDT et al. 1991)

Wild sewage areas were found near treatment terraces. The prepared surfaces were overloaded by directly diverting unpurified water through sluices onto natural land. Sewage water contents were retained during the passage through the soil, adsorbed in topsoil without humus, and treated chemically and biologically. This process supplied agriculturally useful nutrients. Initial yields were high and the majority of fields were used agriculturally and served their own sewage treatment plots. There was a mixed use of grasslands and field cultivation. Most sewage farms were provided during construction with drainage pipelines at regular intervals for a faster discharge of filtered and purified water, and to provide aeration and regeneration of soils as well. Drainage water passed through collecting drains and dewatering trenches into the preclarification outlet trenches. Some water from soil passage percolated into the groundwater (SENSTADTUM, 1992).

Fields were flooded in normal operation, and then left until water seeps away and the soil is re-aerated. The next flooding begins only after re-aeration is completed. These sewage farm rhythms were also oriented to the growth periods of agricultural crops. Four to eight field treatment cycles a year are possible on grasslands, with 2,000-4,000 mm of sewage water.

Sewage farms were overtaxed with increasing amounts of waste water, intensification of agricultural production and the closure of other sewage farms. This stimulated some sewage farm operators to establish "intensive filter areas". These are permanently flooded and surrounded by high embankments. An inadequate degree of purification is performed here because aerobic processes cannot take place. These areas were not used agriculturally.

Sewage farm structures were often leveled after sewage treatment use was discontinued. Trenches and terraces were filled with material from the embankments, themselves land-fill material (SENSTADTUM, 1992).

Sewage farms were the earliest technological facilities for waste water treatment in Berlin. In the first year of operation (1876), in Berlin an area of 1,154 ha with 1.2 million m³ waste water treatment capacity were used as sewage farm land (Figure 2.29) (HEYMANN, 1916; NASCH, 1916; RUTHS, 1928; BÄRTHEL, 2003). At the beginning of the 20th century already 12,723 ha in the vicinity of Berlin were used as sewage farm land holding a waste water treatment capacity of 83 million m^3. In the 1920ies around 17,000 ha sewage farm land with a waste water treatment capacity of 200 million m^3 existed.

At the sewage farms, agricultural yields were high at the start of operation, but dropped considerably after a while (SENSTADTUM, 1992). This fact was mainly due to soil surface sealing by the infiltrating sewage sludge and impaired soil ventilation (SENSTADTUM, 1992, 2001). Some improvement measures have been applied in order to maintain the yield capability of soil like soil aeration with regular soil processing and spreading lime and dung. But when these measures were not successful, the amount of sewage water treated per ha was reduced continuously (SENSTADTUM, 1992).

Daily waste water accumulation of Berlin in the year 1919 was 104,496 m^3 and increased up to 237,000 m^3 per day in the year 1933 (SENSTADTUM, 2001). In the first half of the 20th century the area of sewage farm was not increased with the increasing in waste water production of the city. Consequently, sewage farms could not handle the increasing demands on quality and quantity of waste water treatment. Due to low effectiveness and environmental concerns, almost all sewage farms in Berlin were closed in the late 1980ies (SENSTADTUM, 2001).

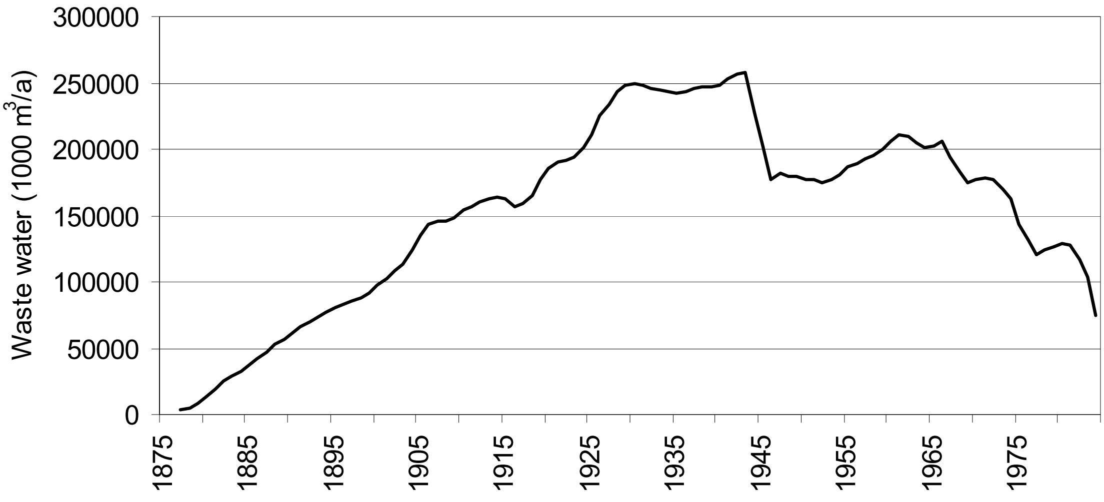

Figure 2.29: Waste water treatment capacity of Berlin sewage farms 1876 – 1985

2.4.3.2 Waste water treatment plants

In consequence of the overloading and in-effectiveness of the sewage farm system, a new waste water treatment system was applied in Berlin to scope with the expansion of the metropolis. In 1927 the first WWTP was built in Waßmannsdorf and four years later in Stahnsdorf a biological treatment plant was put into operation – a symbol of the advanced waste water treatment technology of that time (BÄRTHEL, 2003). From the third WWTP construction in 1963 to the middle of the 1970ies, Berlin has already six WWTPs with biological treatment technology: Waßmannsdorf, Stanhnsdorf, Ruhleben, Falkenberg, Marienfelder and Münchehofe. In 1985, all waste water treatment plants changed to phosphorus elimination technology and a new WWTP was constructed in Schönerlinde (Figures 2.20, 2.30) (SENSTADTUM, 2001; BÄRTHEL, 2003). In general, early improving of the treatment technology in waste water treatment plants of Berlin focus on BOD, COD elimination and then focus on phosphorous elimination and nitrogen removal recently, follow the elimination rates required by the Federal and State's regulations (Table 2.7) (BWB, 2006).

Berlin WWTPs discharged a yearly total of 240 million m^3 (7.6 m^3/s) of purified waste water into the surface water system, representing an important contribution to the runoff. This high contribution has a considerable impact on the quality of the surface water, especially when the inflow water volume was reduced recently. The WWTPs are equipped with biological cleaning stages including nitrogen elimination. The waste water goes through the mechanical cleaning with detritus chambers and sediment basins, thereafter a biological cleaning, whose basins are equipped for the biological phosphorus and nitrogen removal with anaerobic and aerobic zones. The purified waste water is derived in surface waters. The sludge treatment takes place either via mud burn with waste-heat utilization and flue gas purification or via anaerobic sludge fouling with fermentation gas utilization and further utilization of the dried mud (BWB, 2006).

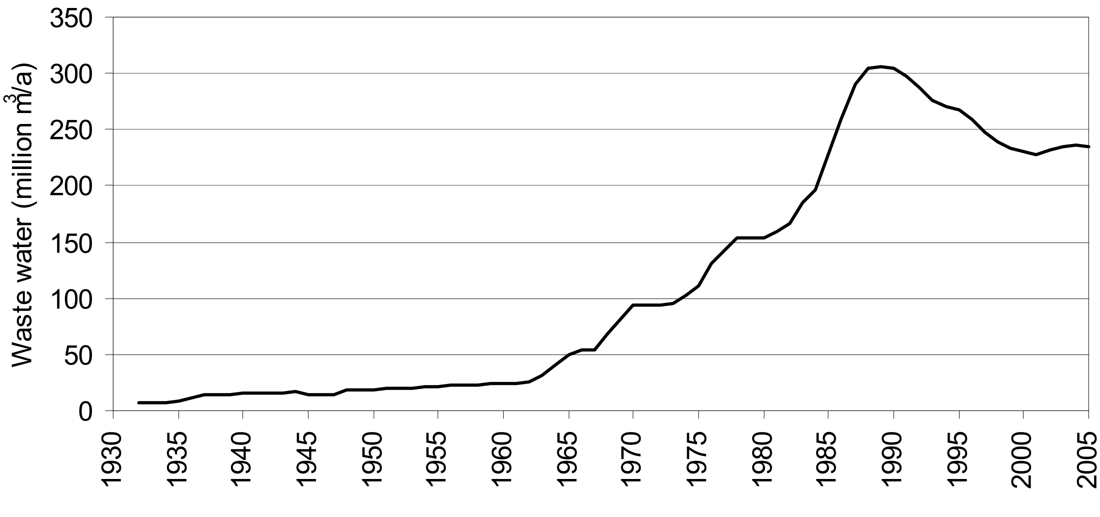

Figure 2.30: Treatment capacity development of the Berlin's WWTPs

Table 2.7: Nitrogen removal performance for various types of treatment plants
(BEHRENDT et al., 2000)

Plant type	N removal (%)		
	1985/East Germany	1985/West Germany	1995/Whole Germany
Wastewater pond (unaerated)	50	50	50
Wastewater pond (aerated)	30	30	30
Activated sludge plant	30	30	30
Activated sludge plant (partly biological)	20	-	-
Activated sludge plant (fully biological)	30	-	-
Mechanical treatment	10	10	10
Submerged trickling filter/percolating filter plant	25	25	25
Treatment using plants	45	45	45
Treatment on wastewater farms	80	-	-
Nitrification	-	45	45
Denitrification	-	75	75

In the sewage treatment plants the sewage sludge is treated or is utilised thermally. The treated waste water is fed through the treatment plant dischargers (ditches, channels or specific penstocks etc.) to the receiving waters and then into the Berlin water bodies (lakes, canals, rivers etc.).

During the winter months the treatment plant at Ruhleben discharged directly into the river Spree, while since 1985 its effluent is redirected into the Teltowkanal in summer time, avoiding the overload situation of nutrient inputs into the lake Unter Havel. The outflow drains of Falkenberg and Münchehofe treatment plants discharge into the rivers Wuhle and Erpe, which eventually flow into the river Spree. The treatment plant at Schönerlinde discharges the treated water through the ditch Commerce and Industry centre Nordgraben into the lake Tegelersee, as well as to a smaller degree into the river Panke, which eventually empties out into the Spree (Figure 2.20) (SENSTADTUM, 2001).

2.5 The development of legal, policies and standards on waste water collection and treatment of Berlin in the last 150 years

Water protection in Germany in the first development phase applied primarily to the reduction of carbon (COD, BOD) to safeguard the dissolved oxygen content in rivers. Later, the focus was on additionally the reduction of nutrients (nitrogen and phosphorus), most importantly for the protection of lakes and seacoasts. The most important step was first of all the reduction of phosphate emissions through the legally required use of phosphate-free washing agents and through the degradation of nutrients in larger WWTP's. The residual pollution today comes essentially from so-called nonpoint sources, such as fertilizer from agriculture, rainwater avulsions, and cross-boundary air pollution. Therefore, pollutant-group oriented action concepts are required which include a coordinated package of various instruments and technological measures (STAFFEL-SCHIERHOFF, 2001).

The overlying framework is anchored in the European Union legislation, including especially the following:

- Directive 2000/60/EC Water Framework Directive (http://europa.eu.int/eur-lex)

- Directive 91/271/EEC, concerning the handling of municipal wastewater

- Directive 96/61/EC, concerning the integrated pollution (IPPC Directive)

- Groundwater Directive (80/86/EEC)

- Drinking Water Directive (98/83/EC)

- Nitrate Directive (Directive 91/676/EEC)

- Pesticide Directive (91/414/EEC)

- Water Protection Directive, concerning the emission of hazardous substances into water bodies (76/464/EEC)

- Bathing Water Bodies Directive (76/160/EEC).

The Water Framework Directive (WFD) which came into force on 22 December 2000 is the most substantial piece of EC water legislation. It requires all inland and coastal waters to reach "good status" by 2015. The basic thinking behind “good status” is that waters may be impaired or changed by human use, but only insofar as the ecological functions of the water are not significantly impaired. As an EU member nation, Germany has to fulfill the requirements of the WFD. The Water Framework Directive was formally implemented into German law by the end of 2003.

At the federal level, the most important regulations within this framework are:

- The Water Management Act

- The Drinking Water Ordinance
- The Groundwater Ordinance
- The Wastewater Ordinance
- The Effluent charge Act
- The Act on the Impact Assessment of Washing and Cleaning Agents
- The Fertilizer Agents Ordinance.

Federal Law Federal Water Act. The Act on the Regulation of Matters Relating to Water of 1957 (Federal Water Act (WHG), last amended in 2001) acting as a framework law of the Federal Government and lays down basic provisions relating to water resources management measures (management of water quantity and quality). It requires that waters are to be safeguarded as a component of the natural balance and as a habitat for fauna and flora. Under the Federal Water Act, waters are to be managed such that they serve the public well-being and that avoidable impairments of their ecological functions are to be avoided (precautionary principle).

Waste water Charges Act. The Waste water Charges Act of 1976 (last amended in 1994) provides that a charge shall be payable when waste water is discharged directly into a body of water. The charge is the first eco-tax levied at the federal level as a steering instrument. It ensures that the polluter-pays principle is applied in practice, since it requires direct discharges to bear at least some of the costs that their use of the environmental medium water involves. The charge is determined on the basis of the quantity and harmfulness of specific constituents discharged into the water. The charge is intended to create an economic incentive to reduce wastewater discharges as far as possible. They are earmarked for measures preventing water pollution.

Washing and Cleaning Agents Law. The Detergents and Cleaners Act of 1975 (last amended in 1986, 1995) lays down requirements for the environmental compatibility of detergents and cleaners. The use of substances harmful to water may be prohibited or restricted. Under this law the producers of detergents and cleaners are bound to notify the Federal Environmental Agency of the formulations of their products. Moreover, consumer information must be provided on the pack about the most important constituents and the proper dosage. The Surfactants Ordinance stipulates that at least 90% of the surfactants contained in the product must be biodegradable (BMU, 2001). In 1995 the criteria for a European environmental symbol for washing agents, drawn up under German leadership, were approved.

Use of Fertilisers Ordinance. The Ordinance on principles of good professional practice in the use of fertilisers (Use of Fertilisers Ordinance) of 26.01.1996 was enacted on the basis of the Fertilisers Act DMG). This is intended to bring about better protection of waters against (diffuse) pollution, especially nitrate, from agricultural sources. The Use of Fertilisers Ordinance also serves to implement the EC Nitrate Directive. According to Section 1a of the Fertilisers Act, fertilisers may only be used in accordance with good professional practice. This means, among other things, that the use of fertilisers in terms of nature, quantity and timing must be geared to the needs of the plants and the soil having regard to the nutrients and organic substances available in the soil and the local and growing conditions (BMU, 2001).