# Ecostream, a Response Model for Aquatic Ecosystems in Lowland Streams

# 6. Ecostream, a Response Model for Aquatic Ecosystems in Lowland Streams

H. Olde Venterink
N. M. Pieterse
M.J. Wassen
A.W.M. Verkroost

*Demonstration project for the Development of Integrated Management Plans for Catchment Areas of Small Trans-Border Lowland Rivers: the River Dommel*

*Administrative project leader: Ir. A. Span (Province of North Brabant, NL)*
*Scientific project leader: Dr. A.W.M. Verkroost (Utrecht University, NL)*



*PO Box 80115*
*3508 TC Utrecht,*
*The Netherlands*



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## *Preface*

This publication is part of a series of technical reports concerning the EU-LIFE Dommel demonstration project for the development of integrated management plans of small trans-border lowland rivers. For this project an integrated model was developed. The structure of this model is shown in the next figure. For further information about the project is referred to the first report in this series: Ecohydrological Modelling and Integrated Management Planning in the Catchment Area of the River Dommel.

The project was supervised by a committee in which the following persons participated:

| | |
|---|---|
| A.S.W. Span (chaiwoman) | Province of North Brabant, The Netherlands |
| J.S. ten Veldhuis (secretary) | Province of North Brabant, The Netherlands |
| A.W.M. Mol | Province of North Brabant, The Netherlands |
| J. Hemelraad | Water board the Dommel, The Netherlands |
| Y. Ronse | Flemish Environmental Company (VMM), Belgium |
| M. Lambrichts | Administration for Environment , Nature and Land Use (AMINAL), Belgium |
| G. Lambrechts | Administration for Environment , Nature and Land Use (AMINAL), Belgium |
| G. Vanderwaeren | Administration for Environment , Nature and Land Use (AMINAL), Belgium |
| H. Awouters | Province of Limburg, Belgium |
| J. van Rijen | Ministry of Agriculture, Nature Conservation and Fisheries (LNV), The Netherlands |

# *Summary*

In this report the model ECOSTREAM is presented. ECOSTREAM was constructed with the aim to develop an instrument by which interventions in the landscape and changes in water quality can be assessed on aquatic ecosystems in lowland streams.

The Aquatic Ecotope system Types (AET), as developed at the DLO-Institute for Forestry and Nature Management (IBN-DLO) and the Centre for Environmental Science (CML) University of Leiden, serve as basic entities for ECOSTREAM. The construction of ECOSTREAM is primary based on aquatic invertebrates of lowland streams. The model concept of ECOSTREAM is based on decision rules and classification.

From a literature study major differentiating environmental variables for aquatic invertebrates in lowland streams were distinguished. These major variables are: stream dimensions (position in the catchment, and whether or not dry periods in summer), current velocity, and saprobic state of the surface water. The aquatic ecotope types were ordered in a 3D- matrix with these variables along the axes. The decision rules of ECOSTREAM are focused on these environmental variables. The model ECOSTREAM is developed in cooperation with the model STREAMFLOW, which simulates the environmental variables.

ECOSTREAM simulations are carried out for streams of the river Dommel catchment and are compared with the distribution of a measured biotic index in this catchment. This biotic index is determined by means of the indication value of aquatic invertebrates for especially organic pollution of the surface water. It can therefore be used as a biotic reference for the saprobic state simulation. Because the simulated ecotope types correspond well with the observed distribution of the biotic index in the field, it is concluded that the saprobic state part of ECOSTREAM functions appropriately. For a complete validation of ECOSTREAM, simulated ecotope types should be compared with observed ecotope types in the field. The necessary data for this purpose, however, are not available for the Dommel catchment.

# *Samenvatting*


In dit rapport wordt het model ECOSTREAM beproken. Het ontwikkelen van dit model had tot doel een instrument te verkrijgen waarmee de effecten van ingrepen in het landschap kunnen worden ingeschat op aquatische ecosystemen in laaglandbeken.

Als basis-eenheden voor ECOSTREAM dienen de Aquatische Ecotoop systeem Typen (AET), die zijn ontwikkeld bij het IBN-DLO en het CML. De ontwikkeling van ECOSTREAM is primair gebaseerd op macrofauna gemeenschappen in laaglandbeken. Het model concept van ECOSTREAM is gebaseerd op beslisregels en classificatie.

Op basis van een literatuurstudie zijn de belangrijkste differentiërende milieu-variabelen voor macrofauna in laaglandbeken onderscheiden. Deze hoofdvariabelen zijn: beekdimensies (positie in het stroomgebied, en al dan niet droogvallen in de zomer), stroomsnelheid en saprobiegraad van het oppervlaktewater. De AET werden geordend in een 3D-matrix met deze hoofdvariabelen op de assen. Beslisregels in ECOSTREAM zijn ook gericht op deze milieu-variabelen. Het model ECOSTREAM is ontwikkeld in samenhang met het model STREAMFLOW dat de voorspelling van de milieu-variabelen verzorgt.

ECOSTREAM simulaties werden uitgevoerd voor beken in het stroomgebied van de Dommel. De simulaties werden vergeleken met de verspreiding van een gemeten biotische index in het stroomgebied. Deze biotische index wordt bepaald op basis van de indicatie waarde van macrofauna voor vooral de organische belasting van het oppervlaktewater. Het is daarom geschikt als biotische referentie voor de saprobie-graad simulatie. Omdat de gesimuleerde verspreiding van ecotoop typen goed overeenkomt met de waargenomen verspreiding van de biotische index in het veld, is geconcludeerd dat het saprobie gedeelte van ECOSTREAM goed functioneert. Voor een volledige validatie van ECOSTREAM moeten gesimuleerde ecotoop typen worden vergeleken met veldwaarnemingen van ecotoop typen. De hiervoor benodigde data zijn echter niet beschikbaar voor het stroomgebied van de Dommel.

# *1. Introduction*

## *1.1 Physical-chemical characteristic of lowland streams*

### *1.1.1 Natural lowland streams*

Lowland streams are the typical type of running waters in The Netherlands (Higler & Verdonschot, 1993) and large parts of Flanders (e.g. Bervoets & Scheiders, 1990). Discharge of lowland streams fluctuates strongly because they are fed dominantly by precipitation and superficial groundwater flow (Moller Pillot, 1971; Gardeniers, 1981; Verdonschot, 1990a; Pieterse et al, 1998). Upper courses of the these streams can even fall dry in summer. The velocity of running water in the stream influences the size and distribution of substrate particles. Substrates in lowland streams range from gravel to silt and detritus in more quiet places, forming a continually changing mosaic pattern of micro habitats (Tolkamp, 1980; Gardeniers, 1981; Verdonschot, 1990a; Higler & Verdonschot, 1993). The longitudinal profile of a natural lowland stream meanders. The streambed is asymmetrical, differing from sandy shallows to strongly overhanging hollow banks. This complex of hydrological and morphological characteristics is called the 'stream-character' (Gardeniers, 1981; Verdonschot, 1990a). The upper courses of natural streams are mostly shaded by their riparian vegetation (Gardeniers, 1981; Higler & Verdonschot, 1993).

In general in natural lowland streams more or less gradual changes are found in physical variables from upper courses towards the lower course. Discharge, width, and depth increases towards the lower course because the catchment area increases; current velocity decreases because the slope decreases (e.g. Pieterse et al, 1998). In addition, in general gradual chemical changes of the water are found as well. For instance a gradual change can be found from oligotrophic conditions in the upper courses towards mesotrophic and in some cases eutrophic conditions in the lower course (Verdonschot et al, 1993; Higler et al, 1995; Mesters, 1997). This change of trophic state is related to the hydrological feeding; upper courses are primarily fed by nutrient-poor rainwater and superficial groundwater while in the direction of the middle courses and lower course the influence of more or less (dependent on the substrate) enriched deep groundwater becomes more important (e.g. Grootjans et al, 1985; Verdonschot et al, 1993; Higler & Verdonschot, 1993).

### *1.1.2 Lowland streams in The Netherlands and Flanders at the end of the 20$^{th}$ century*

In contrast to the picture of natural lowland streams, nowadays the overall picture of streams in The Netherlands and Flanders is that of neat channels with dry banks or even low dikes embedded in intensively used agricultural land (Higler & Verdonschot, 1993; Higler et al, 1995; Bervoets & Schneiders, 1990b). Only 2% of the total length of streams in Overijssel (Nl) has a natural stream character (Verdonschot, 1990), only 6% of the streams in the Achterhoek (Nl) can be considered as the original type of lowland stream (Gardeniers, 1981), and only 6 out of 116 investigated streams in Noord-Brabant (Nl) were characterized as more or less natural (Mol, 1986). A comparable situation is shown for lowland streams in Flanders (e.g. Bervoets & Schneiders, 1990b). These low percentages of natural lowland streams are the result of regulation of streams, which started in the twenties and thirties of this century and was continued at a very large scale after the second world war, to improve drainage of agricultural land (Gardeniers, 1981; Higler et al, 1995). Regulation of streams means straightening of bends, and deepening and widening of the streambed. In addition trees and shrubs on the banks are cut and aquatic vegetation is removed 2-8 times a year. The banks are often consolidated with nylon matting, concrete blocks or wooden frames, to assure an unhampered discharge. Finally movable weirs are placed in the streams to hold the water in times of low discharge. The result of regulation is a channel with reverse characteristics to those of a typical lowland stream. The disappearance of meandering and the reduction of fluctuations of water level and current velocity leads to (almost) stagnant water and a uniform and mostly muddy bottom (sapropel layer) (Gardeniers, 1981; Verdonschot, 1990).

Besides the negative effects of regulation (or normalization), stream ecosystems are affected by water pollution. Pollution disturbs the natural gradient in lowland streams; nutrients and organic matter increase in water and sediment in all stream reaches, habitat conditions and subsequent aquatic ecosystems are equalized throughout the stream (Higler et al, 1995; Gardeniers & Peeters, 1992); lower course conditions are created in the entire stream (Mesters, 1997). There are two main types of pollution sources: point sources and diffuse sources. The major point sources are effluents of: sewage plants, non-treated sewages, industrial sewage, and agricultural drains (Higler et al, 1995). The effluents of sewage plants and agricultural drains pollute the surface water with nutrients causing eutrophication. The share of diffuse pollution to eutrophication of surface water however is unknown.

## *1.2 Aquatic invertebrates and vegetation of lowland streams*

### *1.2.1 Natural lowland streams*

Because the water is running and discharges fluctuate in natural lowland streams, its ecosystems contain especially plant and animal species adapted to these dynamic habitat conditions (Moller Pillot, 1971). Due to differences in current velocity and morphology in the cross section of a meandering stream different habitat conditions are created. This give rise to a high biodiversity.

Compared to hill streams, lowland streams have a relatively low current velocity which is reflected by the absence of typical rheophilic invertebrate species with a flattened or streamlined body (Higler & Verdonschot, 1993). However, although the current velocity of natural lowland streams is relatively low, the greater part of aquatic invertebrate communities of these streams consist of species with a preference of running water (Gardeniers, 1981). Most taxa of aquatic invertebrates are burrowers and sprawlers in and on the sandy and silty substrates, and clingers and climbers in leaf packets and aquatic vegetation. Swimmers become more important in the lower courses, where streams become deeper (fig. 1; Verdonschot, 1990a; Higler & Verdonschot, 1993). Other differences in invertebrate community composition related to the position within the catchment are observed with regard to the frequency of different types of functional feeding groups (e.g. fig. 2). Although the issue is confused because figure 2 contains a large number of observations from non-natural streams, a tendency is shown from organisms which utilize the dominating leaf input (shredders and gathering collectors) at the forested upper courses towards an increased importance of scrapers and filtering collectors at middle and lower courses were primary production becomes more important (fig 2; Higler & Verdonschot, 1993; Verdonschot et al, 1993).

In unshaded sites of streams different macrophyte species occur, reflecting the physical and chemical stream zonation. A range of species and growth forms is observed from merely submerged species in the relatively faster flowing upper courses, via submerged and floating-leaved species in wider and slower flowing zones, to emergent species in the lower courses (Westlake, 1973 cited in Mesters, 1997).

***Figure 1.*** *Frequency of habit types of aquatic invertebrates in lowland streams in the province of Overijssel. Data from Verdonschot (1990) / Higler & Verdonschot (1993)*

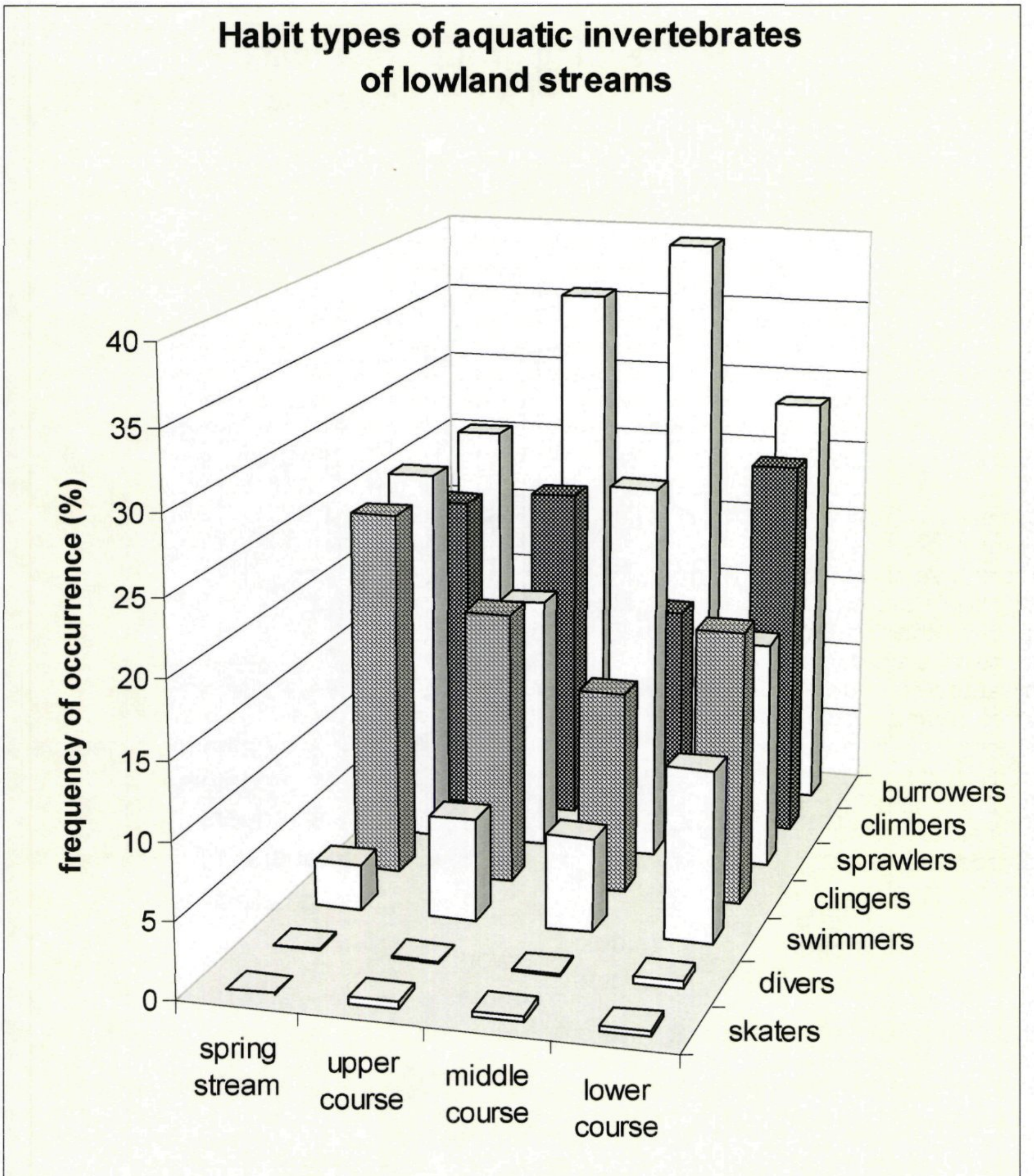
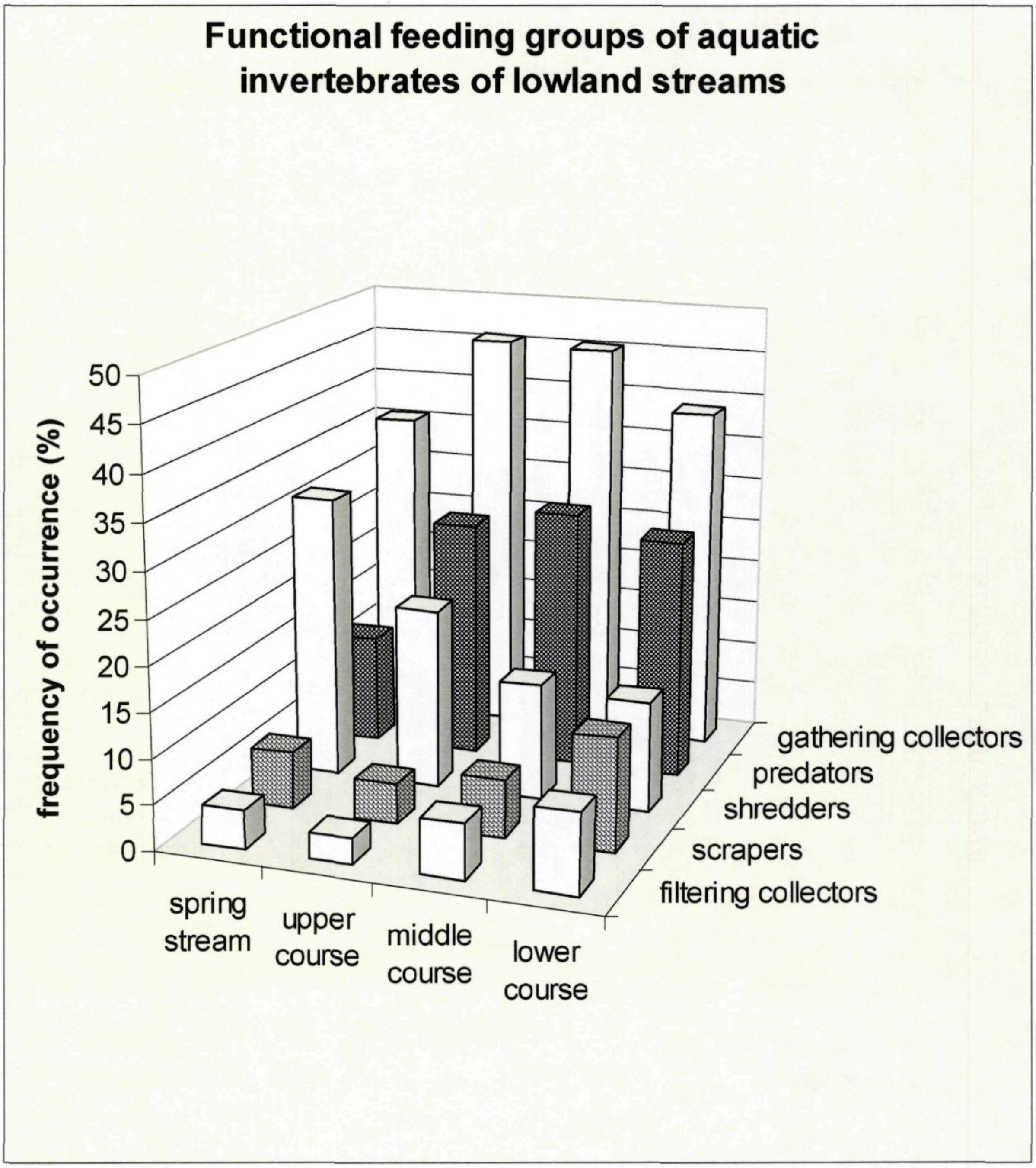


***Figure 2.*** *Frequency of functional feeding groups of aquatic invertebrates in lowland streams in the province of Overijssel. Data from Verdonschot (1990) / Higler & Verdonschot (1993)*



### *1.2.2 Lowland streams in The Netherlands and Flanders at the end of the 20th century*

In contrast to natural streams, regulated streams contain especially very common invertebrate species of ditches and other stagnant waters (Gardeniers, 1981). From a comparison of invertebrate species composition between a regulated- and a natural section of the Stuwbeek (Achterhoek, The Netherlands) it was found that in the regulated section about 90% of the species were species with a preference for stagnant- to running water, while only about 1% were species with a preference for running to stagnant water. In the natural section only 7% were species with a preference for stagnant water, and 91% were species with a preference for running water of which also 91% were species which are only found in running water (Gardeniers, 1981). In addition, in most regulated streams species tolerant to eutrophication and organic pollution are found (Verdonschot, 1990; Higler et al, 1995).

From a comparison of the macrophyte vegetation composition of 28 transboundary streams with historical data, Mesters (1995; 1997) observed a loss of characteristic stream species which are sensitive to turbidity, eutrophication and turbidity. Species, not common in streams but tolerant to turbidity, eutrophication or eutrophication appeared or increased in abundance. In addition Mesters (1995; 1997) also observed a shift in growth forms; submerged species decreased or were replaced by emergent or floating-leaved species, but this shift could not be explained with the environmental variables she measured.

## *1.3 In search for differentiating environmental variables between aquatic ecosystems*

A large number of environmental variables affect habitat conditions of lowland streams and subsequently aquatic ecosystems. During the last decade a number of studies are carried out to distinguish the major differentiating environmental variables for aquatic invertebrates (Verdonschot, 1990a; 1990b; Bervoets & Schneiders, 1990b; Gardeniers & Peeters 1992; Ter Braak & Verdonschot, 1995), and for aquatic vegetation (Bervoets & Schneiders, 1990b; Mesters, 1997) using canonical correspondence analysis or related statistical techniques.

Major differentiating environmental variables for the occurrence of aquatic invertebrates are: stream dimensions or the position within the catchment (upper/middle/lower course) (Verdonschot, 1990a; 1990b; Gardeniers & Peeters 1992; Ter Braak & Verdonschot, 1995), current velocity, saprobic state, temporality (whether a stream runs dry or not) (Verdonschot, 1990a; 1990b; Gardeniers & Peeters 1992), acidity (Gardeniers & Peeters 1992), and the presence of shrubs or trees on the banks (Ter Braak & Verdonschot, 1995). Other environmental variables are of less importance (nutrient concentrations of the water) or are related to the major variables (e.g. relationship 'stream-character', oxygen content of the water and thickness of the sapropel layer to current velocity)

From correlations between vegetation composition of lowland streams and environmental variables Mesters (1997) concluded that the degree of deterioration of the natural stream vegetation zonation depends on the amount and the chemical composition of wastewater. The most important environmental variables are: turbidity and saprobic state of the water, thickness of the sapropel layer, and nutrient and heavy metal availability of the sediment.

## *1.4 Towards an ecological prediction model for lowland streams*

Considering natural lowland streams or even natural parts of lowland streams as rare in The Netherlands and Flanders, further degradation of these important contributors to the landscape should be avoided. Therefore it is of great importance to enable policy makers to assess the impact of interventions in the landscape and on pollution sources on stream ecosystems. This becomes even more important in the light of restoration- and anti-desiccation projects for the benefit of (semi)-terrestrial ecosystems in the stream valleys, which might have negative consequences for aquatic ecosystems in the streams.

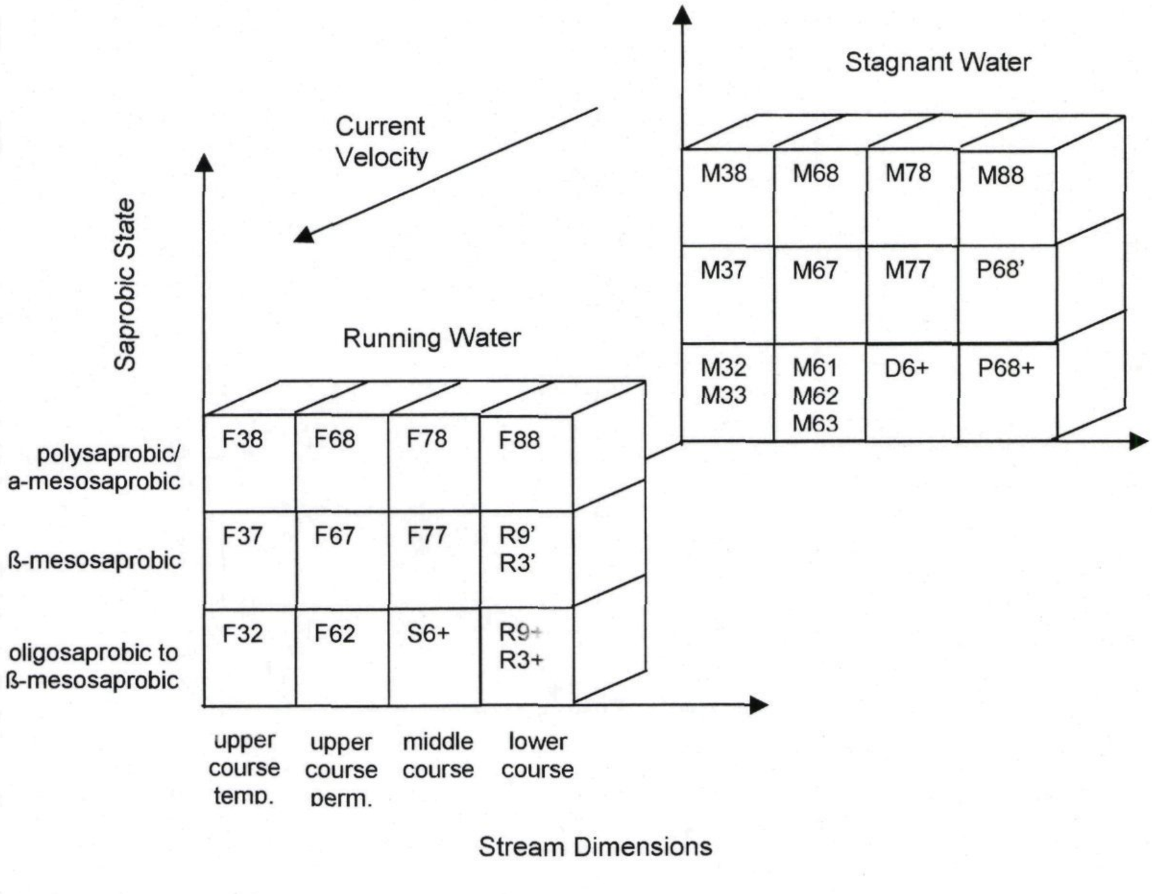
The aim of this study is to develop the model ECOSTREAM by which interventions in the landscape and changes in water quality can be assessed on aquatic ecosystems in lowland streams. For the construction of this model the Aquatic Ecotope system Types (AET), as developed at the DLO-Institute for Forestry and Nature Management (IBN-DLO) and the Centre for Environmental Science (CML) University of Leiden (Verdonschot et al, 1992), will serve as basic entities. The aquatic ecotope system is a classification of aquatic ecosystems specially developed for the purpose of effect predicting (e.g.van der Hoek & Verdonschot, 1994b). Although the AET contain characteristic macrophyte and fish species (e.g. appendix I; van der Hoek & Verdonschot, 1994a), the system is primary based on aquatic invertebrates. Therefore the model ECOSTREAM, and subsequently this report, will also focus on aquatic invertebrates. By using the AET the model ECOSTREAM will benefit from the obtained knowledge and experience, and will be easy to match with other AET-using projects. Finally, aquatic ecosystems of streams in the catchment area of the river Dommel (Belgium/The Netherlands) will be simulated with ECOSTREAM and compared with field observations.

# 2. ECOSTREAM

## 2.1 The model concept

Figure 3 shows the model concept of ECOSTREAM. Basic entities of the model are the aquatic ecotope types (series F and M) as developed by Verdonschot et al (1992) completed with types classified for the river Dinkel (R, P, S types; Verdonschot et al, 1993; D6+; Verdonschot, pers. comm.). The F, R, and S types are ecosystems of lowland streams with running water. The M, P, and D types represent ecosystems of stagnant surface water like pools, ditches, canals and old river branches. Within ecosystems of regulated streams with stagnant or very slow running water, species of these M, P, and S types will dominate over species of streams with running water.

***Figure 3.*** *Schematic presentation of the ECOSTREAM model concept. Basic entities of the model are the aquatic ecotope types (series F and M) as developed by Verdonschot et al (1992) completed with types classified for the river Dinkel (R, P, S types; Verdonschot et al, 1993; D6+;Verdonschot pers. comm.). Based on the position within the catchment, whether a stream is permanent or runs dry (temporal), whether the stream contains running or stagnant water, and the saprobic state of the water, different aquatic ecosystems are predicted. For a list of characteristic aquatic invertebrate-, macrophyte-, and fish species of the different types is referred to appendix I.*



In figure 3 the aquatic ecotope types are ranked according to three environmental axes; stream dimensions, current velocity and saprobic state. On the X-axes the aquatic ecosystems are divided in ecotope types of permanent streams and streams which run dry during summer (temporal), and in types of upper courses, middle courses, and lower courses/small rivers. On the Z-axes the aquatic ecosystems are divided in ecotope types of streams with running water and of (regulated) streams with stagnant or very slow running water. On the Y-axes aquatic ecosystems are grouped into ecotope types on the basis of saprobic state of the water.

***Table 1.*** *Survey of aquatic ecotope types (series F and M) as developed by Verdonschot et al (1992) completed with types classified for the river Dinkel (R, P, S types; Verdonschot et al, 1993; D6+; Verdonschot, pers. comm.), with descriptions of their correlating environmental conditions. (based on Verdonschot et al, 1992; 1993; Van der Hoek & Verdonschot, 1994; Verdonschot, personal communication)*

| AET | course | temporal/ permanent | running/ stagnant | saprobic state | trophic state | acidity |
|---|---|---|---|---|---|---|
| F32 | upper | temporal | running | oligosaprobic to β-mesosaprobic | oligotrophic | acid |
| F37 | upper | temporal | running | β-mesosaprobic | mesotrophic | not acid |
| F38 | upper | temporal | running | α-mesosaprobic to polysaprobic | eutrophic | not acid |
| F62 | upper | permanent | running | oligosaprobic to β-mesosaprobic | oligotrophic | acid |
| F67 | upper | permanent | running | β-mesosaprobic | mesotrophic | not acid |
| F68 | upper | permanent | running | α-mesosaprobic to polysaprobic | eutrophic | not acid |
| S6+ | middle | permanent | running | oligosaprobic to β-mesosaprobic | mesotrophic | not acid |
| F77 | middle | permanent | running | β-mesosaprobic | mesotrophic | not acid |
| F78 | middle | permanent | running | α-mesosaprobic to polysaprobic | eutrophic | not acid |
| R3+ | small river | permanent | running | oligosaprobic to β-mesosaprobic | mesotrophic | not acid |
| R9+ | lower | permanent | running | oligosaprobic to β-mesosaprobic | mesotrophic | not acid |
| R3' | small river | permanent | running | β-mesosaprobic | eutrophic | not acid |
| R9' | lower | permanent | running | β-mesosaprobic | eutrophic | not acid |
| F88 | lower | permanent | running | α-mesosaprobic to polysaprobic | eutrophic | not acid |
| M32 | upper | temporal | stagnant | oligosaprobic to β-mesosaprobic | oligotrophic | acid |
| M33 | upper | temporal | stagnant | oligosaprobic to β-mesosaprobic | oligotrophic | not acid |
| M37 | upper | temporal | stagnant | β-mesosaprobic | mesotrophic | not acid |
| M38 | upper | temporal | stagnant | α-mesosaprobic to polysaprobic | eutrophic | not acid |
| M61 | upper | permanent | stagnant | oligosaprobic to β-mesosaprobic | oligotrophic | very acid |
| M62 | upper | permanent | stagnant | oligosaprobic to β-mesosaprobic | oligotrophic | acid |
| M63 | upper | permanent | stagnant | oligosaprobic to β-mesosaprobic | oligotrophic | not acid |
| M67 | upper | permanent | stagnant | β-mesosaprobic | mesotrophic | not acid |
| M68 | upper | permanent | stagnant | α-mesosaprobic to polysaprobic | eutrophic | not acid |
| D6+ | middle | permanent | stagnant | oligosaprobic to β-mesosaprobic | mesotrophic | not acid |
| M77 | middle | permanent | stagnant | β-mesosaprobic | mesotrophic | not acid |
| M78 | middle | permanent | stagnant | α-mesosaprobic to polysaprobic | eutrophic | not acid |
| P68+ | lower | permanent | stagnant | oligosaprobic to β-mesosaprobic | mesotrophic | not acid |
| P68' | lower | permanent | stagnant | β-mesosaprobic | eutrophic | not acid |
| M88 | lower | permanent | stagnant | α-mesosaprobic to polysaprobic | eutrophic | not acid |

Verdonschot et al (1992) classified aquatic ecotope types on a combination of the water quality variables: saprobic state, acidity and trophic state (e.g. table 1). They not only constructed aquatic ecotope types for lowland streams, but for all surface water types in the Netherlands. For lowland streams, saprobic state is the most differentiating water quality variable (Verdonschot, 1990a; 1990b; Gardeniers & Peeters, 1992). Therefore in ECOSTREAM saprobic state is obtained as the only water quality variable; it covers almost entirely the water quality variation between the aquatic ecotope types. Only for stagnant, oligosaprobic to β-mesosaprobic upper courses, different ecotope types are divided on the base of acidity (table 1). Because of the stagnancy of the water, these types are already considered as degradation stages of natural streams. Therefore acidity is not included in ECOSTREAM.

The environmental variables: stream dimensions, temporality, current velocity, and saprobic state are also designated as the main differentiating factors in two comprehensive studies about correlations between aquatic invertebrates and environmental conditions in Dutch lowland streams (Verdonschot et al, 1990a; 1990b; Gardeniers & Peeters, 1992). For spring streams and streams of chalk-rich areas, acidity (Verdonschot, 1990a; Bervoets & Schneiders, 1990b) or $Ca^{2+}/HCO_3^-$ concentrations (Bervoets & Schneiders, 1990b) can be differentiating between ecosystem types as well, but these stream types are beyond the scope of this study.

The model ECOSTREAM predicts the occurrence of aquatic ecotope types of lowland streams on the base of the variables: stream dimensions, temporality, current velocity and saprobic state of the water. The next paragraphs deal with classification methods and borders for these environmental variables.

## 2.2 Stream dimensions

The variable stream dimensions represents the hydraulic characteristics of a stream segment. In general, for the variable stream dimensions, streams are divided into upper, middle and lower courses. Mostly stream width—sometimes in relation to stream depth or stream order—are used to classify the different stream segments. There are different opinions about the classification borders based on stream width (e.g table 2). Stream width also considerably varies within stream segments (table 2). A more appropriate measure for a differentiation between the hydraulic characteristics of upper-, middle-, and lower courses is the size of the catchment area (e.g. Pieterse et al. 1998; section 3.1).

***Table 2****. Classification of lowland streams based on stream-width. Values are presented in meters.*

| *reference* | spring/ small stream | upper course stream | middle course stream | lower course stream/ small river |
|---|---|---|---|---|
| *Moller Pillot, 1971* | | 3 - 5 | 5 - 10 | > 15 |
| *Verdonschot, 1990b* | 0.5 - 1.5 | 1.5 - 3 | 3 - 5 | 5 - 10 |
| *Verdonschot et al, 1992* | | < 8 | 5 - 25 | > 20 |
| *Gardeniers & Peeters, 1992* | | < 3 | 3 - 10 | > 10 |
| *Higler & Verdonschot, 1993* | | 0.5 - 5* | 5 - 10** | > 10*** |
| *Verdonschot et al, 1993#* | 0.2 - 1.8 | 0.9 - 4.8 | 0.1? - 9.0 | 5 - 41 |
| *Runhaar & Klijn, 1993* | | < 3 | 3 - 15 | 10 - 50 |
| *Van der Hoek & Higler, 1993* | | 0.2 - 1 | 0.5 - 5 | 2.5 - 10 |

stream order:*1-3; **3-4;*** >4

# minimum and maximum values of measured widths

## 2.2 Permanency

According to this variable there are two types of streams. First, streams which contain water throughout the year (permanent streams), and second, streams which run dry in summer (temporal streams). Within the aquatic ecotope system, streams that run dry for at least 6 weeks per year, are considered temporal streams (Verdonschot et al, 1992). This class border is also used in ECOSTREAM.

## 2.3 Current velocity

Current velocity of stream water is assigned as a major differentiating variable for stream ecosystems in many studies (Verdonschot, 1990ab; Gardeniers & Peeters, 1992, and references therein). In ECOSTREAM two major groups of aquatic ecotope types are distinguished: ecosystems of streams with running water throughout the year and ecosystems of streams with at least a part of the year stagnant water. In contrast to streams with running water throughout the year, streams with periods of stagnant water contain especially very common invertebrate species of ditches and other stagnant waters.

Natural lowland streams in general have a current velocity of 20-60 cm/s, while regulated lowland streams have a current velocity of less then 20-30 cm/s (e.g. table 3). At first sight, the decrease of current velocity in lowland streams after regulation seems strange because regulation shortens the length of the stream and therefore increases the slope and subsequently the current velocity. For instance the length of the Belgian part of the Dommel was shortened by 11% (3.65 km) because of regulation (Bervoets & Schneiders, 1990b). However straightening of streams is accompanied by the construction of weirs within the regulation process. Therefore, difference in relief is no longer gradually distributed over the whole streams, but for a large part located at the weirs. In the example of the Belgian part of the Dommel, 4 water mills and 10 weirs in total cause a difference in relief of 14.27 m (Bervoets & Schneiders, 1990b). This equals about 40% of the total difference in relief. For the Belgian part of the Dommel straightening of the stream increased the slope from 0.11% to 0.12%. However after correcting for the 14.27 m loss of height at water mills and weirs, the actual slope for the stream decreased with 60% from 0.11% to 0.07%.

Differences in current velocity between water in regulated and natural lowland streams are caused by the construction of weirs in regulated streams. In front of weirs, a zone with very slow running or stagnant water is created in periods of low discharge, because the weir creates a slope for the stream of near to 0%.The length of this zone depends on the height of the weir (e.g. Pieterse et al, 1998). Within these zones the current velocity is slower than 5-20 cm/s (Verdonschot, 1990a). Natural lowland streams in general have a current velocity of 10 - 100 cm/s, but a velocity of 5- 20 cm/s in summer. Verdonschot et al (1992) use a class border of 10 cm/s for differentiation between ecotope types of running - and stagnant waters. This class border is also used In ECOSTREAM to distinguish between aquatic ecotope types of streams with running water throughout the year and ecosystems of streams with at least a part of the year stagnant water.

***Table 3**. Current velocity of lowland streams (in cm/s).*

| *reference* | natural streams | | | regulated streams |
|---|---|---|---|---|
| | general | summer | winter | |
| *Moller-Pillot, 1971* | | 20 - 50 | | |
| *Gardeniers, 1981* | | 5 - 20 | 30 - 60 | |
| *Verdonschot, 1990a (p 26)* | > 20 | | | 0 - 20 |
| *(p 93)* | | 5 - 30 | 30 - 60 (100) | < 5 |
| *Verdonschot et al, 1992* | 10 - 100 | | | < 20 |
| *Gardeniers & Peeters, 1992 (P1-P10)* | 15 - 45 | | | 0 - 30 |
| *(E1-E5)* | 35 - 60 | | | |
| *Runhaar & Klijn, 1993 (upper course)* | 20 - 40 | | | |
| *(middle course)* | 25 - 65 | | | |
| *(lower course)* | 10 - 60 | | | |

## 2.5 Saprobic state

The saprobic state is a measure for the load of organic matter of surface water (Haslam, 1990; Schwoerbel, 1977). The most important influence of the saprobic state on aquatic ecosystems of streams is its effect on the oxygen availability. Degradation of organic matter demands oxygen which, especially in slow-running or stagnant water, may lead to a shortage of oxygen for aquatic invertebrates. The variables biological oxygen demand (BOD), chemical oxygen demand (COD), and N-Kjeldahl—the sum of N-organic and $NH_4$-N—correlate well with the saprobic state and are therefore often used as indicators (e.g. Gardeniers & Peeters, 1992). For the aquatic ecotope system, and therefore also for ECOSTREAM the variable N-Kjeldahl is used. Table 4 shows the four saprobic state classes, the $NH_4$ class borders of Verdonschot (1990) and the derived class borders based on N-Kjeldahl. The aquatic ecotope system however does not strictly use these class borders. The α-mesosaprobic and polysaprobic classes are combined to one class, and ecotope types of the less organic matter loaded sites are often described as 'oligosaprobic to β-mesosaprobic'. For this saprobic state class we estimated the class border at < 0.2 mg N/l. The classes and class borders used in ECOSTREAM are shown in table 5.

***Table 4**. Saprobic state classes and class borders (average annual concentrations); *from Verdonschot, 1990b; Verdonschot et al, 1992; **based on NH4 class-borders but corrected for N content of NH4 and an estimated NH4-N:N-organic ratio of approximately 4:1 (ratio is based on unpublished data of waterboard the Dommel)*

| saprobic state | NH4* (mg/l) | N-Kjeldahl** (mg N / l) |
|---|---|---|
| oligosaprobic | < 0.1 | < 0.1 |
| β-mesosaprobic | 0.1 - 0.5 | 0.1 - 0.5 |
| α-mesosaprobic | 0.5 - 4.0 | 0.5 - 4.0 |
| polysaprobic | > 4.0 | > 4.0 |

***Table 5**. Saprobic state classes and class borders (average annual concentrations) used in*

*ECOSTREAM.*

| saprobic state | N-Kjeldahl (mg N / l) |
|---|---|
| oligosaprobic to β-mesosaprobic | < 0.2 |
| β-mesosaprobic | 0.2 - 0.5 |
| α-mesosaprobic / polysaprobic | > 0.5 |

There is a complex relationship between saprobic state and trophic state of surface water. Degradation of organic matter increases the inorganic N pool within the aquatic ecosystem. High $NO_3$ and $PO_4$ concentrations in surface water in their turn may lead to explosive growth of algae. Death of these algae increases the saprobic state. This relationship between saprobic state and trophic state is not obtained in ECOSTREAM. For natural streams the impact of algae growth on saprobic state seems limited because in running water a strong accumulation of organic matter from algae growth is unlikely. In stagnant water zones of regulated streams the impact of algae growth on the saprobic state might become significant, especially in periods of low discharge and in stream segments without input of organic matter from non-treated sewages and sewage plants.

# 3. Application of ECOSTREAM in the River Dommel Catchment

## 3.1 Upper-, middle, and lower courses

By means of GIS-applications, Pieterse et al (1998) estimated the width of stream segments (500 m) within the river Dommel catchment (Belgium/The Netherlands) based on the catchment areas of the segments. First, for every stream segment, the size of the catchment area of which the segment receives water was determined. Next from the size of the catchment areas the width of the stream segments was assessed. Figure 4 shows the assessed upper, middle and lower courses of the streams of the Dommel catchment as determined by means of this method.
According to Verdonschot (1990b) upper courses have a stream width of < 3 m; middle courses are in between 3 and 5 m width, and lower courses or small rivers are wider than 5 m. When these class borders are used, the Dommel is called a lower course from Peer to 's Hertogenbosch. The stream width classes however are based on minimal values mostly obtained from regulated streams which are deepened by man and much smaller than natural streams (Verdonschot, pers. comm.). Classification of the aquatic ecotope types for upper, middle and lower courses is based on position in the catchment and subsequently the hydraulic characteristics (Verdonschot, pers. comm.). This general pattern of upper, middle, and lower courses in the Dommel catchment is found when the class borders of Gardeniers & Peeters are used (e.g. table 2 and figure 4).

## 3.2 Permanent- and summer-dry stream segments

The differentiation between permanent stream segments and segments that fall dry for at least six weeks per year is simulated by means of the model STREAMFLOW (Pieterse et al, 1998). The result of this simulation is shown in figure 5. From almost half of all upper courses, the upper parts fall dry in summer. The simulated intermittent segment of the Dommel in Eindhoven is considered an artefact of STREAMFLOW (e.g. Pieterse et al, 1998).

## 3.3 Current velocity

The differentiation between stream segments with permanent running water and segments with stagnant water (current velocity < 10 cm/s), is also simulated by means of the model STREAMFLOW (Pieterse et al, 1998). The result of this simulation is shown in figure 6. This figure shows that the Dommel and Warmbeek/Tongelreep contain running water from the origin to the end. (Names of streams in the Dommel catchment are shown in appendix II) Also the Keersop, and larger parts of the Beerze, Sterkselse Aa, Hooidonksche Beek, Beekse Waterloop, and Run contain running water. The Ekkersrijt contains stagnant water in almost its entire length. The upper course of the Grote Beerze, the Gender, the Strijper Aa, the Buulder Aa, and the Peelrijt contain stream segments with running water and segments with stagnant water.

## 3.4 Saprobic state

Saprobic state of the surface water is also simulated by means of the model STREAMFLOW (Pieterse et al, 1998). The result of this simulation is shown in figure 7. From figure 7 it is concluded that large parts of the streams in the Dommel catchment—especially the streams Dommel, Warmbeek/Tongelreep, and Beerze—are α-mesosaprobic to polysaprobic. Oligosaprobic to β -mesosaprobic, and β -mesosaprobic are especially found in the Keersop, Beekloop, and Run area; the Sterkselse Aa and Peelrijt area, the Beekse Waterloop, the Kleine Dommel, and upper courses parts of the Bollisserbeek, Dommel, and Beerze.

***Figure 4.*** *Assessed upper, middle and lower courses of streams in the Dommel catchment. Assessment is based on the size of the catchment of every stream segment, and a derived stream width from this catchment size (e.g. Pieterse et, 1998) Class borders between upper (< 3 m), middle (> 3 and < 10 m), and lower course (> 10 m) is based on Gardeniers & Peeters (1992).*

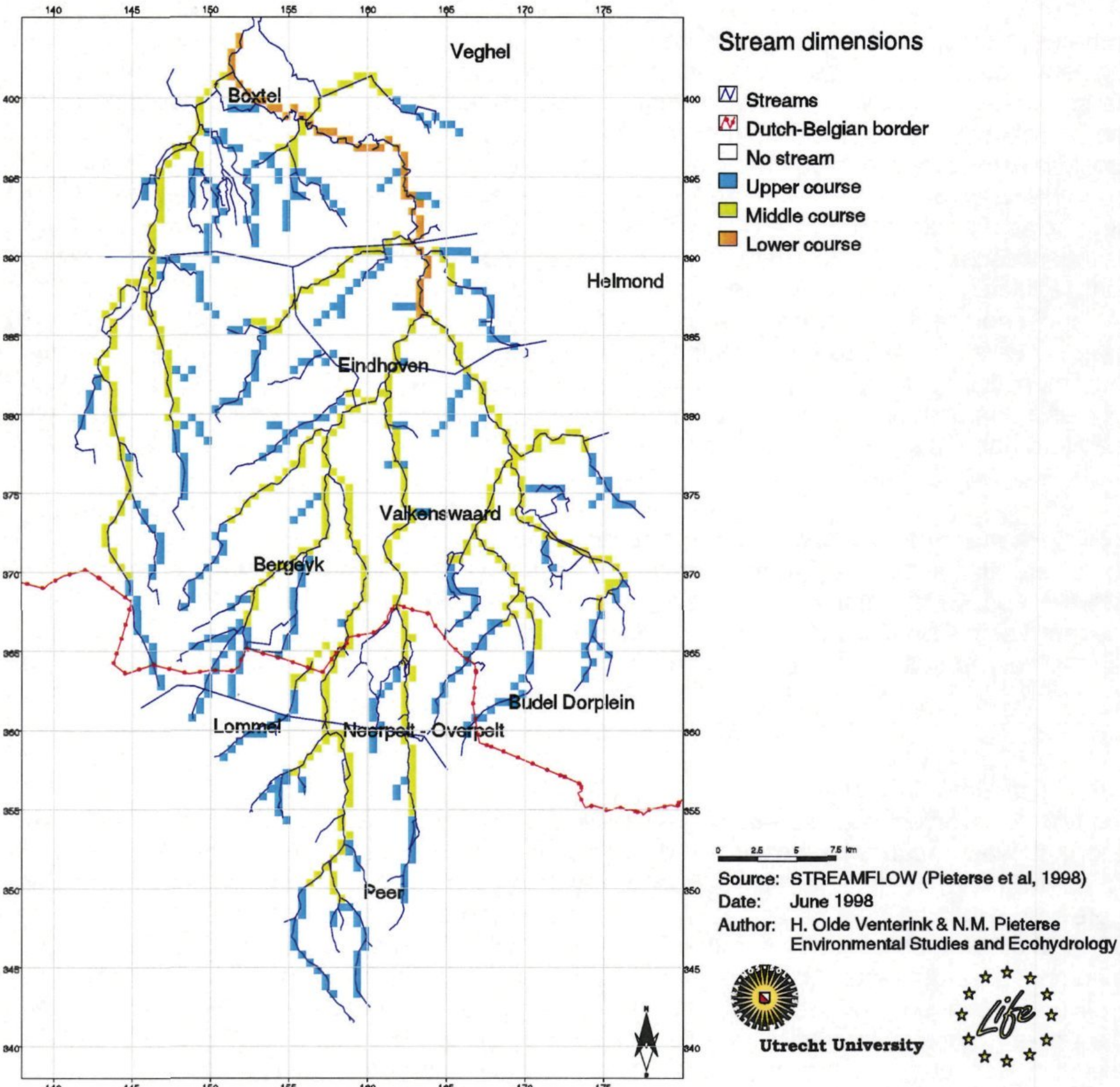


***Figure 5.*** *Permanent stream segments and segments that fall dry for at least 6 weeks per year (intermittent streams) as simulated by means of the model STREAMFLOW (Pieterse et al, 1998)*

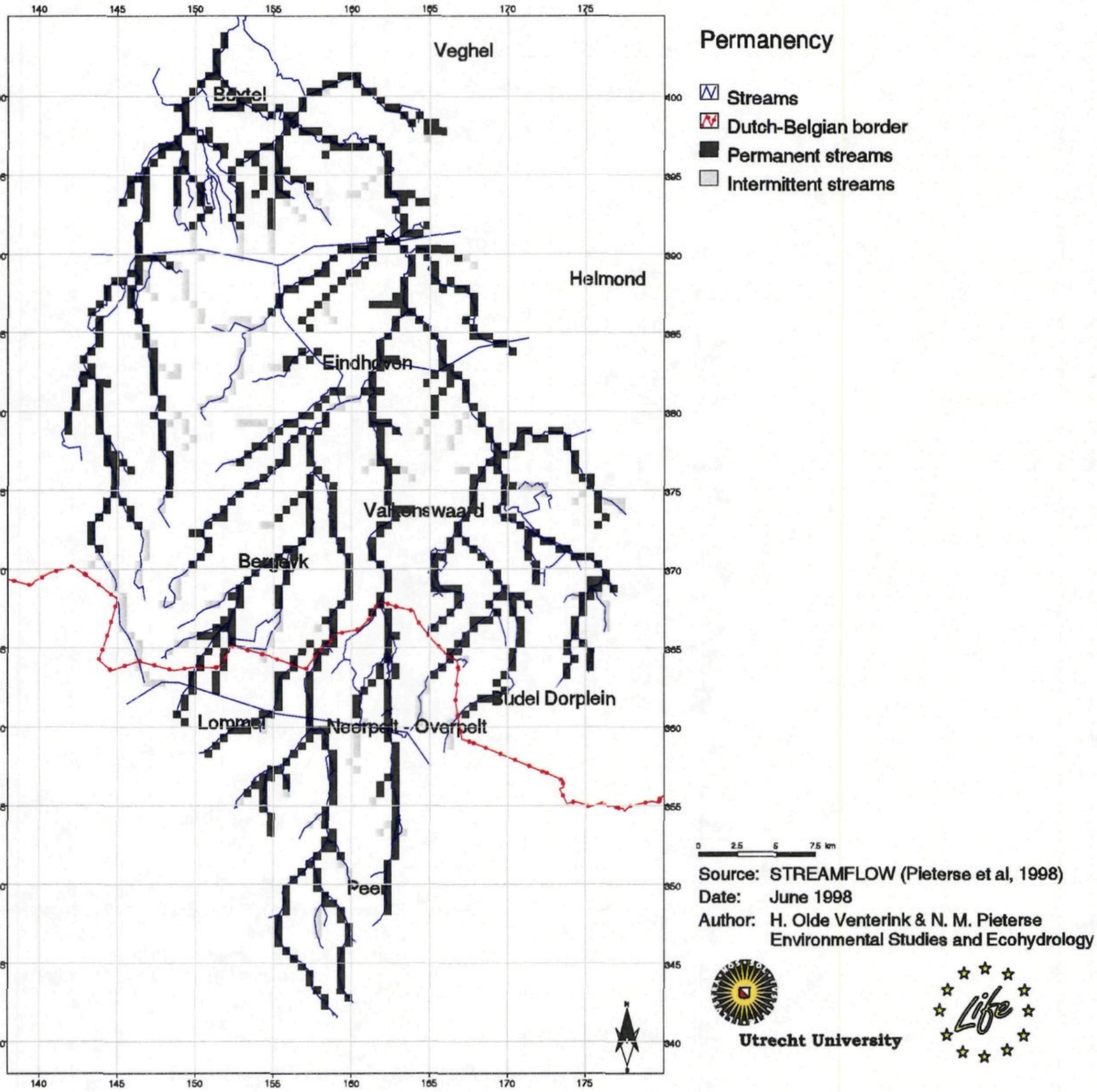


***Figure 6.*** *Stream segments with permanent running water (current velocity > 0.10 m/s) and segments with stagnant water (current velocity ≤ 0.10 m/s), as simulated by means of the model STREAMFLOW (Pieterse et al. 1998).*

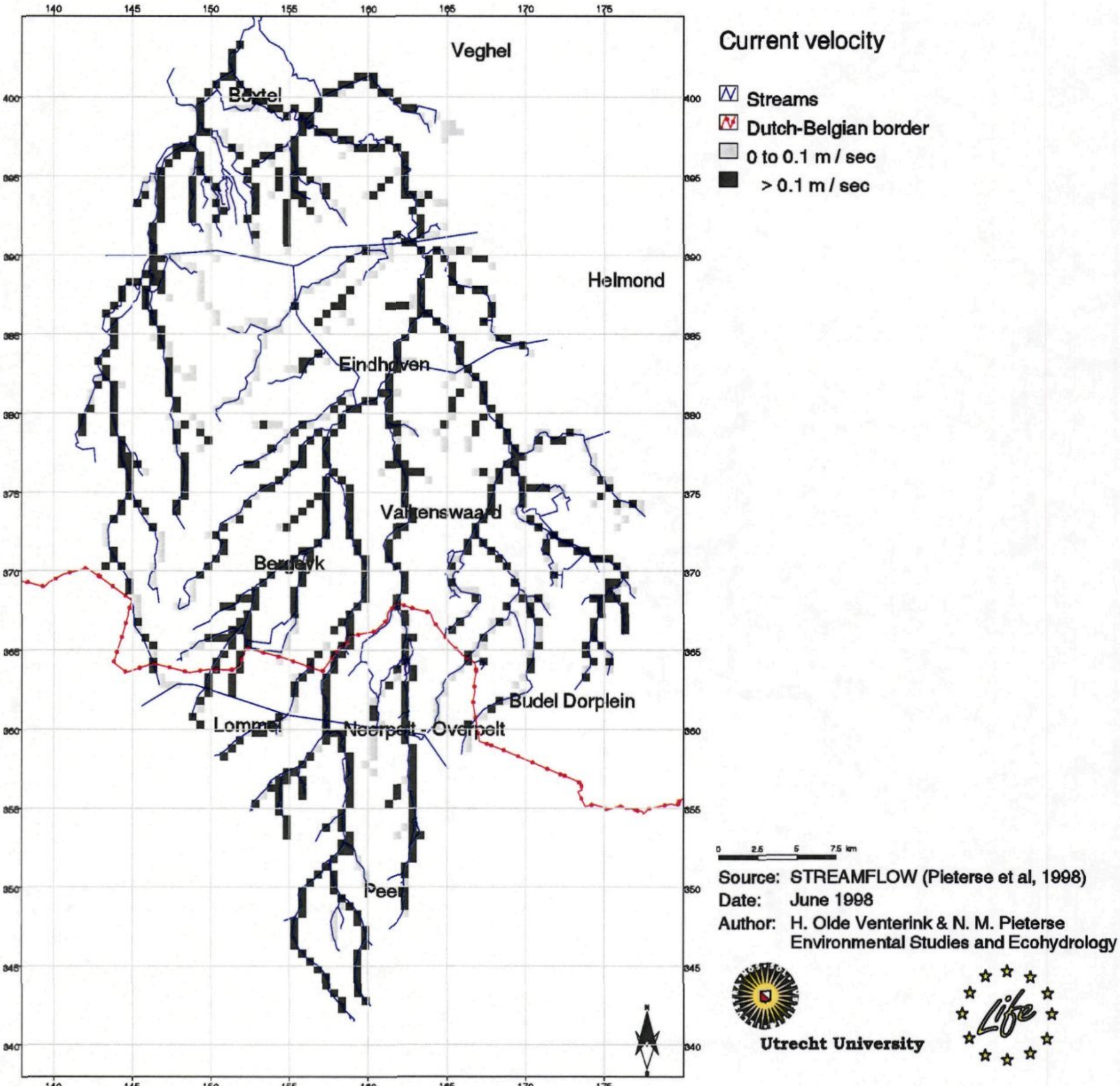
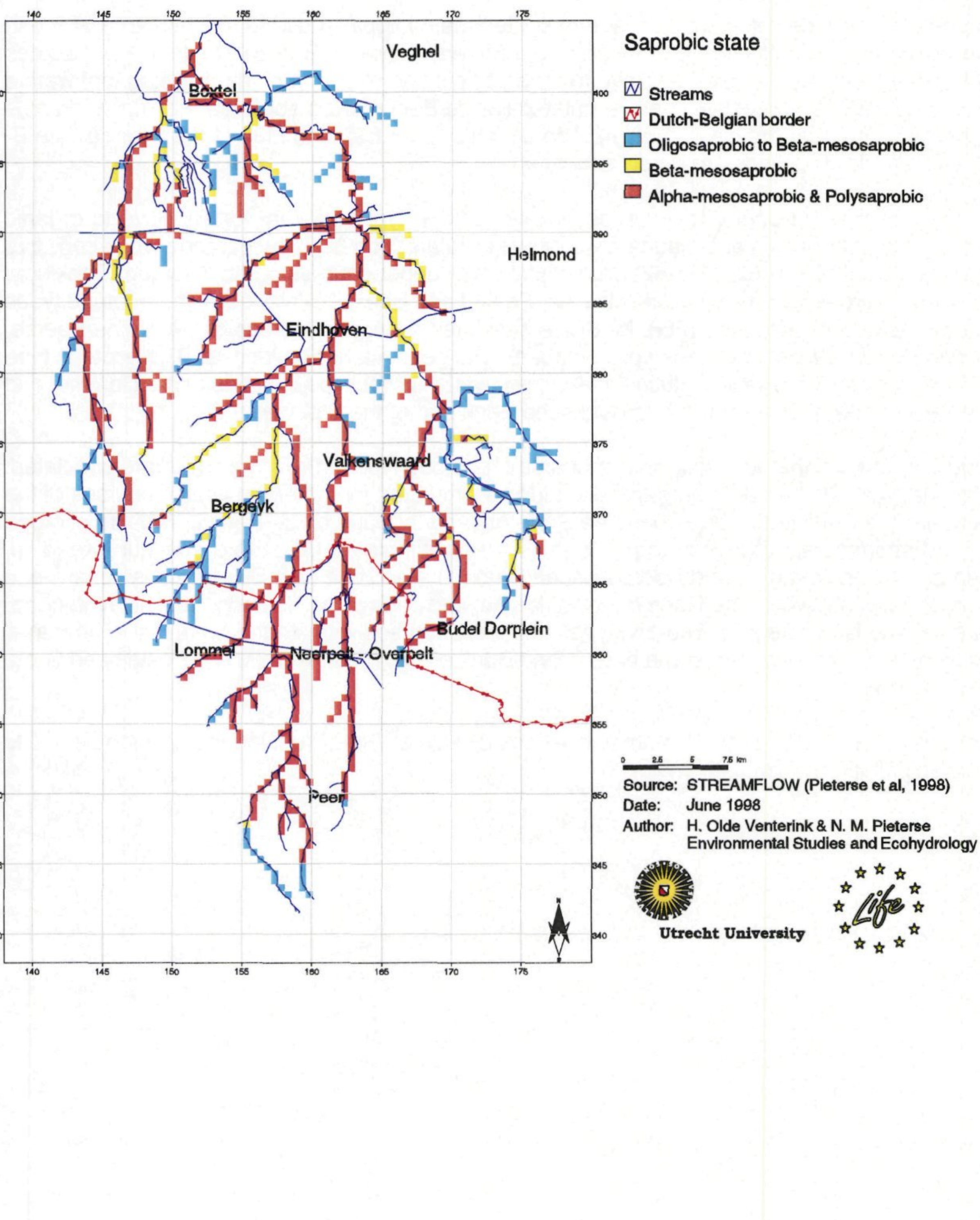


***Figure 7.*** *Simulated saprobic state of the surface water of streams in the catchment area of the river Dommel. Saprobic state is based on N-Kjeldahl concentrations as simulated with the model STREAMFLOW (Pieterse et al. 1998). Oligosaprobic to β-mesosaprobic: N-Kjeldahl ≤ 0.2 mg N/l; β-mesosaprobic: 0.2 > N-Kjeldahl ≤ 0.5 mg N/l; α-mesosaprobic / polysaprobic: N-Kjeldahl > 0.5 mg N/l.*



### *3.5 Simulated distribution of aquatic ecotope types*

The simulated distribution of aquatic ecotope types in streams of the river Dommel catchment in 1991 is obtained from a combination of the maps with ECOSTREAM input variables, described in the paragraphs 3.1 - 3.4. The results are shown in figures 8a to 8d.

Figure 8a shows that for intermittent streams often the ecotope type M38, of stagnant water and tolerant to organic pollution, is simulated (e.g Ekkersrijt, Kleine Beerze, Buulder Aa). Besides M38, also the ecotope types sensitive to organic pollution of both running and stagnant waters (F32, and M32/33 respectively) are simulated (Grote Beerze, Keersop area, Peelrijt, and some upper courses near the city of Boxtel). The ecotope types F37 and M37 of the intermediate B-mesosaprobic conditions are hardly simulated.

Also for permanent upper courses, especially ecotope types tolerant- or sensitive to organic pollution of both running and stagnant water are simulated (fig 8b). The ecotope types sensitive to organic pollution (F62, M61/62) are simulated for upper courses of the Keersop, Beekloop, Run, Bollisserbeek, Dommel, Sterkselse Aa, Peelrijt and Beekse Waterloop. The ecotope types tolerant to organic pollution (F68, M68) are simulated for upper courses of the Kleine Beerze, Gender, Eindergatloop, Neuzenloop, Warmbeek, Strijper Aa, and Buulder Aa. The ecotope type F67 of intermediate organic pollution and running water is simulated for parts of the Dommel and the Beerze near Boxtel, of the Hooidonksche Beek,and of the Sterkselse Aa.

Figure 8c shows that for most middle courses, ecotope types of running water are simulated. Ecotope type F78, tolerant to organic pollution, is simulated for the entire middle courses of the Dommel, the Warmbeek, the Buulder Aa/Grote Aa, and for parts of the Beerze. F77, an ecotope type of intermediate tolerance to pollution, is mainly simulated for parts of the Run, Keersop, Beerze, Kleine Dommel, and Hooidonksche Beek. The ecotope type S6+ which is sensitive to organic pollution is simulated for the Sterkselse Aa, and parts of the Keersop, Beekse Waterloop, Peelrijt, and Grote Beerze. Ecotope types of middle courses with stagnant water are simulated for the Ekkersrijt (M68), and some parts of the Buulder Aa (M78), Run (M77), Peelrijt and Grote Beerze (D6+).

For the lower course of the Dommel, only ecotope type F88 of running water and tolerant to organic pollution is simulated (fig. 8d).

***Figure 8a**. Simulated distribution of aquatic ecotope types of intermittent streams in the Dommel catchment. Characteristic species for ecotope types are shown in appendix I.*

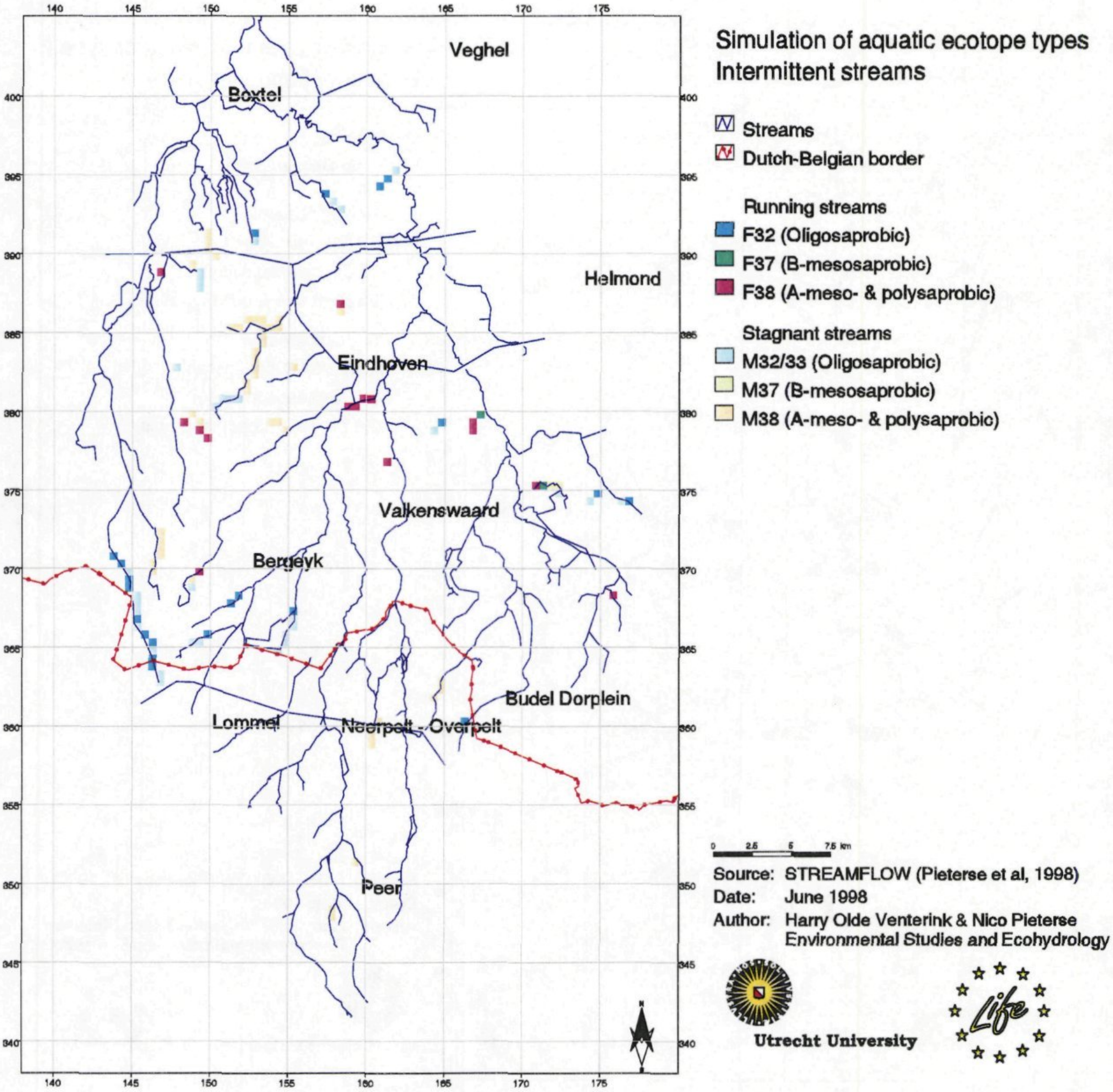


***Figure 8b**. Simulated distribution of aquatic ecotope types of permanent upper courses in the Dommel catchment. Characteristic species for ecotope types are shown in appendix I.*

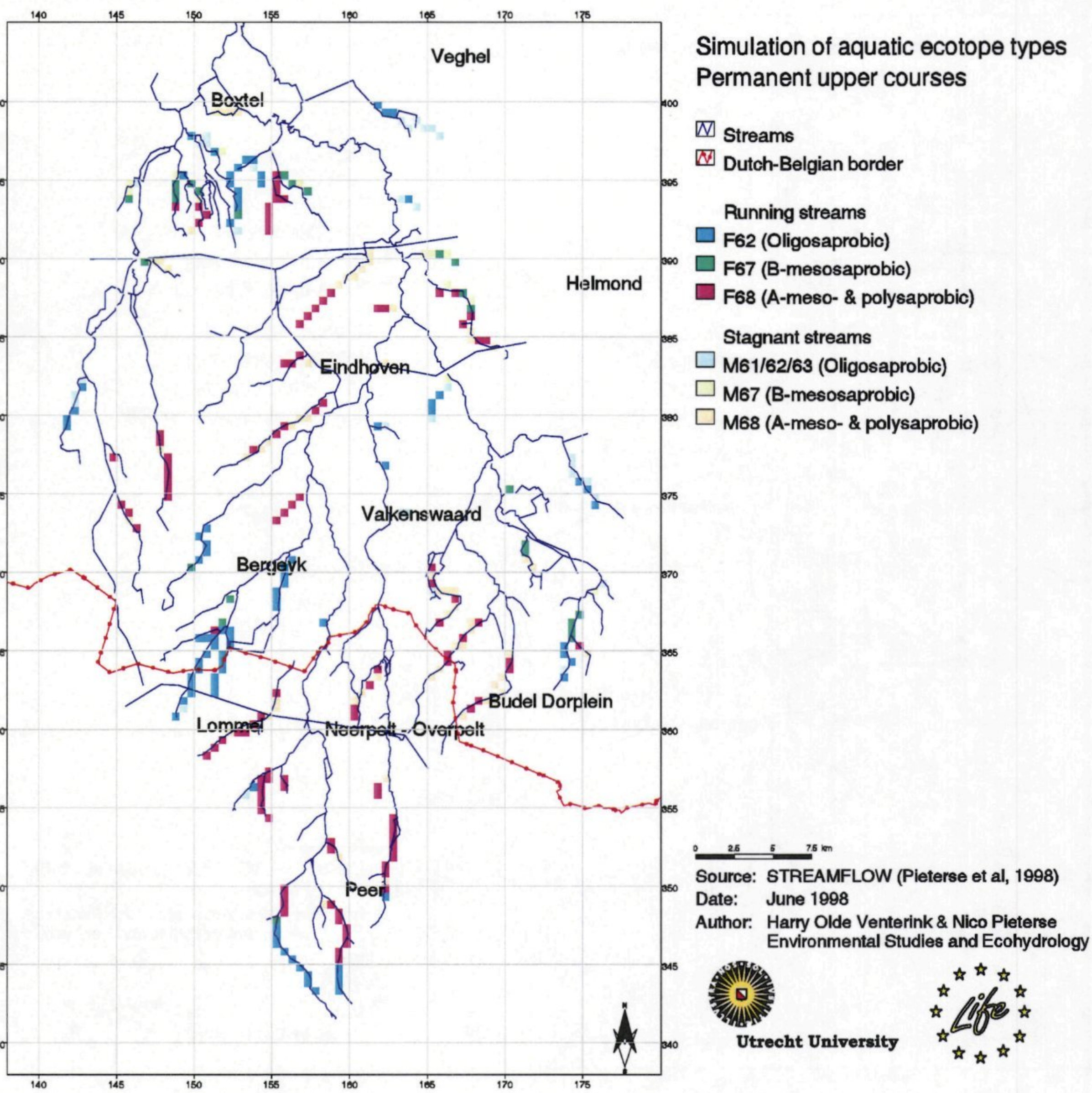


***Figure 8c****. Simulated distribution of aquatic ecotope types of middle courses in the Dommel catchment. Characteristic species for ecotope types are shown in appendix I.*

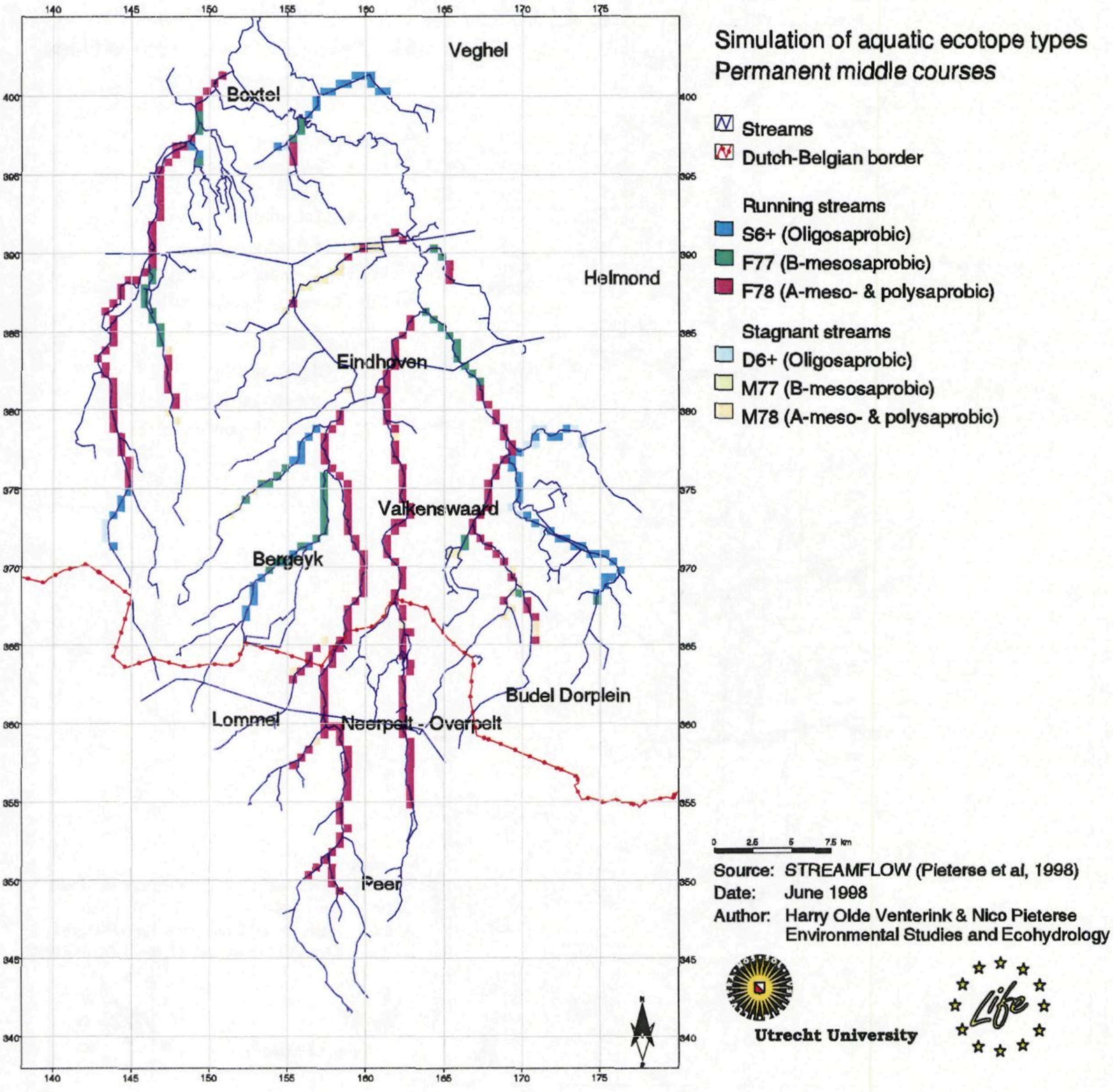
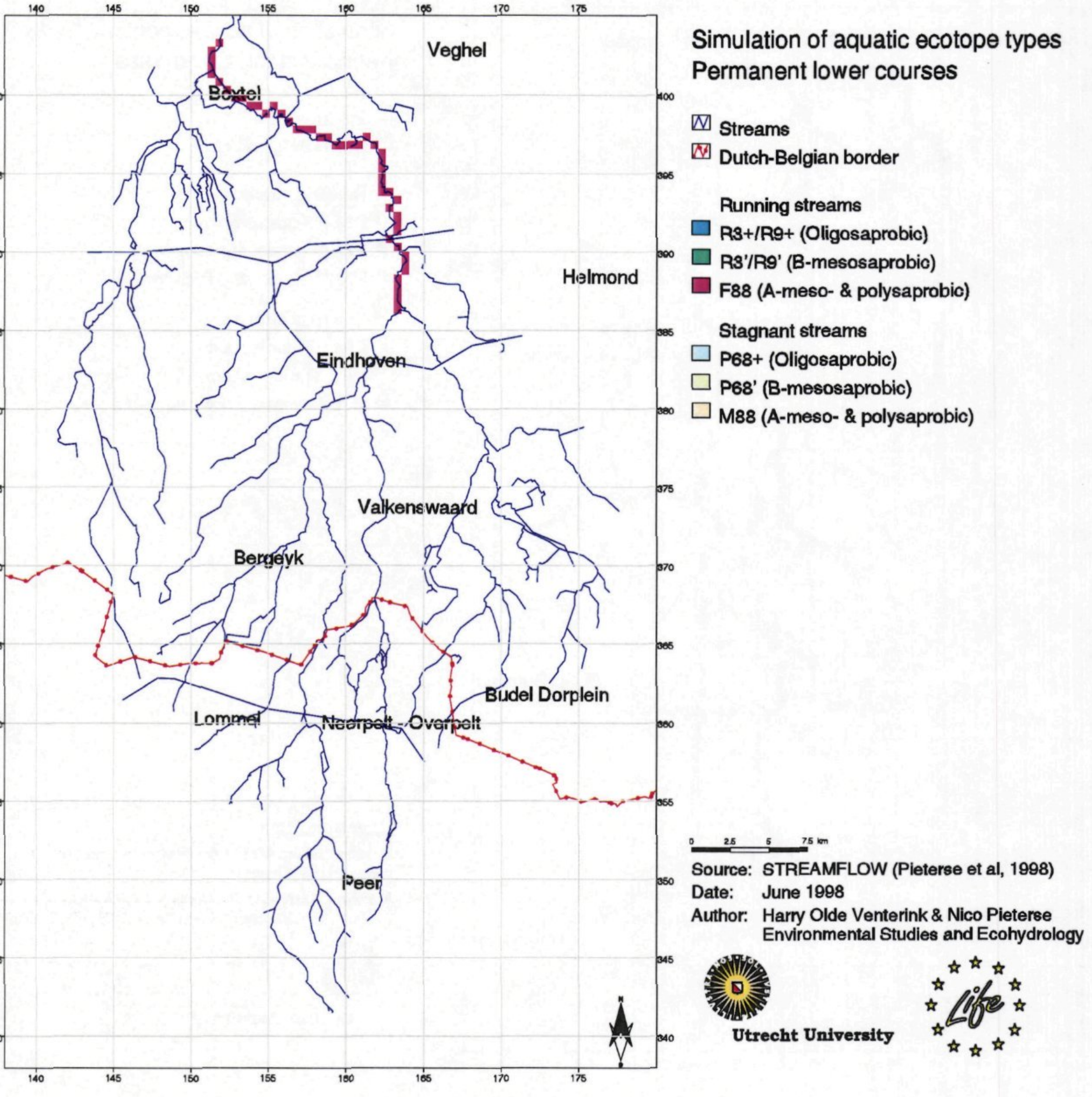


*Figure 8d. Simulated distribution of aquatic ecotope types of lower courses/small rivers in Dommel catchment. Characteristic species for ecotope types are shown in appendix I.*



### 3.6 *Observed distribution of aquatic ecosystems*

To create a map with the actual distribution of aquatic ecotope types in the Dommel catchment, descriptions of aquatic ecosystems at the species level are needed (e.g. appendix I). The data-sets of the water board the Dommel and of the VMM, with inventories of aquatic invertebrate communities in the Dommel catchment, however, don't contain samples with identifications at the species level. Therefore, it is not possible to distinguish aquatic ecotope types from these data. Nevertheless, the biotic indexes in these data-sets—based on the indication values of aquatic invertebrates for especially the organic pollution of the surface water (e.g. Bervoets & Schneiders, 1990a; Anonymous, 1990)—can be used as a biotic reference for the simulation of the saprobic state of the stream water. For the construction of a map with 'biotic index' information for the Dommel catchment, the ten classes of the Belgian biotic index (e.g. Bervoets & Schneiders, 1990a) were converted to the four classes of the Dutch biotic index (e.g. Anonymous, 1990). This conversion is presented in table 6.

***Table 6.*** *Conversion of the biotic indexes used for the Belgian and Dutch part of the Dommel catchment. Anonymous, 1990 and [2]Bervoets & Schneiders (1990a)*

| Biotic index Dutch part of the Dommel catchment[1] | Belgian biotic index[2] | Indication of aquatic invertebrates |
|---|---|---|
| 1 | 8, 9 & 10 | sensitive to organic pollution |
| 2 | 6 & 7 | tolerant to slight organic pollution |
| 3 | 3, 4 & 5 | tolerant to moderate organic pollution |
| 4 | 1 & 2 | tolerant to strong organic pollution |

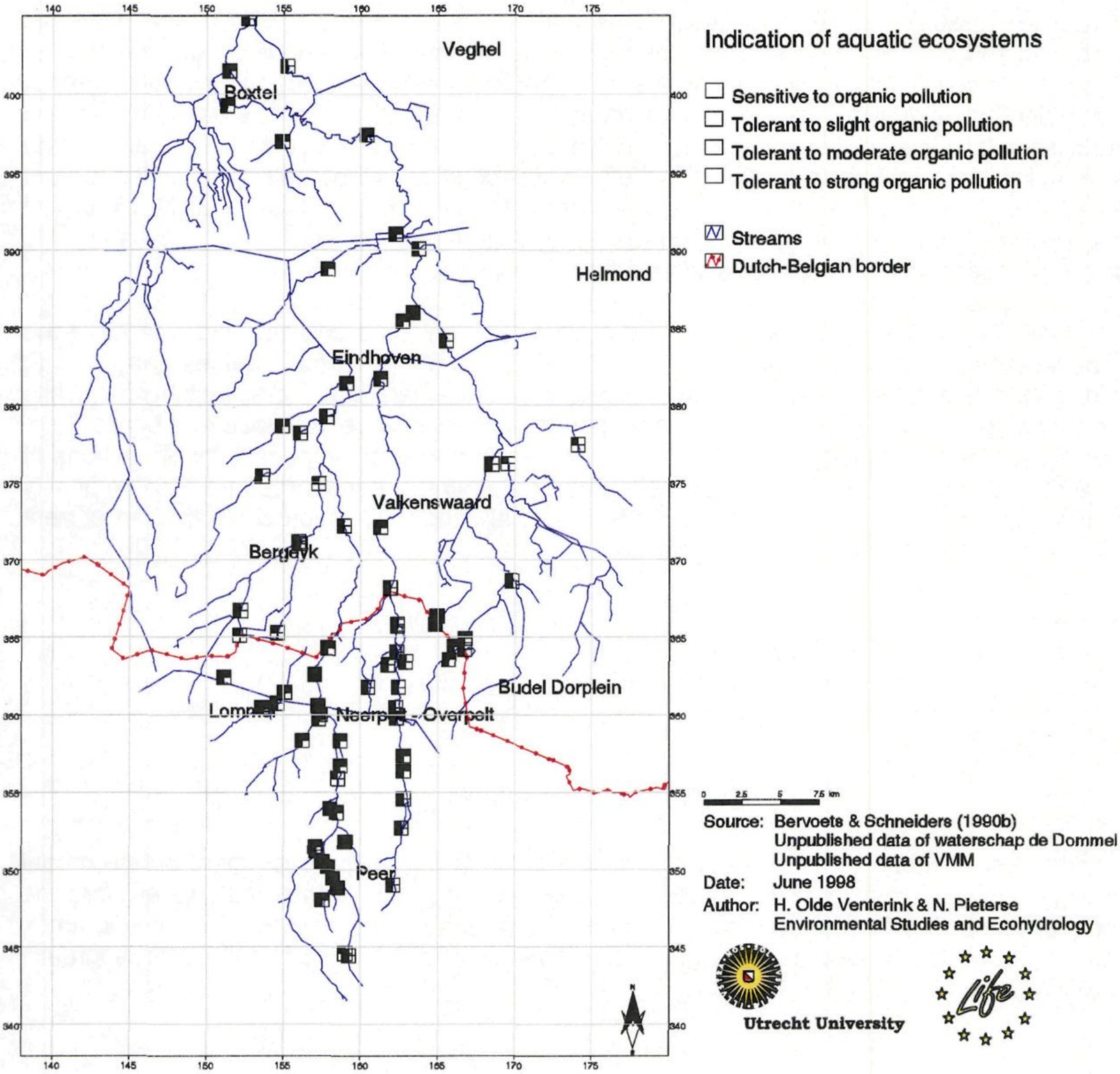
Figure 9 shows the indication of aquatic invertebrates for organic pollution in the Dommel catchment in the period 1989-1992, on the base of the biotic index classification described in table 6. Aquatic ecosystems sensitive to organic pollution are observed in the streams Beekloop, Keersop, Sterkselse Aa, Peelrijt, and the upper course of the Dommel. Ecosystems tolerant to strong organic pollution are observed after waste water treatment plants (Eindhoven, Lommel) or sources of untreated sewages (Dommel near Peer, Rioolbeek/Strijper Aa). In general the middle courses contain ecosystems tolerant to slight or moderate organic pollution, while the lower course of the Dommel contains ecosystems tolerant to moderate organic pollution.

### 3.7 *Comparison of ECOSTREAM simulations with field observations*

An appropriate validation of ECOSTREAM for the Dommel catchment is not possible, because predicted aquatic ecotope types can not be compared with observed ecotope types, while data-sets with information at the species level are not available. However by comparing ECOSTREAM simulations (figures 8a-d) with the distribution of the biotic index (fig 9), at least the simulated saprobic state of the streams can be validated with a biotic reference.

From a comparison of figures 8a to 8d with figure 9, it is concluded that ECOSTREAM simulations for saprobic state and the indication value of observed aquatic ecosystems for organic pollution are quite similar. Aquatic ecosystems sensitive to organic pollution are simulated and observed in the streams Keersop, Beekloop, Sterkselse Aa, and Peelrijt. Ecosystems tolerant to slight organic pollution are simulated and observed in the Run, Hooidonksche Beek, and Kleine Dommel. Ecosystems tolerant to moderate or strong organic pollution are simulated and observed for large parts of the Dommel, Ekkersrijt, Gender, Tongelreep, Eindergatloop, Neuzenloop, Strijper Aa, and Buulder Aa. Only for parts of the Warmbeek and the Dommel ecosystems tolerant to slight organic pollution are observed while ecosystems tolerant to moderate or strong organic pollution are simulated

***Figure 9.*** *Indication of aquatic ecosystems for organic pollution in the catchment area of the river Dommel in the period 1989-1992. The indication is assessed by means of a biotic index based on observed aquatic invertebrate communities (e.g. table 6) Data are from Bervoets & Schneiders (1990b) and unpublished data of waterboard the Dommel and the VMM.*



## *4. Conclusions and Discussion*

By constructing ECOSTREAM, the aim of this study—development of an ecological response model for lowland steams —is achieved. ECOSTREAM is developed on the base of the system of aquatic ecotope types (e.g. Verdonschot et al, 1992), decision rules, and the GIS-software PCRASTER. ECOSTREAM simulations are carried out for streams of the river Dommel catchment and are compared with the distribution of a measured biotic index in this catchment. This biotic index is determined by means of the indication value of aquatic invertebrates for especially organic pollution of the surface water. It can therefore be used as a biotic reference for the saprobic state simulation. Because the simulated ecotope types correspond well with the observed distribution of the biotic index in the field, it is concluded that the saprobic state part of ECOSTREAM functions appropriately. For a complete validation of ECOSTREAM, simulated ecotope types should be compared with observed ecotope types in the field. The necessary data for this purpose, however, are not available for the Dommel catchment.

In contrast to gradient models, models based on decision rules and classification have the disadvantage of strict class borders. Small changes in environmental variables, may lead to predictions of a different ecosystem if the starting conditions were close to a class border, while larger changes may predict no effect if the starting conditions were not close to a border (e.g. Olde Venterink & Wassen, 1997). Because class borders are very important for predictions of these models, the levels of these borders should be determined very appropriate. For the quality of the class borders used in ECOSTREAM, especially those for saprobic state and current velocity, additional research data are desirable.

## *Acknowledgments*

We are very grateful to Dr P. Verdonschot (IBN-DLO) for his helpful comment on the model concept, and for providing the ecotope type descriptions. Dr J. Hemelraad (Waterboard the Dommel) is thanked for his comment on a draft version of this report. Waterboard the Dommel, VMM, and Dr A. Schneiders (University of Antwerp) kindly provided data. This is greatly acknowledged.

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## *Appendices*

## *Appendix I: List of Aquatic Ecotope Types and Characteristic Aquatic Invertebrate-, Macrophyte and Fish Species*

*[1]from Verdonschot et al. 1992; [2]from Verdonschot et al. 1993; [3]from van der Hoek & Verdonschot 1994a; [4]Verdonschot pers. comm.*

### UPPER COURSES

**F32 : natural upper courses, temporal, oligo- to β-mesosaprobic, oligotrophic[1]**

Characteristic invertebrates: *Anacaena lutescens, Beraea pullata, Ephydridae, Hydraena britteni, Hydrobaenus pilipes, Hydroporus discretus, H. incognitus, H. memnonius, Ironoquia dubia, Limnephilus auricula, L. centralis, L. elegans, L. griseus, Metriocnemus hirticollis, Micropterna lateralis, Orthocladius rivulorum, Platambus maculatus, Sigara nigrolineata, Trichostegia minor*

Characteristic macrophytes:

Characteristic fish:

**F37 : natural upper courses, temporal, β-mesosaprobic, mesotrophic[1]**

Characteristic invertebrates: *Agabus paludosus, A. didymus, Aplexa hynorum, Dipocladium cultriger, Eiseniella tetraedra, Ephydridae, Hexatoma sp, Hydraena britteni, Hydrobaenus pilipes, Hydroporus discretus, H. memnonius, H. palustris, H. planus, Ironoquia dubia, Limnephilus auricula, L. elegans, Metriocnemus hirticollis, Micropterna lateralis, Natarsia cinerea, Nepa cinerea, Orthocladius rivulorum, Platambus maculatus, Psychoda sp, Rhyacodrilus coccineus, Sigara nigrolineata, Scatophagidae, Trichostegia minor*

Characteristic macrophytes: *Callitriche hamulata, C. platycarpa, Montia fontana spp fontana, Potamogeton polygonifolius*

Characteristic fish:

**F38 : natural upper courses, temporal, α-mesosaprobic to polysaprobic, eutrophic[1]**

Characteristic invertebrates: *Agabus didymus, Chaetocladius sp, Diplocladius cultriger, Eiseniella tetyraedra, Erioptera sp, Hexatoma sp, Hydrobaenus pilipes, Hydroporus discretus, H. planus, Ironoquia dubia, Macropelopia nebulosa, Metriocnemus hirticollis, Micropterna lateralis, Muscidae, Nais elinguis, Nemoura cinerea, Nepa cinerea, Orthocladius rivulorum, Paratendipes gr albimanus, P. gr nudisquama, Platambus maculatus, Psectrotanypus varius, Psychoda sp, Rhyacodrilus coccineus, Sigara nigrolineata, Smittia sp, Stictochironomus sp, Tabanidae, Tipula sp, Trichostegia minor*

Characteristic macrophytes:

Characteristic fish:

**F62 : natural upper courses, permanent, oligo- to β-mesosaprobic, oligotrophic[1]**

Characteristic invertebrates: *Adicella reducta, Anacaena lutescens, Beraea pullata, Drusus biguttatus, Glyphotaelius pellucidus, Hydroporus discretus, H. incognitus, H. memnonius, Laccobius atratus, Limnephilus nigriceps, L. centralis, Lype reducta, Micropterna sequax, Platambus maculatus, Sigara hellensi*

Characteristic macrophytes:

Characteristic fish: *Lampetra planeri, Salmo trutta fario, (Gobio gobio ?, Noemacheilus barbatulus ?)*[3]

**F67 : natural upper courses, permanent, β-mesosaprobic, mesotrophic[1]**

Characteristic invertebrates: *Agabus chalconatus, A.didymus, Agapetus fuscipes, Athripdodes cinereus, Baetis vernus, Beraeodes minutus, Brillia modesta, Conchapelopia sp, Deronecttes latus, Eiseniella tetraedra, Elmis aenae, Glyphotaelius pellucidus, Goera pilosa, Helophorus arvernicus, Hydraena assimilis, H. excisa, H. metas, H. pygmaea, Hydrochus angustatus, Hydroporus discretus, Hydropsyche angustipennis, Hygrobates longipalpis, H. nigromaculatus, Laccobius obscuratus, L. sinuatus, L. Striatulus, Libertia inaequalis, Limnebius truncatellus, Limnephilus, lunatus, Limnius volckmari, Limnophila sp, Lype reducta, Macropelopia sp, Micronecta poweri, Micropsectra sp, Micropterna sequax, Nemoura cinerea, Ochthebius* *metallescens, Odontomesa fulva, Orectochilus villosus, Oulimnius tuberculatus, Phaenopsectra sp, Platambus maculatus, Polypedilum breviantennatum, P. Laetum agg, Podiamesa olivacea, Ptychoptera sp, Rhyacodrilus coccineus, Sigara hellensi, Silo nigricornis, Simulium sp, Tabanidae, Tipula sp, Velia caprai*

Characteristic macrophytes: *Callitriche hamulata, C. platycarpa, Groenlandia densa, Hottonia palustris, Montia fontana ssp fontana, Myriophyllum alterniflorum, M. spicatum, Potamogeton alpinus, P. nodosus, Ranunculus aquatilis, R. hederaceus, R. peltatus, Sparganium emersum*

Characteristic fish: *Lampetra planeri, Salmo trutta fario, Gobio gobio, Leuciscus leuciscus, Noemacheilus barbatulus*[3]

**F68 : natural upper courses, permanent, α-mesosaprobic to polysaprobic, eutrophic**[1]

Characteristic invertebrates: *Agabus chalconatus, A.didymus, Anabolia nervosa, Athripsodes cinereus, Beraeodes minutus, Cladotanytarsus sp, Conchapelopia sp, Cryptochironomus sp, Deronectes latus, Dicranota bimaculata, Dicrotendipes gr lobiger, D. gr notatus, Elmis aenae, Erpobdella octoculata, Forelia variegator, Glyphotaelius pullucidus, Helophorus arvernicus, Hexatoma sp, Hydraena excisa, Hydroporus discretus, Hygrobates longipalpis, H. nigromaculatus, Laccobius obscuratus, L. sinuatus, L. striatulus, Lebertia inaqualis, Limnebius truncatellus, Limnephilus lunatus, Limnesia koenikei, Limnius volckmari, Limnodrilus claparedeianus, Lype reducta, Macropelopia sp, Micropsectra sp, Micropterna sequax, Mideopsis crassipes, Orectochilus villosus, Oulimnius tuberculatus, Paracladopelma olivacea, Paratanytarsus sp, Platambus maculatus, Procladius sp, Rhyacodrilus coccineus, Sigara hellensi, Silo nigricornis, Tabanidae, Tanytarsus sp, Velia caprai*

Characteristic macrophytes: *Callitriche platycarpa, Hippuris vulgaris, Myriophyllum spicatum, Najas marina, Potamogeton alpinus, P. crispus, P. lucens, P. nodosus, P. pectinatus, P. perfoliatus, Ranunculus aquatilis, R. fluitans, Sparganium emersum*

Characteristic fish: *Lampetra planeri, Salmo trutta fario, Gobio gobio, Leuciscus leuciscus, Noemacheilus barbatulus*[3]

**M32 : stagnant upper courses, temporal, oligo- to β-mesosaprobic, oligotrophic, acid**[1]

Characteristic invertebrates: *Aedes sp, Agabus affinis, A. congener, A. labiatus, A. melanocornis, Anacaena lutescens, Argyroneta aquatica, Bidessus grossepunctatus, B. unistriatus, Ceratopogonidae, Coquillettidia richardii, Culiseta sp, Dixella amphibica, Enochrus affinis, Hagenella clathrata, Hebrus ruficeps, Helocharis punctatus, Helophorus flavipes, H. erythrocephalus, H. notatus, Hydrochus brevis, H. carinatus, Hydroporus glabriusculus, H. gyllenhalii, H. incognitus, H. melanarius, H. morio, H. neglectus, H. scalesianus, H. striola, H. tristis, Hygrotus decoratus, Ilybius aenescens, Leucorrhinia rubicunda, Limnephilus centralis, L. elegans, L. griseus, L. luridus, L. stigma, L. subcentralis, L. vittatus, Limnophyes sp, Mochlonyx culiciformis, Notonecta reuteri, Polypedilum uncinatum agg, Psectrocladium sp, Rhantus suturellus, Sigara nigrolineata, Stylodrilus heringianus, Sympecma fusca, Telmatopelopia nemorum, Tipula sp, Trichostegia minor, Vejdovskyella comata, Zalutschia mucronata*

Characteristic macrophytes: *Juncus bulbosus, Ranunculus ololeucos*

Characteristic fish:

**M33 : stagnant upper courses, temporal, oligo- to β-mesosaprobic, oligotrophic, not acid**[1]

Characteristic invertebrates: *Aedes sp, Agabus affinis, A. congener, A. labiatus, A. melanocornis, A. neglectus, A. striolatus, A. unguicularis, Anacaena lutescens, Coquillettidia richardii, Culiseta sp, Cyphon sp/hydrocyphon sp/scirtes sp, Dixella amphibica, Enochrus affinis, Graptodytes granularis, Hagenella clathrata, Helochares punctatus, Helophorus asperatus, H. flavipes, H. nanus, H. pumilio, H. strigifrons, Hydaticus seminiger, H. transversalis, Hydraena britteni, H. palustris, H. riparia, Hydrochus angustatus, H. brevis, H. carinatus, H. elongatus, H. ignicollis, Hydroporus elongatulus, H. erythrocephalus, H. glabriusculus, H. melanarius, H. neglectus, H. notatus, H. scalesianus, H. striola, Hygrotus decoratus, Ilybius aenescens, I. guttiger, I. quadriguttatus, I. subaeneus, Laccornis oblongus, Leucorrhinia rubicunda, Limnebius aluta, Limnephilus auricula, L. elegans, L. griseus, L. stigma, L. subcentralis, L. vittatus, Metriocnemus hirticollis, Mochlonyx culiciformis, Nartus grapii, Notonecta reuteri, Paracymus* *scutellaris, Sigara nigrolineata, Sympecma fusca, Telmatopelopia nemorum, Trichostegia minor, Vejdovskyella comata, Zalutschia mucronata*

Characteristic macrophytes: *Callitriche hamulata, Echinodorus, E. repens, Elatine hexandra, Juncus bulbosus, Littorella uniflora, Lythrum portula, Pilularia globulifera, Potamogeton coloratus, P. gramineus, P. polygonifolius, Ranunculus ololeucos*

Characteristic fish:

**M37 : stagnant upper courses, temporal, β-mesosaprobic, mesotrophic[1]**

Characteristic invertebrates: *Agabus affinis, A. congener, A. neglectus, A. striolatus, A. uliginosus, A. unguicularis, Arrenurus fimbriatus, Bathyomphalus contortus, Collicorixa praeusta, Coquillettidia richardii, Culiseta sp, Cyphon sp/hydrocyphon sp/scirtes sp, Dixella amphibica, Dryops anglicanus, D. auriculatus, D. griseus, Enochrus coarctatus, Graptodytes granularis, Hagenella clathrata, Helophorus asperatus, H. croaticus, H. nanus, H. pumilio, H. strigifrons, Hydaticus seminiger, H. transversalis, Hydraena britteni, H. palustris, H. riparia, Hydrochus angustatus, H. carinatus, H. elongatus, H. ignicollis, H. megaphallus, Hydroporus glabriusculus, H. melanarius, H. neglectus, H. notatus, H. scalesianus, H. striola, Hygrotus decoratus, Ilybius guttiger, I. quadriguttatus, Laccornis oblongus, Limnebius aluta, L. crinifer, Limnephilus auricula, L. elegans, L. insicus, L. stigma, L. vittatus, Metriocnemus hirticollis, Mochlonyx culiciformis, Nartus grapii, Nepa cinerea, Notonecta reuteri, Odontomyia sp, Paracymus scutellaris, Planorbis planorbis, Planorbarius corneus, Segmentina nitida, Sigara nigrolineata, Stagnicola palustris, Suphrodytes dorsalis, Telmatopelopia nemorum, Trichostegia minor, Xenopelopia nigricans, Zalutschia mucronata*

Characteristic macrophytes: *Callitriche hamulata, C. platycarpa, C. stagnalis, Montia fontana ssp fontana, Myriophyllum verticillatum, Polygonum amphibium, Potamogeton gramineus, Ranunculus aquatilis, Tolypella intricata*

Characteristic fish:

**M38 : stagnant upper courses, temporal, α-mesosaprobic to polysaprobic, eutrophic[1]**

Characteristic invertebrates: *Acricotopus lucens, Agabus affinis, A. congener, A. neglectus, A. striolatus, A. uliginosus, A. unguicularis, Collicorixa praeusta, Chironomus sp, Coelambus impressopunctatus, Colymbetes fuscus, Coquillettidia richardii, Culiseta sp, Dryops auriculatus, Hagenella clathrata, Helophorus croaticus, H. pumilio, H. strigifrons, Hydaticus seminiger, H. transversalis, Hydraena britteni, Hydrochus carinatus, H. megaphallus, Hydroporus glabriusculus, H. melanarius, H. neglectus, H. notatus, H. scalesianus, H. striola, Hygrotus decoratus, Ilybius ater, I. guttiger, I. quadriguttatus, Laccornis oblongus, Limnebius crinifer, Limnephilus insicus, L. stigma, L. vittatus, Macropelopia sp, Metriocnemus hirticollis, Mochlonyx culiciformis, Nepa cinerea, Notonecta reuteri, Pisidium sp, Psectrotanypus varius, Rhantus suturalis, Sigara nigrolineata, Suphrodytes dorsalis, Telmatopelopia nemorum, Trichostegia minor, Zalutschia mucronata*

Characteristic macrophytes: *Callitriche obtusangula, C. palustris, C. platycarpa, C. stagnalis, Hippuris vulgaris, Polygonum amphibium, Ranunculus aquatilis, R. baudotii*

Characteristic fish:

**M61 : stagnant upper courses, permanent, oligo- to β-mesosaprobic, oligotrophic, very acid[1]**

Characteristic invertebrates: *Ablabesmyia phatta, Acilius canaliculatus, Agrypnia obsoleta, Anacaena lutescens, Argyroneta aquatica, Arrenurus neumani, Berosus luridus, B. signaticollis, Brillia longifurca, Ceratopogonidae, Corixa dentipes, Cymatia bonsdorffi, Dytiscus lapponicus, Enallagma cyathigerum, Enochrus affinis, E. coarctatus, E. ochropterus, Glaenocorisa propinqua, Graphoderus zonatus, Gyrinus minutus, Hebrus ruficeps, Helochares punctatus, Helophorus flavipes, Hesperocorixa castanea, Holocentropus dubius, Hydrochus brevis, H. carinatus, Hydroporus erythrocephalus, H. melanarius, H. neglectus, H. pubescens, H. tristis, H. umbrosus, Ilybius aenescens, Leptophlebia vespertina, Leucorrhinia rubicunda, L. sp, Libellula depressa, L. quadrimaculata, Limnephilus luridus, Limnophyes sp, Oligotriche striata, Paralimnophyes hydrophilus, Phalacrocera replicata, Polypedilum uncinatum, Psectrocladius platypus, P. psilopterus, Pseudochironomus prasinatus, Pseudorthocladium curtistylus, Pseudosmittia trilobata, Rhadicoleptus alpestris, Rhantus suturellis, Stenochironomus sp,*

*Sympecma fusca, Vejdovskyella comata, Telmatopelopia nemorum, Tipula sp*
Characteristic macrophytes: *Juncus bulbosus, Utricularia minor*
Characteristic fish:

**M62 : stagnant upper courses, permanent, oligo- to $\beta$-mesosaprobic, oligotrophic, acid[1]**
Characteristic invertebrates: *Ablabesmyia longistyla, A. phatta, Acamptocladius submontanus, Acilius canaliculatus, Agabus affinis, A. congener, A. labiatus, A. melanocornis, Agrypnia obsoleta, Anacaena lutescens, Arctocorisa germari, Argyroneta aquatica, Arrenurus neumani, Berosus luridus, B. signaticollis, Bidessus grossepunctatus, B. unistriatus, Ceratopogonidae, Ceriagrion tenellum, Chaoborus crystallinus, C. obscuripes, C. flavicans, C. orynoneura sp, Chironomus sp, Cloeon dipterum, Colymbetes paykulli, Coquillettidia richardii, Corixa dentipes, Culex sp, Cymatia bonsdorffi, C. coleoptrata, Dixella aestivalis, D. amphibica, Dytiscus lapponicus, D. semisulcatus, Enallagma cyathigerum, Endochironomus tendens, Enochrus affinis, E. coarctatus, E. ochropterus, Gerris gibbifer, G. lateralis, Glaenocorisa propinqua, Graphoderus zonatus, Gyrinus minutus, Hebrus ruficeps, Helochares punctatus, Helophorus flavipes, Hesperocorixa castanea, Holocentropus dubius, H. stagnalis, Hydrochus brevis, H. carinatus, Hydroporus erythrocephalus, H. gyllenhalii, H. incognitus, H. melanarius, H. obscurus, H. neglectus, H. pubescens, H. tristis, H. umbrosus, Ilybius aenescens, Leucorrhinia rubicunda, Limnephilus luridus, L. nigriceps, Microvelia umbricola, Notonecta obliqua, N. reuteri, N. viridis, Phalacrocera replicata, Polypedilum gr nubeculosum, P. gr sordens, P. uncinatum, Procladius sp, Psectrocladius platypus, P. psilopterus, Pyrrhosoma nymphula, Rhantus suturellis, Sigara distincta, S. fossarum, S. limitata, S. semistriata, Stylodrilus heringianus, Sympecma fusca, Vejdovskyella comata, Xenopelopia nigricans*
Characteristic macrophytes: *Juncus bulbosus, Nitella flexilis, N. translucens, Ranunculus ololeucos, Utricularia minor, U. ochroleuca*
Characteristic fish: *Umbra pygmaea*[3]

**M63 : stagnant upper courses, permanent, oligo- to $\beta$-mesosaprobic, oligotrophic, not acid[1]**
Characteristic invertebrates: *Acilius canaliculatus, A. sulcatus, Aedes sp, Aeshna grandis, Agabus congener, A. labiatus, A. melanocornis, A. undulatus, Agrypnia obsoleta, Arctocorisa germari, Bathyomphalus contortus, Berosus luridus, B. signaticollis, Ceriagrion tenellum, Coenagrion puella, Colymbetes paykulli,Corixa dentipes,Cymatia bonsdorffi, C. coleoptrata, Cyphon sp/ hydrocyphonsp/scirtes sp, Dryops auriculatus, D. griseus, D. luridus, Dytiscus lapponicus, D. semisulcatus, Enochrus affinis, E. coarctatus, E. isotae, E. ochropterus, E. quadripunctatus, E. testaceus, Gerris gibbifer, G. lateralis, G. thoracicus, Graphoderus bilineatus, G. cinereus, G. zonatus, Gyrinus caspius, G. minutus, G. suffriani, Haliplus heydeni, H. mucronatus, H. variegatus, Helochares lividus, H. obscurus, Helophorus asperatus, H. flavipes, H. nanus, H. pumilio, H. strigifrons, Hesperocorixa moesta, Hirudo medicinalis, Holocentropus dubius, H. stagnalis, Hydaticus seminiger, H. transversalis, Hydraena britteni, H. palustris, Hydrochara caraboides, Hydrochus angustatus, H. brevis, H. carinatus, H. elongatus, H. ignicollis, H. megaphallus, Hydroporus angustatus, H. erythrocephalus, H. pubescens, Hygrobia hermanni, Ilybius subaeneus, Ilyocoris cimicoides, Laccophilus ponticus, Limnebius aluta, Limnephilus biotatus, L. marmoratus, Microvelia reticulata, Mystacides longicornis, Natarsia sp, Notonecta obliqua, N. reuteri, N. viridis, Ochthebius bicolon, Oecetis lacustris, Paracymus scutellaris, Paralimnophyes hydrophilus, Polypedilum uncinatum, Porhydrus lineatus, Proadellus meridianus, Psectrocladius gr sordidellus/limbatellu, P. obvius, P. psilopterus, Pyrrhosoma nymphula, Segmentina nitida, Sigara nigrolineata, S. scotti, S. semistriata, Stictochironomus sp, Telmatogetoninae, Telmatoscopus sp, Vejdovskyella comata, Xenopelopia nigricans*
Characteristic macrophytes: *Callitriche hamulata, Echinodorus ranunculoides, E. repens, Elatine hexandra, Isoetes echinospora, I. lacustris, Littorella uniflora, Lobelia dortmanna, Luronium natans, Lythrum portula, Myriophyllum alterniflorum, Nitella flexilis, Nymphaea alba, Pilularia globulifera, Potamogeton gramineus, P. polygonifolius, Ranunculus ololeucos, Scirpus fluitans, Sparganium angustifolium, S. natans, Utricularia intermedia, U. minor, U. ochroleuca*
Characteristic fish: *Umbra pygmaea, Leucaspius delineatus, Tinca tinca*[3]

**M67 : stagnant upper courses, permanent, $\beta$-mesosaprobic, mesotrophic[1]**

Characteristic invertebrates: *Acilius canaliculatus, A. sulcatus, Acroloxus lacustris, Agabus undulatus, Anisus vortex, A. vorticulus, Anopheles sp, Argyroneta aquatica, Armiger crista, Arrenurus bifidicodulus, A. buccinator, A. cuspidator, A. globator, A. integrator, A. mulleri, Athripsodes*

**F78 : natural middle courses, α-mesosaprobic to polysaprobic, eutrophic[1]**
Characteristic invertebrates: *Agabus didymus, Anabolia nervosa, Anisus vortex, Aphelocheirus aestivalis, Athripsodes albifrons, A, cinereus, Baetis vernus, Brachycentrum subnubilus, Bithynia tentaculata, Ceracles nigronervosa, Cheumatopsyche lepida, Chironomus sp, Cloeon dipterum, Cricotopus gr sylvestris, Cryptochironomus sp, Elmis aenae, Endochironomus albipennis, Erpobdella octoculata, Gerris najas, Glyptotendipes sp, Limnius volckmari, Limnodrilus claparedeianus, Lype phaeopa, Microtendipes sp, Mystacides azurea, Neureclepsis bimaculata, Notidobia ciliaris, Orectochilus villosus, Orthocladius sp, Oulimnius tuberculatus, Paratanytarsus sp, Polypendilum gr bicrenatum, P. gr nubeculosum, P. gr sordens, Potamophylax rotundipennis, Radix peregra, Rhysa fontinalis, Specaria josinae, Sphaerium sp, Tinodes waeneri, Valvata piscinalis*
Characteristic macrophytes: *Myriophyllum spicatum, Ranunculus fluitans*
Characteristic fish: *Gobio gobio, Leuciscus idus, L. leuciscus*[3]

**D6+ : stagnant courses, oligo- to β-mesosaprobic, mesotrophic[4]**
A description of this ecotope type is not available yet

**M77 : stagnant middle courses, β-mesosaprobic, mesotrophic[1]**
Characteristic invertebrates: *Acilius canaliculatus, A. sulcatus, Acrolous lacustris, Aeshna cyanea, A.isoscelis, A. mix, A. viridis, Agabus congener, Agraylea sexmaculata, Agrypnia varia, Anatopynia plumipes, Anisus vorticulus, Arrenurus claviger, A. knauthei, A. pugionifer, Aulophorus furcatus, Bdellocephala punctata, Caenis robusta, Callicorixa praeusta, Ceraclea fulva, C. senilis, Chaetogaster diaphanus, C. diastrophus, Corixa panzeri, Cybister lateralimarginalis, Cyphon sp/hydrocyphon sp/scirtes sp, Cyrnus crenaticornis, Dytiscus circumcinctus, Endochironomus albipennis, Enochrus melanocephalus, Erotesis baltica, Gerris odontogaster, Glossiphonia heteroclita, Graphoderus bilineatum, G. cinereus, Gyrinus caspius, G. paykulli, Haliplus fulvus, H. furcatus, H. heydeni, Holocentropus picicornis, Hydrophilus piceus, Hydrovatus cuspidatus, Ilybius fenestratus, Laccophilus ponticus, Leptocerus tineiformis, Limnephilus binotatus, L. politus, Limnoxenus niger, Mesovelia furcata, Micronecta minutissima, Mystacides azurea, Myxas glutinosa, Naucoris maculatus, Oecetis furva, Oulimnius major, O. rivularis, Paraponyx stratiotata, Piona alpicola, P. coccinea, P. variabilis, Planorbis carinatus, Plea minutissima, Polycentropus irroratus, Pseudochironomus sp, Radix auricularia, Ranatra linearis, Rhantus exsoletus, Ripistes parasita, Sisyra fuscata, Spercheus emarginatus, Tanypus kraatzi, Tinodes waeneri, Tiphys ornatus, Tricholeiochiton fagesii, Tubifex ignotus, Zavreliella marmorata*
Characteristic macrophytes: *Alisma gramineum, Callitriche hamulata, C. platycarpa, Chara contraria, C. globularis, Hippuris vulgaris, Hottonia palustris, Hydrocharis morsus-ranae, Nitella flexilis, Nymphaea alba, Nymphoides peltata, Polygonum amphibium, Potamogeton lgramineus, P. lucens, P. natans, P. obtusifolius, P. perfoliatus, Ranunculus aquatilis, R. circinatus, Sagittaria sagittifolia, Stratiodes aloides, Tolypella glomerata*
Characteristic fish: *Leucaspius delineatus, Scardinius erythrophthalmus, Tinca tinca, Silurus glanus*[3]

**M78 : stagnant middle courses, α-mesosaprobic to polysaprobic, eutrophic[1]**
Characteristic invertebrates: *Acilius canaliculatus, A. sulcatus, Agrypnia varia, Anacaena bipustulata, Arrenurus crassicaudatus, A. globator, A. sinuator, Bithynia leachi, Caenis honoraria, Cladotanutarsus sp, Cybister lateralimarginalis, Dreissena polymorpha, Eylais extendens, Forelia brevipes, F. liliacea, Gammarus tigrinus, Gerris odontogaster, Graphoderus bilineatum, G. cinereus, Graptodytes pictus, Gyrinus paykulli, Haementeria costata, Haliplus heydeni, Hesperocorixa linnei, H. sahlbergi, Holocentropus picicornis, Hydrophilus piceus, Hydrovatus cuspidatus, Ilybius fenestratus, Limnephilus politus, Limnodrilus claparedeianus, Limnoxenus niger, Mesovelia furcata, Mystacides azurea, Naucoris maculatus, Ophidonais serpentina, Oulimnius major, O. rivularis, Piona alpicola, P. coccinea, P. pusilla, P. variabilis, Pionopsis lutescens, Piscicola geometra, Polypedilum gr bicrenatum, Potamothrix bedoti, Pseudochironomus sp, Sigara falleni, Slavina appendiculata, Stylaria lacustris, Tinodes waeneri, Triaenodes bicolor, Tricholeiochiton fagesii, Unionicola aculeata, U. crassipes, Valvata piscinalis*

Characteristic macrophytes:
Characteristic fish: *Leucaspius delineatus, Scardinius erythrophthalmus, Tinca tinca, Silurus glanus*[3]

**LOWER COURSES**

**R9+ : natural lower courses, oligo- to β-mesosaprobic, mesotrophic**[2]

Characteristic invertebrates: *Specaria josinae, Anodonta anatina, Pisidium henslowanum, P. supinum, Sphaerium rivicola, Unio crassus, U. tumidus, Potamopyrgus jenkinsi, Physa fontinalis, Astacus astacus, Caenis macrura, C. pseudorivulorum, Brachycercus harrisella, Centroptilum luteolum, Paraleptophlebia submarginata, Baetis vernus, Cercion lindenii, Ceriagrion tenellum, Gomphus flavipes, Platycnemis pennipes, Aphelocheirus aestivalis, Gerris najas, Anacaena globulus, Platambus maculatus, Agabus didymus, Elmis aenaea, Helophorus avernicus, Limnebius truncatellus, Limnius volckmari, Orectochilus villosus, Oulimnius tuberculatus, Anabolia nervosa, A. cinereus, A. albifrons, Ceraclea nigronervosa, Cheumatopsyche lepida, Chaetopteryx villosa, Hydropsyche angustipennis, Lype phaeopa, Mystacides azurea, Notidobia ciliaris, Potamophylax rotundipennis, Tinodes waeneri*

Characteristic macrophytes: *Myriophyllum spicatum, Ranunculus fluitans*

Characteristic fish: *Barbus barbus, (Thymallus thymallus ?)*

**R3+ : natural small rivers, oligo- to β-mesosaprobic, mesotrophic**[2]

Characteristic invertebrates: *Psammoryctides albicola, P. barbatus, Anodonta cygnea, A. anatina, Unio crassus, U. tumidus, Pisidium henslowanum, P. supinum, Sphaerium rivicola, Potamopyrgus jenkinsi, Theodoxus fluviatilis, Hygrobates fluviatilis, Astacus astacus, Caenis macrura, C. pseudorivulorum, Brachycercus harrisella, Centroptilum luteolum, Paraleptophlebia submarginata, Ephemerella ignita, Cercion lindenii, Ceriagrion tenellum, Gomphus flavipes, Platycnemis pennipes, Aphelocheirus aestivalis, Orectochilus villosus, Athripsodes albifrons, A. cinereus, Ceraclea nigronervosa, Cheumatopsyche lepida, Cyrnus flavidus, C. trimaculatus, Hydropsyche angustipennis, Mystacides azurea*

Characteristic macrophytes:

Characteristic fish: *Barbus barbus, (Alosa alosa?), (Thymallus thymallus?), (Alburnus bipunctatus ?)*

**R9' : semi-natural lower courses, β-mesosaprobic, eutrophic**[2]

Characteristic invertebrates: *Dugesia tigrina, Potamothrix bavaricus, Pseudanodonta complanata, Ancylus fluviatilis, Hygrobates fluviatilis, Lebertia insignis, Protzia eximia, Gammarus roeselii, Baetis fuscatus, Caenis pseudorivulorum, Ephemera vulgata, Siphlonurus armatus, Haliplus wehnkei, Stictotarsus duodecimpustulatus, Boophtera erythrocephala, Harnischia sp., Nanocladius bicolor, Calopteryx splendens, Brachycentrus subnubilis, Hydropsyche exocellata, Neureclepsis bimaculata, Oecetis ochracea, Oxyethira sp., Phryganea grandis, Athripsodes aterrimus, Tinodes assimilis, Limnephilus extricatus, L. rhombicus, L. lunatus, Molanna angustata*

Characteristic macrophytes:

Characteristic fish: *Noemacheilus barbatulus, Salmo trutta fario, Leuciscus leuciscus, Gobio gobio*

**R3' : semi-natural small rivers, β-mesosaprobic, eutrophic**[2]

Characteristic invertebrates: *Potamothrix bavaricus, Tubifex ignotus, Vejdovskyella intermedia, Lebertia insignis, Atyaephyra desmarestii, Gammarus roeselii, Baetis fuscatus, Heptagenia fuscogrisea, H. sulphurea, Procloeon bifidum, Centroptilum pennulatum, Calopteryx splendens, Stictotarsus duodecimpustulatus, Xenochironomus xenolabis, Nanocladius bicolor, Neureclepsis bimaculata, Orthotrichia sp., Phryganea grandis, Molanna angustata*

Characteristic macrophytes:

Characteristic fish: *Noemacheilus barbatulus, Salmo trutta fario, Leuciscus leuciscus, Gobio gobio, Chondrostoma nasus, Leuciscus idus*

**F88 : natural lower courses, α-mesosaprobic to polysaprobic, eutrophic**[1]

Characteristic invertebrates: *Anabolia nervosa, Anodonta anatina, A. cygnea, Aphelocheirus aestivalis, Athripsodes albifrons, A, cinereus, Caenis horaria, C. luctuosa, Calopteryx splendens, Cladotanytarsus sp, Ceraclea nigronervosa, Cheumatopsyche lepida, Corynoneura sp, Cricotopus sp, Cryptochironomus sp, Cyrnus trimaculatus, Dicrotendipes gr nervosum, Ecnomus tenellus, Ephemerella ignita, Mideopsis orbicularis, Mystacides azurea, Haliplus fluviatilis, Hygrobates longipalpis, Laccophilus hyalinus, Nais barbata, N. pardalis, Nanocladius sp, Neureclepsis bimaculata, Orectochilus villosus, Parachironomus gr arcuatis, Paratanytarsus sp, Phaenopsectra sp, Polypedilum breviantennatum, Potamothrix moldaviensis, Proasellus coxalis, Psammoryctides albicola, P. barbatus, Theodoxus fluviatilis, Thienemanniella sp, Tubifex ignotus, Unio pictorum, Vejdovskyella intermedia*
Characteristic macrophytes: *Callitriche platycarpa, Hippuris vulgaris, Najas marina, Nuphar lutea, Potamogeton lucens, P. pectinatus, P. perfoliatus, Ranunculus aquatilis*
Characteristic fish: *Barbus barbus, Gobio gobio, Leuciscus cephalus, L. idus, L. leuciscus*[3]

**P68+ : old stream-/river-branches, oligo- to β-mesosaprobic, mesotrophic[2]**
Characteristic invertebrates: *Bdellocephala punctata, Chaetogaster diaphanus, C. diastrophus, Aulophorus furcatus, Hirudo medicinalis, Tubifex ignotus, Vejdovskyella comata, Erpobdella nigricollis, Haementeria costata, Anodonta anatina, Musculium lacustre, Acroloxus lacustris, Anisus vorticulus, Myxas glutinosa, Radix auricularia, Arrenurus claviger, A. knauthei, A. pugionifer, Eylais extendens, E. tantilla, Piona alpicola/coccinea, P. variabilis, Tiphys ornatus, Unionicola crassipes, Aeshna cyanea, A. isoscelis, A. mixta, A. viridis, Coenagrion puella, Cordulegaster boltonii, Cordulia aenea, Erythromma najas, Pyrrhosoma nymphula, Somatochlora metallica, Sympecma fusca, S. flaveolum, Arctocorisa germari, Callicorixa praeusta, Corixa dentipes, C. panzeri, Cymatia bonsdorffi, C. coleoptrata, Gerris gibbifer, G. thoracicus, Hesperocorixa moesta, Mesovelia furcata, Micronecta minutissima, Naucoris maculatus, Notonecta obliqua, N. reuteri, Plea minutissima, Ranatra linearis, Sigara scotti, S. semistriata, Acilius canaliculatus, A. sulcatus, Agabus congener, A. labiatus, A. melanocornis, Berosus luridus, B. signaticollis, Coelambus novemlineatus, Cybister lateralimarginalis, Cyphon sp/Hydrocyphon sp/Scirtes sp, Dytiscus circumcinctus, D. lapponicus, D. semisulcatus, Enochrus melanocephalus, Graphoderus bilineatus, G. cinereus, G. zonatus, Gyrinus caspius, G. minutus, G. paykulli, Haliplus fulvus, H. furcatus, H. heydeni, H. mucronatus, H. variegatus, Helophorus flavipes, Hydrochus carinatus, Hydrophilus piceus, Hydroporus pubescens, Hydrovatus cuspidatus, Ilybius aenescens, I. fenestratus, I. subaeneus, Laccophilus ponticus, Leptophlebia vespertina, Limnoxenes niger, Oulimnius major, O. rivularis, Rhantus exsoletus, R. suturalis, Spercheus emarginatus, Sisyra fuscata, Ablabesmyia longistyla, A. monilis, Chaoborus flavicans, Corynoneura scutellata agg, Cryptocladopelma gr lateralis, Dicrotendipes gr tritomus, Endochironomus albipennis, E. tendens, Microchironomus tener, Paracladius conversus, Phalacrocera replicata, Polypedilum gr sordens, P. uncinatum, Prodiamesa olivacea, Psectrocladius gr sordidellus/limbatellus, P. obvius, Psectrotanypus varius, Pseudochironomus sp, Pseudorthocladius curtistylus, Stenochironomus sp, Stictochironomus sp, Tribelos intextus, Zavreliella marmorata, Agraylea sexmaculata, Agrypnia pagetana, A. varia, Ceraclea fulva, C. senilis, Cyrnus crenaticornis, C. flavidus, C. insolutus, Erotesis baltica, Holocentropus dubius, H. stagnalis, Leptocerus tineiformis, Limnephilus binotatus, L. politus, Lype phaeopa, Mystacides azurea, Oecetis furva, O. lacustris, Polycentropus irroratus, Tinodes waeneri, Tricholeiochiton fagesii, Paraponyx stratiotata*
Characteristic macrophytes: *Callitriche hamulata, Hottonia palustris, Myriophyllum alterniflorum, Nitella flexilis, Potamogeton gramineus, P. obtusifolius, Sparganium angustifolium, Tolypella glomerata*
Characteristic fish: *Esox lucius, Perca fluviatilis, Rutilus erythrophthalmus, Rhodeus sericeus*

**P68' : old stream-/river-branches, β-mesosaprobic, eutrophic[2]**
Characteristic invertebrates: *Haementeria costata, Arrenurus pugionifer, A. securiformis, A. tetracyphus, Frontipoda musculus, Hydrachna leegei, Oxus nodigerus, Piona paucipora, Tiphys bullatus, Unionicola figuralis, Somatochlora metallica, Sympetrum flaveolum, S. sanguineum, Corixa dentipes, Hesperocorixa castanea, Hydrometra gracilenta, Sigara scotti, Dytiscus circumflexus, Enochrus quadripunctatus, Graphoderus zonatus, Haliplus obliquus, Hydrochus carinatus, Hydroporus tristis, Rhantus latitans, Cryptotendipes sp, Einfeldia gr pagana, Stenochironomus sp, Zavrelia pentatoma, Zavreliella marmorata, Limnephilus nigriceps, L.*

*politus, Paraponyx sp*

Characteristic macrophytes: *Alisma gramineum, Callitriche platycarpa, Chara contraria, C. globularis, Hippurus vulgaris, Hydrocharis morsus-ranae, Nymphaea alba, Nymphoides peltata, Polygonum amphibium, Potamogeton lucens, P. natans, P. perfoliatus, Ranunculus aquatilis, R. circinatus, Sagitaria sagittifolia, Stratiotes aloides*

Characteristic fish: *Tinca tinca, Rutilus rutilus, Perca fluviatilis*

**M88 : stagnant lower courses, α-mesosaprobic to polysaprobic, eutrophic[1]**

Characteristic invertebrates: *Anodonta cygnea, Branchiura sowerbyi, Coenagrion pulchellum, Cladotanytarsus sp, Cryptochironomus sp, Cybister lateralimarginalis, Endochironomus albipennis, Einfeldia gr insolita, Fleuria lacustris, Forelia variegator, Gyraulus laevis, Hydrovatus cuspidatus, Hygrobates nigromaculatus, Ilybius fenestratus, Limnesia maculata, Limnodrilus claparedeianus, Lipiniella arenicola, Lithoglyphus naticoides, Microchironomus tener, Mideopsis orbicularis, Mystacides azurea, M. nigra, Noterus clavicornis, Ophidonais serpentina, Orchestia cavimana, Orthotrichia costalis, Oulimnius major, Parachironomus gr arcuatis, Paranais frici, Piscicola geometra, Polypedilum gr bicrenatum, P. gr sordens, Potamopyrgus jenkinski, Potamothrix bavaricus, P. moldaviensis, Psammoryctides albicola, P. barbatus, P. moravicus, Slavina appendiculata, Tanypus kraatzi, Theromyzon tessulatum, Tinodes waeneri, Tubifex nerthus, T. newaensis, Unio pictorum, Valvata macrostoma*

Characteristic macrophytes: *Chara contraria, Nitella hyalina, N. mucronata, N. opaca, Nitellopsis obtusa*

Characteristic fish: *Leuciscus idus, Scardinius erythrophthalmus, Silurus glanus, Gymnocephalus cernua*[3]

## *Appendix II: Map with Names of Streams in the Dommel Catchment*