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The Hydrogeology of the Chalk of North-West Europe

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8. Belgium

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Geographical distribution of the Chalk

The Chalk in Belgium was deposited mainly during Cretaceous times. The only exception is in the Mons Basin, where chalks of early Tertiary age (Danian and Montian) occur. The formation is found in the northern part of the country, but it crops out in only two areas—near Mons in the west and near Liège in the east (Fig. 8.1). During the Cretaceous, a major transgression led to marine sedimentation over almost the entire country. The transgression was not uniform and all regions were not affected simultaneously.

Cretaceous marine sedimentation, comprising calcareous and glauconitic sands and sandstones, glauconitic marls and limestones and conglomerates, began in the west of the country during Albian times. Near the city of Mons, regional transgression along a north–south line can be recognized as extending east from the sedimentation centre of the Paris Basin (Fig. 8.2). During Albian and Cenomanian times, many transgressions and regressions of the sea occurred. In the Late Cenomanian, a major advance covered the western part of the country. The sediments deposited were not chalk but green, clayey marls, the lateral equivalents of the chalky marls of the Pas de Calais. This transgression continued during Turonian times when pure chalk was deposited for the first time in the western part of Belgium. During the early Cretaceous, Cenomanian and Turonian, the northern and north-eastern parts of the country were not submerged by the Cretaceous sea.

Sedimentation continued near Mons and in eastern Flanders (Fig. 8.1) in Coniacian and Santonian times, but it was not until Campanian times that transgressive seas, advancing from the west, extended over the Brabant Massif and the area between the Sambre and Meuse rivers (Fig. 8.2).

The first marine transgression in the north-east of Belgium was also in Campanian times. In the Late Campanian, a major advance of the sea from the north-east deposited chalk over the Pays de Herve and the Hesbaye region, and at the end of the Campanian the sea probably covered most of Belgium. The boundary between the southern sea advancing from the Paris Basin and the north-eastern sea advancing from the Netherlands was along the eastern side of the Brabant Massif, between Lonzee and the western part of Hesbaye (Fig. 8.1). Chalk sedimentation continued into Maastrichtian times over north-east Belgium, and into Montian (Early Eocene) times in the Mons Basin.

The distribution of the various stages of the Chalk is shown in Fig. 8.2. Over most of the country, the outcrop, or subcrop below the Tertiary cover, is of Late Campanian to Maastrichtian age. The total thickness increases away from the Brabant Massif, exceeding 250 m in the north-east; in the outcrop areas it is generally up to between 50 and 100 m thick, although in the centre of the Mons Basin as much as 400 m occurs (Fig. 8.3). The top of the formation slopes to the north and is over 600 m below sea level in the north-east of Belgium (Fig. 8.4).

Stratigraphy

In Belgium, the Chalk is mainly represented by sediments ranging in age from Turonian to Maastrichtian. As a result of the geological history, summarized in the previous section, the nature of the sequence in different districts varies in detail. The differences can be recognized particularly in and near the outcrops.

The various types of chalk, of Turonian to Maastrichtian ages in the Mons and Tournai basins, are described in Table 8.1.

In north-eastern Belgium, in the Pays de Herve, Hesbaye, the Campine Basin and northern Brabant, the Chalk is Campanian to Maastrichtian in age. Lateral changes in lithology and facies are common,

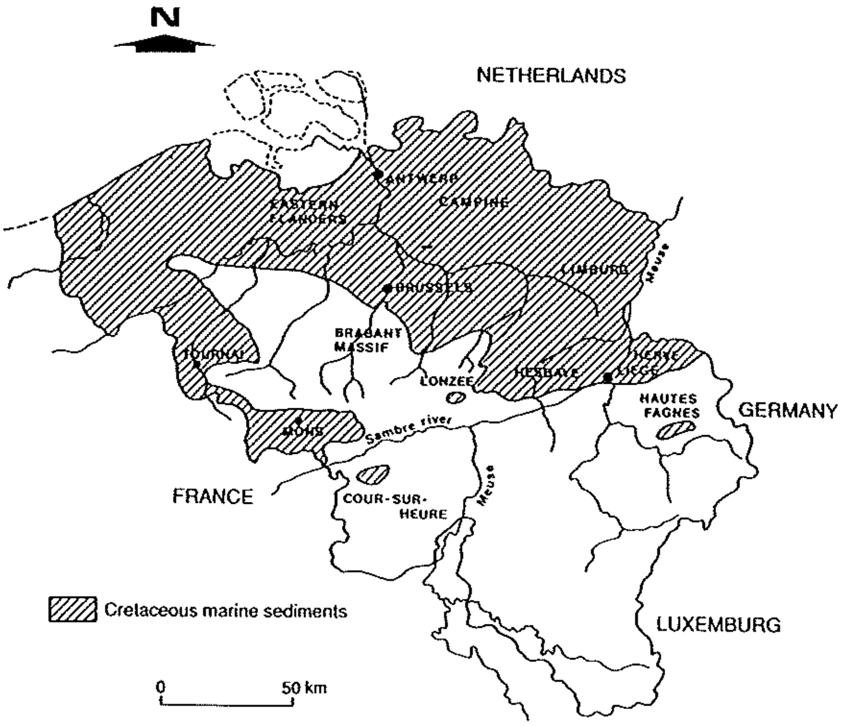

Fig. 8.1. Distribution of Cretaceous marine sediments in Belgium (after Legrand 1951).

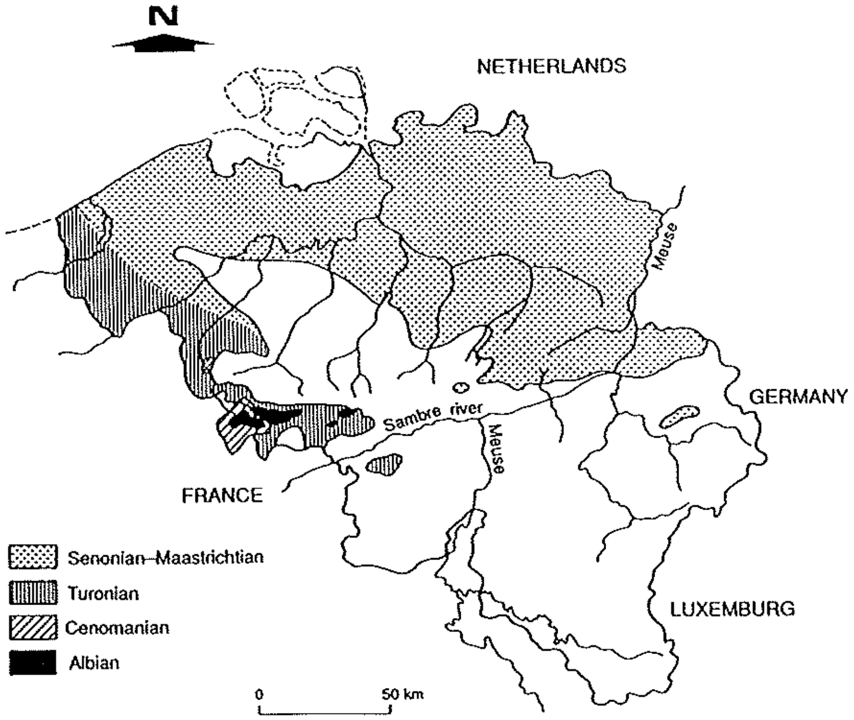

Fig. 8.2. Distribution of Albian, Cenomanian, Turonian and Senonian–Maastrichtian deposits in Belgium. The chalk facies occurs from the Upper Turonian (in the Mons Basin) to the Maastrichtian. Limited areas of Tertiary chalks occur in the Mons Basin.

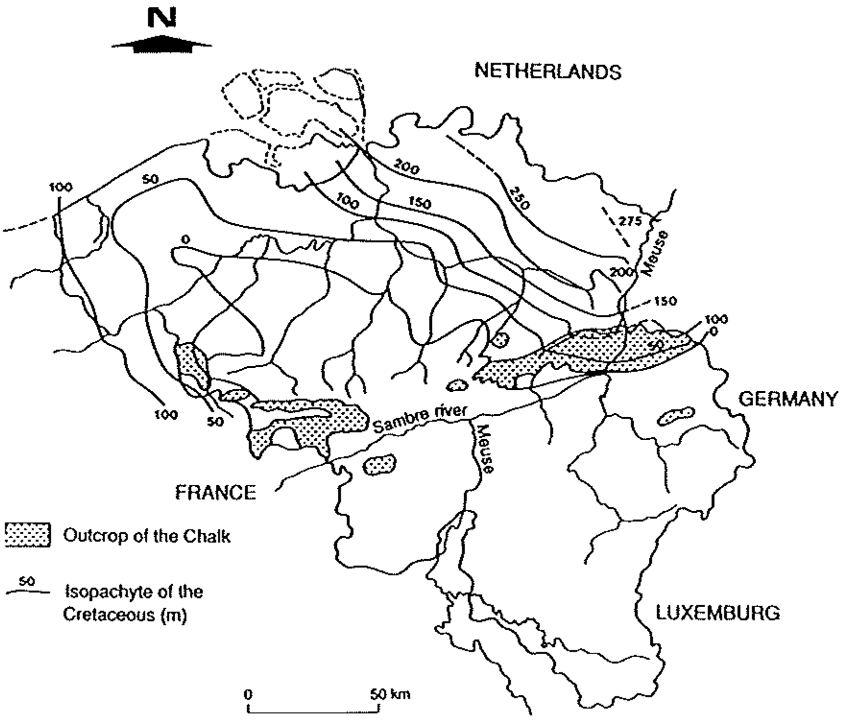

Fig. 8.3. Isopachytes (in metres) of Cretaceous marine sediments in Belgium. In the centre of the Mons Basin the thickness reaches 400 m but the isopachytes are not drawn because of the scale of the map. Most of the Cretaceous sequence is chalk (after Legrand 1951).

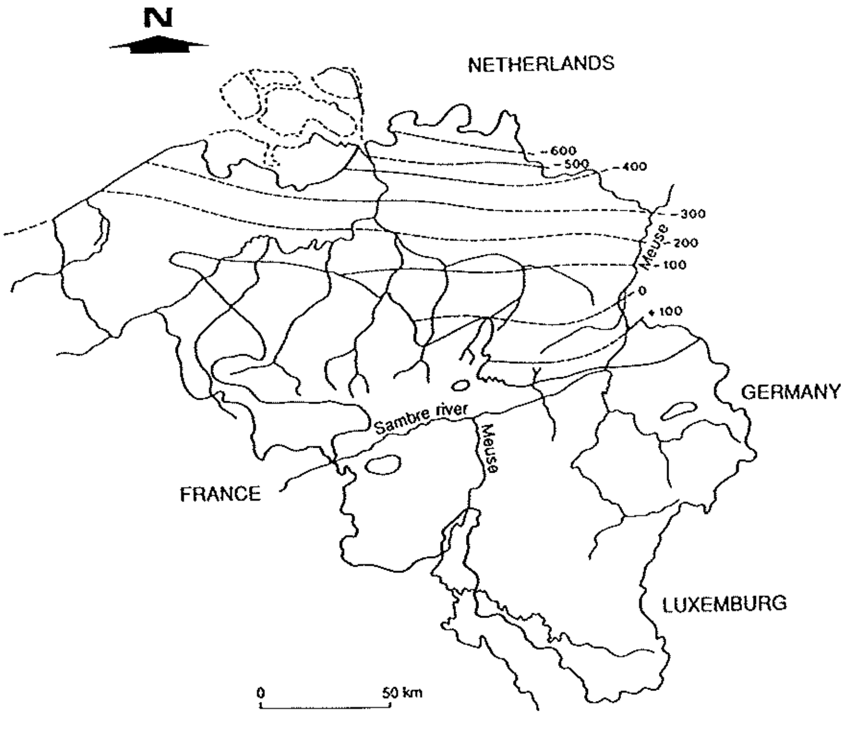

Fig. 8.4. Contours of the top of the Chalk (in metres relative to sea level).

Table 8.1 The nature of the Chalk in the Mons and Tournai basins

Stage	*Local name*	*Nature*	*Thickness (m)*
Maastrichtian	Ciply chalk	Brown or white-chalk, moderately hard, many phosphatic nodules which decrease downwards in the centre of the Mons Basin. At the margins of the basin the base is marked by a phosphatic conglomerate.	20–75
	Spiennes chalk	White coarse-grained chalk. Many large flints at the base with a poorly developed phosphatic conglomerate. Very good aquifer.	*c*.50
Campanian	Nouvelles chalk	Pure, fine white chalk without flints. Similar to Obourg chalk except for absence of flints.	13–20
	Obourg chalk	Fine white chalk; in the north of Mons Basin contains dark flints. Phosphatic conglomerate at base.	*c*.30
	Trivières chalk	White to grey marly chalk, without flints. Contains ferruginous and phosphatic beds. Phosphatic conglomerate at base. Separated from Saint-Vaast chalk by very short stratigraphic break.	*c*.80
Santonian and Coniacian	Saint-Vaast chalk	White-chalk with grey or dark flints. Glauconitic at base.	15–50
Upper Turonian	Maisières chalk	Very homogeneous over entire area. Uneven, highly friable very glauconitic chalk, with phosphatic nodules in places.	1.5–4.0
	Rabots	Uneven, white coarse-grained chalk with glauconite. Dark brown bedding plane flints. Locally the chalk is replaced by siliceous grit.	*c*.20–25

particularly to the west near Gembloux and to the north in the Campine. The Chalk overlies glauconitic marls and sands that are locally replaced by a hard calcareous clay called the Smectite de Herve. The Campanian is represented by chalk with glauconite and grey flints. It becomes uneven and coarse-grained in the upper part before grading up into white, pure chalk without flints; flints occur again at the top of the formation. Westwards in the valleys of the Mehaigne and Petite Gette rivers, the

Campanian Chalk is replaced by sandy tuffeau, an uneven coarse-grained limestone. An organic, detrital arenaceous facies prevails rather than chalk in the Campine Basin.

The overlying Maastrichtian can be divided into lower and upper divisions. The lower division is the Lanaye chalk, an uneven, white chalk containing virtually no phosphate but interbedded with continuous layers of brown flints. The upper part of the Lanaye chalk becomes more uneven and coarse-grained, and passes up into the tufaceous chalk (or tuffeau) that is well known in Limburg, in the Netherlands, where it is called the Kunrade chalk (see Chapter 9). In the north-eastern part of the Campine Basin, the chalk of this part of the sequence is replaced by silty and sandy marls.

The Chalk is overlain in north-east Belgium by a yellowish, organic, detrital, coarse-grained calcareous rock containing many flints and cherts called the Maastricht tuffeau. Where erosion has been considerable, as to the south of Hesbaye, Tertiary loess and loam overlie the Chalk.

The chalk sequences of the outliers of Lonzee and Cour-sur-Heure massif (Fig. 8.1) are similar to that of the Mons Basin, and the outlier of the Hautes Fagnes resembles the deposits of north-east Belgium. Over most of northern Belgium, the Chalk is overlain by thick Tertiary deposits, which are mainly uncemented sands, silts and clays that are complexly interlayered.

Structure

The overall distribution and form of the Chalk in Belgium is strongly influenced by the Brabant Massif. As already described, this restricted sedimentation, and the thickness of the formation increases away from the structure (Fig. 8.3). Subsequently, the Chalk's surface tilted towards the north as increasing thicknesses of Tertiary deposits covered the aquifer.

An important hydrogeological basin occurs in the south-west of Belgium, around the city of Mons. The Mons Basin (Figs. 8.1 and 8.3) is a large syncline with a general east–west axis and an average westerly pitch of 1 in 20. The decreasing thicknesses of the various deposits towards the east and at the margins of the basin indicate synsedimentary subsidence. However, more rapid and dramatic variations in thickness were caused by halokinetic structures in Palaeozoic anhydrite, underlying the Cretaceous (Fig. 8.5).

The Chalk crops out in the Hesbaye and Herve areas but towards Campine the thickness of the Tertiary and Quaternary cover gradually increases. The thickness of cover rocks is strongly influenced by faulting (Fig. 8.6). In the north-east of Belgium, the Chalk is characterized by regular horizontal or sub-horizontal layers dipping slightly towards the north.

Stratigraphic non-sequences occur in the Chalk in both the Mons Basin and north-east Belgium. South of the Dutch–Belgian border, in the northern Campine, the irregular base of the Cretaceous, indicated by seismic reflection surveys, illustrates the scale of the unconformity at the base of the Upper Cretaceous. The topography at the beginning of the Cretaceous marine transgression was influenced by the composition and nature of the Palaeozoic rocks.

Although the extents of the Cretaceous transgressions were linked to general rises of sea level, they were also influenced by local subsidence which determined some of the local variations in thickness of the deposits. The principal areas of subsidence were the Mons Basin and north-east Belgium. In the latter area, subsidence was controlled by faults extending from the Limburg area of the Netherlands. In general, the zones of subsidence reflect Palaeozoic tectonic features. At the end of Cretaceous times, almost the entire country was raised above sea level before early Tertiary lacustrine lagoonal sediments were deposited.

Groundwater in the Chalk

About $127 \times 10^6 m^3$ of groundwater are pumped annually from the Chalk, of which more than 90 per cent is used as drinking water. The aquifer provides about 20 per cent of the total volume of groundwater used for industrial and drinking purposes in Belgium. Overexploitation of the resources is not a problem as yet.

The main centres of abstraction are the outcrop areas across the centre of the country—the Mons Basin, the Hesbaye region and the Pays de Herve—and the confined areas in Limburg in the east, and in Brabant near and to the south of Brussels. Near Brussels, some $9 \times 10^6 m^3$ are abstracted each year

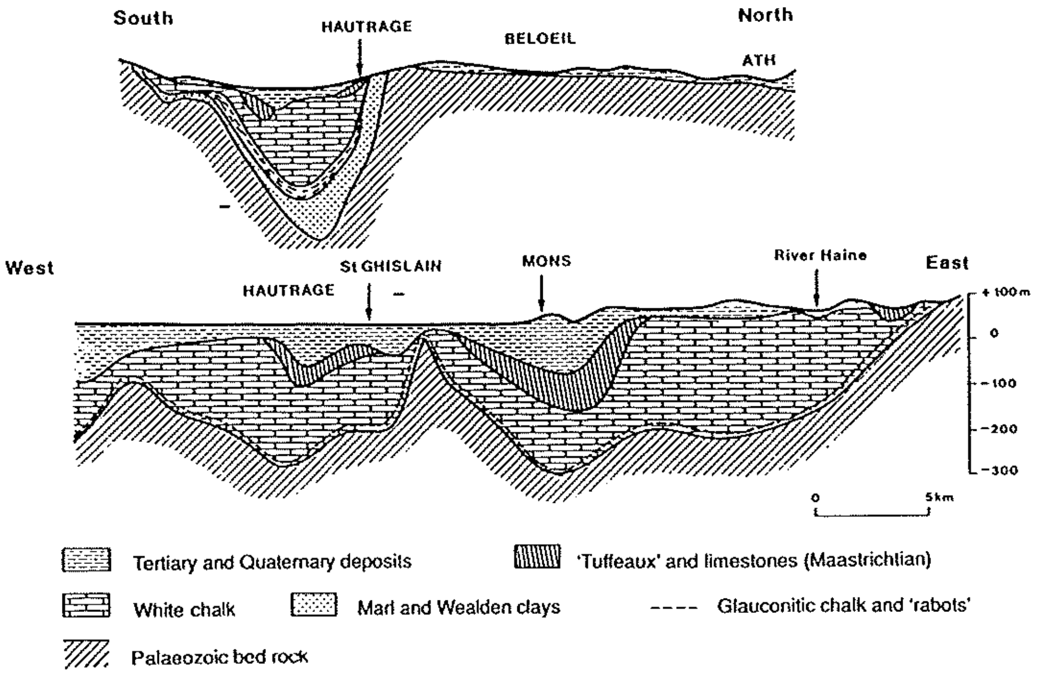

Fig. 8.5. Transverse (S–N) and longitudinal (W–E) cross-sections of the Mons Basin (after Gulinck 1966).

but the city itself is partly supplied by pipeline from the Chalk of the Mons Basin. Intensive pumping near Brussels has led to large drawdowns of water level and as a consequence saline waters in the north of the country have migrated south, the 500 mg l^{-1} isochlor now lying about 20 km north of Brussels. In Brabant province, especially to the south of Brussels, the thickness and lateral extent of the aquifer are limited and recharge by infiltration is, of course, very low. The Turonian chalk is ex-

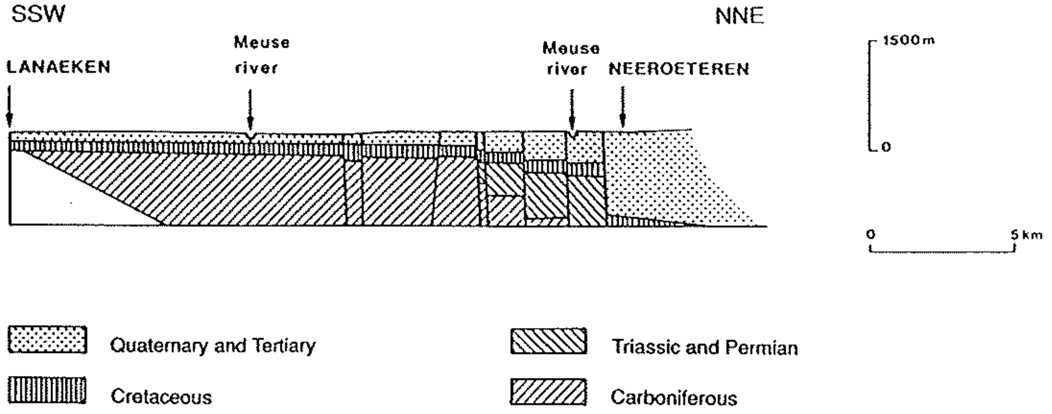

Fig. 8.6. Influence of faults on the thickness of the Cretaceous sediments in north-east Belgium. The section illustrates the horst and graben structure. The section is nearly parallel to the River Meuse in north-east Belgium, near the Dutch border.

ploited in the provinces of Flanders but the wells also penetrate the fissured aquifers of the underlying Palaeozoic.

Unconfined conditions exist in the outcrop areas of central Belgium except in the limited areas where alluvial deposits and, locally, thin Quaternary and Tertiary deposits create confined conditions. In the east, in the Hesbaye and the Pays de Herve aquifers, water levels range from about 100 m to over 250 m above sea level (asl). Further west, in the Mons Basin, levels fall from some 70–100 m asl in the east of the basin, below the higher ground, to less than 20 m asl in the lower parts of the basin in the extreme west. Throughout the northern part of the country, groundwater in the Chalk is confined by the Tertiary sediments and the piezometric surface is generally less than 20 m asl (Fig. 8.7). The most detailed information is available for the three main Chalk aquifers—the Hesbaye aquifer, the Mons Basin and the confined aquifer of northern Belgium, which are each discussed below.

Hesbaye aquifer

This aquifer is represented by a Chalk outcrop of 350 km^2 lying to the north of the River Meuse near Liège (Fig. 8.8). It provides about 60 000 m^{3}d^{-1} of potable water for Liège and its suburbs. An interesting feature of the Hesbaye aquifer is that it is developed by about 45 km of galleries driven in the lower part of the Chalk, with as much as 15 km constructed as recently as the 1970s. The cross-section of the galleries is about 2–2.5 m^2. Water drains into them from the Chalk and flows by gravity to supply Liège and its suburbs. Neither pumps nor filters are used. It is the only example in Belgium of large-scale groundwater development using galleries.

Recently, a complete set of data relating to the geology, hydrology, geomorphology, and geophysics has been collected in order to build a numerical three-dimensional finite-element model of the aquifer. This model has been developed by the University of Liège to forecast changes in the form of the water table and to provide additional hydrogeological interpretation, particularly about the main drainage axes in the aquifer.

The geological sequence (Fig. 8.9) may be summarized as follow:

- Recent alluvial and colluvial deposits; up to 5 m thick.
- Quaternary and Tertiary—sands and loess; 2–20 m thick.
- Residual conglomerate; 2–15 m thick.
- Maastrichtian Chalk—locally referred to as 'upper chalk'. It has been exposed to weathering and hence it is fractured; 10–15 m thick.
- Thin (less than 1 m) layer of hardened Upper Campanian Chalk (or hardground).
- Campanian Chalk—compact massive white-chalk, referred to as 'lower chalk', with many fracture zones providing preferred flow routes for groundwater; 20–40 m thick.
- Smectite de Herve—a layer of hardened calcareous clay of Campanian age, about 10 m thick, that forms the impermeable base of the Chalk aquifer.

Maps and cross-sections (for example, Fig. 8.9) have been drawn using geological and groundwater-level data from more than 500 boreholes.

Recharge to the aquifer is by infiltration through the overlying loess and the residual conglomerate and is estimated to be between 175 and 275 mm a^{-1}. The hydrological balance for the period 1952–66 has been assessed (Monjoie 1967) as follows:

rainfall (*R*)	740 mm a^{-1}
evapotranspiration (*E*)	525 mm a^{-1}
effective infiltration	175–275 mm a^{-1}
flow of the R. Geer (*Ru*)	52 × 10^6 m^{3}a^{-1}, equivalent to 120 mm a^{-1}
groundwater abstraction (*G*)	60 000 m^{3}d^{-1} equivalent to 65 mm a^{-1}
mean storage (*S*)	15 mm a^{-1}

giving a balance of:

$$\begin{array}{l} R = E + Ru + G + S + \text{losses} \\ 740 = 525 + 120 + 65 + 15 + 15\ \text{mm} \end{array}$$

The 'losses' term includes flow across the boundaries of the aquifer when water levels are very high, as well as water flowing below the River Geer in response to high pumping rates north of the river.

Values for the aquifer properties have been obtained from 150 pumping tests in the different lithological units (Table 8.2). Because water-table

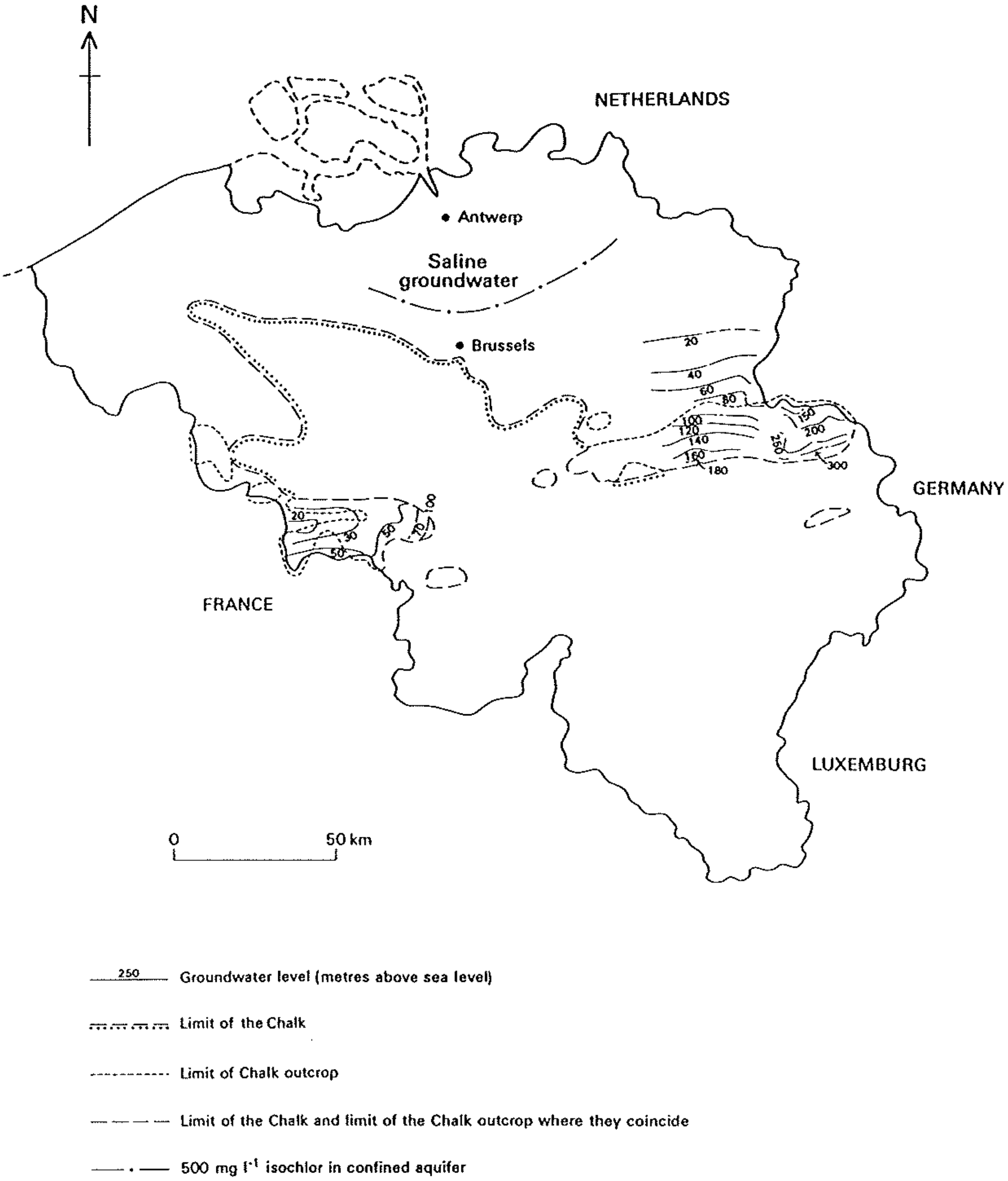

Fig. 8.7. Groundwater levels in the Chalk.

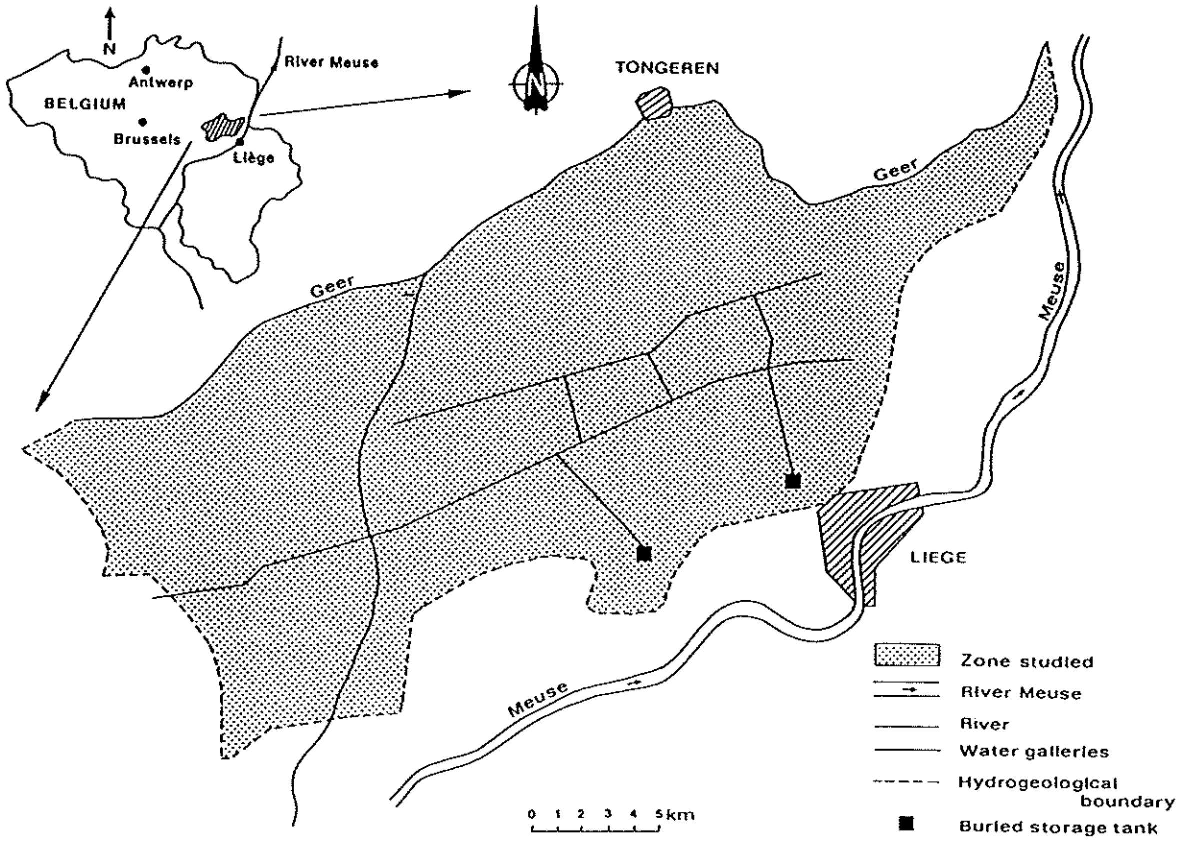

Fig. 8.8. Location of the Hesbaye aquifer.

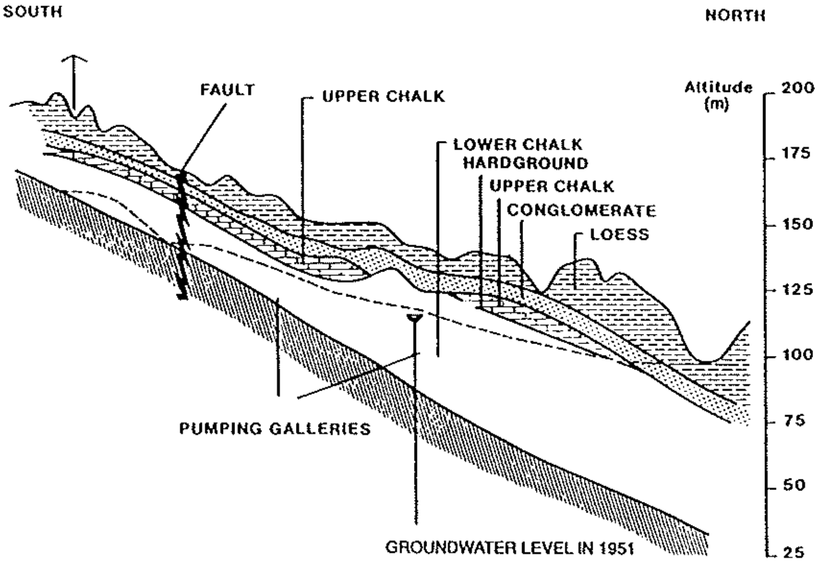

Fig. 8.9. Vertical cross-section through the Hesbaye aquifer.

Table 8.2 Aquifer properties of the Chalk in the Hesbaye aquifer

	Hydraulic conductivity (m s^{-1})	Storage coefficient
Loess	10^{-9} to 2×10^{-7}	–
Residual-conglomerate	10^{-5} to 8×10^{-3}	0.05 to 0.1
Maastrichtian ('upper chalk')	2×10^{-4} to 5×10^{-3}	0.07 to 0.15
Campanian ('lower chalk')	10^{-5} to 5×10^{-4}	0.05 to 0.15

conditions exist, the storage coefficient is the effective porosity (or specific yield) and values are very high because it includes both fracture and matrix porosities.

The main drainage axes of the aquifer are below dry valleys in the Chalk, and are characterized by high hydraulic conductivities because of the presence of fractures and karstic features (Fig. 8.10). The direction of flow is towards the north-northwest. Because of the high permeability, surface drainage is very limited.

Groundwater levels have been carefully measured since 1951 and annual water level maps and cross-sections prepared. At specific points in the aquifer the change of elevation with time is known reliably. The flow of the River Geer, abstraction of groundwater from galleries, and the recharge of the aquifer by rainfall also give reliable time-distributed data.

The aquifer has been modelled by the finite-element method, which is well adapted for such a geometrically complex and heterogeneous system because the finite elements can readily follow the limits of the different layers or boundaries (Dassargues *et al.* 1988). Elements representing the porous medium, infiltration, and the abstraction galleries can be combined into a comprehensive model of the aquifer (Figs. 8.11 and 8.12). The transient form of the water-table surface has been modelled with a fixed-mesh network using a storage relationship dependent upon the groundwater elevation. The model has been carefully calibrated against historical data and tested against variations in permeability and storage coefficient. Figure 8.13 shows maps of groundwater flow for the 'upper' and 'lower' chalk aquifers as derived from the model. The flow is concentrated along a few preferred flow directions (corresponding to the axes of dry valleys) in the 'lower' aquifer because of the large contrast between values for hydraulic conductivity of frac-

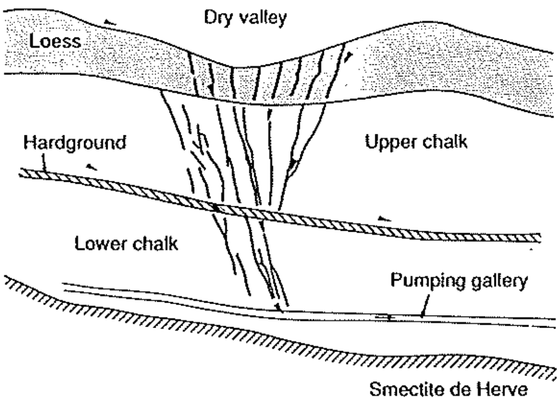

Fig. 8.10. Dry valley corresponding to a principal subsurface drainage axis through fractured chalk.

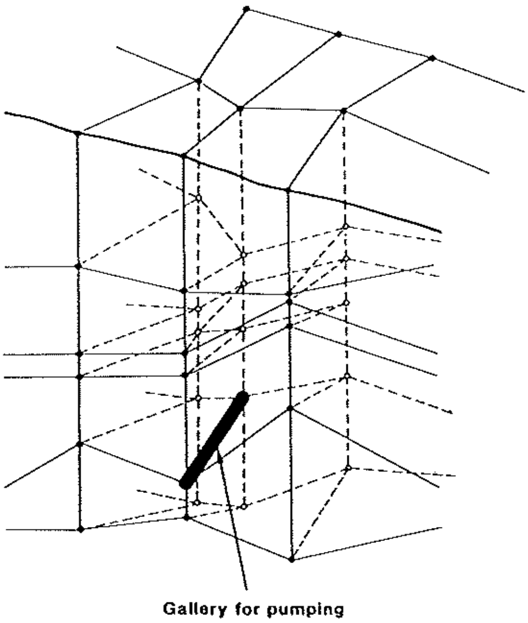

Fig. 8.11. One-dimensional 'pipe' elements representing galleries have been introduced into the mesh of the finite-element model (after Dassargues *et al.* 1988). These elements are given infinite permeability.

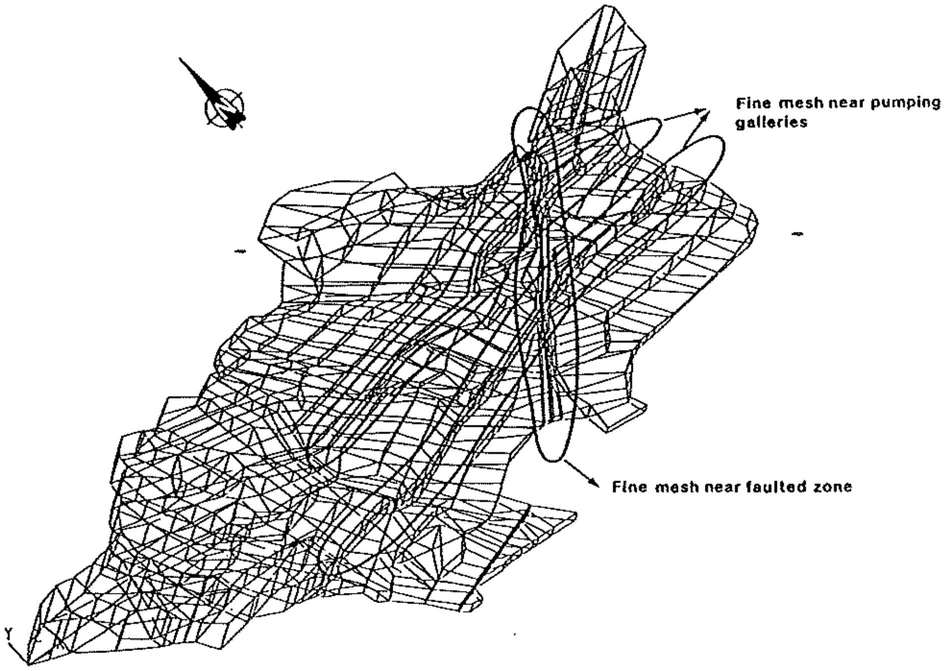

Fig. 8.12. The fourth of five layers of the finite-element model depicting the Hesbaye aquifer (after Dassargues 1991). The three-dimensional finite-element network incorporates a large body of geological and hydrogeological data including pumping wells and galleries, faults, and the boundaries of the basin or geological units. The total mesh is composed of 3300 8-node brick elements and 3600 nodes. The figure shows the complexity of the mesh network for one of the layers.

tured chalk below the dry valleys and those of the aquifer away from these axes. While these preferred directions can still be recognized in the 'upper' aquifer, the flow is more evenly distributed as the permeability values throughout this aquifer are of the same order of magnitude. A computed groundwater-level map for the Hesbaye aquifer for 1984 is shown in Fig. 8.14.

The model can be used to predict future conditions in the aquifer because groundwater levels, hydraulic gradients and volume of flow can be computed for any year as a function of infiltration and abstraction rates. The model also provides a basic framework for the simulation of contamination of the aquifer by pollutants as it incorporates advection and dispersion. With regard to pollution, the concentration of nitrites and nitrates (Figs. 8.15 and 8.16) is particularly relevant since nitrate concentrations exceed 100 mg l^{-1} over extensive parts of the upper aquifer. So far concentrations are less than 50 mg l^{-1} in the lower aquifer, where the galleries are located.

Mons Basin

The Chalk aquifer in the Mons Basin is in the form of an east–west syncline, covering an area of some 400 km^2. Drainage is by the Haine river, flowing in a westerly direction along the axis of the structure. The estimate of the mean annual infiltration, $80 \times 10^6 m^3$, is based on rainfall measurements and evapotranspiration calculations using the Thornthwaite and Turc formulae. The total annual abstraction of groundwater is estimated to be between 50 and $60 \times 10^6 m^3$. The water is supplied to Mons and its surrounding area as well as providing part of the requirements of Flanders and Brussels.

The lower part of the aquifer is formed by the Upper Turonian Chalk which overlies Cenomanian marls. The aquifer is, however, mainly in the Senonian and Maastrichtian Chalk and locally in the chalk and calcarenites of the Early Tertiary (Danian and Montian).

Water-table conditions exist over an area of about 240 km^2 but confined conditions prevail over some

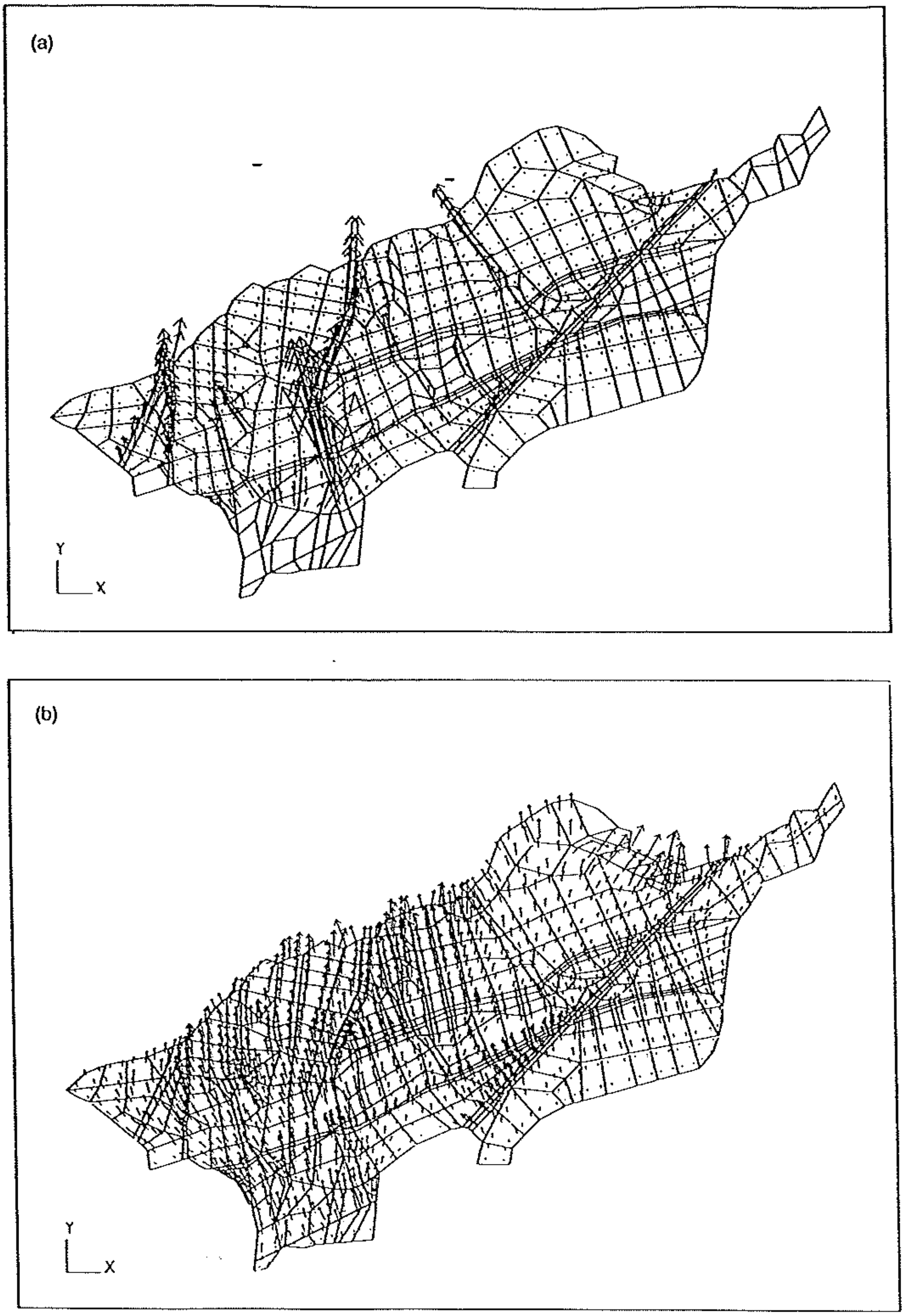

Fig. 8.13. Computed flows in (a) the 'lower chalk' and (b) the 'upper chalk' of the Hesbaye aquifer, in 1966.

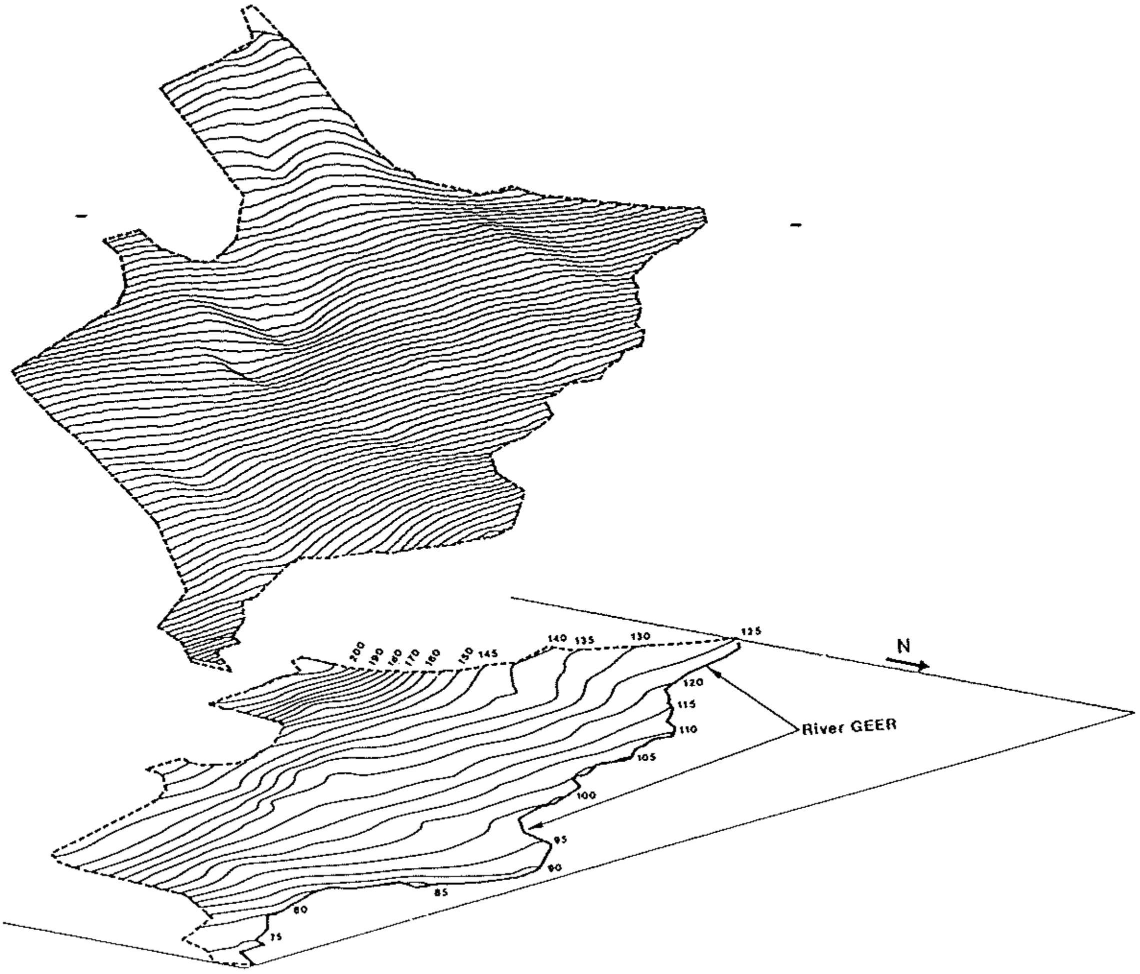

Fig. 8.14. Computed map of groundwater levels in the Hesbaye aquifer for 1984.

100 km^2 as a result of the presence of clays of the Ypresian, overlain by the silty and sandy formations of the Landenian (Fig. 8.17). The drawdown of groundwater levels due to abstraction has induced land subsidence where the aquifer is confined by Tertiary and alluvial clays and peats. In the Haine valley, drainage of peat lenses has induced severe differential settlement. Cumulative values for land subsidence due to water abstraction can attain 0.7–1.2 m.

The structure and thickness of the aquifer have been modified by synsedimentary subsidence during the Cretaceous period and by halokinetic migration in the underlying Palaeozoic rocks. As a consequence, the aquifer is relatively thin near its margins but in places it is as much as 200–400 m thick, especially near the centre of the basin. The vertical movements have led to the fracturing of the aquifer and the formation of peat in low-lying areas. Palaeokarst has developed in the fracture zones at the top of the Chalk and local uplifts of the Palaeozoic rocks have created barriers to groundwater flow within the Chalk, for example the Jemappes Sill, the Hornu Uplift and the Hensies Sill. The uplifts of impermeable bedrock divide the aquifer into compartments, and modify the general regional westerly flow (Calembert and Monjoie, 1975*a*). In 1907, the principal flow direction was towards the west, along the axis of the basin, but drawdowns of the groundwater level due to intensive pumping have accentuated the influence of the uplifts in the Palaeozoic basement on the flow

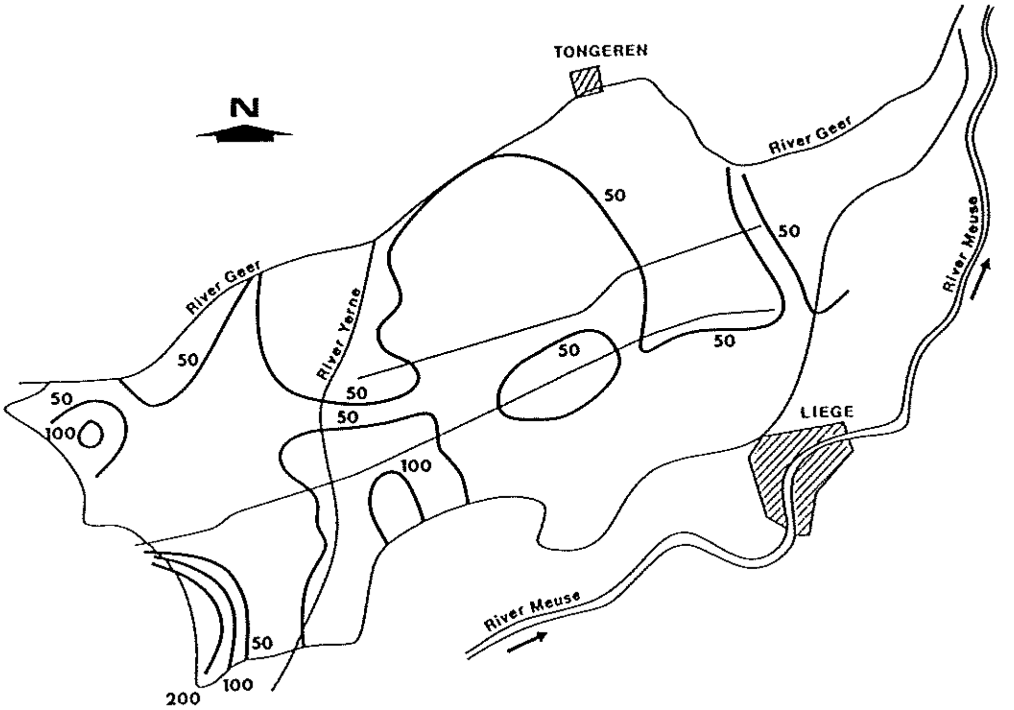

Fig. 8.15. Isoconcentration lines (in milligrams per litre) for the nitrite ion *at the top* of the Hesbaye aquifer in 1984.

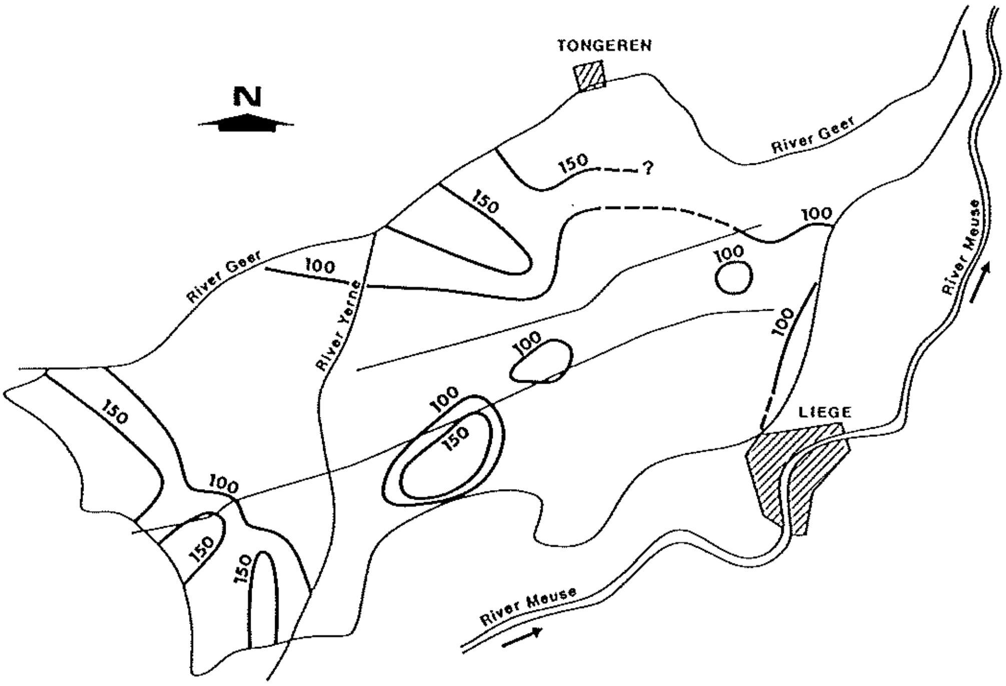

Fig. 8.16. Isoconcentration lines (in milligrams per litre) for the nitrate ion *at the top* of the Hesbaye aquifer in 1984.

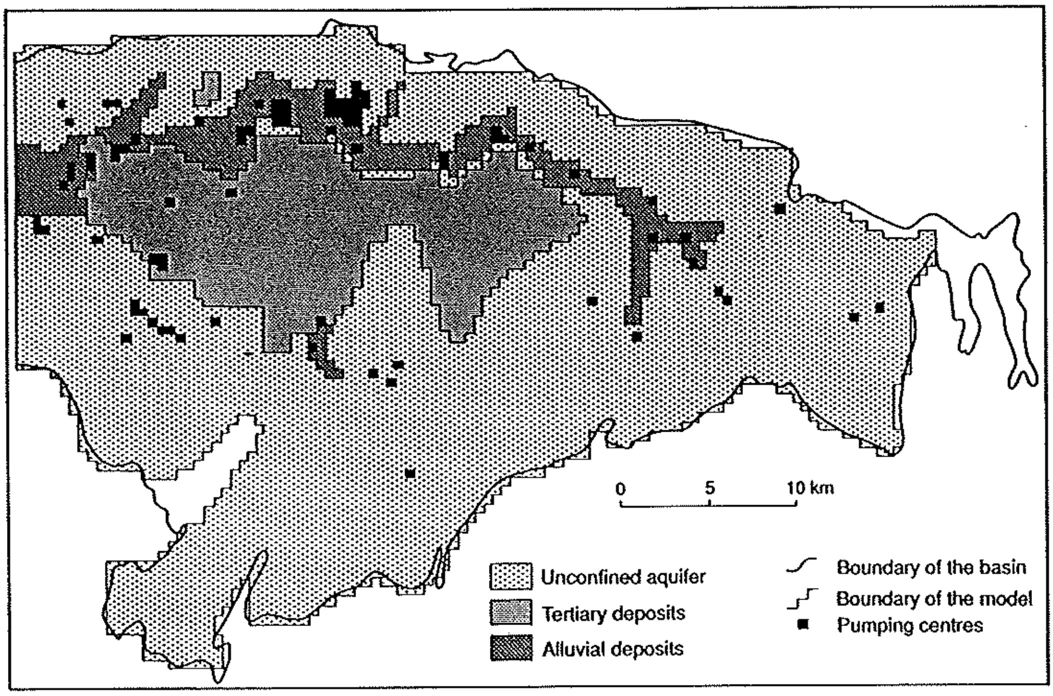

Fig. 8.17. The Chalk aquifer of the Mons Basin showing the factors that affect the aquifer's behaviour (after Rorive 1987).

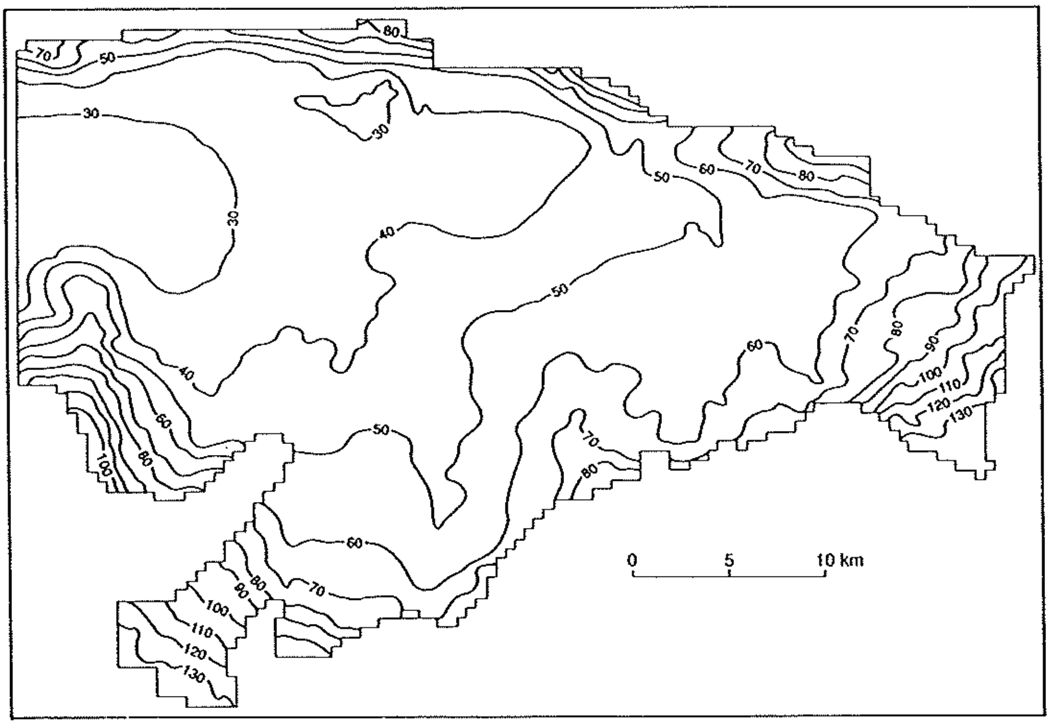

Fig. 8.18. Groundwater levels (in metres above sea level) in the Chalk of the Mons Basin (after Rorive 1987).

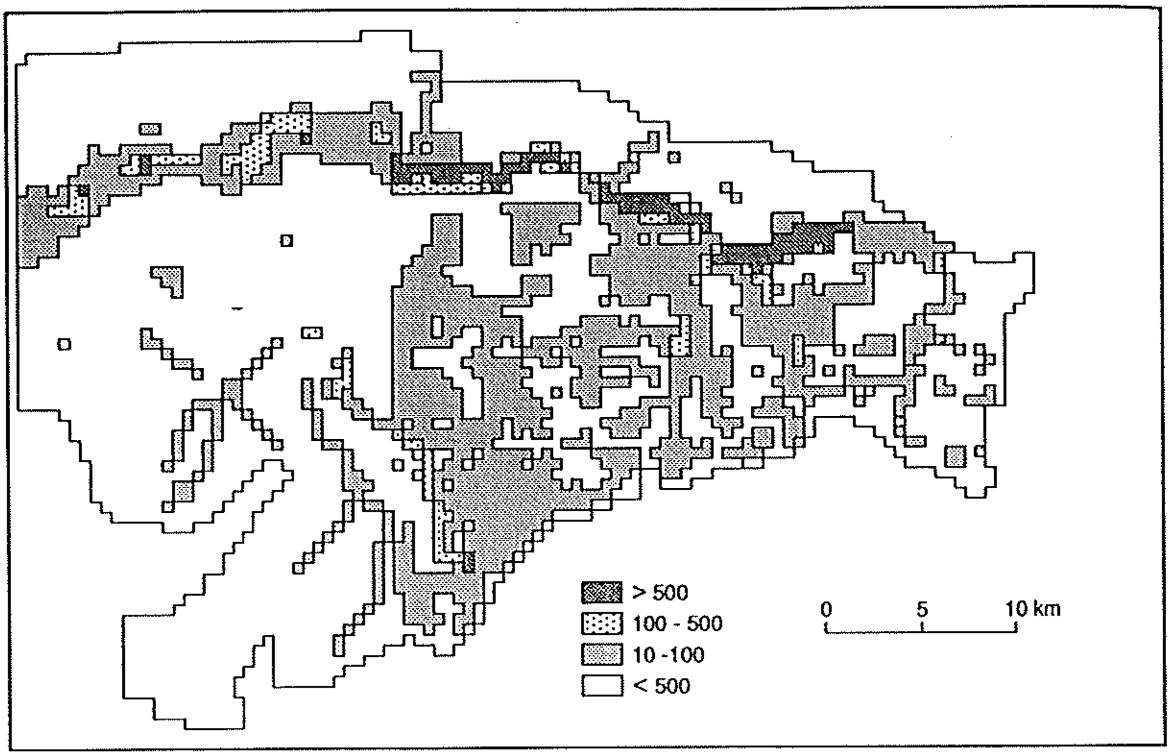

Fig. 8.19. The hydraulic conductivity of the Chalk in the Mons Basin deduced by calibrating a numerical model (after Rorive 1987). Units are $10^{-6}\,ms^{-1}$.

pattern between the different parts of the aquifer (Calembert and Monjoie 1975*b*)

The hydrogeological characteristics of the different lithological formations in the Mons Basin have been determined from about 100 pumping tests, and the mean values (Godfriaux and Rorive 1987) are as follows:

Peat	10^{-6} to $10^{-5}\,m\,s^{-1}$
Alluvial deposits of R. Haine	10^{-6}
Ypresian clay and clayey sand	10^{-9} to 10^{-8}
Landenian glauconitic or quartzitic sands	about 10^{-6}
Very fissured, palaeokarstic chalk	about 10^{-2}
Coarse-grained, fissured chalk	10^{-5} to 10^{-4}
Fine-grained chalk with virtually no fissures	5×10^{-10} to 5×10^{-8}

Because the saturated thickness of the Chalk is very variable, the transmissivity ranges from 6×10^{-4} to $8 \times 10^{-2}\,m^2\,s^{-1}$, while the storage coefficient is between 2.4×10^{-4} and 3×10^{-2}.

Since 1975, many studies of the nature of the Chalk aquifer have been made, and its behaviour has been simulated with a numerical model developed by the Polytechnical Faculty of Mons (Godfriaux and Rorive 1987; Derijcke 1978). The model is based on the finite-difference method and uses the Trepila program of the US Geological Survey. It is a two-dimensional model with a cell dimension representing about 250 m. Transient simulation takes into account unconfined, semi-confined and confined conditions (Fig 8.17). Monthly (and sometimes annual) measurements of water level at 300 locations, together with historical data for about 2000 sites, have been used in the model.

It has been calibrated by trial and error using historical groundwater levels while ensuring that the overall total flow through the aquifer is correctly balanced. Computed and measured water levels agree within 1 m in the unconfined and confined zones and within 2–3 m in the semi-confined zone (Fig. 8.18). The spatial distribution of hydraulic conductivity of the Chalk, as deduced from the model, is shown in Fig. 8.19; the high values along the axis of the basin are very evident as well as the generally higher values in the eastern part of the basin.

The model allows the computation, in each cell, of the recharge, abstraction by pumping, and lateral transfer and leakage between cells. It is a vital tool for the optimum management of the water resource of the Mons Basin and it can take into account the important aspect of land-surface settlement induced by the fall in groundwater levels and the consequent consolidation of the superficial peaty layers.

Confined aquifer in northern Belgium

In the north of Belgium, the Cretaceous, particularly the Maastrichtian, is covered by Tertiary deposits and a large confined aquifer exists, covering an area of 824 km^2 in Flanders, the Campine and part of Limburg. Some $5 \times 10^6 m^3$ of water are pumped annually to supply the Kempen area (Derijcke 1978), with over $9 \times 10^6 m^3$ near Brussels and $12 \times 10^6 m^3$ at Wavre, Jodoigne and Perwez in Brabant. The mean hydraulic conductivity of the Chalk is estimated to be about $10^{-4} m s^{-1}$. The geological sequence is:

- Tertiary—silts, sands and clays, 300–600 m thick, with a marl at least 20 m thick at the base which forms the top of the confined Chalk aquifer.
- Cretaceous—chalks with a thickness of 200–300 m.
- Herve Formation (Lower Campanian)—a marl, 20–50 m thick, that passes laterally into sand and clayey sand of the Aachen Formation.
- Permo-Triassic—occurs locally, mainly in the north-east.
- Carboniferous—shales and sandstones with interbedded coals.

These deposits dip between 1 in 50 and 1 in 10 to the north. They are intersected by many sub-vertical faults orientated NW–SE and NNW–SSE that have created a horst and graben structural pattern (Fig. 8.6). There is also a conjugate NE–SW fault system. Coal has been extensively mined in the past and some mines are still operating in the Kempen area. Because of mining, settlement and subsidence have occurred in the lower part of the Chalk, producing preferential flow channels between the Chalk and underlying Carboniferous aquifer. Intensive pumping is necessary for mine-drainage purposes and as a consequence large volumes of groundwater flow from the Chalk into the Carboniferous. When the coalmines are finally closed there will be a risk that the direction of flow will reverse and acid waters, with high iron and sulphate contents, will flow from the Carboniferous into the Chalk.

Chemical composition of the groundwater

Where the Chalk crops out, the groundwater in the aquifer is of the calcium bicarbonate type and it has a high calcium hardness. Below the Tertiary cover, hard waters persist initially but ion exchange gradually converts the water into a sodium bicarbonate type. In the north of the country, north of Brussels, and in Flanders and around Antwerp, the water is saline (Fig. 8.7).

Steadily rising contamination by nitrate is a feature of the Chalk's outcrop, particularly in the upper part of the aquifer. Water-supply distribution systems are now designed so that the nitrate content can be reduced by mixing groundwater with water from surface reservoirs. Although few data are currently available, pesticides are likely to become an increasing problem in the future. At present one of the main causes of groundwater contamination is leakage of oil and its by-products from literally thousands of storage tanks. This problem is being compounded by more and more accidents involving oil-carrying road tankers.