4. Database development

4.1 Spatial input data

The following data were made available as geo-referenced datasets in ArcGIS:

Berlin city

- Surface water bodies (Figure 2.3),
- Administrative boundaries (Figure 2.9),
- Surface water monitoring stations and water level gauges (Figure 4.1),
- Waste water collection system (Figure 2.20).
- Sewage farm system (Figure 2.27),
- Waste water treatment plants and outflow locations (Figure 2.20),

The Havel catchment and its sub-catchments (Upper Havel, Spree and Dahme)

- River network map (Figure 2.4)
- Hydrogeological and geology maps (Figures 2.1, 4.3)
- Elevation map
- Population density map (Figure 2.5)
- Sewer connection degree maps (Figure 4.4)
- Map on waste water treatment plants (location, year of establishment, capacity and technology) (Figure 4.5)
- Land use map.
- Administrative boundaries (present and in GDR time) (Figure 2.5, 4.4)

Additional maps in raster format (TIF) were geo-referenced:

- Berlin historical map (in 1738, 1760, 1789, 1836, 1869, 1875, 1890, 1893, 1894, 1895, 1897, 1906, 1921, 1926, 1928, 1952, 1966, 1987, 2003) (Figure 2.10).
- Berlin Environmental Atlas Maps on Soil, Water (surface and underground water), Air, Climate, Biotopes, Land use, Traffic/Noise, Energy
- Berlin Geological Map (1:100.000)
- Bodenübersichtskarte des Landes Brandenburg (1:300.000)

4.2 Data for reconstruction of urban development, waster water collection and treatment of Berlin

4.2.1 Data on population and urban development

For the period of 1875-1920, data on the urban development were available only for the Old Berlin city, mainly derived from the Berlin statistical yearbooks and other documents. From these sources information on population, total urban area, impervious area and rate of new house building were collected.

Since 1920, data on the urban development of Greater Berlin were derived from:

- Berlin - the Berlin statistical yearbooks (Statistisches Jahrbuch der Stadt Berlin, 1878-1943; Berlin in Zahlen, 1927-1951),
- West Berlin - statistical yearbooks (Statistisches Jahrbuch - Berlin <West>, 1952-1990),
- East Berlin statistics (Statistisches Jahrbuch der Hauptstadt der Deutschen Demokratischen Republik Berlin, 1961-1983),
- GDR statistical year books (Statistisches Jahrbuch der Deutschen Demokratischen Republik, 1956-1990), and
- Berlin statistics (Statistisches Jahrbuch berlin, 1991-2006).

Population data at the district level of the Havel catchment and its sub-catchments were extracted from the statistical yearbooks of the federal states Mecklenburg-Westpommerania, Brandenburg, Saxony and Lower Saxony (Statistisches Jahrbuch Mecklenburg-Vorpommern, 2007; Historisches Gemeindeverzeichnis des Landes Brandenburg 1875 bis 2005, 2006; Flächenerhebung nach Art der tatsächlichen Nutzung im Land Brandenburg, 2004; Statistisches Jahrbuch des Freistaates Sachsen, 2006; Statistisches Jahrbuch Sachsen Anhalt, 2000)

4.2.2 Data on waste water collection and treatment

Data on the sewer system of Berlin originate from statistical yearbooks of the Old Berlin city for the period of 1875-1920 and Greater Berlin since 1920 and other documents (VIRCHOW, 1873; BROOKS, 1905; HEYMANN, 1916; NASCH, 1916; RUTHS, 1928, NÜTZMANN, 1998; SENSTADTUM, 1999; BEHRENDT, 2000; BÄRTHEL, 2003; MOHAJERI, 2005).

For the Old Berlin city, data are available for design, the length of the sewer system (the combined system), the number of connected houses, the total collected waste water volume per year (Figures 2.21, 2.22, 2.23).

Since 1920, Berlin statistical yearbooks and other reports provide data on the area connected to the combined sewer system and the separate sewer system in the extension parts of Greater Berlin, the connected houses and also the total collected waste water per year (Figure 2.21, 2.23).

Data on the development of sewer and waste water treatment system and their capacities, connected population in the Havel catchment area is extracted from the statistic books, documents from the environmental agencies and digital database of IGB (Figures 4.3, 4.4 and 4.5).

Brown coal mining contributed an important nitrogen load to the river Spree via ground water extract activities. Data on the brown coal mining in Lusatia area for the period of 1936-2005 are available in reports of the Coal-Industry Statistics Association of Germany (STATISTIK DER KOHLENWIRTSCHAFT e.V., 2003) and statistical yearbooks of the GDR (1956-1990).

Data on waste water collection and treatment system are not always available in the term of spatial and temporal resolutions. Therefore, in this study the empirical method was applied for estimating required data from the available information .

4.3 Monitoring data for surface waters

4.3.1 Monitoring data for the water bodies of Berlin

Data on water quality of Berlin's water bodies are surveyed by varying bureaus and institutions since the middle of the 19th century by public contract. The data available vary in temporal resolution and spatial coverage. The different used data sources cover the period 1850-2004.

- For the period of 1966-1987, surface water quality and discharge data are available in “Gewässerkundlicher Jahresbericht des Landes Berlin, Abflußjahr 1966-1987” as mean summer values. The mean annual values of nutrient concentrations in the surface waters of Berlin were estimated from the mean summer values by regression formulas (Table 4.1).
- For the period 1984-2004, surface water quality data and discharge data are available for 29 monitoring stations on a monthly base as part of the Quality Measurement Program by The Berlin Department of Urban Development and Environmental Protection, Department IV.

Table 4.1: Relationship between the mean annual and summer nutrient concentrations in surface water of Berlin, 1984-2003

Station	NH_4-N	NO_2 - N	NO_3 - N	TN	PO_4 - P	TP
145 (n=20) Inner city Spree	y = 0.95x - 0.098 r^2 = 0.98	y = 1.52x - 0.02 r^2 = 0.96	y = 1.14x - 0.40 r^2 = 0.79	y = 1.11x - 0.47 r^2 = 0.95	y = 1.11x - 0.003 r^2 = 0.98	y = 1.25x - 0.012 r^2 = 0.88
160 (n=20) Inner city Spree	y = 0.84x - 0.10 r^2 = 0.92	y = 1.13x - 0.01 r^2 = 0.65	y = 0.51x + 0.52 r^2 = 0.27	y = 0.26x + 1.63 r^2 = 0.22	y = 0.97x + 0.01 r^2 = 0.98	y = 1.32x - 0.024 r^2 = 0.78
305 (n=20) Upper Havel	y = 0.83x - 0.03 r^2 = 0.74	y = 1.14x - 0.004 r^2 = 0.85	y = 0.53x - 0.02 r^2 = 0.35	y = 0.97x - 0.10 r^2= 0.87	y = 0.7x + 0.016 r^2 = 0.55	y = 0.86x + 0.03 r^2= 0.66
320 (n=20) Lower Havel	y = 0.98x - 0.047 r^2 = 0.94	y = 1.40x - 0.01 r^2= 0.91	y = 0.89x - 0.13 r^2= 0.90	y = 0.83x + 0.11 r^2 = 0.94	y = 1.03x - 0.011 r^2 = 0.95	y = 1.18x - 0.014 r^2 = 0.94
335 (n=20) Lower Havel	y = 0.69x - 0.01 r^2 = 0.91	y = 1.17x - 0.011 r^2 = 0.84	y = 0.10x - 0.28 r^2 = 0.68	y = 0.86x + 0.02 r^2 = 0.69	y = 1.08x + 0.01 r^2 = 0.97	y = 1.40x - 0.045 r^2 = 0.92
345 (n=20) Lower Havel	y = 0.60x + 0.02 r^2 = 0.82	y = 1.26x - 0.015 r^2= 0.87	y = 1.14x - 0.50 r^2 = 0.74	y = 0.98x - 0.36 r^2 = 0.92	y = 1.11x +0.002 r^2 = 0.98	y = 1.16x -0.0001 r^2 = 0.85
405 (n=20) Teltowkanal	y = 0.92x + 0.04 r^2 = 0.86	y = 1.29x - 0.033 r^2 = 0.88	y = 1.18x - 0.41 r^2 = 0.98	y = 1.21x - 1.07 r^2 = 0.94	y = 1.06x +0.003 r^2 = 0.96	y = 1.3x - 0.041 r^2 = 0.90
420 (n = 20) Teltowkanal	y = 0.83x - 0.07 r^2= 0.97	y = 1.25x +0.006 r^2= 0.96	y = 1.20x - 0.17 r^2 = 0.82	y = 1.20x - 0.13 r^2 = 0.96	y = 1.06x -0.006 r^2 = 0.98	y = 0.93x + 0.037 r^2 = 0.65
430 (n=20) Teltowkanal	y = 0.77x + 0.07 r^2 = 0.89	y = 1.22x - 0.019 r^2 = 0.93	y = 1.03x + 0.20 r^2 = 0.91	y = 0.82x + 1.32 r^2 = 0.91	y = 0.99x +0.005 r^2 = 0.98	y = 0.36x +0.167 r^2 = 0.37

Notes: *y = mean annual concentration (mg/l),*
x = mean summer concentration (mg/l).

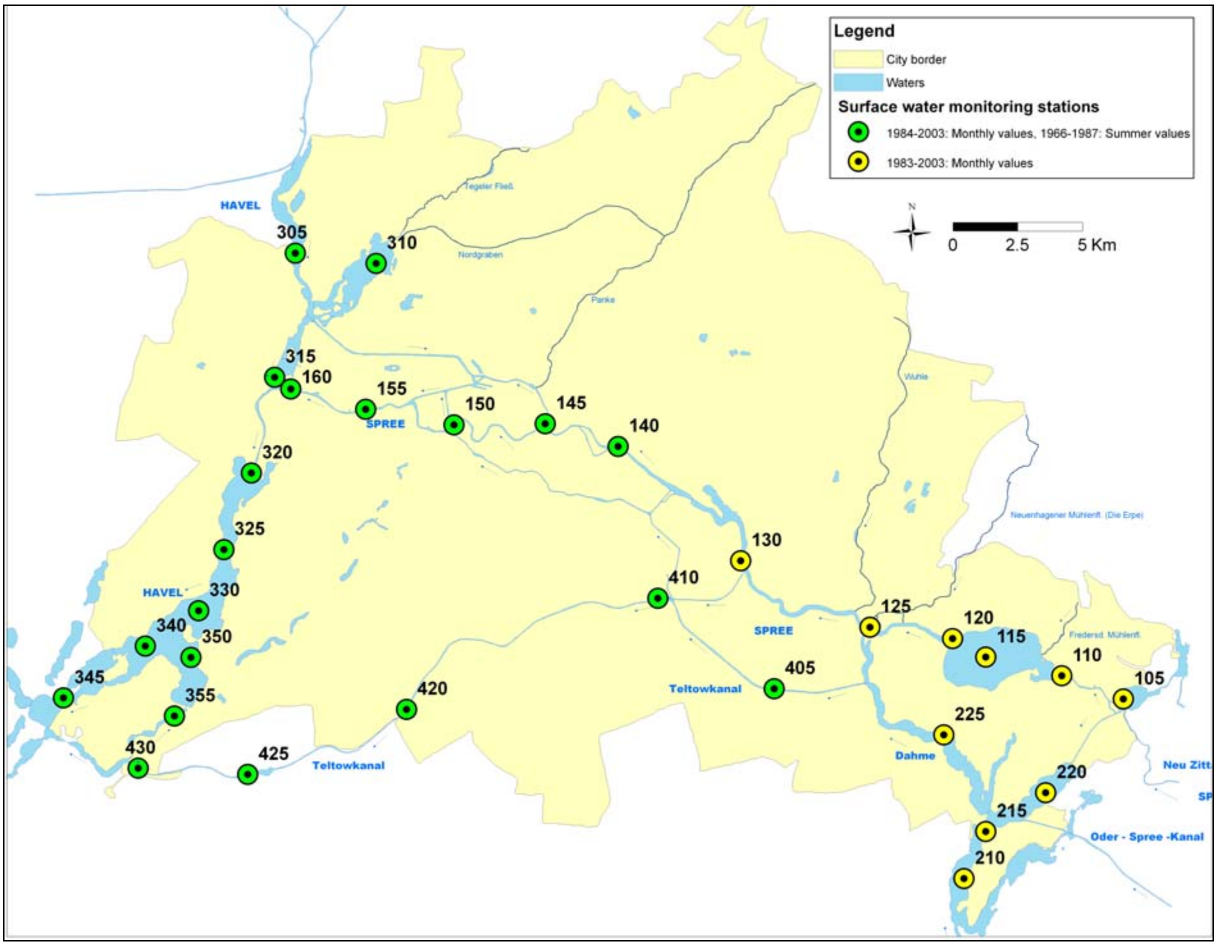

Figure 4.1: Surface water monitoring stations of Berlin *(SENSTADTUM, 1968-2004)*

In order to characterize the surface water quality of Berlin, 14 parameters (electric conductivity, temperature, pH, TSS, DO, nitrogen and phosphorous compounds and chlorophyll-a) have been considered (SENSTADTUM, 2004). On this data base the transport and fate of nutrients in the water bodies of Berlin is designed and driving forces behind nutrient-related environmental issues are spotted:

In the Berlin area, correlative data from three monitoring station systems – respective to three different development periods were used (Table 4.2).

Table 4.2: Berlin surface water monitoring stations

Monitoring station labels 1966-1985	Monitoring station labels 1986-1992	Labels in current system 1984-2003	Location
SPREE			
B18	11001	145	Spree, ca. 50m unterhalb Molkebrüke
B19	11002	150	Spree, ca. 100m oberhalb Einmündung Landwehrkanal
B22	13003	130-140	Landwehrkanal, ca. 100m o. Einmündung Neuköllner Schiffahrtskanal
B23	13001	405	Neuköllner Schiffahrtskanal, ca. 10m o. Lohmühlenbrüke
B39	13004	130	Landwehrkanal, unmittelbar u. U-Bahn Hochbrüke
B20	13005	130	Landwehrkanal, ca. 10m o. Dovebrücke
B17	12003	150	Charlottenburger Verbindungskanal, ca. 75m vor Einmündung in die Spree
B14	12001	145	Berlin-Spandauer Schiffahrtskanal, Einmündung in den Nordhafen
B15	12002	145	Berlin-Spandauer Schiffahrtskanal, ca.150m o. Nördliche Britzer Kreuz
B41	12004	145	Westhafenkanal, ca. 20 m o. Mörschbrüke
B21	11003	155	Spree, ca. 100m u. Schleuse Charlottenburg
B5	11007	160	Spree, Spandau, ca. 50m vor Einmündung in die Havel
HAVEL			
B1	21002	305	Oberhavel, Havelmtte, Konradshöhe ("Feengrotte"/Bürgerablage)
B2	22003		Oberhavel, Aalemannkanal, Ende
B37	23003	310	Tegeler See, "Am Forsthaus"/WW Tegel
B4	24002	310	Hohenzollernkanal, Saatwinkel
B35	21005	325	Oberhavel, Havel, ca. 50m o. Schleuse Spandau (Wehr)
B5	11007	160	Spree, Spandau, ca. 50 vor Einmündung in die Havel
B35	25001	325	Unterhavel Spandau (Südhafen), ca. 50m nördlich Kleiner Jüngengraben
B6	25002	325	Unterhavel, Havel u. Pichelssee (Gemünd)
B34	25008	330	Unterhavel, Havelmitte, Höhe Grunewaldturm
B33	25011	335	Unterhavel, Havelmitte, Höhe Großes Fenster
B8	25013	345	Unterhavel, Havel, ca 200m o. Kälberwerder
B32	25014	345	Unterhavel, Havel, linkes Ufer, 50m vor der Scrower Fähre
TELTOWKANAL			
B24	31001	405	Teltowkanal, 50m nördlich Wredebrücke, Hafen Rudow Ost
B25	31003	405	Teltowkanal, 400 m südlich Britzer Kreuz
B26	32001	130	Britzer Zweigkanal, ca. 100 m vor Einmündung in den Teltowkanal
B27	13002	130+405	Neuköller Schiffahrtskanal, ca. 100m nördlich Britzer Kreuz
B40	31006	410	Teltowkanal zwischen Fußgänger - u. S-Bahnbrüke Mariendorf
B28	31010	420	Eugen-Kleine-Brücke, Lichterfelde, o. Schilfluchgraben
B11	31013	430	Teltowkanal, Kohlhassenbrück, Höhe Nathanbrüke
B10	26004	355	Prinz-Friedrich-Leopold Kanal (87-03)

(Source: Gewässerkundlicher Jahresbericht des Landes Berlin, Abflußjahr 1966-1992, The Berlin Department of Urban Development and Environmental Protection, Department IV.)

4.3.2 Monitoring data for upstream and downstream surface waters

To calculate the total nutrient emissions to the surface waters of Berlin, the data from 5 monitoring stations were grouped for the three major inputs (Hennigsdorf for the river Upper Havel input; Neuzittau and Wernsdorf for the river Spree input and Neue Mühle together with the Nottekanal for the river Dahme input). Regarding the nutrient emissions in the upper part of the river Spree, the station at Leibsch was also included for comparison the changing of nutrient loads in different river sections and to consider the flow from the Spree to the Dahme by the Dahme-Umflut-Kanal (Figure 4.2).

The monitoring data of these stations are aggregated to monthly average values. The observed parameters include: water temperature, ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total nitrogen, othro-phosphate and total phosphorus concentrations as well as water discharges. In some periods, whenever the necessary parameters are not available, the regression method is applied to close gaps (see Table 4.2).

For calculating and estimating nutrient loads of inflows and outflows of Berlin, monitoring data on some upstream and downstream rivers belonging to the Havel, the Spree and the Dahme sub-catchments are extracted from IGB Database (Table 4.3).

Table 4.3: Monitoring data on upstream and downstream of Berlin

River	Segment	Water quality	
		Period	Data
HAVEL	Hennigsdorf	1971-2004	Monthly values of temperature, NH_4-N, NO_2-N, NO_3-N, TN, Ortho-P, TP,
	Potsdam	1976-2004	
	Havelberg	1974-2004	
SPREE	Leibst	1976-2004	
	Neu Zittau	1976-2004	
	Wenzdorf	1976-2004	
DAHME	Neue Mühle	1983-2004	
	Notte Kanal	1976-2004	

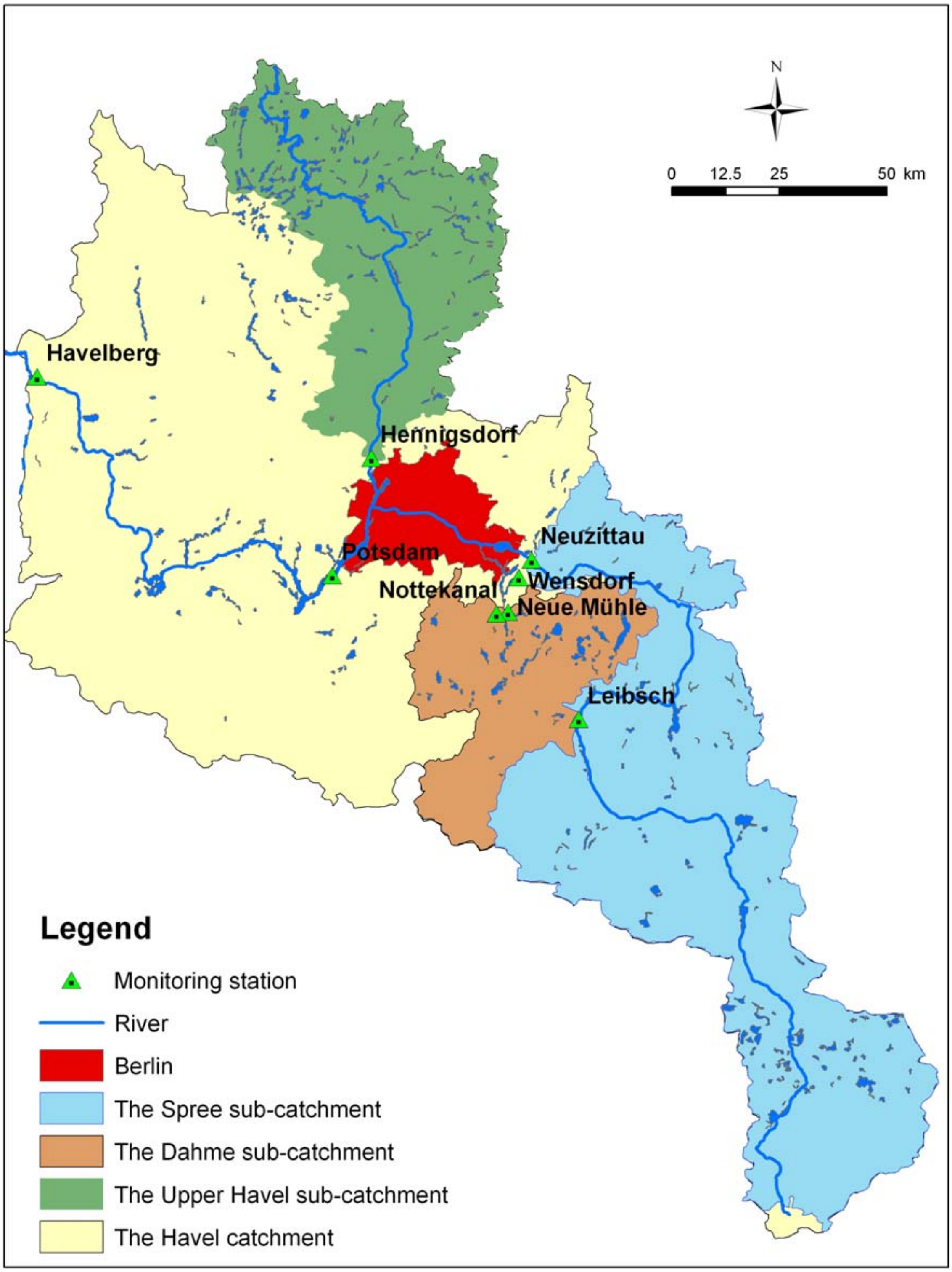

Figure 4.2: Monitoring stations for surface water quality in upstream and downstream areas of Berlin *(Data source: IGB)*

4.4 Data on climate and hydrology

4.4.1 Discharge data

Discharge data of inflow- and outflow-rivers as well as water bodies in Berlin are available from the monitoring program of The Berlin Department of Urban Development and Environmental Protection, Department IV for the period of 1983-2003 (SENSTADTUM, 2004).

For the period of 1966-1987, monthly data on discharge of Berlin water bodies was extracted from Gewässerkundlicher Jahresbericht des Landes Berlin (Abflußjahre 1967-1991) (SENSTADTUM, 1968-2004). Monthly data on discharge as well as water level of German river segments were found in Jahrbuch für die Gewässerkunde Norddeutschlands and Deutsche Gewässerkundliche Jahrbuch (1896-1989) (Table 4.4). The missing discharge values were estimated from the water level data by regression model.

Discharge data are not always available in all stations and all periods. Therefore, an empirical method was applied for estimating discharge data at one station from neighboring stations (Table 4.5).

Table 4.4: Water level and discharge at main gauges of the Havel, Spree and Dahme river

River	Gauge	Water level (W)	Discharge (Q)	Note
HAVEL	Zehdenick	1905-1970	1940-1965	Q = -451.18 + 0.12 W *r^2= 0.46 (1940-1944)*
	Spandau	1905-1989	1984-2003	Q = -27.71 + 0.25 W *r^2 = 0.76*
	Ketzin	1971-1989	1971-1996	Q = -115.18 + 1.87 W *r^2 = 0.75*
	Rathenow	1905-1989	1940-1989	Q = -40.61 + 0.81 W *r^2 = 0.97*
SPREE	S - Kottbus	1905-1989	1940-1989	Q = -881.62+ 0.38 W *r^2 = 0.98*
	Spree - Berlin, Muehlendamm, U.P.	1905-1989	1984-2003	Q = -488.2+ 1.87 W *1984-1989, r^2 = 0.88*
	S - Berlin, Muehlendamm, O.P	1905-1915 1940-1990	1986-1990	
	S - Charlottenburg	1905-1989	1984-2003	Q = -99.88 + 0.79 W *1984-1989, r^2 = 0.98*
Oder - Spree - Kanal	Kersdorf, U.P Wernsdorf OP	1912-1965	1986-1996	
Dahme	Dahme - Neue Mühle	1905-1913 1946-1989	1946-1989	Q = -34.97 + 0.35 W *1946-1956, r^2 = 0.69*
	Dahme - Köpenick	1946-1989		

Notes: Q = mean discharge (m^3/s), W = water level (m).

Table 4.5: Relationship of discharges at different stations in the Havel catchment

Station	Formula
Havel at Potsdam	$Q_{Potsdam} = -0.5 + 0.27 \cdot Q_{Havelberg}$, r^2= 0.91 Period of 1970-1999
	$Q_{Potsdam} = 0.7546 \cdot Q_{Rathenow}^{0.7928}$, r^2= 0.85 Period of 1970-1999
Spree at Neuzittau	$Q_{Neuzittau} = 2.853 \cdot Q_{Beskow}^{0.529}$, r^2= 0.63 Period of 1970-1999
Spree at Wernsdorf	$Q_{Wernsdorf} = 0.35 \cdot Q_{Beskow}^{1.751}$, r^2= 0.87 Period of 1970-1999
Spree (Neuzittau + Wernsdorf)	$Q_{\mathrm{Neuzittau+Wernsdorf}} = 1.271 \cdot Q_{Beskow}^{0.949}$, r^2= 0.94 Period of 1970-1999
Dahme (Neue Mühle + Nottekanal)	$Q_{\mathrm{Neue\ Mühle+Nottekanal}} = 0.56 + 0.11 \cdot Q_{NeueMühle}$, r^2= 0.99 Period of 1976-1994

4.4.2 Precipitation and climate data

For Berlin area, the precipitation data of six stations (Alex, Buch, Dahlem, Schönerfeld, Tegel, Tempelhof) with monthly resolution in the period of 1983-2003 were provided by the Berlin Department of Urban Development and Environmental Protection, Department IV (SENSTADTUM, 2004).

The historical data on precipitation in Berlin were mainly extracted from the statistical yearbooks of the Old Berlin city in the period of 1875-1920, and Greater Berlin since 1920 (Statistisches Jahrbuch der Stadt Berlin, 1878-1943; Berlin in Zahlen, 1927-1951; Statistisches Jahrbuch - Berlin <West>, 1952-1990; Statistisches Jahrbuch der Hauptstadt der Deutschen Demokratischen Republik Berlin, 1961-1983; Statistisches Jahrbuch berlin, 1991-2006).

For upstream and downstream locations, precipitation data were delivered from German Weather Service (DWS) and database of the Global Precipitation Climate data Center database (period 1951-2005).

4.4.3 Data on nutrient deposition

For calculating the nutrient deposition from the atmosphere, data on nitrogen dioxides and ammonium and phosphorous in wet and dry depositions with a solution of 50 km were collected from the inventory and report of EMEP program (Co-operative programme for monitoring and evaluation of the long-range transmission of air-pollution in Europe), the IPCC Data Distribution Centre and German Weather Service.

Data on the long-term nutrient depositions in Berlin for the most recent time period, 1950-2000, were used according to BEHRENDT et al. (2000, 2003) and BEHRENDT (pers. comm.). Data on the total carbon dioxide emission or coal burning of Germany could be used to extrapolate the estimations back to 1850. Data the total carbon dioxide emission of Germany in the period of 1850-2000 were extracted from CIDAC database (CIDAC, 2006).

4.5 Data for calculating point source emissions

4.5.1 Data on sewage farms

Data on catchment area, length of sewers, number of connected houses, purified waste water volume, size of the sprinkled area and annual capacity of each sewage farm was extracted from the statistic yearbooks of Berlin (1876-2004), “Die Stadtenwässerung in Deutschland” in 1916 and 1934 and other sources (VIRCHOW, 1873; BROOKS, 1905; HEYMANN, 1916; NASCH, 1916; RUTHS, 1928, NÜTZMANN, 1998; SENSTADTUM, 1999, BEHRENDT, 2000; BÄRTHEL, 2003; MOHAJERI, 2005). A digital map on the location, capacity and inflow, outflow location of sewage farms was developed based on this information.

4.5.2 Data on WWTPs

Daily data on discharge and chemical compounds of effluent from WWTPs were provided by IGB database originated from Berlin Water Work Company (BWB) for the period of 1992-1999. Data on the treatment capacity and nutrient removal capacity of Berlin WWTPs were extracted from BWB reports/document as well as from Berlin statistic yearbooks and other literatures (SENSTADTUM, 1999-2005).

A digital map on the location of Berlin WWTPs and their outflow locations were created based on information from BWB. A digital map on the location, capacity and technology of WWTPs of the Havel catchment and its sub-catchment was complied based on statistics of IGB and environmental agencies of States Mecklenburg-Vorpommern, Brandenburg, Saxony and Lower Saxony (Figure 4.5).

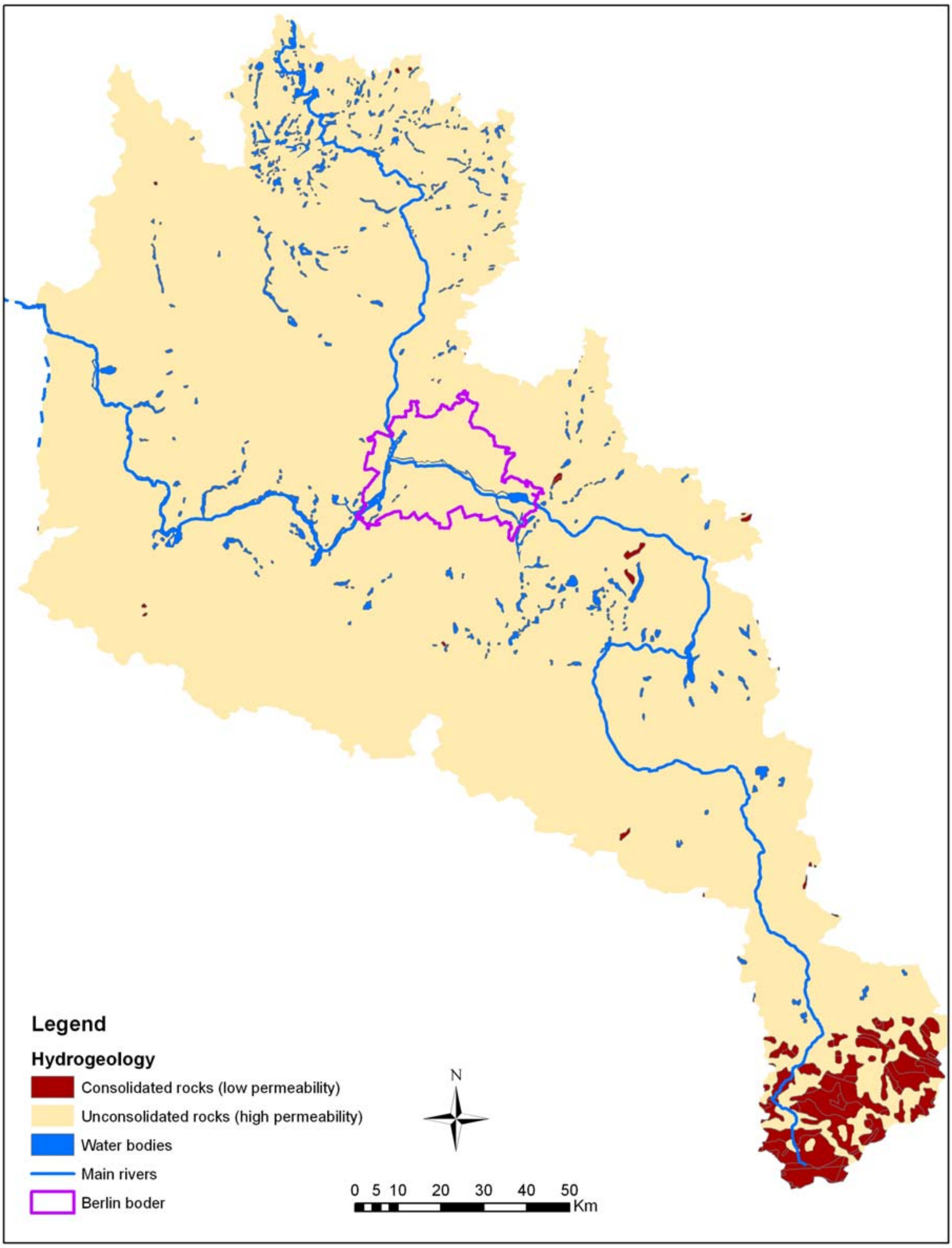

Figure 4.3: Hydrogeological map of the Havel catchment

(Data source: IGB)

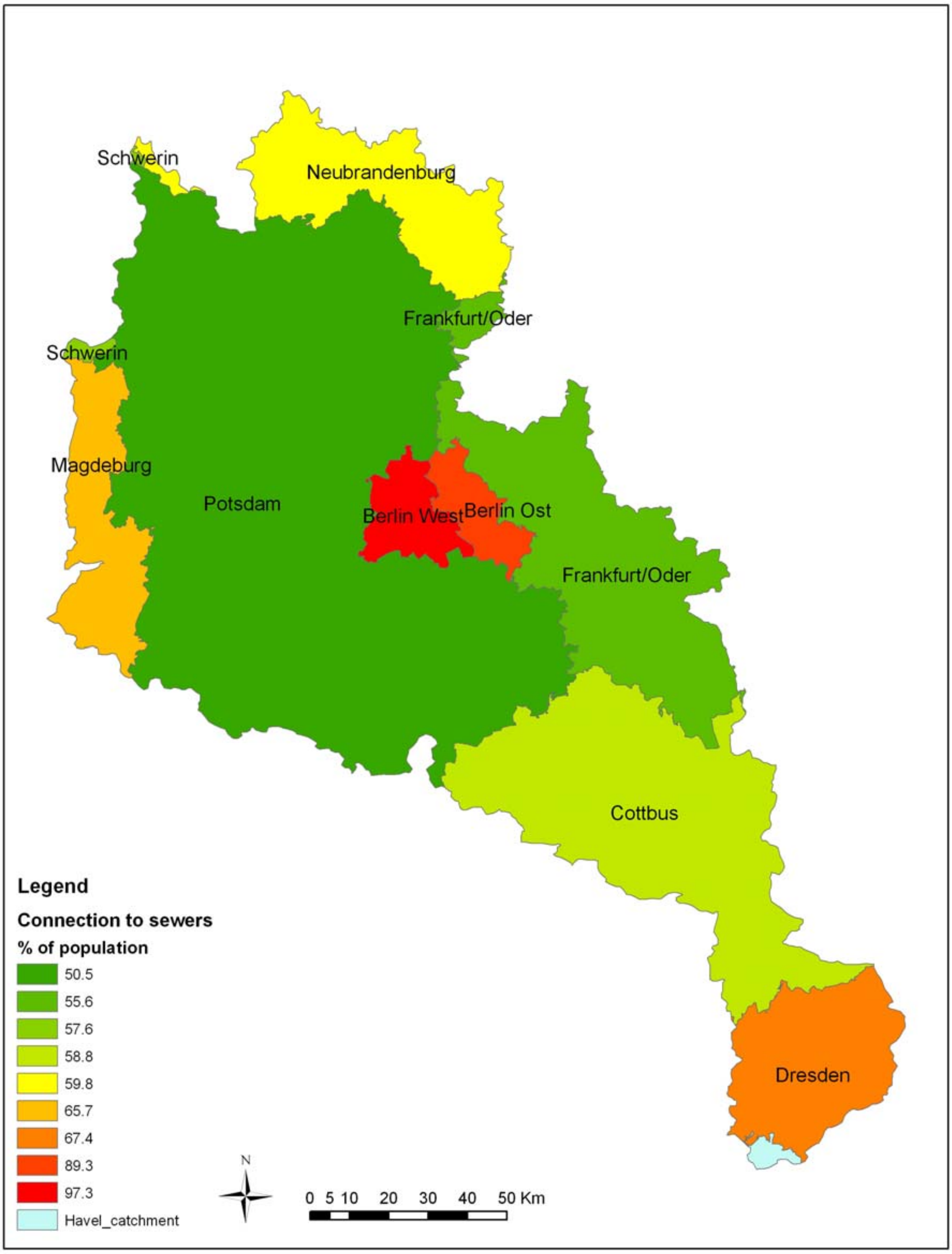

Figure 4.4: Connection degree to sewer system in the Havel catchment area in 1989 (with the administrative borders in GDR time)

(Data source: IGB)

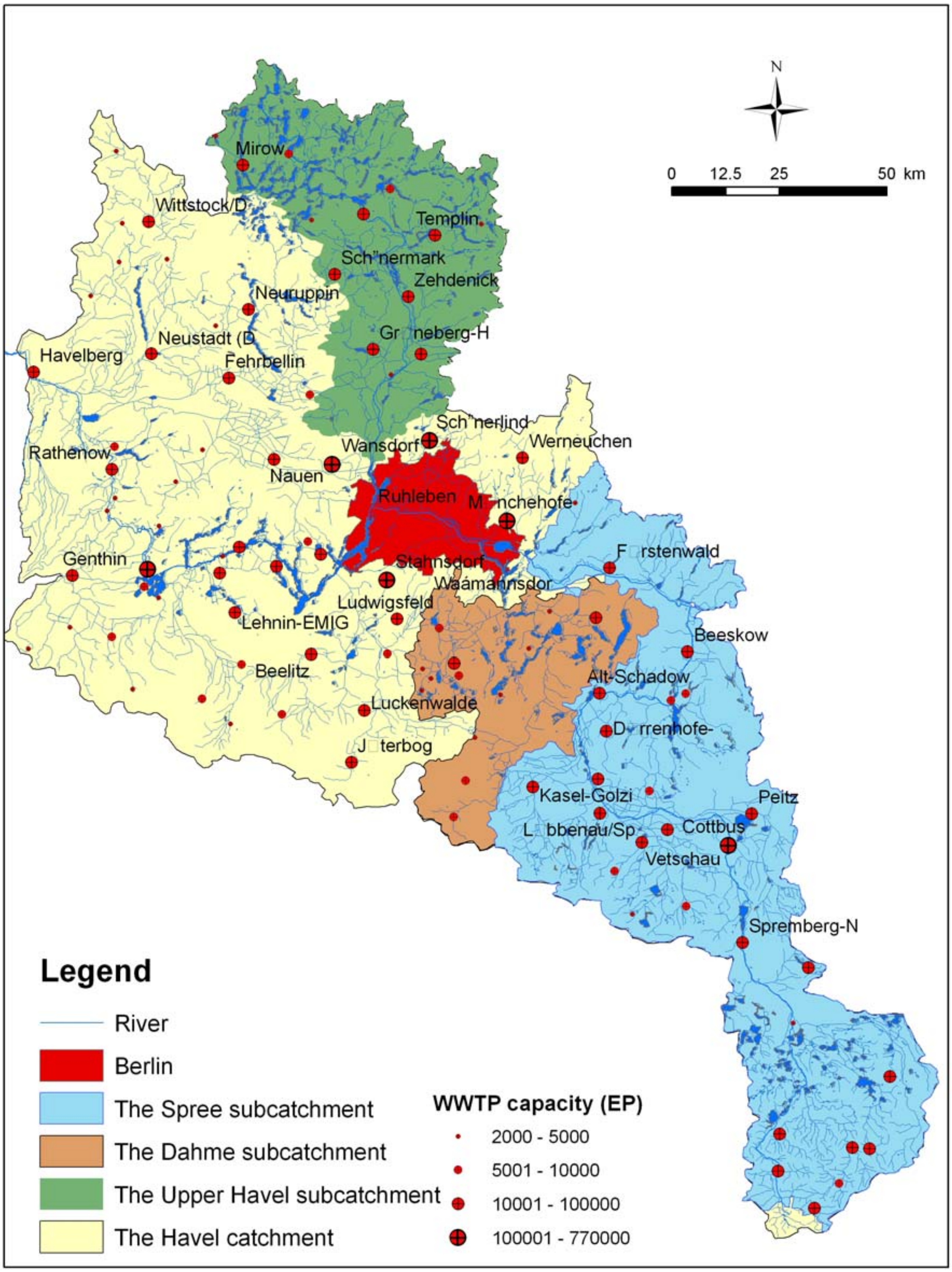

Figure 4.5: Existing waste water treatment plants in Havel catchment

(Data source: LUA Brandenburg, IGB)