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Monitoring effectiveness of the EU Nitrates Directive Action Programmes

Results of the international $MonNO_3$ workshop in the Netherlands, 11-12 June 2003

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Abstract

Monitoring effectiveness of the EU Nitrates Directive Action Programmes:
Results of the international MonNO$_3$ workshop in the Netherlands, 11-12 June 2003

The contributions of the participants to the MonNO$_3$ workshop, organised by RIVM, GEUS and DMU in The Hague (Scheveningen), the Netherlands on 11-12 June 2003 are assembled in this report. More specifically, the report provides a synthesis of the papers and an outline of the workshop discussions on the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes. The legal requirements for this type of monitoring have been incorporated in Article 5(6) of the Nitrates Directive. Two different approaches −upscaling and interpolation− for describing the effect of Action Programmes on a national scale were defined but not discussed in detail, since this was beyond the scope of the MonNO$_3$ workshop. All contributions presented make clear that water quality is not only influenced by agricultural practice but by other factors as well. Soil type, hydrological and geological characteristics of sediments or rocks (or of the surface water system), and climate and weather are examples of environmental factors that may cause differences in water quality, either between locations or in time.

Keywords: water quality, nitrate, eutrophication, Nitrates Directive, Action Programme, MonNO$_3$ workshop

Rapport in het kort

Monitoren van de effectiviteit van de EU Nitraatrichtlijn Actieprogramma's:
Resultaten van de internationale MonNO$_3$ workshop gehouden in Nederland, 11-12 juni 200.

Dit rapport bevat de bijdragen van de deelnemers aan de MonNO$_3$ workshop, georganiseerd door het RIVM, GEUS en DMU. De workshop is gehouden op 11 en 12 juni 2003 en vond plaats in Den Haag (Scheveningen). Het rapport geeft ook een synthese van deze bijdragen en de workshopdiscussies over de methoden om de effectiviteit van de EU Nitraatrichtlijn Actieprogramma's te monitoren. De wettelijke grondslag voor dit type monitor staat in de Nitraatrichtlijn, artikel 5(6). Er zijn twee verschillende benaderingswijzen om de effecten van de Actieprogramma's op nationale schaal te beschrijven, te weten opschalen en interpolatie. Deze benaderingswijzen zijn niet in detail bediscussieerd omdat dit buiten het terrein van de MonNO$_3$ workshop lag. Uit alle bijdragen blijkt dat waterkwaliteit niet alleen wordt beïnvloed door de landbouwpraktijk maar ook door andere factoren. Bodemtype, hydrogeologische karakteristieken van de bodem en de ondergrond, karakteristieken van het oppervlaktewatersysteem en karakteristieken van het klimaat en het weer zijn voorbeelden van "omgevingsfactoren" die de oorzaak kunnen zijn van in tijd en ruimte gemeten verschillen in waterkwaliteit.

Trefwoorden: waterkwaliteit, nitraat, eutrofiëring, Nitraatrichtlijn, Actieprogramma, MonNO$_3$ workshop

Resumé

Overvågning af effektiviteten af EU Nitratdirektivets handlingsprogram:
Resultater af den internationale MonNO$_3$ workshop i Holland, 11.-12. juni 2003

Denne rapport indeholder bidrag fra deltagerne i MonNO$_3$ workshoppen, der blev organiseret af RIVM, GEUS og DMU i Haag (Scheveningen) i Holland den 11.-12. juni 2003. Rapporten giver endvidere en syntese af bidragene og en oversigt over diskussionerne på workshoppen om metoder for overvågning af effektiviteten af EU Nitratdirektivets handlingsprogram. De lovmæssige krav til denne form for overvågning fremgår af Nitratdirektivets artikel 5 (6). Der blev defineret to forskellige tilgange til beskrivelse af handlingsprogrammers effekt på national skala, opskalering og interpolation, men de blev ikke diskuteret i detaljer, fordi det lå udenfor MonNO$_3$ workshoppens formål. Alle de præsenterede bidrag viser at vandkvaliteten ikke kun påvirkes af landbrugspraksis, men også af andre faktorer. Jordtype, sedimenters eller bjergarters hydrogeologiske karakteristika, overfladevandets karakteristika, klima og vejr er eksempler på miljøfaktorer der kan medføre variation i vandkvaliteten, enten fra sted til sted eller med tiden.

Nøgleord: vandkvalitet, nitrat, eutrofiering, Nitratdirektiv, handlingsprogram, MonNO$_3$ workshop

Preface

This report, prepared in close co-operation with the participants, is the ultimate, tangible result of the MonNO_3 workshop held in the Netherlands in June 2003. However, we consider the intangible results to be probably just as important. A very informal atmosphere at the workshop stimulated a free exchange of information and knowledge. During our two days and nights in one location, where we not only worked hard but also enjoyed the sea and the beach during the barbecue, bonds of co-operation were forged. The process of updating the Member States' contribution, coupled with writing and commenting on the synthesis after the workshop, strengthened the bonds that had been built during the workshop.

The success of the workshop is also the result of all the preparatory work done in advance. All participasting Member States provided a pre-workshop paper either before or at the beginning of the workshop. We had pre-workshop meetings in Copenhagen, London, Berlin, and Brussels, where not only the participants attended but also other colleagues involved in the monitoring or implementation of the Nitrates Directive.

The final meeting of the workshop Organising Committee took place in December 2004. Here, the last draft version of the synthesis chapter and comments made by the participants were discussed, as well as the latest developments with regard to monitoring and reporting, and the possibilities for a follow-up. We hope that others will take up this initiative of the Netherlands and Denmark in the form of a workshop in the near future.

We would like to thank Herman van Keulen of the Wageningen University Research Centre, who did a marvellous job as chairman of the workshop plenary sessions. We also wish to thank Simon Gardner of the UK Environment Agency and Rüdiger Wolter of the German Federal Environmental Agency (UBA), who chaired parallel sessions and helped us tremendously in their role as members of the Organising Committee. Finally, we thank Ruth de Wijs–Christensen and Cécile van Dijk, our colleagues at RIVM, for their suggestions and critical comments on the draft version of this report.

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Dico Fraters, Karel Kovar, Jaap Willems, Jens Stockmarr and Ruth Grant

Contents

Samenvatting 11
Summary 13
Sammenfatning 15

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Introduction
B. Fraters, K. Kovar, W.J. Willems, J. Stockmarr & R. Grant **17**

1. Background and History 17
2. Workshop on effect monitoring in the EU Member States 19
3. The workshop report 21
References and official sources 21

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Synthesis of workshop contributions
B. Fraters, K. Kovar, W.J. Willems, J. Stockmarr & R. Grant **23**

1. Introduction 23
2. Water use and Agriculture 24
2.1 Water use 24
2.2 Agriculture 26
3. Implementation of the Nitrates Directive 28
4. Monitoring 30
4.1 General 30
4.2 Monitoring networks 33
4.3 Effect monitoring 36
5. Environmental goals and quality standards 36
6. Workshop results and follow up 39
References and official sources 40

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Austria
K. Schwaiger **41**

1. Introduction 41
1.1 General 41
1.2 Description of natural factors influencing nitrate occurrence 41
1.3 Description of human factors influencing nitrates occurrence 43
1.4 Overview of networks monitoring water quality 46
1.5 Environmental goals 49
2. Effect monitoring 51
2.1 Strategy for monitoring 51
2.2 Detailed technical description of effect monitoring 52
2.3 Data interpretation and discussion 54
References and official sources 55

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Flemish region (Belgium)
R. Eppinger, D. Vandevelde, A. Dobbelaere & H. Maeckelberghe **57**

1. Introduction 58
1.1 Description of natural factors influencing nitrate occurrence 58
1.2 Description of human factors influencing nitrate occurrence 59
1.3 Headlines of the Flemish action plan 65
1.4 Overview of monitoring networks in Flanders 67
1.5 Regional environmental goals with respect to nitrate and eutrophication 69

2. Effect monitoring 70
2.1 Strategy for effect monitoring 70
2.2 Technical description of networks used for effect monitoring 74
2.3 Data interpretation 78

3. Discussion 81
3.1 Surface waters 81
3.2 Groundwater 82

References and official sources 82

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Walloon Region (Belgium)
F. Delloye, A. Dewez, O. Gerard, Ph. Guillaume, R. Lambert, A. Peeters, C. Vandenberghe & J.M. Marcoen **85**

1. Introduction 86
1.1 General 86
1.2 Description of natural factors influencing nitrate occurrence 87
1.3 Description of human factors influencing nitrate occurrence 88
1.4 Overview of monitoring networks 93

2. Effect monitoring 94
2.1 Strategy for effect monitoring 94
2.2 Detailed technical description of networks used for effect monitoring 95

3. Discussion 104
3.1 Data interpretation 104
3.2 Difficulties encountered 104

References and official sources 105

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Denmark
J. Stockmarr, R. Grant & U. Jørgensen **107**

1. Introduction 107
1.1 General 107
1.2 Description of natural factors influencing nitrate concentrations 108
1.3 Description of human factors influencing nitrate occurrence 111
1.4 Environmental goals 117

2. Effect monitoring 119
2.1 Strategy for effect monitoring 119
2.2 Detailed description of effect monitoring programme 120
2.3 Monitoring 123

3. Discussion and data interpretation 132
3.1 Evaluation of Action Plans 132
3.2 Danish derogation from the Nitrates Directive 134
3.3 Coherence between variations in groundwater chemistry and groundwater infiltration 135

References and official sources 137

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Germany
R. Wolter & V. Mohaupt **139**

1. Introduction 139
1.1 General 139
1.2 Description of natural factors influencing nitrate occurrence 141
1.3 Description of human factors influencing nitrate occurrence 143
1.4 Overview of monitoring networks 143
1.5 Environmental goals 150

2. Effect monitoring 150
2.1 General 150
2.2 Effect monitoring for surface waters 151
2.3 Effect monitoring for groundwater 153
2.4 Prognosis 156

3. Discussion 156
3.1 Eutrophication monitoring 156
3.2 Chlorophyll concentration 157

References and official sources 157

Strategies for reducing nitrate inputs in groundwater and methods of efficiency control – The Lower Saxony co-operation model for groundwater protection and requirements of the EU Nitrates Directive
H. Schültken **159**

1. Introduction 159

2. The Lower Saxony co-operation model 160
2.1 General 160
2.2 The advisory service for water protection 161
2.3 Voluntary agreements 161
2.4 Pilot projects 161
2.5 Methods of efficiency control 162
2.6 Success stories 165
2.7 Land use management 165

Conclusions 166

References and official sources 167

Monitoring Effectiveness of the EU Nitrates Directive Action Programmes: Approach by Ireland
M. Mac Cárthaigh **169**

1. Introduction 169
1.1 General 169
1.2 Description of the natural factors influencing nitrate occurrence 170
1.3 Description of human factors influencing nitrate occurrence 173
1.4 Overview of monitoring networks 174

2. Effect monitoring 177
2.1 General 177
2.2 Rivers 178
2.3 Groundwater 179
2.4 Estuarine, coastal and marine waters 187
2.5 Lakes 188
2.6 Strategy for effect monitoring 190

3. Discussion 190

References and official sources 191

Appendix 1 Nitrate concentrations measured at Irish EUROWATERNET river stations 192
Appendxi 2 Nitrate concentrations in groundwater at the national monitoring stations 194

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Sweden
M. Bång **199**

1. Introduction *199*
1.1 General *199*
1.2 Description of natural factors influencing nitrate occurrence *199*
1.3 Description of human factors influencing nitrate occurrence *202*
1.4 Overview of monitoring networks *207*
1.5 Environmental goals *208*
2. Effect monitoring *210*
2.1 Strategy for effect monitoring *210*
2.2 Detailed technical description of networks used for effect monitoring *211*
2.3 Data interpretation *213*
3. Discussion *214*
References and official sources *215*

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Netherlands
B. Fraters, L.J.M. Boumans, T.C. van Leeuwen & P. Boers **217**

1. Introduction *217*
1.1 General *217*
1.2 Description of natural factors influencing nitrate occurrence *218*
1.3 Description of human factors influencing nitrate occurrence *224*
1.4 Overview of monitoring networks *226*
1.5 Environmental goals *231*
2. Effect monitoring *233*
2.1 Strategy for effect monitoring *233*
2.2 Detailed technical description of networks used for effect monitoring *236*
2.3 Data interpretation *239*
3. Discussion *241*
References and official sources *242*
Appendix *245*

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the United Kingdom
A.R. Cambray, M.J. Marks, S. Dawes, S. Gardner, R. Ward, M. Hallard, A.M. MacDonald, O. Ruddle & P. McConvey **247**

1. Introduction *248*
1.1 Description of natural factors influencing nitrate occurrence *248*
1.2 Description of human factors influencing nitrate occurrence *251*
1.3 Overview of monitoring networks *255*
1.4 Environmental goals *268*
2. Effect monitoring *269*
2.1 Action Programme measures and derogation *269*
2.2 Strategy for effect monitoring *269*
2.3 Detailed technical description of networks used for effect monitoring *271*
3. Discussion *277*
References and official sources *278*

Appendix 1: List of workshop participants **281**

Appendix 2: Workshop programme **289**

Samenvatting

Dit rapport bevat de bijdragen van de deelnemers aan de MonNO_3 workshop, georganiseerd door het Nederlandse Rijksinstituut voor Volksgezondheid en Milieu (RIVM), het Geologische Instituut voor Denemarken en Groenland (GEUS) en het Deense Milieuonderzoekinstituut (DMU). De workshop heeft plaatsgevonden in Den Haag (Scheveningen) op 11-12 juni 2003. Het rapport geeft tevens een synthese van de bijdragen en de discussies gevoerd tijdens de workshop. In totaal hebben acht lidstaten van de Europese Unie deelgenomen en een bijdrage geleverd (België, Denemarken, Duitsland, Ierland, Nederland, Oostenrijk, Verenigd Koninkrijk en Zweden). Drie van de toenmalige kandidaat-lidstaten hebben eveneens aan de workshop deelgenomen (Polen, Slowakije en Tsjechië).

Er bleken grote verschillen te bestaan tussen landen met betrekking tot het gebruik van grond- en oppervlaktewater en de intensiteit en de structuur van de landbouw. Er bleek echter geen relatie te zijn tussen de intensiteit van de landbouw en de keuze van de lidstaten voor het aanwijzen van Nitraat Uitspoelinggevoelige Gebieden of voor het van toepassing verklaren van het Actieprogramma op het gehele grondgebied. Derogatie voor de in de Nitraatrichtlijn opgenomen maximum stikstofgift met dierlijke mest van 170 kg ha^{-1} N is tot nu toe alleen aangevraagd of wordt alleen overwogen door lidstaten met een aanzienlijke veedichtheid, zoals bijvoorbeeld Denemarken en Nederland.

De lidstaten investeren op dit moment een aanzienlijke hoeveelheid tijd en geld in de monitornetwerken, waarbij verschillende lidstaten nog doende zijn de netwerken uit te breiden. Tijdens de workshop was er overeenstemming over de algemene strategie voor het monitoren van effecten van de Actieprogramma's; desalniettemin wil dit niet zeggen dat alle lidstaten op dezelfde wijze dienen te monitoren. Het richtsnoer voor de monitor ten behoeve van de Nitraatrichtlijn, nog steeds in concept, beschrijft een globale werkwijze voor het monitoren van de landbouw en de waterkwaliteit om de stikstofbelasting op grond- en oppervlaktewater in beeld te brengen. Uit alle bijdragen blijkt dat waterkwaliteit niet alleen wordt beïnvloed door de landbouwpraktijk maar ook door andere factoren. Bodemtype, hydrogeologische karakteristieken van de bodem en de ondergrond, karakteristieken van het oppervlaktewatersysteem en karakteristieken van het klimaat en het weer zijn voorbeelden van "omgevingsfactoren" die de oorzaak kunnen zijn van in tijd en ruimte gemeten verschillen in waterkwaliteit. Het type en de structuur van het landbouwbedrijf, het opleidingsniveau van de ondernemer en de aan- of afwezigheid van een bedrijfsopvolger zijn voorbeelden van "bedrijfsfactoren". Deze bedrijfsfactoren zijn van invloed op de wijze waarop wet- en regelgeving op het bedrijf in feitelijk handelen wordt omgezet. Om inzicht te krijgen in de effecten van beleidsmaatregelen dienen omgevingsfactoren en bedrijfsfactoren ook gemonitord te worden.

Er zijn twee verschillende benaderingswijzen om de effecten van de Actieprogramma's op nationale schaal te beschrijven, te weten opschalen en interpolatie. Deze benaderingswijzen

zijn niet in detail bediscussieerd omdat dit buiten het terrein van de MonNO_3 workshop lag. De opschalingsbenadering maakt gebruik van de resultaten van studies naar de effecten van landbouwkundig handelen op de uitspoeling van nitraat (en waterkwaliteit) op proefvelden of observaties bij landbouwbedrijven op (homogene) delen van percelen. Procesmodellen en gegevens over de verandering van de landbouwpraktijk op nationale schaal worden gebruikt om de resultaten van de veldstudies op te schalen om de effecten van de Actieprogramma’s op de uitspoeling van nitraat en de waterkwaliteit op nationale schaal te beschrijven. De interpolatiebenadering maakt gebruik van resultaten van monitorprogramma’s waarbij nitraatuitspoeling (waterkwaliteit) en landbouwpraktijk op aselect gekozen locaties worden gemeten, bijvoorbeeld op landbouwbedrijven. Met behulp van statistische modellen, ontwikkeld mede op basis van proceskennis en de op nationale schaal verzamelde gegevens over de veranderingen in de landbouwpraktijk, wordt een beschrijving gegeven van de effecten van de Actieprogramma’s op de nitraatuitspoeling en waterkwaliteit op nationale schaal.

Summary

The contributions of the participants to the MonNO$_3$ workshop, organised by the Dutch National Institute for Public Health and the Environment (RIVM), the Geological Survey for Denmark and Greenland (GEUS) and the Danish National Environmental Research Institute (DMU) are assembled in this report. The workshop took place in The Hague (Scheveningen), the Netherlands from 11 to 12 June 2003. Specifically, this report provides a synthesis of the papers and an outline of the workshop discussions. Eight EU Member States −Austria, Belgium, Denmark, Germany, Ireland, Sweden, the Netherlands and the United Kingdom− participated, with each of these countries delivering a paper. Three other countries participating in the workshop, the Czech Republic, Poland and Slovakia, were EU candidate Member States at that time.

Countries show large differences with respect to both use of surface waters and groundwater, and in the intensity and structure of agriculture. However, there does not seem to be a relationship between the intensity of agriculture and whether Member States have either designated Nitrate Vulnerable Zones or applied their Nitrates Directive Action Programmes to their entire territory. Only Member States with a substantial livestock density apply for or consider derogation for the maximum allowable nitrogen application rate of 170 kg ha^{-1} N for manure, for example Denmark and the Netherlands.

Member States are currently investing considerable time and money in monitoring networks, with several of them still busy extending their own networks. Although there was agreement at the workshop on the general strategy for effect monitoring of the Action Programmes, this does not imply that all Member States have to monitor in the same way. The guidelines for monitoring under the Nitrates Directive, still in draft form, outline the monitoring of agriculture and water quality to show the effects of nitrogen input in surface water and groundwater. All contributions presented make clear that water quality is not only influenced by agricultural practice but by other factors as well. Soil type, hydrological and geological characteristics of sediments or rocks (or of the surface water system), and climate and weather are examples of environmental factors that may cause differences in water quality, either between locations or in time. The type and structure of the farm, the educational level of the farmer, and whether the farmer has a successor or not are examples of “farm factors”. These farm factors influence the way policy measures are implemented in farm practice, forming another reason for monitoring these factors.

Two different approaches −upscaling and interpolation− for describing the effect of Action Programmes on a national scale were defined but not discussed in detail, since this was beyond the scope of the MonNO$_3$ workshop. The upscaling approach uses the results of studies on the effects of change in agricultural practice on nitrate leaching (and water quality) on experimental sites (e.g. homogeneous plots or parcels). Numerical process models and data on agricultural practice covering national-scale change are used to upscale the experimental-site results. This allows Member States to describe the effect of the Action Programme on nitrate leaching and water quality on the national scale. The interpolation approach uses the results on monitoring agricultural practice and nitrate leaching (and water quality) for a random sample of locations, e.g. farms. Statistical models based on knowledge of processes and national-scale monitored changes in agricultural practice are used on the national scale to describe the effect of their Action Programmes on nitrate leaching and water quality.

Sammenfatning

Denne rapport omfatter bidrag fra deltagerne i MonNO_3 workshoppen, der blev organiseret af det Hollandske Rigsinstitut for Folkesundhed og Miljø (RIVM), Danmarks og Grønlands Geologiske Undersøgelse (GEUS) og Danmarks Miljøundersøgelser (DMU). Workshoppen fandt sted i Haag (Scheveningen) i Holland fra den 11. til den 12. juni 2003. Rapporten giver endvidere en syntese af bidragene og en oversigt over diskussionerne på workshoppen. Otte EU medlemsstater deltog - Østrig, Belgien, Danmark, Tyskland, Irland, Sverige, Holland og Storbritannien - og hvert land har leveret et bidrag. Tre andre lande, der deltog i workshoppen, Tjekkiet, Polen og Slovakiet, var EU kandidat medlemsstater på det tidspunkt.

Der er store forskelle mellem landene, både med hensyn til brug af overfladevand og grundvand og med hensyn til landbrugsintensitet og -struktur. Imidlertid synes der ikke at være nogen sammenhæng mellem landbrugsintensitet og hvorvidt medlemsstaterne har udpeget Nitratfølsomme områder eller har indført Nitratdirektivets handlingsprogram i hele landet. Kun medlemsstater med betydelig dyretæthed har søgt om fritagelse fra kravet om maksimalt tilladt tilførsel på 170 kg N/ha for dyregødning, f.eks. Danmark og Holland.

Medlemsstaterne anvender løbende betydelige ressourcer (tid og penge) på overvågningsnetværk og flere lande er stadig optaget af at udvide deres netværk. Selv om der var enighed på workshoppen om den generelle strategi for effektovervågning af handlingsprogrammet betyder det ikke at medlemsstaterne skal overvåge på samme måde. Overvågningsvejledningen til Nitratdirektivet, der kun foreligger i udkast, redegør for at overvågning af landbrug og vandkvalitet skal vise effekten af kvælstoftilførsel til overfladevand og grundvand. Alle de præsenterede bidrag viser at vandkvaliteten ikke kun påvirkes af landbrugspraksis, men også af andre faktorer. Jordtype, sedimenters eller bjergarters hydrogeologiske karakteristika, overfladevandets karakteristika, klima og vejr er eksempler på miljøfaktorer der kan medføre variation i vandkvaliteten, enten fra sted til sted eller med tiden. Landbrugstyper og -struktur, landmandens uddannelsesniveau eller om landmanden har efterfølgere eller ej er eksempler på "landbrugsfaktorer" der influerer på hvorledes midler og regler implementeres i landbruget og giver endnu en grund til at disse faktorer overvåges.

Der blev defineret to forskellige tilgange til beskrivelse af handlingsprogrammers effekt på national skala, opskalering og interpolation, men de blev ikke diskuteret i detaljer, fordi det lå udenfor MonNO_3 workshoppens formål. Opskalering anvender resultater af effektstudier af ændringer i landbrugspraksis på nitratudvaskning (og vandkvalitet) på forsøgslokaliteter (f.eks. ensartede lokaliteter eller arealer). Numeriske procesmodeller og data for landbrugspraksis på national plan bruges til at opskalere resultaterne fra forsøgslokaliteterne. Det giver medlemsstaterne mulighed for at beskrive effekten af handlingsprogrammet på nitratudvaskning og vandkvalitet på nationalt plan. Interpolation bruger overvågningsresultater fra landbrugspraksis og nitratudvaskning (vandkvalitet) fra et tilfældigt udvalgt antal lokaliteter, f.eks. landbrug. Statistiske modeller baseret på procesforståelse og landsdækkende overvågede ændringer i landbrugspraksis bruges til at beskrive effekten af handlingsprogrammer for nitratudvaskning og vandkvalitet på landsplan.

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Introduction

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Abstract This introduction chapter describes the general background for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the European Community. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5(6). (EC, 1991). In 1999 the European Commission published the Draft Monitoring Guidelines (EC, 1999). The lack of clarity with respect to the monitor obligation in general and effect monitoring more specifically was the driving force behind the organisation of a workshop on effect monitoring for the Nitrates Directive, the MonNO_3 workshop. This report discusses the outcome of this workshop organised by RIVM, GEUS and DMU. The workshop was held on 11-12 June 2003 in The Hague, the Netherlands.

1. BACKGROUND AND HISTORY

In the 1980s it was widely recognised that agricultural practice might have adverse effects on water quality and ecosystems (Strebel *et al.*, 1989; Duynisveld *et al.*, 1988; Baker & Johnson, 1981). Several European countries started to formulate policy measures to counteract these effects and to regulate agricultural practices (Anonymous, 1984, 1985, 1986, 1991; Danish Parliament, 1987). Also on international level initiatives were taken. The initiatives within the European Union resulted in 1991 in a directive that should eventually lead up to an environmentally sound agriculture with respect to nitrogen losses to groundwater and surface waters, the Nitrates Directive (EC, 1991).

Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources or, shortly, the Nitrates Directive requires all Member States to establish a code of Good Agricultural Practice (GAP). Also areas that are vulnerable to nitrates, the Nitrates Vulnerable Zones (NVZ), should be designated. For these areas Action Programmes have to be established. A Member State may choose to not designate NVZ but to apply the Action Programmes to the entire territory. An Action Programme must contain at least the measures prescribed in the Nitrates Directive, such as the obligation for livestock farms to establish enough storage capacity for animal manure and the prohibition for all farmers to apply more nitrogen with animal manure than 170 kg ha^{-1}. With respect to the latter, the Nitrates Directive explicitly offers Members States the possibility to deviate from this manure application maximum of 170 kg ha^{-1}. This derogation has to be approved by the European Commission.

The EU Nitrates Directive also requires all Member States to monitor their groundwater, surface water and the effectiveness of their action programmes. In 1999 the European Commission published a draft monitoring guideline (EC, 1999), which outlines how monitoring should be carried out. A new draft version was released in 2003 (EC, 2003). According to these Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC) (EC, 2003), the following three types of monitoring can be distinguished:

- *Monitoring for the identification of water*
  Monitoring required if a number of Nitrate Vulnerable Zones (NVZ) are to be designated within the country or region. If a country or region decides that Action Programmes will be applied to the entire territory, i.e. no designation of NVZs, this type of monitoring is irrelevant. Obviously, if this type of monitoring is required, use will be made of other existing networks (see the next point), possibly combined with an adapted monitoring programme (focus on specific areas, higher observation frequency in time, etcetera).

- *Monitoring for countries applying the Action Programme to the whole of their territory*
  Quoting from the Draft guidelines, this embraces "*baseline monitoring of important water bodies and intensively cropped regions*". Examples are the national monitoring networks for groundwater and surface water, (probably) available in all the relevant countries or regions.

- *Monitoring to assess the effectiveness of Action Programmes*
  Quoting from the Draft guidelines:
  "*This monitoring, required under the first sentence of Article 5(6), should be carried out in all areas where action programmes apply and should have regard to the objectives of Article 1 of the Directive. Monitoring the effectiveness of the action programmes requires baseline information for comparison purposes. Thus, the monitoring described in sections 3 and 4 above must be undertaken in zones subject to action programmes and may need to be supplemented. All major river systems should contain sampling points that are representative of the catchment and are sufficiently sensitive to the results expected of the action programme measures.*"

For effect monitoring
(a) some countries will make use of existing networks (identification monitoring, baseline monitoring, or other networks such as those used for agricultural monitoring[1];
(b) while other countries will make use of networks that have been specifically designed for this purpose.

It is clear that countries have given their own interpretation on how the monitoring

[1] for example, networks for the collection of accountancy data on the incomes and business operation of agricultural holdings, as described in Council Regulation No. 79/65/EEC of 15 June 1965 as last amended by Regulation (EC) No 1256/97

should be carried out. At the meeting of the EU Nitrate Committee in June 2002 Professor Bjørn Kløve of the Norwegian Centre for Soil and Environmental Research concluded in his presentation that "*The present draft guidelines (1999 version):*

- *Are very general and somewhat unclear, and*
- *Do not provide guidelines for monitoring the effects of action programmes."*

In the meeting of the EU Nitrate Committee in March 2003 the Commission has issued a new and final draft version of the Nitrates Directive monitoring guideline (EC, 2003). All Member States were asked to comment on it before 15 May 2003. The question whether this new version settles the comments on the 1999 version is not yet answered. Until presently the European Commission has not upgraded the draft monitoring guideline (EC, 2003), making it an official EU monitoring guideline.

This lack of clarity with respect to the monitor obligation in general and effect monitoring more specifically was the driving force behind the organisation of a workshop on effect monitoring for the Nitrates Directive, the MonNO_3 workshop.

2. WORKSHOP ON EFFECT MONITORING IN THE EU MEMBER STATES

With respect to the monitoring of (deep) groundwater and surface water, monitoring networks have been in place in several countries for many years. However, for monitoring the effects of Action Programmes on agriculture and the environment, experience, in general, is still limited. As already mentioned, for the effect monitoring either use will be only made of other existing (identification, baseline, etcetera) networks, or additional networks will be used that have been specifically designed for this purpose. For example, Denmark and the Netherlands have such specific monitoring networks for any length of time. In Denmark, as well as the Netherlands, the effectiveness has been established by simultaneously monitoring agricultural practices and nitrate concentrations in recently formed groundwater and/or surface water. In 2002, there was only a limited picture of the situation in other Member States, much of this being realised through informal contacts.

The initiative to organise a workshop on effect monitoring was taken by the Netherlands. This is because not only the Dutch Parliament, but also the agricultural sector, for example, has regularly raised question with respect to monitoring. The main issue was whether monitoring the quality of water leaching from the agricultural soil, i.e. the upper metre of shallow groundwater, tile drain water or ditch water, is unique to the Netherlands and on whether co-ordination should be sought with other EU Member States. Hence, there appeared to be a need for a broader exchange of scientific ideas on monitoring the effects of the Action Programmes. A workshop could provide the means for optimising the existing monitoring networks and/or the analytical methods used.

The workshop, called the MonNO_3 workshop, was organised by the National Institute for Public Health and the Environment of the Netherlands (RIVM), in co-operation with the Geological Survey of Denmark and Greenland (GEUS) and the National Environmental Research Institute of Denmark (DMU). The workshop was held 11-12 June 2003 in The Hague, the Netherlands. A list of participants and the workshop programme are given, respectively, in Appendix 1 and 2.

Goal of the workshop

The $MonNO_3$ workshop focused on the scientific and methodological aspects within the theme: monitoring the effects of action programmes on the environment. This theme is set up in the framework of the EU Nitrates Directive and described in the Draft guidelines for the monitoring required under the Nitrates Directive (91/676/EEC); section 5 of the 1999-version (EC, 1999) and section 6 and 7 of the 2003 version (EC, 2003).

The workshop's goal was threefold:
1) To give participants insight into and to inform them about the monitoring network in each other's countries, considering both the strategy behind the design of the monitoring programmes, and the standard analytical methods and techniques (e.g. for sampling).
2) To identify common goals, problems and solutions for improving the effectiveness and efficiency of monitoring and, possibly, for improving the comparability.
3) To create a network of experts.

Workshop target group

The workshop was intended for those actively concerned with scientific and methodological aspects of the design, operation and reporting of the effect monitoring in relation to the Nitrates Directive Action Programme in their own countries.

Besides the Netherlands and Denmark, this workshop involved the following countries (selected for their similar climates, soil types and crops): Austria, Belgium (Flanders and Walloon regions), Germany, the United Kingdom (England/Wales, Northern Ireland and Scotland), Ireland and Sweden. France has been invited but was not able to participate. In this way, countries with "*an easy point of departure with respect to nitrate pollution*" are represented (Austria and Sweden), as well as those with "*a difficult point of departure*" (Belgium, Denmark and the Netherlands) and "intermediate ones" (other countries).

The entire range of countries and regions is dealing with the Programme's implementation in national legislation. Some countries apply the Action Programmes to their entire territory (e.g. Austria, Denmark, Germany, Ireland and the Netherlands) and others apply it to specific areas i.e. the Nitrate Vulnerable Zones (e.g. Belgium, United Kingdom and Sweden). From a technical viewpoint, it is also true that the differences in the monitoring approach will be related to specific soil and groundwater conditions in the European countries (soil type, depth of groundwater table, type of aquifer etcetera). These aspects have obviously been addressed as well in this workshop.

In addition to the above-mentioned countries, observers have participated from three of the EU –at the time of the workshop– candidate countries with similar climates, soil types and crops: the Czech Republic, Poland, and Slovakia.

3. THE WORKSHOP REPORT

All participating countries were asked to provide on forehand a paper on its monitoring network for assessing effectiveness of the Nitrates Directive Action Programme. All the authors used the same framework for their contribution, which covers not only effect monitoring but also provides national background information on agriculture, environmental pressure and other monitoring networks. These papers have been published in a pre-workshop report that was only available for the workshop participants.

In order to share the knowledge generated by the workshop to a broader public all participating countries and regions have provided the final version of their paper after the workshop. Those papers were edited to provide a consistent report, with all papers having a similar structure. Each of the papers usually contains the following sections:

- Abstract;
- Introduction with, a description of natural and human factors influencing nitrate occurrence, an overview of monitoring networks and the environmental goals;
- Effect monitoring, with details about the strategy for effect monitoring, a technical description of networks used for effect monitoring and data interpretation;
- Discussion, with points of attention for future development and amelioration of effect monitoring;
- References.

This report also contains a chapter with the synthesis of the workshop findings, including overviews and conclusions. The draft version of this chapter has been sent to all participants for comments begin November 2004. In mid December 2004 the chapter and comments have been discussed in the final meeting of the Organising Committee in Copenhagen.

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Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Synthesis of workshop contributions

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Abstract Our paper will summarise the contributions of the participants to the MonNO_3 workshop, organised by RIVM, GEUS and DMU in The Hague (Scheveningen), the Netherlands on 11-12 June 2003. More specifically, it will provide synthesis of the papers and outline the workshop discussions on the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes. The legal requirements for this type of monitoring are set down in the Nitrates Directive, article 5(6) (EC, 1991). In 1999 the European Commission published the Draft Monitoring Guidelines (EC, 1999). There are large differences between countries with respect to use of surface waters and groundwater, and with respect to the intensity and structure of the agriculture. There seems however no relationship between intensity of agriculture and whether Member States have designated Nitrate Vulnerable Zones or whether they apply their Nitrates Directive Action Programmes to the entire territory. Derogation with respect to the maximum allowable nitrogen application rate of 170 kg ha^{-1} of N with manure is only applied for or considered by Member States with a substantial livestock density. Member States are investing a lot of time and money in monitoring networks, with several Member States still extending their networks. There was an agreement on the general strategy for effect monitoring of the Action Programmes and the fact that this does not imply that all Member States have to monitor in the same way. Two different approaches of effect monitoring were defined but not discussed in detail, because this was beyond the scope of this workshop. Several focal points for further study have been drawn up, along with discussions that would be of interest to several or all of the countries, but which could not be discussed during the workshop. It was concluded that it is important to ensure a follow-up to this workshop to fortify this budding co-operation and prevent it from blowing over.

1. INTRODUCTION

Eleven countries, all with comparable climate and crops in north-west and central Europe, participated in the MonNO_3 workshop held in Scheveningen (The Hague), the Netherlands, during 11 and 12 June 2003. Eight countries (Austria, Belgium, Denmark, Germany, Ireland, Sweden, the Netherlands and the United Kingdom) were member states of the European Union, and three (Czech Republic, Poland and

Slovakia) were candidate member states at the time of the workshop. The eight Member States have each presented a paper. These papers are included in this report a separate chapters. The contributions for the Flemish and Walloon regions of Belgium were presented separately. The Lower Saxony co-operation model has been presented as a German case study in addition to the German contribution.

The goals of the workshop were:
a) To give insight into and provide information on the monitoring network in each other's countries, considering both the strategy behind the design of the monitoring programmes and the standard analytical methods and techniques (e.g. for sampling).
b) To identify common goals and problems and to suggest solutions for improving the effectiveness and efficiency of monitoring and, where possible, also the comparability.
c) To create a network of experts on monitoring and reporting effects of the EU Nitrates Directive Action Programmes.

The implementation of the Nitrates Directive, designation of the Nitrate Vulnerable Zones (NVZ), notification of derogation from the maximum allowable manure application rate of 170 kg of nitrogen per hectare and reporting are all "delicate" subjects. Most Member States are still in discussion with the European Commission (EC) about the way the Nitrates Directive should be implemented. In addition, the EC is putting legal pressure on Member States who fail to correctly implement the different steps of the Directive's process. For this reason, the Organising Committee paid a lot of attention in this workshop to creating an informal atmosphere to stimulate an open discussion on all subjects, including the delicate ones. Considering the discussions and reactions of the participants, this was a good choice.

In the next sections more insight into the way the participating countries have implemented or are implementing the Nitrates Directive with regard to designation of NVZ and notification of derogation will be provided (Chapter 3). Especially with regard to the operation of the existing monitoring networks and the way effects of the Action Programmes are or will be monitored (Chapter 4). Additionally in Chapter 5 an overview is provided of environmental goals and quality standard and in Chapter 6 the workshop results are summarised and a follow up is discussed. First, in Chapter 2, the general setting will be presented based on statistical information provided by the participants in their papers or derived from open sources.

2. WATER USE AND AGRICULTURE

2.1 Water use

Water is used for drinking water production, industrial use, irrigation, hydropower (energy), recreational use and transport. There are differences in total water use and sectoral use between countries that attended the workshop, see Fig. 1. The high water use in Belgium, Germany and the Netherlands in the energy sector is related to the use of river water for cooling of power plants.

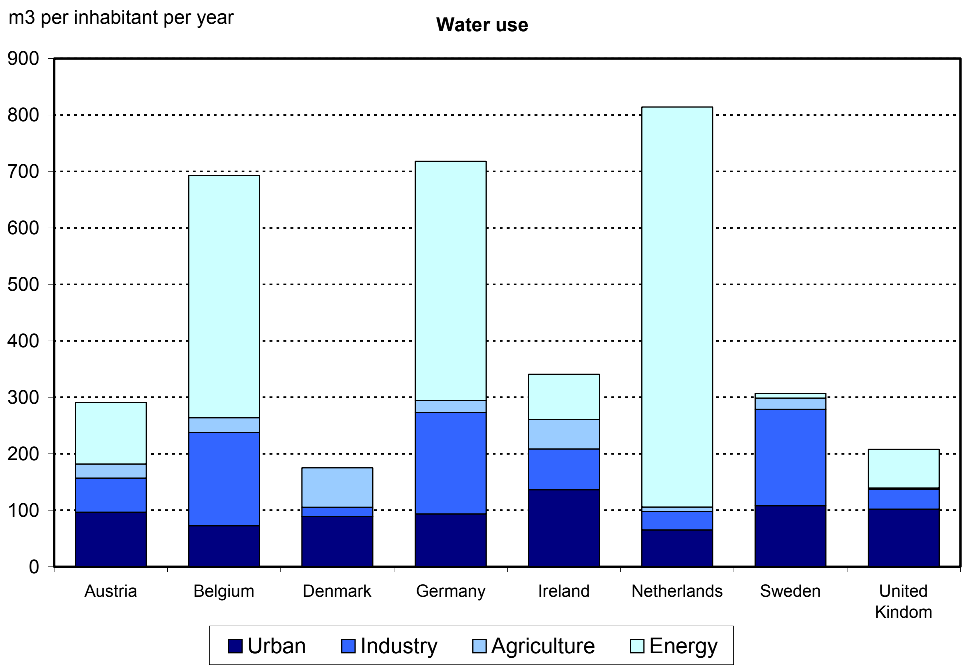

Fig. 1 Sectoral use of abstracted water. Source: EEA (1999). Figures based on estimation by ETC/IW, sectoral use for Belgium, Germany and United Kingdom based on "Task Force estimation".

Groundwater is almost the only source for drinking water in Austria and Denmark, while in the Walloon region of Belgium, Germany and the Netherlands it is the most important source. Surface water is important as source in Ireland, Sweden, the United Kingdom and the Flemish region of Belgium, see Fig. 2.

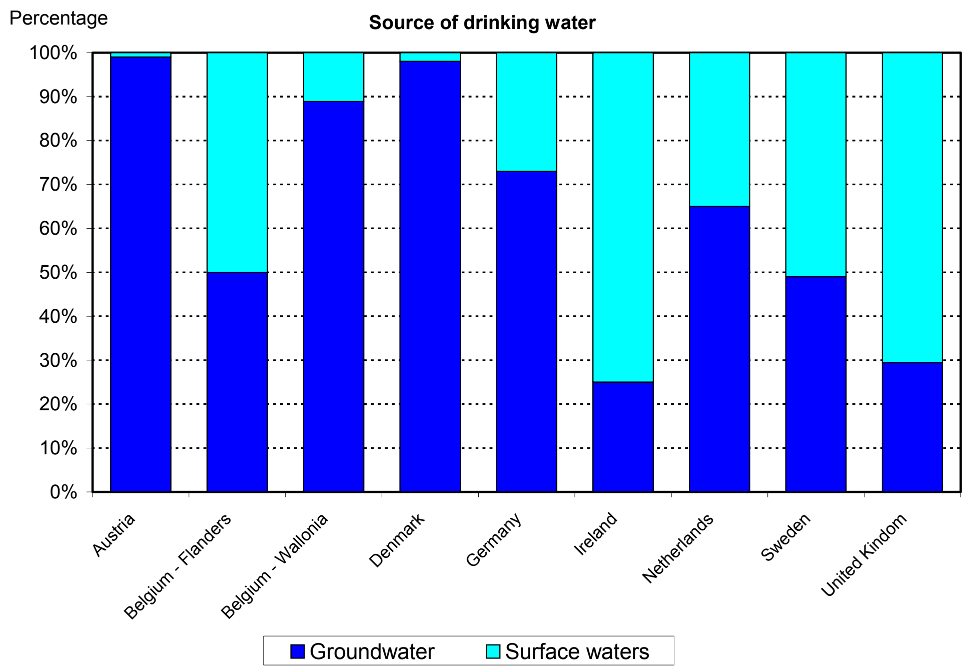

Fig. 2 Source of drinking water. Notes: in Sweden groundwater is for about half produced with artificial infiltration. Sources: Austria, Walloon region, the Netherlands see presented papers; other countries several internet pages (Anonymous, 2004).

2.2 Agriculture

The percentage of land used for agriculture ranges from as low as 8% in Sweden to as high as 69% in the Netherlands, see Fig. 3. There are large differences in agricultural land use between countries. In Ireland almost 90% of the agricultural land is used for pasture, hay or silage while in, for example, in Denmark only 7% is used for this. Average farm acreage ranges from 17 ha in Austria up to 53 ha in Denmark (see Fig. 4).

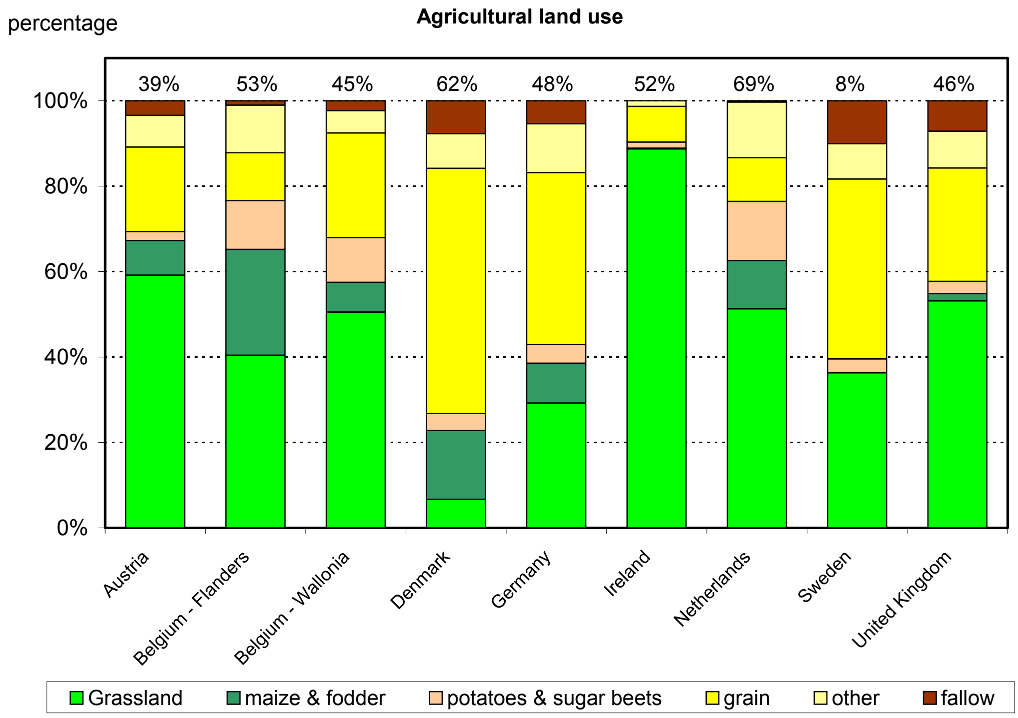

Fig. 3 Percentage of agricultural-used land –given at the top of each bar– and distribution of land use of agricultural used land in 2000. The percentage of agricultural-used land refers to the total area of land and not to the total area.
Notes: land use of Austria includes about 1.0 million ha of extensively used grassland. Land use in Ireland and UK used for rough grazing, about 0.44 million ha for Ireland (6% of total land area) and 6.3 million ha for the UK (26% of total land area), respectively, is not included.
Source: based on calculations with data provided in Member State papers; for Germany: http://www.env-it.de/umweltdaten/open.do, for Ireland additional information was found on: http://www.teagasc.ie/agrifood/#landuse.

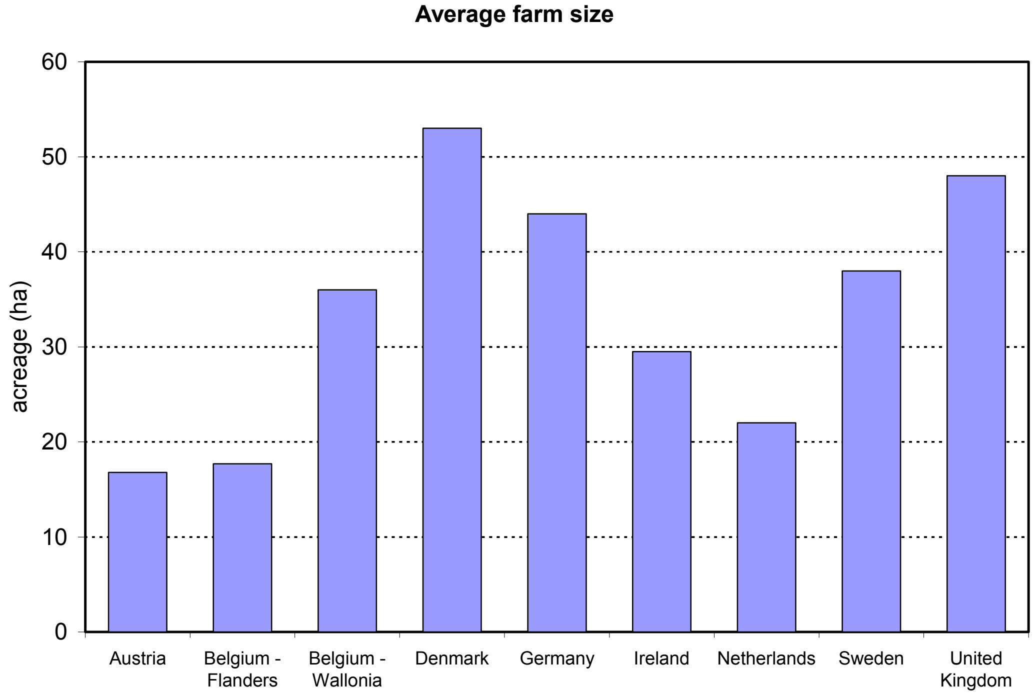

Fig. 4 Average farm acreage (ha). Note: average size of farm in Austria including forest is 31 ha. See also notes Fig. 3. Source: based on calculations with data provided in Member State papers; for Germany: http://www.env-it.de/umweltdaten/open.do.

Livestock density is high in the Flemish region of Belgium, Denmark and the Netherlands, see Table 1. Ireland and the United Kingdom have a high density of sheep (other), and there are a relatively high number of cattle per ha in Ireland and of poultry in the United Kingdom.

Table 1 Livestock density, standing number of animals per ha of agricultural land, for cattle, pigs, poultry and other animals in 2000.

Country	Cattle	Pigs	Poultry	Other
Austria [1]	0.7	1.0	3.4	-
Belgium – Flanders	2.2	9.4	47.6	0.3
Belgium – Wallonia	2.0	0.4	5.2	-
Denmark	0.7	4.5	8.1	-
Germany	0.8	1.5	7.2	0.2
Ireland [1]	2.1	0.5	3.7	2.2
Netherlands	2.0	5.9	51.8	0.3
Sweden	0.6	0.7	0.5	0.2
United Kingdom [1]	0.9	0.5	77.8	2.2

1 Agricultural-used land for Austria includes about 1.0 million ha of extensively used grassland, for Ireland and UK land for rough grazing is not included, respectively for Ireland about 0.44 million ha (6% of total land area) and for the UK 6.3 million ha (26% of total land area). Source: based on calculations with data provided in Member State papers; for Germany: http://www.env-it.de/umweltdaten/open.do.

Nitrogen and phosphorous fertiliser use in 2000 is depicted in Fig. 5. Fertiliser use is low in Austria and high in the Netherlands.

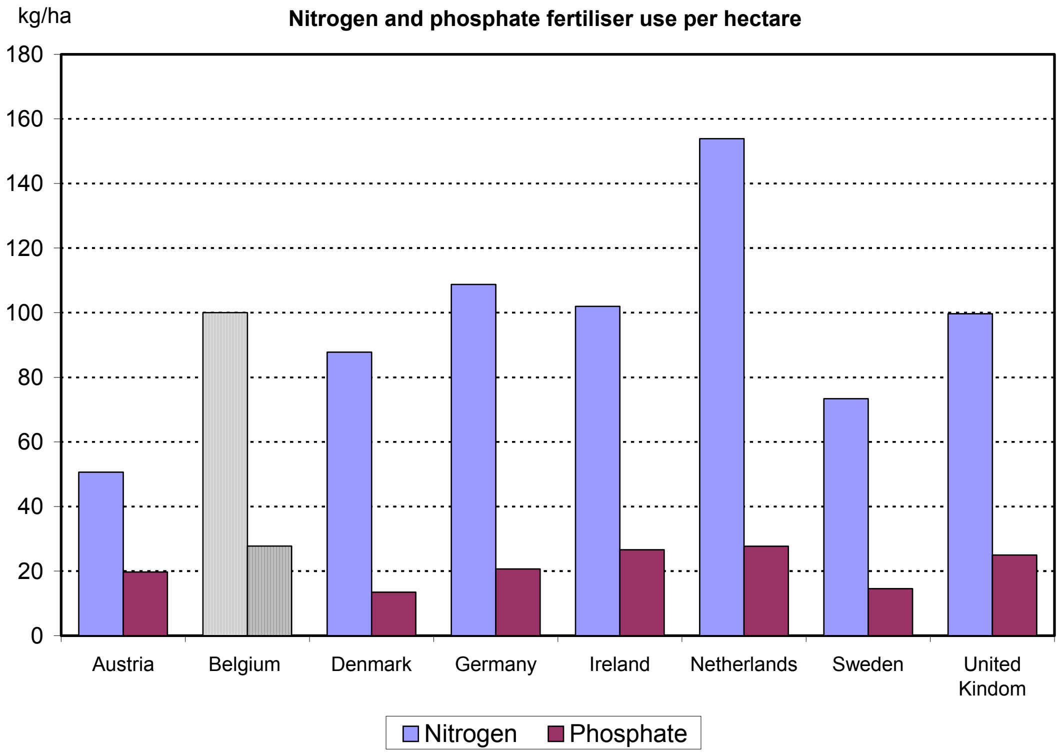

Fig. 5 Nitrogen (N) and phosphate (P_2O_5) fertiliser use on agricultural land (kg ha^{-1}), calculated using EUROSTAT fertiliser consumption data for 2000 and agricultural acreage as given in Member State papers. Data for Belgium presented in grey because average includes data for Luxembourg. For United Kingdom and Ireland see notes at Fig. 3. For Austria fertiliser use is calculated for the agricultural-used land without the area of extensively used grassland.

3. IMPLEMENTATION OF THE NITRATES DIRECTIVE

The general picture of the implementation of the Nitrates Directive in the countries involved in the workshop is given in Table 2. This regards the designation of NVZs and derogation with respect to the maximum allowable nitrogen application rate of 170 kg of N with manure per hectare per year.

Table 2 Implementation of Nitrates Directive by Member States participating in $MonNO_3$ workshop, 11-12 June 2003. Implementation with respect to designation of Nitrate Vulnerable Zones and derogation, or intention to apply for derogation with respect to the maximum allowable nitrogen application rate of 170 kg of N with manure per hectare per year.

	Designation of Nitrate Vulnerable Zones	
Derogation "170 kg ha^{-1}"	Yes	No
Yes	Belgium United Kingdom	Denmark Germany Ireland The Netherlands
No	Sweden Czech Republic[1] Poland[1] Slovakia[1]	Austria

[1] At the time of the workshop, these countries were candidate Member States, and it was not certain how the Nitrates Directive would be implemented, especially with respect to derogation.

The designation of NVZs is a difficult and laborious process, constrained by scientific and technical problems, and taking place in the midst of large social pressures in addition to pressure exerted by the EC.

The influence of the European Commission has been part of the reason for the sharp increase in the acreage of NVZs in the last few years. England has recently designated 55% of its territory as NVZ instead of the 8% that were initially designated in April 1996. Also in the Flemish region the percentage of land designated increased from 5% in 1995 to 37% in 2002 (46% of the agricultural area). It is open to debate whether application of the Action Programme to the entire UK would in hindsight have been more practical than a discrete approach towards NVZ designation. Northern Ireland has adopted a whole territory approach in October 2004 and will be applying its Action Programme to the country some time in mid 2005. The seven NVZs remain designated until the new Action Programme is implemented. In 2003 Ireland has decided to apply Action Programme measures to its entire territory instead of designating NVZs under which initially 40% of Irish territory would have been designated.

The Nitrates Directive has a secondary purpose directed towards the control of eutrophication. Traditionally, the focus in this area has been directed at the role of nitrogen in coastal and transitional waters. However, in recent years the European Commission has increasingly focused on the need to assess the impact of nitrogen in freshwaters (ECJ Case C-258-00). There is a need for Member States to develop assessment methodologies in order to assess the role of N in freshwater eutrophication and how these sites can be most effectively managed. However, one should realise that nitrogen is hardly seen as being important for eutrophication of fresh waters; unlike phosphorus that plays a crucial role. The question here is whether the Nitrates Directive should be considered as a legal instrument to regulate nitrogen, in general, and phosphorus. Most of the participating countries use a broad interpretation of the Directive when designating NVZ or applying the Action Programme to the entire country.

Derogation with respect to the maximum allowable nitrogen application rate of 170 kg of N with manure per hectare per year is a topic that is much less developed. The EC agreed with the derogation for Denmark. This is a temporary agreement only, and the effects of the derogation have to be evaluated. The Netherlands are waiting for further technical details of their negotiations with the EC. Austria and Sweden appear to have no intention of making an application to the EC for a formal derogation. For Poland, Slovakia and the Czech Republic the issue of a derogation does not seem relevant for the moment (June 2003). Other participating Member States are either in the process of notification (Belgium, United Kingdom), or it is assumed that notification of a derogation is something that will eventually happen (Germany, Ireland).

There seems to be no relationship between the intensity of agricultural land use and whether Member States designate NVZ or apply their Action Programmes to the entire territory. Derogation on the other hand is only applied for or considered by Member States with a substantial livestock density.

4. MONITORING

4.1 General

Water quality and the threat to the quality of water is monitored in many ways. By monitoring human activities (e.g. agriculture, industry, consumers) one may get a general idea of the potential threat to water quality. By monitoring soil or soil moisture (water in the unsaturated part of the soil profile) a more direct idea of the threat to groundwater and indirectly to surface waters can be achieved. In most countries quality of water and changes therein are monitored in both groundwater and surface waters. Figure 6 summarises the ranges of possibilities.

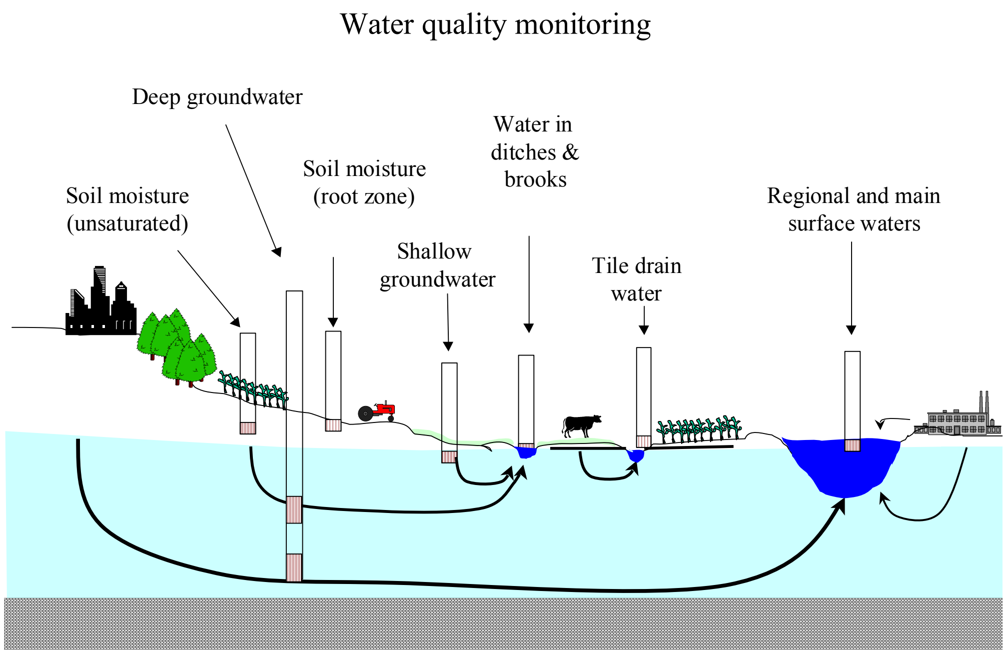

Fig. 6 Range of possibilities of water quality monitoring.

When focusing on monitoring effects of measures on water quality we can evaluate the pros and cons of each of these possibilities. Three main factors have to be considered, these are:

- the time between the implementation of the measure and the moment that a change in water quality will occur as a consequence of this measure, this we call the lag time;
- the ability to distinguish between the effects of different measures, actions and/or sources of pollution, this we term resolution power;
- the occurrence of interfering processes in soil or water system, for example, denitrification lowers the nitrate concentration during transport of water through the soil and/or the surface water system.

Table 3 gives an overview of the importance of these factors for each of the main monitoring possibilities. It is evident that the closer to the source of pollution the shorter the time between measure and effect and the smaller the chances that other sources of system processes may influence water quality. Monitoring the quality of regional or national surface waters provides essential information for users of these waters, but it usually does not provide adequate information for detecting effects of changes in agricultural practice. The travel times of surface waters and especially groundwater feeding the regional and national surface waters are long and therefore the lag time is long. In addition to nutrients from agriculture, these waters receive nutrients from other sources such as industries and water treatment plants, and therefore the resolution power is low. Due to the long path of flows of water feeding regional and national surface waters all types of interfering processes will occur such as adsorption and desorption and decomposition and formation.

Table 3 Overview of the merits and demerits of different types of water quality monitoring for monitoring the effects of changes in agricultural practice.

Type of monitor	Lag time	Resolution power	Importance of interfering processes
Soil moisture	short	high	little
Tile drains	short	high	little
Shallow groundwater	short – moderate	moderate – high	little – moderate
Deep groundwater	moderate – long	low – moderate	moderate – significant
Ditches & brooks	short – moderate	moderate	moderate
Regional & main waters	long	low	significant

Viewing Table 3, it should be realised that there is a scale dependency. A soil moisture sample is only representative of a few square meters, while a deeper pumping borehole (as long as no denitrification) will usually be representative of a larger area. But well-screen length and pumping capacity will have large effects on representativeness. Representativeness can be assessed by knowledge of the system to be monitored.

In addition to types of monitoring water quality the scale of monitoring is a point of interest as well. In Fig. 7 the different levels of scale of monitoring agricultural practice and water-quality are summarised. In studying the relationship between the effects of agriculture and water quality, collection of data should preferably be on the same scale for both agriculture and water quality.

Agricultural practice and water quality

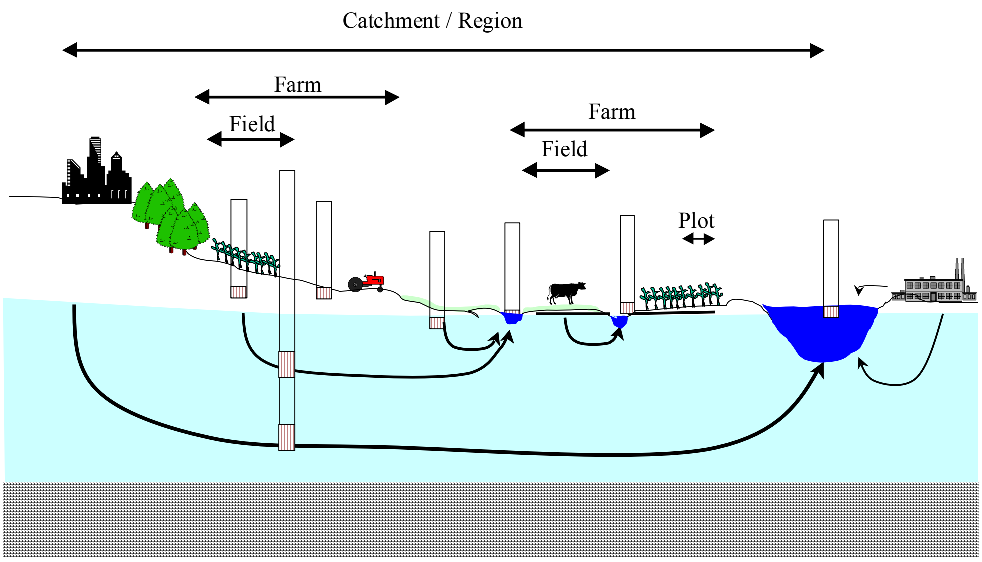

Fig. 7 Levels of scale of monitoring agricultural practice and water quality.

The choice for a certain level of scale for effect monitoring depends, amongst others, on the scale used in existing monitoring networks and level of scale of data collection by regional and/or national authorities for other purposes.

The guidelines for monitoring under the Nitrates Directive (EC, 1999, 2003), still in draft form, outline the monitoring of both agriculture –nutrient balances, changes in land use and manure storage capacity– and water quality –effects of nitrate input to surface water and groundwater. All contributions presented in this report make clear that water quality is not only influenced by agricultural practice but by other factors as well. Soil type, hydro(geo)logical characteristics of sediments or rocks, or of the surface water system, and climate and weather are examples of environmental factors that may cause differences in water quality between locations or in time. The type and structure of the farm, the educational level of the farmer, and whether the farmer has a successor or not are examples of "farm factors". These farm factors influence the way policy measures are implemented in farm practice.

Figure 8 depicts in a very simplified manner the general relationships between entities that are relevant for effect monitoring. The "classical" approach described in the draft monitoring guidelines is to monitor agricultural practice and environmental quality. However to interpret a change or a lack of change in agricultural practice and water quality other factors (farm and environmental factors) should be monitored as well.

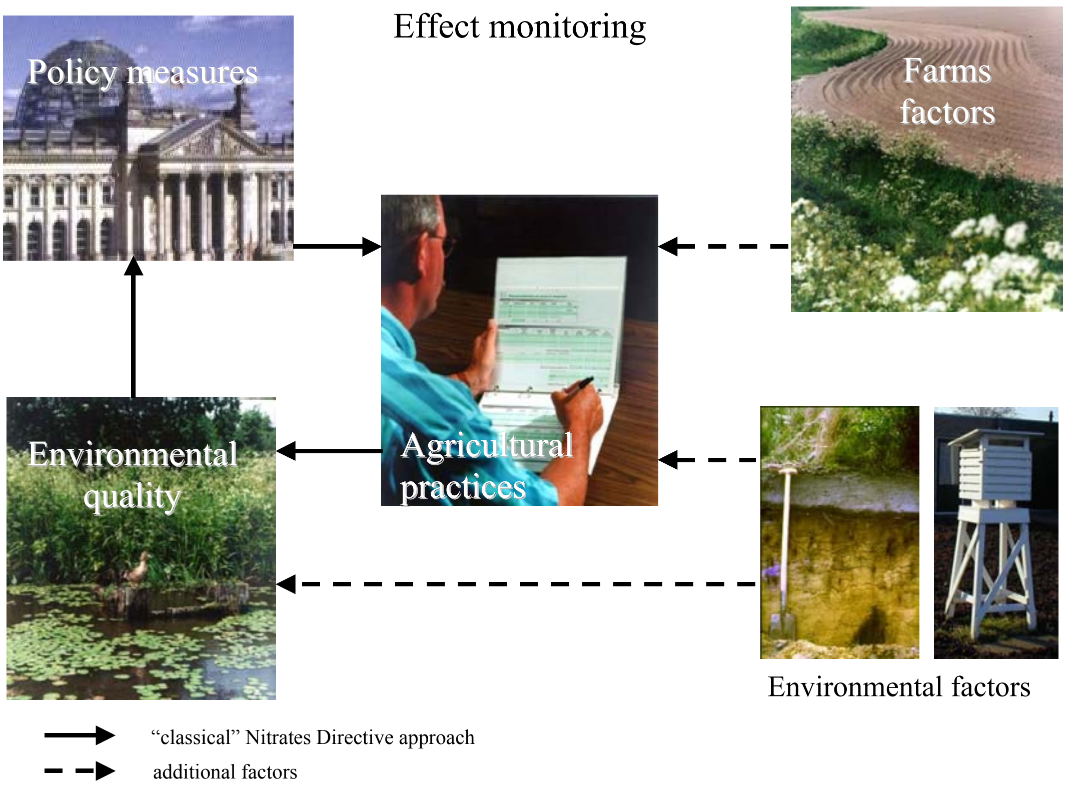

Fig. 8 General picture of monitoring the effects of policy measures. Solid lines indicate the relationships between entities that should be monitored according to the draft guidelines (EC, 1999, 2003), i.e. policy measures, agricultural practice and environmental quality. Dashed lines indicate relationships between the entities that have to be monitored and factors needed to underpin claims that policy measures change agricultural practice and thereby ameliorate environmental quality.

There are different approaches for effect monitoring as became clear at the workshop. These will be discussed in section 4.3. First an overview of the monitoring networks in the participating Member States and regions is given in section 4.2.

4.2 Monitoring networks

The general impression conveyed at the workshop was that countries are currently investing considerable time and money in monitoring networks, with several of them still busy extending their networks. Table 4 summarises the networks of the participating Member States. Some initiatives for extension are outlined below.

The Flemish Region of Belgium expanded the old shallow groundwater-monitoring network in 2003 by implementing 2109 new wells with screens at three levels. Wells will be sampled twice a year. Denmark will increase the density of the shallow groundwater-monitoring network by adding 330 wells (two samples per year). The Netherlands increased the number of farms sampled per year in the effect monitor network LMM from 150 to about 230 farms in 2004.

There are differences between countries in the way they have designed and set up their monitoring networks. This may be partly due to the fact that there are no specific official guidelines and/or protocols in the European Union. Certainly, important factors include:

- the way the Nitrates Directive is implemented and the stage of implementation: designation of NVZ or application of the Action Programme to the entire country, notification of derogation or not, etcetera;
- differences in local conditions, including hydrogeology, and type and intensity of agriculture;
- the fact that monitoring networks (already) existed in many countries before the EU Nitrates Directive came into force;
- the availability of expertise and the type of organisations involved in monitoring before 1991 and those involved in the implementation of the Nitrates Directive;
- the degree of the Directive's implementation or monitoring is delegated to or is under the responsibility of regional authorities. This latter factor is, *de facto*, important in Germany and Belgium, the Bundesländer (16) and the regions (3), respectively. A similar situation is found in the UK with England, Wales, Scotland and Northern Ireland. In Denmark 16 counties carry out the actual monitoring but the monitoring programme has been settled by the Ministry of Environment in collaboration with the counties (i.e. there is one common monitoring programme). Due to recent structural changes the water monitoring programme will be transferred to be a 100% Ministry of Environment responsibility from 2007;
- the political constellation and the degree of pressure exerted on the politicians by the public opinion and stakeholders.

Table 4 Overview of main monitoring networks in the EU Member States, participating in the $MonNO_3$ workshop, in 2003.

	Monitoring networks			
Country	Agriculture	Groundwater quality	Surface waters quality	Effects
Austria	Agricultural census concerning all farms, yearly	National network since 1991, 238 springs + 1780 porous aquifers; sampling 2-4 times per year; additional investigative monitoring by nine Länder; Drinking water survey by Länder	National network since 1991, 244 sites; sampling 12-24 times per year; additional investigative monitoring by nine Länder	With existing networks
Belgium, Flemish Region	Agricultural census, each year	Nitrate monitoring network since 1999, around 260 pumping wells of farmers, since end 2003, 2109 observation wells, 3 depths, sampling twice a year; Primary network, deep groundwater; Network of drinking water supply companies; Networks of other organisations and private supply wells	Regional network since 1991, 1000 sites, sampling 12 times per year; Agricultural network (MAP = nitrate monitoring) since 1999, 266 sites, since end 2002, 800 sites sampling about 12 times per year (9-15)	With existing networks
Belgium, Walloon Region	Soil linkage rate (SL) of each farm in Wallonia	Network of 88 drinking-water supply companies since 1994, 1232 well and springs (*); (*) additional DGRNE monitor in springs and private wells for NVZ; (*) network addapted to Nitrates Directive composed of 858 sites	Regional network since 1988, 180 sites, sampling 12-24 per year; In bathing zone lake water monitor, sampling weekly during summer	With existing networks; Soil profile mineral N measurements for the purpose of Quality Approach (QA) monitor (26 reference farms plus farms involved in QA with high livestock density)
Denmark	Agricultural census concerning all farms, yearly; Sampling of 1900 farms	National network since 1988, 70 sites with 1400 well sampling points, sampling once a year (o/a nitrate) to once per six years; Water supply well monitoring since 1989, 6000 wells at 3000 sites, sampling once per 3-5 year	National fresh water network, 231 locations, sampling 12-26 per year; Lake monitor, 31 lakes with 1-20 samples per year and 58 locations with one sample per year. Marine & coastal water monitor, 96 locations with 3-26 samples per year	With existing networks; 20 representative catchments with different levels of monitoring since 1990, agriculture and water quality, 32 rootzone stations, 7 drain-water stations, 100 upper groundwater stations and 5 stream stations
Germany	Agricultural census concerning all farms, yearly	National network since 1999, 800 sites, sampling at least once a year; Networks of Bundesländer	National fresh water network since (LAWA) 1984, 152 sites; National coastal water network, 10 sites	with existing networks; Nitrate groundwater network, 180 sites specially selected based on occurrence of nitrate in groundwater
Ireland	Agricultural census	National network since 1995, 250 sites, sampling twice per year; Drinking water supply network operated by local authorities.	2000 river locations sampled for chemical sampling and 3000 river locations sampled for biological sampling since the late 1980's; since 1971, 74 surface water locations are used for Eurowaternet reporting purposes; Lake monitor, 300 sites, sampling once in 3-years; Estuary, coastal and marine water monitor	With existing networks.

Table 4 continued

	Monitoring networks			
Country	Agriculture	Groundwater quality	Surface waters quality	Effects
Sweden	Agricultural census, yearly; Survey of fertiliser and manure practice, every second year	National groundwater network since 1968, 100 reference sites, sampling 4 times a year.	River mouth network, 50 sites, sampling 12 times per year; Lakes network, 4 large and 80 medium an small size; regional networks; Inventory of lakes (3000) and watercourses (1500) since 1975, every 5 year; Marine & coastal water monitor programme.	With existing networks; Network of 35 Small agricultural catchments started in 1975, since 2002 8 intensive and 15 extensive areas; Agricultural observation fields, 13.
The Netherlands	Agricultural census concerning all farms, yearly; FADN (Farm Accountancy Data Network) representative samples of 1500 farms, yearly	National Groundwater quality Network (LMG), since 1984, about 360 locations, two depths (10 and 25 m below surface), sampling once per year – once per 4 years; Drinking water productions sites (), sampling 4-times per year; Provincial networks.	Monitoring Water Status of the Country (MWTL), about 30 locations in main fresh waters (large rivers and lakes), and 39 locations in marine and coastal waters, sampling frequency 12-24 times per year; Regional Water Status Networks, about several thousands locations in regional fresh waters, about 650 used for national reports, sampling frequency once every four weeks.	With existing networks; National Monitoring Programme for the effectiveness of the Minerals Policy (LMM), about 150 representative farms, monitoring both agricultural practice and water quality; National Soil Monitoring Network (LMB), about 180 farms and 20 forest locations, monitoring soil quality. Upper Groundwater Acidification Network (TMV), about 150 nature location, monitoring shallow groundwater.
United Kingdom, England & Wales	Farm Practice Survey; British Survey of Fertiliser Practice, since 1983; Agricultural Census	Groundwater Network since 1990, 3700 sites, sampled approx. 4 times per year, currently under revision to meet requirements of the WFD	General Quality Assessment network (GQA) and SWAD network; over 7000 sites; sampling 12 times per year	Specific project established in 2004, 16 study micro-catchments representative of a range of environmental and agricultural conditions, fram practice and water quality monitoring data collected and used to validate N loss models; use national-scale change in agricultural practice to describe effects on water quality at national level
United Kingdom, Northern Ireland	Agricultural Census; Ad-hoc surveys to meet specific needs	Groundwater Network since 2000, 80 sites, sampling 4 times per year	River & lake monitor network since 1970's, GQA network since 1999, 337 sites; Drinking water abstraction sites, 53 sites; sampling 12 times per year	With existing networks; Programme is being developed
United Kingdom, Scotland	Agricultural Census; British Survey of Fertiliser Practice, since 1983	Groundwater Network since 2000, 150 sites, since 2002 220 sites, sampling 4 times per year; Private water supply sites	Fresh surface water network of 233 sites, sampling 12 times per year	With existing networks; Programme is being developed

4.3 Effect monitoring

The general strategy for effect monitoring was briefly discussed in section 4.1. Two main approaches of effect monitoring can be distinguished: upscaling and interpolation.

The upscaling approach uses the results of studies on effects of changes in agricultural practice on nitrate leaching (and water quality) on experimental sites (e.g. plots or parcels). Process models and data on national-scale change in agricultural practice are used to upscale the experimental-sites results to describe the effect of the Action Programme on nitrate leaching and water quality on the national scale. Countries employing an approach that could be classified as upscaling include Denmark, Sweden and the United Kingdom.

The interpolation approach uses the results of the monitoring of agricultural practice and nitrate leaching (and water quality) on a random sample of locations, e.g. farms. Statistical models and national-scale monitored changes in agricultural practice are used to describe the effect of the Action Programme on nitrate leaching and water quality on the national scale. Countries employing an approach that could be classified as interpolation include Austria, Belgium, Germany, Ireland and the Netherlands.

It was beyond the scope of the MonNO_3 workshop and is beyond of the scope this report to compare both approaches in detail. In general the upscaling approach has the advantage of gaining an insight into effects of specific measures on water quality, while the interpolation approach has the advantage that it provides an unbiased estimation of the changes in water quality on the national scale.

For both approaches the major focal points with respect to effect monitoring are:

- Confounding factors, i.e. the factors that complicate the analyses such as weather, soil type, etcetera. For interpretation of the actually measured water quality in relation to measurements one should be able to quantify the effects of the confounding factors on water quality measured.
- Choice of the type of water to be monitored, i.e. soil water, upper groundwater, tile-drain water, etcetera). This point deserves attention because it influences the strength of the relationship between measures and effects due to the lag time (time between measure and effect), resolution power (ability to discriminate between sources of measured nitrate in waters) and interfering processes (e.g. denitrification along the pathway).
- Choice of the level of scale used for research: e.g. plot, parcel, field, catchment, farm. There has to be a balance between the levels of scale for which different types of data are available, i.e. data on agricultural practice, water quality and confounding factors.

5. ENVIRONMENTAL GOALS AND QUALITY STANDARDS

In natural waters without human influences, nitrate only occurs in low to very low concentrations. Due to human activities, nitrate concentrations in groundwater and surface waters are measured at values that are higher than background levels. The World Health Organisation set a standard for nitrate in drinking water for the first time in 1958 (WHO, 1958). The current standard of 50 mg l^{-1} was set in 1993 (WHO, 1993) and later by the Drinking Water Directive (EC, 1998), and it was concluded in 1998 and 2000 that the guideline document did not need to be revised (WHO, 1998, 2000). The Nitrates Directive introduces this value to identify waters affected by pollution (EC, 1991).

In addition this Directive states that eutrophic waters or those that may become eutrophic in the near future are to be identified as affected by pollution. Eutrophication is defined as, *"... the enrichment of waters by nitrogen compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned..."*. For fresh surface waters phosphorous is commonly seen as the limiting nutrient (Hudson and Schindler, 2000; Correll, 1998). Exceptions are hyper-eutrophic fresh water (Newton and Jarrell, 1999) and soft water lakes in areas without high atmospheric nitrogen deposition (Roelofs, 1996). In marine and coastal waters nitrogen is considered as the main limiting nutrient (Ryhther & Dustan, 1971; Hecky & Kilham, 1988).

The way countries deal with environmental quality standards and objectives given in the Nitrates Directive (eutrophication and 50 mg l^{-1} nitrate) depends chiefly on:
- The manner and stage of implementation of the Nitrates Directive and
- The political constellation and the degree of pressure exerted on the politicians by public opinion and the stake-holders.

In Table 5 we illustrate how countries deal with these standards. The participants were of the opinion that the 50 mg l^{-1} nitrate should be realised in recently formed groundwater (water leaching from agricultural soils). Some individual country examples are given below.

The Danish goals are possibly the most comprehensive. Their 50% reduction target for nitrate leaching from the root zone is to be realised within 10 years. In principle, the nitrate concentration in water leaching from the root zone should not exceed 50 mg l^{-1}. Austria has a control and decision system for groundwater-quality additional action programmes. This is surprising because Austria applies its Action Programme to the entire territory, with no derogation for the manure application rate. In each groundwater body (50-1000 km^2) water quality is monitored partly with the use of wells used also for individual drinking-water abstraction and partly with the use of wells used exclusively for monitoring purposes concentrating mostly on recently formed (< 4 years) groundwater. Wells are sampled about four times a year. In locations where over 30% of the wells in a groundwater body have an average nitrate concentration of more than 45 mg l^{-1}, additional agricultural measures are a prerequisite for the entire groundwater body.

The "observation-depth discussion", i.e. the discussion at what depth below the groundwater table groundwater should contain less than 50 mg l^{-1} nitrate, seems to be a phenomenon limited to Denmark and the Netherlands. This is partly because other countries use drinking-water wells or have only very deep groundwater. In many countries, deep groundwater is still aerobic and denitrification does not take place – therefore deeper observations still show an influence of human activities. Especially in the Netherlands, there are reducing conditions at depth, which lead to denitrification and "confuse" the monitoring. On the other hand, agriculture is nowhere as intensive and nitrogen use as high as in the Netherlands.

Table 5 Use of water quality standards in the EU Member States participating in the $MonNO_3$ workshop, in 2003.

Country	Soil	Groundwater	Surface waters
Austria		NO_3 <45 mg l^{-1}, if >30% of samples have a higher value additional remediation measures have to be taken for the entire groundwater body	chlorophyll not relevant
Belgium Flemish region	NO_3-N residue in upper 90 cm of soil in autumn <90 kg ha^{-1}	All sample locations: NO_3 <50 mg l^{-1}	Sum of NO_3-N+ NO_2-N <10 mg l^{-1}; orthophosphate: <0.3 mg l^{-1} as P (running waters); <0.05 mg l^{-1} as P (stagnant waters); maximum allowable exceedance of 50% for N and P in at most 10% of measurements; chlorophyll-a <100 µg l^{-1} (mean value); Use for drinking water: NO_3 <50 mg l^{-1} in 95% of samples, always <75 mg l^{-1}
Belgium Walloon region	Soil linkage rate (SL) of each farm < 1; Respect of mix of basic and chosen rules for farm involved in QA to reduce nitrate leaching	Drinking water: annual average NO_3 <50 mg l^{-1}; Average value for groundwater body <37.5 mg l^{-1} (not legally binding)	Drinking water NO_3: <50 mg l^{-1} in 95% of samples, always <75 mg l^{-1}; total P <1 mg l^{-1} (not legally binding); chlorophyll-a <75 µg l^{-1} (not legally binding)
Denmark	50% reduction goal for nitrate leaching from root zone (1 m below surface level)	Drinking water: annual average NO_3 <50 mg l^{-1}	Average annual target values set by counties
Germany			Total N ≤ 2.5 mg l^{-1} (not legally binding)
Ireland		These are to be considered in 2005 in preparation of regulations under the Nitrates Directive	
Sweden	Reduction of nitrate leaching from root zone with 8000 ton until 2010 (goal for national action programme)	NO_3 < 50 mg l^{-1}	Quality criteria for total N is under revision total P < 0.025 mg l^{-1}
The Netherlands		NO_3 <50 mg l^{-1}	Total N <2.2 mg l^{-1} ; total-P <0.15 mg l^{-1} ; chlorophyll-a <100 µg l^{-1}
United Kingdom		NO_3 <50 mg l^{-1}	NO_3 <50 mg l^{-1} at least 95% of the time (used for designation)

There are large differences in targets applying to surface water. The UK and Belgium have used a 50 mg l^{-1} nitrate target value in designation of NVZs with respect to surface water. Both used statistical approach towards quantifying the target-value scale. Germany, Ireland and the Netherlands have target values for total nitrogen in surface waters of between 2 and 3 mg l^{-1}. In Denmark a nitrate target value of 35 mg l^{-1} for groundwater flowing directly to surface water could be extrapolated from the nitrate target value in treated wastewater discharge to surface water. The majority of participants expect the Water Framework Directive (WFD) to provide us something to go on for the definition of eutrophication because the WFD target of achieving “Good Ecological Status” will hopefully lead to the consideration of P as nutrient.

6. WORKSHOP RESULTS AND FOLLOW UP

In the opinion of the participants, the goals of the workshop were largely achieved by:
- Realising a good exchange of information, which is formalised by means of reporting on the findings of the workshop in this report.
- Making a start with the identification of common goals and problems. It is too early for solutions, but the exchange of knowledge and experience has clearly generated new ideas for use by participants.
- Providing an initial, and valuable, impetus to the creation of a network of experts. It is important to ensure a follow-up to this initiative to fortify this budding co-operation and prevent it from blowing over.

The workshop has provided more insight into the way the participating countries have implemented or are implementing the Nitrates Directive with regard to designation of NVZ and notification of derogation. This is also true for the operation of the existing monitoring networks and the way effects of the Action Programmes are or will be monitored.

To fortify the above mentioned budding co-operation between Member States and prevent it from blowing over. Several focal points for further study were mentioned, along with discussions that would be of interest to several or all of the countries, but which could not be discussed during the workshop. These are:
- Consequences of the Water Framework Directive for effect monitoring, designation of NVZ and definition of environmental quality targets.
- How to translate monitoring results in statements and judgements on a national scale with respect to the effect of Action Programmes on agricultural practice and water quality, e.g. through the use of process-oriented models and/or statistical techniques.
- The way in which Member States interpret the general statement in the Nitrates Directive that there should be “a balance between (i) the foreseeable nitrogen requirements of the crops and (ii) the nitrogen supply to the crops from the soil and fertilisation”, and how this is implemented in national legislation.
- Discussion of what to include in optimal monitoring of effects of Action Programmes:
- Advantages and disadvantages of using the method of determining mineral N in the root zone in autumn for control or effect monitoring.
- Advantages and disadvantages of tile drain-water sampling especially in areas with clay soils.
- The interest in the involvement of stakeholders, and the like, in the design, implementation and reporting of effect monitoring.

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Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Austria

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Abstract This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programme in Austria. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5(6) (EC, 1991). In 1999 the European Commission published the Draft Monitoring Guidelines (EC, 1999b). Austria has established and now applies an action programme that is used throughout its entire territory. In other words, based on Article 3(5), Austria has not identified specific nitrate vulnerable zones. As this provision of Article 3(5) is frequently misinterpreted, we underline that this does not necessarily mean that the entire Austrian territory meets the criteria for vulnerable zones; this is definitely not the case. The specific situation in Austria is outlined here with regard to the natural factors influencing nitrate occurrence, the driving forces for and the impact of nitrates on our freshwater resources, and finally, the details and strategy of Austria's national programme for monitoring freshwater quality. The development of nitrate concentrations is seen to be the key indicator for a following up the progress of the action programmes. The results of Austria's national monitoring programme form the main tool for monitoring and assessing effectiveness of Austria's Nitrates Action Programme tailor-made to Austria's specific situation.

1. INTRODUCTION

1.1 General

National strategies to implement the EU Nitrates Directive (EC 1991) depend strongly on the specific situation. Austria's situation may be very simply characterised by a broad range of geologic and climatic conditions and – compared with such countries of the EU as the Netherlands, Belgium and Luxembourg – by an agriculture operating at a low to medium intensity with a low input of nutrients. This chapter describes the basic facts of importance to understanding Austria's strategy for implementing the EU Nitrates Directive.

1.2 Description of natural factors influencing nitrate occurrence

The main natural factors influencing nitrate occurrence in Austria are climate, precipitation, hydrogeology and soil types. Other factors, such as "redox conditions" and "interaction between surface waters and groundwater" are of less, and exclusively local, importance. Based on the results of our national network for water quality monitoring, the influence of hill slopes or mountain slopes on nitrate concentrations seems to be small, in particular, for groundwater. However, a certain impact of slopes on water quality is observed in terms of phosphorus, in particular, during floods.

Climate

Austria's climate is fairly continental, with warm summers and cold winters. The mean annual temperature is 5.8°C, the monthly January mean, -3.6°C and the monthly July mean, 15.0°C (Data from the Central Institute of Meteorology and Geodynamics). Nevertheless, there are also regional differences within Austria: the extreme west has a tendency to a more Atlantic climate, the east to a more continental climate and the south towards a Mediterranean climate. Furthermore, differences in the altitude contribute further to regional particularities.

Precipitation

The mean annual precipitation is 1170 mm. Between the more western and central parts mean precipitation may be more than 2500 mm, while the eastern and north-eastern parts of Austria have a mean of less than 500 mm of rainfall (see Fig. 1). In the eastern and north-eastern parts: for example, in Austria's largest groundwater body called "Marchfeld" that is situated east of Vienna, recharge of groundwater is less than 100 mm per year. As a consequence, even a leakage of just about 10 kg nitrogen per hectare (which is regarded by agricultural experts to be even below the unavoidable losses of arable land), will lead to concentrations of nitrates in soil water above 50 mg l^{-1}.

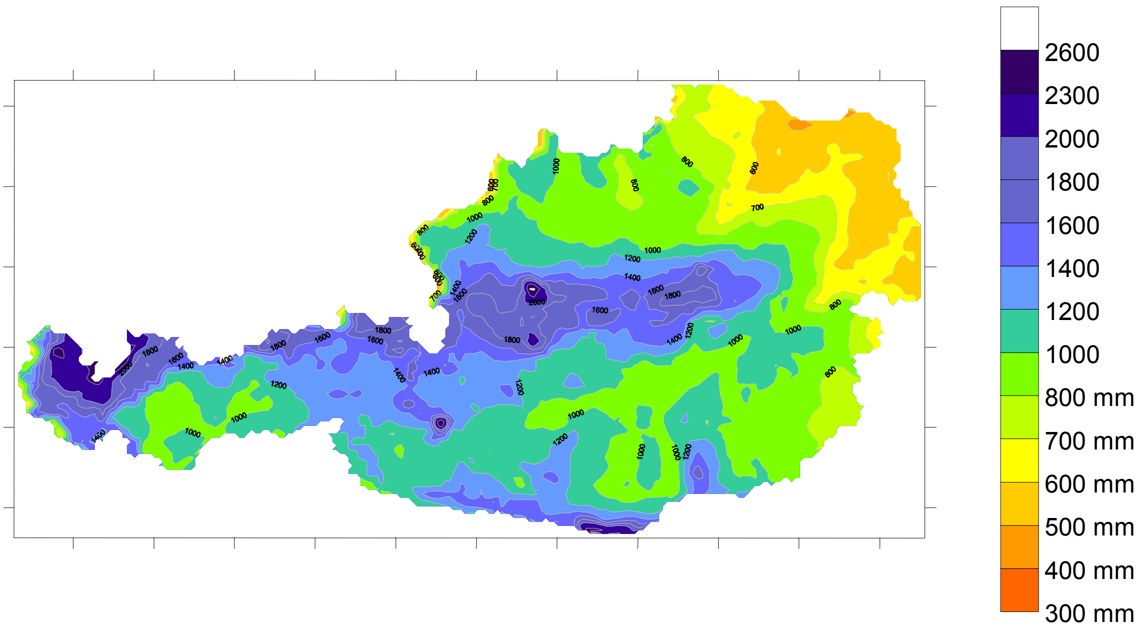

Fig. 1 Mean precipitation in Austria in 1961-1990. Source: BMLFUW (2001a).

Hydrogeology

Two-thirds of Austria's territory consists of mountainous areas. The high precipitation in the central alpine parts and the crystalline rock structure in other parts have resulted in Austria's dense network of surface waters.

Important groundwater resources are located in porous aquifers as well as in aquifers within fissured rock structures (in particular, in karst structures). The porous aquifers are situated either in the narrow alpine valleys or basins or along the Danube and its major tributaries. The overwhelming majority of Austria's porous aquifers are unconfined shallow aquifers in which the reaction to changing impacts is fast, as can be seen by the atrazine example. After the atrazine application was restricted to 3 kg ha^{-1} in 1990 and, when the registration was finally withdrawn in 1994, concentrations fell rapidly (see Fig. 2). Most of those aquifers cover an area of a few square kilometres or even less, while Austria's largest shallow aquifer, called "Marchfeld", covers about 1000 square kilometres.

Austria also has some major, well-protected, deep groundwater aquifers with prevailing abstractions for thermal use and use at spas (e.g. along the Austrian–Bavarian and the Austrian–Hungarian–Slovenian borders). Some regions also dispose of some confined aquifers of local importance (in particular, in the southeast of Austria). Both types of groundwater aquifers show just natural background concentrations and – being well protected against agricultural impacts – are not considered to be relevant for the implementation the EU Nitrates Directive.

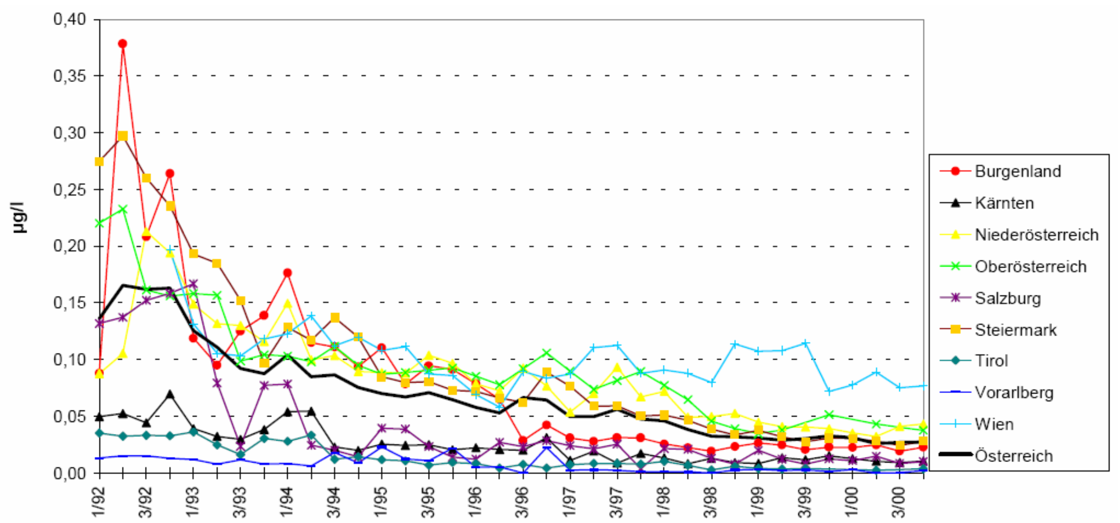

Fig. 2 Decline of atrazine concentrations after restrictions on use and withdrawal of registration. The bold black line illustrates mean concentration for the whole of Austria; coloured lines illustrate mean concentrations in the nine Austrian Länder. Source: BMLFUW (2003a).

1.3 Description of human factors influencing nitrates occurrence

The most important human factors are the different types of land use, crops (crops such as maize, potatoes and beets in particular), methods of cultivation (impact on water quality may be reduced considerably, even for crops such as maize, for example, by green covers during autumn and winter) and intensity of agricultural production. In Austria small- to medium-sized farms – nearly exclusively run by the same families for generations – prevail thus providing an excellent basis for ongoing and future sustainable farming. Important incentives are provided to farmers on the basis of EC Regulation 2078/92 (EC, 1992) to maintain environmentally friendly production.

Global information on land use

The predominant use of land in Austria is forestry and grassland; only a very minor share is used for arable land and other special crops. The major changes in land use within the last 40 years led to a significant reduction of grassland and arable land farmed at low intensity – in other words, producing low yields – and a moderate increase of forest area and the area for productive farmland.

One of the driving forces for increasing productive farmland was formed by the striking experiences due to hunger periods after World War II that led to the increasing focus on agricultural production as a national priority.

In the last 10 years the pattern of land use has remained more or less the same, except for a certain decline in the area cultivated with crops such as maize, beets and potatoes, an increase in arable land set aside in conformance with co-financed measures of EU Agricultural Policy and a further slow increase in forestry due to reforestation of less productive land.

Table 1 Development of land use (in 1000 hectares).

Land use	1960	1979	1990	1995	2000
Agricultural land	4052	3728	3498	3432	3389
Forestry	3142	3282	3227	3285	3260
Arable land	1647	1475	1423	1405	1395
Grass land total	2298	2107	1993	1940	1956
Commercial grassland	781	903	884	930	910
Extensive grassland	1517	1204	1109	1010	1007

Source: BMLFUW (1996) and BMLFUW (2001b).

Main crops

The area of arable land cultivated for cereals and maize has declined in the last decade, while fodder crops (apart from silage maize) and other products (e.g. oil seeds) have expanded. Irrigation and horticulture do not play a major role in Austria, at least in terms of area.

Table 2 Development of land use and specific crops (in ha).

Crops	1980	1990	1995	2000
Arable land	1487	1423	1405	1382
Cereals (excluding maize)	877	752	636	642
Maize (including silage)	299	305	264	262
Potatoes and beets	115	85	80	68
Fodder crops (excluding maize)	157	97	112	131
Oil seeds	10	80	144	109
Fallow land, Set aside land	15	20	124	111

Source: BMLFUW (2001b).

Characterisation of agriculture

One of the overriding objectives of Austria's agricultural policy is to maintain agricultural production on a sustainable basis throughout the entire territory, including the disfavoured areas in the mountainous parts of Austria. Therefore important efforts have been undertaken to maintain agriculture, not only in the areas most favoured by nature for agricultural production (the fertile plains and hilly parts along the Danube and in the eastern parts of Austria, with predominant or, at least, major shares of arable land (see Fig. 3)) but also in the less favoured mountainous areas. In comparison with farms in other Member States, these farms are small- to medium-sized in terms of agricultural land, livestock units and nutrient input.

Manure nitrogen due to storage, and without taking losses in animal housings into account, amounted to 166,000 tonnes of nitrogen in the 1996/1998 period (BMLFUW 2001c) and fertiliser sales to 120,500 tonnes of nitrogen. Summing up both sources of nitrogen, this results in respective applications of 84.5 kg N ha^{-1} agricultural land and 120.3 kg N ha^{-1}agricultural land with worthwhile fertilisation. The 84.5 kg N ha^{-1} application is valid for the agricultural land reduced by land not fertilised or fertilised with only low amounts of fertiliser e.g. alpine pastures and other extensive grassland. Because this relatively low input of nitrogen is well below the economic optimum of production, the main challenge of implementing Austria's Nitrates Action Programme is not to control in detail the amount of nitrogen applied per hectare but to avoid spreading manure in periods and zones, where spreading of manure is forbidden or limited in the "Austrian Nitrates Action Programme".

In spite of all efforts several elevated concentrations of nitrates have been observed in the areas naturally favoured for agricultural production. One of the main particularities of the Austrian situation is that most of the elevated concentrations of nitrates are situated in areas with less or just around 500 mm of rainfall and less than 0.5 livestock units per hectare. As already outlined when describing precipitation, even a leakage of just about 10 kg nitrogen per hectare may lead to concentrations of nitrates in soil water above 50 mg l^{-1} in these areas.

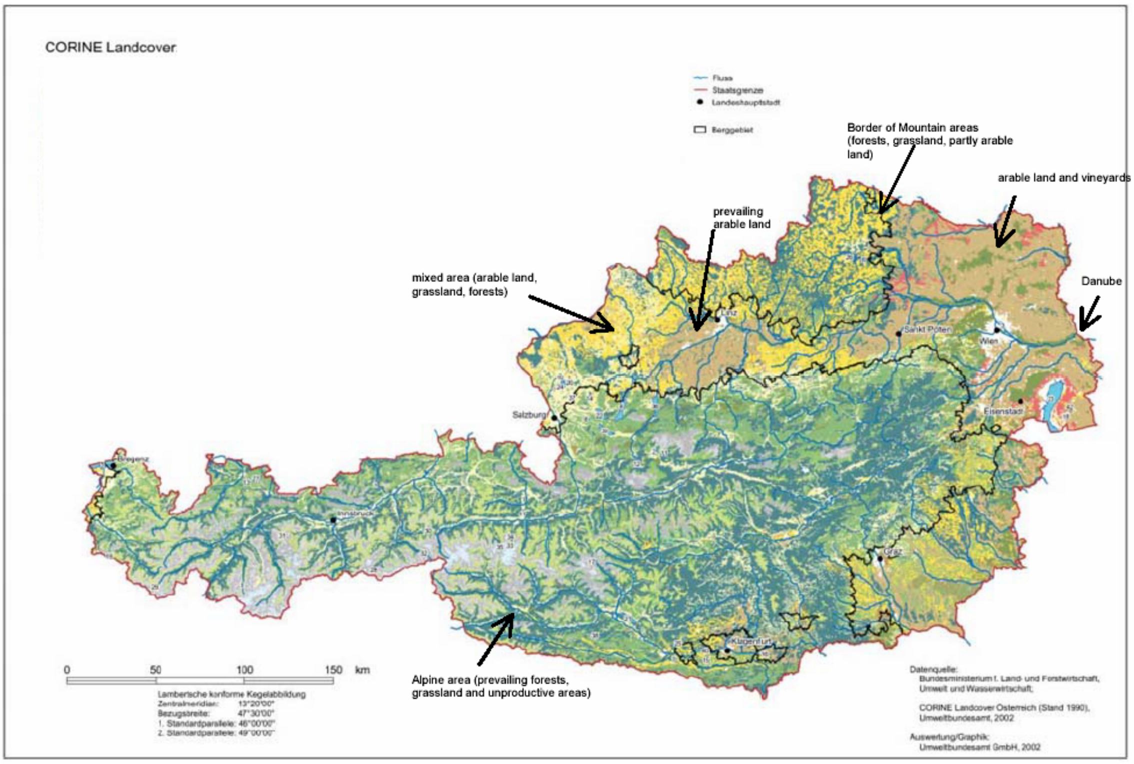

Fig. 3 CORINE Land Cover with land uses. Source: BMLFUW (2001c).

Table 3 Development of livestock.

Category of livestock	1980	1990	1995	2000
Cattle	2,516,900	2,583,900	2,271,949	2,155,447
Pigs	3,706,200	3,688,000	3,663,747	3,347,931
Poultry	14,159,600	13,139 ,000	12,215,194	11,077,343

Source: BMLFUW (2001b).

Table 4 Structure of farms (average size of farm).

Year	Overall number of farmers	Average size of farm: agricultural land + forestry (in ha)	Average size of farm: agricultural land (in ha)
1960	402,286	17.9	10.1
1980	318,085	22.8	12.1
1990	281,910	24.2	12.6
1995	239,099	28.0	15.3
2000	217,508	30.9	16.8

Source: BMLFUW (2001b) and BMLFUW (2002a).

Table 5 Structure of stock breeder and density of livestock units per agricultural land.

Year	Stock breeders	Livestock units	Average LUs per breeder	Stock breeders >200 livestock	LU per ha agricultural land
2000	123,585	2,074,307	16.8	17	0.61

Source: BMLFUW (2001b) and BMLFUW (2002a).

Table 6 Fertiliser application (nitrogen) in Austria.

Year	Total use (N in kg)	All agricultural land (in ha)	N use per ha (kg ha^{-1})	Agricultural land with worthwhile fertilisation (ha)	N use per ha (kg ha^{-1})
1990	140,400	3,498,000	40.1	2,389,000	58.8
1995	128,000	3,432,000	37.3	2,422,000	52.8
2000	120,500	3,389,000, (1999)	35.5	2,382,000 (1999)	50.6

Source: BMLFUW (2000) and BMLFUW (2001b).

1.4 Overview of networks monitoring water quality

The Austrian Water Act envelopes a general but comprehensive protection of all waters in Austria, a goal that is broadly supported by Austria's citizens. Waters in Austria have a broad range of use, such as for drinking-water abstraction, recreation (e.g. used as bathing water in all the Austrian lakes, and for fishing), navigation and hydroelectric power generation.

One of Austria's particularities is that more than 99% of the drinking-water demand is met by groundwater (about one-half from spring water, particularly from karst areas, and one-half from porous aquifers). The quality is such that removal of pollutants to meet drinking-water provisions is an extremely rare exception. Because of this, efforts in monitoring groundwater, both quantity and quality, have quite a long tradition in Austria, going back much further than the year 1991, when a comprehensive and dense national network of sites for monitoring quality of surface waters and groundwater was set up.

National network for monitoring water quality

This monitoring network set up in 1991 serves a broad set of objectives and functions, in particular, the provision of such items as:

- comprehensive information on the state of the water environment in Austria;
- all necessary quality information required to meet reporting obligations at international (e.g. EC and EEA) and national level (for annual reporting to the general public and for triennial reporting to the Austrian parliament);
- the databases necessary for triggering off remediation programmes as well as for following the progress of these remediation programmes. These programmes include potentially assessing the following: background concentrations, the impact of pressures and trends, compliance to standards set, and tracing areas of interaction between surface waters and groundwater.

This programme is financed and run jointly by the federal state and Austria's nine Länder. Results are regularly published, for example on the sites, www.lebensministerium.at and www.ubavie.gv.at. This national monitoring network is currently being revised to meet the requirements of the EU Water Framework Directive.

The national monitoring network covers:

- **Surface waters:**
  - 244 sites strategically placed at transboundary sections of rivers entering or leaving Austria's territory, at confluences of rivers and tributaries and at locations downstream from impacts e.g. wastewater treatment plants. Sampling frequency is 12 times a year for a comprehensive set of chemical parameters and 24 times per year for sites of overriding interest (for example, to monitor important transboundary rivers: the Danube, Mur and Drau). The median concentrations of surface water sites all over Austria is 1.1 mg nitrate–nitrogen per litre.
- **Groundwater:**
  - 238 sites for monitoring springs of high quality and usually subject to low pressures and impacts.
  - 1780 sites for monitoring porous aquifers. These flat areas are preferred, and due to the predominant mountainous character of Austria are often the only possible locations for settlements, industry, traffic and agriculture; for this reason they are usually characterised by a highly intensive use. Sampling frequency is usually 4 times per year or 2 times per year for groundwater bodies with a high or close to high chemical quality.

  According to BMLFUW (2003a) the median in nitrate-N concentrations is about 0.6 mg l^{-1} N in karstic springs and 0.35 mg l^{-1} in all other springs.

Nitrate concentrations are found to be low in the alpine parts due to low pressures and good dilution, acceptable in large regions along the Danube and elevated in the dry regions in the northeast, east and southeast parts of Austria (see above-mentioned websites and maps in Austria's report to the EC, based on Article 10 of the EU Nitrates Directive). Density of the monitoring network in terms of sites per 100 square kilometres is much higher within the porous aquifers – compared to all other areas – as those aquifers are under pressure. Due to the higher density of sites in those aquifers the monitoring results shown below for Austria are biased, since impacted areas are overrepresented.

Results of our national monitoring are routinely assessed per groundwater body in terms of concentration as well as trends. The aggregated results per administrative unit (our nine Länder) are presented in Tables 7, 8 and 9.

Table 7 Concentrations of nitrates in Austria's groundwater per "Land" for porous groundwater and springs from 1 January 1999 to 31 December 2000 according to national monitoring network measurements.

Conc. (mg l^{-1})	Bgld	Ktn	NÖ	OÖ	Sbg	Stmk	Tir	Vbg	Wien	Total	Porous GW	Springs
< 10	433	752	996	420	669	1013	654	400	38	6672	5375	1297
> 10 - 30	170	657	1111	770	193	789	244	70	35	4076	4039	37
> 30 - 45	113	135	503	324	32	342	3	0	55	1522	1507	15
> 45 - 50	25	32	133	76	0	70	0	0	14	350	350	0
> 50	202	62	691	127	2	186	0	0	214	1486	1484	2
Total	943	1638	3434	1717	896	2400	901	470	356	14106	12755	1351

Source: BMLFUW (2003a).

Table 8 Concentrations in per cent of nitrates in Austria's groundwater per 'Land' for porous groundwater and springs from 1 January 1999 to 31 December 2000 according to national monitoring network measurements.

Concentr. (mg l^{-1})	Bgld	Ktn	NÖ	OÖ	Sbg	Stmk	Tir	Vbg	Wien	Total	Porous GW	Springs
< 10	45.9	45.9	29.0	24.5	74.7	42.2	72.6	85.1	10.7	47.3	42.1	96.0
> 10 – 30	18.0	40.1	32.4	44.8	21.5	32.9	27.1	14.9	9.8	28.9	31.7	2.7
> 30 – 45	12.0	8.2	14.6	18.9	3.6	14.3	0.3	0.0	15.4	10.8	11.8	1.1
> 45 – 50	2.7	2.0	3.9	4.4	0.0	2.9	0.0	0.0	3.9	2.5	2.7	0.0
> 50	21.4	3.8	20.1	7.4	0.2	7.8	0.0	0.0	60.1	10.5	11.6	0.1
Total	100	100	100	100	100	100	100	100	100	100	100	100

Source: BMLFUW (2003a).

Table 9 Percentage of groundwater sites with upward, downward or no trend in nitrate concentration, according to national monitoring network measurements.

Land	Number of Sites	Upward trend (%)	Downward trend (%)	No change (%)
Burgenland (Bgld)	119	1	18	81
Carinthia (Ktn)	206	2	14	84
Lower Austria (NÖ)	413	8	13	79
Upper Austria (OÖ)	254	5	18	77
Salzburg (Sbg)	128	2	23	75
Styria (Stmk)	302	3	20	77
Tirol (Tir)	178	17	13	70
Vorarlberg (Vbg)	61	2	3	95
Vienna (Wien)	44	23	16	61
Austria	1705*	6 (%)	16 (%)	78 (%)

* Sites with sufficient length of observations.
Source: BMLFUW (2003a).

Investigative monitoring

This monitoring is run by the competent authorities of Austria's nine Länder (regional authorities) within the framework of the "Water inspectorates" (Gewässeraufsicht). Results of this monitoring supplement those of the national monitoring network.

Drinking-water surveillance

Drinking water is surveyed by the competent authorities of Austria's nine Länder in line with the provisions of the EU Drinking Water Directive. As already pointed out, drinking-water demand in Austria is almost exclusively met by groundwater – with a very few exceptions – without any prior removal of pollutants. Thus the results of this monitoring provide an important additional source of information on water quality in Austria.

1.5 Environmental goals

Austria's environmental goals (both for surface waters and groundwater) are at present under revision so as to meet the provisions of the EU Water Framework Directive and the forthcoming new EU Groundwater Directive. The new target value for nitrates in surface waters in the future will be part of the ongoing definition of good ecological status. To achieve this status, levels of nitrate concentration will have to be well below 50 mg per litre. Chlorophyll-*a* is not considered to be a meaningful parameter for Austria's fast-flowing surface waters.

The national target values for groundwater enshrined in "Austria's Groundwater Threshold Ordinance" (BGBL, 1991; BGBL, 1997; BGBL, 2002) are derived from drinking-water standards geared to the widespread use of groundwater for drinking-water purposes. The target value for nitrates in groundwater is 45 mg nitrate per litre. Compliance with this national threshold has to be achieved per groundwater body. If 30% of sampling sites exceed this target value, additional remediation measures going beyond those of the Nitrates Action Programme have to be taken, first on a voluntary basis, later on an obligatory basis. Basis for this compliance regime is the mean concentration of nitrates per site calculated with at least five measurements within a period of two years (As a rule eight samples are taken; a minimum of at least five samples has been fixed legally to avoid legal difficulties if some samples are missing on a few sites within a groundwater body.) New environmental goals (e.g. an obligation to reverse significant upward trends) will be set once the technical details have been clarified by the European Commission; these may be adapted once a new compliance regime for assessing good status has been agreed upon at Community level.

Basis for compliance are the samples taken within our national monitoring network from the upper part of Austria's shallow aquifers. Concentrations of nitrates of these sites usually do not change excessively from one season to the other, with the exception of areas where there is interaction of groundwater and surface water (see Fig. 4 for surface waters and Figs 5 and 6 for groundwater). A period of four years has been, so far, considered to be appropriate to take changes in precipitation and other variable influences sufficiently into account.

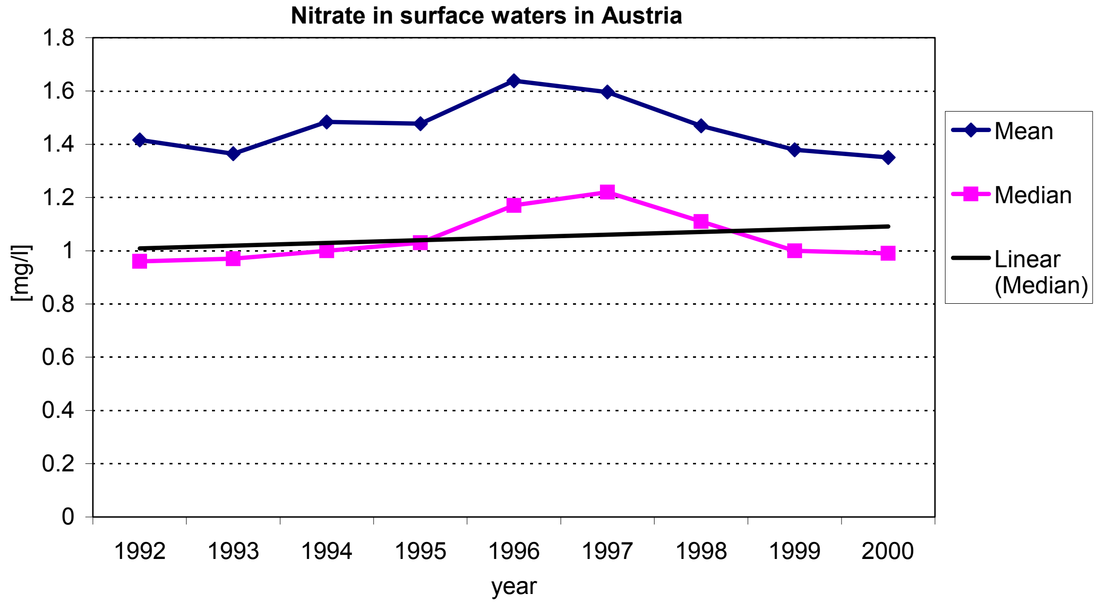

Fig. 4 Seasonal variation of nitrate concentrations in surface waters (Austria, all sites). Source: BMLFUW (2003a).

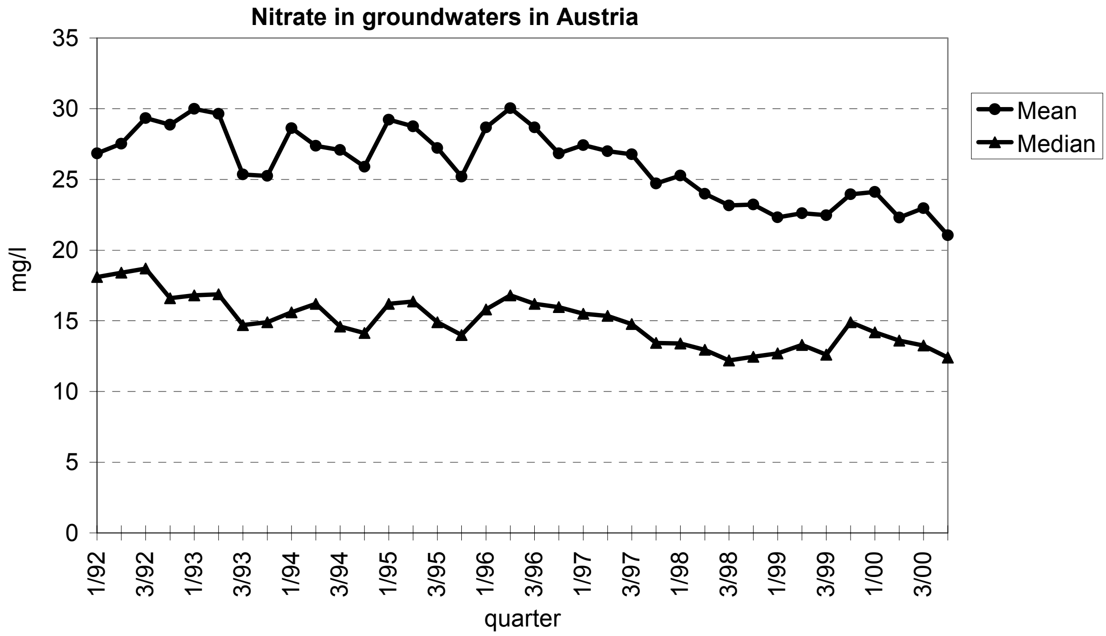

Fig. 5 Seasonal variation of nitrate concentrations in groundwater (Austria, all sites). Source: BMLFUW (2003a).

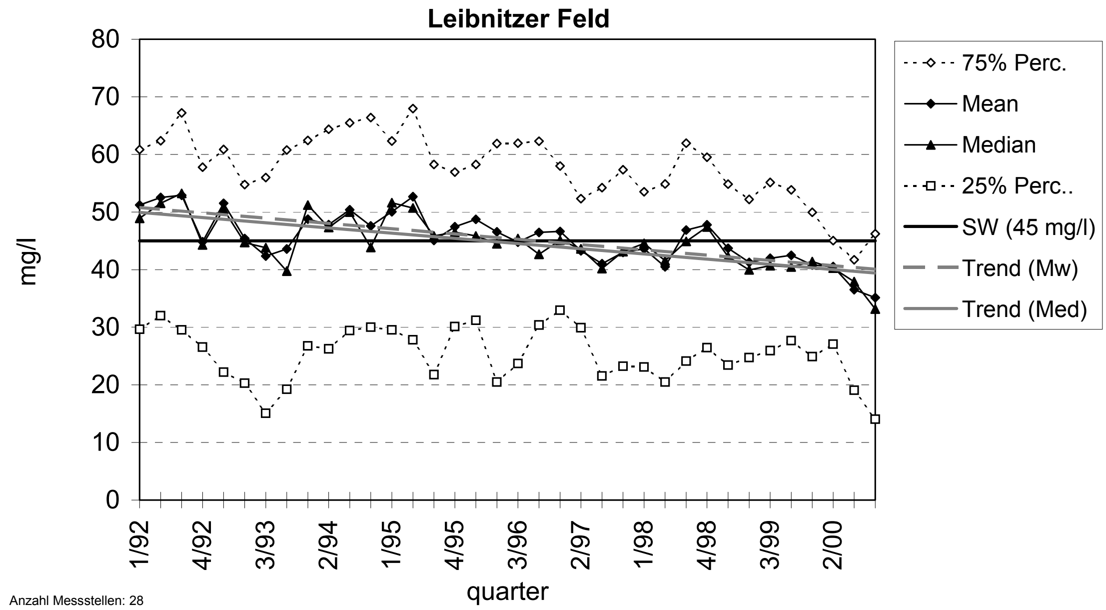

Fig. 6 Seasonal variation of nitrate concentrations in a groundwater body (28 sites). Source: BMLFUW (2003a).

2. EFFECT MONITORING

2.1 Strategy for monitoring

As the development of concentrations in nitrates is seen to be the decisive indicator for success of the EU Nitrates Directive Action Programme, monitoring the effects is mainly based on the results of Austria's dense network for monitoring surface water and groundwater quality. This approach is favoured because of the comparatively fast reaction of Austria's shallow and unconfined aquifers (e.g. atrazine in Fig. 2; see BMLFUW, 2003a).

Investigative monitoring within the framework of the regional "Water inspectorate" of our nine Länder, as well as the controls of good agricultural practice within the EU co-financed environmental programmes, supplement the national monitoring efforts. While these controls of good agricultural practice are performed on a random basis, the investigative monitoring focuses on problem areas and on the control of the provisions for spreading manure (buffer strips and time periods showing when spreading is forbidden).

The mean nitrogen application in Austria (sum of nitrogen from manure and chemical fertiliser application) is well below the economic optimum of most crops. Therefore the farmer will make the best use of nitrogen from manure in order to minimise expenses for buying chemical fertiliser otherwise necessary to meet nitrogen demand of crops. We are firmly convinced that manure will be spread at the wrong time and in excess of plant demand only in cases where storage capacity is not sufficient and where there is no possibility for its meaningful use in agriculture.

We therefore concentrate our monitoring efforts on both the development of nitrate concentrations in our waters and on the farmers, to determine their respect for the provisions of our Nitrates Action Programme (in particular, the spreading of manure, which is easily to monitor). We regard monitoring nitrate concentrations in our waters to be the only reliable criteria holistically integrating the broad range of influencing factors resulting from climate, crops, method of cultivation, soils, characteristics of the aquifer, etcetera.

Other approaches to effect monitoring, an example of which is supplementary obligatory documentation of farm gate balances, are seen to be excessive, taking into account the general low input of nutrients, the predominantly small size and the large number of Austria's farms.

2.2 Detailed technical description of effect monitoring

The national network for monitoring the quality of surface water and groundwater is run jointly by the federal state and Austria's nine Länder, while the investigative monitoring is run exclusively by the administrations of Austria's nine Länder. Two-thirds of the sampling and analysing costs for national monitoring are financed by the state government and one-third by the nine Länder. The design of the monitoring network (studies and new sites) is entirely financed by the federal state.

Monitoring is under the direction of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), Unit VII 1, Marxergasse 2, A-1030 Vienna; regional guidance falls within the responsibility of the Länder administrations.

Sampling and analysis is put out for tender to private laboratories every two to three years. This has led to a considerable decline in costs per sample (Pavlik, 2002). As can be seen from Fig. 7, costs for taking samples even at the tap – without the additional costs for taking samples from wells – considerably exceed costs for analysing a comprehensive set of parameters. Thus the main decision within the national monitoring system is not how many parameters from standardised sets should be analysed but whether it is worthwhile to take a sample or not.

Considerable efforts are taken (see BMLFUW, 2003b) to ensure high quality data by:
- obliging tenderers to disclose the anticipated performance criteria of their methods for analysis, as well as the concrete extent of quality assurance measures (tenders with excellent quality assurance measures are explicitly favoured within the tendering process);
- assessing laboratories at the site (assisted by auditors experienced in the accreditation process from universities);
- holding frequent inter-laboratory comparison tests in which all contractors have to participate and disclose their results, which may be obtained via www.ifatest.at.

A high degree of standardisation for this monitoring has been achieved by:
- enshrining the basic provisions for monitoring (objectives, design of network, methods for sampling and analysing, data transfer, publication of results, responsibilities, sharing costs between federal state and Länder) in a separate ordinance (Source: BGBL, 1990);
- the elaboration of guidance documents (e.g. Philippitsch and Grath, 2001; BMLFUW, 2001c) by the BMLFUW;

- workshops for taking samples, for example;
- joint meetings of administrations involved in convening the whole programme;
- frequent publications of monitoring results and tendering (e.g. BMLFUW, 2001c; BMLFUW, 2002b, BMLFUW, 2003a; Pavlik, 2002).

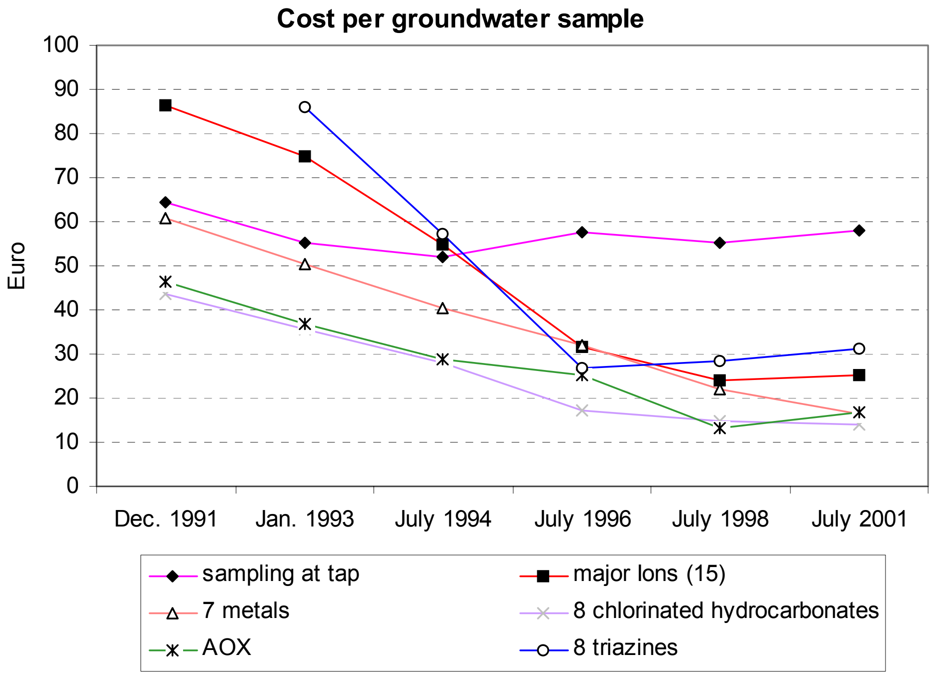

Fig. 7 Costs per sample in groundwater. Source: Pavlik (2002).

Location of sampling sites

Sampling sites consist of a mix of:

- existing abstraction points where large amounts of water are abstracted regularly (for industry, small enterprises, households / major farms, etcetera);
- abstraction sites of small suppliers of drinking water; large suppliers are not taken as they usually have sufficient possibilities to abstract water of good quality, thus possibly adding to a bias of results;
- wells particularly drilled for monitoring purposes.

Monitoring is concentrated in the upper layers of the shallow aquifers. Apart from the shallow aquifers, important springs and deep aquifers are also monitored regularly.

Standard operation procedure(SOP) for sampling

The contractor has to forward all details for sampling to the client. Part of the SOP deals with where to take samples (the contractor gets a documentation of the site and is obliged to document all new changes), how to take samples, how to treat them, and defining the periods of time in which they will have to be analysed. One of the core provisions is that the contractor has to document in detail (via automatic devices) stability of temperature, electric conductivity, pH and oxygen concentration before a sample is taken.

Chemical analysis

Chemical analysis has to be performed in line with the European standards, DIN–standards or the Austrian national standards. As already described the concrete performance criteria of methods and the quality measures foreseen have to be disclosed within the tender and must be granted for the whole working period.

Data storage

Monitoring data are forwarded by the laboratories to the Länder administrations in a standardised format. After data have been checked they are forwarded to the central database jointly run by the BMLFUW and the Federal Environmental Agency in Vienna. Data are centrally available and accessible via Internet.

2.3 Data interpretation and discussion

Data are jointly assessed by the BMLFUW and the Federal Environmental Agency according to the algorithm already described for each individual groundwater body to check compliance with the national target values. Results form part of the publication of monitoring results (BMLFUW, 2003a).

Austria has made use of Article 3(5) of the EU Nitrates Directive to aggregate data for the entire Austrian territory into Austria's report to the Commission. Nevertheless, the aggregated individual monitoring results per groundwater body, as well as per surface-water site are disclosed in annexes and maps of this report to the Commission. Additional key data on developments in agriculture (e.g. nitrogen per hectare of agricultural land, livestock densities and development of total area cultivated with "problem crops") are included to supplement monitoring data on water quality.

This Austrian report to the Commission on the basis of Article 10 of the EU Nitrates Directive is drafted to conform to the Commission's guidance document (EC 1999a). Part of this reporting is meant to compare concentrations of nitrates from one subsequent 4-year period to another. The subdivision of trends into classes (where less than 1 mg l^{-1} signifies no trend, 1-5 mg l^{-1}, a moderate trend & more than 5 mg l^{-1}, a strong trend) is somehow arbitrary and not statistically sound. Nevertheless we acknowledge that an assessment of trends in nitrate concentrations in water is a vital piece of information for ascertaining whether the action programmes lead to any positive progress. We welcome the comparison of nitrate concentrations between 4-year periods as this averages out the influence of individual years. We strongly support those comparisons as we see the development of nitrate concentrations to be the decisive indicator in judging whether action programmes are beneficial to water quality or not. If we take into account the often long reaction time in large and/or deep groundwater bodies, additional indicators (e.g. development of good agricultural practice and nutrient balances) or models can supplement the monitoring of water quality, but because of too many uncertainties in these alternative approaches, may never replace it.

The present monitoring guidance document (EC, 2003; 1999b) suggests including simple indicators of agricultural practice in Member States reports, for example, average distances between fertilised areas and water courses, percentage of cattle holdings with adequate manure storage, or the mean percentage of areas left as bare soil in winter/rainy periods. This may be an adequate tool for situations where the monitoring of water quality is less dense or for a limited size of vulnerable areas. For Austria, with its dense monitoring network, those statistics will add a considerable burden, perhaps even excessive and technically not really necessary. Insufficient buffer strips or inadequate distance from water courses for spreading manure should inevitably show up in the nitrate concentrations monitored at national level. Therefore we would prefer a thorough monitoring of water quality via our dense national network to compilation of data, which are only available at local level.

Appropriate storage capacity for manure can be monitored with great effort at the sites of each of Austria's more than 120,000 stock breeders. Alternatively, storage capacity can be monitored much easier by controls to check if the closed application periods, where spreading of manure is forbidden, are respected. We are, of course, open to options to report on those statistics on a strictly voluntary basis, in particular for individual vulnerable areas of limited size. However, we have severe reservations to proposals, which would result in additional obligations for Member States applying action programmes throughout their entire territory.

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Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Flemish region (Belgium)

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Abstract This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programme in Flanders, Belgium. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5(6) (EC, 1991). In 1999 the European Commission published the Draft Monitoring Guidelines (EC, 1999). Already in 1991 the Flemish legislation has approved a Fertiliser Decree and set up a manure bank to control and limit the excess of production and use of fertilisers. The pollution of the environment caused by fertilisation had to be limited. In 1995 the Decree was adapted to the Nitrates Directive. Vulnerable zones 'water' were designated and the use of fertilisers as well as the period of fertilisation were limited in these vulnerable zones. The former action plan was insufficient and the problems with the pollution of surface and groundwater with nitrogen and phosphorus compounds did not improve or even deteriorated. Part of this problem was the insufficient knowledge of the spreading of nitrogen in subsoils and the mechanism of surface run-off, mainly related to insufficient monitoring networks and research programmes. The Flemish government approved an adapted decree in 2000. The effectiveness of the new action plan and the sufficiency of the limitation of fertiliser use have to be controlled by expanded monitoring networks for surface water and phreatic groundwater. Furthermore derogation tests are running on farm scale level and a proposal has been made to the European commission for a couple of crops. The results of the monitoring network for surface water led to a considerable expansion of the vulnerable zones 'water' with limited fertiliser use (now 46.6% of all arable land), because of measured nitrate concentrations above the limit of 50 mg l^{-1} (NO_3). The expanded monitoring network for phreatic groundwater is still in implementation. Results of older groundwater networks reveal pollution problems in strongly permeable aquifers.

1. INTRODUCTION

1.1 Description of natural factors influencing nitrate occurrence

Flanders is situated in the northern part of the federal state of Belgium. Flanders covers about 1,350,000 ha. The population of the Flemish region is about 5.9 million people. The climate prevailing is a temperate maritime one with mild winters (on average 3.1°C) and cool summers (on average 16.5°C), a mean annual rainfall of 781 mm, equally spread over the year and dominant winds of the Southwest. The evapotranspiration is about 300 mm less than the rainfall. Flanders is covered by the European River basin districts (cf. Water Framework Directive) of the Scheldt and the Meuse, both draining into the North Sea. The basin of the Yzer has been integrated into the Scheldt river basin district. This river, located in West-Flanders, has its source in France and drains also directly into the North Sea. Important lake systems do not exist in Flanders. The big rivers and their tributaries transport significant amounts of nitrogen and phosphourous compounds coming from surface run-off and base flow.

The mean agricultural regions are: the Polders, the sandy area, the sandy-loamy area and the loamy area. The Polders are situated along the coast, in the northern part of the province East–Flanders and next to the Scheldt estuary and contain mainly clayey soils. The sandy area is situated in the northern part of the provinces West-Flanders, East-Flanders, and Limburg and the totality of the province of Antwerp. The sandy-loamy area covers the rest of the province West-Flanders and the southwest of the province of East-Flanders, as well as the upper part of the province of Flemish-Brabant and the middle part of Limburg. The loamy area covers the southeast of the province of East-Flanders and the south of the provinces Flemish-Brabant and Limburg. Flanders is situated below 250 m above sea level and the altitude is increasing from the west and the north to the south and the east. The Polders and the sandy area have a flat landscape. The landscape of the sandy loam and the loam area is more undulating with rather slight slopes.

The near-surface Flemish subsoil consists mainly of sedimentary deposits of Tertiary and Quaternary age of shallow marine and fluvio-periglacial origin. Only in the region south of Brussels outcropping bedrocks of Paleozoic age are found. In Southeast-Limburg a small band of Cretaceous outcrops is situated. Grain-size distribution, permeability and topographic position determine the general flow conditions in groundwater. Due to the alternation of clayey and sandy layers several important aquifers are formed that dip slightly in northern direction. This alternation has an important impact on the spread of nitrate. Water can hardly infiltrate in areas where the outcrops of the clayey sediments are situated. This results in a stronger surface run-off or interflow. In these areas surface water gets polluted by nitrate more easily, for example in the south of West-Flanders. Therefore nitrate infiltrates in the Tertiary and Quaternary sandy aquifers and here contamination problems are located in the groundwater. Sandy aquifers in the hilly region in the south of Flanders are especially endangered, because rapid groundwater flow leads to thick unsaturated zones. Nitrate spreads to deeper parts of these aquifers without being reduced to nitrogen gas. Also the highly permeable gravel, marl and chalk layers in the eastern and southern parts of Flanders form especially vulnerable aquifers.

Thus the regions where nitrate pollution problems occur in surface water are basically complementary to the ones where nitrate pollution in groundwater is observed.

Exceptions are the regions where the rivers and brooks are fed by sufficient base flow and the biodegradation capacity of the aquifers is low. The average change of the depth of the water table during one hydrologic year is about 1.5 to 2 m in the recharge areas of the aquifers. In the discharge areas the variation of the depth of the water table is less significant.

1.2 Description of human factors influencing nitrate occurrence

Global information on land use

The partition over the different forms of land use as given by the "Ruimtelijk Structuurplan Vlaanderen" (Ministerie van de Vlaamse Gemeenschap, 1997) is as follows: 227,500 ha urban area, 55,000 ha for enterprises, 112,000 ha nature area, 43,000 ha woods, 34,000 ha green area, parks and buffer area and 806,000 ha agricultural area. Towards 2007 the partition will change into 227,500 ha urban area, 62,000 ha for enterprises, 150,000 ha nature area, 53,000 ha woods, 34,000 ha green area, parks and buffer area and 750,000 ha agricultural area. All these surfaces are gross numbers including buildings, ways and waterways etcetera and cannot be directly compared to the agricultural surfaces mentioned below which are net surfaces. The overall agricultural area is about 671,907 ha in Flanders and has been stable during the last five years.

Main crops

Table 1 below shows the distribution of the agricultural area over the different crops.

Table 1 Acreage of main crops in hectares in Flanders and per province in 2002 (VLM, 2003).

Crop	Province					Total Flanders
	ANTW	LIMB	E-FL	FL-BRA	W-FL	
Grass (permanent)	45,265	27,144	58,700	24,463	65,994	221,566
Maize	35,203	22,196	48,020	17,569	43,378	166,367
Winterwheat	1,037	8,785	11,665	17,238	26,860	65,584
Grass (temporary)	10,594	8,932	10,871	2,738	16,904	50,039
Potatoes	2,957	2,096	9,808	4,695	20,401	39,957
Sugar beat	1,108	6,545	6,107	8,279	14,701	36,740
Vegetables (industry)	2,027	1,092	1,561	818	13,677	19,175
Fruit (trees)	383	8,215	1,386	4,107	337	14,427
Winter barley	166	2,629	1,455	4,906	802	9,958
Horticulture	1,602	1,456	2,380	558	959	6,955
Fallow	458	1,414	789	2,401	1,660	6,723
Other crops	2,540	6,172	8,406	5,421	11,881	34,416
Total	103,340	96,676	161,148	93,193	217,554	671,907

Characteristics of agriculture

(a) Number of animals

Table 2 shows the evolution of the number of animals in Flanders during the last 10 year.

Table 2 Number of animals (x 1,000) during the last 10 years (Mestbank, 2002a).

Category	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Pigs	4,657	4,835	4,927	4,996	5,066	5,284	5,341	5,605	5,536	6,574	6,301
Cattle	1,596	1,590	1,586	1,614	1,625	1,599	1,556	1,569	1,538	1,506	1,464
Poultry	25,461	25,691	26,902	28,923	30,120	32,249	33,476	34,466	32,984	32,912	31,918
Other animals	258	267	297	316	350	360	391	415	395	190	173

(b) Number of animals per unit of area

The animal density, expressed as number of animals per ha (Table 3), differs a lot between the provinces, especially for pigs and poultry. In the province West–Flanders the number of pigs/ha raised is more than eight times the number in the province Flemish–Brabant. The animal density for poultry in the province Antwerp is eight times bigger than in the province Flemish-Brabant.

Table 3 Number of animals per ha in 2001 (based on VLM, 2003).

	Province					
Category	Antwerp	Fl-Brabant	W-Flanders	E-Flanders	Limburg	TOTAL Flanders
Cattle	3.3	1.4	2.1	2.3	1.6	2.2
Pigs	9.7	1.9	15.2	8.0	5.4	9.4
Poultry	91.6	11.9	55.8	32.9	40.9	47.6
Other animals	0.4	0.2	0.2	0.3	0.2	0.3

(c) Areas in the region with intensive agriculture

The number of agricultural holdings (37,913) has been decreasing since the early seventies. The mean area per holding is 17.72 ha. The livestock production is very intensive in Flanders especially in the sandy area. It was increasing until the end of the previous century. The increase of the intensive livestock production in Flanders in the past, is linked to the fact that land was sparse and expensive, which forced farmers to increase their production per unit of area or to eliminate the production factor land, in order to maintain their income. The proximity of harbours allowing an easy import of raw materials for the production of concentrates also influenced the intensive livestock production unit with little or no agricultural area for feed production. Cattle production is spread all over the region but pig production is concentrated in West-Flanders, East-Flanders and Antwerp; the densest population of poultry is situated in the provinces Antwerp and West-Flanders.

(d) Main farm types

Most of the farms in Flanders cultivate land and keep animals (Table 4). Yet some regional differences occur: in the provinces Flemish-Brabant and Limburg there are relatively more specialised arable farms and in the provinces Antwerp and West-Flanders more farms are exclusively occupied with animal breeding.

Table 4 Number of farms per farm type in relation to the use agricultural land and animal breeding in 2001 (VLM, 2003).

	Province					
Farm type	Antwerp	Fl-Brabant	W-Flanders	E-Flanders	Limburg	Total Flanders
Without agricultural land	147	56	302	114	106	725
Without animals	955	1,356	2,107	1,436	1,329	7,183
With animals and agricultural land	4,507	2,801	9,393	7,366	3,128	27,195

Table 5 Main farm types in Flanders and their production of P_2O_5 and N (Mestbank, 2002b).

Main farm types	Production of P_2O_5 (x1000 kg) in animal manure	Production of N (x1000kg) in animal manure	Number of farms	Surplus of N (x1000 kg)	surplus P_2O_5 (x1000 kg)	Gras (ha)	Maize (ha)	Other crops (ha)	Crops with low N needs (ha)
Arable farms	1,143	3,028	6,214	534	203	10,627	9,367	60,982	26,289
Combination of different cattle	4,597	12,783	6,641	1,689	482	50,128	23,644	10,922	1,058
Dairy farms	15,053	46,569	8,537	3,778	518	115,688	66,181	15,791	1,377
Beef cattle	1,272	3,402	1,027	860	272	7,783	2,416	562	57
Pigs	18,795	43,992	3,159	34,099	14,266	10,454	16,541	8,935	1,099
Poultry	4,827	9,338	534	9,011	4,685	593	400	96	16
Combination of cattle and arable farming	3,855	11,540	3,777	469	88	30,683	19,959	40,051	5,727
Combination of cattle+ pig/poultry and arable farming	14,095	34,909	3,192	14,357	4,840	29,065	24,225	25,162	3,547
Veal calves	705	1,954,451	300	1,143	368	1,616	968	250	12
Mixed farms	4,382	11,368	1,925	3,938	1,338	16,308	8,057	11,611	1,684
Total	68,724	178,882	35,306	69,877	27,061	272,944	171,757	174,362	40,866

remarks:

- Production and surpluses are reduced with 15% ammonia emission.
- Surpluses are the sum of the surpluses at farm level without surfaces used outside Flanders and without the surface used by foreign farms in Flanders.

Manure production and fertiliser use

(a) Manure production

In Flanders animal breeding produced in 2001 about 179 million kg of N and 69 million kg of P_2O_5 in 2001. More than 40% of the nutrient production in animal manure were produced in the province of West-Flanders (Table 6).

Cattle were responsible for the half of the nitrogen production in animal manure and for 45% of the phosphate production. The part of the pigs in the nutrient production in animal manure was respectively 38% for nitrogen and 43% for phosphate. For poultry the part was respectively 11% of the nitrogen and 13% of the phosphate (Table 8).

The production of nutrient in animal manure is decreasing since 1998 for all the categories of animals. In the period before is was increasing for pigs and poultry (Table 7 and 8).

Table 6 Production of nutrients in animal manure in Flanders and per province in 2001 (VLM, 2003).

	Province					
	Antwerp	Fl-Brabant	W-Flanders	E-Flanders	Limburg	Total Flanders
Phosphate ()	13,220,194	3,949,754	29,094,482	15,589,242	6,916,018	68,769,690
Nitrogen (kg N)	34,138,380	11,119,646	73,775,786	41,650,450	18,210,514	178,894,776
Net N production (kg N) minus 15% N emission	29,017,623	9,451,699	62,709,418	35,402,883	15,478,937	152,060,560

Table 7 Evolution of the production of N (x 1000 kg) in animal manure in Flanders (Mestbank, 2002a).

Category	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle	92,393	91,524	90,857	91,587	93,120	90,737	88,869	89,478	87,840
Pigs	51,351	53,404	55,287	56,449	57,705	60,152	60,758	63,2263	62,088
Poultry	8,236	8,466	9,007	9,786	10,354	10,943	11,346	11,561	11,054
Other	2,011	2,024	2,053	2,126	2,293	2,544	2,671	2,877	3,123
Total	153,991	155,418	157,204	159,948	163,472	164,376	163,644	167,142	164,104

Remark:
Since the year 2000, different excretion numbers were used to calculate the production of nutrients.

Table 8 The production of nutrients per animal category 2000-2001 (Mestbank, 2002a).

	2000			2001			Evolution 2001 versus 2000		
Category	Number of animals	Kg N	Kg P_2O_5	Number of animals	kg N	kg P_2O_5	nr. of animals	kg N	Kg P_2O_5
Cattle	1,507,636	91,589,417	29,749,555	1,464,182	88,851,111	28,852,022	-2.9%	-3.0%	-3.0%
Pigs	6,578,353	71,638,432	31,979,541	6,301,474	67,279,686	29,431,106	-4.2%	-6.1%	-8.0%
Poultry	32,971,298	20,637,392	9,917,120	31,917,960	19,920,037	9,345,410	-3.2%	-3.5%	-5.8%
Other animals	187,613	2,907,289	1,295,074	172,520	2,806,184	1,234,941		-3.5%	-4.6%
Total		186,772,530	72,941,290		178,857,018	68,863,479		-4.2%	-5.6%

(b) Use of manure and fertilisers
In Flanders the use of three types of fertilisers are monitored by the Mestbank: animal manure, chemical fertilisers and "other" fertilisers (e.g. compost and other organic products containing nitrogen or phosphate) (Table 9).

The mean use of N and P_2O_5 is respectively 221 kg/ha and 98 kg /ha in the year 2000, of which almost 80% of the nitrogen and almost 90% of the phosphate originates from animal manure. In 2000 the mean use of nitrogen had decreased with 56 kg of N and 11 kg P_2O_5 since 1992 (Table 10).

Table 9 Use of nutrients from different sources in Flanders and per province 2001 (VLM, 2003).

	Province					
	Antwerp	Fl-Brabant	W-Flanders	E-Flanders	Limburg	Total Flanders
Use of animal manure						
Phosphate (kg P_2O_5)	11,200,130	6,804,542	23,217,693	15,399,217	7,525,091	64,146,673
Nitrogen (kg N)	25,373,459	14,044,703	51,920,650	34,574,927	16,210,972	142,124,710
Use of chemical fertilisers						
Phosphate (kg P_2O_5)	557,482	1,400,974	706,491	1,503,990	885,982	5,054,919
Nitrogen (kg N)	4,627,738	6,844,825	12,970,819	10,342,088	4,795,046	39,580,516
Use of other fertilisers						
Phosphate (kg P_2O_5)	93,248	367,982	320,827	176,084	183,624	1,141,765
Nitrogen (kg N)	143,619	452,074	269,866	219,271	210,069	1,294,899
Total use of fertilisers						
Phosphate (kg P_2O_5)	11,850,860	8,573,498	24,245,011	17,079,291	8,594,697	70,343,357
Nitrogen (kg N)	30,144,816	21,341,602	65,161,335	45,136,286	21,216,087	183,000,125

Table 10 Evolution of the use of fertilisers in Flanders (Mestbank, 2002a).

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Use of nutrients from animal manure per ha									
Nitrogen (kg N ha^{-1})	247	243	247	251	245	249	246	239	221
Phosphate (kg P_2O_5 ha^{-1})	110	103	109	112	107	111	102	100	98
Use of nutrients from chemical fertiliser per ha									
Nitrogen (kg N ha^{-1})	98	88	86	94	79	76	78	70	66
Phosphate (kg P_2O_5 ha^{-1})	29	22	20	18	16	14	13	13	10
Use of nutrients from other fertilisers per ha									
Nitrogen (kg N ha^{-1})	-	-	-	0.2	0.4	0.9	1.1	1.5	1.7
Phosphate (kg P_2O_5 ha^{-1})	-	-	-	0.2	0.4	0.9	1.1	1.5	1.6
Use of nutrients per ha									
Nitrogen (kg N ha^{-1})	345	331	333	345	324	325	325	312	289
Phosphate (kg P_2O_5 ha^{-1})	139	125	129	130	123	126	116	115	109

In nitrate vulnerable zones the use of N from animal manure is limited to 170 kg N ha^{-1}. The surface of the nitrate vulnerable zones was raised in from 62,000 to 311,500 ha or 46.4% of the total agricultural surface. The fertilisation limits for N from animal manure outside the vulnerable zones are shown in Fig. 1.

(c) Surpluses

A balance can be calculated on different levels (farm, community, and province) and can be based on the different types of fertiliser use (Table 11). A surplus exists when the nutrient production surpasses the possibility of use within the legal limitations. At farm level, about one third of the farms produce a surplus of nutrients and must transport the surplus to other farms. On community level, in one third of the communities exists a surplus. The agricultural land in the provinces of Antwerp and

West–Flanders does not suffice to use the production of nutrients in animal manure in those provinces within the legal limitation.

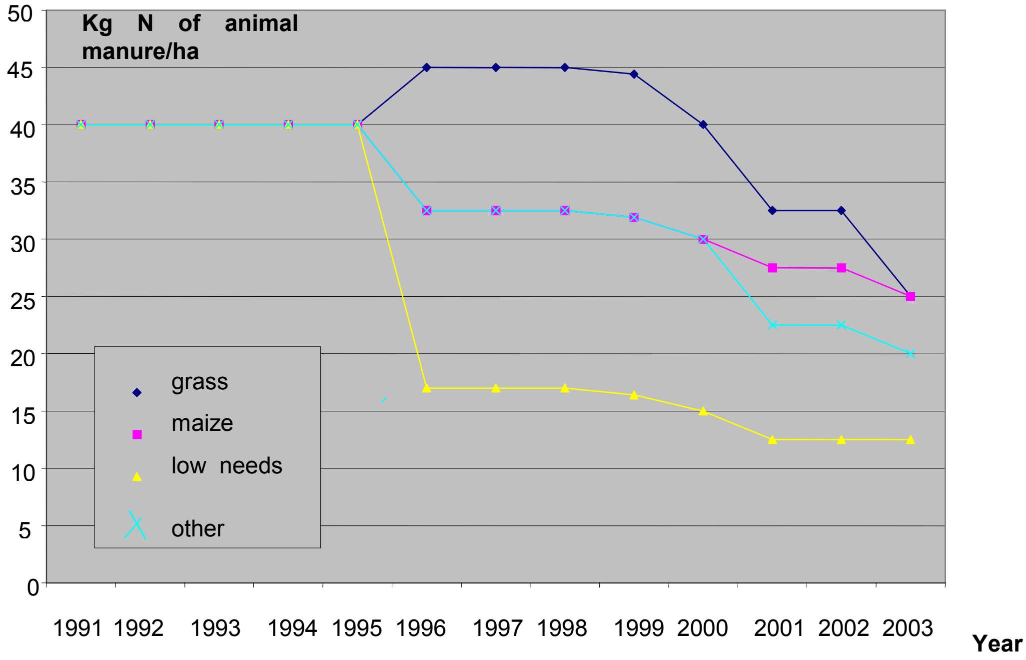


Fig. 1 Evolution of the fertilisation limits for N from animal manure in kg ha^{-1} outside vulnerable zones (Mestbank, 2002a).

Table 11 Sum of the nutrient surpluses (in kg) and number of farms with a surplus in Flanders and per province in 2001 (VLM, 2003).

	Province					
	Antwerp	Fl-Brabant	W-Flanders	E-Flanders	Limburg	TOTAL Flanders
Surplus at farm level (including chemical fertilisers)						
Phosphate (kg P_2O_5)	6,316,673	716,076	13,085,144	5,316,939	2,599,681	28,034,513
Nitrogen (kg N)	15,071,199	2,065,714	34,254,153	14,638,930	6,437,250	72,467,246
Number of farms	2,382	748	6,086	3,247	1,427	13,890
Surplus at farm level (excluding chemical fertilisers)						
Phosphate (kg P_2O_5)	6,289,203	666,052	13,007,330	5,188,852	2,556,333	27,707,770
Nitrogen (kg N)	14,849,539	1,803,218	33,573,843	14,159,859	6,282,416	70,668,875
Number of farms	2,207	513	5,670	2,832	1,262	12,484
Surplus at community level (excluding chemical fertilisers)						
Phosphate (kg P_2O_5)	8,928,056	12,064	20,414,043	6,339,972	1,408,957	37,103,092
Nitrogen (kg N)	3,003,584	1,972	6,057,681	1,085,292	220,791	10,369,320
Number of communities	19	2	41	23	13	98
Surplus at province level (excluding chemical fertilisers)						
Phosphate (kg P_2O_5)	50,168	0	2,902,907	0	0	2,953,075
Nitrogen (kg N)	4,025,189	0	16,426,617	0	0	20,451,806

1.3 Headlines of the Flemish action plan

The Nitrates Directive was transposed in the Flemish legislation by the Fertiliser Decree (Vlaamse regering, 1991). This decree dates from the period before the Nitrates Directive and was called “the decree concerning the protection of the environment against pollution from fertilisers” (23 January 1991). It imposed maximum fertilisation levels for N and P_2O_5 and mentioned periods in which it was forbidden to use animal manure. It also installed the Manure Bank, which has to scoop the manure surpluses. Furthermore the Manure Bank is responsible for the follow up of manure transports and manure exchange between farms, the raising of levies and the control on the implementation of the rules stipulated in the decree.

The decree was adapted to the Nitrates Directive in December 1995. Hence vulnerable zones ‘water’ were designated, in which more stringent rules for the maximum levels of fertilisation for nutrients from all types of fertilisers where imposed. Furthermore the period in which fertilisation can take place was restricted. A code of good agricultural practice was developed.

As the European Commission did not accept this decree as a sufficient action plan, a new adaptation of the decree was voted by the Flemish parliament and came into effect from 1 January 2000 on. As a result of this change and of the monitoring programme that was set up, 46.6% of the agricultural surface was designated as “vulnerable zone water”; this was communicated to the European Commission in 2002.

The Flemish government started a strategy focused on repartition of farm and regional surpluses. In this period the cattle breeders with no or insufficient land were forced to transport their manure to arable farms and learned to deal with an environmental cost of the manure handling. Farmers possessing arable land were taught to valorise organic fertilisers and to decrease the use of chemical fertilisers. The regional nutrient balance for Flanders will reveal a surplus on regional level; hence the strategy is based on the following three pillars since 2000:

- Source approach:
  - immediate reduction of manure production by using better feeding techniques and more efficient concentrates with a lower protein and phosphate content and the stimulation of keeping records of nutrient excretion balances;
  - restriction of the animal production including voluntary reduction of the live stock;
  - a stop in granting environmental permits for breeding of animals and a limitation of the production to the level of the recent past.

- Rational fertilisation:
  - the recording of a soil nutrient balance;
  - control of the nitrate residue after the crop;
  - treatment or exchange of manure between farms in order to obtain a better valorisation of the nutrient in relation to the soil properties and the needs of the crops.

- Manure treatment, physical, chemical or biological treatment in a way that:
  - the manure can be exported;

- the nutrients are transposed to a form without environmental impact (e.g. N_2). The obligation to treat manure surpluses is linked to the size of the phosphate production.

The fertilisation limits for not vulnerable and for vulnerable zones water are:
- general limitation: maximum nitrate residue of 90 kg NO_3-N ha^{-1}, in the zone 0 to 90 cm during the period of the 1st of October till the 15th of November;
- non vulnerable zones (see Table 12);
- vulnerable zones (see Table 13).

Table 12 Fertilisation limits for non-vulnerable zones in Flanders.

Crop	P_2O_5 kg ha^{-1}	Total N kg ha^{-1}	N from animal manure kg ha^{-1}	N from chemical fertilisers kg ha^{-1}
Grass	130	450	250	350
Maize	100	275	250	150
Crops with low needs for N	100	125	125	100
Other crops	100	275	200	200

Table 13 Fertilisation limits for Nitrate Vulnerable Zones in Flanders.

Crop	P_2O_5 kg ha^{-1}	Total N kg ha^{-1}	N from animal manure kg ha^{-1}	N from chemical fertilisers kg ha^{-1}
Grass	100	350	170	250
Maize	100	275	170	150
Crops with low needs for N	80	125	125	70
Other crops	100	275	170	175

A proposition of derogation is handed to the European commission. The derogation concerns the crops given in Table 14.

Table 14 Derogation from fertilisation limits for Nitrate Vulnerable Zones in Flanders.

Crop	P_2O_5 kg ha^{-1}	Total N kg ha^{-1}	N from animal manure kg ha^{-1}
Grass	100	350	230
1 cut of grass +maize	100	275	230
Winter wheat + green manure (non-leguninose)	100	275	200
Sugar and fodder beets, Brussels sprout	100	275	200

A specific derogation is possible for all types of crops on the base of soil nutrient balance including soil analysis. Table 15 shows the periods in which fertilisation is forbidden (from 16 February 2003).

Table 15 Periods in which Fertilisation is forbidden.

	Non-vulnerable zones	Vulnerable zones
Grass	15 September - 31 January	1 September - 15 February
Other crops	15 September - 15 February	1 September - 15 February

Remark:
All types of fertilisation except stable manure (stable manure: 15 November – 15 January)

The use of fertilisers is forbidden on wet, flooded, frozen or snow-covered land and within a distance of 5 to 10 m (slopes and natural areas) of a watercourse. Manure should be spread with low emission techniques (injection, trailing hoses or incorporation within 2 hours).

1.4 Overview of monitoring networks in Flanders

1.4.1 Surface water quality

The 'Vlaamse Milieumaatschappij' (VMM or Flemish Environment Agency) is a Flemish Public service under the supervision of the Flemish Minister of Environment and Agriculture. One of its decretal and statutal tasks is the exploitation and the management of a monitoring network for surface water quality.

Since 1991 the VMM manages a monitoring network with more than 1000 stations on canals, brooks, rivers and lakes spread all over Flanders. Nitrate and phosphate are monitored every month. Supplementary, since 1999, there is a more specific nitrate-monitoring network with 266 locations in rural areas. Figure 2 illustrates the evolution with respect to nitrate in the Flemish region (the data refer to all available nitrate data of the VMM).

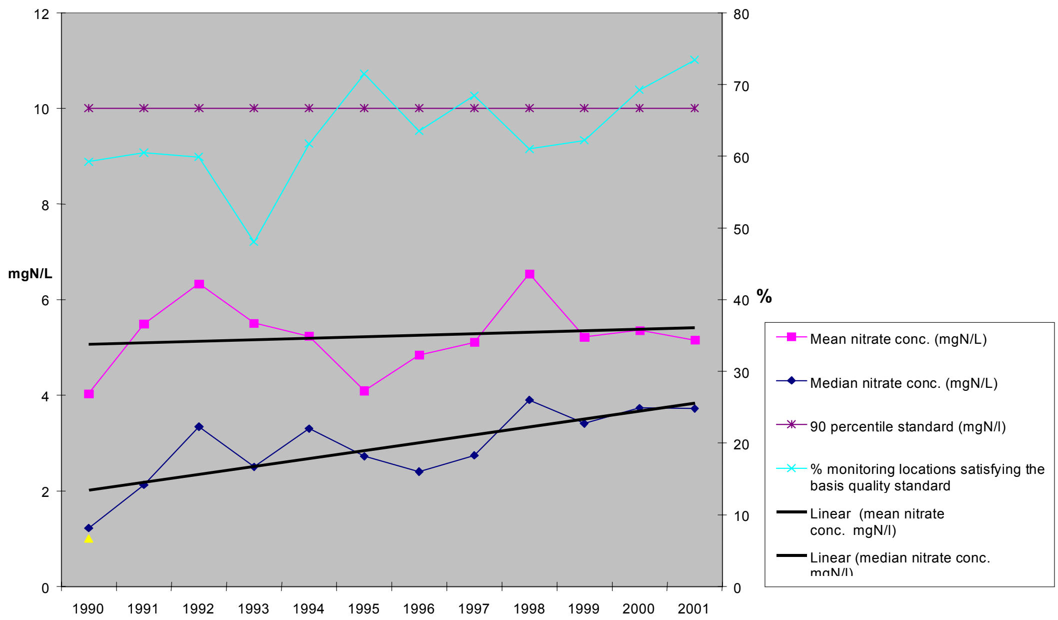


Fig. 2 Evolution of nitrate concentration of surface water in Flanders (source: VMM, personal communication).

It appears that policy measures have complex results. On the one hand, treatment of urban wastewater and increasing nutrient removal in wastewater treatment plants have a positive effect on nitrate concentrations. On the other hand wastewater treatment plants without nutrient removal produce nitrate. The policy of manure spreading lead to a decrease of very high nitrate maxima in problem areas (formerly more than 200 mg l^{-1}), but at the same time nitrate-free areas tend to disappear.

1.4.2 Groundwater quality

Up to now different networks for monitoring the groundwater quality exist in Flanders.

Primary monitoring network

The water division of the AMINAL (Environment, Nature, Land and Water Administration) runs a primary monitoring network for measuring the evolution of quantity and quality of groundwater in important aquifer systems. Most of the wells are too deep to measure near-surface pollution. A lot of filters are situated in confined aquifers or in the reduction zone of deep phreatic aquifer systems for example in the region of the Campine region. The background water quality can be measured with this network. This groundwater is practically not effected by human activities. However there are a few wells of this network where nitrate contamination also occurs. These wells are located in regions where nitrate pollution can reach deeper parts of the aquifers like in the sedimentary basin of the Meuse valley.

Networks of drinking water supply companies

These networks of observation wells have been used for a first evaluation of the vulnerability of aquifers towards nitrate pollution. In some supply areas nitrate concentrations exceeding the limit of 50 mg NO_3 l^{-1} were measured. These networks can give some indications, but they are limited to the supply areas. The depth of the observation wells is normally not related to the near-surface pollution but to the depth of exploration. Moreover the pumping effects have influence on the groundwater flow and the advective transport.

Networks of other organisations

The Institute of Nature Conservation (Instituut voor Natuurbehoud) has developed a groundwater-monitoring network in around 170 forests and nature reserves. The filters of the wells are located in the shallow part of the phreatic aquifers. In the majority of the filters only low nitrate concentrations can be measured; however; there are some wells in 19 preserves with higher concentrations, mainly related to groundwater flow and historical pollution events. This network cannot fulfil the function of a monitoring network in the scope of the Nitrates Directive that obliges to measure the influences of agricultural activities as main source of diffuse nitrate pollution. Nevertheless this network can be a useful addition to the new nitrate-monitoring network. It can give information about lateral replacement of contamination plumes, background values and the barrier function of forests and natural reserves.

The Belgian Geological Survey has also a limited number of mainly deep wells. Furthermore there are some tens of thousands of wells of private companies, farms and private households that could give indications of existing nitrate pollution problems.

However only companies with well installations that pump more than 30,000 m^3 groundwater per year are obliged to analyse the water quality. The information that reaches the water division of the AMINAL is limited and the majority of these wells are situated in deeper non-polluted aquifers. A selection of private supply wells of farmers has been used for a first insufficient nitrate-monitoring network (see chapter “Effect monitoring”).

Nitrate Monitoring Network

In November 2002 the water division of the AMINAL started to implement a phreatic monitoring network with the purpose to measure the influence of agricultural activities on the evolution of nitrate concentrations in shallow groundwater. Once the new Nitrate Monitoring Network is completed it will consist of around 2100 observation wells spread over all agricultural regions of Flanders. Further detailed description is found in the chapter “Effect monitoring”.

1.5 Regional environmental goals with respect to nitrate and eutrophication

Surface water

The Flemish Environmental Regulation (VLAREM II; Vlaamse regering, 1995a) specifies the quality standards for surface water. Beside a basic quality, there are also quality standards for surface water with a specific use in execution of the EU-directives, such as fishing water, shellfish water, swimming water and fresh surface water used for the production of drinking water.

The basic quality standards for surface water were determined independent of the Nitrates Directive. For vulnerable zones the same standards apply as anywhere else. The testing of the results against the standard is done on the basis of a series of measurements over one year. With respect to nitrate there is no specific nitrate standard. The quality standard for nitrate was determined as the sum parametre “nitrate plus nitrite” (10 mg N l^{-1}). In normal conditions there is just a minimal fraction of nitrite in surface water, it is therefore justifiable to use the limiting value concerning nitrate as 10 mg N l^{-1} (or 44.3 mg NO_3 l^{-1}). This threshold value can be exceeded by no more than 50% in no more than 10% of the measurements per location.

The ecological criterion “eutrophication” that has been established in the Nitrates Directive, cannot be determined by a legal environmental standard in Flanders. In the present basic quality standards only the standard for orthophosphate aims at the prevention of eutrophication (the limiting value for still waters is 0.05 mg P l^{-1}. This concentration may not be exceeded by 50% in 10% of the measurements per location).

The basic quality standard for surface water for chlorophyll is a threshold value of 100 µg l^{-1} for the mean concentration.

By referring explicitly to the European directive, which determines the quality objectives with respect to fresh surface water used for the production of drinking water (EC, 1975), the Nitrates Directive compels us to compare the quality of surface water to the 50 mg NO_3 l^{-1}-standard.

The threshold value for nitrate in surface water intended for the production of drinking water is 50 mg NO_3 l^{-1}. This means that at least 95% of the observations may not be higher than 50 mg NO_3 l^{-1} and the observations, which exceed this value, may not be higher than 75 mg NO_3 l^{-1} (this is an exceeding of 50%).

Groundwater

According to drinking water and groundwater quality standards established in the Flemish Environmental Regulation (VLAREM I and II; Vlaamse regering, 1991 and 1995a) and due to the European Nitrates Directive, the limit of 50 mg NO_3 l^{-1} should not be exceeded in any of the sampling locations for groundwater. The no-deterioration clause obliges to reverse negative trends even if there is no exceeding of the nitrate limit yet.

Furthermore there is no limitation to groundwater depth below that the water has to reach a good quality, because every kind of groundwater resource is considered to be protectable. Main objective must be an optimal farming adapted to the local boundary conditions, so that an exceeding of the nitrate limit in groundwater does not occur and the European guide norm of 25 mg NO_3 l^{-1} becomes a realistic goal.

Direct consequences for the designation of a vulnerable zone, based on one measured value above the nitrate limit in one evaluation period, seems to be a hard verdict. Therefore the evaluation units and the locations of the observation wells have to be chosen in a responsible way to get reliable results (see technical description of the Nitrate Monitoring Network for groundwater).

2. EFFECT MONITORING

2.1 Strategy for effect monitoring

2.1.1 Surface water

In the draft environmental policy agreement of the Manure Action Plan 2 (MAP2, Vlaamse regering, 1991) it was stipulated that on 1 July 1999 at the latest the Flemish Environment Agency (VMM) had to expand her surface water monitoring network with sampling points in exclusively rural areas (cf. Art. 6). This extension will further be mentioned as “MAP-network”.

The requested extension gives the opportunity to give a feedback of the consequences of the (changed) manuring (fertilising) practices regarding the quality of surface water to the agricultural organisations. The data will be used by these organisations to inform their members, and to sensitize and to motivate them.

Thus, the monitoring network has to give an answer to the following questions:
- which Flemish surface waters have a nitrate concentration higher than 50 mg NO_3 l^{-1} in 95% of the measurements and/or higher than 75 mg NO_3 l^{-1} in 5% of the measurements?
- in which Flemish surface waters the concentration of nitrogen compounds can lead to eutrophication?

2.1.2 Groundwater

Actions taken for monitoring and protection of Flemish groundwater in the scope of the European Nitrates Directive (EC, 1991):

1) In December 1995 the Flemish Government decided to protect mainly the areas of public drinking-water supply by generating protection areas around water supply installations and to protect nitrate vulnerable aquifers. Shape and expansion of created protection areas are related to a proposal of De Smedt (1984), mainly based on the evolution of nitrate measurements in observation and production wells of the Flemish water supply companies. Around 9% of the Flemish territory were indicated as Nitrate Vulnerable Zone and nitrate risk zone to groundwater. The use of manure for fertilisation is limited in the designated Nitrate Vulnerable Zones, For the nitrate risk zones a shorter yearly fertilisation period was fixed. This method of designating nitrate vulnerable areas with regard to groundwater later appeared to be insufficient for the following reasons:
   - no decrease in nitrate concentrations in already protected areas could be observed;
   - only that part of Flanders was monitored where intensive drinking water supply is situated;
   - not all drinking water supply installations are located in the direct neighbourhood of arable land and do pump water from the most vulnerable phreatic aquifer; so the monitoring data is not representative;
   - high nitrate concentrations have been detected in groundwater outside the designated areas;
   - the designation of the protection areas are partially based on administrative borders.

2) In 1998 the Flemish government decided to monitor the nitrate problem related to groundwater on a larger scale, The water division of AMINAL was instructed to choose around 260 water production wells of farms located in the direct neighbourhood of arable land. This was executed in co-operation with the Flemish farming organisations. The aim of this research programme was to establish the relationship between the use of agricultural parcels and the nitrate concentrations in groundwater. In the year 2000 four analyse campaigns were executed by two external laboratories. Around 30% of the groundwater samples were contaminated with nitrate concentrations above the limit of 50 mg NO_3 l^{-1}. However, no clear relationship between land use, fertilisation and measured nitrate concentrations in groundwater could be observed. The water division started an external research project executed by the Ghent University. The aim of this project was to evaluate the existing network of farming wells and to give recommendations on how to improve the monitoring network. Eppinger *et al.* (2001) found out that the following shortcomings led to the non-correlation between arable land use and observed concentrations:
   - sediment boundary conditions and groundwater flow conditions were insufficiently known or not taken into account;
   - no natural flow conditions occur in pumping wells;
   - around two-third of the wells pumped water from the deeper part of the phreatic aquifers. The filters were situated in the reduction zone of the groundwater where naturally no nitrate is present due to the existing redox conditions;

- the age of the pumped groundwater was not known, neither has it been estimated;
- some wells were probably effected by point sources (local manure disposal, sewage) and the depth of the filters was not known;
- insufficient information existed about the quantities of fertilisers that were used.

After removal of the unsuitable wells, only 97 wells were left that fulfilled nearly the obligatory boundary conditions. In more than 70% of these wells, with filters in the oxidation zone of the phreatic aquifers, the limit of 50 mg l^{-1} (NO_3) in groundwater was exceeded. In 90% of the wells concentrations above 25 mg l^{-1} (NO_3) were measured (see Fig. 3).

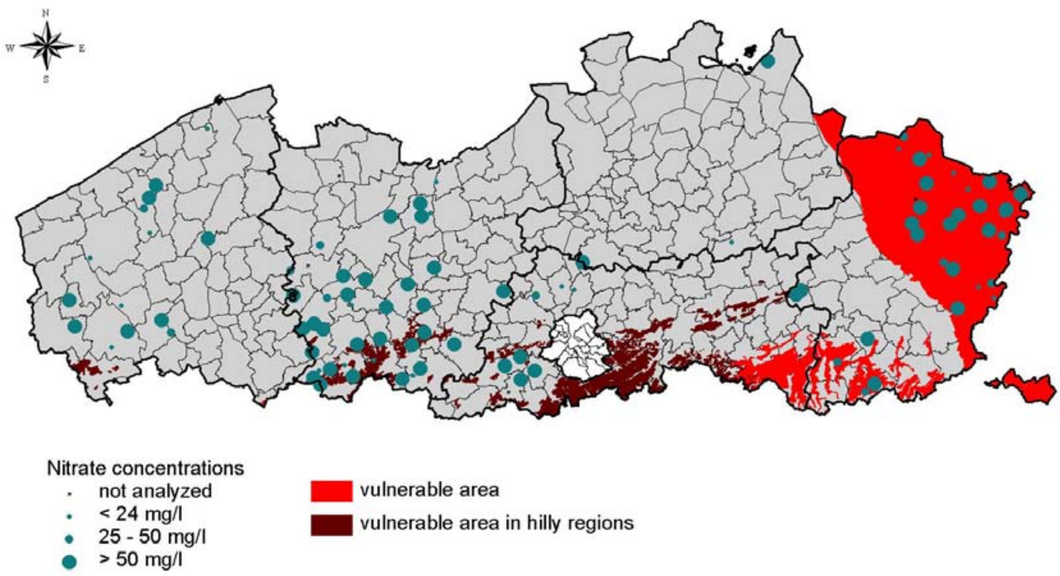


Fig. 3 Vulnerable zones in groundwater in Flanders, based on measurements of production wells of the first nitrate monitoring network.

However the remaining wells could not give a complete idea about the nitrate pollution problem in Flanders, because the wells are effected by daily or temporary use and not made for research purposes. Furthermore they are not spread over the whole entire territory of Flanders. No information exists about some regions.

3) In co-operation with the Institute of Applied Geology and Hydrogeology of the Ghent University, the water division of AMINAL made a proposal on how to improve the monitoring network for groundwater quality and on how Nitrate Vulnerable Zones can be designated, The Nitrates Directive allows to create Nitrate Vulnerable Zones based on direct measurements or based on physical boundary conditions of endangered phreatic aquifers, so the potentiality of being polluted in case no actions of prevention are taken.

A map with 33 (originally 26 main divisions, further subdivided due to lithological differences) hydrogeologically homogeneous zones was made (Eppinger *et al.*, 2002, see Fig. 4). These are zones with comparable physical boundary conditions, where natural nitrate removal inside the most shallow aquifer systems follows a comparable process. In a first step it was suggested only to protect the most vulnerable zones, where pollution can reach deeper parts of the phreatic aquifers (more than 20 m below surface) due to fast groundwater flow conditions (high permeability and hydraulic gradients) and/or absence of reducing compounds like organic matter or pyrite in the sediments, used by anaerobic micro-organisms for nitrate removal. The analyses of nitrate concentrations in research wells should be used as indicators of the vulnerability. In a second step other, less deep contaminated areas could have been evaluated for taking actions for groundwater protection. The Flemish government rejected this proposal mainly due to the lack of sufficient indication wells and reference material.

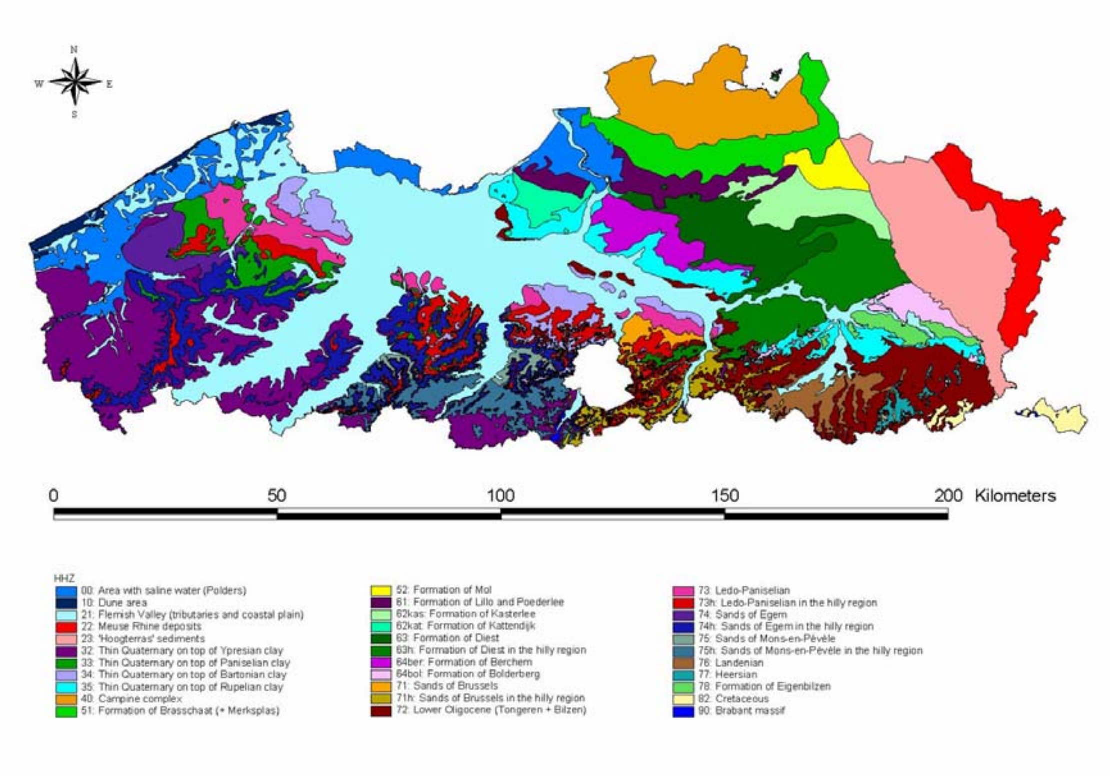


Fig. 4 Thirty-three (26 main divisions) hydrogeologically homogeneous zones (Eppinger *et al.*, 2002).

4) Therefore the government decided to expand the monitoring network for groundwater and to designate Nitrate Vulnerable Zones based on direct quality measurements and not on the potential vulnerability of phreatic aquifer systems. As a result the water division of AMINAL suggested a concept for the implementation of a completely new Nitrate Monitoring Network mainly based on the research project of nitrate spread in Flanders by Eppinger *et al.* (2002). In December 2002 the Flemish government officially agreed to install this Nitrate Monitoring Network for groundwater with the special purpose to detect the nitrate pollution problems due to the vulnerability of the different phreatic aquifersystems (buffer capacity of sediments) and the insufficient adaptation of fertiliser use in case there are pollution problems. This network, consisting of 2100 wells spread over the arable land of whole Flanders, will be the basic instrument for observing and controlling the effects of an adapted Fertiliser Decree (MAP2) with respect to groundwater pollution.

2.2 Technical description of networks used for effect monitoring

2.2.1 Surface water

In 1999 it was initially the aim to choose two to three monitoring stations in each of the 253 hydrographic zones or sub-basins in close consultation with the agricultural organisations. Unfortunately, it was not always possible to find enough monitoring stations, which met the criteria.
For each monitoring location the following criteria are applicable:
- the catchment area has an agricultural character;
- there is no impact of industrial waste water discharges;
- there is no impact of overflows (sewerage or collectors) or effluent discharge of a waste water treatment plant;
- the amount of nitrogen in discharged domestic wastewater can be calculated and has only a small impact (every inhabitant discharges an average of 10 g N a day).

A consensus was reached for a network of 266 monitoring stations, after a screening on the basis of topographic maps, the data of the VMM database concerning industrial discharges and the number and the discharge patterns of the inhabitants inside the catchment areas. Additionally, the Flemish Environment Agency (VMM) and the agricultural organisations carried out a field survey.

Taking the stringent criteria into account, no MAP (manure action plan) monitoring station could be pointed out in 102 zones. In 87 zones only one MAP location was appointed (in 62 zones two or more MAP locations were chosen). The MAP monitoring stations are spread all over the Flemish region. In urban areas there are no monitoring stations. In region ‘Central-Limburg’ surface water is less present, therefore the amount of locations is limited.

Every month each MAP station is monitored. Additionally, on an annual basis three samples are taken after or during spells of rain, because it is expected that the wash out of nitrate is maximal at these moments, thus leading to maximum concentrations of nitrate in surface water. This monitoring strategy is in accordance with the provisions of the Nitrates Directive.

The first sampling took place during July and August 1999. Beside the analysis of the nitrate concentration, there are also a few fysico-chemical parametres measured during the sampling, particularly dissolved oxygen, the pH, the conductivity and the water temperature. Chlorophyll and phosphate concentrations are not determined.
After validation and confirmation all data are filed in the Flemish Environment Database, where they are publicly accessible (website www.vmm.be).

In July 2002 the VMM was ordered to expand its MAP monitoring network up to 800 monitoring stations by the Flemish government. Thus more detailed information will be available in the future when reviewing the designation of vulnerable zones.

From 2003 onwards, the designation of vulnerable zones will be reviewed every year. According to the Nitrates Directive this review must be executed at least every 4 years, but a higher frequency is allowed. At the end of 2003 there will be a review on the basis of the monitoring results in the evaluation period November 2002 – October 2003.

In the second half of 2002 the VMM presented a list of suitable locations which meet the monitoring criteria to the agricultural organisations for comment. These comments were taken into consideration, before the VMM began the exploitation of this extended MAP-network, which comprises almost 800 monitoring stations today. The first sampling took place in November 2002.

2.2.2 Groundwater

Special Nitrate Monitoring Network

The density of wells to be installed in arable land is related to the expected vulnerability of so called hydrogeologically homogeneous zones (HHZ). A HHZ has to been seen as an area where sediment layers with special characteristics form the shallow phreatic aquifer. The boundary conditions for the occurrence of nitrate and nitrate removal are comparable for the whole HHZ. Originally there were 26 HHZ's. Later, some of them were split in a hilly and a flat part, due to expected differences in groundwater flow and advective transport. Now there are 33 different HHZ's (see Fig. 4). Based on the hydraulic conductivity, the hydraulic gradient and the thickness of the unsaturated area, the oxidation status of the sediment during deposition, the thickness of the water saturated oxidation zone of the aquifer and the absence of reducing compounds, a weight between 3 and 17 has been given to the different HHZ's (see also Table 16). The evaluation is based on geological maps, soil association maps, drilling descriptions, water sampling and different research projects as well as research literature related to near-surface groundwater. Higher weight indicates a higher vulnerability of the HHZ. The number of wells to be installed is in direct relation to the weight. There will be one well:
a) per 200 ha arable land in the most vulnerable zones;
b) per 1133 ha arable land in the less vulnerable ones.

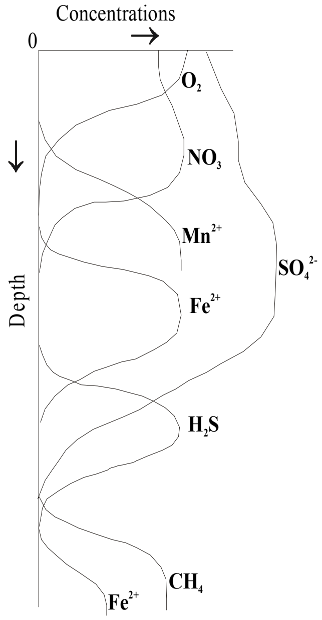
The aim of this distribution is to protect the most endangered zones in a better way. The absolute number of wells per HHZ is related to the surface of arable land per HHZ and not to the surface of the HHZ itself (see Table 17). The choice of the well locations and the depth of filters is related to the network purpose.

Well locations

The following boundary conditions are given for the choice of well locations:
a) located in arable land;
b) in a distance of minimum 100 m downstream of houses, farms and industry;
c) in a distance of minimum five times the width of running surface water;
d) in a distance of minimum 100 m downstream of nature reserves and forests;
e) in a distance of minimum 100 m downstream of manure and waste disposals;
f) easily accessible to drilling companies and laboratories;
g) in a distance of minimum 100 m of watersheds and border zones between different HHZ's.

<u>Well construction</u>

The installation of filters in a depth where nitrate pollution potentially can occur, is a basic requirement for the observation of nitrate contamination in groundwater. The filters for the direct measurement of nitrate concentrations must be located in the oxidation zone of the endangered shallow aquifer system belonging to the investigated HHZ. Only here nitrate is stable, due to the presence of sufficient oxygen inhibiting the reduction of nitrate by anaerobe micro-organisms (see Fig. 5 modified after Berner (1981)).



Environment			Processes
Oxic			Aerobic oxidation of organic matter Forming of iron hydroxides Oxidation of sulphides (pyrite) Dissolution of $CaCO_3$
Anoxic	Post-oxic	Nitric	1. Denitrification by organic matter 2. Nitrate reduction by pyrite oxidation 3. Nitrate reduction by Fe^{2+} 4. Dissolution of $CaCO_3$
		Mn + Fe	1. Reduction of manganese oxides 2. Reduction of iron hydroxides and oxides 3. Forming of carbonates (e.g. siderite)
	Sulphidic		1. Reduction of sulphate 2. Forming of sulphide minerals 3. Forming of carbonates ($CaCO_3$)
	Methanic		1. Forming of CH_4 2. Forming of NH_4^+

Fig. 5 The sequence of reduction processes (modified after Berner, 1981).

The majority of the wells will consist of three filters with a length between 0.5 and 1 m:

a) the shallowest one in the first oxidised metres below the water table, to follow the recent evolution of groundwater quality;
b) the second one at the base of the oxidation zone, to see the historical evolution and to check the general vulnerability of the sediments indicated by the real contamination depth (total quantity of polluted water);
c) the deepest one in the first two metres of reduced sediment, to measure background values or by fast water replacement the change of ion composition in groundwater due to nitrate reduction.

More than 95% of Flanders is covered by phreatic aquifers consisting of quaternary and tertiary soft rocks (sediments). The water transport is regulated by pore spaces, so that oxidation and reduction zones are easier to distinguish than in hard rocks.

However a local change of the redox zones in an aquifer can lead to an adaptation of this general well construction, Total amount of filters and the depth of installation will be evaluated per location by the present geologist.

Table 16 Hydrogeologically homogeneous zones (HHZ), characteristics and number of well locations.

HHZ	Agricultural area	% total agricultural area	Weight*	Number of well locations	Number of well locations per km²	ha per well location
00	469,699,468	6.86	3	41	0,09	1133
10	7,762,337	0.11	14	3	0,41	243
21	1,382,933,732	20.19	10	407	0,29	340
22	168,251,586	2.46	17	84	0,50	200
23	263,938,353	3.85	17	132	0,50	200
32	925,696,236	13.52	7	191	0,21	486
33	195,420,910	2.85	7	40	0,21	486
34	160,036,142	2.34	7	33	0,21	486
35	183,657,984	2.68	7	38	0,21	486
40	361,857,884	5.28	12	128	0,35	283
51	138,088,507	2.02	8	32	0,24	425
52	46,746,246	0.68	12	16	0,35	283
61	78,725,240	1.15	7	16	0,21	486
62kas	89,764,103	1.31	13	34	0,38	262
62kat	53,648,763	0.78	8	13	0,24	425
63	157,376,318	2.30	12	56	0,35	283
63h	184,022,685	2.69	17	92	0,50	200
64ber	70,874,352	1.03	8	17	0,24	425
64bol	23,138,408	0.34	11	7	0,32	309
71	18,281,315	0.27	9	5	0,26	378
71h	58,027,049	0.85	16	27	0,47	213
72	422,964,575	6.18	11	137	0,32	309
73	143,986,255	2.10	10	42	0,29	340
73h	236,396,441	3.45	15	104	0,44	227
74	152,119,371	2.22	10	45	0,29	340
74h	434,387,089	6.34	15	192	0,44	227
75	22,771,170	0.33	10	7	0,29	340
75h	180,626,263	2.64	15	80	0,44	227
76	108,814,335	1.59	14	45	0,41	243
77	26,933,314	0.39	13	10	0,38	262
78	29,098,774	0.42	10	9	0,29	340
82	50,158,123	0.73	16	24	0,47	213
90	3,105,832	0.05	10	1	0,29	340
Total	6,849,309,158	100.00		2107	average	347

* Weight: higher weight indicates a higher vulnerability of the HHZ to nitrate leaching, see previous text.

The water division of the AMINAL is responsible for the implementation, administration and adaptation of the Nitrate Monitoring Network. The data collection and storage (sediment and water samples) is also a task of the water division. Nevertheless, external laboratories execute the water analyses.

The Nitrate Monitoring Network is already adapted to its special purpose because of the choice of the locations and the positioning of filters inside the aquifers. The chemical analysis of the groundwater is following a standard procedure. On every filter has to be pumped till stable conductivity values can be measured to be sure to get water directly from the aquifer, not effected from the bore hole zone. Next to the fysico-chemical parametres as pH, redox-potential, conductivity and temperature, also the oxygen and total organic concentrations (TOC) in groundwater have to be measured. Furthermore all mains-ions including all nitrogen compounds will be measured to be able to make complete ionic balances and to ensure the quality of the analyses.

In the scope of the requested transparency to the public all water analyses made per filter will be linked to the sampled network location, and will be available to everybody on the internet site http://DOV.vlaanderen.be.

2.3 Data interpretation

2.3.1 Surface water

In areas characterised by manure surpluses nitrate concentration exceeds often 50 mg l^{-1} (NO_3), especially during winter months with peak concentrations around New Year. Therefore it makes more sense to evaluate winters instead of calendar years.

The testing criterium in Table 17 is the 50 mg NO_3 l^{-1} standard of the Nitrates Directive and the Manure Action Plan (MAP). The percentage of the MAP locations where the nitrate concentration in surface water exceeded at least one time the 50 mg l^{-1} limit in the considered period is shown. A trend of a significant improvement is being set.

Table 17 Percentage of the MAP locations where the nitrate concentration exceeded at least one time the 50 mg l^{-1} standard in the considered period.

	Basin	July 1999 – June2000	July 2000 – June 2001	July 2001 – June 2002	July 2002 – March 2003
1	Yzer	74%	74%	69%	47%
2	Polders of Bruges	56%	52%	46%	25%
3	Canals around Ghent	70%	52%	24%	30%
4	Lower-Scheldt	58%	8%	17%	0%
5	Leie	90%	86%	71%	64%
6	Upper-Scheldt	62%	58%	50%	35%
7	Dender	11%	0%	10%	0%
8	Dijle Zenne	33%	31%	33%	12%
9	Demer	40%	33%	26%	10%
10	Nete	29%	18%	5%	4%
11	Meuse	75%	58%	49%	33%
	Flanders	59%	49%	41%	29%

The comparison of the percentages is indicative, because the compared periods are related to a slightly different MAP network: a few monitoring points were deleted and others added. The data illustrate the global improvement of the situation. In spite of this positive evolution, the nitrate pollution stays problematical, especially in the western part of Flanders (basins of Yzer and Leie).

The monitoring results show that:

- the extent of the nitrate pollution of Flemish surface water caused by the agricultural sector remains important and problematical;
- even in the catchment area of some drinking water production centres several monitoring stations are characterised by the presence of very high nitrate concentrations;

- the situation differs significantly from region to region; and the link with intensive cattle breeding and horticulture is very obvious.

Evolution of the mean monthly nitrate concentrations

There is a downward trend of the mean monthly concentration of nitrate per litre from January 1999 to the early months of 2003. The figure (Fig. 6) shows that the mean concentration of nitrate at MAP network stations is almost always higher compared with the mean concentration for all monitoring stations in Flanders (MAP stations included).

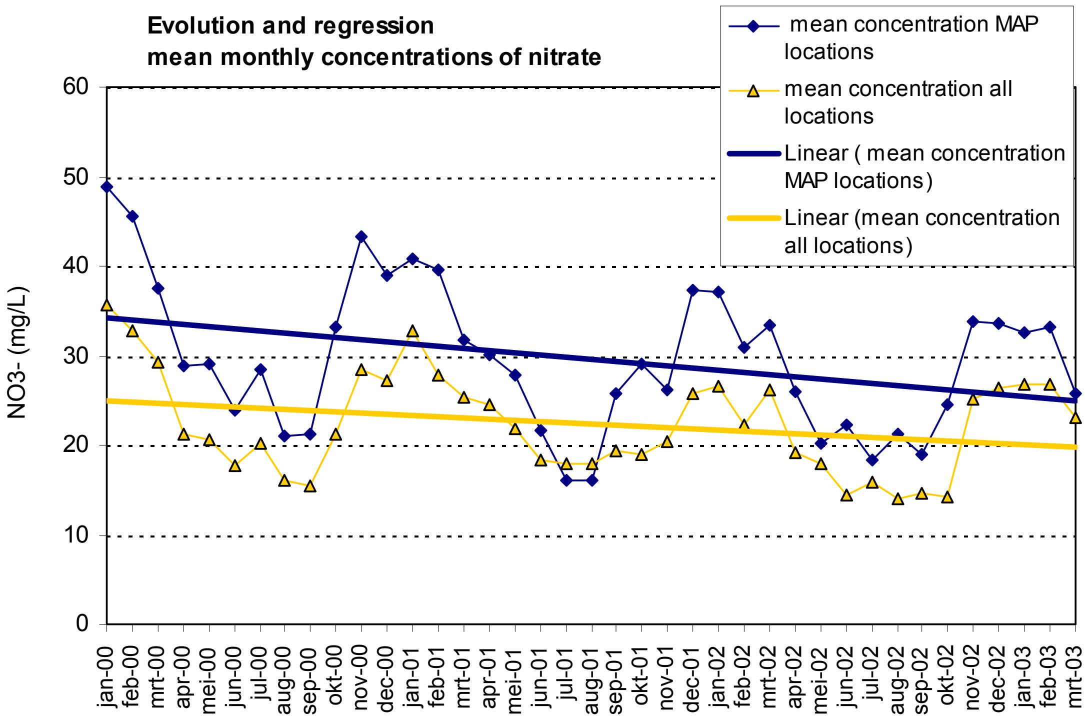


Fig. 6 Evolution concerning the vulnerable zones.

For the first time the mean nitrate concentration was lower in the MAP stations than in the global network during the summer of 2001. The trend of the regression lines shows that the improvement is significantly higher for the MAP stations in comparison with the whole monitoring network.

The evolution of the nitrate concentration in the monitoring stations in the present vulnerable zones was also compared with the evolution in the whole region of Flanders, for the MAP locations as well as for all monitoring locations. The comparison of the regression lines shows that the improvement of the nitrate concentrations in the present vulnerable zones is not more important then in the whole region of Flanders.

2.3.2 Groundwater

For the designation of vulnerable zones an overlay has been made between the HHZ zones and the hydrographic zones or sub-basins of Flanders (VHA-zones) (see Fig. 7). This leads to the creation of around 1000 different evaluation units (sub-zones). All parts of the same HHZ inside one sub-basin form one evaluation unit, which can be designated as Nitrate Vulnerable Zone. The sub-basins are considered to be separated zones for the water recharge to the phreatic water saturated area in of one HHZ, so that the overlay is acceptable for the creation of subdivisions.

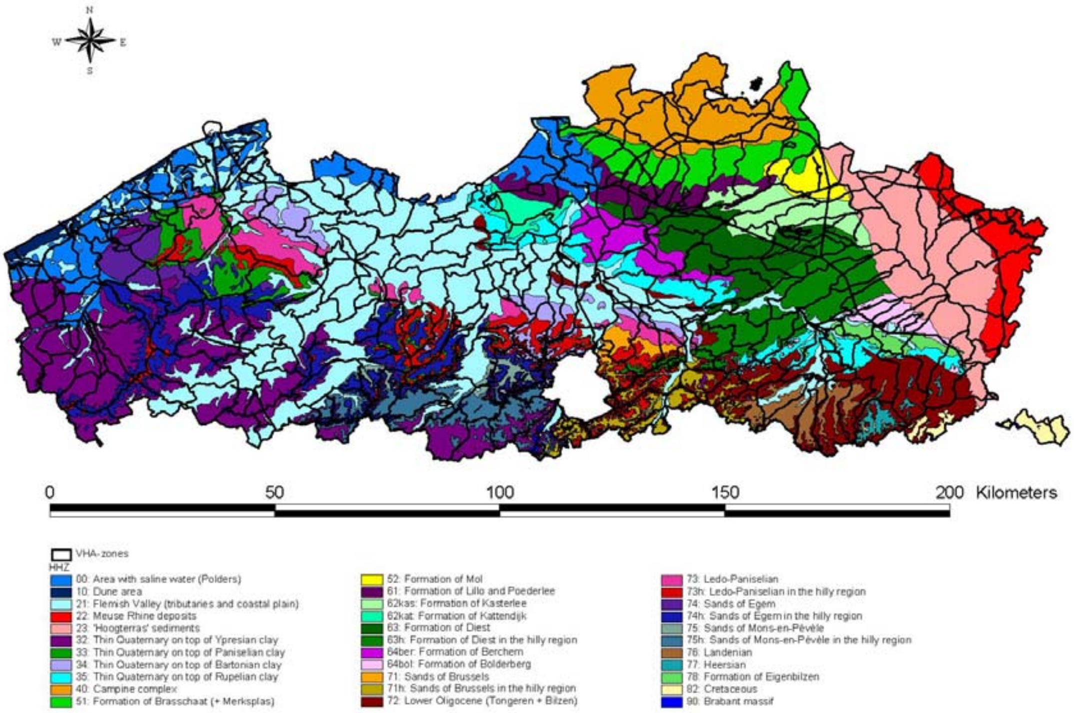


Fig. 7 Overlay between HHZ-zones and sub-basins in Flanders.

The evolution of the groundwater quality due to the effects of agricultural adaptation in the scope of the Fertiliser Decree can be followed because of

a) the type of well installations (vertical profiles);
b) the measurement of the change of the groundwater quality:
   - four times per year in the zones expected to be most vulnerable and
   - twice per year in all other zones;
c) knowledge of the general flow direction, the crops planted in the capture zone of the well and the use of fertilisers.

The evaluation of every single sub-zone is based on the results of the analyses of all wells in the same zone during one year. Exceeding of the limit of 50 mg NO_3 l^{-1} in between this period will lead to the designation of the zone as a vulnerable area. A decrease of the concentrations below the limit in a zone that was designated earlier as a vulnerable area can lead to a removal of this status.

a) In case of systematically measured nitrate concentrations exceeding the groundwater limit unless restrictions in fertilisation of the surrounding arable land, the following actions and conclusions have to be taken:
   - the limitation is insufficient and has to be, next to crops and soil conditions, also put into direct relation to the vulnerability of the aquifer sediments (HHZ's);
   - the zone should be made permanently vulnerable due to the existing physical boundary conditions;
   - the limitation of fertilisers is not respected;

- a detailed research of the groundwater flow conditions by modelling can be executed to determine the origin and the age of the contamination in case the problem is related to historical pollution;
- to analyse the biodegradation capacity of the sediment (HHZ) towards nitrate. Is there a natural heterogeneity of the HHZ leading to different observations?

b) In case the nitrate concentrations are clearly below the limit of the directive and there is no sign of deterioration or the concentrations are even decreasing:
   - a derogation for crops with limited nitrate loss is possible, the increase of the use of fertilisers has to be followed in detail to avoid deterioration of groundwater quality.

By decision of the Flemish government of 18/12/2002, the evaluation of the results of the special nitrate monitoring network of groundwater in the scope of the Nitrates Directive and the designation of the vulnerable zones will take place in three steps:

a) Till the end of 2003 the 'most vulnerable' areas already designated in 1995 and 2002 will be evaluated without additional research, just based on the water analyses inside this areas. The designation of vulnerable zones will come into force by the first of January 2004. Only the HHZ's of the Meuse-Rhine deposits, the Cretaceous aquifer and the Sands of Brussels in the hilly region are supposed to be most vulnerable.
b) Till the end of 2004 the vulnerable areas will be evaluated. In case of doubts due to the homogeneity of HHZ's and the groundwater flow conditions, additional research will be executed. The designation of vulnerable zones will come into force by the first of January 2005. The vulnerable zones are the HHZ of the "Hoogterras" sediments and all sandy HHZ's in the hilly regions in the south of Flanders.
c) All other zones will be evaluated till the end of 2005. The designation of vulnerable zones will come into force by the first of January 2006.

3. DISCUSSION

3.1 Surface waters

The basic principles for the final designation of vulnerable zones in 2002 were:

- the judgement of the situation per hydrographic zone, the smallest entity which the integral water management takes into account at the moment;
- aggregated data related to all monitoring locations inside a hydrographic zone, were tested to the criteria described before. Data on high concentrations which are due to the impact of non-agricultural nitrate sources were not hold back;
- the evaluation took place on the basis of the monitoring results from the period November 2000 - February 2002.

The legal designation of the vulnerable zones took place by decision of the Flemish government (14 June 2002). In spite of the stringent criteria which are used for the selection of MAP monitoring stations on the one hand, and the spatial chaos in the Flemish region on the other hand (a lot of built-up areas and industrial sites), the surface of the area that drains to a MAP monitoring station is often limited to some tens of hectares. The representativeness of the results for a whole catchment area is sometimes doubtful.

An other potential problem is the analytical fault on the nitrate analysis (about 5%), when the measured concentration exceeds the critical standard of 50 and 75 mg NO_3 per litre for only a few milligrams.

3.2 Groundwater

The first monitoring campaign on the new groundwater-monitoring network has started in spring 2003. Results were not available at the time the workshop took place.

There is a discussion about the heterogeneity of some HHZ's. In case of unexpected deviations by the spread of nitrates in groundwater, an additional analysis of the homogeneity of a HHZ by measuring the total reduction capacity of the sediments will be executed. However, the impact of a possible natural heterogeneity of one HHZ will be of minor importance, because of the creation of quite small evaluation units (sub-zones).

On some locations there will be a discussion about the origin of the contamination, in case of measured nitrate concentrations exceeding the limit. The travel times of the groundwater and the advective transport lead to doubts about the age of the contamination and if the measured concentrations reflect the recent adaptation of the fertilisation procedures due to the Fertiliser Decree. In case there are uncertainties about the vulnerability of some aquifers (or sub-units) a research could be done about the origin of the nitrates by groundwater flow modelling and age determination of the pumped water.

Another problem could be the bordering of the sub-zone, that has to be designated as vulnerable area. The natural borders of the HHZ's (mainly sediment layers) and the watersheds do not fit with the borders of the agricultural parcels. It has to be chosen for administrative (parcel) borders, probably depending on the percentage of the field belonging to the designated sub-zone. Furthermore not all natural border lines are perfectly mapped, so there could be a difference between mapped and real world situation.

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Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Walloon Region (Belgium)

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Abstract Wallonia (the Walloon Region of Belgium) has implemented the Nitrates Directive by designating four vulnerable zones (15% of the territory) and introducing an Action programme at the start of November 2002. The Action programme entails various means of reducing the risks of the pollution of water by nitrate: (a) struggle against nitrate losses in fields using a range of good agricultural practices, including certain restrictions on the use of fertilisers (quantities, time periods, soil conditions, etcetera), (b) keeping a balance on each farm between the organic nitrogen produced and utilisation capacities on agricultural land, (c) adapting storehouses for livestock effluent to a capacity of 6 months and perfect watertightness, and (d) promoting transfers of livestock effluent between farms in excess and farms which still have a way of using it on their land. In Wallonia, nitrate-related problems are obvious in several groundwater bodies and the development over the past 30 years is worrying. In general, the average pollution level is of agricultural origin. On the other hand, the pollution peaks observed in several places come often from domestic sewage. The aims of the measures taken within the framework of the Nitrates Directive are therefore above all to contain the nitrogen pressure from agriculture within sustainable limits and to remove point source pollution at the scale of large hydrographic basins. For more local cases, additional legislation deals specifically with the direct protection of water catchments against nitrate and also all other potential pollutants.

1. INTRODUCTION

1.1 General

The geology and land use of the Walloon territory is varied for such a small area. All agriculture is intensive there, but significant differences exist between the regions and between farms in the same region.

Overall, the nitrate concentration in groundwater is far below 50 mg l^{-1}. In vulnerable aquifers, concentrations above 50 mg NO_3 l^{-1} appear in less than 10% of the monitored sites. However, the trend is worrying. Surface water eutrophication is only present in some much-localised situations. The nitrogen pollution observed comes rather from isolated poor agricultural practices and not from a structural surplus at regional level. It is also sometimes due to discharges of domestic wastewater.

The programme to combat nitrate of agricultural origin is therefore mainly focused on prevention, with a view to the sustainable management of nitrogen in agriculture. There are four vulnerable zones (designated in 1994 and 2002), a code of good agricultural practices and one single action programme for these four zones. The measures provided for in this unique programme are designed to meet the need to limit isolated and/or temporary cases of waste discharge, while limiting spreading to under 170 kg of organic nitrogen per ha on average on the territory as a whole.

Preliminary scientific studies have not proven that it was necessary to take account of the specificities of each vulnerable zone in this first action programme. A total of 26 pilot sites are spread over each zone in order to check the effects of the action programme and to adapt it to each zone if necessary. The action programme started off in October 2002; it is developed on three complementary levels: the field, the farm and the Walloon Region.

In the field, the objectives are to limit nitrate leaching in winter and to prevent losses by leaking. The farmer must respect a number of good agricultural practices, particularly time periods for spreading manure and slurry, maximum doses of organic and mineral nitrogen per crop and per year, distances in relation to waterways, storage conditions for field manure, etcetera.

At farm level, the objective is to limit the pressure of organic nitrogen on agricultural land and to fight against point source pollution. The farmer must make sure to always take a soil-based approach, i.e. respect the balance between the organic nitrogen to be spread (coming from the herd or from the importation of matter) and the total spreading capacity on crops and pastures (calculated by multiplying the surface areas by maximum permissible levels according to the zones). A limited derogation may be granted if the farmer undertakes to follow a “Quality Approach” with very close surveillance and the implementation of specific techniques proving his control of nitrogen. Again at farm level, the farmers must be sure to have a sufficient watertight storage capacity for manure, slurry and other silage effluent.

Finally, on the scale of Wallonia, the objective is to optimise the utilisation of organic fertilisers between farms. The action programme promotes transfers of livestock effluent between farms in surplus and those with low organic amounts.

1.2 Description of natural factors influencing nitrate occurrence

The climate of the Walloon Region comes under the Atlantic temperate climate. Annual rainfall amounts to 15,000 million m³ (887 mm year^{-1}), 550 (33 mm year^{-1}) of which refill the subsoil water, 7950 (470 mm year^{-1}) sustain the surface waters, and 6500 (384 mm year^{-1}) are reabsorbed into the atmosphere by evapotranspiration. Several differences can be observed between sub-regions (Fig. 1). For all sub-regions, the refilling of the groundwater layers mainly takes place between October and March.

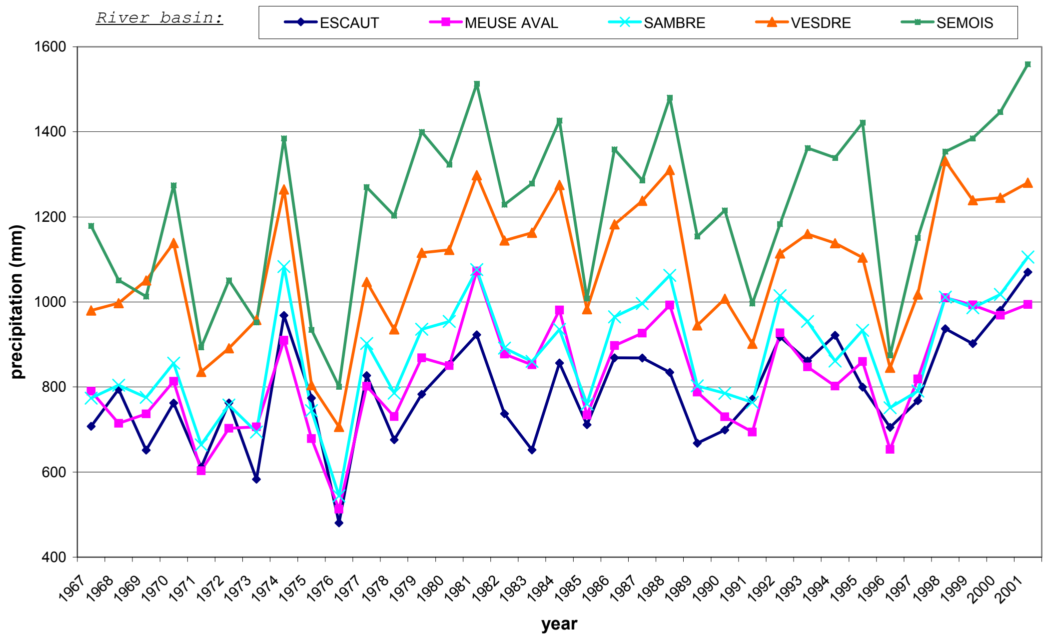

Fig. 1 Average annual precipitation (mm) of some stations in the Walloon region in the 1967-2001 period.

The geology and the soil types are rather varied: more than 60 associations of different soils are listed over the 17,000 km² of Wallonia, from deep sandy silt soils to very superficial clay-like, stony soils. When crossing the Region from the north to the south, one first sees wide agricultural plains with many crops and little pastureland, followed by a landscape of small valleys in which crops, pastures and forests alternate, ending finally in the high Ardennes plateau that is mainly covered by forest and pastureland, with deeper valleys. Within these large zones, a distinction can be made between eight to ten agricultural regions with homogenous soil, climatic and ecological characteristics.

In the subsoil, several types of aquifers are to be found (from north to south and from west to east – see also the corresponding colours on Fig. 6):

- the sands of the Yperian-Thanetian, of the Brusselian and the Landenian (yellow);
- the chalk of Mons, Brabant, Hesbaye and Pays de Herve regions (green);
- the limestone of the Tournaisis, of the central part of the Namur synclinorium, of the Dinant synclinorium and the Vesdre mounts (blue);
- the shales and sandstone aquifer in the Dinant synclinorium and in the Ardenne mounts (grey);
- the Jurassic sands and sandstone in the south of the Luxembourg province (pink);
- the gravels of the Meuse and other alluvia in the large valleys (orange).

The most used groundwater bodies are situated in the unconsolidated strata and the coherent rocks of the north and the centre of Wallonia. Overall, these reservoirs are situated deep in the ground and are covered by loams or sands. The nitrogen transfer times measured and modelled between the surface and the aquifer amount to 5 to 15 years according to the place.

In the more superficial aquifers, which are less used for drinking water production, the transfer times scarcely exceed 3 years.

1.3 Description of human factors influencing nitrate occurrence

Global information on land use

The 10 agricultural regions of Wallonia are characterised by pedological and climatic parameters (Fig. 2); two categories of regions can be distinguished:

- regions used for pastureland and fodder crops: the Ardennes, Famenne, the grassland region of Liège, the Jurassic region, the Haute Ardenne and the grassland region of Fagnes (pastureland represents between 70% and 90% of the agricultural area);
- regions used for cereals and industrial crops (sugar beet and potatoes): the silt region, the Condroz and the sandy silt region.

In the regions used for pastureland, forests take up an average of over 50% of the total area.

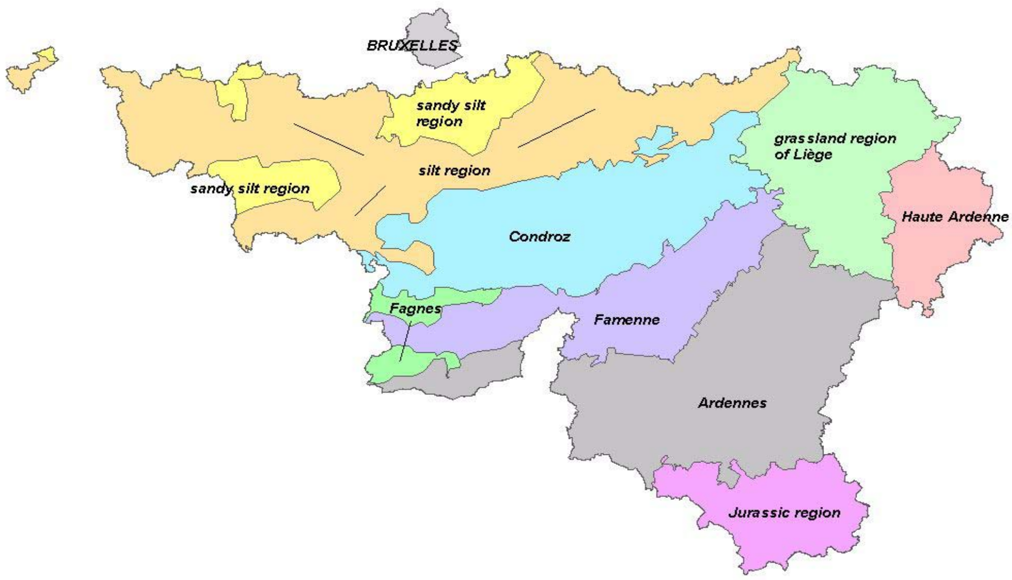

Fig. 2 Map of the agricultural areas in the Walloon Region.

Main crops (year 2000, unless otherwise indicated)

The utilised agricultural area (UAA) in the Walloon Region is 757,000 ha, that means 45% of the territory. Forests cover 32% of the territory. The rest is occupied by settlement areas, economic activity zones and road infrastructure. The UAA comprises 50% pastureland and 50% arable land, see Table 1 (MRW–CSWAAA, 2000). Between 1985 and 2000, the UAA decreased by 1.7%. It reached a minimum level in 1992, and has since undergone a slight increase.

Table 1 Surface area (ha), percentage of utilised agricultural area and development of the area between 1985 and 2000 (%) for the main commodities in the Walloon Region.

		Surface area (ha)	UAA (%)	Development 1985-2000 (%)
Pastureland		378859	50.1	- 3.2
	Permanent pasture	326075	43.1	- 15.4
	Temporary pasture	52785	7.0	+ 795.4
Fodder crops		55612	7.3	+ 14.8
	Silage maize	52295	6.7	+ 23.4
Main crops				
	Cereals	183675	24.3	- 16.9
	Sugar beet	56900	7.5	- 25.3
	Inulin chicory	11700	1.5	+ 8257.1
	Textile flax	8658	1.1	+ 64.5
	Rapeseed	4520	0.6	+ 89.4
	Potatoes	21527	2.8	+ 131.7
Horticulture				
	Vegetable crops	9898	1.3	+ 15.1
	Fruit crops	1438	0.2	+ 47.5
Fallow		17086	2.3	+ 7393.9 (*)

Maize cultivated for silage represents more than 90% of the area used for fodder crops other than pastureland (52,000 ha). In the Walloon Region, irrigable land areas are very limited: 5513 ha in 1997, i.e. 0.7% of the UAA. However, irrigable areas have undergone some raise since 1985 (+444 ha). They concern vegetable field crops in rotation with agricultural crops in the sandy silt and silt regions (MRW–DGRNE et coll., 2000).

Characteristics of agriculture (agricultural practices)

In 2000, the Walloon Region had 21,000 farms, 66% of which were professional and 30% occasional producers. Between 1985 and 2000 the number of farms decreased by 37%. Consequently, between 1985 and 2000 the average farm size increased by 57%. In 2000, the average agricultural area of farms in the Walloon Region was 36 ha (MRW–CSWAAA, 2000).

In 1999, farms were mainly technically and economically orientated towards the dairy sector (20% of farms), the beef sector (19%) and arable crops (17%). Arable crop farms are mainly situated in the silt and sandy silt regions and in the Condroz. Dairy specialisation predominates in the Haute Ardenne and the grassland region of Liège. The farming of livestock for meat is above all practised in the Ardennes, in the Jurassic region, Fagne and Famenne. Seventy-five percent of farms in the Walloon Region (16,000) have cattle (Table 2). The number of cattle has been decreasing since 1996 (-4.5%) following the BSE crisis.

Table 2 Livestock in the Walloon Region: animal numbers, production of nitrogen and development between 1985 and 2000.

		Number of heads (x1000) and development (% between 1985 and 2000)		Number of heads ha^{-1}	Total production of organic nitrogen (tonnes of organic nitrogen year^{-1})	Percentage of organic nitrogen production
		number	%			
Cattle		1480	+ 1.8	1.96	81775	93.1
	Dairy cows	273	- 38.8	0.36		
	Suckler cows	336	+ 168.3	0.44		
Pigs		317	- 4.5	0.42	3726	4.2
Poultry					1409	1.6
	Laying hens	900	+ 28.6	1.19		
	Broilers	3000	+ 499.3	3.96		
Other (*)					952	1.1

(*) Other = Sheep (304,580 kg org. N year^{-1}) + Goats (41,783 kg org. N year^{-1}) + Equidae (horses) (585,536 kg org. N year^{-1}) + Ostriches (3,424 kg org. N year^{-1}) + Suckler rabbits (16,589 kg org. N year^{-1})

The Walloon Region has 7800 dairy farms, in other words 37% of the total number of farms. Since 1985, the number of dairy farms has fallen by 57%. Only 6% of farms have pigs, in comparison to 20% in 1985. In the pig production sector, 50% of farms have less than 50 pigs and 80% less than 400 pigs per farm. Poultry production has undergone significant development over the past few years (MRW–CSWAAA, 2000).

Total organic nitrogen production on farms in the Walloon region totals 88,000 tonnes. The cattle stock produces 93% of this quantity of organic nitrogen, pigs 4% and poultry 2% (Table 2). This annual production corresponds to 116 kg of organic nitrogen per ha of UAA. This average value disguises the disparities specific to agricultural regions dominated by certain commodities. The percentage of livestock fodder in intermediary consumption (fertilisers, energy, feeding stuffs, others) is 31%.

Production of effluent and use of fertilisers

In terms of volume and apart from direct pastureland recovery, two-third of organic fertilisation in Wallonia is in solid form (manure, compost) and one-third is in liquid form (liquid manure and slurry).

The average mineral nitrogenous fertilisation is presented (Table 3) for the main arable crops in different agricultural regions (information from Agricultural Economic Analysis Division of the Walloon Region - Ministère des Classes Moyennes et de l'Agriculture for 2001). These results consist of the arithmetical averages of the observations made over five consecutive financial years (1997-2001) on 2500 farms (horticulture not included).

Table 3 Mineral nitrogenous fertilisation (kg N ha^{-1}) of arable crops in different agricultural regions; averages for the 1997-2001 period.

Agricultural regions	Sugar beet	Potatoes	Wheat	Silage Maize	Temporary pasture	Permanent pasture
Sandy silt	145	184	180	149	235	142
Silt	156	165	178	144	314	160
Condroz	161	160	182	134	238	115
Liège grassland	137	(x)	157	100	126	113
Famenne + Fagnes	188	125	172	126	125	78
Ardennes + Jurassic	(x)	(x)	138	116	106	59
Haute Ardenne	(x)	(x)	(x)	22	(x)	126

(x) Missing data: no observation in the sample or insufficient observed area

For assessment purposes, the calculations based on the method described by the Association for Research on Nitrogen Indicators (ARIA) have been made on 89 farms (Lambert *et al.*, 2001) situated in the silt and sandy silt regions (Table 4).

Table 4 Annual nitrogen assessments for the main types of agricultural commodities (kg N ha^{-1}) in silt and sandy silt regions (plus/minus sign means standard deviation).

	Farm-gate balance	Surface balance
Crop + battery farming	219 ± 23	200 ± 36
Crop + dairy	225 ± 33	205 ± 41
Crop + dairy and meat	178 ± 32	153 ± 42
Crop + meat	113 ± 17	115 ± 24
Arable crops	63 ± 11	64 ± 10

1.4 Overview of monitoring networks

1.4.1 Monitoring for the identification of waters

Each year, the Walloon Region produces 400 million m³ of water for the public water supply. Of this, it exports around 150 million m³ to Brussels and Flanders. Eighty percent of this water comes from groundwater spread throughout the entire territory. There are 1600 water catchments (wells or springs) recorded, forming around 500 important production sites. The other 20%, produced from potentially potable surface waters, are located over the south of the region on nine water intake and treatment sites (five direct river intakes and four dam reservoirs).

If in addition to this we add the numerous bottled water producers and the agri-food industries supplied with drinking water from the aquifers, it is evident that groundwater is particularly valuable.

In the Walloon Region, all producers of potential drinking water are therefore first of all called upon to carry out a control of the water taken and to transmit the results to the Administration (DGRNE, Direction générale des Ressources naturelles et de l'Environnment –Directorate General for Natural Resources and the Environment – Water Division). In a large majority of cases (with the exception of water mixes or treatments that affect nitrogen concentrations), the analyses of distributed or bottled water (obligatory in accordance with the Directive on water for human consumption) are therefore likewise used to monitor nitrates. The range of parameters (NO_3 + NO_2 +

NH_4) is required to control possible cases of oxidation reduction caused in conveyances and during potabilization treatments (chlorination for example).

The DGRNE undertakes further monitoring in regions for which the data is insufficient, in aquifers (often superficial) that are scarcely used. Moreover, it of course manages the main part of the surface water monitoring.

1.4.2 Monitoring in vulnerable zones

In the Walloon Region, as far as water is concerned, there are no major differences between monitoring to identify vulnerable zones and monitoring to control them. Surveys of surface water are ongoing. For groundwater, the checks are more systematic and no derogations are granted to water producers for the implementation of analyses ($NO_3 + NO_2 + NH_4$).

However, concerning groundwater, the DGRNE sees to completing the network in the vulnerable zones in order to obtain sufficient coverage of the territory and the aquifers, particularly the superficial aquifers which are not used much by producers of potential drinking water.

This is for example how, in the eastern part of the vulnerable Brusselian sand zone (1260 km^2), remarkable springs are included in the network (equipped and accessible to the public, continual flow).

For the vulnerable zone of Hesbaye chalks (293 km^2), which has a relatively homogenous aquifer, the results transmitted by producers for 14 sites (in fact 21 catchments) are deemed to be insufficient.

For the small vulnerable zone of Comines-Warneton (61.4 km^2), sixteen traditional wells belonging to farmers or private persons have been exclusively chosen in agricultural areas or in rural settlements.

In order to survey the Berwinne and Gueule basins (200 km^2), east of Liège, where the land use is quite homogenous (mainly pastureland), a network of 32 points has been set up; this network, which is represented in Fig. 3, takes account of the complexity of the main aquifer of Cretaceous while ensuring good territorial coverage.

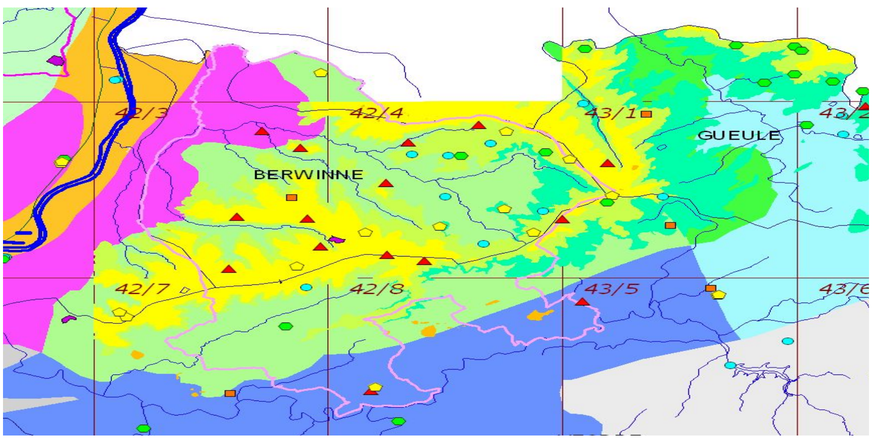

Fig. 3 Example of a surveillance network for the Berwinne and Gueule basins.

For the Brusselian sand (hydrogeologically homogenous aquifer but divided up by watersheds) and the vulnerable South Namur zone (composed of several adjoining aquifers with varying characteristics), a selection must be made from among the data transmitted because the survey sites are many and badly distributed. Apart from geographical frequency, the selection criteria are the volume of the water catchments, the need to measure the impact of diffuse, non-point source pollution and the presence of protected zones (Natura 2000 zones for instance, which are presented on www.natura2000.wallonie.be).

This selection of sites then makes it possible to calculate a rather robust average indicator that is part of the guidelines for monitoring the effectiveness of the Action programmes. The development of this indicator is represented in Fig. 4 for the three largest vulnerable zones (NVZ).

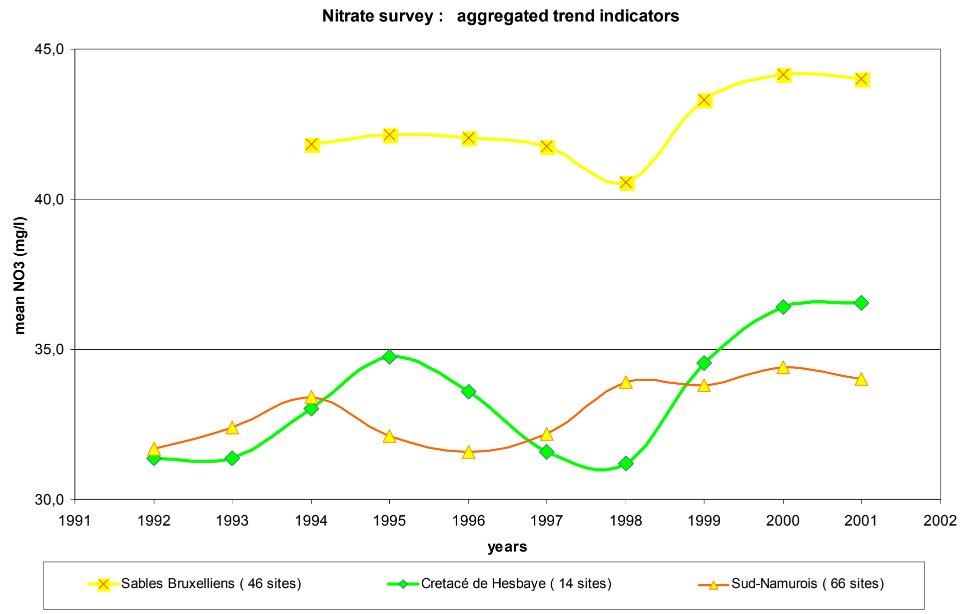

Fig. 4 Aggregated results from the nitrate survey for the three largest NVZ.

For the Crétacé de Hesbaye and, to a lesser extent, Brusselian sand, the unfavourable development observed in recent years is clearly related to the development of the aquifer level. The “Programme-Action Hesbaye” study (Dautrebande *et al*., 1996) has in fact clearly shown that the infiltration of nitrate is delayed in the silt cover and in the non-saturated chalk zone. Consequently, the effect of the action programmes cannot be measured directly in the water catchments and will take several years before becoming evident.

With regard to the surveillance of the groundwater, the justified particularity in the Walloon region of calling upon numerous producers of drinking water for nitrogen monitoring purposes allows to save substantial resources but brings problems of representativity for the sites measured in relation to agricultural pressure and of continuity in the transmitted results.

The administration, which is supported by the company Aquawal S.A. (the association of operators of the water cycle), manages this by issuing frequent reminders, using an electronic transfer file of entirely precise format, and by taking over the monitoring of abandoned and particularly well situated water catchments.

1.4.3 Monitoring of changes in agricultural practices

With regard to the changes in agricultural practices, several indicators have been established. Among these, the following indicators are measured each year for all of the farms in the Walloon Region, which are discussed in detail in § 2.2.4. :
a) the soil linkage rate of the farm;
b) the number of effluent exchanges between farms.

On farms that are involved in the Quality Approach (Q.A.), other indicators are also measured:
c) the application of environmentally friendly agricultural practices (winter soil coverage, grass strips, integrated fertilisation techniques, etcetera);
d) the nitrogen farm gate balance and surface balance;
e) the soil profiles of nitric nitrogen concentration, drawn up in the autumn on five parcels of land.

Finally, technical information meetings are organised regularly. The chosen indicator of access to the farmers' information is:
f) the rate of attendance at these meetings.

This annual monitoring makes it possible to estimate changes in agricultural practices. The effect of these changes could be estimated on the scale of the parcel thanks to the three indicators monitored on the farms involved in the Q.A.

2. EFFECT MONITORING

2.1 Strategy for effect monitoring

The Walloon Region bases its monitoring strategy on two aspects: the development of water quality, and the monitoring of the changes in farm management practice. Tendency indicators are established in order to analyse the improvement or worsening of nitrate pollution of agricultural origin.

The development of water quality is of course the ultimate measure of the efficacy of the Action programme. It is thus studied using the monitoring network of the DGRNE and the water production companies, and especially the nitrate survey. However, this measure in itself only reveals part of the efficacy because, on the one hand, nitrate pollution also comes from other sources (domestic wastewater) and on the other hand, there is often a delayed "response" of several years or decades between the surface and the groundwater.

The Action programme therefore provides a set of specific indicators for the monitoring of agricultural practices. Among these indicators, some are result-orientated and measure the effect of agricultural practices, such as the survey of agricultural soils, or deal with the nitrogen farm gate and surface balances. Other indicators are directed at the methods employed by farmers, such as the soil linkage rate of the farm and the surveillance of transfers of organic fertilisers between farms, or, in a different vein, the effective participation in technical information sessions organised by the supervisory services, see § 2.2.4.

2.2 Detailed technical description of networks used for effect monitoring

2.2.1 Groundwater

Since 1994 when the nitrate survey was made obligatory for producers of potential drinking water by the government, 88 companies have carried out 45,000 analyses of 1232 water catchments and communicated the results to the DGRNE (figures compiled on 1 January 2002).

The minimum control frequency is three analyses in the course of the year, but this increases depending on the volume produced according to annex IIb of Directive 80/778/EEC (European Consilium, 1980).

If nitrates exceed 25 mg NO_3 l^{-1}, the water producer is generally obliged to transmit results each year, except in the Ardenne region, where the agricultural pressure is low. The postponement of the survey every 8 years provided for by the Directive for levels below 25 mg NO_3 l^{-1} has only been granted for some mineral or thermal springs.

Moreover, the records of available data in water companies have been given to the Administration and the earliest analysis dates back to 1957, as revealed by the record of a well situated in Waremme in the Hesbaye chalks (Fig. 5).

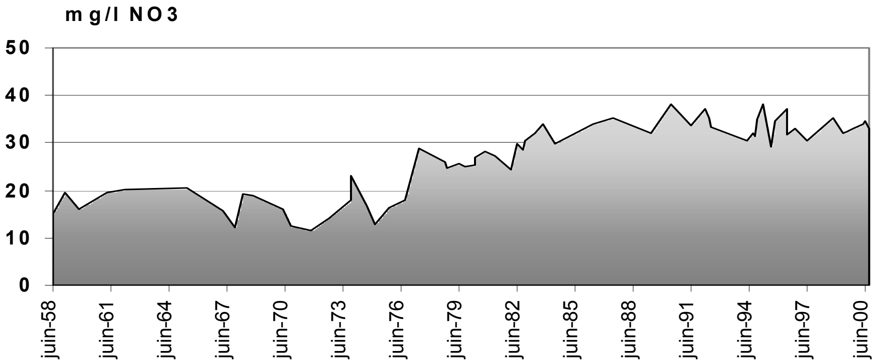

Fig. 5 Trend in the Hesbaye Chalk – Waremme catchment.

On its part, the DGRNE meticulously carried out between 1993 and 1995 a considerable nitrate survey on 491 springs and household or farm wells that were not used for the production of drinking water. These data are used as a basis for the selection of additional survey sites, particularly in the existing vulnerable zones and for few abstracted aquifers.

Thus, 29 sites situated in agricultural areas were taken for the cretaceous aquifer in Pays de Herve (East Wallonia) and 16 others for the Yperian-Thanetian sands of Mouscron-Comines (West). Two samples are taken from them each year.

The type of aquifer (phreatic/confined) and whether it holds a vulnerable or assimilated zone are indicated in Table 5 above. For phreatic aquifers, apart from the numerous springs and tunnels, the depths of the water catchments generally varied between 10 and 50 metres, with the aquifer level generally varying between 5 and 20 metres. In the more superficial aquifers, the piezometers used were generally active wells (in order to avoid pumping and to benefit from a preliminary homogenisation of the aquifer). Numerous traditional wells less than 5 meters in depth were discarded as far as possible during the sampling process, in order to avoid sub-surface flows and perched aquifers.

Table 5 number of sites regularly sampled grouped according to large water bodies (a total of 870, i.e. an average density of 1 site per 20 km^2).

Groundwater body	Typology	Including a vulnerable zone ?	Total sites	Mean NO_3 value (2001)
Superficial thanétian sands	Phreatic	Yes	16	57,5
Brusselian and landenian sands	Phreatic	Yes	86	44,9
Chalk of the Pays de Herve	Phreatic	Yes	32	39,5
Hesbaye chalk	Phreatic	Yes	21	34,2
Aquifers of the Vesdre mounts	Phreatic	Yes	11	30,9
Dinant shale-sandstone mounts	Phreatic	Yes	72	30,6
Dinant devonian limestone	Phreatic	Yes	35	29,9
Mons bassin chalk	Phreatic/Confined	No	49	27,4
Dinant carboniferous limestone	Phreatic	Yes	91	26,8
Meuse gravels	Phreatic	No	31	19,0
Brabant confined chalk	Confined	No	13	17,1
Brabant cambro-silurian platform	Confined	No	10	16,0
South Luxembourg jurassic aquifers	Phreatic/Confined	No	49	13,2
Ardenne platform and shale-sandstone mounts	Phreatic	No	279	10,9
Limestone of northern edge of Namur basin	Phreatic/Confined	No	61	10,7
Carboniferous limestone of Tournaisis	Confined	No	14	6,7
Total for Wallonia			870	

Figure 6 shows the distribution of the measured sites as far as groundwater is concerned. The next DGRNE investigations (survey in 2004) will deal in particular with the (agricultural) south of the Mons basin cretaceous aquifer (red points on the map).

Finally, it is pointed out that since 1994, around one hundred water catchments have been abandoned following restructuring of water production or qualitative problems (15 of which were due to excessive nitrate content and not only due to agricultural activities). For the most relevant of them (agricultural area, unconfined aquifer), monitoring was then taken over by the DGRNE with the agreement of the producer, so as to maintain surveillance and to continue with the observation of the tendencies on these particularly representative sites.

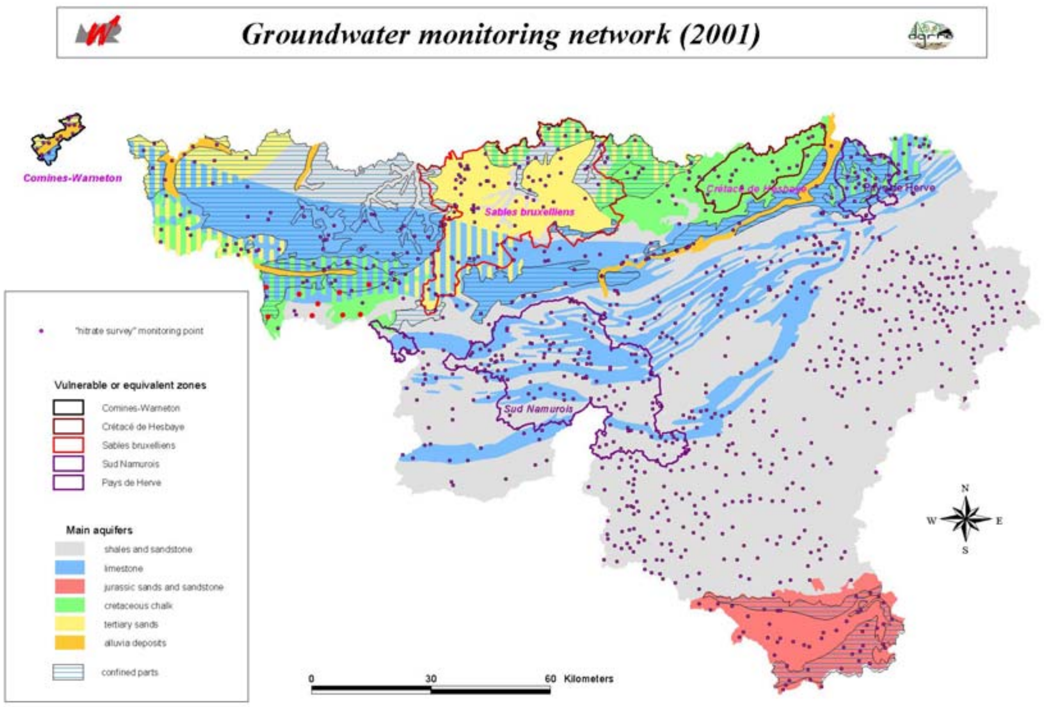

Fig. 6 The groundwater monitoring network, Nitrate Vulnerable Zones, and main aquifers in the Walloon Region.

2.2.2 Surface water

In the Walloon Region, the network for measuring the quality of the surface waters is managed by the DGRNE and, since 1993, the operational side has been entrusted as an assignment to the ISSeP (Institut Scientifique de Service Public - Scientific Institute of Public Service).

This permanent network is composed of 180 stations divided over all of the Walloon watersheds. In 2003, 160 points were sampled once a month and 20 points on a bimonthly basis. The stations controlled the most frequently are situated on the two rivers (the Meuse and the Escaut) and at the point of confluence of their main tributaries.

Nitrate and also nitrite and ammoniacal nitrogen are measured at all of the points in the network. At around 80 stations, all of the nitrogenous parameters are measured (Kjeldahl nitrogen, ammoniacal nitrogen, nitrite and nitrate) or calculated (organic nitrogen and total nitrogen).

The network –presented in Fig. 7– offers a spatial coverage of 1 point for 100 km^2 of territory.

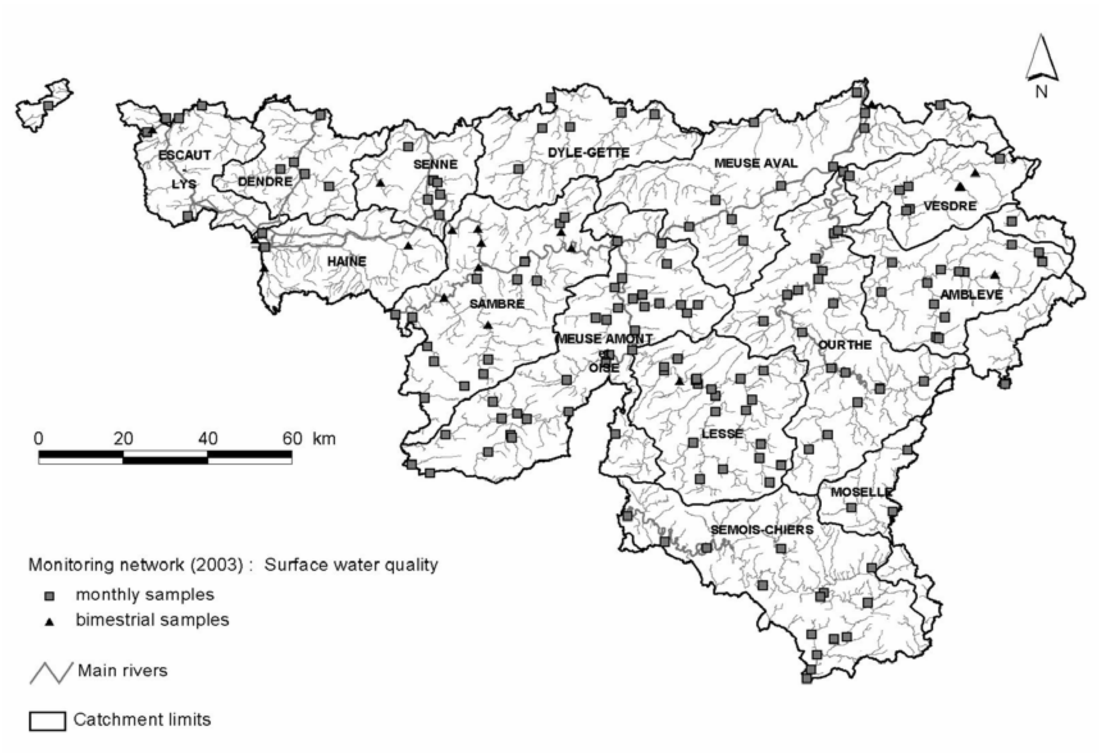

Fig. 7 The surface water monitoring network and catchments in the Walloon Region.

In the Walloon region, the upper lakes of the Haute Ardenne, generally located in natural areas or in zones subject to very low anthropogenic pressure, do not show contamination by nitrate, as demonstrated by the analyses transmitted by the water producers.

The intakes of potential drinking water in rivers, for example in the Meuse in Lustin or the Ourthe in Nisramont, are controlled at high annual frequencies. Figure 8 shows the monthly nitrate averages calculated for the Ourthe in Nisramont on the basis of daily samples.

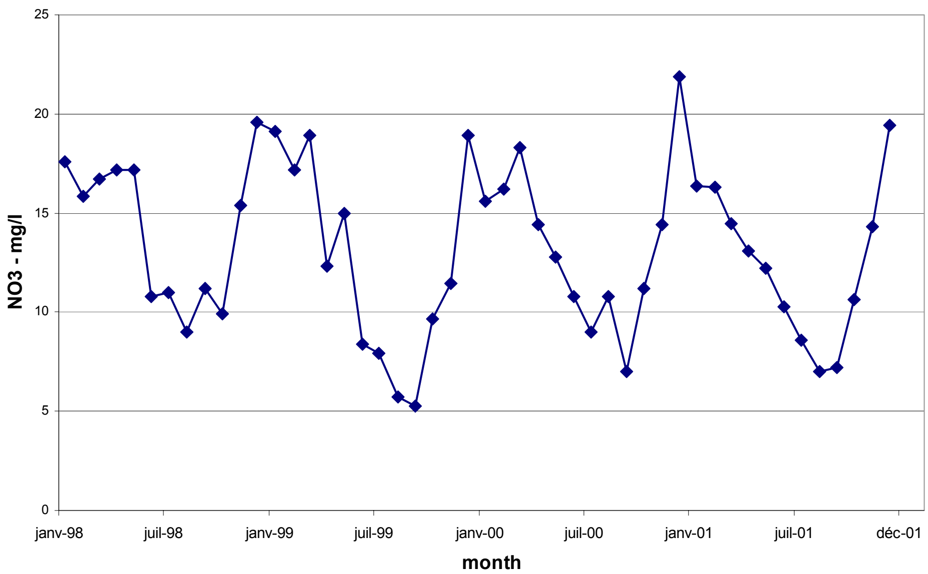

Fig. 8 NO_3 time series in the Nisramont reservoir (Ourthe River).

2.2.3 Eutrophication

The Walloon Region has only three lakes of over 1 km^2. In the largest, which is called Complexe des barrages de l'Eau d'Heure and with a total surface area of 5.9 km^2, significant eutrophication has been observed, with the development of cyan bacteria. A study has been planned to investigate the phenomenon and to pinpoint both its domestic and agricultural origin.

Most of the lakes in the Walloon region are bathing zones and are therefore monitored weekly during summer (microbiology and visual control).

The following relevant parameters are regularly measured on the quality measurement network for surface waters (rivers): NO_3, NH_4 and N-Kjeldahl, chlorophyll-a, P-total, O-PO_4, dissolved oxygen (daytime) and DBO5.

It is first of all important to calculate the loads emitted per watershed and particularly those exported to Flanders and the Netherlands, and thus towards the North Sea.

The limnigraph stations take daily measurements of the water flow rates close to the main sampling stations; Fig. 9 shows the amounts of NO_3, total-nitrogen and total-phosphorous estimated for the Dyle basin upstream from the Wavre urban sewage works station (area predominantly agricultural in nature and located in vulnerable zone). They are obviously conditioned by the rainfall intensity also measured by the IRM (Institut Royal Météorologique - Royal Meteorological Institute) in each basin, which has been particularly unfavourable in recent years.

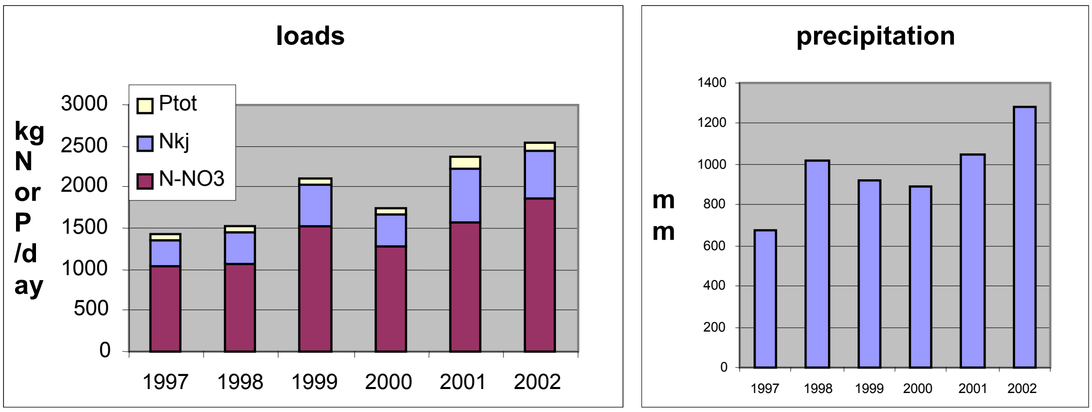

Fig. 9 N and P loads at the outlet of the Dyle River (left) versus rainfall (right).

With regard to actual eutrophication, the summer averages in chlorophyll-a confirm that the phenomenon is rather limited in waterways in the Walloon region (those affected are some canals and rivers deficient in oxygen, although their nitrate content is generally converted into ammonium).

Within the framework of the International Commission for the Protection of the Meuse, the nitrogenous, phosphorous and chlorophyll parameters are controlled two times a month between March and October at the two stations selected to survey eutrophication.

For phosphorous, an index varying between 0 and 100 (best quality) is calculated using the following quality grid (see Table 6, source: SEQ-EAU France, 1999) applied to the measured annual 90 percentiles.

Table 6 Eutrophication index for phosphorous matters.

Eutrophication level:	I	II	III	IV	V	Unit
SEQ-EAU index	>80	80-60	60-40	40-20	<20	
Ortho-phosphates	≤ 0.1	≤ 0.5	≤ 1	≤ 2	> 2	mg/l PO_4
Total phosphorous	≤ 0.05	≤ 0.2	≤ 0.5	≤ 1	> 1	mg/l P

This indicator of the alteration in “phosphorous matter”, in the same way as that concerning “nitrogenous matter” is strongly correlated to the “diatoma” indicators such as the IBD (Diatom Biological Index; AFNOR NF T 90-354 standard, 2000) or the IPS index (Pollution Sensitivity Indicator; Coste, 1982). These two biological indicators, based on the diatoma, which are unicellular microscopic algae belonging to the periphyton of the waterways, work together with chemical analyses and other bioindicators (benthic macroinvertebrates, etcetera) to allow a reliable estimation of the quality of the surface waters (in particular of eutrophication). The two maps of Fig. 10 provide a convincing demonstration of this (acknowledgements to Prof. J.P. Descy of FUNDP in Namur, and D.Wylock, attaché at DGRNE).

2.2.4 Agricultural practices

Several indicators have been developed to monitor the change in agricultural practices and its consequences on the nitrogen flows and residues in the soil in autumn. Three groups of actors are involved in the implementation of the Action Programme and in the follow-up of these indicators. These are:

a) the Directorate-General of Natural Resources and the Environment (DGRNE) of the Ministry of the Walloon Region (M.R.W.);
b) the Directorate-General of Agriculture (DGA) of the M.R.W;
c) Nitrawal.

Nitrawal is an association composed of 15 agricultural advisers supported by:

- the two agronomic universities (University Faculty of Agronomic Sciences of Gembloux and Université Catholique de Louvain-la-Neuve);
- the company of operators of the water cycle (Aquawal S.A.);
- a professional agricultural organisation (Fédération Wallonne de l’Agriculture - FWA).

Six indicators monitor the change in agricultural practices and its consequences; they are discussed in the following:

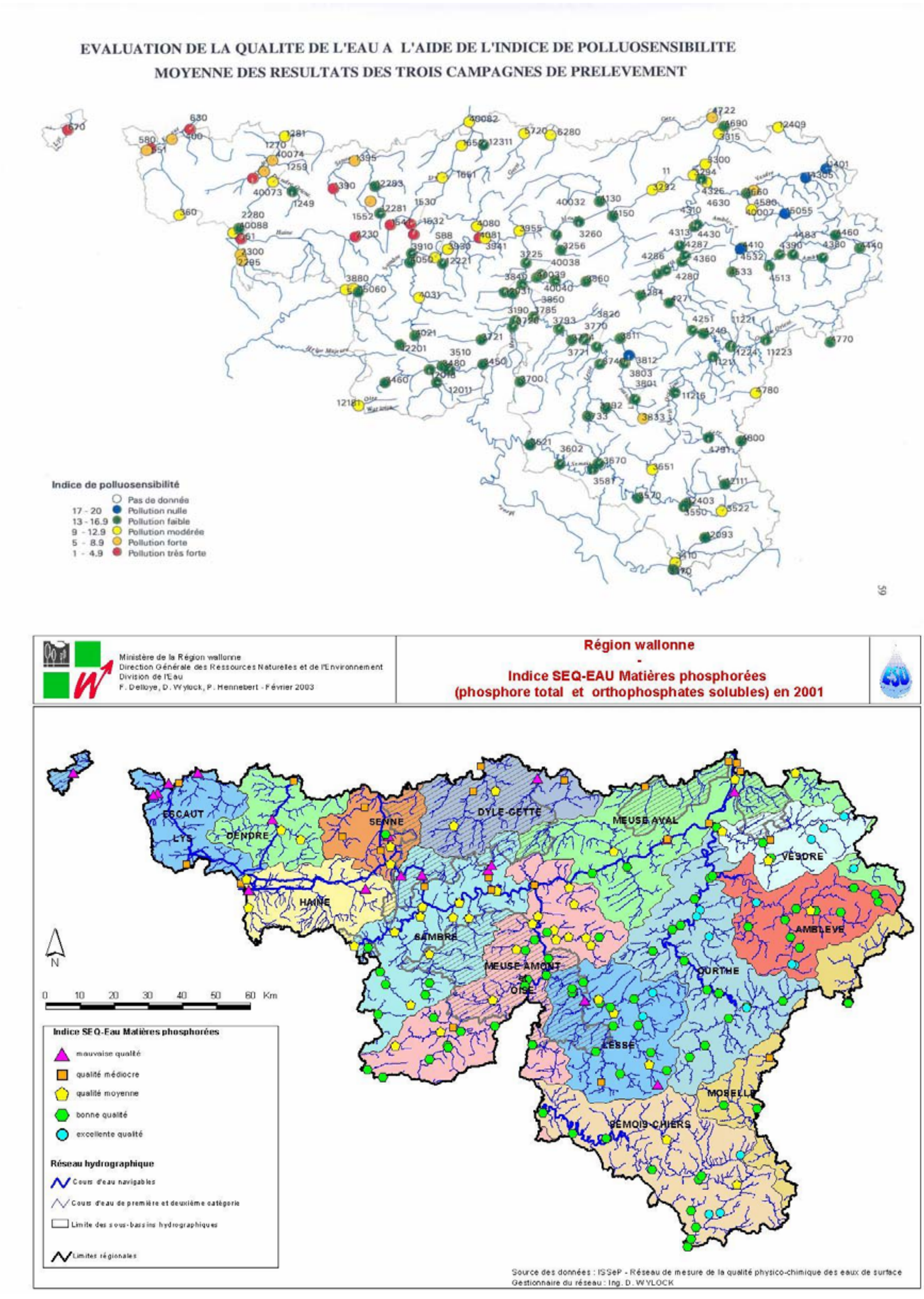

Fig. 10 Surface water network: comparison between the Diatom Biological Index (upper map) and the SEQEAU Phosphorus matter Index (lower map).

Indicator 1

The first indicator is the soil linkage rate (SL) of the farm. It is calculated annually by the DGRNE for each farm in the Walloon region:

An SL higher than 1 means, that the farm is considered to have an excess of nitrogen production in relation to its utilisation capacity.

The DGRNE and the DGA manage two databases that contain sufficient information for the calculation of the nitrogen quantity produced by the livestock on each farm (on the basis of nitrogen production standards per animal category) and the utilisation capacity for this nitrogen.

In the four vulnerable zones of the Walloon Region, the content of organic nitrogen cannot exceed 80 kg ha^{-1} annually on land under crops and 210 kg ha^{-1} on land under pasture. Outside these vulnerable zones, organic nitrogen content cannot exceed an annual amount of 120 kg ha^{-1} on land under crops and 210 kg ha^{-1} on land under pasture.

Year “1” of the implementation of the Action Programme in the Walloon Region is 2003. On the basis of the calculations carried out by the DGRNE, it appears that:
- 15% (3,000/20,000) of farms in Wallonia have an SL higher than 1;
- 1.5% (300/20,000) of farms in Wallonia have an SL higher than 2.

These percentages are also specifically measured in each vulnerable zone.

The farm with an SL above 1 has four possibilities of recovering a balance between production and the utilisation of its organic nitrogen:
a) reducing its organic nitrogen production by decreasing livestock numbers;
b) giving the excess amount of this organic nitrogen to another farm that can use it (cf. indicator 2);
c) boosting its utilisation capacity by increasing its manurable surface area or the proportion of pastureland under crop rotation;
d) becoming involved in the Q.A. (cf. indicators 3, 4, 5).

Indicator 2
The second indicator is the traceability of the effluent exchanges between farms, which relates to:
- the quantities of organic nitrogen transferred between farms;
- the number of contracts concluded.

The producer, whose farm has a SL value higher than 1 can also choose to take part in the Q.A. In this case, there is an upward change of the manuring rules to 130 kg of organic nitrogen per hectare and per year on cropland and to 250 kg of organic nitrogen per hectare and per year on pastureland.

A new SL value is calculated for their farm on the basis of these rules. If this value is still higher than the unit, they must establish effluent transfer contracts in parallel to the latter in order to bring their SL below the unit.

Indicator 3
On these Q.A. farms, the implementation dynamics for good agricultural practices constitute a third implementation indicator for the Action Programme.

The farmer will benefit from the support of Nitrawal to optimise actions in favour of controlling nitrogenous flows, such as:

- the reduction of the annual pasturage duty;
- the protection of waterways (reduction of access to waterways for livestock, the installation of off-ground drinking troughs, etcetera);
- integrated nitrogenous fertilisation;
- winter coverage for a significant percentage of the harvested land before 15 October;
- recourse to an efficient manuring method.

Each year, Nitrawal will compile an inventory of the good agricultural practices applied on each farm in the Q.A.

Indicator 4
The systematic nitrogen balance constitutes the fourth implementation indicator for the Action Programme. It is implemented annually at farm and crop rotation level. The balance amount is constituted of the nitrogen losses in the air and the water and of storage in the organic soil matter. This amount will be compared with a theoretical amount calculated on the basis of optimal nitrogen effectiveness, while taking account of the crops and the type of livestock on the farm.

Indicator 5
A fifth indicator is an indicator of the risk of nitrate lixiviation over all farmland. It is obtained by the combination of two indicators. These two indicators are calculated annually on each farm involved in the Q.A.

a) On the one hand, a theoretical risk indicator is calculated for crop rotation. This indicator takes account of the part of the farm area which is used for high risk crops (e.g. potatoes and maize), medium risk crops (e.g. beet) and low risk crops (e.g. cereals with catch crop and hay-fields).
b) A performance indicator for nitrogenous manure is also calculated using profile concentration measures for nitric nitrogen. Each year, the farmer carries out soil analyses on five of his parcels of land in order to determine the nitric nitrogen concentration profile (90 cm in depth in three layers of 30 cm).

The results of these analyses are compared with the reference values established annually per crop through the agricultural area survey (see Data interpretation). In order to guarantee the quality of the measurement of the nitrogenous remainder, the two agronomic universities worked together with reference laboratory REQUASUD (Walloon Agricultural Research Center, B-5030 Gembloux, Belgium) to draft a sampling and soil analysis protocol (determination of the nitric nitrogen concentration) (Marcoen *et al.*, 2003). The labor atories involved in these analyses must participate three times per year in a ring test organised by REQUASUD with the support of the DGA.

At the end of a 4-year commitment to the Quality Approach, Nitrawal develops an overview of the indicators and their development. On the basis of the latter, the DGRNE will consider the renewal of the Quality Approach for the farmer concerned. In the case of a negative opinion, the farmer must adapt his farm or export surplus nitrogen so as to re-establish an SL value lower than the unit. This SL will be calculated using the basic rules (80/210 kg N ha^{-1} in vulnerable zones and 120/210 kg N ha^{-1} outside vulnerable zones).

Indicator 6

The sixth indicator is an indicator of technical knowledge. It is the attendance frequency at the information and technical meetings organised regularly by Nitrawal and the FWA. In 2002 for instance, 133 meetings brought together 4200 farmers. A summary is made each year in order to measure the farmers' interest in the integrated management of nitrogen (Nitrawal asbl, 2003).

3. DISCUSSION

3.1 Data interpretation

The implementation of this Action Programme has just started, as the law (Decree from the Walloon Government concerning the sustainable management of nitrogen in agriculture) was promulgated in the Moniteur Belge on 29 November 2002. Consequently, little information is available and open to interpretation.

The aforementioned agricultural area survey is comprised of a number of representative points. The methods used to understand the nitrogen flows are concentrated on these sites and the references locally acquired can then be extrapolated to the agricultural regions.

Twenty-six farms were thus selected on the basis, among other things, of pedological criteria, in order to be representative of the regions to which they belong. They constitute the referential for the “agricultural area survey”. Around 200 parcels of land were consequently chosen on these 26 farms. These farms benefit from supervision consisting in part in the generous provision of suitable manuring advice, the aim of which is to minimise nitrogenous residue as much as possible for the crop being grown.

The nitrogenous residue reference values are established on the basis of the measurements of nitric nitrogen concentration profiles developed three times each autumn (in October, November and December) on the parcels of land in the agricultural area survey.

Since the beginning of this year, lysimetric sinks have been installed on several parcels in the agricultural area survey. The objective is to establish a relationship between these nitrogenous residue reference values for the soil and the concentration of nitrate in the water gathered under the root zone.

Alongside this instrument, a model which was developed and validated within one vulnerable zone will soon be used and defined on these parcels.

3.2 Difficulties encountered

In addition to the production rules per animal category, legislation provides for the possibility of determining the quantities of effluent to be transferred between farms on the basis of the organic nitrogen quantity actually contained in the effluent. The determination of this quantity poses significant difficulties in practice. The results of the effluent analysis differ from one laboratory to another and make it difficult to determine the precise quantities of effluent to be transferred. Work on the harmonisation of the laboratories' analysis methods is under way, as is the finalisation of a method of estimating the losses based on the nitrogen (N) and phosphorous (P) excretion balances and the analysis of the effluent. P is a relatively immobile element that can be used as a reference to evaluate nitrogen losses. The comparison of the N:P ratio measured in the effluent and the N/P ratio expected on the basis of the excretion balances makes it possible to quantify the loss of nitrogen in the particular conditions of the farm concerned.

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Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Denmark

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Abstract This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Denmark (EC, 1991 and EC, 1999). The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5(6). Denmark is an intensive farming country (60% of the country area) and during the last 15 years the pig and poultry production has increased considerably. Thus agriculture is the main source of nitrate pollution in groundwater and surface water. More than 40% of the shallow groundwater (0-30 m) is heavily polluted with nitrate and periods of oxygen depletion in the inner Danish seas are common. Natural and human factors influence the nitrate concentrations and action programmes for reducing nitrate pollution in the aquatic environment are presented. Finally, the effect of monitoring programmes for groundwater and surface water is described and some results are presented.

1. INTRODUCTION

1.1 General

Denmark is traditionally a farming country with about 60% of the entire country used for intensive farming and a high livestock concentration. Therefore, although many attempts have been made to minimise nitrogen leaching, farming is the main pollutant source for Danish groundwater, surface water and seawater (Fig. 1). Natural conditions such as climate, precipitation, soil and geology are important factors for the understanding of the water quality and pollution.

After the approval of the first Action Plan for the Aquatic Environment in 1987 (Folketinget, 1987) nitrogen leaching from wastewater treatment plants has been considerably reduced, namely by more than 80%. However, farming is still in some parts of the country causing considerable nitrate pollution of surface water and groundwater.

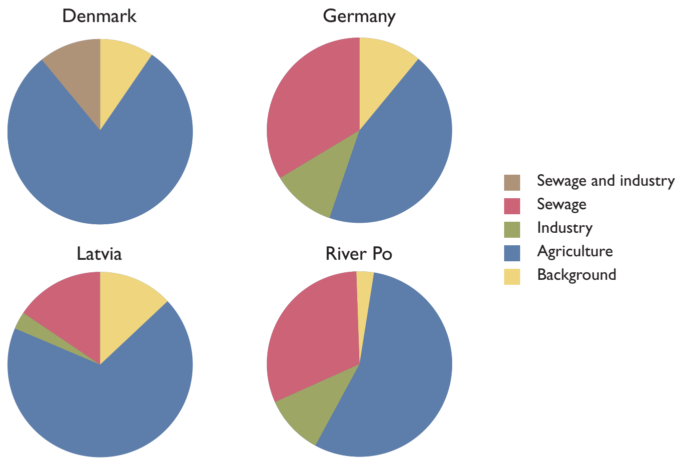

Fig. 1 Nitrogen sources to surface water pollution in three European countries and the river Po catchment (source: European Environmental Agency).

1.2 Description of natural factors influencing nitrate concentrations

Climate

The dominant wind direction is westerly and the highest precipitation levels are on sandy soils in the western part of the country. A good indicator of groundwater formation is the winter precipitation, October-March (Fig. 2, left). The winter precipitation varies in the country from 350 to 650 mm and the winter evaporation is about 90 mm (Fig. 2, right illustrates the annual potential evaporation).

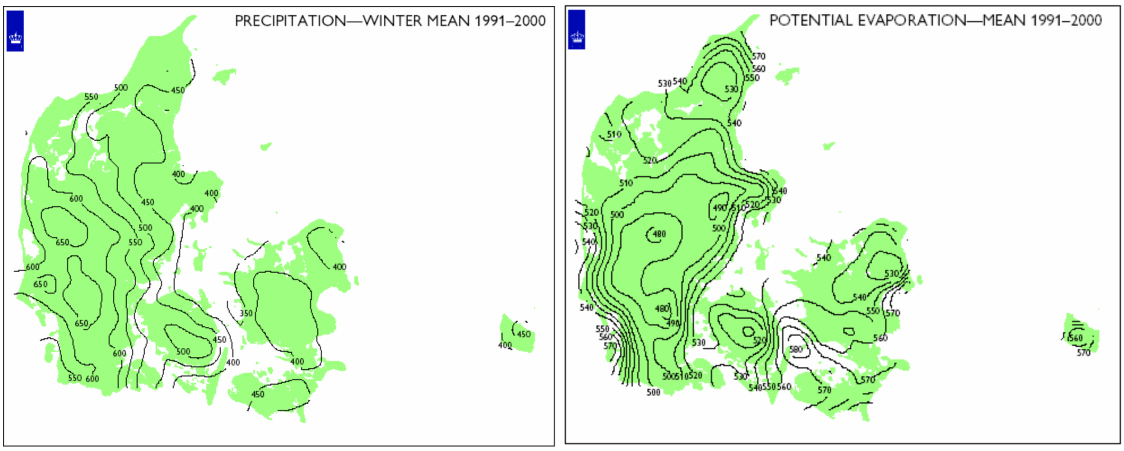

Fig. 2 Regional distribution of observed winter precipitation, 1991-2000 (left) and regional distribution of annual potential evaporation (right). Winter evaporation is about 90 mm; modified Penmann (Henriksen & Sonnenborg, 2003; Scharling & Kern-Hansen, 2002).

Groundwater level

There is a good relationship between the winter precipitation and the groundwater level, as seen in Fig. 3. It is therefore important that the leaching from the soil is kept to a minimum and since 1988 it has been compulsory to grow winter crops on 65% of the cultivated area (Miljøministeriet, 1988; Danish Plant Directorate, 2003). These include wheat and barley although these plants may not be able to capture the leaching nutrients.

Monitoring the groundwater level makes it possible to evaluate changes in the groundwater resource. Variations in precipitation and evaporation during the year cause that the groundwater level to vary naturally with a maximum around April and a minimum around October. In some years the groundwater level may, however, change significantly due to changes in precipitation or groundwater abstraction – or both.

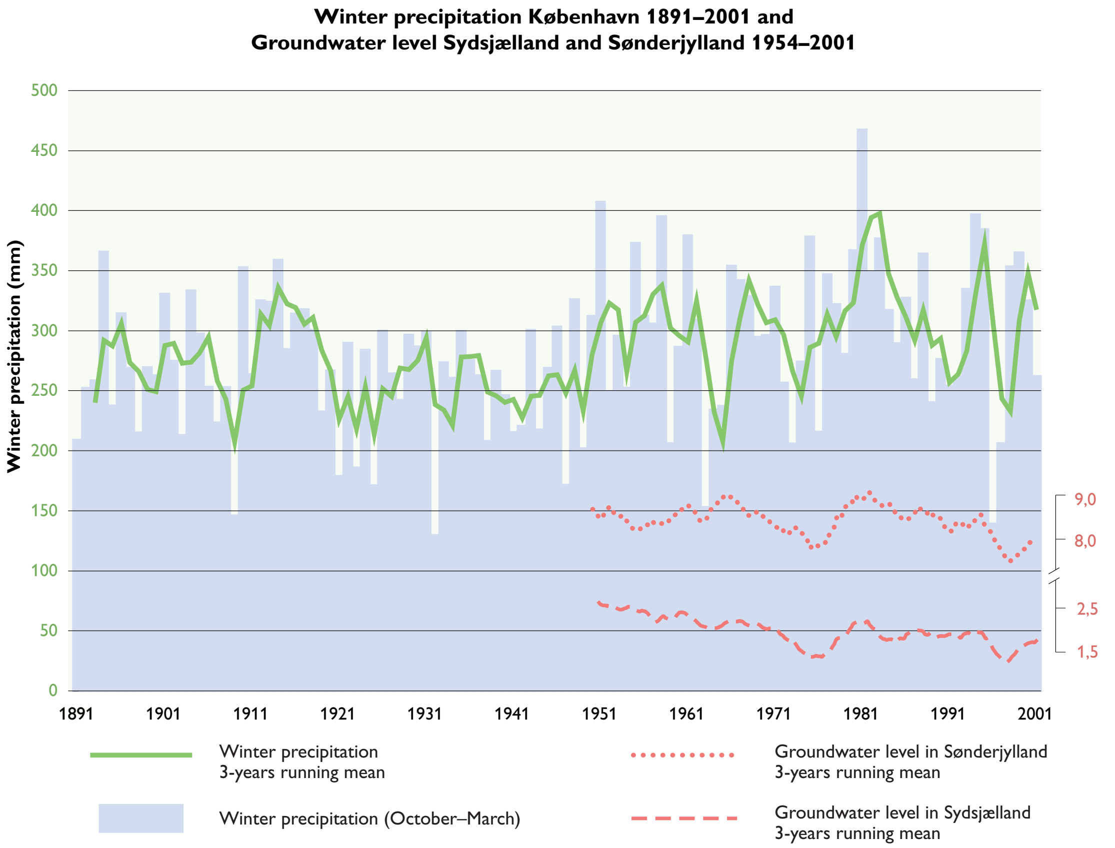

Fig. 3 Groundwater level is now normal after high precipitation in the winters 1997/98-2001/02. The background curve is the winter precipitation for Copenhagen, the green curve is the 3-year running mean. The hatched red curves show the groundwater level at two localities in Denmark (GEUS, 2002).

In Fig. 4 four groundwater level monitoring series illustrate different situations: (1) shallow aquifer with rapid response to precipitation and climate; (2) deep aquifer with moderate, delayed and/or reduced response to year-to-year variations in precipitation; (3) abstraction strategy in a nearby well or well field and (4) short time or seasonal abstraction, e.g. irrigation. (GEUS, 2002).

Geology

Nitrogen leaching is also dependent on pedological and geological conditions. The glacial sediments are to a major degree formed by the underlying sediments (Fig. 5). Miocene and Oligocene sands dominate central Jutland; clayey Oligocene and Palaeocene sediments dominate east Jutland and the islands; and limestones are found in east and northern Denmark.

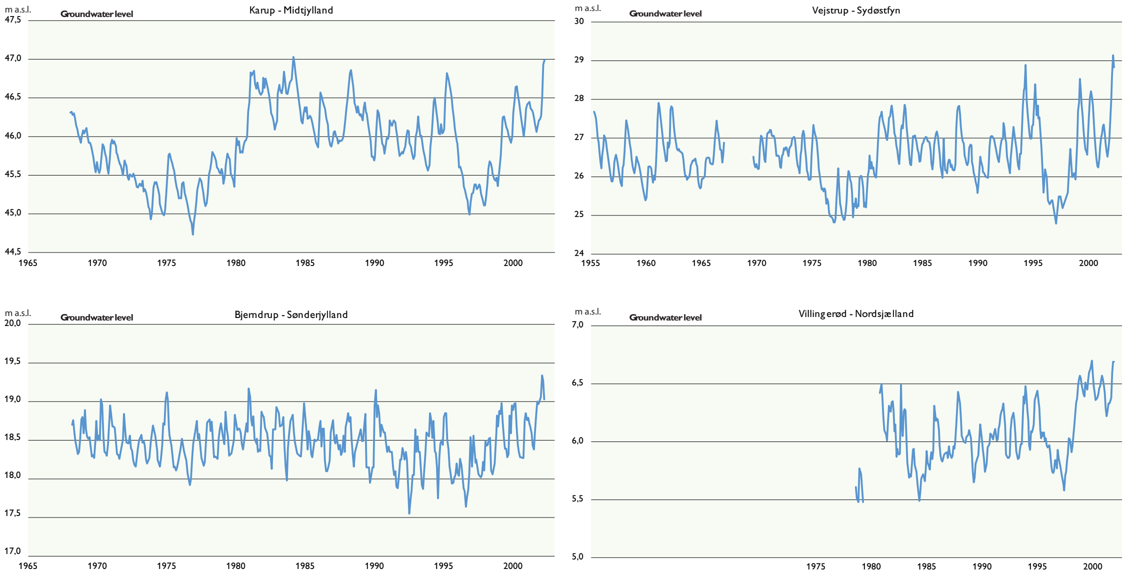

Fig. 4 Groundwater level at four monitoring wells (GEUS, 2002);
1. Upper left: shallow aquifer with rapid response.
2. Lower left: deep aquifer with moderate, delayed/reduced response.
3. Upper right: abstraction strategy in a nearby well or well field.
4. Lower right: short time or seasonal abstraction, e.g. irrigation.

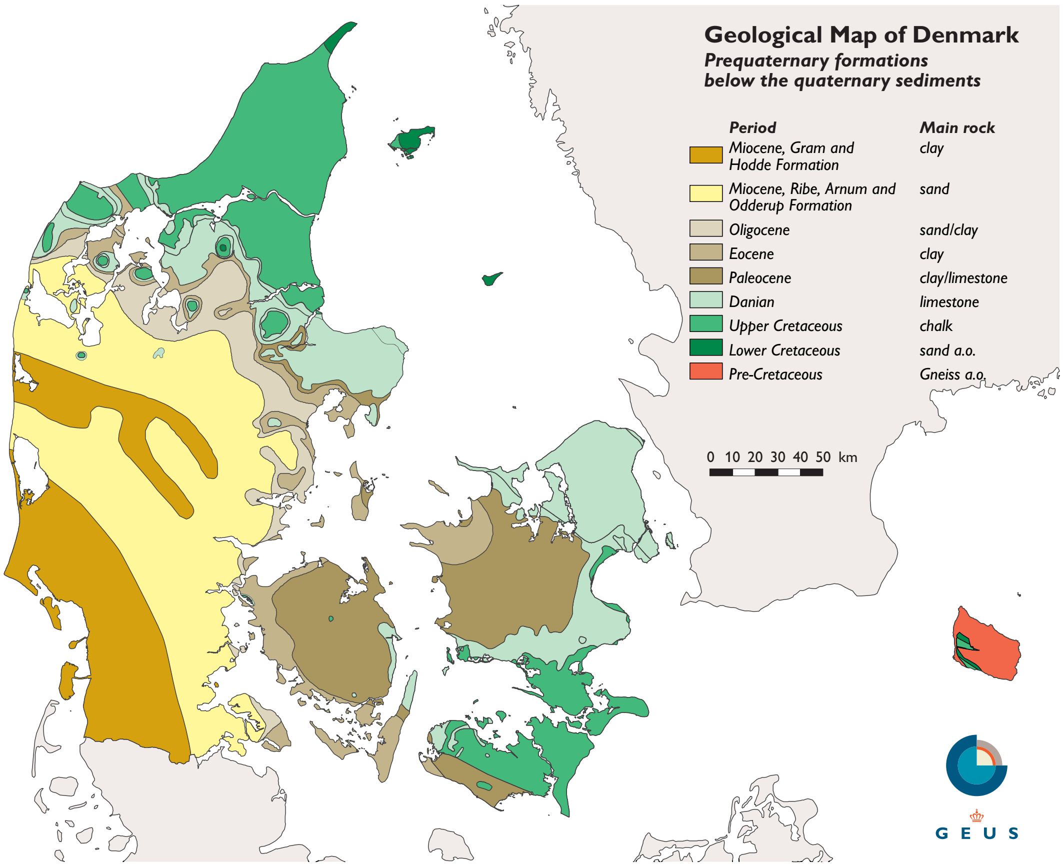

Fig. 5 Pre-Quaternary formations at the basis of the Quaternary sediments (after Sorgenfrei 1954, slightly revised by Knudsen, 1998).

Western Jutland is therefore generally characterised by sand and unconfined aquifers while eastern Jutland and the Danish islands are characterised by rather clayey sediments, tills and confined aquifers (Fig. 6). Another characteristic factor is that western Jutland was not covered by ice during the latest glaciation. Therefore this part of the country is flatter and the aeration of the sediments has taken place during more than 100,000 years, as compared to 15,000 years in the rest of the country.

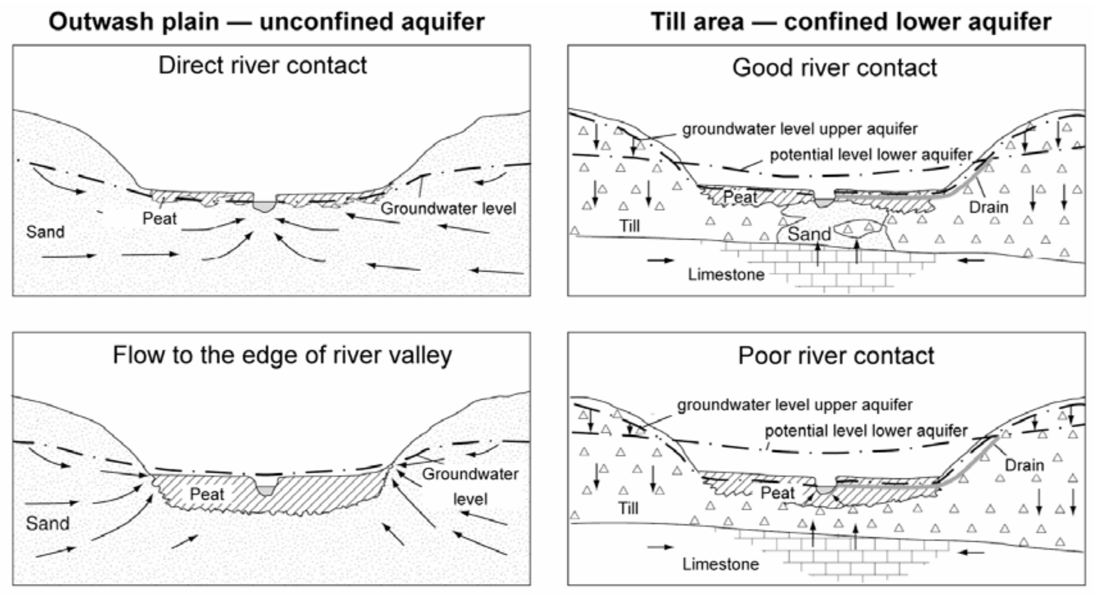

Fig. 6 Typical groundwater flow directions to rivers. Examples from west and east Denmark (GEUS, 2003).

Soils

Danish soils are rather sandy in general (Fig. 7). Of the agricultural land 34% has clay contents of less than 5%. Only 7% of the land has clay contents above 15%. Another 7% has a high organic content constituting more than 10% of the soil by weight.

Stream networks in Denmark

Discharge from the stream networks in Denmark to the coastal section is shown in Fig. 8.

1.3 Description of human factors influencing nitrate occurrence

Land use

More than 60% of the total Danish area is utilised for agriculture (Table 1). However, the total agricultural area is decreasing due to enlargements of towns and roads and due to increased afforestation. During the latest 20 years almost 200,000 (7%) ha have been taken out of agricultural production.

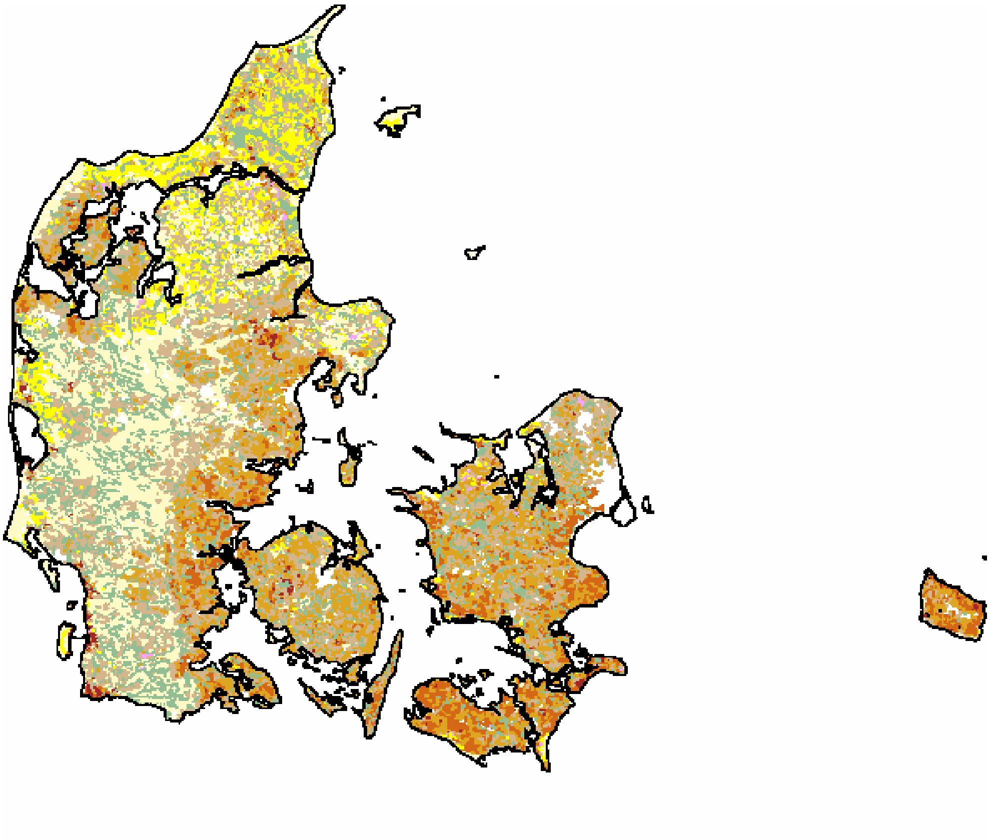

Fig. 7 Danish soil types. Dark (brown) colours indicate the highest clay contents. Green colours indicate peaty soils and yellowish indicate fine sands. Sandy soils occur primarily in Jutland.

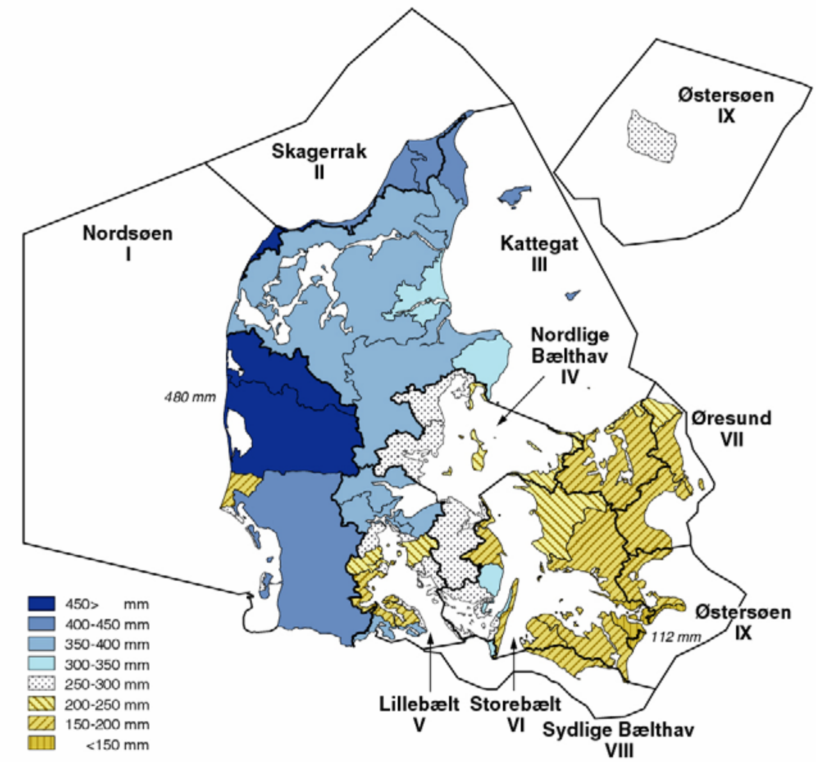

Fig. 8 Freshwater discharges (mm) to nine first order coastal sections (Bøgestrand, 2002).

Table 1 Land use in Denmark (Danish Forest and Nature Agency, 2003).

Land use	1000 ha	%
Agriculture	2659	62
Forestry	486	11
Protected nature	411	9
Other areas	753	18
Total	4310	100

Source of nitrate in surface and groundwater

Agriculture is the main source of nitrogen in streams and groundwater. Thus, in 2001 agriculture accounted for 82% of the nitrogen emissions to streams. During the transport through the freshwater courses and lakes to the marine waters some of the nitrogen is retained. In 2001 about 9% of the riverine nitrogen transported was found to be retained (Table 2).

Table 2 Nitrogen transport via streams to marine waters, 2000 (Bøgestrand, 2002).

Contributions	Nitrogen (tonnes)
Background	8,400
Agriculture	62,900
Point sources in open land	1,000
Point sources, industry and sewage	4,000
Export to streams	76,300
Retention in freshwater	-6,700
Transport to coastal waters	69,600

Main crops

The largest proportion (57% in year 2002; Table 3) of Danish agricultural land is cropped with cereals, approximately half of which is winter cereals and half is spring-sown cereals. The second largest group of crops is green fodder crops in rotations, of which area about half is grown with grass.

Due to the set-aside regulation, approximately 8% of total agricultural land is set-aside with grass or self-sown weeds. Another 7% of the land is permanent grassland (Table 3).

Table 3 Acreage of main crops in Denmark in 2002 (Statistics Denmark, 2003).

Main Agriculture Crop - 2002	Hectares
Grain crops	1,531,443
Green fodder crops	429,823
Set aside with grass	204,721
Permanent grassland	177,546
Root crops	105,410
Seeds for industry (mainly rape)	84,025
Seeds for sowing	71,040
Pulse crops	40,184
Horticultural crops	19,478
Other areas	1,834
Total agricultural area	2,665,507

The cereal area has decreased by more than 200,000 ha (12%) over the last 20 years (Fig. 9). The area under forest was in year 1989 approximately 415,000 ha and the political aim is to double this area within the next 80-100 years. Afforestation has been one element in the latest Action Plan for the aquatic environment, 1998-2003, in which period some 14,000 ha of new forest on former agricultural land are expected (Grant & Waagepetersen, 2003).

Rape and leguminous crops were given high area payments and were thus common crops 10-15 years back with up till 279,000 ha rape and 204,000 ha of pulse crops. In year 2002, however, the areas have dropped to 84,000 and 40,000 ha, respectively. In contrast, the maize area has increased during the last decade (92,000 ha in 2002) due to the use of varieties better suited to the Danish climate and possibly due to increasing temperatures. The areas with permanent grassland and with grass crops within rotation have remained quite stable over the years.

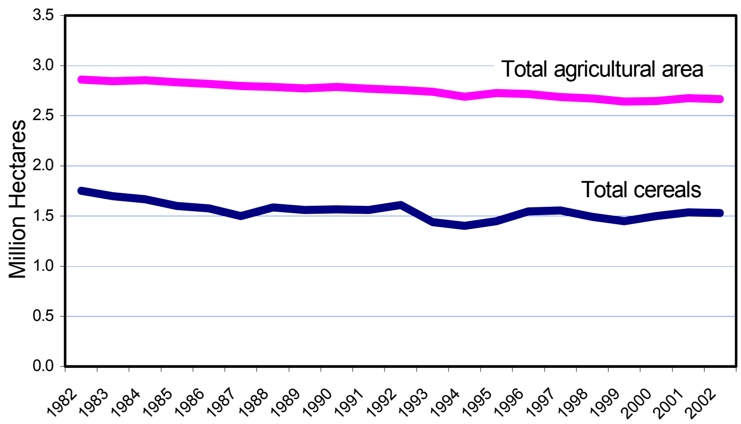

Fig. 9 Development of total agricultural area and area grown with cereals during the last 20 years in Denmark (Statistics Denmark, 2003).

Characteristics of agriculture

Danish agriculture is characterised by a large livestock production (Figs 10 and 11). The number of pigs in production at any time is almost 13 million with an annual production of slaughter pigs of approximately 23 million. The numbers of poultry and pigs are increasing, while the number of cattle is decreasing (Fig. 10). This tendency is expected to continue during the coming years (Illerup *et al.,* 2002).

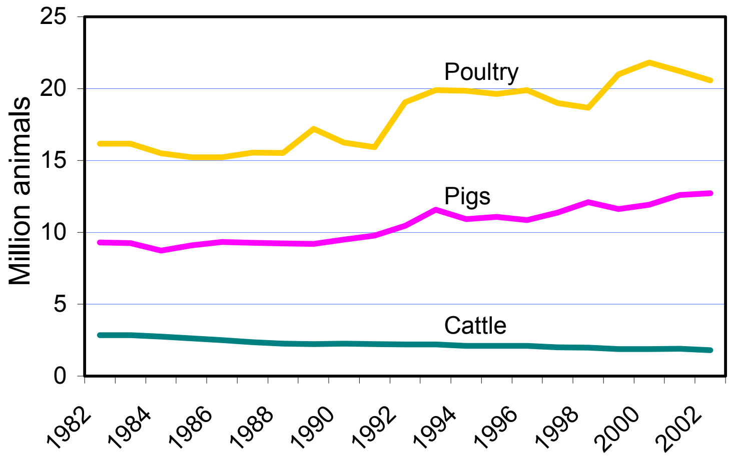

Fig. 10 Standing number of animals during the last 20 years in Denmark (Statistics Denmark, 2003).

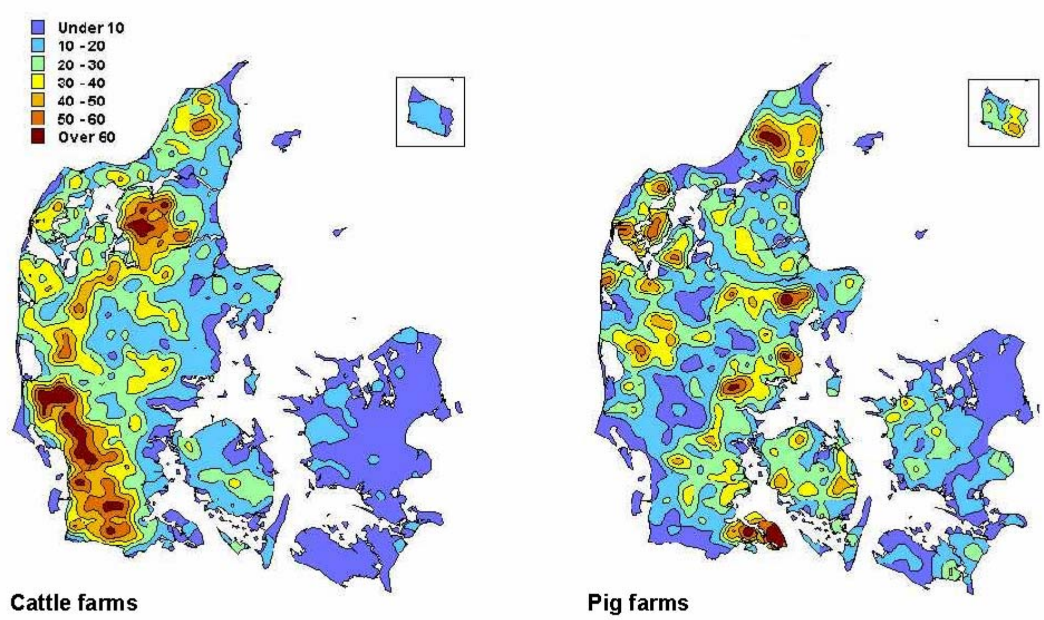

Fig. 11 Number of 'livestock units' (one livestock unit produces 100 kg N ex storage annually) per square kilometre in 1998 (Kristensen, 2002a). Left: cattle farms; right: pig farms.

Unfortunately there is an uneven distribution of livestock farms over the country with the highest concentration of especially cattle farms on the sandy soils of western Jutland (compare Figs 7 and 11). Also pig production has its "hot spots", which are, however, often on the more fertile soils. In these hot spots, land prices have increased dramatically, due to the increasingly strict stipulations in Danish legislation for a correspondence between the size of the land area and the size of the livestock production. This and the general structural development in agriculture is causing a steep increase in average farm size. The average size of Danish farms is not more than 53 ha (year 2002), but the average size of pig farms is about 80 ha (Fig. 12).

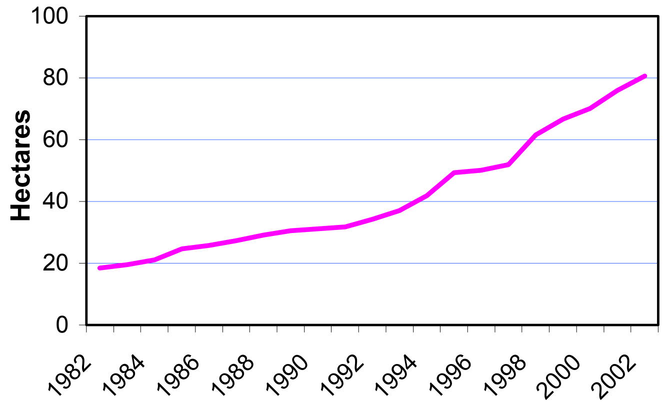

Fig. 12 Mean size of pig farms in Denmark during the last 20 years (Statistics Denmark, 2003).

Manure production and fertiliser use

Total N excretion from farm livestock was calculated at 267,000 tonnes in year 2000 (Poulsen *et al.*, 2001). Distribution of livestock manure is very uneven over the country with highest loads in the western parts (Fig. 13). Of the total excreted amount of nitrogen an estimated 32,000 tonnes were excreted directly on grass. A further estimated 38,000 tonnes were lost through ammonia volatilisation from livestock buildings, leaving 197,000 tonnes for spreading. A similar amount was lost during spreading of manure, but recent technical developments and legislative tightening has caused a reduction in spreading losses, which means that now the highest ammonia losses are from buildings (Table 4).

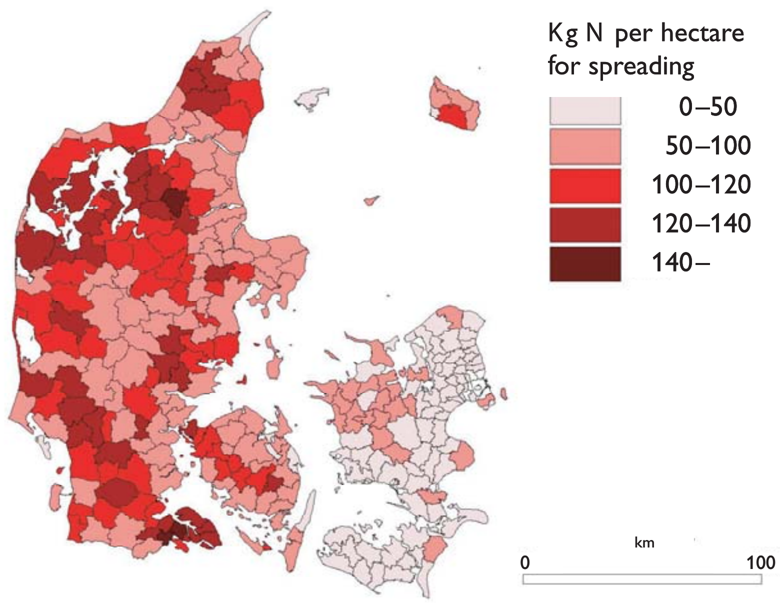

Fig. 13 Distribution of livestock manure production per hectare agricultural land in each county in 1999 (Dalgaard, 2002).

Table 4 Development (1990-2001) and projection (2002-2004) of total ammonia losses from Danish agriculture and percentage distribution of losses from housing, storage, manure spreading and from grazing livestock (based on Illerup *et al.,* 2002).

Year	Stable pct.	Storage pct.	Spreading pct.	Grazing pct.	Total NH3-N tonnes
1990	36.96	15.52	44.48	3.05	79,249
1991	37.53	15.68	43.59	3.19	77,358
1992	38.79	15.83	42.17	3.20	77,091
1993	38.71	16.22	41.74	3.33	75,449
1994	39.87	16.34	40.34	3.44	71,497
1995	40.25	16.53	39.51	3.71	67,294
1996	41.06	16.69	38.45	3.81	66,095
1997	41.91	16.65	37.76	3.68	66,376
1998	42.41	16.58	37.44	3.58	67,910
1999	42.15	16.81	37.44	3.60	65,732
2000	43.19	15.63	37.54	3.63	65,228
2001	44.16	15.58	36.80	3.46	64,413
2002	45.27	15.91	35.09	3.73	62,489
2003	46.12	16.00	34.11	3.76	61,452
2004	46.30	15.87	34.09	3.74	61,305

Of the total excreted nitrogen, 43% was produced by pigs, 47% by cattle and 5% by poultry. The major manure type is slurry, but due to animal welfare demands, deep straw bedding is now also used in many livestock buildings.

The fertiliser use in Denmark is strictly regulated with detailed standards for each crop depending on soil type and pre-crop history (Table 5). Since 1998 the standards have been reduced to what is considered 10% below the economically optimal fertilisation level. The requirement to utilise nitrogen in livestock manure has been tightened during the last decade, the required utilisation amounting to 75% of total N content for pig slurry and 70% for cattle slurry in 2003 (Danish Plant Directorate, 2003).

Nitrogen surpluses at the farm level on livestock farms are typically in the range 100-200 kg N per ha with a tendency towards slightly higher levels on dairy farms than on pig farms. The main factor determining the level of nitrogen surplus is the number of “livestock units” i.e. the livestock density per ha (Fig. 14). There is a tendency to lower surpluses on organic dairy farms and high surpluses on farms with outdoor pigs.

1.4 Environmental goals

National Action Plan for the Aquatic Environment (Folketinget, 1987) prescribe that the nitrate concentration should not exceed 50 mg per litre in soil water leaving the root-zone. According to the same National Action Plan for the Aquatic Environment the nitrate concentration in the treated wastewater should not exceed 8 mg N per litre at the discharge point to the surface water.

Table 5 Yield and nitrogen standards for winter wheat in one region of Denmark for the year 2002-2003 (Danish Plant Directorate, 2003). If grain yields higher than the standard can be documented, a higher nitrogen standard may be calculated using the yield correction factor in the right column. hkg equals hectokilogram (100 kg). Details on other regions and other crops can be seen at http://www.pdir.dk/vejled/godn_02/tab01.htm.

Crop and previous crop	Non-irrigated Coarse sand		Non-irrigated fine sand		Irrigated sand		Clay		
	Yield standard hkg ha^{-1}	Nitrogen standard kg N ha^{-1}	Yield standard hkg ha^{-1}	Nitrogen standard kg N ha^{-1}	Yield standard hkg ha^{-1}	Nitrogen standard kg N ha^{-1}	Yield standard hkg ha^{-1}	Nitrogen standard kg N ha^{-1}	Yield-correction kg N hkg^{-1}
Winter wheat after grain or set aside	52	156	66	159	70	178	83	170	1.3
Winter wheat after grain or set aside after clover grass or Lucerne	52	108	66	111	70	130	83	121	1.3
Winter wheat after winter rape	52	117	66	120	70	139	83	131	1.3
Winter wheat after pulse, spring rape or oil flax	52	121	66	124	70	143	83	135	1.3
Winter wheat after grass for seed	52	134	66	137	70	156	83	148	1.3
Winter wheat after clover grass or lucerne	52	91	66	93	70	112	83	104	1.3
Winter wheat after other crops	52	134	66	137	70	156	83	148	1.3
Addition for bread wheat	52	37	66	42	70	44	83	48	0.4

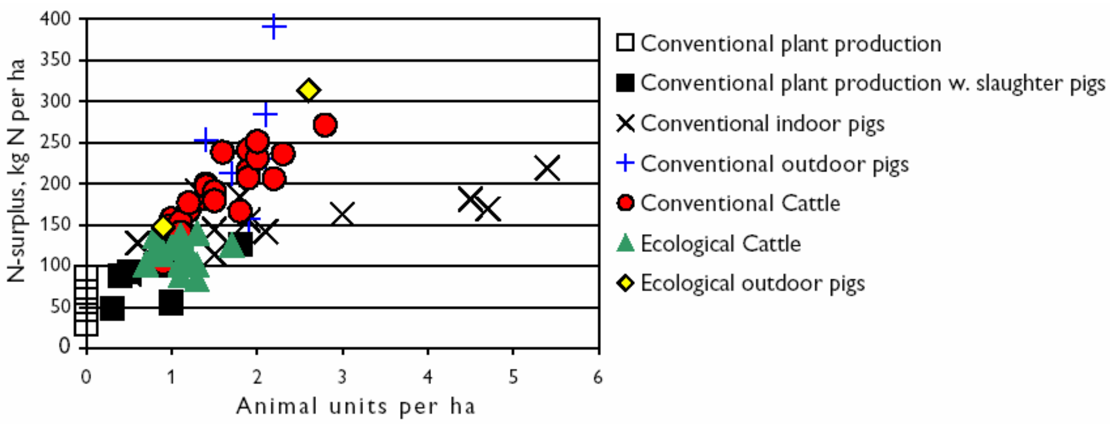

Fig. 14 Relation between livestock units per hectare and nitrogen surplus at the farm level per hectare on different farm types in Denmark (Kristensen *et al.*, 2003).

Agriculture

The first Action Plan on the Aquatic Environment in Denmark was passed in 1987. The goal was to reduce nitrogen leaching by 50%, with 49% to be met by agriculture and 1% by industries and sewage plants. This goal has been maintained in later Action Plans and was actually attained by 2003.

The reduction target for agriculture is defined as a reduction of the nitrate leaching from the root zone, i.e. from a soil depth of about 1 m. Nitrate leaching at the national level is estimated by model calculations based on statistical data for soils and agriculture, knowledge of agricultural practice, and climatic data for an average year.

Surface water

The responsibility for the environmental state of streams and lakes in Denmark lies with the regional counties. Each county defines its own quality objectives, some apply average annual target values, others apply average summer target values, and there are no standardised principles with respect to frequency of sampling.

Groundwater

There is no official target value. However, public water authorities use the same yearly mean values as in the drinking water regulation.

For small private water supplies, which comprise by an estimated 75,000 families, many of them being dug wells, it is assumed that the value of 50 mg nitrate per litre is the target value.

2. EFFECT MONITORING

2.1 Strategy for effect monitoring

The national nature and water monitoring programme, NOVANA, is directed by political and administrative demands, not least the requirements in EU directives, regulations, conventions, etcetera. This means that all monitoring must relate to environmental goals.

The NOVANA programme is thus part of strategic environmental planning. The monitoring serves to document if the state of the water and nature environment is developing in the right direction and if the environmental goals are being fulfilled. It will also be the scientific basis for identifying requirements for new activities.

The link between monitoring and strategic environmental planning means that the monitoring should be organised according to the DPSIR concept (see below).

In connection with the first Action Plan for the Aquatic Environment, a nation-wide monitoring programme was established in Denmark. This programme includes all aspects of the aquatic environment (Kronvang *et al.*, 1993). It also contains the aspects of effect monitoring required by the EU Nitrates Directive. The strategies for the monitoring are outlined below (Miljøstyrelsen, 2000).

The monitoring programme is principally a continuous programme. Long time series are necessary to document statistically significant changes over time in order to support short-term actions.

It is also important to document baseline conditions in order to identify anthropogenic influences, including the effect of action and management plans. In order to understand the climatic effects, climatic data are also included in the data interpretation.

The monitoring programme is set up according to the *DPSIR concept* (Fig. 15), where:

- *D* are the driving forces
- *P* are pressures

- *S* is state
- *I* is impact
- *R* is response

The national water monitoring programme in principle covers *P*, *S* and *I*, while *D* and *R* among others are covered by the Environmental Protection Agency, the Forest and Nature Agency and the county administrations.

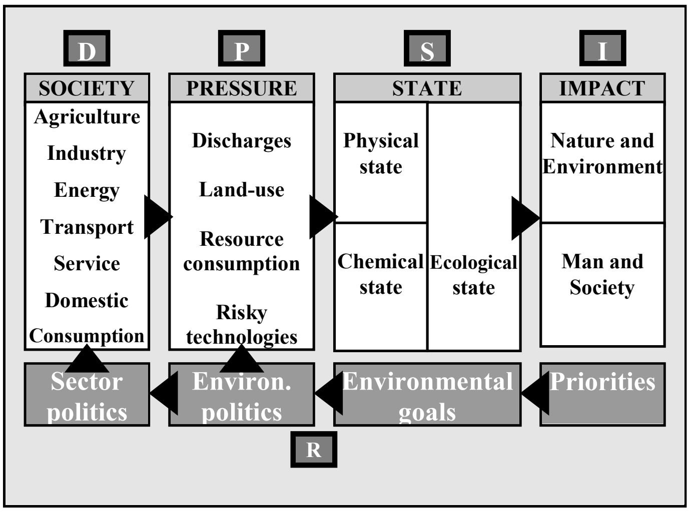

Fig. 15 *DPSIR* concept (after NERI, 2004).

2.2 Detailed description of effect monitoring programme

2.2.1 Introduction

The Danish water quality monitoring programme, covering almost the entire water cycle, from atmospheric precipitation via groundwater to the sea, is managed by the Ministry of Environment in co-operation with the Danish counties. This programme also includes hydrometric monitoring and registration of abstracted groundwater. Other climatic parameters, such as precipitation, are monitored by the Danish Meteorological Institute. However actual evaporation is not monitored sufficiently.

2.2.2 Organisation

The NOVANA programme is conducted in co-operation between the involved Ministry of Environment agencies (NERI, GEUS, EPA, NFNA) and the Danish counties and Copenhagen municipalities.

The Programme is headed by a board, with members from the involved parties, Fig. 16. Chairman and secretariat are from the National Environmental Research Institute, NERI. The board has four yearly meetings and decisions are taken by consensus. All decisions on economy must be taken at board level.

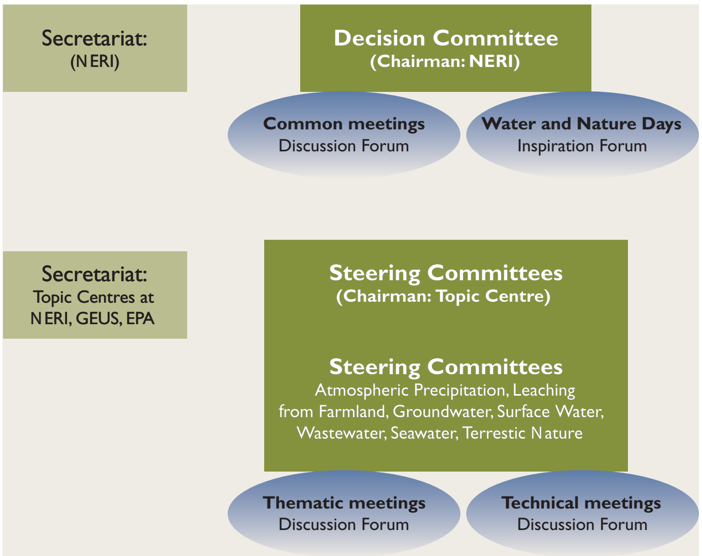

Fig. 16 Decision structure in the Danish Monitoring Programme for Water Environment and Nature, NOVANA (After NERI, 2004).

Topic Centres are bodies with special knowledge on the relevant media within the Ministry of Environment agencies/institutes. The seven topic centres cover the fields of atmosphere, leaching from cultivated areas, groundwater, freshwater, seawater, point sources, biodiversity and terrestrial nature. The majority of the topic centres are situated within NERI, groundwater is covered by GEUS and the EPA covers point source pollution.

The topic centres are responsible for maintaining the scientific level of the monitoring, developing guidelines, collecting the monitoring data and management of the national database on the topic. Under the board, seven steering groups, in co-operation with the topic centres manage the respective programmes.

The steering groups comprise members from the relevant institutions and members of the board. The topic centres at the research institutes of the Ministry of Environment the chairmanship and the secretariat of the steering groups. Decisions that cannot be taken collectively are taken at board level, as are all decisions on economy.

Finally, the counties are the executive bodies that establish and maintain the monitoring facilities, and implement the sampling, chemical analyses and yearly data reporting to the topic centre. Counties publish yearly reports on the state of the different topics. Based on these and on their own conclusions, the topic centres also provide an yearly report.

For the main components the chemical analyses are performed according to Danish standards (DS or ISO). However, a few analyses are made as field analyses, e.g. temperature, dissolved oxygen, conductivity, acidity (pH) and oxidation potential (E_h)]. Sampling procedures are described in the guidelines developed by the topic centre. County technicians normally carry out the sampling and deliver the samples to the laboratories as described in the standards. Detection limits are defined in the programme description. Data are returned in a special format (STANDAT) that is readable by all partners in the programme. Once a year data are transformed to the database structure at the relevant topic centre (Fig. 17).

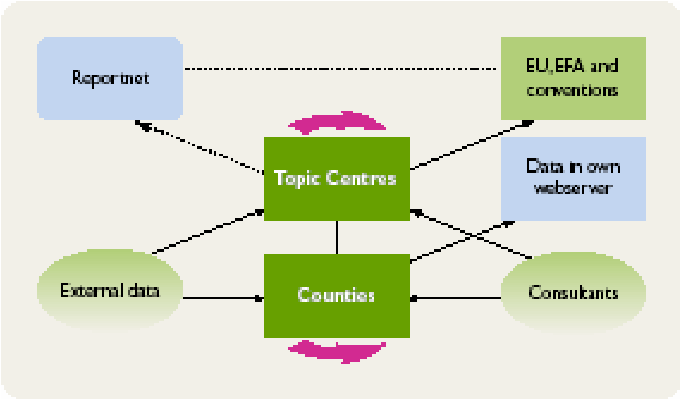

Fig. 17 Principle for data flow. The lines indicate that for the time being only the NERI topic centres report via the common European initiative Reportnet. (http://cdr.eionet.eu.int) (after NERI, 2004).

2.2.3 Agriculture

The monitoring in the agricultural areas is designed to document the effect of the measures implemented to reduce losses of nutrients to the aquatic environment. The results will also form the basis for decisions on the need to implement further measures to limit pollution in order to attain the politically adopted objectives for the quality of the Danish aquatic environment. Finally, the monitoring programme in agricultural areas has provided data for justification of the Danish derogation from the Nitrates Directive.

The monitoring is carried out in a number of agricultural catchments. The strategy for the agricultural catchment monitoring programme has been subdivided into levels. At the lowest level the monitoring is characterised by a general description of agricultural practice at a large number of locations (20 catchments) throughout the country, with the environmental effects solely being described through measurements of water quality parameters in streams.

The objective of monitoring at this level is to collect information on the sources of nutrient loading of streams from agriculture and to provide necessary data for evaluation of agricultural practice and extrapolation to the regional and national levels. The monitoring encompasses extensive collection of information on agricultural practice and measurement of water flow and nutrients in streams.

The highest level of monitoring only encompasses a few catchments (five) covering the main soil types in Denmark. Agricultural practice in these catchments is described regularly and in detail. The environmental effects are described for the whole hydrological cycle.

The objective of this level of monitoring is to collect data for determination of the current agricultural practice, for consequence calculations and for extrapolation to the national level. The catchments have been chosen to represent the main soil types and the variation in livestock density, crops and climatic conditions. The monitoring encompasses an intensive collection of information on agricultural practices at field and farm level by interview surveys. The monitoring employs direct measurements of soil water, drainage water, upper groundwater and stream water (Table 6).

Table 6 Number of monitoring stations in the five catchments with intensive measurements, and sampling frequency for nutrient analysis at each station.

	Number of stations	Sampling frequency (number of samplings per station per year)
Root zone (1 m)	32	30
Drainage water	7	26
Upper groundwater (1.5-5 m)	100	6
Streams	5	26

Modelling is employed to determine the relationships between agricultural practice and loss of nutrients to the surroundings.

2.3 Monitoring

2.3.1 Groundwater monitoring

Denmark has decided that the entire area is vulnerable to nitrate pollution and thus the monitoring programme should cover the entire country.

As Danish drinking water supply is based 100% on groundwater, the groundwater monitoring includes the water-supply well monitoring (Fig. 18) (Miljø- og Energiministeriet, 2001; EC, 1998), the groundwater monitoring network (Fig. 19) and some special groundwater monitoring arrangements such as multi-screened wells.
Nitrate in Danish groundwater

2.3.2 Nitrate in Danish groundwater

The water-supply wells generally have long screens and are intended to give a representative distribution of the nitrate contents in the primary groundwater reservoirs. On the other hand, the data from the water abstraction wells are biased, as the water works must produce drinking water with nitrate concentration below the maximum admissible concentration at 50 mg nitrate per litre (Fig. 20). Groundwater monitoring wells give a more accurate picture of the general nitrate pollution in the Danish groundwater. Of these, 16.4% have nitrate concentrations above the maximum admissible concentration for drinking water and about 60% have no nitrate (below 1 mg nitrate per litre).

The spatial distributions of nitrate in the groundwater reservoirs (Fig. 21) vary from western to eastern Denmark. The differences in the vertical distribution show that unconfined reservoirs in western Denmark have at much higher fraction of screens with more than 25 mg nitrate per litre.

The high concentrations of nitrate have also reached a deeper level in areas with unconfined reservoirs. The reason for this is a much lower nitrate reduction capacity in the sandy meltwater deposits than in the clayey till deposits. The western sandy areas have also been exposed to oxidising conditions for a long time. An additional factor is the higher rainfall in the western part of Denmark than in the eastern, which leads to a higher degree of nitrate leaching from the topsoil. The western part also has a more intensive livestock production.

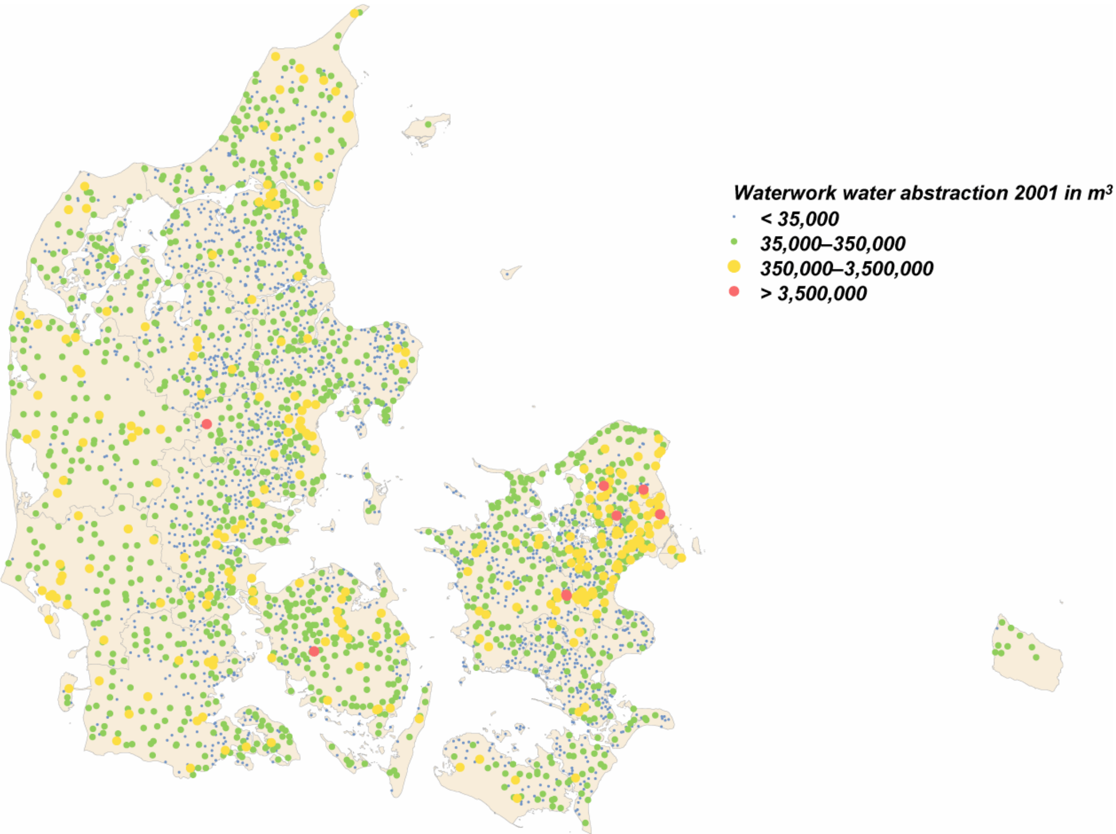

Fig. 18 Distribution of Danish Waterworks for domestic consumption. All waterworks are based on groundwater abstraction.

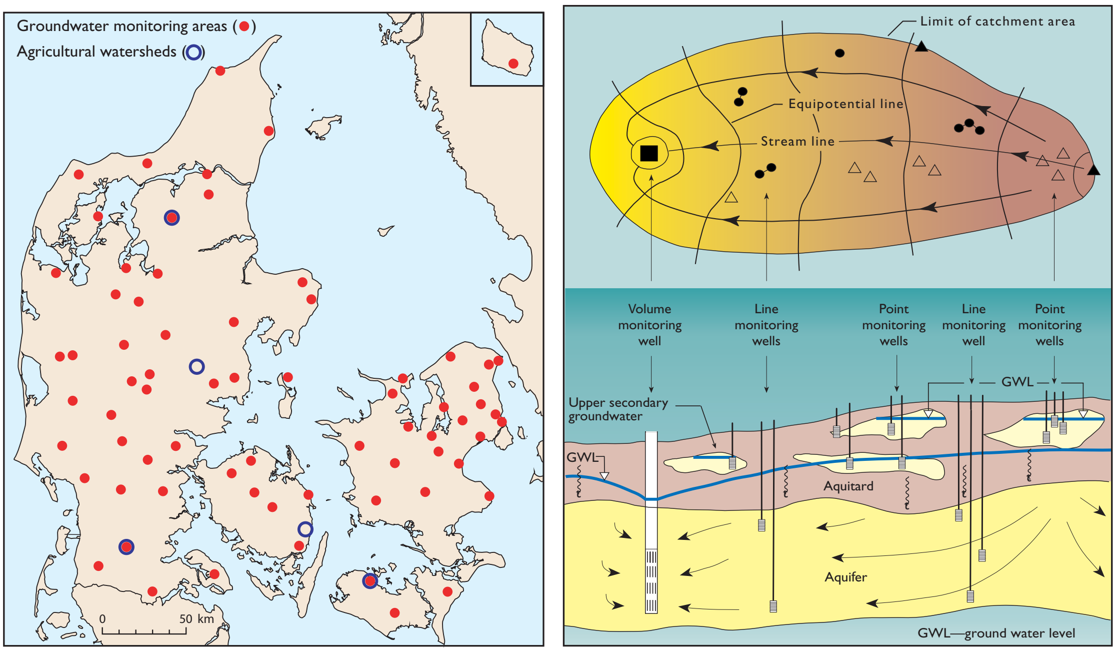

Fig. 19 Groundwater monitoring stations with comprehensive monitoring programme (left; Stockmarr & Nyegaard, 2004) and principle for a groundwater monitoring stations (right; GEUS, 2001).

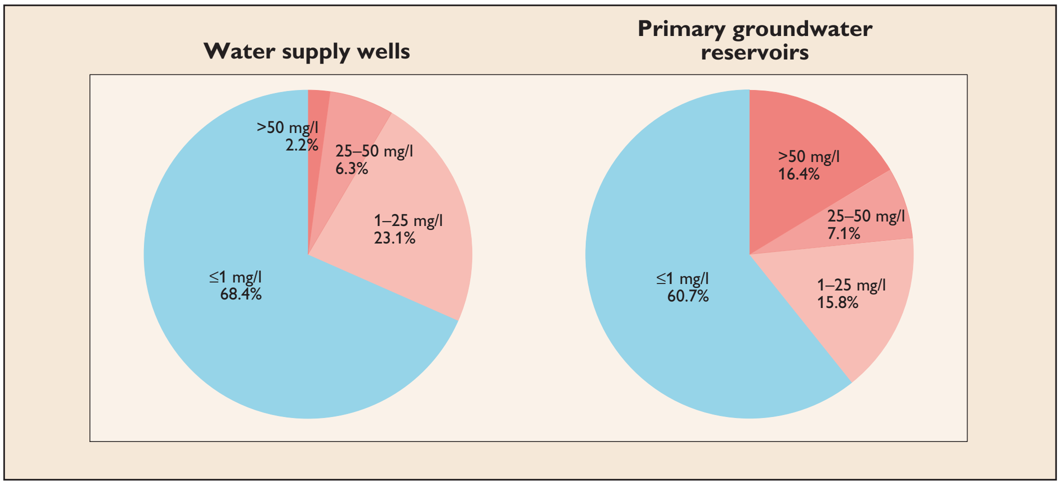

Fig. 20 Distribution of nitrate in groundwater from water supply wells and monitoring wells in four classes: <1 mg l^{-1} nitrate, 1-25 mg l^{-1} nitrate, 25-50 mg l^{-1} nitrate and >50 mg l^{-1} nitrate. Median values for all nitrate data 1990-2000 (Stockmarr & Nyegaard, 2004).

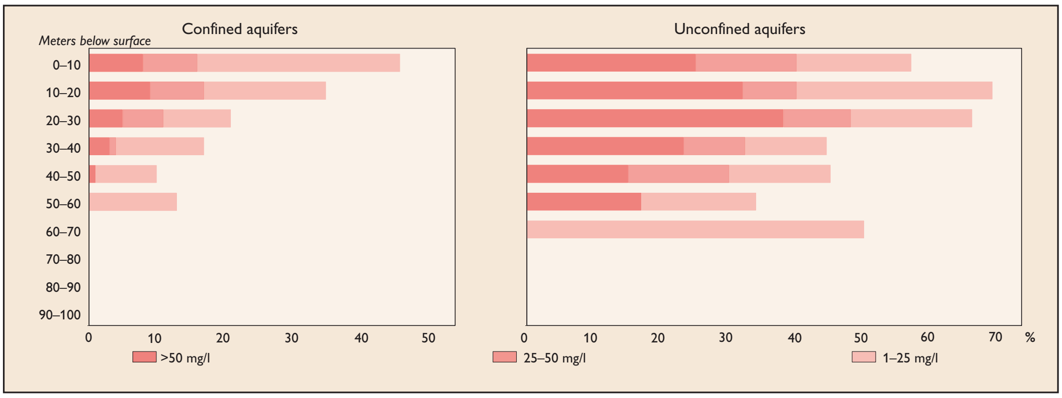

Fig. 21 Depth distribution of nitrate in groundwater monitoring screens (Stockmarr & Nyegaard, 2004).

In the last half century farming has intensified and hence the use of fertilisers. The groundwater from the monitoring screens has been dated by the CFC content (GEUS, 2001) and in Fig. 22 the nitrate content is given as a function of the CFC age. The use of fertilisers in kilograms per hectare is shown for comparison (Danish Plant Directorate, 2003).

2.3.3 Nitrate development in the groundwater monitoring areas

The evaluation of the nitrate development in the groundwater monitoring areas is based on all nitrate monitoring data from the period 1990-2000 with a median value for the period 1990-2000 above 1 mg l^{-1} nitrate (ca. 40% of the well screens, see Fig. 22). This means that data can be divided into groundwater under oxic conditions and groundwater under anoxic conditions. The maximum number of well screens is 254 screens in the oxic groundwater and 154 in the anoxic groundwater (Fig. 23).

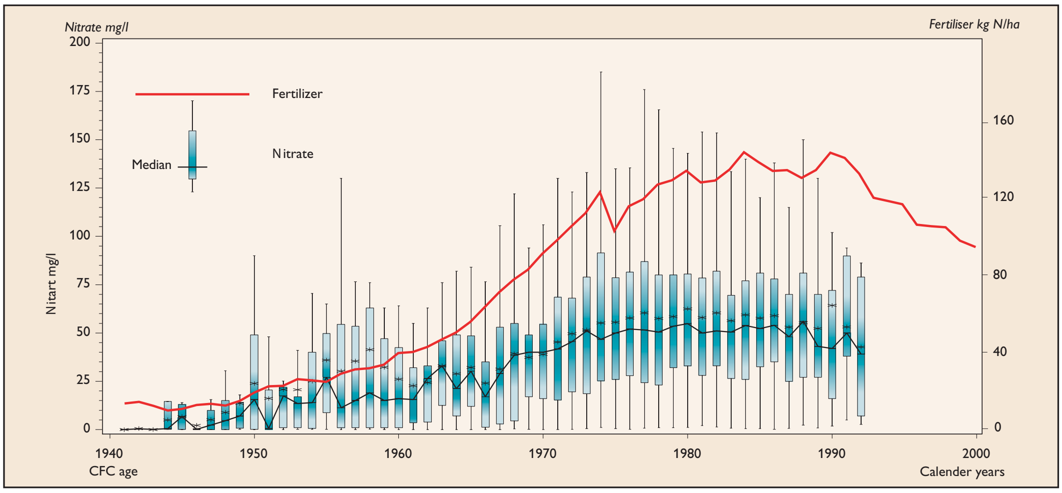

Fig. 22 Nitrate content versus the CFC-age in groundwater monitoring together with the use of fertilisers in kg ha^{-1}. (Danish Plant Directorate, 2003). Only samples with nitrate and oxygen above 1 mg l^{-1} are included. Very few samples are younger than 1992 (Stockmarr & Nyegaard, 2004).

In the groundwater monitoring areas the nitrate content of the two redox zones vary in every single screen, but the median nitrate value for the period 1990 – 2000 only show little variation and with a high degree of deviation. In general, no change in the nitrate concentration is seen even in the shallow-depth aquifers where the nitrate concentration is mainly dependent on winter precipitation.

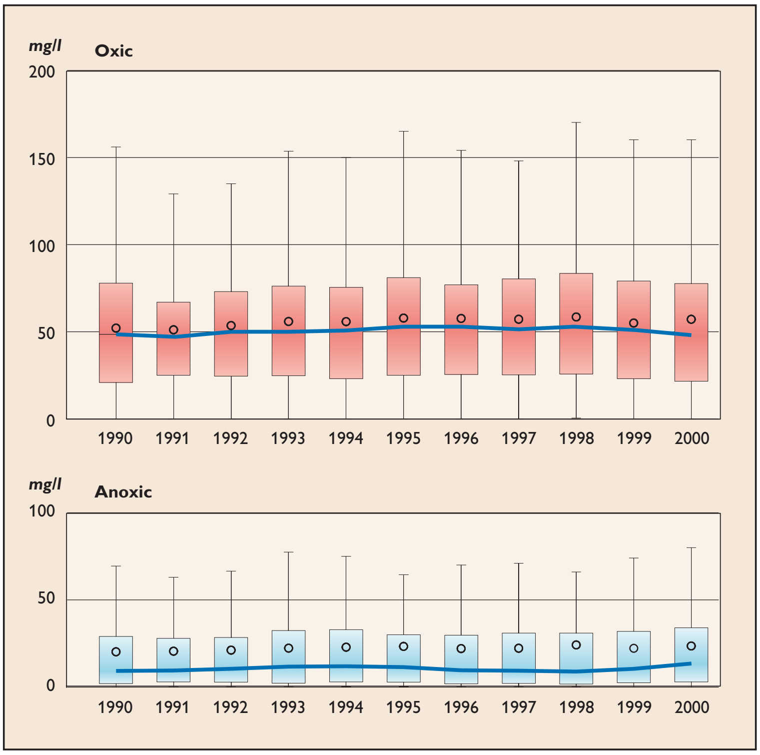

Fig. 23 Nitrate development in mg l^{-1} from the period 1990-2000 based on data from all monitoring screens with more than 1 mg l^{-1} in the entire period. The redox zones are oxic (with oxygen) with up to 254 monitoring screens and anoxic (with nitrate) with up to 154 monitoring screens (GEUS, 2001).

A high deviation can be seen on the nitrate data and the concentrations are somewhat higher in sandy soils than in clayey soils. Comparing the median values for the nitrate concentration with the winter precipitation a clear coherence is seen. The first high winter precipitation shows a high nitrate infiltration that again the next year results in a decrease in nitrate concentration probably due to thinning effect during the next winter with high precipitation. There is a quicker reaction in sandy sediments than in clay sediments.

In summary the leaching of nitrate from the topsoil is strongly influenced by the magnitude of the precipitation, and it can be very difficult, by measuring in the groundwater, to document minor changes in leaching from agricultural soils due to minor changes in the land use.

2.3.4 Redox conditions in groundwater

The Danish sediments are rather young as the ice melted away only 13-14,000 years ago. Therefore the reduction capacity is only used to a minor depth, a few metres in clayey areas and 20-30 m in unconfined sandy sediments (Fig. 24).

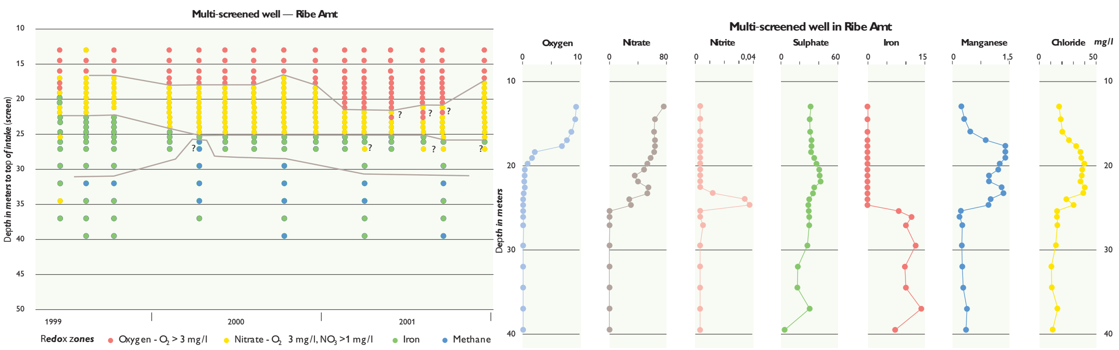

Fig. 24 Variation in redox conditions in the multi-screened well at Grindsted, central Jutland – unconfined sand aquifer for the period 1999-2001 (left) and variation in content of oxygen, nitrate, nitrite, sulphate, iron, manganese and chloride in relation to depth in the multi-screened well at Grindsted. Median values for the period 2000-2001 (right) (GEUS, 2002).

To get more detailed information on the possible movements of the nitrate 'front', four multi-screened monitoring wells were constructed in unconfined sandy aquifers mainly of glacial origin, and more will follow.

The multi-screened wells have at least 15 screens installed in each. The screens are only a few centimetres long and the spacing between the screens is generally below 1 meter in the anoxic zone (nitrate zone). The analyses frequency is six times a year and we already know that the concentrations results vary, but still the results are still too poorly understood to be presented.

The division between the different redox zones is always dependent on the quality of the analyses. The oxygen analyses must be made in the field and the detection limit should be as low as 1 mg l^{-1}. In the Danish case, the detection limits for field analyses for oxygen vary between 1 and 3 mg l^{-1} and the lower limit of the oxygen zone is therefore today placed at 3 mg l^{-1}. However, a limit of 1 or 2 mg l^{-1} will not change the picture significantly.

The lower limit for the anoxic zone (nitrate zone) is <1 mg nitrate per litre, and below this zone the reduced zone or iron-sulphate zone is normally developed.

2.3.5 Outline of nitrate in groundwater monitoring

In order to assess if nitrate data from groundwater monitoring show a increasing or decreasing tendencies, at first all nitrate data were used. Later only wells with a nitrate concentration above 1 mg nitrate per litre were used and the median values were calculated for the periods 1991-1993 and 1998-2000 for each groundwater monitoring area, and the results compared (Fig. 25).

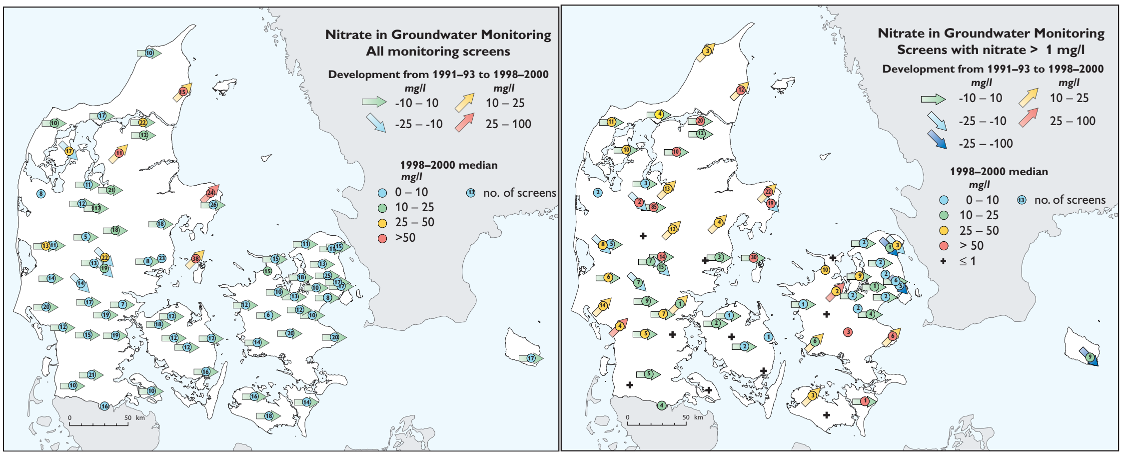

Fig. 25 Nitrate content and development based on nitrate data above 1 mg l^{-1} (left) and based on all nitrate data in the groundwater monitoring network (right) (Nyegaard & Stockmarr, 2000).

The figure shows that the majority of monitoring areas has less than 10 mg nitrate per litre and the change in nitrate concentration from the period 1991-1993 to the period 1998-2000 varies in most areas between –10 and +10 mg nitrate per litre.

2.3.6 Nitrate in water supply wells

Many water supply wells have been closed due to nitrate concentrations exceeding the limit. However, about 2% still show a concentration above 50 mg nitrate per litre (Fig. 20). These water supplies are shown in Fig. 26. However, most of these waterworks can now be expected to have closed.

2.3.7. Stream monitoring

The stream monitoring programme is designed to provide estimates of water and nutrient transport to lakes and marine water and to follow the trends in stream quality. The monitoring programme also has to elucidate the relationship between inputs from the catchments and nutrient concentrations in the streams.

A large number of marine loading stations and lake inflow stations have been established. However, they do not cover the entire country and inputs from unmonitored catchments have to be calculated separately based on information about their size and characteristics. The sources of the nutrient transport are quantified based on knowledge of, among others, wastewater discharges and land use in the individual catchments. Nutrient turnover in the streams and lakes is also determined, by such means as calculating denitrification and phosphorus retention in lakes.

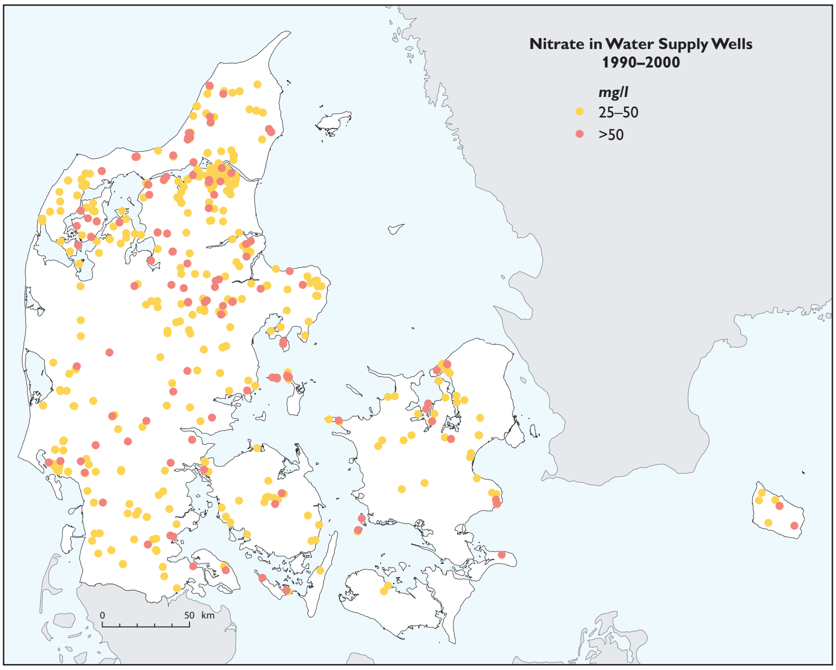

Fig. 26 Nitrate concentration in water-supply wells based on all analyses from the period 1990-2000. Only wells with above 25 mg l^{-1} nitrate are included (GEUS, 2001).

Several of the stream stations in marine loading and lake inlet network and a number of additional stations make up the stream catchment loading network. These streams can be grouped according to the natural and anthropogenic conditions in the catchments. Thus, the monitoring results can be used to assess the current state and developmental trend in water quality and nutrient transport for each of the catchment loading category networks (Table 7).

Table 7 Number of monitored stream stations grouped according to the natural and anthropogenic conditions in the catchments and sampling frequency for nutrient analysis.

	Number of stream stations	Sampling frequency(number of samplings per station per year)
Uncultivated rural catchments	9	12-26
Agricultural catchments without point sources	94	12-26
Catchments with point sources	70	12-26
Catchments with freshwater fish farms	5	12-26
Unclassified catchments	53	12-26

The monitoring also includes a biological programme, e.g. assessment of fauna indexes.

2.3.8 Nitrogen concentrations in streams

Average nitrogen concentrations in stream water at monitoring stations are shown in Fig. 27. It can be seen that nitrogen concentrations are higher on the loamy soils of east Denmark than on the sandy soils of west and north Denmark. This is because water drains through the upper layers of the loamy soils where nitrate reduction is sparse. On the sandy soils the hydrological pathways are much deeper, often through nitrate reducing soil layers. Hence, nitrate reduction is much more pronounced. However, there is a belt on the sandy areas in north Jutland with high nitrogen concentrations in the streams. This is due to lack of reduced soil layers.

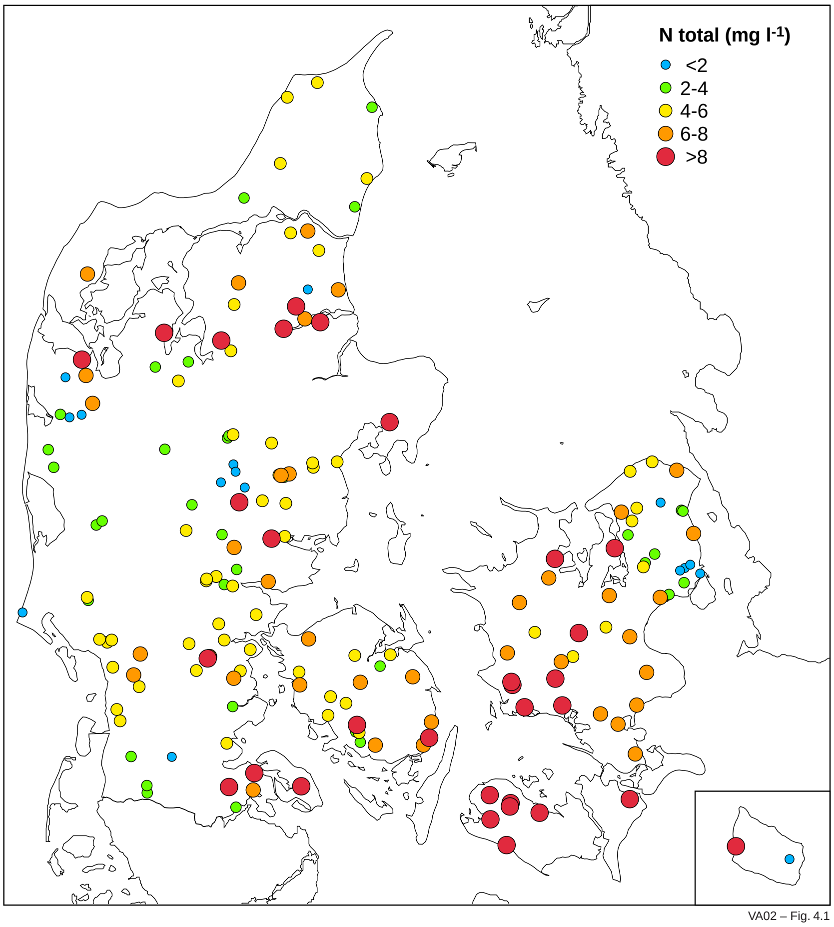

Fig. 27 Concentrations of total nitrogen in monitored streams in 2001. Flow weighted concentrations (Bøgestrand, 2002).

2.3.9 Lake monitoring

The lake monitoring programme encompasses two different, but mutually dependent knowledge levels:

- A knowledge level supported by the results of an intensive programme in selected lakes designed to reveal causal relationships between both the important elements and processes in the lake and between external pressures and consequences for lake environmental state (Table 8). The intensive monitoring programme for these lakes thus encompasses all the important descriptive variables in order to ensure a sound basis for comparative description of their environmental state and development. These variables are water, chemical and physical variables, phyto- and zooplankton, sediment chemistry, macrophytes, fish stock and composition.
- A knowledge level encompassing results for a few, primary variables from a large number of lakes aimed at providing a general picture of the environmental state and developmental trends in Danish lakes (Table 8).

The results of the intensive and extensive national programmes can be combined to provide a national assessment of lake environmental state and developmental trend.

Table 8 Number of monitored lakes and frequency of sampling.

	Number of lake stations	Sampling frequency (per station)
Intensive programme	31	19 per year, many descriptive variables
Extensive programme	192	1 every three years, few variables

2.3.10 Additional data – registers on agriculture

The Ministry of Agriculture collects large numbers of agricultural data for administrative purposes. There are three main sources: fertiliser accounts, livestock register and general agricultural register.

Fertiliser accounts: The Danish Action Plans involve tight regulations on nutrient utilisation employing nitrogen quotas and requirements to the effectiveness of utilisation of nitrogen in organic manure. All farmers are given a nitrogen quota based on nitrogen fertiliser standards for each crop (Table 5). The nitrogen standards refer to the effective nitrogen, i.e. immediately available for plant growth. All nitrogen in inorganic fertilisers is regarded as effective. For organic manure only part of the nitrogen is readily available for plants, the legislative requirement to utilise nitrogen in organic manure being considered as effective (Table 9). The consumption of fertiliser nitrogen and required utilisation of nitrogen in organic manure is not to exceed the nitrogen quota at farm level, in other words:

Fertiliser N + Required utilisation of N in organic manure ≤ Farm N quota

Table 9 First-year-requirement (%) to utilise nitrogen in organic manure. The requirement has been tightened several times throughout the Action Plan periods. Second-year-requirement is 10% for slurry and farmyard manure and 15% for deep straw bedding.

	1994	1996	1998	2000	2002	2003
Pig slurry	45	45	50	55	60	65
Cattle slurry	40	40	45	50	55	60
Farmyard manure	30	40	40	45	No data	55
Deep straw bedding	15	15	15	20	25	30

In order to ensure that farmers comply with these regulations, all farmers must submit a fertiliser account to the Plant Directorate under the Ministry of Agriculture. The accounts must include information on:

- number and type of livestock,
- crop area and winter crop coverage,
- farm nitrogen quota (based on crops acreage),
- use of nitrogen in inorganic fertilisers,
- application of organic manure (based on number of livestock and export/import of organic manure),
- requirement to utilise nitrogen in organic manure (depends on the source and type of manure, Table 9).

In 2001 about 60,000 farmers reported to the Plant Directorate. The data are stored in a “fertiliser account” database.

Livestock register: All livestock farms supply information on their farm size, and number and type of animals.

General agricultural register: All farmers applying for EU crop area subsidies supply information on their crops, the data being linked to geographical block units.

Future water monitoring will be influenced the implementation of the Water Framework Directive (EC, 2000) and the Groundwater Protection Directive (EC, 2003)

3. DISCUSSION AND DATA INTERPRETATION

3.1 Evaluation of Action Plans

In Denmark the first Action Plan on the Aquatic Environment was passed in 1987. The environmental target was to reduce nitrogen emissions to water by 50%. This target was not easy to reach and further Action Plans were adopted; the Action Plan for Sustainable Agriculture in 1991 and 1996, and the Action Plan for the Aquatic Environment II in 1998. The environmental target has been maintained and was met in 2003. The Action Plan II also provides justification for the Danish implementation of the Nitrates Directive.

Evaluations of the Action Plans have been carried out at politically agreed dates. An evaluation of Action Plan II was published in December 2003 (Grant & Waagepetersen, 2003). Several data sources were employed for the evaluation: agricultural statistics, registry data from the Ministry of Agriculture and monitoring data. An evaluation must include:

- status for the implementation of the agricultural measures;
- a trend analysis of the consumption of nitrogen fertilisers;
- an evaluation of the effect on the environment.

Examples of these three steps are shown in Figs 28 to 30.

The environmental effects of the Action Plan have been assessed by modelling nitrate leaching from agricultural fields, partly for the fields of the agricultural monitoring catchments, partly for the entire country.

For the agricultural monitoring catchments modelling was carried out by means of an empirical model and detailed monitoring data on agricultural practice at the field level. The applied model (N-LES) was first developed in 1991 (Simmelsgaard & Djurhuus, 1998) and revised in 2000 and again in 2002 (Kristensen, 2002b). The model is based on measurements of nitrate leaching obtained partly from the agricultural monitoring programme and partly from other research programmes in Denmark.

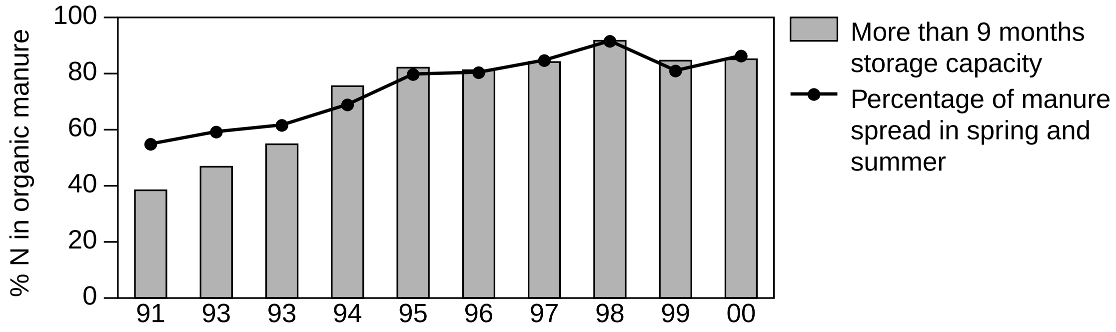

Fig. 28 Development in storage capacity and spreading time for livestock manure in Denmark, the agricultural catchment monitoring Programme 1991-2001 (Grant and Blicher-Mathiesen, 2002). The observed development is due to the obligation for farmers to build slurry tanks with minimum 9 months storage capacity and the prohibition to spread slurry and manure in the autumn and winter. However, on grassland and areas with winter rape slurry application is allowed in the autumn.

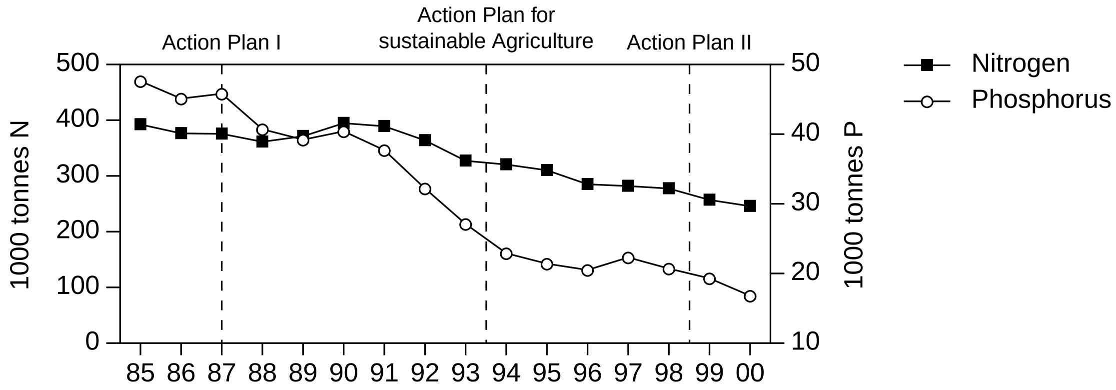

Fig. 29 Consumption of nitrogen and phosphorus fertilisers in Denmark during three Actions Plans on the Aquatic Environment (Statistics Denmark, 2001).

For the entire country, a large number of hypothetical farm management systems were defined so that the values of the main variables corresponded to the statistics for each region. Fertilisation plans for the individual fields of these hypothetical systems were established using information from the agricultural monitoring programme. Nitrate leaching was then calculated by means of both the empirical model described above (N-LES) and a deterministic model (Daisy). Modelling was done for an average weather year (Table 10).

Based on all modelling results, it was estimated that nitrate leaching had been reduced from 311,000 tonnes N in 1985 to 168,000 tonnes N in 2002, a reduction of 37%. This trend is verified by a similar reduction in the total nitrogen surpluses in Danish agriculture (184,000 tonnes N) during the same period (Fig. 30).

Table 10 Modelled nitrate leaching for the entire agricultural area in Denmark from 1985 till 2000, based on three different methods: the agricultural catchment monitoring programme using the empirical model N-LES, and calculations for the entire country using both N-LES and the deterministic model Daisy (Grant & Blicher-Mathiesen, 2002).

Scenarios	Before Action Plan I 83-85[2)]	Action Plan I + Sustainable Agriculture 88-90	94-96	95-97	96-98	97-99	Action Plan II 98-00	99-01
	1000 tonnes N	-----------------		1000 tonnes N	----------------		1000 tonnes N	
Agricultural Catchment Monitoring (N-LES)		288	225	218	215	208	201	183
Entire Country								
DAISY	311	271	263	246	236	236	217	211
N-LES	317	290	232	220	222	219	212	209
Average	315	280	240	230	225	220	210	200

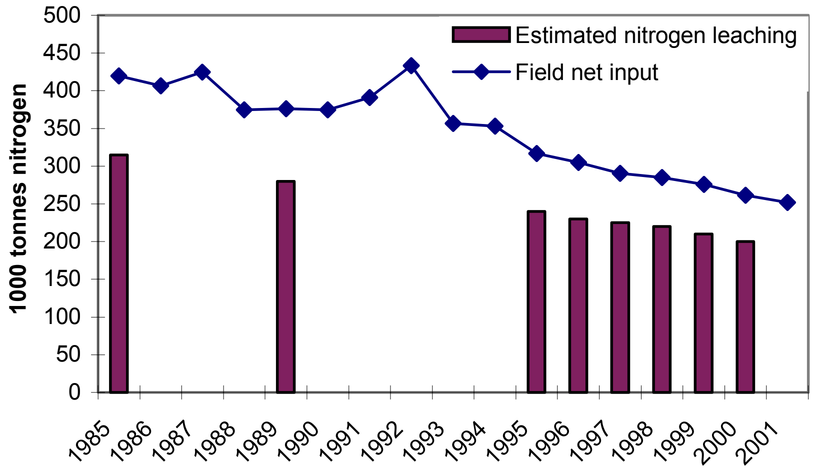

Fig. 30 Net input of nitrogen to the agricultural area in Denmark based on statistical data and the estimated development in nitrate leaching from the agricultural area (Grant & Waagepetersen, 2003).

The environmental effect on surface waters may also be calculated based on monitoring data for soil water, streams and lakes. There is a large variation in nutrient concentrations between years, hence it has been necessary to employ a statistical trend analysis allowing for this variation. We have used a “Kendall seasonal test” (Hirsch & Slack, 1984). For the period 1989-‘90 till 2002 we found a reduction in nitrate concentrations of 41% and 31% respectively, for soil water and streams in agricultural areas.

3.2 Danish derogation from the Nitrates Directive

In connection with the Danish derogation request to the Nitrates Directive, the effect of applying 230 *vs.* 170 kg organic N ha^{-1} on nitrate leaching was estimated. This was done assuming full implementation of the Action Plan II with respect to nitrogen fertiliser standards and requirement level of utilisation of livestock manure. The calculation has been done in three steps:

1. average crop rotations were established on basis of data obtained from the agricultural catchment monitoring programme;

2. fertilisation plans for these rotations were established on basis of the nitrogen fertiliser standards, available nitrogen in organic manure and the utilisation requirement and the permitted amount of nitrogen fertiliser;
3. modelling of nitrate leaching from these crop rotations and fertilisation plans was carried out for two soil types: sand (5% clay) and loam (12.5% clay), and for two regions with different levels of precipitation (Table 11).

Table 11 Model estimation of N-leaching and nitrate concentrations in water leaving the root zone for cattle holdings with livestock densities of 2.3 and 1.7 livestock units (LU) per ha, two soil types and two climate zones. N standards and utilisation of organic N apply to regulations of Action Plan II.

	LU	East-Mid Denmark precititation 820 mm		West Denmark precipitation 970 mm	
		N-leaching	Nitrate conc.	N-leaching	Nitrate conc.
	per ha	kg N ha^{-1}	mg NO_3 l^{-1}	kg N ha^{-1}	mg NO_3 l^{-1}
Sand	2.3	71	70	80	58
Loam	2.3	53	67	59	58
Sand	1.7	67	66	76	55
Loam	1.7	49	62	56	55

It was estimated that nitrate concentrations in the root zone water for livestock farms with more than 70% of the land cropped with beet, grass and grass catch crops and 170 kg nitrogen in organic manure per hectare will be 55-66 mg N l^{-1} after full implementation of Action Plan II with respect to stipulated fertiliser standards and utilisation of livestock manure. The Danish derogation of 230 kg nitrogen in organic manure per hectare was calculated to increase nitrate concentrations by 3-5 mg N l^{-1} (approximately 6%).

3.3 Coherence between variations in groundwater chemistry and groundwater infiltration

The premises for doing meaningful analyses of time series are that the phenomena one describes are dependent on time in a transparent way. This means that when samples are taken, the age of the water should increases regularly with depth and that the catchment of a screen does not change.

These premises are not fulfilled if the groundwater potential changes and then induces changes in the flow pattern (Fig. 31). It is therefore very important to know all the factors that may interfere when the groundwater quality changes. It may be due to changes in land use, but it may also be changes in the natural conditions.

Four wells in Fig. 31 show a clear coherence between the variations in groundwater level and changes in groundwater chemistry. In the four cases the peak in the groundwater level from 1994 to 1997 induces an increase or decrease in the concentration of nitrate or sulphate which may be due to changes in the flow pattern to the screens. If the aquifer is homogenous and unconfined. increasing nitrate with a decrease in groundwater level should indicate a higher nitrate concentration in the upper aquifer (Samsø well no. 25.1 and Fillerup well no.20.2). However, in the two other cases (Samsø well no. 12.1 and Hvinningdal well no.2.1) the reaction is opposite, indicating that increasing groundwater level also increases the nitrate concentration, to be reduced later on. Changes between clear oxic conditions and clear reducing conditions are also seen.

Fig. 31 Nitrate and sulphate concentrations compared to time-variable groundwater level in monitoring wells in Århus Amt (1999).

The nitrate content in the youngest groundwater is monitored in the five agricultural watersheds both in sandy and clayey areas, and the variations in the nitrate content together with the winter precipitation from the last 12 years are illustrated in Fig. 32. The screens in these watersheds are located from 1.5 to 5 metres below the surface. The median values of the nitrate content is 2-3 times higher in the sandy areas than in the clayey areas, but for both types the trend in nitrate content roughly follows the trend of the winter precipitation.

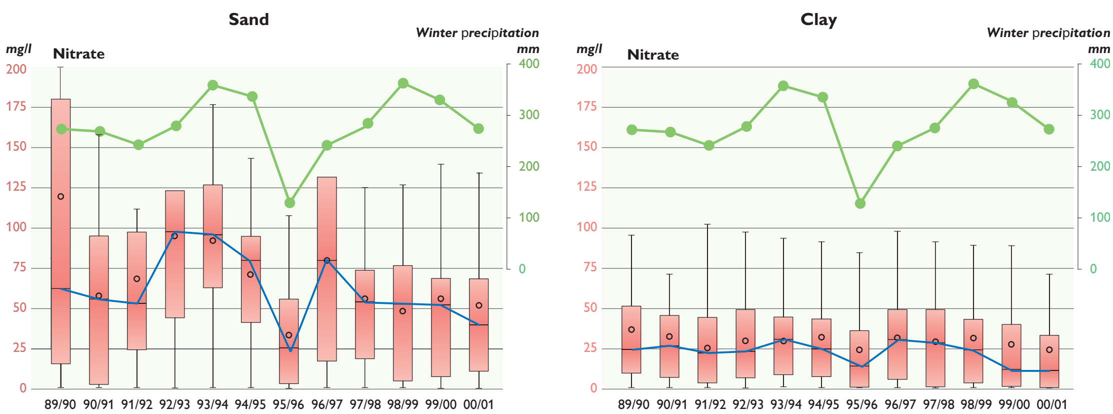

Fig. 32 Nitrate in the agricultural watershed areas divided in sandy and clayey soils, compared to winter precipitation from the 4th and 1st quarter of the years (upper curve). (GEUS, 2002).

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Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Germany

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Abstract Germany applies the action programmes across its entire territory, pursuant to Article 3 (5) of the Nitrates Directive. The main subjects of the action programmes are defined by the Use of Fertilisers Ordinance (Düngeverordnung) of 26 January 1996 which is legally binding throughout Germany. The effectiveness of the action programmes is monitored by several surface-water, groundwater and coastal-water networks. In accordance with the Nitrates Directive the results of the actions programmes and the development of nitrate concentrations in groundwater and surface waters are reported to the Commission every four years. At Länder (Federal States) level a multitude of specific regional and local action programmes have been established. In addition, effects monitoring programmes are carried out at Länder and regional level. In many Federal States co-operation between farmers, local water authorities and water suppliers plays an important role in reducing nitrate concentrations in groundwater and surface water.

1. INTRODUCTION

1.1 General

The starting point for many discussions was the increasing nitrogen surplus in many European countries, which led to increasing nitrate concentrations in groundwater and surface waters. This situation throughout Europe is described in Fig. 1.

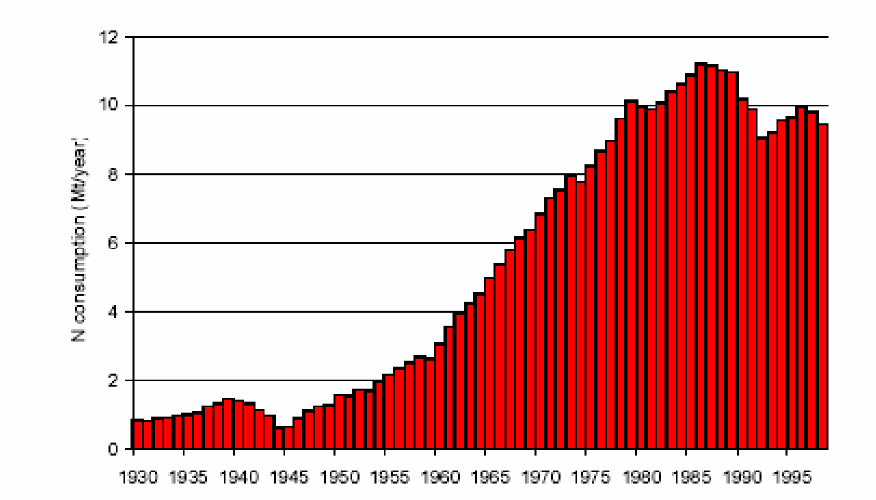

Fig. 1 Mineral N fertiliser consumption – EU15 Member States, from 1930 to 1999. Source: European Fertilizer Manufacturer Association (EFMA) (millions of tonnes of nitrogen per year).

More than half of all nitrogen inputs and over 40% of all phosphate inputs to Germany's water resources originate from agricultural land. The nutrient content in German water bodies has multiplied over the last 30 to 40 years. For decades now, a continuous rise has been observed in the nitrate content of groundwater and drinking water, especially in regions where agriculture is intensive. The quality of drinking water in such areas is severely at risk.

According to the "Nitrogen Reduction Programme" (report of a working group convened by the German Conference of Environment and Agriculture Ministers) agriculture accounts for 48% of total nitrogen emissions in Germany. Transport (22%), human nutrition and wastewater (17%), energy, heating and industrial processes (13%) all account for a much lower proportion of emissions than agriculture.

To reduce nutrient losses from agriculture and to meet the obligations of the Nitrates Directive 91/676/EEC the German government adopted in 1996 a code of good agricultural practice in the use of fertilisers, legally binding by the Use of Fertilisers Ordinance (Düngeverordnung), which includes a wide range of measures to reduce nutrient losses. For example nitrogenous fertilisers may only be applied in a way that supplies the nutrients they contain in accordance with the needs, and mainly during plant growth. Moreover, soils must be capable of absorbing fertilisers. Application equipment must comply with technological standards and must guarantee proper dosing and distribution as well as low-loss application. And fertilisers may not be discharged directly into water bodies or float on to adjacent land. In addition, livestock manure must be analysed for total nitrogen and phosphate (slurry also for ammonia). Generally livestock manure must be applied in the same way as comparable mineral fertiliser. Furthermore immediate ploughing-in after spreading on fallow land to avoid ammonia emissions is obligatory. Moreover, at farm level, there are upper limits for the application rate of total nitrogen in livestock manure. And farms with more than 10 ha of agricultural land must draw up a balance sheet of nutrient inputs and outputs.

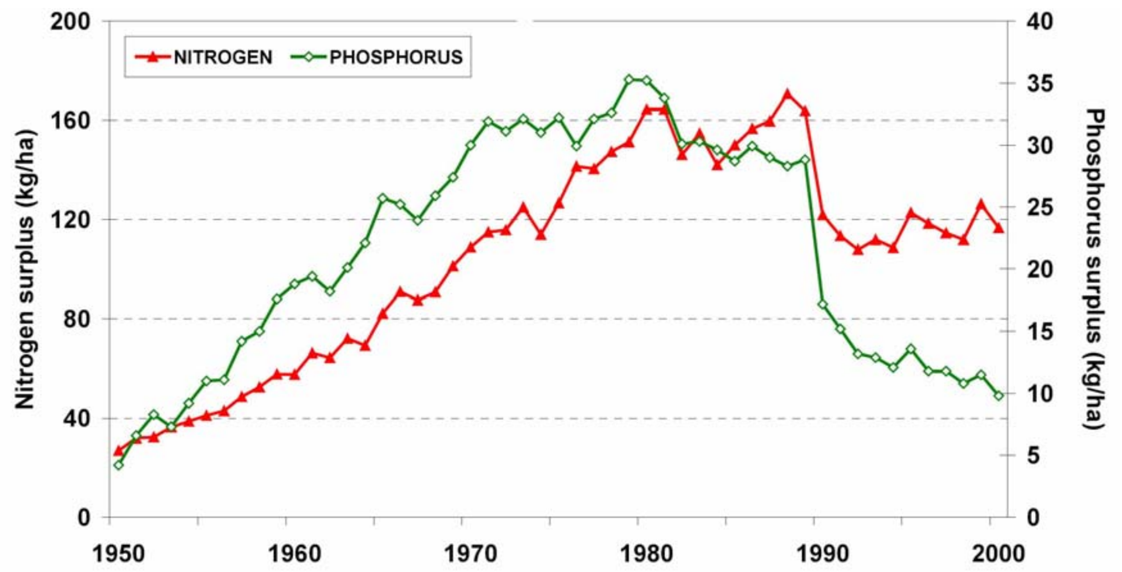

Fig. 2 Development of the nutrient surplus of farmland in Germany from 1950 to 2000 (farm gate balance; calculation according to PARCOM Guideline); Source: Behrendt *et al.* (2003).

The starting point and most important information on the potential risk of contamination by nitrate is the nitrogen surplus under arable land and areas with intensive animal husbandry. In Germany the nitrogen surplus increased from about 28 kg N ha^{-1} (arable land) in 1950 to about 140 kg N ha^{-1} in 1989, see Fig. 2. In Germany the nitrogen surplus shows a trend very similar to the situation throughout Europe. It has fallen by 27% since reaching its peak in 1987. Nevertheless the calculated resulting nitrate concentrations in water are significantly higher than 50 mg l^{-1}, the limit value for nitrate in the Drinking Water Directive.

1.2 Description of natural factors influencing nitrate occurrence

Climate and climatic regions

Germany has a variable climate with frequent weather changes from day to day. Summers and winter weather patterns may also change from year to year depending on whether oceanic or continental influences dominate. The country can be divided into six climatic zones: North Sea coastland, Baltic coastland, North German plain, central and southern uplands, upper Rhine valley, and the Bavarian Alps.

The North Sea coastland, which includes the coast from the mouth of the river Ems to the mouth of the Elbe, the East Frisian Islands and the west coast of Schleswig-Holstein, is the mildest area of Germany in winter although cold fronts are brought into it with eastern winds. Prolonged periods of temperatures below 0 ºC are rare. While autumn is the wettest season, precipitation occurs all year round. The region is open to the influences of Atlantic storms.

The Baltic coastland includes the east coast of Schleswig-Holstein. It has a more severe winter than the North Sea coast although long freezing spells are not frequent. The wettest months are July-September, but there is rainfall all year round. Rain in the summer tends to be thundery.

In the North German Plain, a low-lying area, winter is significantly colder and severe cold spells may last for several months. However, some years these spells may be short and infrequent. Although it is the wettest season rainfall in summer is often thundery and of short duration.

Central and southern Germany includes all uplands south of the North German plain up to the alpine foothills west of the Rhine gorge. Temperatures vary mainly as a function of altitude so that the higher parts of Bavaria and the Harz mountains have the coldest winters and the longest duration of snow cover. Summer is generally warm despite the heavier rainfall. As in much of Central Europe summers may vary in character from one year to another, some being warm and dry, others cloudy and wet.

The upper Rhine valley, a small district in south-western Germany, is the warmest part of Germany in spring and summer and can be very sunny. On the other hand, winters can be cold because of the proximity of the Alps and the distance from the ocean. Rainfall is relatively evenly distributed throughout the year, summer having the wettest months.

In the Bavarian Alps, the wettest months are the summer months with rainfall above 130 mm per month. Temperatures can be below zero over periods of three months or more, with the lowest in December and January.

Distribution of rainfall and groundwater recharge

Precipitation is quite unevenly distributed all over Germany. The mean annual rainfall is about 660 mm. Neumann & Wycisk (2002) calculated groundwater recharge rates for Germany. The calculation was done using corrected figures for the precipitation distribution minus direct run-off and evapotranspiration. The average was 137 mm $year^{-1}$ ranging from less than 25 to over 400 mm $year^{-1}$ (Fig. 3).

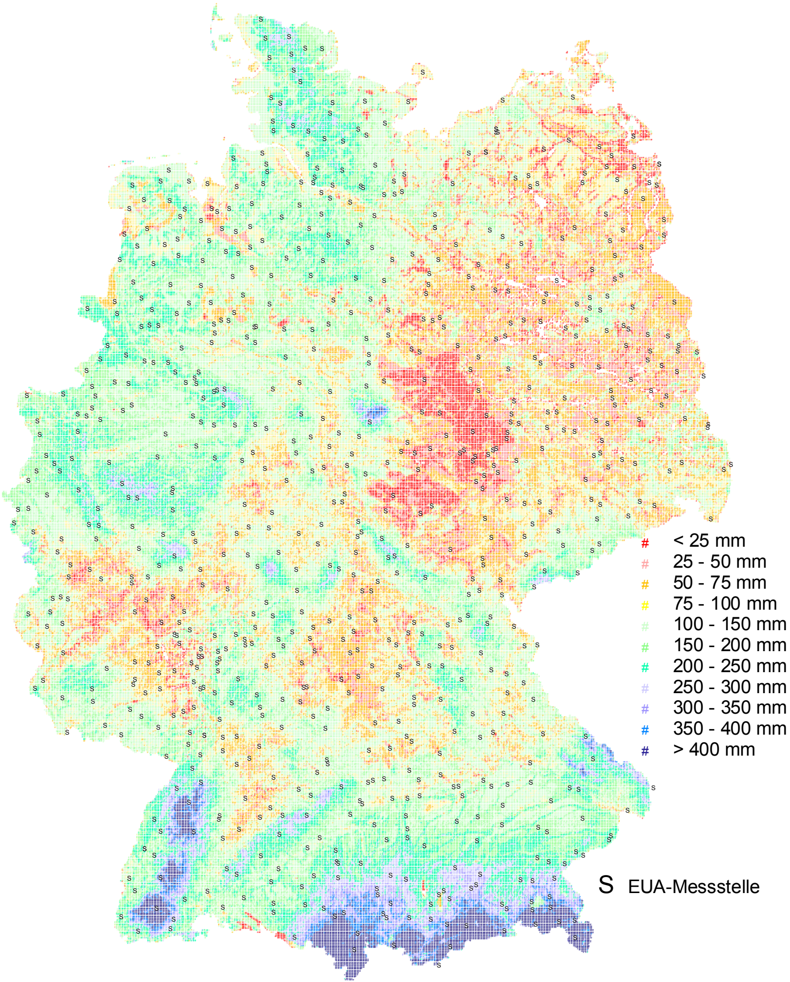

Fig. 3 Groundwater recharge rates according to Neumann &Wycisk (2002) and position of sampling sites used for reporting to the **E**uropean **E**nvironmental **A**gency (EEA-monitoring sites) (in German: **E**uropäische **U**mwelt**A**gentur = EUA–Messstelle).

Aquifer type and hydrogeological units

Another important factor influencing nitrate occurrence is the type of aquifer. Under comparable conditions with respect to depth, type of overlying strata and agricultural use, aquifers in unconsolidated rock are generally less vulnerable than comparable ones in fractured rock. Figure 4 gives a rough idea of the percent distribution of these types of aquifer in Germany's main hydrogeological units (Hydrogeologische

Großräume). It should be noted that that Fig. 4 only shows the number of sampling sites (in percent) situated in each of the aquifer types. The percent distribution of aquifer types might be somewhat different.

1.3 Description of human factors influencing nitrate occurrence

Approximately 50% of the land area in Germany is used for agriculture, mostly intensively. The area covered by forests is slightly less than 30%, and only 4% are nearly natural areas (nature reserves and national parks). The total arable land is about 17 million hectares, of which 11.9 million ha are areas under cultivation and 5.3 million ha are grassland and pasture. About 10.5 million ha is covered by forest.

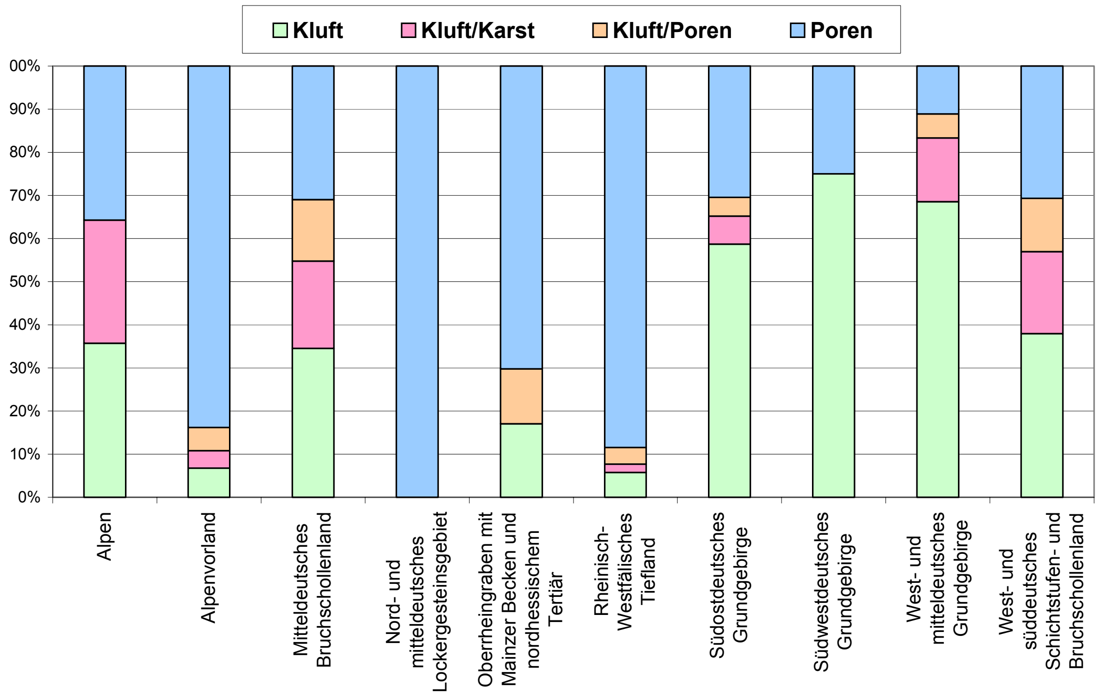

Fig. 4 Number of sampling sites (in percent) situated in different types of aquifer (fractured rock = Kluft), karst = Karst, and unconsolidated rock = Poren) in Germany's main hydrogeological units (Hydrogeologische Großräume).

1.4 Overview of monitoring networks

As Germany applies the action programmes across its entire territory, there are no monitoring programmes for the identification of nitrate vulnerable zones (NVZ).

1.4.1 Monitoring network for surface water

For more than 20 years inorganic nitrogen components (ammonia, nitrite and nitrate) have been analysed at many surface water sampling sites in Germany. The map in Fig. 5 shows the location of 152 representative sites at major watercourses in Germany (LAWA network). This "water quality map of nitrate" gives an overview of the development of the nitrate concentration in surface water from 1992 to 2001. In Germany nitrate concentrations are classified according to a system (LAWA, 1998) consisting of seven quality classes (Table 1).

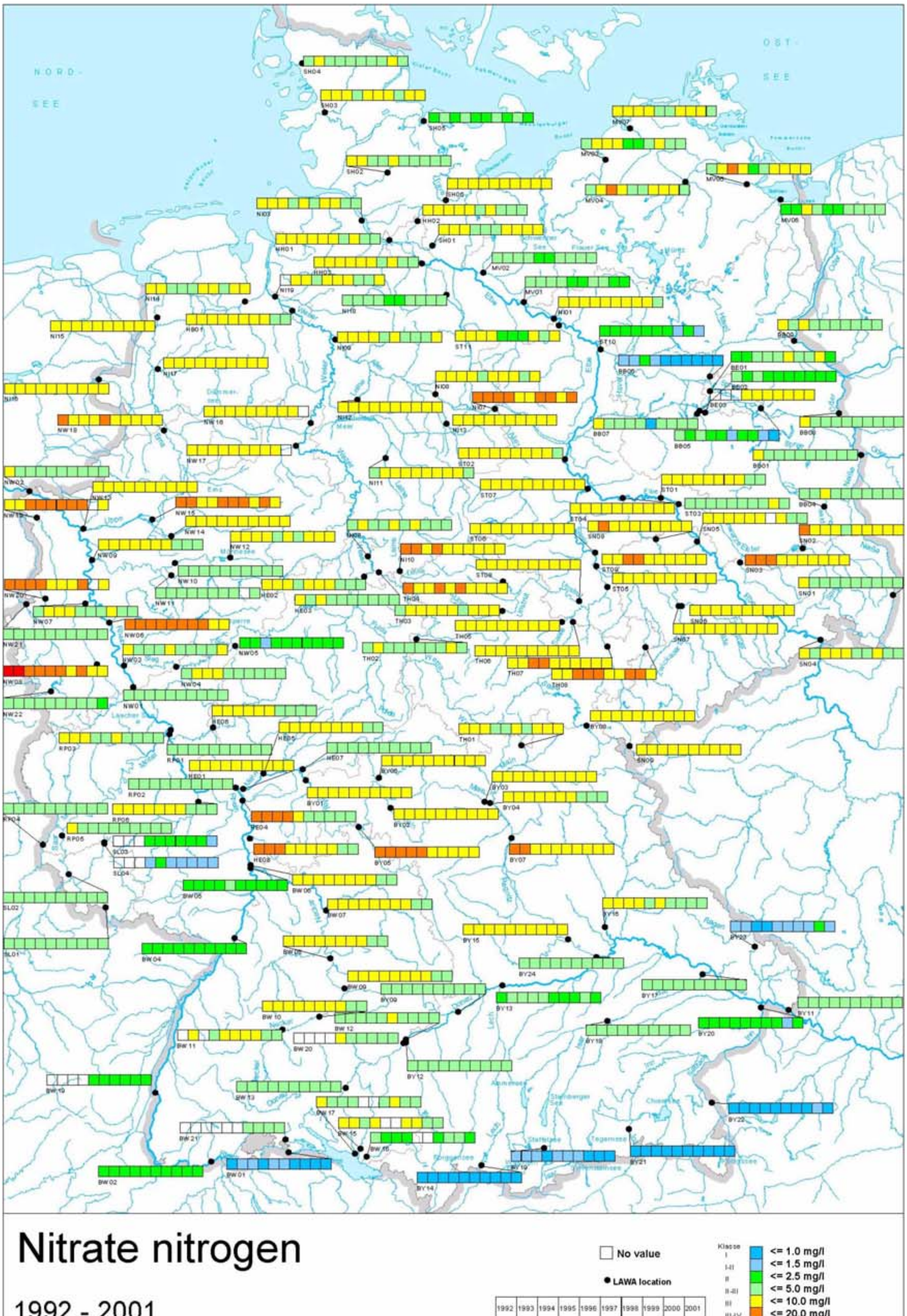

Fig. 5 Development of nitrate nitrogen concentration in surface waters (90-percentile) from 1992 to 2001. (Classification: see Table 1 – mg l^{-1} NO_3).

Table 1 German classification system of nitrogen/nitrate in surface waters.

Class	mg l^{-1} N	mg l^{-1} NO_3
I	≤ 1	≤ 4.4
I – II	≤ 1.5	> 4.4 - 6.6
II	≤ 2.5	> 6.6 - 11.1
II – III	≤ 5	>11.1 - 22.1
III	≤ 10	> 22.1 - 44.3
III – IV	≤ 20	> 44.3 - 88.5
IV	> 20	> 88.5

In Table 1, class II with an upper limit of 2.5 mg N l^{-1} is the target value. For classification the 90-percentile values of all analyses within a year are used.

For the second German Nitrates Directive Member States report available in 2000 it was necessary to estimate the development of the nitrate concentration between the 1992-1995 and 1996-1999 action programmes. A total of 15 surface water-sampling sites at major German rivers were selected for this purpose. For these sites a sufficient number of data as well as suitable time series were available (see chapter 2 "Effect Monitoring").

1.4.2 Monitoring network for coastal waters

For reporting on the development of nitrate concentrations in coastal waters, a total of ten sampling sites were selected, i.e. five at the North Sea and five at the Baltic Sea. The North Sea sites are representative of the estuaries of the rivers Elbe, Eider and Jade as well as the Wadden Sea. The marine environment is covered by these sites. The Baltic Sea sites represent the inner as well as the outer coastal waters. The geographical location of these sites is shown in Fig. 6.

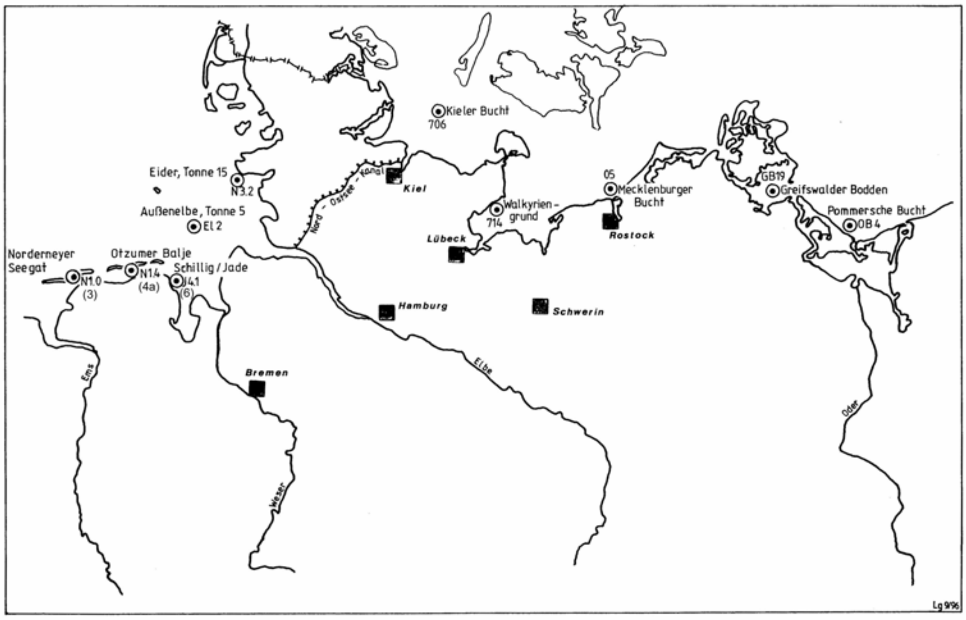

Fig. 6 Sampling sites in German coastal waters for monitoring of nitrate concentrations.

1.4.3 Monitoring networks for groundwater

For the first German Nitrates Directive Member States report the so-called “EU nitrate network” was established. It consists of about 180 sampling sites, located in areas with high nitrate concentrations in groundwater. The sites were selected and are operated by the Federal States. The criteria for the selection of sites were:
- site must be located in the upper aquifer, and
- contamination by nitrate has to be caused by agriculture.

The Commission’s report “Implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources - Synthesis from year 2000 Member States reports” stated that (quote) “*in Germany the network is unbalanced and incomplete, focusing only on areas of polluted groundwaters”*.

Therefore in its third Nitrates Directive Member States report to the Commission in 2004, Germany will add data of its representative groundwater monitoring network. As it was originally installed to fulfil existing obligations for reporting to the European Environment Agency (EEA), it is also referred to as the “EEA network” or “Groundwater Monitoring Network”.

The investigative concept of the “EEA network” is based on the idea of providing a representative survey of groundwater quality. Of major interest are the impacts of diffuse (non point source) anthropogenic inputs of contaminants, for example, nitrates, pesticides, acidifying components and other pollutants, on groundwater quality (Wolter *et al*., 2000).

Table 2 Number of EEA groundwater monitoring network sampling sites in each of the Federal States of Germany.

Federal state	Sampling sites	Area (km²)	Federal state	Sampling sites	Area (km²)
Bremen	2	400	Saxony-Anhalt	51	20,400
Hamburg	5	800	Hesse	49	21,100
Berlin	5	900	Mecklenburg-Western Pomerania	38	23,800
Saarland	6	2,600	Brandenburg	60	29,100
Schleswig-Holstein	36	15,700	North Rhine-Westphalia	77	34,100
Thuringia	30	16,300	Baden-Württemberg	79	35,800
Saxony	39	18,300	Lower Saxony	106	47,400
Rhineland-Palatinate	50	19,800	Bavaria	158	70,600
			Total:	791	357,100

Sampling sites for the EEA network were selected from existing monitoring networks of the federal states (Table 2). They reflect the known distribution of contaminated and uncontaminated groundwater bodies within each state. Sampling sites representing contaminated bodies of groundwater are located in regions in which groundwater contamination is more frequent.

The ”EEA network” consists of about 800 sampling sites distributed more or less equally over the 16 Federal States. The number of sampling sites in each state depends on its size.

City states, that is Berlin, Hamburg and Bremen, are over-represented in terms of number of sampling sites in relation to their area. This apparent overweighing was found necessary in order to better describe groundwater quality in these states and the variations therein. At present there is an average of one sampling site per 450 km^2. In close co-operation with the Federal States, the Federal Environmental Agency defined the set of data necessary to characterise the sampling site and its catchment area. Important parameters are location and type of sampling site, petrographic composition of the aquifer, and predominant land use in the catchment area.

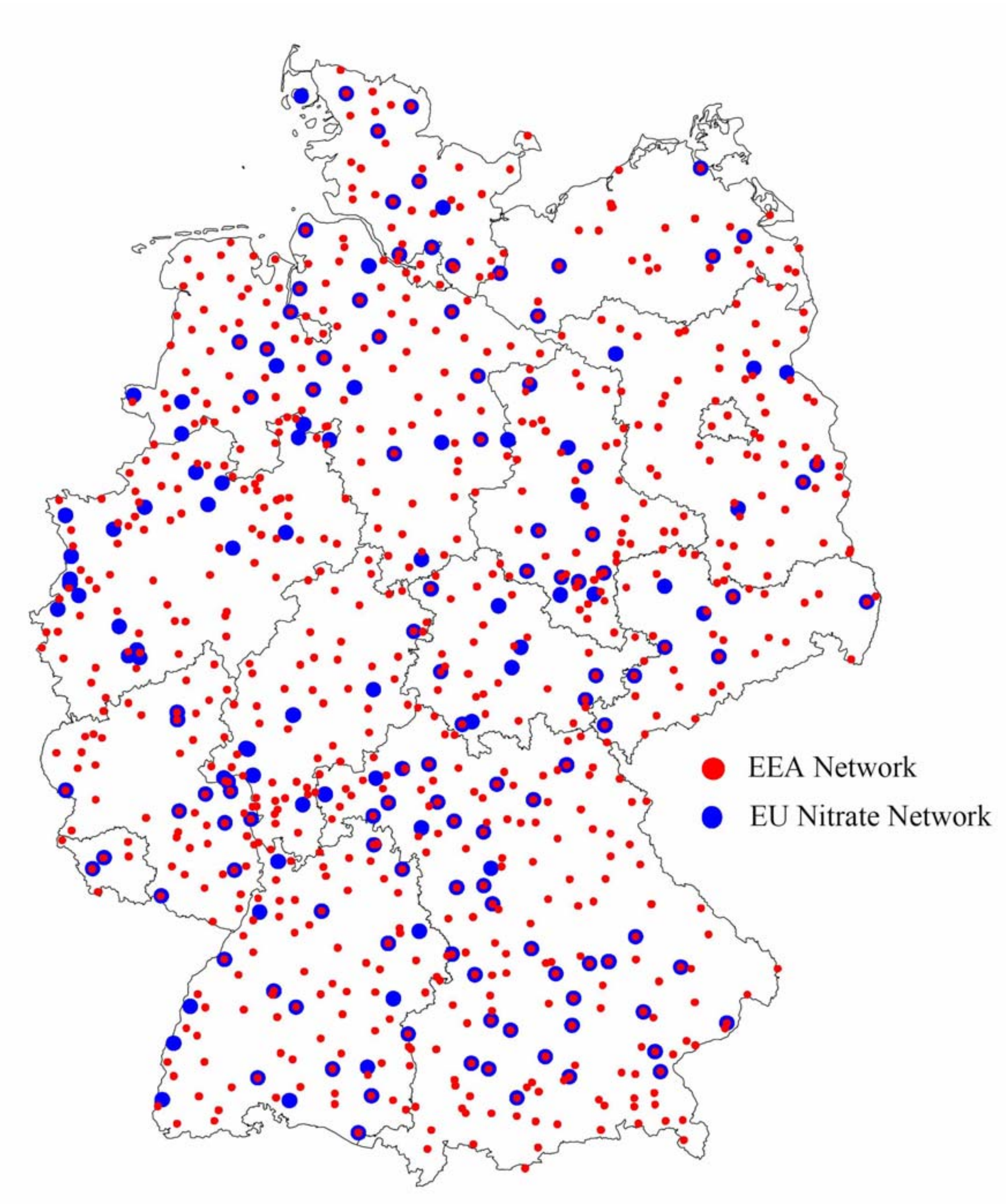

Fig. 7 Sampling sites of the EEA Network (red) and the EU Nitrate Network (blue).

In addition to temperature, conductivity and acidity, parameters characterising groundwater quality include all major anions and cations, selected heavy metals, metalloids, some organic components and selected pesticides (Table 3).

Table 3 Important parameters to characterise the sampling site, catchment area and groundwater status.

Sampling site:	Important parameters analysed:
Code number and location of sampling site	Groundwater specific data
Altitude of site and filter position	Temperature; pH; electrical conductivity.
Type of sampling site (well, spring, etc.)	O_2; NH_4; NO_2; NO_3; o-PO_4; Cl; SO_4; B; DOC
Land use	K; Na; Ca; Mg
Hydrogeology (stratigraphy, petrography)	Heavy metals/metals/metalloids Al; As; Pb; Cd; Cr; Fe; Cu; Mn; Ni; Zn
Type of aquifer (unconsolidated rock, fractured rock, karst)	Aliphatic halogenated hydrocarbons
River basin	Pesticides

In general sampling at the sites of the "EEA network" should be conducted at least twice a year. The data have to be reported to the Federal Environmental Agency once a year using a specific data transfer format. The Federal States have agreed to deliver data from earlier years for these 800 sampling sites, starting in 1990. In June 2000 a database was installed at the Federal Environmental Agency to store, verify and summarise the information delivered. In the meantime some ten thousand sets of data have arrived and have to be verified. After checking for compliance with certain formal criteria, data validity is verified by drawing up the ion balance and by comparing the reported concentrations with known concentration ranges of similar types of groundwater and of the sites where they were measured. The EEA network is designed to give a representative picture of groundwater quality in Germany (Fig. 8).

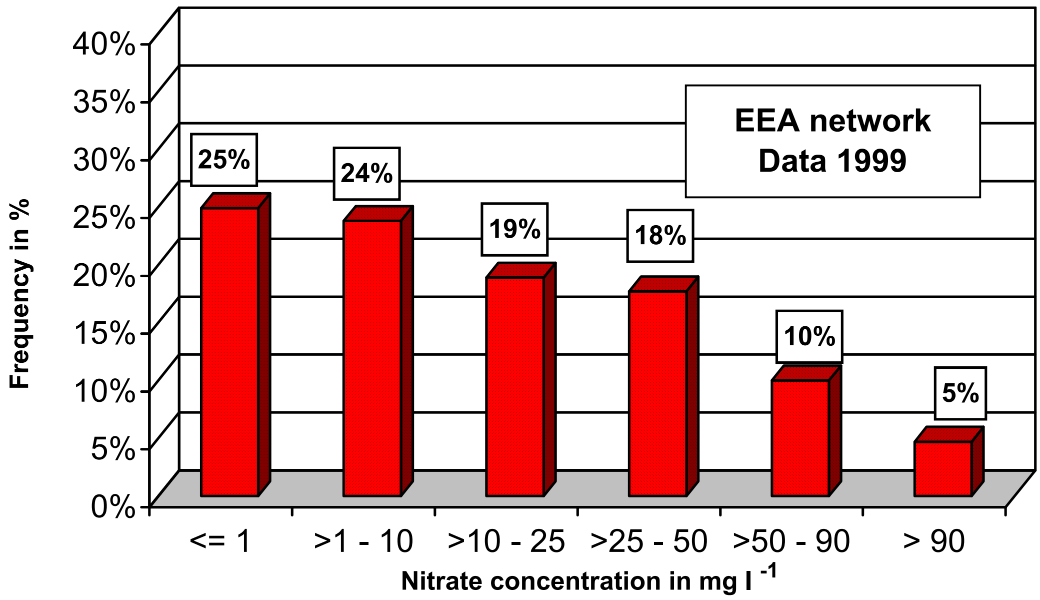

Fig. 8 Frequency distribution of nitrate in German groundwater according to the results of measurements in 1999 at 747 sites of the EEA groundwater monitoring network.

The German "EU nitrate network" was a specifically designed groundwater monitoring network for reporting in accordance with the Nitrates Directive. The Nitrates Directive requires regular reporting about the preventive measures taken by the member states. It provides that, at the end of each four-year programme (1995-1999, 2000-2003), and for each water monitoring report of measures associated with this programme, a report describing the situation and its development be submitted to the Commission. Germany has not designated vulnerable zones since the measures to limit nitrate contamination are applied throughout its territory.

The EU nitrate network was set up in order to depict the existing nitrate contamination of German groundwater resources and to evaluate the effectiveness of the measures enforced. It is focused on regions with significant groundwater contamination by nitrates. The network consists of 181 monitoring sites predominantly situated in the upper groundwater layer. Sampling sites selected had to be significantly influenced by nitrate from agricultural sources (see Fig. 7).

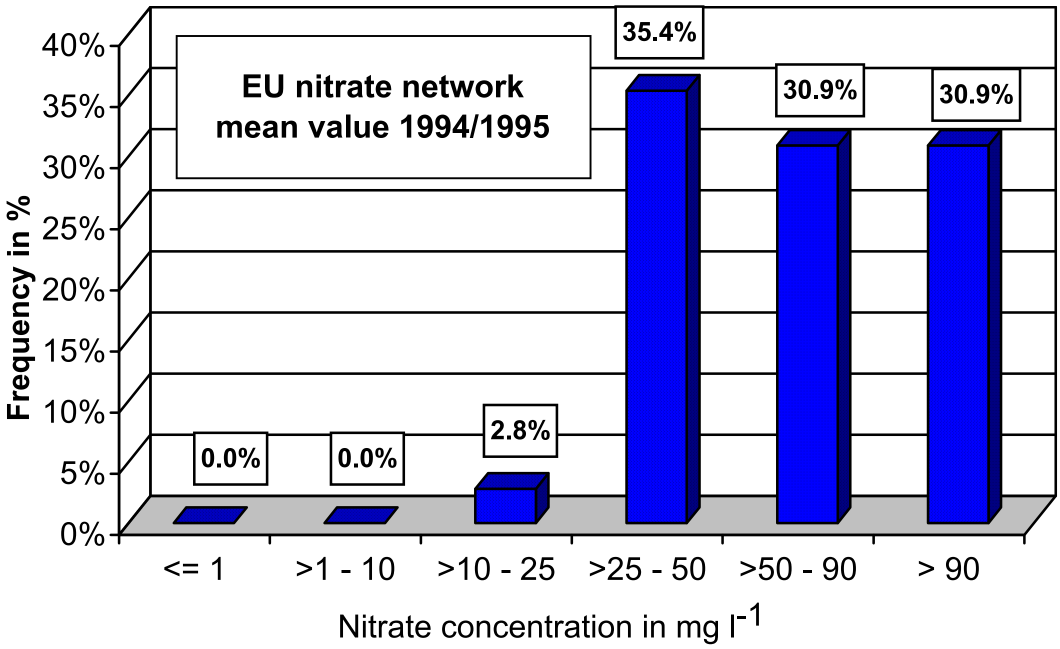

Fig. 9 Frequency distribution of the nitrate concentrations measured at stations of the German EU Nitrate Network in 1994/1995.

This means that unlike the EEA groundwater monitoring network, the EU nitrate network is not representative of the nitrate status of Germany's groundwater bodies. Compared to the "representative" nitrate distribution represented in Fig. 8, a significant shift is to be seen for the frequency distribution of the nitrate concentrations measured in the nitrate network (Fig. 9).

The reporting guidelines for the Nitrates Directive (EC, 1999) provide that the trend in nitrate contamination must be evaluated. The general trend is derived from the change in concentrations between the first and the second monitoring programme, carried out in 1994/1995 and 1998/1999 respectively. An upward trend was found for about 37% of the measuring sites, whereas 57% showed a downward trend. On the whole, a decrease in nitrate pollution can be observed in affected areas (see also Chapter 5).

In addition to these national networks, the Federal States have independent groundwater monitoring networks. Many of them are sub-networks to identify natural background levels as well as diffuse and point source pollution. Several Federal States have sub-networks to determine the impact of agriculture on groundwater quality. The number of sampling sites in these networks differs significantly from state to state.

Further information on these networks can be obtained from the environment or water resources management reports of the Federal States.

1.5 Environmental goals

In Germany there are no legally binding quality targets for groundwater and surface waters. Article 1a (Principle) of the Act on the Regulation of Matters Pertaining to Water (WHG, 2002) states:

(1) As an integral part of the natural environment and as a habitat for animals and plants, waters must be protected. They shall be managed in such a way that they serve the public interest, and in harmony with this interest, benefit individual users, and that avoidable impairments to their ecological functions and to the terrestrial ecosystems and wetlands directly depending on them do not occur, and hence that overall sustainable development is ensured. In this respect, account should be taken of the possibility that detrimental effects could be transferred from one protected commodity to another; a high level of protection for the environment as a whole, with due regard for the requirements of climate protection, shall be guaranteed.

(2) Where activities can have an impact on a body of water, everyone shall be obliged to take the care necessary under the circumstances in order to ***prevent pollution*** *of the water or* ***any other detrimental change in its properties****, in order to ensure that water is used economically, as is required in the interests of natural water resources, in order to preserve the vitality of natural water resources and in order to prevent the increase and acceleration of water runoff.*

That means all water bodies throughout Germany have to be protected. Good water status should be preserved, and contamination or any other detrimental change has to be avoided. Quality targets for groundwater were not defined in order to avoid any “filling up” of concentrations to these targets. It should be noted that the limit values of the German Drinking Water Ordinance (e.g. 50 mg l^{-1} NO_3) may not be applied to groundwater because in Germany legally binding groundwater quality targets do not exist.

For surface water the quality target for nitrogen is $\leq$ 2.5 mg l^{-1} (~ 11 mg l^{-1} NO_3), but this value too is not legally binding.

2. EFFECT MONITORING

2.1 General

In Germany, a country with a federal structure, competencies for agricultural and agri-environmental policy are shared between the State (Bund) level and the regional level (Federal States, Länder). Thus, with regard to policy implementation structures, the German situation is characterised by the fact that a considerable amount of implementation power is delegated to the individual regions (Länder), which may be one of the reasons why Germany has one of the most complex set of agri-environmental policies in the EU. Since the mid-1980s, and therefore long before the enforcement of Regulation 2078/92 (EEC, 1992), most Länder had already implemented their own agri-environmental programmes. These programmes were already partly co-financed by the EC under Regulation 797/85 (Art. 19) (EEC, 1985). In most cases, the programmes were initially implemented by the environmental administrations of the Länder and not by their ministries of agriculture.

Similar arrangements apply to the implementation of the EU Nitrates Directive. While Germany applies one action programme across its whole territory, the Use of Fertilisers Ordinance (*Düngeverordnung*, *DVO*, of 26 January 1996; BMELF, 1996) clearly states that it remains the responsibility of the Federal States (Länder) to more precisely define certain measures and to implement them. The same applies to the Code of Good Agricultural Practice (GAP). At Federal level it is defined through the Use of Fertilisers Ordinance, which is binding on all farmers. In addition, however, each of the Länder has worked out additional, more precise and often more restrictive regulations (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, BMELF, 1996, page 2).

Because Germany applies the action programmes across its entire territory, effect monitoring has to give a general overview of the effects of these programmes throughout Germany. According to the draft ”Guidelines for the Monitoring Required under the Nitrates Directive” (EC, 2003, 1999) effects should be monitored in regions where the most significant changes in agricultural practice are expected.

2.2 Effect monitoring for surface waters

Evaluating the development of nitrate concentrations and total nitrogen respectively in surface water is the simplest method to carry out effect monitoring. Based on the data of the 152 sites of the German LAWA network a reduction of nitrate-nitrogen concentrations in German surface waters has been visible since 1993 (Fig. 10).

The target of 2.5 mg N l^{-1} (90-percentile) -classes I, I-II and II- was reached only at 13% of the sites, but an improvement is visible. The number of sites with elevated nitrate concentrations (classes III to IV) is decreasing. But this development is due mainly to the installation of additional nitrification systems in municipal waste-water treatment plants instead of the measures that resulted from the Nitrates Directive.

Another type of effect monitoring is the evaluation of specific nitrate-trends according to the requirements of the reporting guidelines of the Commission (EC, 1999). This was carried out at 15 sites representing important watercourses in Germany. They are thought to be representative for Germany as a whole. As depicted in the map (Fig. 11) about half of the sites show a slight reduction of nitrate concentrations whereas the nitrate concentrations at the other sites remained stable. In addition in 2001 at all sites (see Fig. 5) the nitrate concentration was below the target value of 50 mg l^{-1}.

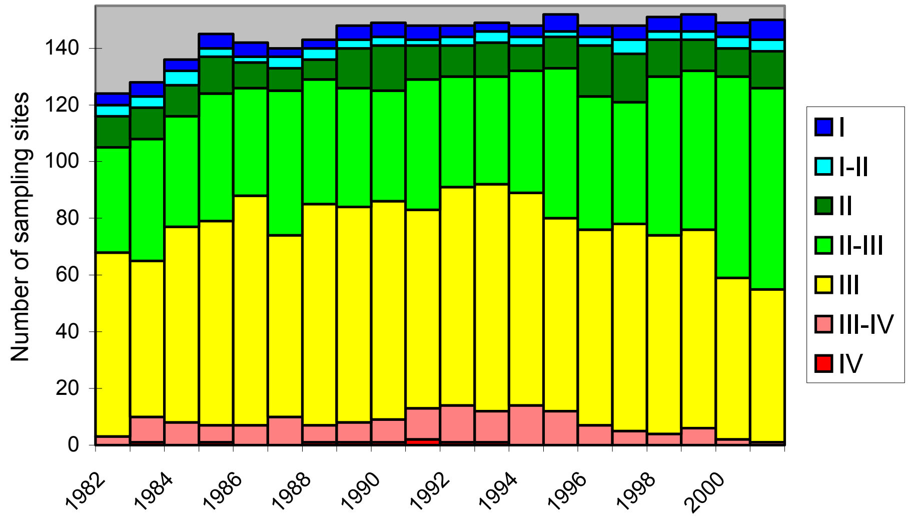

Fig. 10 Development of NO_3-N concentration in German surface waters from 1982 to 2001. Classification is based on observations from LAWA network (152 sites). The seven concentration classes are listed in Table 1.

The MONERIS model is another possible tool for effect monitoring. The **MONERIS** (**MO**delling **N**utrient **E**missions in **RI**ver **S**ystems) model was developed and applied to estimate nutrient inputs entering surface waters in river basins in Germany both from point sources and via all the diffuse pathways. This model is based on conceptual approaches for the quantification of different pathways for point sources, diffuse sources and retention, and also applies a geographical information system (GIS) including digital maps and extensive statistical information (Behrendt *et al.*, 1999 and 2003). This GIS-supported method can be used to obtain regionally-differentiated estimates for river basins more than 500 km^2 in size. The sub-models used for the quantification of diffuse sources are sub-models for groundwater, erosion, surface runoff, tile drainage, urban areas and atmospheric deposition.

MONERIS was applied separately to about 300 German rivers with an average catchment area of 1000 km^2, so that after up-scaling the whole German area is covered (Behrendt *et al.*, 2003).

As shown in Fig. 12 total nitrogen emissions decreased from 1985 to 2000, but mainly due to reduced emissions from municipal sewage plants and industrial direct dischargers, and to a significantly lower extent due to reduced emissions via drainage waters. Between 1995 and 2000 nitrogen inputs to surface waters from groundwater increased again.

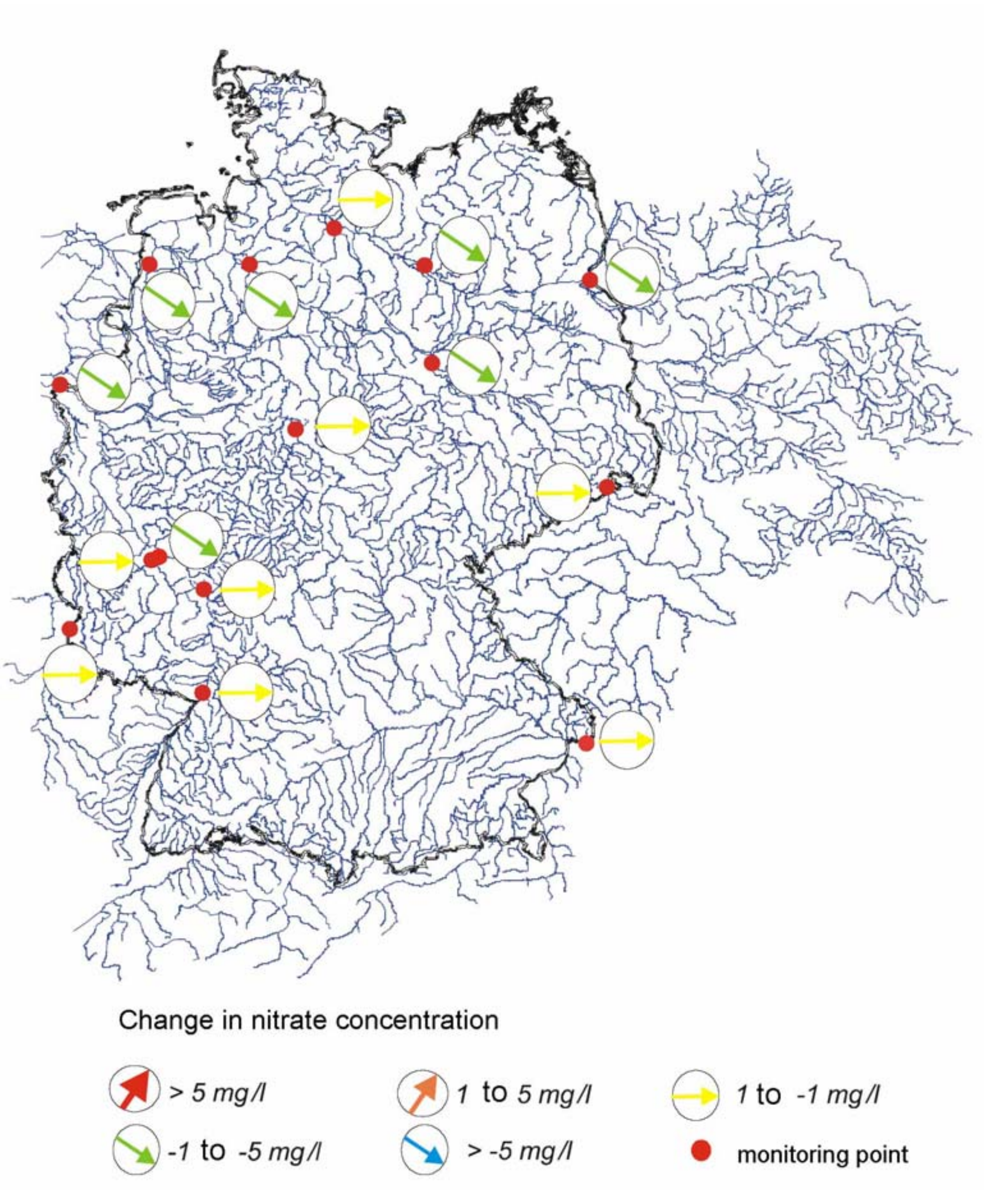

Fig. 11 Sampling sites and changes of mean nitrate concentration in winter from 1996-1999 to 1992-1995.

2.3 Effect monitoring for groundwater

For groundwater effects monitoring at federal level is simply based on the evaluation of nitrate trends. As stipulated in the reporting guidelines (EC 1999), mean nitrate concentrations at point 'zero', that is 1992-1994, and at the end of the first Nitrates Directive Action programme (or the second monitoring reporting period 1996-1998) have to be compared (see Fig. 13).

Of the 178 common EU nitrate network points analysed, about 58% show decreasing nitrate concentrations whereas 36% still show an increase in nitrate concentrations. Overall the action programmes are judged to be effective. Effect monitoring at federal level does not comprise detailed investigations at the site or its catchment. The Action programmes might also be effective at many sites at which nitrate concentrations are still currently increasing, because in some areas it takes years or even decades until the water reaches the top of the aquifer. In these cases effect monitoring should comprise a farm-gate balance, estimation of groundwater recharge, flow velocity, attenuation capacity, etcetera.

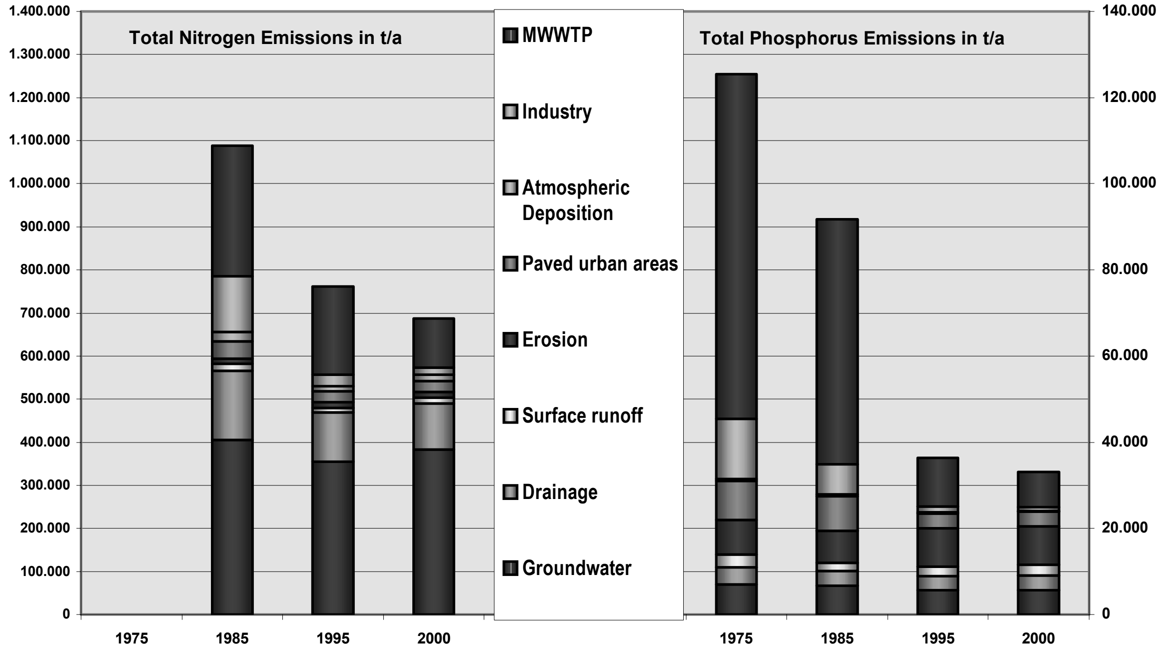

Fig. 12 Amount (tonnes per year) and distribution of total nitrogen- and phosphorus emissions in Germany from 1975 to 2000.

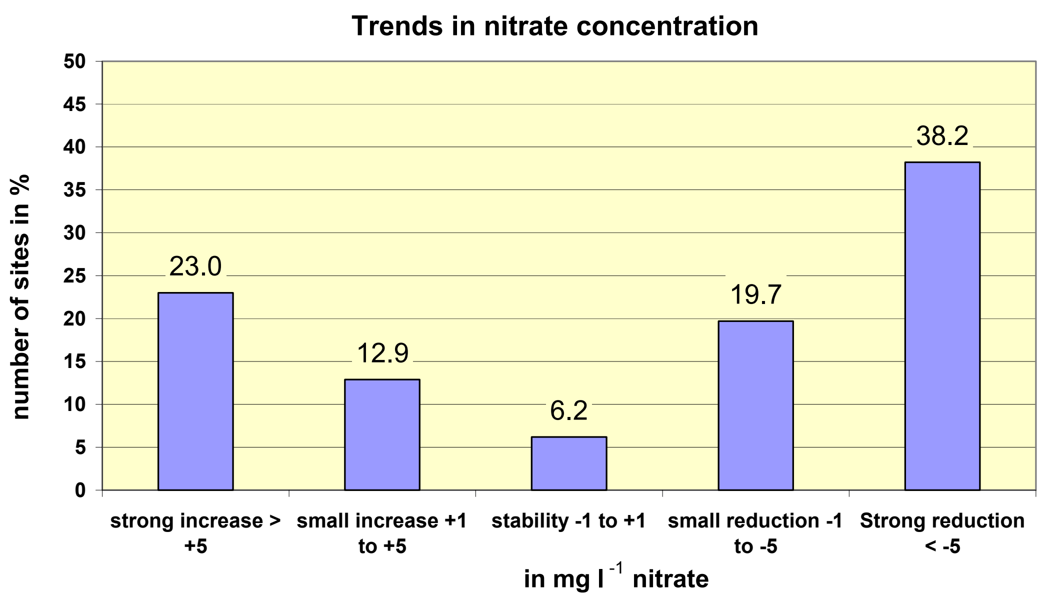

Fig. 13 Change in nitrate concentration (mg l^{-1}) in groundwater in Germany between the first Nitrates Directive reporting period (1992-1994) and second reporting period (1996-1998), based on data of the German EU Nitrate Network.

Figure 14 shows the trend in the mean nitrate concentration for each of the sampling sites summarised in Fig. 13.

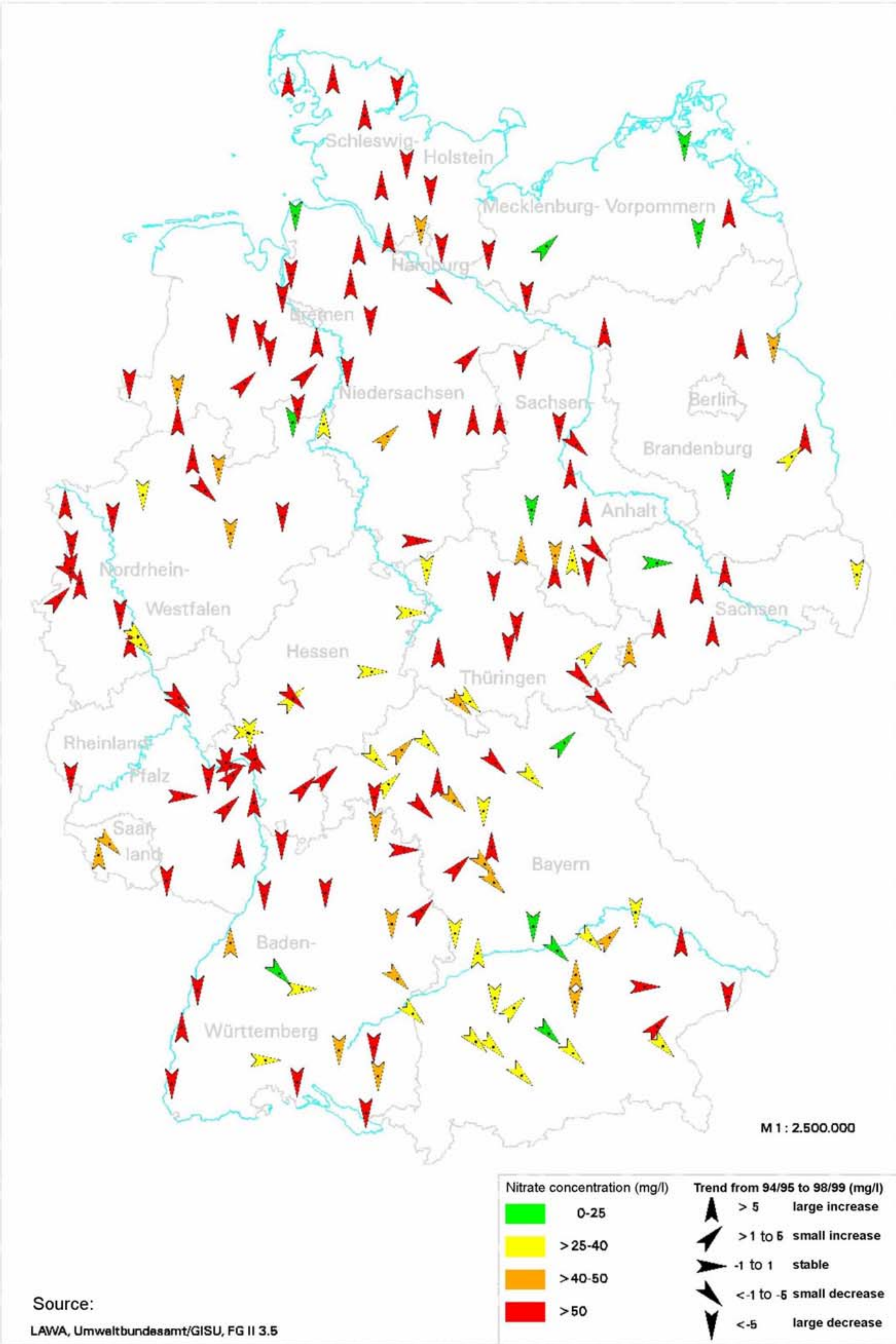

Fig. 14 Mean nitrate concentrations in groundwater in 1998/1999 and changes compared to 1994/1995 at the sites of the German EU Nitrate Network. Source: LAWA, Umweltbundesamt/GISU, FG II 3.5.

It should be noted that the Federal States have a multitude of action programmes. Many of these programmes are not intimately connected with the implementation of the Nitrates Directive and have been started before the Nitrates Directive came into force. Results of these programmes are not reported to the Commission even though they are very important for the protection of groundwater and surface waters.

In his paper Schültken (2005; in this report) gives examples of specific action programmes at Länder and local level on strategies for reducing nitrate inputs with a view to groundwater protection and the requirements of the EU Nitrates Directive.

2.4 Prognosis

The Nitrates Directive requires that a prognosis be made of reaction delay due to natural flow processes. For surface water Germany has used correlation analysis and numerical modelling to calculate the travel time of water through the underground (soil) of lowland catchments in the unconsolidated-rock region. In the correlation analysis, time-series data on nitrate concentrations in major rivers were compared with soil surface surpluses in their catchments. Table 4 summarizes the results of these calculations for some major rivers in Germany. For the unconsolidated-rock areas of the Elbe River a model of the flow processes (WEKU) was developed (Kunkel & Wendland, 1999). The range of the calculated travel times was between 1.5 and 500 years with a median value of 25 years. The modelled median value agrees very well with the results of correlation analysis.

Table 4 Summary of calculated ranges of (median) travel times of water from soil surfaces to river.

River	Travel times
Rhine	2 to 10 years
Danube	5 to 15 years
Weser	8 to 20 years
Elbe	14 to 22 years
	Travel time model WEKU: about 25 years

3. DISCUSSION

3.1 Eutrophication monitoring

The Nitrates Directive defines eutrophication as "enrichment of water by nitrogen compounds causing an accelerated growth of algae and higher forms of plant life" (EC, 1991, Art. 2 (i)). Therefore this directive might not be a suitable legal basis for comprehensive eutrophication monitoring including also phosphorus, chlorophyll, algae mass and composition, macrophyte mass and composition and further parameters describing eutrophication effects.

In the scientific sense the Nitrates Directive gives an incomplete definition of the term "eutrophication". The most important limiting nutrient for eutrophication is phosphorus. Especially in inland surface waters eutrophication effects are by far more related to phosphorus than to nitrogen pollution. Which other EU directives could form a basis for comprehensive eutrophication monitoring and control? One candidate is the Urban Wastewater Directive. It includes nitrogen and phosphorus in its eutrophication definition, but does not require monitoring for surface waters or groundwater.

Therefore this directive is not an adequate basis, either. The comprehensive directive under which an area as complex as eutrophication should be tackled is the Water Framework Directive.

3.2 Chlorophyll concentration

The reporting guidelines require reporting on the development of the chlorophyll concentration in surface waters. Obviously the chlorophyll concentration is influenced by a wide variety of parameters that are not intimately connected to nitrate inputs. Therefore there is only a very weak and doubtful correlation between chlorophyll concentration, nitrate concentration and agriculture induced inputs of nitrate to surface waters. In our opinion chlorophyll concentration is not a suitable parameter for monitoring the effectiveness of action programmes.

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Strategies for reducing nitrate inputs in groundwater and methods of efficiency control – The Lower Saxony co-operation model for groundwater protection and requirements of the EU Nitrates Directive

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1. INTRODUCTION

The Lower Saxony Bundesland is situated in the northern part of the Federal Republic of Germany. It is an area of about 48,000 km^2 and has approximately 7.8 million inhabitants. This corresponds to a population density of about 165 inhabitants per square kilometre.

From the geological point of view, a considerable part of Lower Saxony is covered with glacial melt-water sands. The soils, which have developed from these sands, are very prone to leaching processes, especially in respect of nitrates. In the south of Hannover and in the east around Brunswick there are very fertile loess soils. As it is possible to achieve very high yields with crops such as sugar beet and winter wheat, animal husbandry plays only a minor role here. Soils of weathered sandstone and limestone prevail in the hilly areas in the southern part of Lower Saxony. Marshlands with a high groundwater level can be found along the coast.

Most of Lower Saxony is used for agriculture. Approximately 28,000 km^2 (2.8 million hectares) are used by about 60,000 farms and 2000 market-gardening companies, which corresponds to about 60% of the entire area of the land. The average size of a farm is about 40 ha. Of the cultivated areas, arable land is the most prominent, while pasture is only of greater importance in the parts of the state closer to the coast and in the hill regions. Only 23% of Lower Saxony is covered with forest.

In western Lower Saxony animal husbandry constitutes the dominant production sector. The high percentage of organic fertilisers, and a high consumption of industrial fertilisers in combination with leaching-sensitive sandy soils, have led to serious nitrate contamination of such media as groundwater.

Nitrogen contamination – case studies

Studies of the University of Giessen show very remarkable excess nitrogen levels in the areas of intensive animal husbandry; for example, in the region between the rivers Weser and Ems (100-200 kg N ha^{-1}). On the other hand, the level of excess nitrogen is low (50 kg N ha^{-1}) where the livestock density is fairly low. The case study “Große Aue” shows that almost 90% of the nitrogen load comes from agricultural use, especially arable land use.

Drinking-water supply in Lower Saxony

The public water supply of Lower Saxony is ensured by some 400 water supply companies that together provide an annual quantity of 550 million cubic metres of drinking water. About 86% of this demand is covered by groundwater and spring water. To maintain groundwater quality approximately 6500 km² of the land area, that is 14%, have been declared water protection areas or priority areas for the production of drinking water in the framework of regional development programmes.

These water protection areas frequently lie in regions of intensive agricultural activity. In many of these areas, years of intensive agricultural activity have resulted in high nitrate levels in soils and – even more important - in groundwater. In 2000, the results of the groundwater quality monitoring network of Lower Saxony showed that about 26% of the samples examined from measuring sites close to the surface (< 25 m below the surface) still contained quantities of nitrate exceeding the limit of 50 mg of nitrate per litre, as prescribed by the Drinking Water Regulation. In contrast, the groundwater in deeper layers, which is used as drinking water, is not very polluted so far (NLÖ, 1999).

Facing these problems, the State of Lower Saxony introduced a water abstraction charge in 1992 with the aim of safeguarding drinking-water supply in the long term. In total, the water abstraction charge comes to an amount of up to 65 million euro per year, of which about 22 million euro is invested in a large number of water conservation measures in water catchment areas. The rest is invested in environmental protection programmes.

2. THE LOWER SAXONY CO-OPERATION MODEL

2.1 General

The philosophy of the water conservation policy in Lower Saxony is to have agriculture and federal water management cooperate with each other. The aim for the different parties who are locally involved – farmers, water suppliers and local government – is to develop appropriate concepts in a common effort, and then to put these concepts into practice. The local participants in this co-operative effort are:
- the regional government (co-ordinator),
- the local water supplier,
- the chamber of agriculture,
- the designated co-operation farmer representing the local farming community,
- the consultant for water conservation issues (chamber of agriculture, private office) and
- the office for water management at community level.

A very promising indication of the success of this co-operative agreement model can be seen in the fact that there are now 115 co-operatives throughout the state, representing a total area of about 300,000 hectares, where more than 6000 farmers are involved. The evaluation of the activities of the first few years prompted the development of a priority programme, which is now the guideline for the groundwater protection agenda in water catchment areas (MU, 1999).

2.2 The advisory service for water protection

One of the main tasks of the advisory service for the protection of water resources is to provide advice on water conservation for the farming community. The advisory service, which is voluntary for the farmers in catchment areas, is normally fixed in a one-year contract between the water management authority or the water supplier and the consultants. The different consultants apply for the contract via a special competition. The implemented measures are described and the results of the effectiveness control are pointed out in an annual report. For example, the report describes the development of nitrogen balances or the nitrate residues in autumn. The focus of the consultants' activities is on the improvement of fertilising management. With regard to the special needs in a catchment area they try to implement appropriate strategies in order to reduce the nitrate input into the ecosystem.

2.3 Voluntary agreements

In addition, so-called *voluntary agreements* for putting groundwater protection measures into practice are arranged with the farmers involved. Voluntary agreements for minimising the contamination of soils and the groundwater are already in place.

Obviously, an important aim of the agreements is to reduce the excessively high nitrogen levels. Therefore main topics for the agreements are reducing the use of mineral and organic fertilisers and employing new techniques to apply liquid manure. Furthermore, the use of mechanical techniques instead of pesticides for dealing with weeds is also included here. Moreover, the nitrogen in the soil can be retained by planting suitable supplementary crops. This helps to prevent nitrogen leaching out of the soil root-zone. Supplementary crops include the intermediate crops such as green manure and catch crops. So-called mulch sowing, i.e. sowing the seed directly without preparing the field by ploughing in spring, helps to prevent erosion.

Other important measures include using pasture with fewer cattle, and converting arable land into pasture, this being the most beneficial agreement for the long term. However, the high costs constitute a limiting factor here.

2.4 Pilot projects

As a support to the advisory service, research on specific questions concerning groundwater protection and preventive groundwater management research is conducted by pilot projects. These projects are supervised by the Lower Saxony State Agency for Ecology. The results from individual projects are published in brochures and guidelines so as to apply the experiences to comparable areas in Lower Saxony and to contribute to the state-wide groundwater strategy at conceptual level.

Various brochures and guidelines for practical use in the consultation process have been produced using the results from various projects. The main research areas are outlined below.

- Four projects on organic farming were initiated in and distributed throughout Lower Saxony in each of the four administrative regions. Besides the advice for farmers on conversion measures, the projects focused on establishing marketing structures and informing the public about the issues involved. One remarkable result was that 1500 ha of conventional farmland was converted into organic farmland during the project period (NLÖ, 2000).

- Strategies were developed for optimising the fertilising management (NLÖ, 2001a).

- Reforestation measures were introduced with the aim of protecting groundwater resources and developing healthy and diversified mixed coniferous and deciduous forests (Stadtwerke Hannover/NLÖ, 2000).

- Methods for assessing results and effectiveness were established. Common standards had to be defined. These included, for example, standards for taking soil samples so as to analyse the nitrogen residues in the soil or standards for calculating nitrogen balances so as to generate a comparable database at state level (NLÖ, 2001b).

- Methods were generated and hydrogeological models developed for identifying areas with high priorities within a catchment by considering the unsaturated (root zone) and saturated zone.

- An information system for data from the water protection advisory service, DIWA (Digital information system for water protection), was set up to enable authorities on different levels (regional and state-wide) to evaluate the data on a state-wide basis, for instance, to determine how the available money was distributed amongst the various adopted measures. By combining the information system with a geographic information system – ArcView – it is possible to present the results in cartographic form.

- Land use management was included with the aim of integrating environmental planning into a comprehensive land use concept (see more details below).

2.5 Methods of efficiency control

An important aspect in the co-operation programme is the implementation of site-specific measures. Considering that the budget for this groundwater protection programme is being gradually cut back, the question of priorities for investments in the different catchments and the question of efficiency control is becoming more and more important. A set of methods for assessing the implemented measures has been put together to evaluate the groundwater protection-related activities.

In fact a broad and useful set of instruments and methods was established in the consultation process and applied in the evaluation process. Table 1 compares a number of methods for efficiency control.

Table 1 Methods for efficiency control (NLÖ, 2001b).

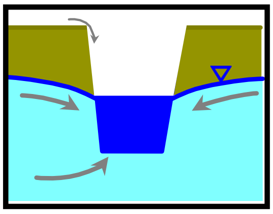
Method	Examined medium	Spatial reference	Temporal reference	Costs (€)
Balancing - farm-gate level - parcel level	cultivated area	- area-specific - farm-specific -parcel-specific	single year, crop rotation	- farm gate according to type of farm approx. € 200-400 - single parcel approx. € 10
Soil sampling for NO_3 + NH_4 (0-90 cm, in late fall)	soil soil extract	parcel-specific	single year	approx. € 50
Deep soil sampling	soil soil extract	site-specific	point of time / derived time series	- approx. € 30-40 m^{-1} - approx. € 15/sample (NO_3+ NH_4)
Groundwater surface probe	uppermost groundwater	site-specific	point of time	- approx. € 30-40 m^{-1} - approx. € 15 per sample (NO_3+ NH_4)
Shallow groundwater measuring point	upper groundwater	small areas	point of time / period of time	- approx. € 3000-5000 in unconsolidated material - approx. € 280 per sample and analysis of main substances
Multilevel groundwater measuring point	groundwater, depth-specific	-small to large catchments -high resolution	point of time / derived time series	- € 10.000-30.000 in unconsolidated material - approx. € 280 per sample and analysis of main substances
Multiple groundwater measuring point	groundwater, depth-specific	small to large catchments	period of time / derived time series	see directly above

Every method is related to the medium examined, the spatial and temporal reference, the resolution in time and the costs. For example, the balancing, on farm-gate or parcel level, is a calculated value, whereas the result from a measuring point is an analytical value.

Obviously, in a comparison the methods are related to specific media, where both the spatial and the temporal reference can differ a lot. Looking at the costs makes the wide range evident. The maintenance and use of groundwater measuring points is very expensive. However, as a rule, the water supplier maintains an extensive net of (shallow) groundwater measuring points, in which case, only the costs of the analysis have to be paid.

The set of methods includes those for the unsaturated and the saturated zones. Figure 1 below provides information on the method, result and suitability in relation to the different zones.

Root zone	soil sampling for NO_3 + NH_4 in late fall	kg mineral-N ha^{-1} after mineralisation, before leaching	potential nitrate loss by leaching
Drainage zone	deep soil sampling, layer-specific	depth gradient of concentration	pre-control of quality in groundwater replenishment
Groundwater	groundwater surface probe	quality of recent groundwater	quality control of groundwater replenishment
Surface	shallow measuring points		
Top of groundwater zone	multilevel measuring points	depth gradient of groundwater quality	quality control of groundwater replenishment over several years
Main aquifer	well catchment measuring point	groundwater quality	early recognition of changing groundwater quality
With well	raw water analysis	in deeper aquifers	current quality control



testing drains and discharge systems	parcel or catchment-specific concentrations	indication for quality of groundwater replenishment

Fig. 1 Zone-related methods (NLÖ, 2001b).

In the unsaturated zone, soil sampling in autumn (mineral-N) is very common and widespread and the costs are fairly low. This method, originally developed for the loess soils, is now established state-wide. Important are common standards, for example, for the appropriate point of time of sampling (before leaching) so as to get a comparable database on the state level.

In the saturated zone shallow or multilevel measuring points may be appropriate, depending on the specific question. If there are ditches with drainage systems, it is possible to control parcel-specific emissions. Because of very different site conditions, feasible efficiency control should not only apply to a single instrument. A well-elaborated and site-specific set of methods is necessary to get firm results.

2.6 Success stories

The success of the groundwater protection activities implemented in the last 10 years is illustrated by referring to four "success stories" in different areas of Lower Saxony:

1. In the first case, remarkable successes can be pointed out in the hill region of the Weserbergland (southern part of Lower Saxony) with respect to the nitrogen balance. New techniques for applying liquid manure and special agreements for crop sequences have been shown to reduce the nitrogen excess by almost two-thirds, from 140 kg N ha^{-1} down to 50 kg N ha^{-1} within two years.

2. In a catchment in northern Lower Saxony it can be proven that growing intercrops could reduce the mineral nitrogen level in the soil by half.

3. In the catchment area of Liebenau, west of Hannover, the results of just four years of intensive advisory service show that the average nitrate concentration in the root zone has gone down from 104 to 30 mg l^{-1}. This was also achieved by implementing different measures (e.g. low input crop rotation systems, conversion from arable land into pasture) .

4. An example from the water catchment area, Thülsfelde, in the Weser-Ems region, illustrates that nitrate concentrations in shallow groundwater could be reduced from 110 to 50 mg l^{-1} within 10 years by practising catch-crop growing, employing new techniques to apply liquid manure and by converting arable land to pasture.

These examples give evidence that the co-operative approach has led to very significant successes in drinking-water conservation and protection in Lower Saxony.

2.7 Land use management

An important aspect of co-operative activities is the recognition that it is not only the agriculture and water suppliers in the respective area who have legitimate claims to be taken into account. In each case many issues are involved: for instance, those of town and country planning. Therefore to achieve the aim of increased effectiveness, it is appropriate to widen the scope of the co-operation to include other participants from the fields of nature conservation, agricultural or settlement planning, etcetera. The approved bilateral co-operative agreements will be opened up to include multilateral co-operation. One of the main aspects is to combine agricultural and environmental measures, with the aim of integrating environmental planning into a comprehensive land use concept.

A current project of the Lower Saxony State Agency for Ecology is focusing on these aspects. The region in question lies to the south of Hannover and stretches from the Deister Hills towards the east. This region, called the Deistervorland, contains three water supply areas. For the purpose of planning and carrying out a number of different activities a round-table group has been established called the "Forum Deistervorland". In addition to the usual co-operation participants, the Forum Deistervorland also contains the office for agricultural planning, the office for nature protection, the local government and the Lower Saxony State Agency for Ecology. The essential task facing the Forum is to develop an integrated land use concept which identifies and takes into account a range of different claims and requirements.

Bringing together different people, interests and disciplines has the important advantage of encouraging synergetic effects. In addition, the integrated approach increases the degree of acceptance amongst the direct participants and the general public of measures such as the drinking-water protection measures and nature conservation measures. In this step-by-step process it became more and more obvious that in many respects the various interests were closely allied to each other. This process shows how useful it is to “join forces” and develop common strategies.

The project has now been successfully completed. Both the different results of this project and the experiences of the Forum process have been published in a guideline (NLÖ, 2004) in an effort to encourage other communities to create forums like this and to work on comprehensive land use management concepts.

3. CONCLUSIONS

The co-operative approach practised in Lower Saxony has been successfully demonstrated as leading to a very marked drop in nutrient input into the soil and groundwater. This success was the result of having a system of different measures that are site-specifically implemented.

In evaluating this approach success was found to be due to the different instruments and methods. These methods are suitable for assessing the efficiency of groundwater protection activities according to site-specific goals and available funds. Use of this set of methods led to the creation of a state-wide standard. These instruments can be employed to achieve results for both regional and state-wide planning. An information system now being set up will enable a state-wide data management in the future.

However, apart from many technical aspects, water management and agriculture, have, in the course of time, been significant in creating an atmosphere of and a basis for mutual trust. This means that there is a current exchange and a growing awareness of the issues relating to nature conservation and water protection amongst the farmers and other stakeholders.

The co-operative approach will provide the foundation for wider, multilateral co-operation with further participants. The trend is towards an even more wide-ranging integration of environmentally relevant planning with other planning sectors − in other words − the development of truly comprehensive overall planning concepts.

The experience gained through the groundwater protection scheme also provides useful strategies and approaches to possible solutions in respect of the EU Nitrates Directive and the requirements of the EU Water Framework Directive. The Water Framework Directive requires that in cases where river catchment areas or groundwater reservoirs are either under threat of contamination or indeed already contaminated, programmes of measures must be drawn up. This means that in many cases a large amount of well-founded data and information will be needed. As a result of the effort that has already been invested in the co-operation, a lot of experience has been accumulated that will pay off a second time in helping to meet this challenge as well.

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Monitoring Effectiveness of the EU Nitrates Directive Action Programmes: Approach by Ireland

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Abstract This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Ireland. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5 (6) (EC, 1991). In 1999 the European Commission published the Draft Monitoring Guidelines (EC, 1999). This paper deals with monitoring for nitrates carried by a number of State agencies in accordance with the requirements of the Drinking Water Regulations. Additional monitoring is carried by local authorities and under the EPA's National Groundwater Quality Monitoring Programme. This report contains the results of sampling for nitrate in the period 1998-2000 for both the 75 EUROWATERNET river water quality sites and the 189 groundwater quality sampling sites and contains a comparison with the corresponding data for the period 1995-1998. On 30 May 2003, regulation was made by the Minister for the Environment and Local Government which identifies the national territory of Ireland as the area to which an action programme will be applied to protect water quality against pollution caused from agricultural sources (Department of the Environment and Local Government, 2003). Summaries of the position in regard to Lake Monitoring as well as Estuarine, Coastal and Marine Monitoring are also provided.

1. INTRODUCTION

1.1 General

The information presented here is based on data obtained from the Environmental Protection Agency's (EPA) and contains data on the results of monitoring by both the EPA, Marine Institute and local authorities. A summary of the data was published in the EPA report, Water Quality in Ireland 1998-2000 (McGarrigle *et al*., 2002). Corresponding data for the 1995-1997 period are also given for comparison.

Ireland has a total land area of just over 7 million ha and a population of about 3.9 million people. The island of Ireland is bounded on the north, west and south by the Atlantic Ocean and on the east by the Irish Sea. The topography can be approximately described as a flat, low central plain surrounded by mountains and hills with peaks ranging from 500 to 1000 m. Only about 5% of the country is above 300 m O.D. (located in Counties Galway, Kerry, Mayo and Wicklow) and most of this is within 50 km of the sea.

1.2 Description of the natural factors influencing nitrate occurrence

Geology

The total area of the island of Ireland, including Northern Ireland is about 84,430 km² and the Republic of Ireland has an area of around 70,000 km². The island is made up of a large central plain, underlain by limestone, surrounded by a discontinuous rim of coastal mountains formed largely from basement rocks. The central plain, which is broken in places by low hills, is extensively covered with glacial deposits of clay and sand and gravel.

The geological structure of Ireland is a continuation of the geological structure of Europe and of Britain. The oldest rocks are the Precambrian schists and quartzites. Small areas of Cambrian slates and quartzite's occur on the east coast. Rocks of Ordovician and Silurian age are more widely distributed in the east. Devonian sandstones are widespread in the midlands and the south. The Carboniferous limestone is the most important rock system in Ireland, underlying about half of the country. Apart from a small area of Permo-Triassic sandstone at Kingscourt, all bedrock types have fissure permeability only. The only widespread aquifers with intergrannular permeability only are the Quaternary deposits. One of the consequences of this is that in areas where subsoils are thin or absent the groundwater in the bedrock is extremely vulnerable to contamination.

Climate

The climate is influenced by the North Atlantic Drift and the prevailing south westerly winds. The Irish climate is characterised by high humidity, mild winters (4.5°C) and cool summers (15.5°C). Rainfall varies from 800 mm in the south-east to 2500 mm in the mountainous areas of the west (Lee *et al.*, 1994).

Taking the average rainfall as 1150 mm per annum, and the average evapotranspiration losses as 450 mm per annum, the average runoff in Ireland is estimated at some 700 mm per annum.

Hydrology

Information on the general physical features of the State are shown on the accompanying map, see Fig. 1, which shows the boundaries of the hydrometric areas delineated for water resource assessment and lying wholly or partially within the State.

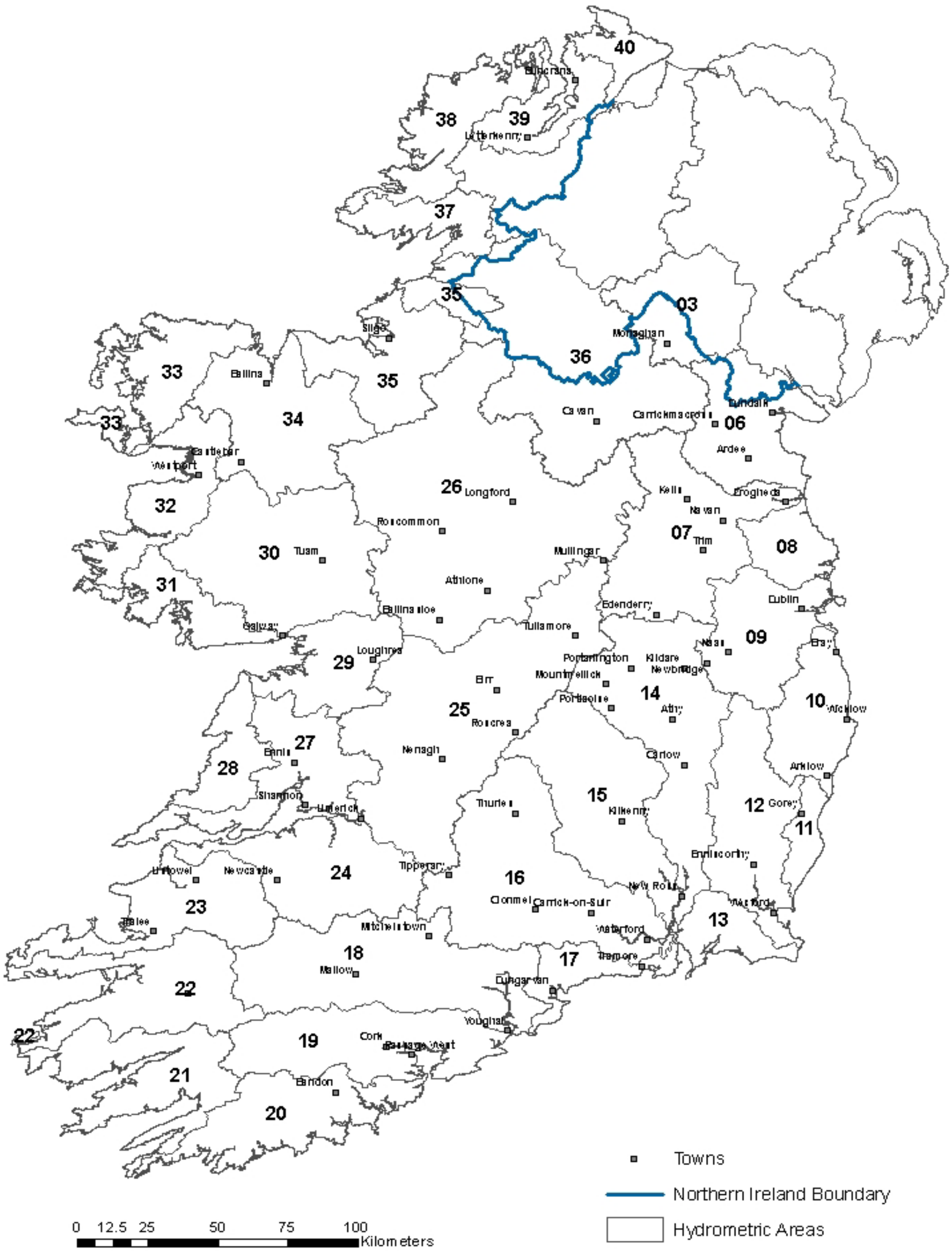

Fig. 1 Map of hydrometric areas and towns in the Republic of Ireland.

The pattern of river flow in Ireland reflects the rainfall pattern and, in general, there is a prompt response to rainfall although the rate of response varies from catchment to catchment. Some catchments have a very quick response to rainfall and are regarded as flashy catchments, with little or negligible storage. In other catchments, the rate of increase in runoff resulting from rainfall may not be as severe as water goes into storage and then contributes to river flow from storage.

The normal pattern of flow in rivers in Ireland is that the groundwater recession commences in the Spring and continues at a steady rate until the Autumn. Rainfall in the late spring/summer does not alter the trend of the recession once it is established, although such rainfall may lead to an increase in river flows.

Recovery of groundwater flow to normal winter levels depends on the rainfall pattern after the end of the low flow period.

Features of the low flow rivers in Ireland are:
- the wide variation in the ratio of low flow to average flow;
- low flows vary both from region to region and within regions and
- in absolute terms, the flowrates are quite small.

The Ordnance Survey map, Ireland: Rivers and their Catchment Basins (Ordnance Survey, 1958), lists the catchment areas of over 400 river catchments and coastal areas in the island of Ireland. These catchment areas are summarised in Fig. 2 (islands are omitted).

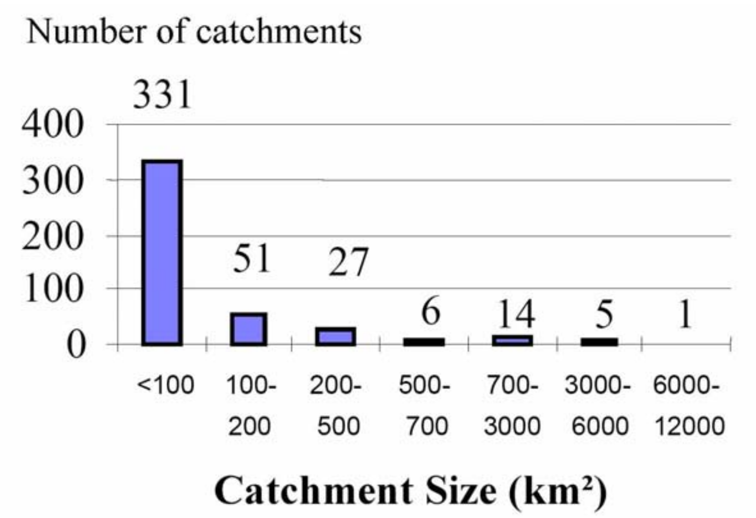

Fig. 2 Summary of size of catchments of rivers in Ireland (Ordnance Survey of Ireland, 1958).

In the Republic of Ireland, the largest catchments are as follows: Shannon (to Limerick) 11,700 km^2, Bann 5800, Suir 3600, Blackwater (Munster) 3300, Corrib 3100, Barrow 3060, Boyne 2694, Erne 2624, Nore 2530, Moy 2086, Slaney 1762, Liffey 1369, Lee 1252, Feale 1154, Maigue 1097, Fergus 1041 and Laune 829 km^2. While there are around 430 individual catchments and minor coastal areas noted on the Ordnance Survey, 1958 map, the largest twenty catchments occupy around 64% of the island of Ireland.

<u>*Soils*</u>

Dry lowland mineral soils account for 40% of the total land area. Approximately, 13% of land has soils that are classified as moderately wet mineral soils (mainly associated with the limestone area and subject to high water table, or seepage and spring problems). Eleven percent of soils are classified as wet impermeable mineral soils occurring on drumlins and carboniferous shales (Coulter *et al.*, 1996). Mountain, hill and high-level peat land account for 1.53 million ha with low-level peat land (blanket and basin peat) accounting for the remainder. The relatively high proportion of peat and wet mineral soils distinguish Irish soils compared with many of its European neighbours.

1.3 Description of human factors influencing nitrate occurrence

Irish agriculture utilises a land area of approximately 4.4 million ha. Climate and soils largely dictate the agriculture practised *i.e.* primarily grass based livestock production with pasture, hay and silage accounting for almost 90% of agricultural land use. Cereals and non-cereal crops (sugar beet, potatoes, and etceteras) account for approximately 7% and 3%, respectively, of agricultural land use. Barley and wheat account for almost 94% of the cereal production. These tillage-based enterprises tend to be concentrated in the drier regions of the south and east. Gross agricultural output in 1998 was valued at 4.2 billion Euro with the output from grass-based enterprises accounting for over 85% of the total.

There are a total of 146,000 farms with an average size of 29.5 ha (Teagasc, 1999). Almost 70% of farms have less than 20 ha. The national bovine herd was 7.55 million in 1999 including 1.28 million dairy cows. The sheep flock was 7.9 million of which 4.4 million were ewes. The national pig herd comprises of 1.78 million pigs including 0.17 million breeding sows and the poultry flock consists of 13.2 million birds. Organic farming is relatively under developed with less than 1000 farms (<1% of total farms) officially registered as such. The land area devoted to organic farming is less than 0.5% of total agricultural land compared with a European average of approximately 2%.

Agriculture is important to the national economy being responsible for 11% of total exports. In 1997, almost 9% of the working population were involved in agriculture and it was responsible for approximately 3.4% of Gross Domestic Product compared with European averages for these indices of 5% and 1.6%, respectively.

Any nitrate found in natural waters above background levels is of anthropogenic origin, coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. Sewage (either of human or animal origin) is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. The presence of nitrates in groundwater is cause for suspicion of past sewage pollution or of excess levels of fertilisers or manure slurries spread on land (Flanagan, 1990). High nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation. Under natural conditions, nitrate is present only in low concentrations - normally in the range 5-9 mg l^{-1} NO_3. Standard drinking water treatment does not remove nitrate.

Nitrate in drinking water is a minor component of total nitrate intake but may make an important contribution to total nitrate intake when concentrations are significantly raised. The health risks associated with nitrate consumption in the human diet include methaemoglobinaemia in infants (blue baby syndrome) and potential carcinogenic hazards for the general population (UN, 1983). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite which reacts with blood haemoglobin to cause methaemoglobinaemia.

Pollution from septic tank effluent is usually shown in groundwater by high concentrations of ammonia, nitrate, chloride, bacteria and total dissolved solids.

1.4 Overview of monitoring networks

1.4.1 General

Monitoring in Ireland is based on the requirements of Section 4 of the Draft Guidelines for the monitoring required under the Nitrates Directive (EC, 1999) which is required for monitoring for countries applying the Action Programme across the whole of their territory. In Ireland monitoring is carried out for the following purposes:

- Drinking Water Regulations.
  This monitoring is carried out by the local authorities or by the Health Board or EPA as an agent of the local authorities. All water used for drinking water must be sampled in accordance with the requirements of the Directive.
- National Groundwater Quality Monitoring Programme.
  In November 1995 the EPA commenced monitoring groundwater quality twice yearly: when groundwater levels (1) are at or near their lowest level and (2) when groundwater levels are at or near their highest levels. The objective of this monitoring programme is to establish the quality of our groundwaters and to detect trends in groundwater quality.
- Groundwater Monitoring Programmes.
  These are specific sampling programmes undertaken by the local authorities.
- Estuarine, Coastal and Marine Monitoring.
  This sampling programme is undertaken by the Environmental Protection Agency and the Marine Institute.
- National Lake Water Quality Monitoring Programme.
  This sampling programme is undertaken by the Environmental Protection Agency.

1.4.2 Rivers

The information presented here for nitrate concentrations in rivers relates to the locations that have been identified for inclusion in the EEA EUROWATERNET Scheme. This set of stations has been selected on the basis of its representativeness and, together with the corresponding nitrate data, is considered the most appropriate for reporting purposes. These data however represent only a proportion of river monitoring in Ireland. The locations of the 74 (as below) sampling stations used for the EEA EUROWATERNET for river water are shown in Fig. 3. Of the 74 EUROWATERNET sites nitrate monitoring data is available for a subset in any particular monitoring period – 45 sites in 1991-1994 period, 57 in the 1995-1997 period and 49 in the 1998-2000 period. The variation in number from one period to the next is due to logistical considerations within local authorities and regional EPA laboratories tasked with taking the samples.

Appendix 1 gives the mean and maximum nitrate concentrations recorded at the EUROWATERNET stations, in 1995-1997 and 1998-2000. The mean nitrate concentration in the period 1998-2000 are shown in Fig. 5 and the difference in the mean nitrate between 1998-2000 and the 1995-1997 are shown in Fig. 6. The maximum nitrate concentration in the period 1998-2000 are shown in Fig. 7 and the difference in the maximum nitrate between 1998-2000 and the 1995-1997 are shown in Fig. 8.

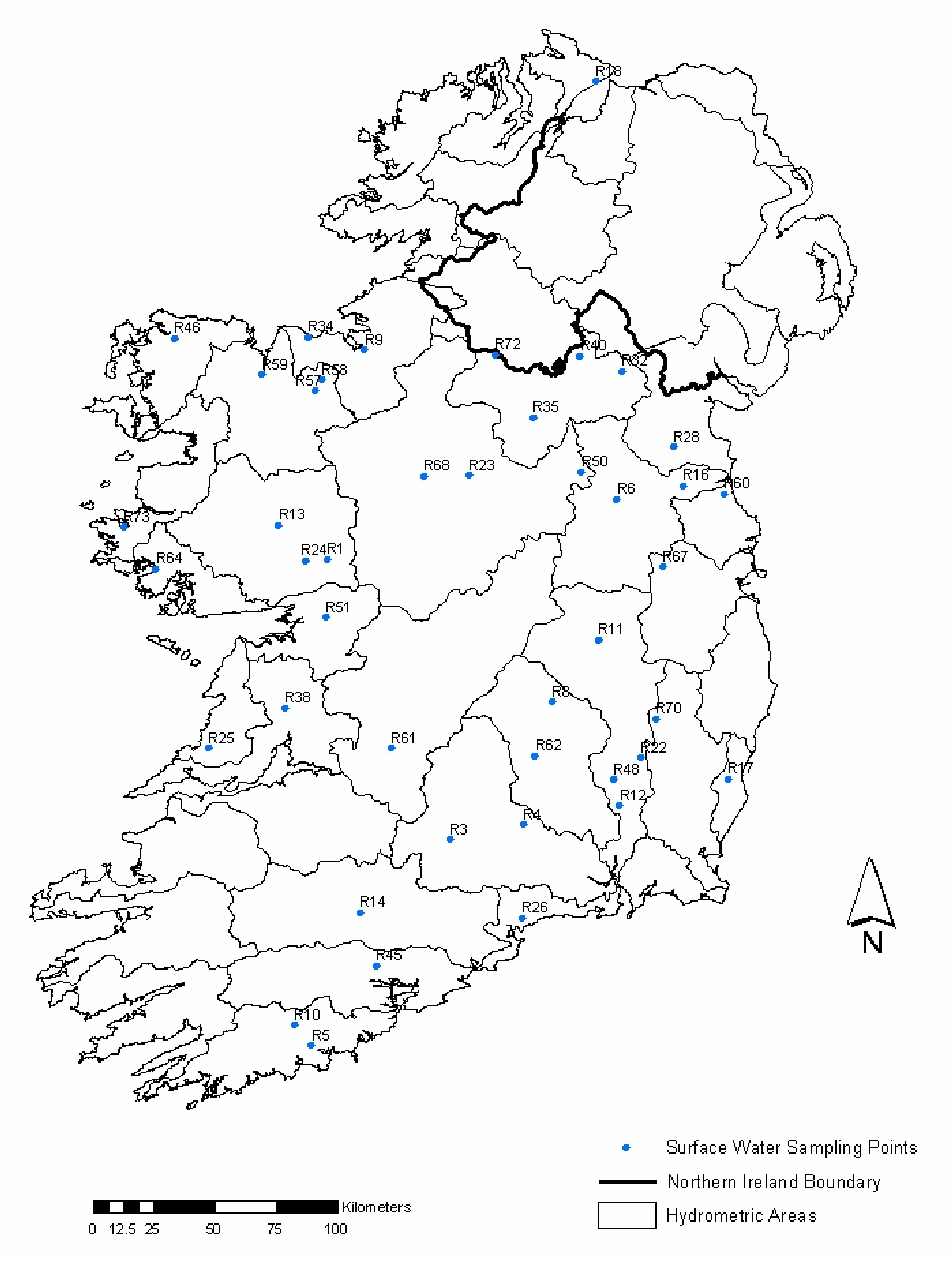

Fig. 3 EUROWATERNET surface water nitrate sampling points in the Republic of Ireland.

1.4.3 Groundwater

In 1995 the EPA commenced a national programme of sampling of groundwater quality. The sources are sampled twice a year: (1) when groundwater levels are at or approaching their minimum level and (2) when groundwater levels are at or approaching their maximum level. The groundwater levels are confirmed by reference to the groundwater level monitoring programme which is also undertaken by the EPA. The number of sources sampled for groundwater quality has now stabilised at around 300 groundwater sources and covers the major groundwater sources in the country. The locations of the sources sampled under the EPA's National Programme of Groundwater Quality are shown in Fig. 4.

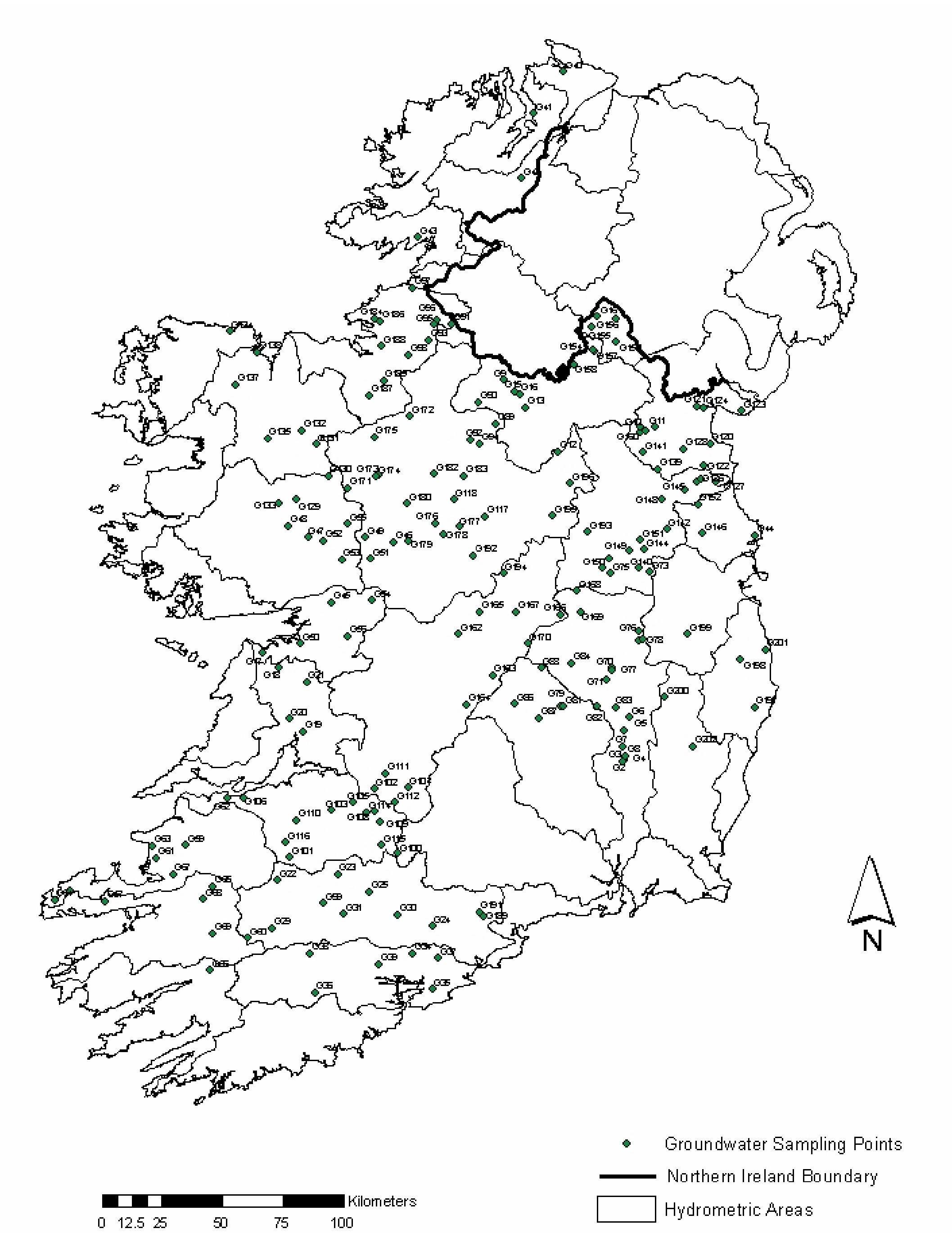

Fig. 4 Groundwater sampling points in the Republic of Ireland.

The mean and maximum nitrate concentrations recorded at 189 stations in 1995-1997 and 1998-2000 are provided in Appendix 2. The mean nitrate concentrations in the period 1998-2000 are shown in Fig. 9 and the difference in the mean nitrate concentrations between 1998-2000 and the 1995-1997 are shown in Fig. 10. The maximum nitrate concentrations in the period 1998-2000 are shown in Fig. 11 and the difference in the maximum nitrate concentration between 1998-2000 and the 1995-1997 are shown in Fig. 12. Nitrate data were available for all stations in the 1995-1887 period and unavailable for 13 stations in the period 1998-2000.

1.4.4 Estuarine, coastal and marine monitoring

Under the OSPAR Convention (Riverine Inputs and Direct Discharges (RID) and Nutrient Monitoring Programmes), monitoring of winter inputs and ambient concentrations in coastal waters is carried out in addition to the EPA estuarine and coastal monitoring programme.

1.4.5 Lakes

The results of the water quality monitoring carried out on Irish lakes during the three-year period 1998-2000 are given in the EPA report Water Quality in Ireland 1998-2000 (McGarrigle *et al.*, 2002). During this period 304 lakes were examined which represented a significant increase over previous reporting periods and is due, largely, to the commencement of the National Lake Monitoring Programme in 2000. This database is quite representative of such waters describing the quality of almost 1000 km^2, or 64 percent, of the surface area covered by lakes in the country, including 24 of the 25 larger (surface area >7.5 km^2) and important lakes wholly or partly in the State.

2. EFFECT MONITORING

2.1 General

On 30 May 2003 regulation was made by the Minister for the Environment and Local Government (Department of the Environment and Local Government, 2003) which identifies the national territory of Ireland as the area to which an action programme will be applied to protect water quality against pollution caused from agricultural sources. Detailed provisions of the action programme will be developed over the coming months in consultation with farming organisations and other interested parties, in accordance with the Agricultural Chapter of the national partnership agreement “Sustaining Progress”.

The action programme will provide for a range of measures, including Regulations, to strengthen the application of established “good housekeeping” rules for farming in all areas. It will consist primarily of measures to provide better protection for the environment at farm level and to monitor the effect of these measures on farming practices and water quality. This approach aims to secure better protection for the environment by the application of good agricultural practice on a more consistent basis.

The “whole territory” approach in relation to implementation of the Nitrates Directive will include the operation in all areas of a limit of 210 kg per hectare per annum on the amount of organic nitrogen (e.g. in animal manure) that can be applied to land during the first four years of the action programme. A derogation will be sought from the European Commission for higher amounts (up to 250 kg per ha per annum) to be

allowable subject to appropriate conditions. In the absence of appropriate derogations, a limit of 170 kg of organic nitrogen would apply after an initial four-year period.
The appropriate standards for good agricultural practice to protect the environment, especially water quality, are well established and understood. These good housekeeping rules were developed jointly by the Departments of Agriculture and Environment in 1996, with the agreement of the main farming organisations.

However sampling of lakes, river, coastal estuarine and marine in addition to groundwater quality sampling has continued and their analysis for nitrate has continued and we wish to report progress in relation to rivers (§2.2), groundwater (§2.3), estuarine, coastal and marine waters (§2.4) and lakes (§2.5) as follows:

2.2 Rivers

The information presented here for nitrate concentrations in rivers relates to the locations that have been identified for inclusion in the EEA EUROWATERNET Scheme. This set of stations has been selected on the basis of its representativeness (using the standard EUROWATERNET selection methodology) and was considered appropriate for reporting purposes under Article 6(1)(a)(i). These data however represent only a proportion of river monitoring in Ireland.

The statistics for nitrate concentrations recorded at the EUROWATERNET stations in 1998-2000 and in 1995-1987 are given in Appendix 1. The mean and maximum nitrate concentration in the period 1998-2000 are also shown in Figs 5 and 7. For those stations where nitrate data are available for both periods, the changes between 1995-1997 and 1998-2000 are depicted in Figs 6 and 8.

A summary of the position is presented in Table 1, based on the median, 95 percentile and ranges of the mean and maximum values recorded at the stations in the 1998-2000 period. It is clear that concentrations at the stations did not exceed 50 mg l^{-1} in this period at the locations sampled, suggesting a decline or stabilisation in nitrate concentrations albeit not statistically significant.

Table 1 Statistics for mean and maximum concentrations of nitrate (mg l^{-1} NO_3) recorded at 48 of the EUROWATERNET stations in 1998-2000.

Values	Median	95 percentile	Range
Means	6.9	22.2	0.24 – 29.6
Maxima	15.0	33.0	0.44 – 35.9

Nitrate data are available for both the 1995-1997 and 1998-2000 periods at a total of 44 stations. Summaries of these data are compared in Table 2.

Table 2 Statistics for mean and maximum concentrations of nitrate (mg/l NO3) measured in the periods 1995-1997 and 1998-2000 at the 44 Irish EUROWATERNET river stations for which data are available for both periods.

	1995– 1997			1998–2000		
Values	Median	95 %ile	Range	Median	95 %ile	Range
Means	9.0	24.4	0.24-31.2	6.7	22.7	0.24-29.6
Maxima	17.9	38.1	0.62-47.1	14.0	33.0	0.44-35.9

The data in Tables 1 and 2, and shown in Figs 5 to 8, at the 44 stations sampled in both periods, indicates that nitrate levels (1) in the east, south and south-east regions in the period 1998-2000 appear to have stabilised and (2) in the remainder of the country have minimal changes compared to the period 1995-1997. No statistically significant changes were recorded between the two periods. These data reflect the overall position for nitrate levels in Irish rivers as set out in the most recent national report on water quality (McGarrigle *et al*., 2002).

2.3 Groundwater

In November 1995 the Environmental Protection Agency of Ireland initiated a national groundwater quality monitoring programme. Before this, local authorities undertook the monitoring of groundwater for the purposes of the Nitrates Directive and Drinking Water Regulations. The national groundwater monitoring programme is currently based on some 250 sampling points chosen to be representative of both the main aquifers and the groundwater in use. Most of the sampling stations are production wells, with water quality samples being taken **before** any treatment process. In the surveys carried out in 1998-2000, approximately 189 only of the sampling locations were covered as circumstances precluded detailed sampling in the Southeast area. However this area has been included in more recent surveys (i.e. since February 2001).

The mean and maximum nitrate levels measured in 1995-1997 and 1998-2000 at the national network of groundwater quality monitoring points are given in Appendix 2. The mean and maximum nitrate levels in the period 1998-2000 are shown in Figs 9 and 11, respectively. There were 14 sampling stations, which were sampled in the period 1995-1997 that were not sampled in the period 1998-2000.

A summary of the data gathered in the period, based on the mean and maximum concentrations is given below in Tables 3 and 4.

Table 3 Statistics for mean and maximum concentrations of nitrate (mg l^{-1} NO_3) recorded at the 189 groundwater quality sampling stations in 1998-2000.

Values	median	95 percentile	Range
Means	11.97	36.25	0.04 – 65.2
Maxima	15.69	52.7	0.04 – 120.6

Table 4 Statistics for the mean and maximum concentrations of nitrate (mg l^{-1} NO_3) measured in the periods 1995-1997 and 1998-2000 at the 189 groundwater quality sampling stations for which data are available for both periods.

	1995-1997			1998-2000		
Values	median	95%tile	range	median	95%tile	range
Means	12	45	0.05 – 121	12	36	0.04 – 65
Maximum	17	62	0.09 – 168	16	53	0.04 – 121

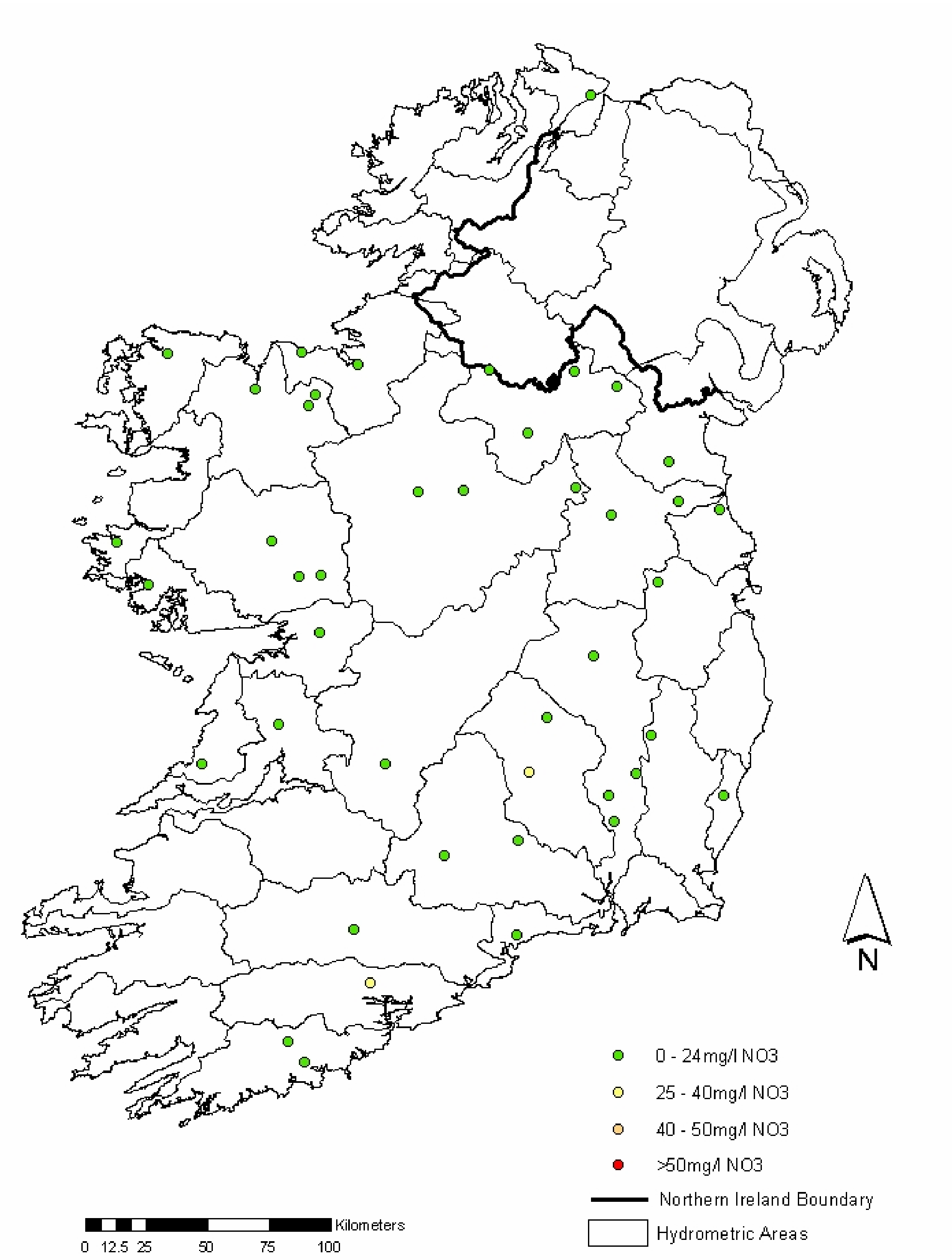

Fig. 5 Mean nitrate concentrations in river water in the 1998-2000 period.

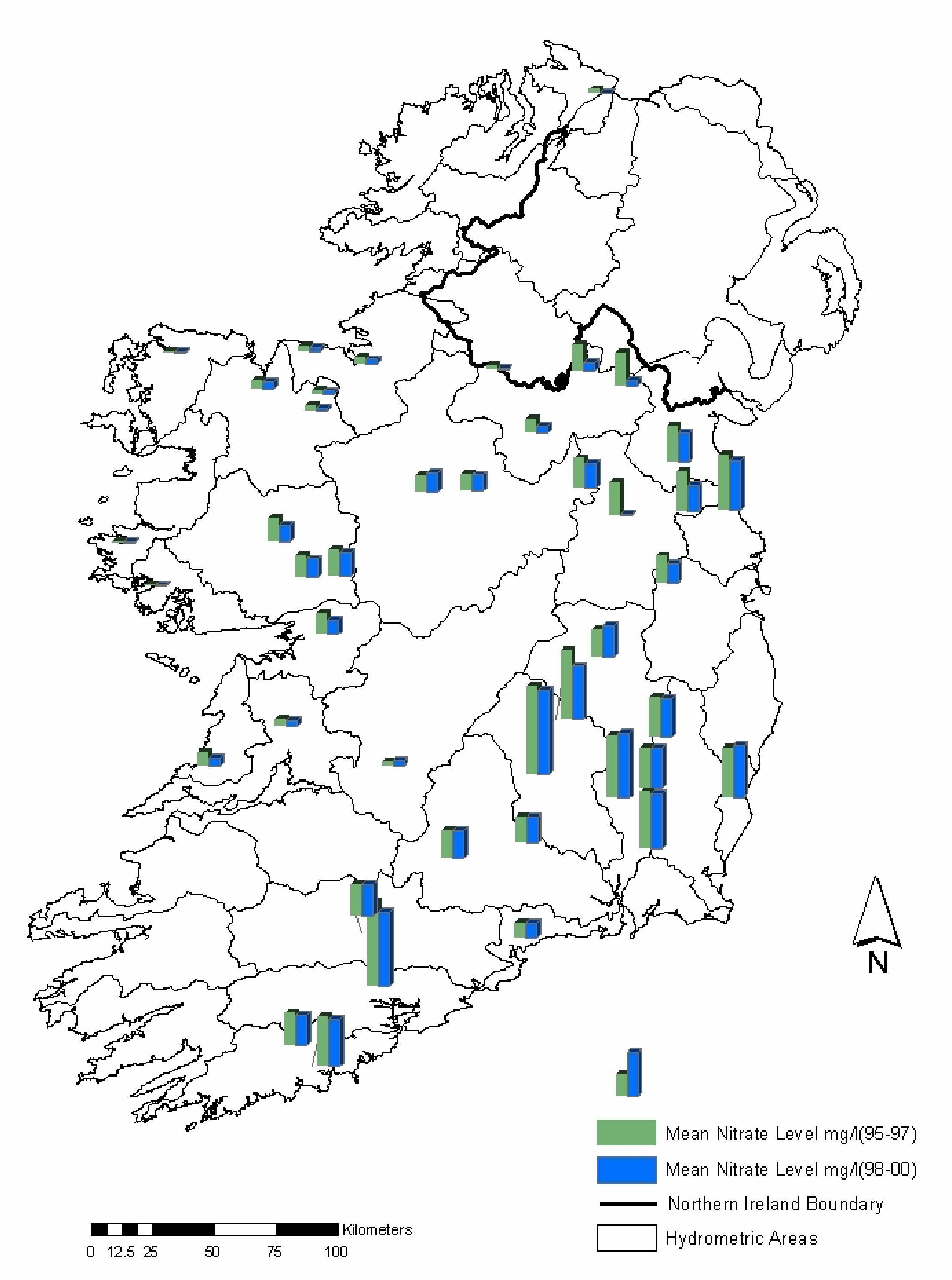

Fig. 6 Comparison of mean nitrate concentrations in river water between the 1995-1997 and 1998-2000 period.

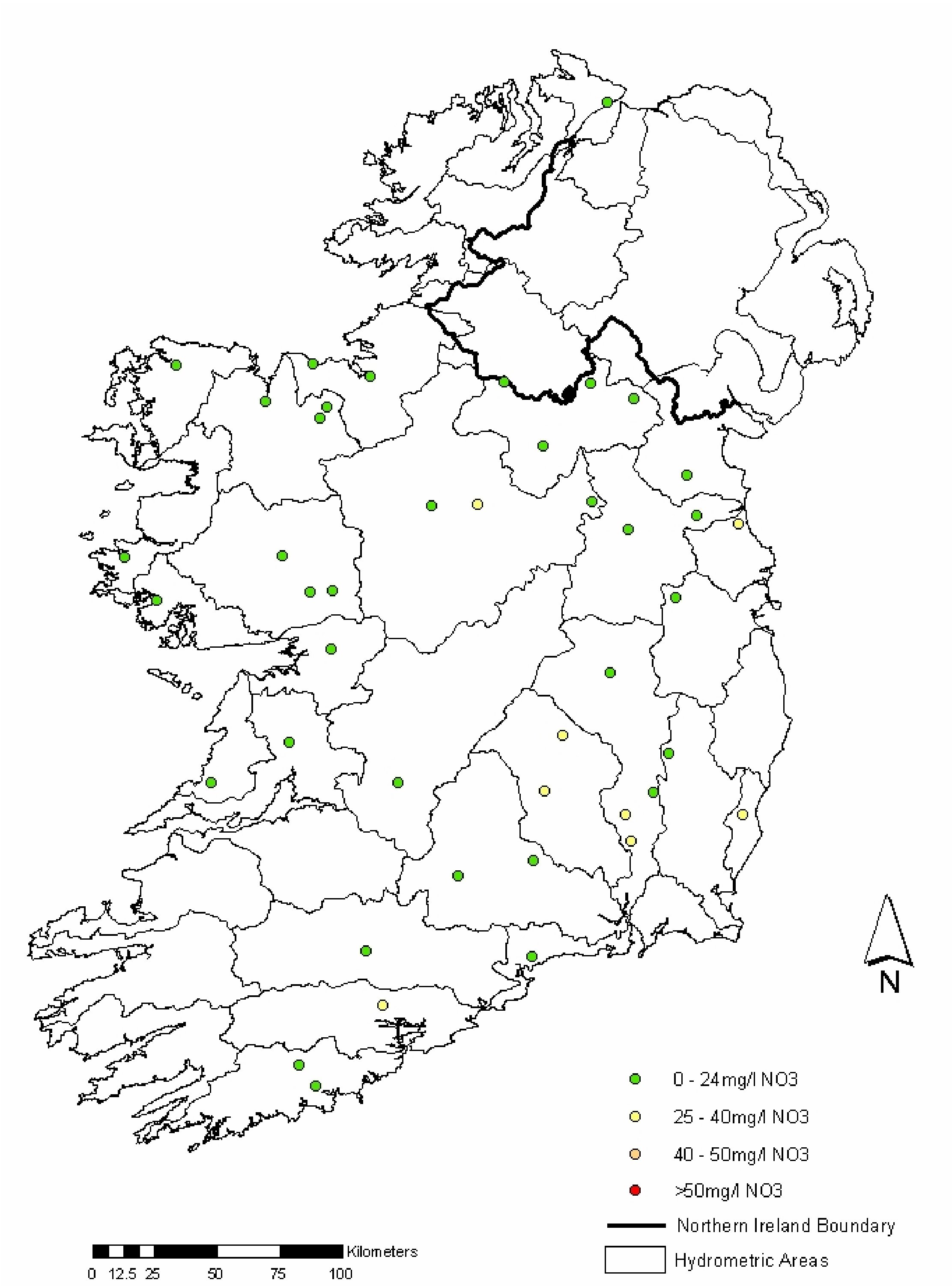

Fig. 7 Maximum nitrate concentrations in river water in the 1998-2000 period.

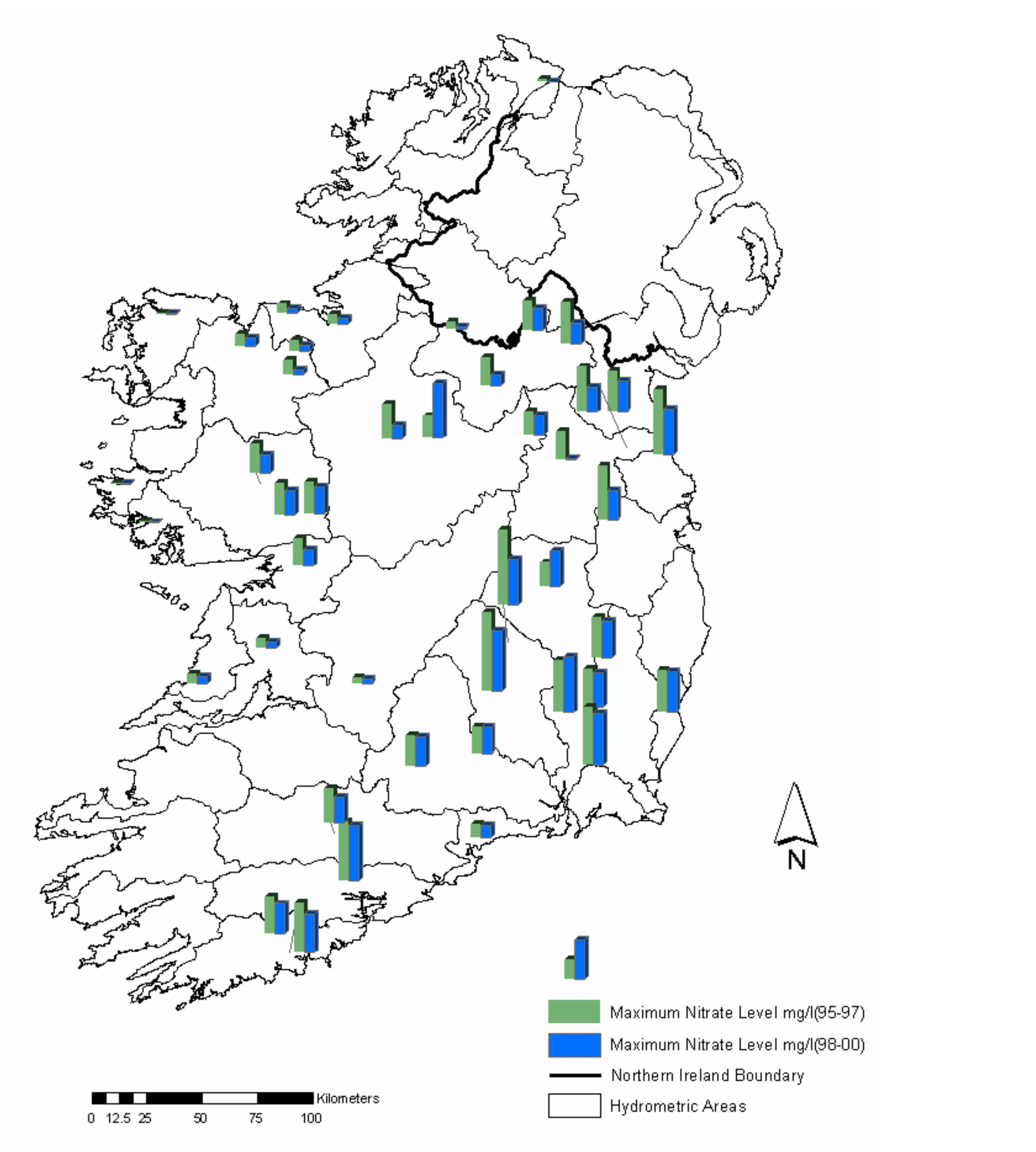

Fig. 8 Comparison of maximum nitrate concentrations in river water between the 1995-1997 and 1998-2000 period.

Comparing the data in Appendix 1 and 2, the groundwater concentrations are, in general considerably higher than those for rivers and indicate that localised contamination is widespread in some counties (i.e. Carlow, Cork, Kildare and Louth). Of the 188 stations sampled, mean concentrations were greater than 50 mg l^{-1} at two stations (Waterford 108 and Louth 9). Maximum concentrations exceeded the guide level of 25 mg l^{-1} at 62 of the sampling stations and mean concentrations exceeded this value at the following 29 sampling stations: Offaly 13, Limerick 56, Carlow 14, Carlow 15, Kerry 56, Kerry 53, Cork (N) 82, Waterford 113, Kerry 66, Wicklow 26, Laois 3, Offaly 10, Kildare 6, Louth 12, Louth 54, Kerry 47, Carlow 1, Carlow 1+2+3, Carlow 16, Carlow 3, Laois 39, Cork (S) 52, Carlow 2, Waterford 111, Kildare 18, Cork (N) 28, Carlow 17, Waterford 108, Louth 49.

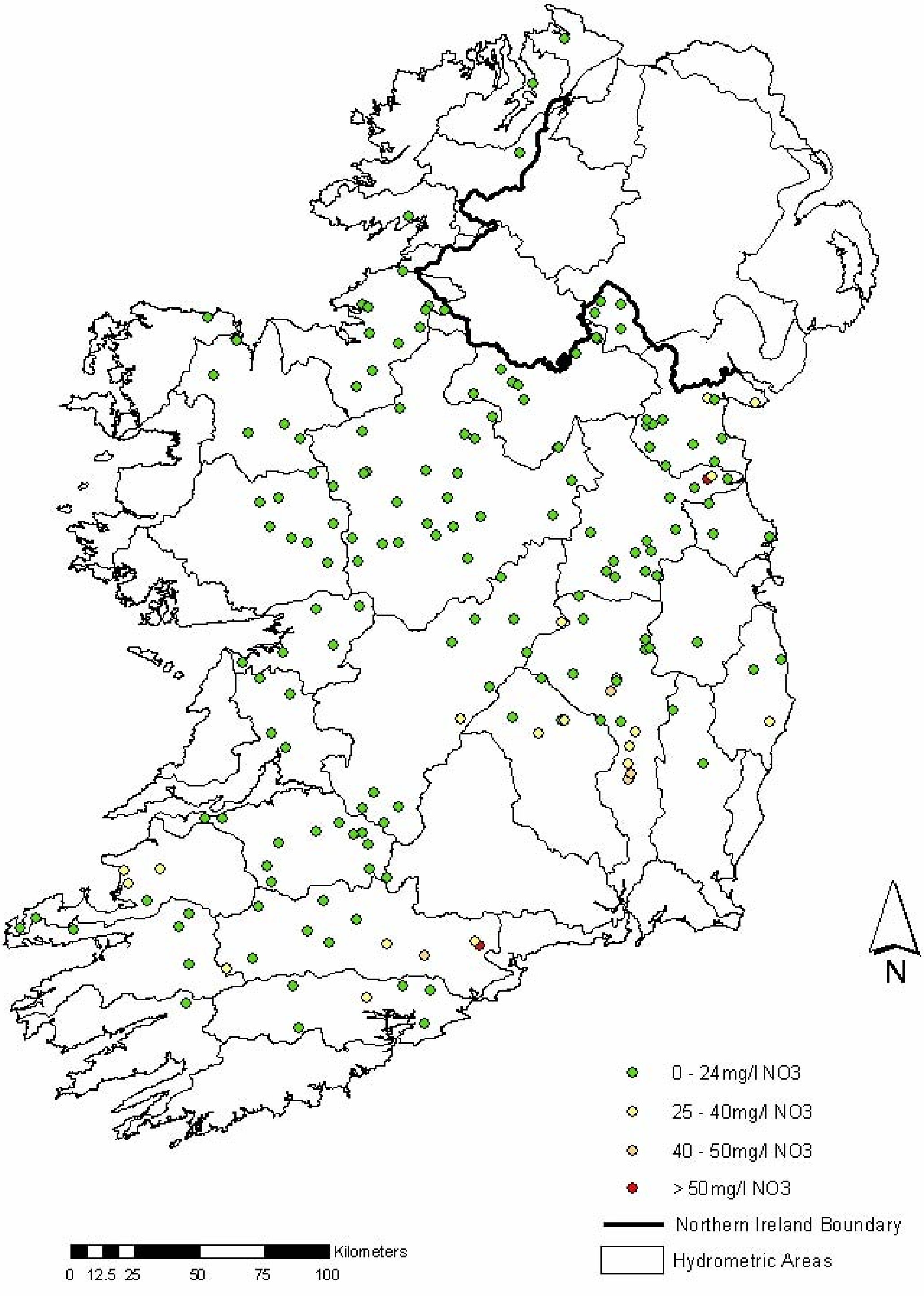

Fig. 9 Mean nitrate concentrations in groundwater in the 1998-2000 period.

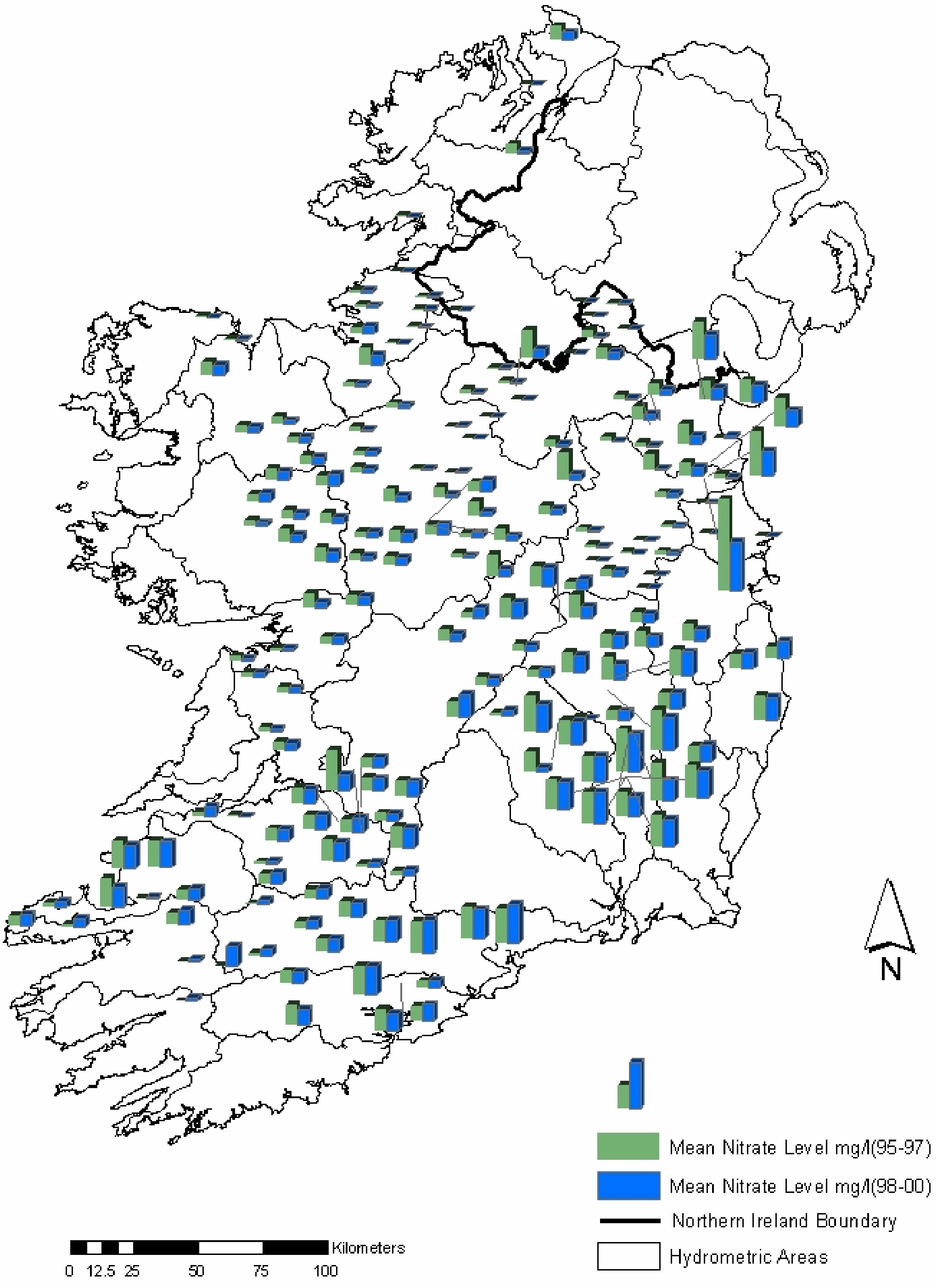

Fig. 10 Comparison of mean nitrate concentrations in groundwater between the 1995-1997 and 1998-2000 period.

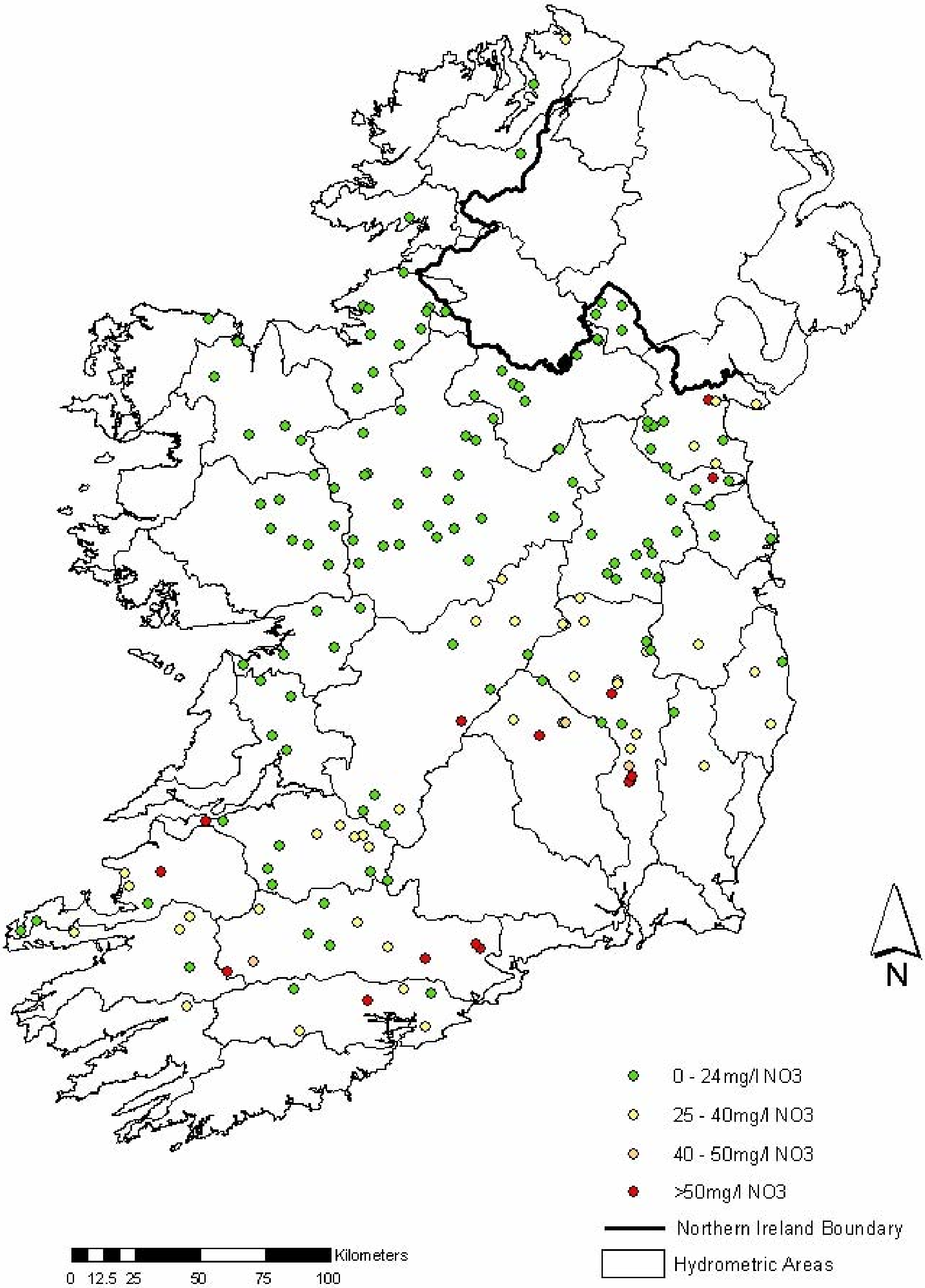

Fig. 11 Maximum nitrate concentrations in groundwater in the 1998-2000 period.

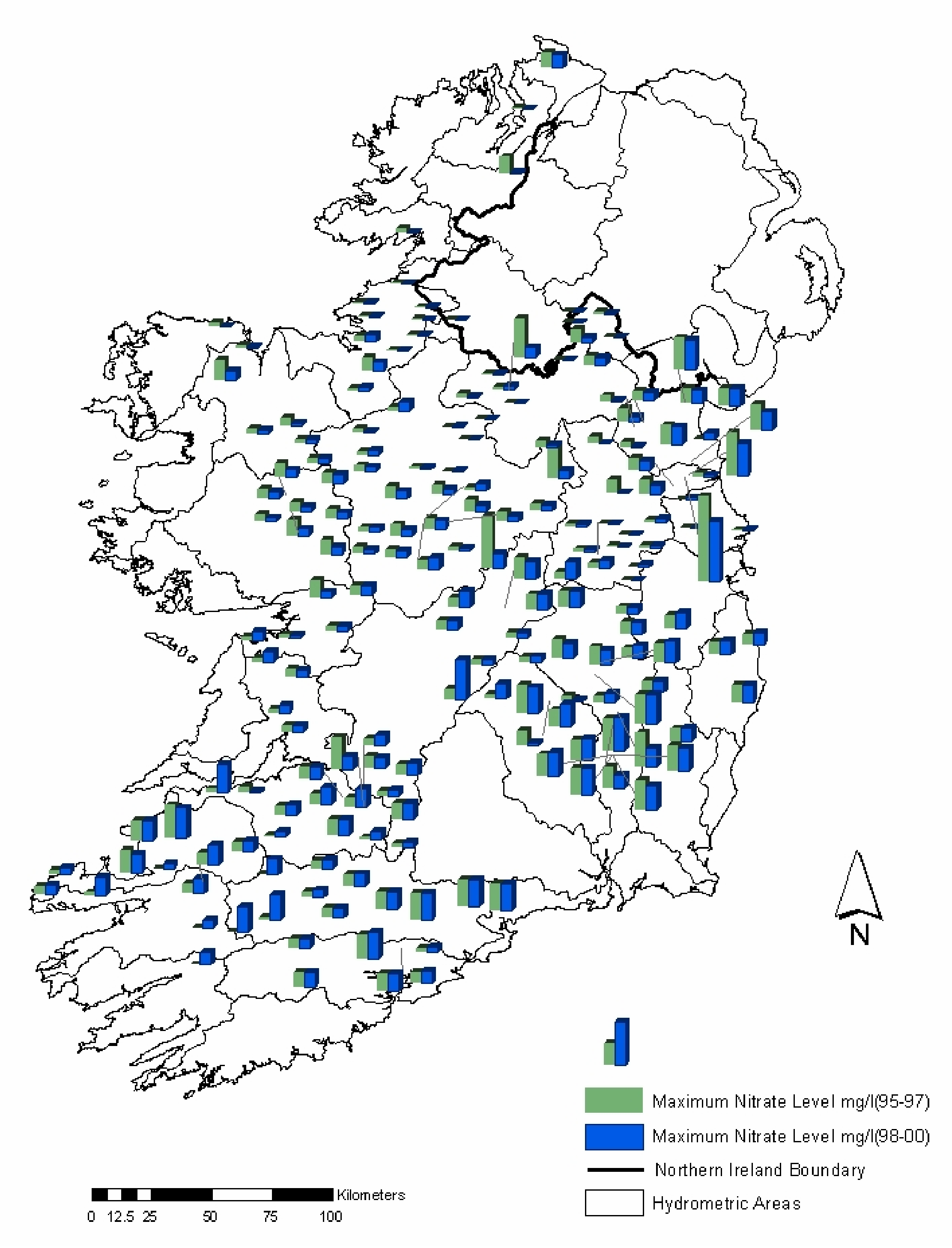

Fig. 12 Comparison of maximum nitrate concentrations in groundwater between the 1995-1997 and 1998-2000 period.

2.4 Estuarine, coastal and marine waters

An assessment has been made of the trophic status of the principal tidal waters in Ireland receiving inputs of nutrients either directly or via rivers. The assessment is made for the purposes of the EU Directives on urban waste water treatment and on nitrates from agricultural sources. The assessment is based mainly on survey data gathered over the period 1995 to 1999. These data provide for the first time a sufficient body of information for a formal assessment to be made of the trophic status of estuaries and bays in Ireland.

A set of quantitative water quality criteria has been developed. The assessment has been based mainly on the application of these criteria to the survey data. Where relevant, other factors, such as problems caused by macro algae, have been taken into account.

As a result of the assessment the following tidal waters in Ireland are considered to be eutrophic:

- Broadmeadow Estuary Inner
- Liffey Estuary
- Slaney Estuary Upper
- Slaney Estuary Lower
- Barrow Estuary
- Suir Estuary Upper
- Lee Estuary/Lough Mahon
- Upper Bandon Estuary
- Lower Bandon Estuary
- Upper Lee Estuary (Tralee)
- Upper Feale Estuary
- Cashen/Feale Estuary
- Killybegs Harbour

The following waters are considered to be potentially eutrophic:

- Castletown Estuary
- Blackwater Estuary Upper
- Blackwater Estuary Lower
- Owennacurra Estuary/North Channel

It is intended that the trophic status of these latter estuaries will be further clarified in the context of ongoing monitoring. This position in relation to estuarine, coastal and marine monitoring is summarised in Fig. 13.

2.5 Lakes

During the three-year period 1998-2000, 304 lakes were examined which represented a significant increase over previous reporting periods and is due, largely, to the commencement of the National Lake Monitoring Programme in 2000. This database is quite representative of such waters describing the quality of almost 1000 km^2, or 64 percent, of the surface area covered by lakes in the country, including 24 of the 25 larger (surface area >7.5 km^2) and important lakes wholly or partly in the State. The lakes examined are principally located in the counties along the western seaboard and in the north midlands, reflecting the higher number of lakes in these areas. A national classification of the lakes according to their trophic status, by total number and total surface area in each trophic category is presented in the EPA report, Water quality in Ireland 1998-2000 (McGarrigle, 2002).

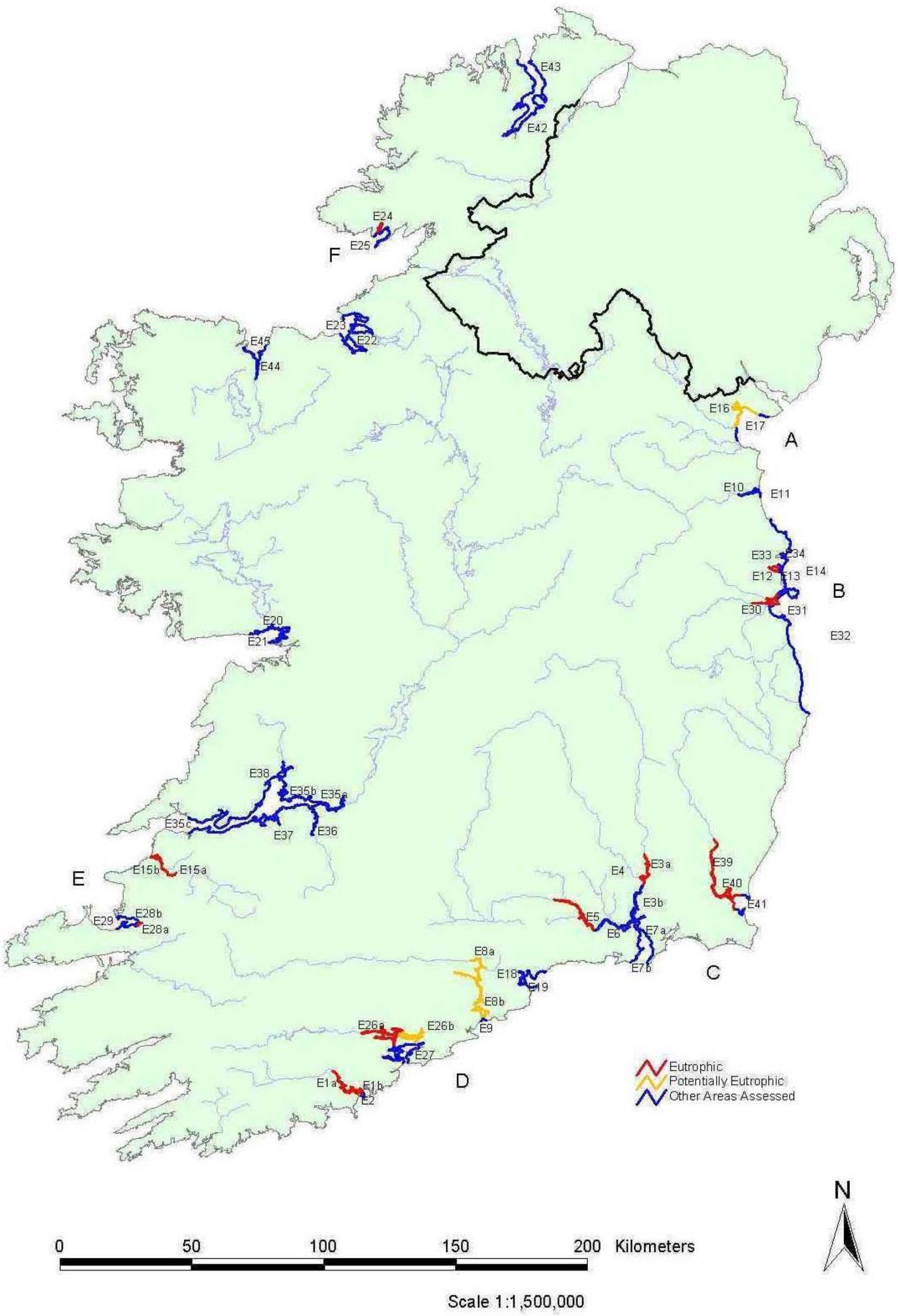

Fig. 13 Assessment of trophic status of tidal waters.

The trophic classification system used for Irish lakes (Table 5) is a modification of a scheme proposed by the OECD and considers only the annual maxima of the chlorophyll concentrations. The oligotrophic and mesotrophic classes reflect satisfactory water quality, with respect particularly to the requirements of salmonid fish, although the impairment of beneficial uses in the moderately eutrophic waters may not be serious. In most cases, sampling is confined to the summer-autumn months and it is considered that the highest concentrations of chlorophyll recorded in this period represent the annual maxima. However, this confined period of sampling may underestimate the annual maximum concentration of nitrate.

Table 5 Trophic classification scheme used for Irish lakes.

Trophic category	Annual maximum chlorophyll (mg m^{-3})
Oligotrophic	<8
Mesotrophic	8-25
Moderately eutrophic	26-35
Strongly eutrophic	36-55
Highly eutrophic	56-75
Hypertrophic	>75

As in the case of rivers, excess phosphorus inputs are considered to be the prime cause of the instances of eutrophication in lakes. The national counter-eutrophication strategy described above is also intended to address the over enrichment of lakes and phosphorus standards have been set for these waters.

2.6 Strategy for effect monitoring

On 30 May 2003, regulation was made by the Minister for the Environment and Local Government which identifies the national territory of Ireland as the area to which an action programme will be applied to protect water quality against pollution caused from agricultural sources. Details have not been worked out.

3. DISCUSSION

The measurements detailed in this paper bear our previous assessment that the level of nitrate enrichment in Irish waters is generally low and well within the limits set for abstraction and drinking water. However the data also shows that appreciable contamination affects a considerable number of rivers and streams at times, particularly in the east, south, and south-east and that in the latter area, there is evidence of a continued high level of nitrate.

The highest annual river nitrate concentrations normally occur in the months of January/February with the lowest concentrations in July/August.

When comparing nitrate concentrations in Irish rivers, with those of the larger rivers in mainland Europe, the following should be taken into account:

- In Irish rivers, nitrate concentrations are generally greater in winter than in summer. However during winter, much of the precipitation in mainland Europe remains frozen as snow and therefore is not available for leaching nitrate from soil;

- In Irish rivers, flows are generally greatest in winter whereas in mainland Europe rivers, the higher flows are as a result of snowmelt in spring/summer;

- In five European countries with relevant data- the highest levels of nitrate are found in small or medium sized rivers (EEA, 2001). On a European scale, most Irish rivers fit into the small or medium sized category.

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Appendix 1

Statistics for nitrate concentrations measured at the Irish EUROWATERNET river stations in the periods 1995-1997 and 1998-2000 (station 1-48).

No.	River	River Code	Stat.	Easting	Northing	1995-1997 Nitrate mg/l		1998-2000 Nitrate mg/l	
						Mean	Max	Mean	Max
R1	Abbert	30A01	300	151643	243848	8.9	19.0	8.1	16.0
R2	Adrigole	21A01	200	81169	050753	NM		1.1	
R3	Aherlow	16A01	900	201692	129529	9.9	18.8	10.1	17.7
R4	Anner	16A02	600	231401	135540	9.5	16.4	9.7	16.6
R5	Argideen	20A02	200	145195	045566	17.9	29.6	16.7	23.3
R6	Athboy	07A01	100	269620	268160	11.7	17.1	0.3	0.4
R7	Awbeg (Buttevant)	18A05	400			NM		NM	
R8	Ballyroan	15B01	150	243145	185604	24.8	44.3	19.0	27.1
R9	Ballysodare	35B05	100	166835	329016	2.7	6.3	1.9	4.0
R10	Bandon	20B02	600	138112	054015	11.6	22.1	10.9	18.2
R11	Barrow	14B01	1000	262200	210900	9.6	14.3	11.2	21.2
R12	Barrow	14B01	3500	270724	143544	20.3	34.6	19.7	31.0
R13	Black (Shrule)	30B02	100	131740	257635	8.3	18.0	5.6	11.5
R14	Blackwater (Munster)	18B02	1900	164780	099793	11.5	21.0	11.4	15.6
R15	Boor	26B07	1100			6.1	11.1		
R16	Boyne	07B04	2100	296400	273610	13.8	27.3	8.9	15.3
R17	Brackan	11B04	200	314720	154330	17.3	24.6	18.5	24.1
R18	Bredagh	40B02	400	261158	438464	1.4	1.9	0.1	0.1
R19	Brosna	25B09	760	219000	225700	NM		9.1	16.4
R20	Bunowen (Louisburgh	32B03	100			0.6	1.2	NM	
R21	Burnfoot	39B02	600			NM		NM	
R22	Burren	14B05	100	279240	162880	14.4	22.6	14.2	20.8
R23	Camlin	26C01	1000	209500	277800	6.0	13.2	5.8	33.0
R24	Clare (Galway)	30C01	800	142702	243205	7.7	19.3	6.5	14.6
R25	Creegh	28C02	1400	103361	166850	4.8	5.8	2.9	4.4
R26	Dalligan	17D01	100	231044	097532	5.2	8.0	5.4	7.1
R27	Dead	25D01	200			7.3	9.4	NM	
R28	Dee	06D01	600	292540	289690	12.9	24.4	10.2	18.6
R29	Deel (Crossmolina)	34D01	400			NM		NM	
R30	Deel (Newcastlewest)	24D02	400			NM		NM	
R31	Douglas (Ballon)	12D03	200			18.8	35.5	NM	
R32	Dromore	36D02	150	271670	320515	11.5	24.7	1.7	12.3
R33	Duag	16D03	100			14.1	22.6	NM	
R34	Dunneill	35D06	200	143843	334186	1.8	5.6	1.6	2.7
R35	Erne	36E01	1100	235615	301510	5.0	16.7	2.6	6.7
R36	Feale	23F01	600			4.5	9.6	NM	
R37	Feorish	26F02	400	189902	310790	3.9	15.5	2.3	
R38	Fergus	27F01	500	134334	183305	2.3	5.3	1.6	3.1
R39	Finn (Donegal)	01F01	900			0.5	2.8	NM	
R40	Finn (Monaghan)	36F01	200	254560	326490	9.2	17.9	2.9	13.3
R41	Flesk (Kerry)	22F02	100			NM		NM	
R42	Flesk (Kerry)	22F02	300			11.5	154.8	NM	
R43	Funshion	18F05	500	172324	110811	NM		11.9	16.7
R44	Gaddagh	22G01	500			4.1	7.3	NM	
R45	Glashaboy	19G01	400	171464	078294	29.7	35.0	26.0	32.9
R46	Glenamoy	33G01	100	089323	333783	0.4	0.6	0.2	0.4
R47	Glencree	10G01	200	320500	214800	NM		0.7	0.9
R48	Gowran	14G03	300	268206	153927	22.3	31.4	23.1	33.2

Continued

Appendix 1 continued Statistics for nitrate concentrations measured at the Irish EUROWATERNET river stations in the periods 1995-1997 and 1998-2000 (stations 49-74).

No.	River	River Code	Stat.	Easting	Northing	1995-1997 Nitrate mg/l		1998-2000 Nitrate mg/l	
						Mean	Max	Mean	Max
R49	Inagh	28I01	100			2.5	3.5	NM	
R50	Inny	26I01	100	255100	279200	10.5	13.9	8.6	11.9
R51	Kilcolgan	29K01	400	151085	220017	7.7	16.4	5.1	10.2
R52	Laney	19L01	100			NM		NM	
R53	Liffey	09LO1	700			NM		NM	
R54	Little (Cloghan)	25L01	200			NM		NM	
R55	Maigue	24M01	200			6.6	11.4	NM	
R56	Maigue	24M01	900			7.4	14.9	NM	
R57	Moy	34M02	100	146633	312323	2.1	8.6	1.2	3.0
R58	Moy	34M02	300	149283	316808	1.7	6.6	1.4	3.9
R59	Moy	34M02	1200	124870	319010	3.0	7.5	2.6	5.3
R60	Nanny (Meath)	08N01	700	313330	270430	19.3	38.6	17.3	26.8
R61	Newport (Tipperary)	25N02	100	177500	166900	1.7	3.9	2.1	3.2
R62	Nuenna	15N02	100	236284	163710	31.2	47.1	29.6	35.8
R63	Owenbaun	18O05	900			NM		NM	
R64	Owengowla	31O02	300	081841	239723	0.2	1.0	0.2	0.4
R65	Owentocker	38O06	300			NM		NM	
R66	Owvane (Cork)	21O07	400			NM		NM	
R67	Rye Water	09R01	100	288100	240700	9.7	32.6	7.0	18.0
R68	Scramoge	26S01	300	190984	277522	5.9	20.4	6.8	8.0
R69	Shannon	26S01	2600			4.9	8.0	NM	
R70	Slaney	12S02	1100	285610	178610	14.0	24.2	13.5	22.1
R71	Sullane	19S02	400			NM		NM	
R72	Swanlinbar	36S01	300	219750	327139	1.4	3.9	0.6	1.1
R73	Traheen	32T01	100	068859	256922	0.4	0.8	0.4	1.0
R74	Tyshe	23T02	500			NM		NM	

Appendix 2

Mean and maximum concentrations of nitrate recorded in samples of groundwater taken at the national monitoring stations in the period 1995-1997 and 1998-2000. NA: Not Available (station G1-G56).

No.[1]	County	Source number	Easting	Northing	Population served	Quantity	1995-1997 Nitrate mg/l NO_3		1998-2000 Nitrate mg/l NO_3	
						m3/day	Mean	Max	Mean	Max
G1	Carlow	1	271300	162000	see note No. 2	165	42	51	35	45
G2	Carlow	2	270800	161900	see note No. 2	650	40	44	37	49
G3	Carlow	3	271000	162000	see note No. 2	90	42	58	36	49
G8	Carlow	17	271500	163800	20	5	55	63	49	65
G4	Carlow[2]	1+2+3	270500	161500	3000	905	43	53	43	53
G5	Carlow[3]	14	271200	174400	75	30	31	43	26	27
G6	Carlow[4]	15	273500	179460	NA	360	49	67	27	38
G7	Carlow[5]	16	270700	167700	700	364	35	39	36	41
G9	Cavan	4	221800	319000	160	45	3	4.6	2.8	4.5
G11	Cavan	21	280100	298000	4	1	5.5	12	1.6	2.5
G14	Cavan	40	221700	318500	4	1	0.28	0.44	NA	NA
G16	Cavan	89	228100	313200	48	12	36	76	10	19
G10	Cavan[6]	18	277600	297700	NA	1.5	4.9	13	0.1	0.1
G12	Cavan[7]	26	244100	289300	NA	120	9.2	12	3.1	4.4
G13	Cavan[8]	33	230700	307500	NA	3500	0.05	0.09	0.1	0.2
G15	Cavan[9]	52	226200	314200	NA	70	3.6	4.7	2.8	7.5
G17	Clare	1	121900	206308	200	568	6.1	9.6	3.9	19
G18	Clare	4	128587	200287	120	40	5.2	7.5	5.8	21
G19	Clare	6	138756	173604	24	8	12	13	9.5	12
G20	Clare	9	133000	179000	19000	5909	6.2	9.1	4.3	16
G21	Clare	21	140300	194400	270	84	6.2	15	5.8	11
G22	Cork (N)	2	128300	112200	8500	6362	1.9	2.3	7.1	32
G23	Cork (N)	26	153000	114700	3000	2500	12	17	14	18
G24	Cork (N)	28	191900	93400	1350	270	43	53	45	53
G25	Cork (N)	34	166200	107400	4000	3200	22	24	20	26
G26	Cork (N)	37	176300	107700	1250	841	67	78	NA	NA
G27	Cork (N)	44	169400	114000	200	114	14	14	NA	NA
G28	Cork (N)	45	172300	110900	1500	450	49	73	NA	NA
G29	Cork (N)	62	126000	92400	3500	1700	4.5	4.9	10	50
G30	Cork (N)	82	177800	98000	5500	3000	28	34	28	35
G32	Cork (N)	158	182400	101800	2500	1000	43	53	NA	NA
G31	Cork (N)[10]	133	155600	98500	NA	1635	17	19	17	20
G33	Cork (N)[11]	159			NA	NA	34	48	NA	NA
G34	Cork (S)	4	184100	82000	800	200	28	34	23	33
G35	Cork (S)	21	191900	67200	2500	1360	20	23	23	25
G36	Cork (S)	24	143600	66000	300	100	26	28	20	29
G37	Cork (S)	25	194500	80100	100	30	9	9.3	9.7	11
G38	Cork (S)	48	141700	82100	400	150	16	17	15	18
G39	Cork (S)[12]	52	169800	77700	NA	NA	37	47	37	51
G42	Donegal	22	228800	402300	6	3	13	34	4.2	4.2
G43	Donegal	25	185900	377900	6	3	3.2	8.2	0.8	0.8
G40	Donegal[13]	4	246200	446200	3300	1680	19	30	11	26
G41	Donegal[14]	13	234000	429000	NA	432	1.2	3.2	0.4	0.6
G44	Dublin	4	325200	254800	nil	40-80	0.36	0.93	0.6	1.6
G45	Galway	4	150600	227200	2400	1450	19	34	7.3	11
G46	Galway	9	176100	252200	2000	550	11	15	8.3	12
G47	Galway	55	141200	253900	1600	764	12	19	8.5	11
G48	Galway	56	132600	258600	1400	909	8.4	13	4.9	6.6
G49	Galway	59	164400	253900	3000	1100	8.5	11	8.6	11
G50	Galway	62	137800	210100	800	1136	5.2	7.5	4.7	7.0
G51	Galway	73	166500	245000	2000	1270	11	14	7.3	9.4
G53	Galway	89	154700	244700	2000	825	19	29	13	16
G54	Galway	92	167400	227900	1000	178	14	19	13	19
G55	Galway	94	157200	259500	1600	796	14	19	8.7	13
G56	Galway	113	157100	213100	132	76	9.9	12	8.6	10

Continued

Appendix 2 continued Mean and maximum concentrations of nitrate recorded in samples of groundwater taken at the national monitoring stations in the period 1995-1997 and 1998-2000. NA: Not Available (station G52-G118).

No.[1]	County	Source number	Easting	Northing	Population served	Quantity	1995-1997 Nitrate mg/l NO_3		1998-2000 Nitrate mg/l NO_3	
						m3/day	Mean	Max	Mean	Max
G52	Galway[15]	85	147100	252600	NA	NA	17	31	8.5	14
G57	Kerry	1	57400	103700	450	200	3.1	6.1	11	37
G58	Kerry	5	42500	107800	100	27	6.2	8.4	8.9	14
G59	Kerry	47	90600	126700	480	910	36	65	34	61
G60	Kerry	53	116100	88500	2000	455	1	1.3	27	50
G61	Kerry	56	78200	121600	1500	2270	37	45	27	36
G62	Kerry	58	107500	146400	600	182	5.5	6.6	13	55
G63	Kerry	66	76800	126500	NA	2090	35	38	30	39
G64	Kerry	68	36400	104400	NA	NA	12	14	14	18
G65	Kerry	69	101700	109800	NA	NA	13	23	15	40
G66	Kerry	70	100400	75000	NA	NA	0.08	0.15	5.0	26
G67	Kerry	82	85300	114700	NA	140	0.46	0.66	2.4	10
G68	Kerry	98	97602	104457	NA	206	16	19	20	31
G69	Kerry	112	101800	90300	NA	NA	0.48	0.62	3.5	15
G70	Kildare	6	266200	200000	1500	430	35	38	32	42
G71	Kildare	18	264000	195500	300	120	53	58	43	58
G72	Kildare	20	263507	206482	800	220	34	37	NA	NA
G73	Kildare	22	281850	239447	100	17	0.36	0.58	0.9	6.0
G75	Kildare	40	265500	239000	130	11	9.4	11	8.3	17
G76	Kildare	42	277011	211522	3000	1000	19	20	17	25
G78	Kildare	50	278814	211736	incl in G76	450	22	25	15	23
G74	Kildare[16]	23	277282	215459	NA	NA	13	14	11	14
G77	Kilkenny	46	265859	199335	NA	NA	29	35	21	28
G82	Laois	5	260200	183900	NA	450	2.9	11	1.1	3.3
G83	Laois	13	267800	183600	40	15	13	14	12	18
G84	Laois	23	249400	201900	10500	4300	26	38	23	28
G85	Laois	28	256400	182400	1000	500	0.06	0.12	NA	NA
G86	Laois	37	226000	185000	180	90	5.5	9.9	8.7	31
G79	Laois[17]	1	245200	184100	2000	240	28	29	6.6	7.2
G80	Laois[17]	2	245800	183500	see note 17	260	24	26	NA	NA
G81	Laois[17]	3	245900	183900	see note 17	400	33	34	31	45
G87	Laois[18]	39	236100	179100	see note No.18	see note No.18	48	55	37	52
G88	Laois[19]	40	237000	200100	NA	NA	10	11	11	13
G89	Leitrim	2	218300	301000	75	25	0.13	0.44	0.1	0.1
G91	Leitrim	13	200200	342000	18	6	0.15	0.27	0.2	0.4
G92	Leitrim	17	208000	294300	15	5	0.17	0.53	0.6	2.5
G93	Leitrim	22	190600	335300	425	142	1.3	1.8	1.1	2.5
G95	Leitrim	26	194100	343800	300	90	0.44	0.62	1.6	2.5
G96	Leitrim	37	192500	342100	100	35	1.6	2.1	0.8	0.9
G98	Leitrim	57	182200	329400	NA	0.1	0.2	0.58	0.1	0.4
G90	Leitrim[20]	5	211300	309900	NA	NA	4.8	6.8	1.2	2.5
G94	Leitrim[21]	24	211800	292500	NA	NA	0.18	0.49	0.1	0.1
G97	Leitrim[22]	44	183900	357000	NA	0.1	0.47	1.2	0.1	0.2
G99	Limerick	7	147200	102800	704	570	10	11	12	16
G100	Limerick	11	177800	123800	600	150	5.8	6	6.6	11
G101	Limerick	19	133400	121700	230	70	12	18	15	20
G102	Limerick	25	168000	150000	1672	470	13	13	13	22
G103	Limerick	41	150748	141252	1424	700	19	22	20	34
G104	Limerick	42	182000	150600	1624	570	22	23	20	25
G105	Limerick	46	159260	144531	240	160	20	24	19	24
G106	Limerick	49	114200	146100	1044	300	3.1	12	1.6	3.6
G107	Limerick	55	168500	140900	488	300	53	62	20	27
G108	Limerick	56	170600	136300	1696	570	28	31	26	31
G109	Limerick	57	170500	136500	NA	505	28	32	24	30
G110	Limerick	62	136008	137027	2000	2200	16	19	15	20
G111	Limerick	82	172700	156300	2064	600	18	24	16	23
G112	Limerick	89	176700	144600	1632	430	11	12	10	15
G113	Limerick	105	137100	134500	NA	NA	18	20	NA	NA
G114	Limerick	109	165000	140500	200	NA	16	17	18	37
G115	Limerick	110	171000	126800	400	129	4.3	4.8	6.2	16
G116	Limerick	111	131800	127900	NA	1250	3.4	3.5	4.9	11
G117	Longford	12	214000	262500	800	550	19	24	5.7	13
G118	Longford	13	200800	269500	2250	2000	14	19	4.5	12

Continued

Appendix 2 continued Mean and maximum concentrations of nitrate recorded in samples of groundwater taken at the national monitoring stations in the period 1995-1997 and 1998-2000. NA: Not Available (station G120-G181).

No.[1]	County	Source number	Easting	Northing	Population served	Quantity	1995-1997 Nitrate mg/l NO_3		1998-2000 Nitrate mg/l NO_3	
						m3/day	Mean	Max	Mean	Max
G120	Louth	9	306500	292500	6000	1527	0.05	0.09	4.0	13
G121	Louth	12	300800	308300	40	60	50	61	32	57
G122	Louth	18	304100	283700	80	70	38	50	22	36
G123	Louth	22	319400	306200	1900	1309	30	35	24	35
G124	Louth	32	304100	307500	na	27	25	29	15	25
G125	Louth	49	301200	276800	80	76	121	168	65	121
G126	Louth	54	302500	278100	450	130	59	84	32	62
G127	Louth	56	309100	277000	1000	475	5.1	6.3	2.3	3.9
G128	Louth	57	295700	290300	7000	2163	27	38	11	36
G130	Mayo	4	149200	279100	NA	900	11	13	9	12
G131	Mayo	16	144200	292300	NA	318	6.5	7.8	7.0	8.0
G132	Mayo	24	138500	298000	NA	1000	9.6	17	5.1	6.3
G133	Mayo	32	129000	268100	600	100	9.4	18	11	13
G134	Mayo	34	108700	339000	NA	250	3.1	9.3	0.8	1.0
G135	Mayo	46	124300	294800	NA	168	8.7	11	6.7	8.4
G136	Mayo	47	145600	299600	NA	850	9.3	16	NA	NA
G137	Mayo	48	111000	317200	NA	1	17	39	12	17
G138	Mayo	50	120000	330300	NA		2.1	5.6	2.0	2.1
G129	Mayo[23]	2	136300	269600	NA	NA	15	25	11	13
G139	Meath	9	285000	282000	144	33	21	27	2.5	2.5
G140	Meath	12	277400	241300	370	240	0.11	0.31	0.3	0.4
G141	Meath	15	279100	289000	170	54	7.1	12	2.4	3.6
G142	Meath	16	288700	257300	676	275	4.5	5.5	2.7	7.8
G143	Meath	20	282800	286100	453	87	14	17	NA	NA
G144	Meath	21	279400	249200	75	7	4.9	5.8	3.2	4.9
G145	Meath	23	296200	273700	2787	1760	18	23	12	17
G147	Meath	93	264800	245200	NA	20	0.1	0.27	0.3	1.3
G148	Meath	102	286800	269900	NA	15	6.1	29	5.5	17
G149	Meath	106	273100	248800	NA	4	2.2	3	1.1	2.1
G150	Meath	107	262300	241600	NA	5	3.4	5.9	1.8	5.3
G151	Meath	111	277900	252800	300	50	0.46	1.0	0.7	0.9
G152	Meath	115	301400	267500	NA	4	0.1	0.18	1.0	4.3
G146	Meath[24]	26	303300	255700	6000	NA	0.16	0.49	0.04	0.04
G153	Monaghan	8	267900	334600	8500	4260	0.22	0.53	0.1	0.1
G154	Monaghan	10	258900	330700	300	130	15	18	10	16
G155	Monaghan	11	257700	340700	2040	1300	0.82	1.5	1.1	1.5
G156	Monaghan	13	260000	345300	NA	5.5	0.18	0.4	0.1	0.1
G157	Monaghan	21	258200	331200	NA	1046	9.6	26	2.8	12
G158	Monaghan	39	250400	325100	NA	120	0.06	0.09	0.1	0.1
G159	Monaghan	80	283900	299700	NA	7	16	18	8.2	15
G160	Monaghan	104	278000	299500	NA	15	18	27	8.3	12
G161	Monaghan	105	267800	344400	NA	650	1.2	3.7	0.5	0.9
G162	Offaly	3	202900	214000	1750	818	16	19	11	19
G163	Offaly	4	216900	197000	500	380	11	12	10	13
G164	Offaly	10	206200	184800	1800	1161	20	21	31	78
G165	Offaly	11	211800	223300	1050	590	7.4	17	13	30
G166	Offaly	13	244700	222000	610	230	26	30	25	31
G167	Offaly	21	226700	223300	2900	1976	25	44	20	36
G168	Offaly	23	251600	231700	4500	1818	10	14	13	34
G169	Offaly	27	253500	223300	550	277	29	30	14	30
G170	Offaly	28	231400	210000	300	200	10	11	8.2	11
G171	Roscommon	10	157400	274200	3600	3500	14	20	15	18
G172	Roscommon	11	183000	304000	4500	4203	7.4	9.5	5.5	20
G173	Roscommon	16	170000	279500	2000	1374	5.5	6.9	5.8	9.7
G174	Roscommon	17	169000	279000	3000	2000	8.9	13	6.7	10
G175	Roscommon	19	168200	295300	600	1100	5.5	7.3	1.9	2.7
G176	Roscommon	27	193400	259700	350	131	5.5	6.8	6.4	15
G177	Roscommon	29	193400	259700	1600	646	12	18	15	24
G178	Roscommon	30	196400	255100	1500	636	14	21	15	18
G179	Roscommon	32	182100	252400	3400	2496	16	23	12	15
G180	Roscommon	39	181800	267800	5900	5453	17	24	9.2	16
G181	Roscommon	42	188700	240600	5300	4540	13	22	NA	NA

Continued

Appendix 2 continued Mean and maximum concentrations of nitrate recorded in samples of groundwater taken at the national monitoring stations in the period 1995-1997 and 1998-2000. NA: Not Available (station G182-G202).

No.[1]	County	Source number	Easting	Northing	Population served	Quantity	1995-1997 Nitrate mg/l NO_3		1998-2000 Nitrate mg/l NO_3	
						m3/day	Mean	Max	Mean	Max
G183	Roscommon[26]	45	205200	279100	NA	NA	1	1.5	1.5	3.1
G184	Sligo	3	168400	344400	150	58	3.3	4.3	3.4	4.2
G185	Sligo	8	171900	318700	25	11	21.8	26.7	13	17
G186	Sligo	10	170600	343100	600	150	3.2	3.3	2.8	3.1
G187	Sligo	13	166000	312500	500	130	4.8	6.4	4.6	8.9
G188	Sligo[27]	19	171000	332800	NA	NA	9.2	12	11	15
G191	Waterford	111	211490	99280	NA	see note 28	41	52	38	52
G190	Waterford	113	210600	975000	NA	see note 28	21	42	29	49
G189	Waterford[28]	108	213500	97600	NA	668	45	52	51	53
G193	Westmeath	7	256200	256200	20	7	5.4	7.2	3.3	6.7
G194	Westmeath	9	221400	238900	3000	1136	30	103	10	30
G195	Westmeath	12	241700	262800	NA	165	13	14	8.7	12
G196	Westmeath	17	249100	276300	NA	82	37	62	7.2	17
G192	Westmeath[29]	5	209000	246500	NA	NA	5.8	7	2.5	5.4
G197	Wicklow	26	324715	183690	NA	138	32	33	30	35
G198	Wicklow	27	318685	203393	420	136	20	25	22	28
G199	Wicklow	33	297460	214046	NA	110	23	27	16	31
G200	Wicklow	43	287839	187759	NA	450	22	23	22	22
G201	Wicklow	44	329188	207672	NA	60	15	20	22	23
G202	Wicklow	47	299504	167727	NA	600	20	24	22	26

1 Numbers identify corresponding location symbols on Maps
2 This is a blend of sources 1, 2 and 3 taken from the supply system
3 Scheme closed 1998. Now connected to Carlow Town Supply (surface water)
4 Used for irrigation in glasshouses
5 Scheme now supplied from a new groundwater source from the end of 1999.
6 Water used in growing mushrooms. Not used for drinking water
7 Water used in procesing mushrooms.
8 Dairy processing use.
9 Domestic use and pig farm use.
10 Industrial process use (food processing)
11 Included in Cork (North) 44 and Cork (North) 45
12 Not normally used. Pumps normally only turned on for sampling purposes. Booster bore for Cork City suburbs supply.
13 Water sampled prior to mixing with surface water. The full (mixed) scheme supplies 4000 people and total volume is 2000 m³/d
14 Water used for process water only - not for drinking water.
15 Flowing spring. Scheme now supplied from Lough Corrib.
16 Flowing spring.
17 Water scheme (900 m³/d) supplied from three sources Laois 1, 2 & 3.
18 Included in Laois 14 Durrow. The combined population is 1100 and abstraction is 370 m³/d.
19 Mountrath WSS is supplied from a surface source at Drim and a groundwater source at Knocks (Laois 40).
20 Flowing spring. No longer used for public supply.
21 Bored well no longer in use. Now (in 2000) connected to Regional WSS (surface water)
22 Bored well no longer in use. Now (in 2000) connected to regional WSS (surface water)
23 Flowing spring. No longer used for public supply.
24 Scheme closed down October 1998.
25 No longer used as a public water supply source. Flowing spring.
26 No longer in use as a public water supply source. Closed down 2000.
27 Not used as a public water supply source. Flowing spring.
28 The three sources for the Cappoquin WS are Waterford 108, 111 & 113. Waterford 113 out of use since 15/5/1996. Data indicates that Waterford 113 is subject to general pollution, incl. nitrates.
29 Flowing spring. No longer in use for public supply.

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by Sweden

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Abstract This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in Sweden. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5(6) (EC, 1991). In 1999 the European Commission published the Draft Monitoring Guidelines (EC, 1999). The environmental monitoring in Sweden is carried out within different programme areas on a national and a regional level. In this paper an overview is given of the Swedish monitoring networks within the programme areas of Freshwater, and Seas and Coastal Water. These monitoring networks are also used for monitoring the effectiveness of the Action programmes. For the same purpose two sub-programmes within the programme area of Agriculture are used. One interim target to the environmental quality objective “Zero Eutrophication” is that the waterborne anthropogenous nitrogen emissions shall be reduced by 30% by 2010. A model approach is used to assess the outcome of the interim target.

1. INTRODUCTION

1.1 General

Most of Sweden’s land area is forest, and only 8% is arable land. As a result of climate factors, the conditions for agricultural production are very different in the north and in the south. The most important agricultural areas are in the south. It is mostly in these areas that agriculture has had a negative impact on the environment, and it is also where most measures aimed at reducing this negative effect have been taken.

1.2 Description of natural factors influencing nitrate occurrence

The climate in Sweden varies from sub-arctic in the north, influenced by the Gulf Stream, to maritime and continental in the south. In the northern parts of Sweden the winters are long, lasting 8-9 months while in the southernmost parts the winter is shorter and the soil does not freeze every year.

The dominant wind direction is south-westerly to westerly. Precipitation is the highest along the Scandinavian mountains and the south-west coast. In the eastern parts of the country, it seldom exceeds 700 mm per year, see Fig. 1. Average precipitation per month is at its highest during summer and autumn, but due to high evapotranspiration the average discharge is low during the summer months.

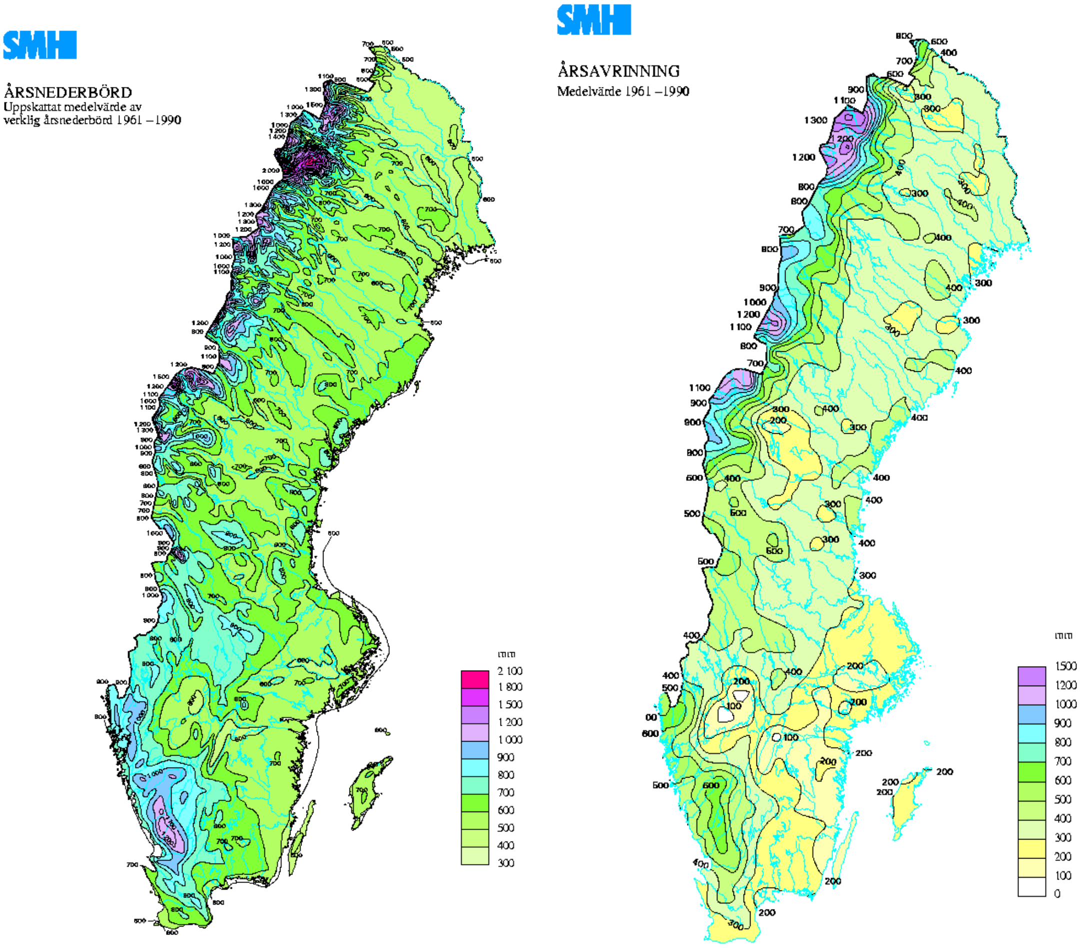

Fig. 1 Precipitation per year, average for the period 1960-1990 (left) and discharge per year, average for the period 1960-1990 (right). Source: Swedish Meteorological and Hydrological Institute (SMHI).

The arable land in Sweden consists of glacial and post-glacial sediments of different origin and characteristics. In the southernmost parts of the country and on the islands Gotland and Öland, the most common soil types are clay tills derived from calcareous sedimentary. The dominant soil types in the southern Highlands are sandy soils rocks poor in clay derived from Archean till, see Fig. 2. Heavy clays are mainly found in the region around the two lakes Mälaren and Hjälmaren. This region is surrounded by areas with medium to light clay soils. Silty soils with varying clay content are found along the coast north of the Mälaren-Hjälmaren region to the northernmost parts of the country.

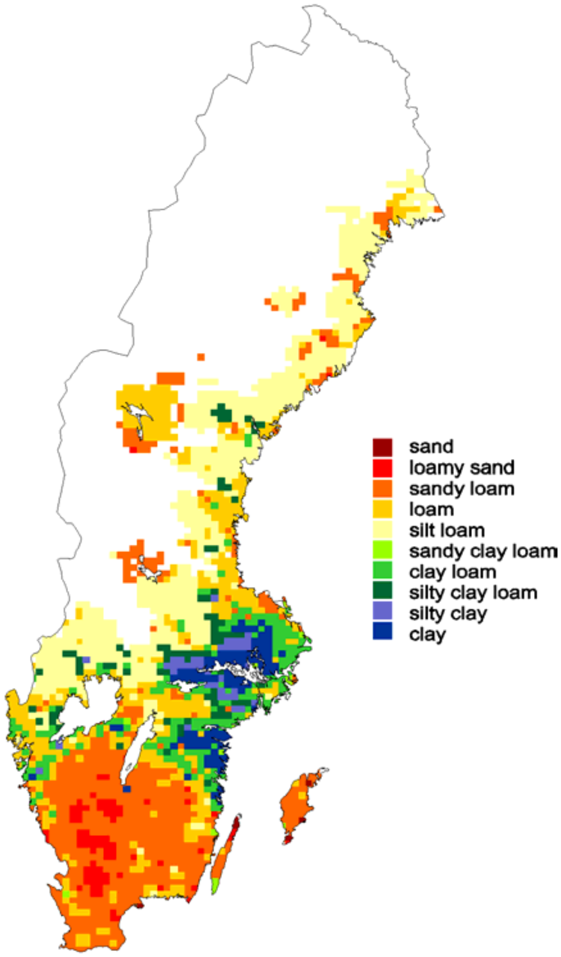

Fig. 2 Textures of agricultural topsoils (0-20 cm) according to the international classification system (FAO, 1990) (Source: Eriksson *et al.*, 1999).

There are two main types of aquifers in Sweden: bedrock without primary porosity but with water-bearing joints and fractures, and Quaternary superficial deposits with primary porosity. The groundwater resources in Swedish bedrock are limited. Only in the county of Skåne in southernmost Sweden and sporadically in other parts of the country are the conditions favourable for large-scale groundwater abstraction. The groundwater level varies over the year with a pattern that, due to the climate, is different in different parts of the country. In the north of Sweden the melting away of snow in spring has a great influence on the formation of groundwater. In the southern parts, however, the formation of groundwater occurs more or less continuously from October to April due to a relatively low evapotranspiration during that period.

Sweden has an abundance of surface watercourses of varying kinds, which include crystal-clear oligotrophic mountain rivers and lakes, forest lakes stained brown by humus and more nutrient-rich watercourses crossing lowland areas. There are some 90,000 lakes having an area of at least one hectare that cover approximately 9% of the total area of Sweden. Most lakes are small although some are very extensive. Lakes Vänern and Vättern are among the largest lakes in Europe. The two next largest lakes in Sweden are lakes Mälaren and Hjälmaren. Compared to the rest of the country there are very few lakes in the flatland in the southern parts of Sweden. Most Swedish lakes have low or moderate concentrations of total nitrogen, nitrate and total phosphorous (Wilander *et al.*, 2003). In agricultural and urban areas, lakes with higher concentrations can be found.

The main Swedish marine areas are the Baltic Sea, the Sound and the Kattegat and Skagerrak. The Skagerrak, with a deep trench descending to over 700 m, is an inlet of the North Sea. The Kattegat is shallow, having an average depth of less than 25 m. The Baltic Sea is a large brackish sea and consists of a number of different basins separated by sills. It is connected to the Kattegat and Skagerrak by the Sound and the Great and the Little Belt. Surface water with low salinity is flowing out of the Baltic Sea and deep water with higher salinity is flowing in the opposite direction from the North Sea.

In the Baltic Proper a pronounced boundary layer at a depth of 40-70 m is formed between the deep water and the upper layer. This halocline impedes the vertical water exchange and prevents highly oxygenated surface water from penetrating downwards. This is causing an oxygen deficiency under the halocline which is partly natural but has been aggravated by eutrophication and an increase in plankton production. In the Kattegat a halocline occurs at a depth of about 15 m. Under this halocline more or less widespread oxygen deficiency now occurs in the autumn. Also along the coast and in bays and archipelago coves with limited water exchange, the oxygen level can become very low at the bottom. Increased nitrogen input into the Baltic proper and the Kattegat has increased the nitrate content. In these areas there has been a rise in plankton production, and algal bloom occurs more frequently in spring and summer.

1.3 Description of human factors influencing nitrate occurrence

Not quite 8% of Sweden's total area is agricultural land. The main agricultural areas are on the southern plains and around the two lakes Mälaren and Hjälmaren. The total area of arable land was at its largest in the beginning of the 20th century. Since the middle of that century there has been a strong decline, by more than 900,000 ha. In 2002, the total arable land area was 2.7 million ha.

On average, some 40% of the arable land was used for growing cereals in 2002, see Table 1. One-third of the cereals area was used for winter crops, and the rest for spring crops. The area of leys and pastures was approximately 941,000 ha. Other feed grains, mostly cereals for forage, were sown on some 32,000 ha. There is also some limited growing of maize in the south of Sweden. Some 10% of the arable land was set aside in 2002. Almost half of this area lay fallow as perennial grassland.

Table 1 Arable area use in 1990, 1995 and 2002 (Source: Statistics Sweden, 1991, 1996, 2003a).

Crop	1990	1995	2002
Cereals	1,335,700	1,104,500	1,129,300
of which wheat	*349,700*	*261,400*	*339,600*
barley	*543,400*	*453,400*	*416,800*
oats	*387,800*	*278,300*	*295,000*
Leguminous plants	32,700	12,000	41,500
Ley	968,500	1,066,800	973,400
Potatoes	36,200	35,000	31,700
Sugar beets	49,900	57,500	54,800
Oilseed rape and turnip rape	167,900	104,600	67,500
Other crops	31,200	47,800	42,500
Set aside	176,100	278,600	268,500
Other areas	46,400	59,800	70,700
Total	2,844,600	2,766,600	2,679,900

Milk production is undergoing structural change, which has led to a decrease in the number of dairy cows and enterprises, and to more animals per enterprise. There has been no corresponding decline in the number of other cattle, see Figs 3 and 4. As regards pigs, the trend is the same as for dairy cows, i.e. fewer animals and enterprises in combination with more animals per enterprise.

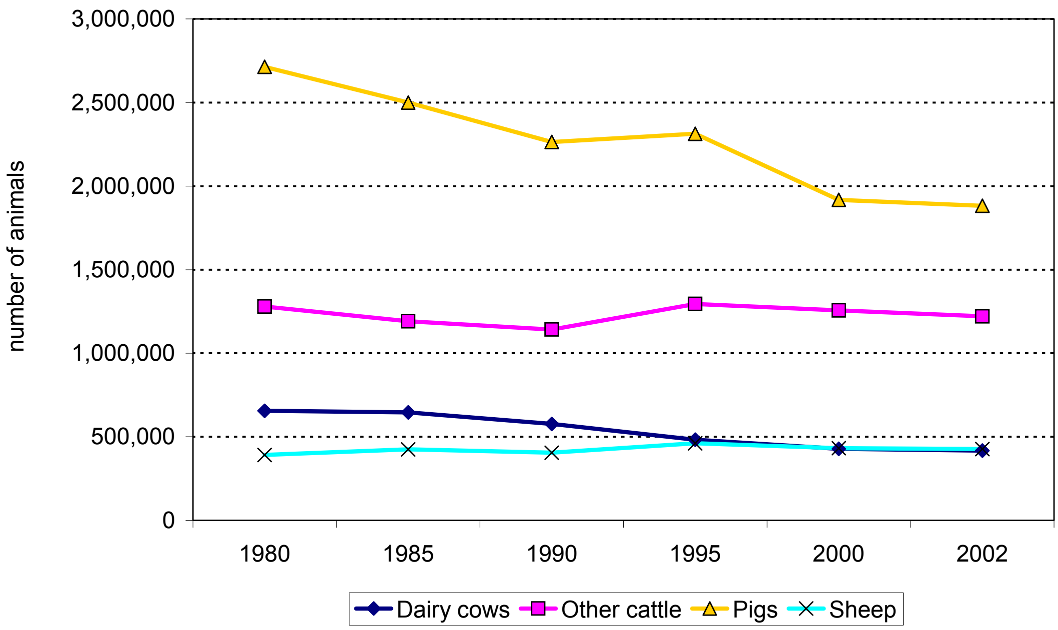

Fig. 3 Number of animals in Sweden in 1980-2002 (Source: Statistics Sweden, 2003a).

During the period 1980-1999, livestock density has decreased at the national level, mostly as a result of the reduced number of dairy cows, see Fig. 4.

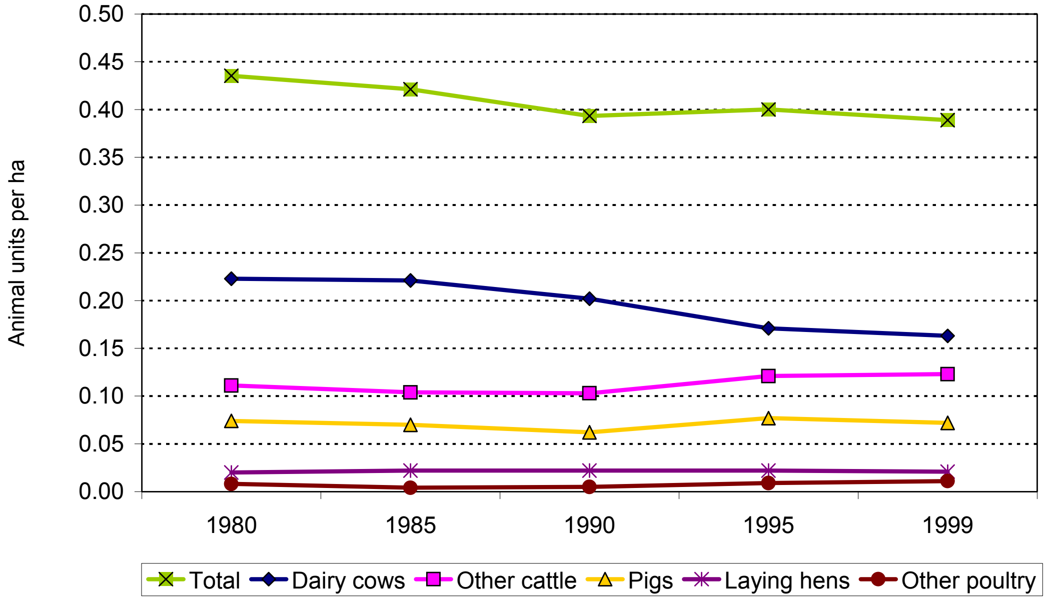

Fig. 4 Livestock density, totals and per species, during the period 1980-1999 (Source: Swedish Board of Agriculture, 2003).

The total number of enterprises (>2.0 ha arable land) was 71,000 in 2002 (Statistics Sweden, 2003a). For 28% of the enterprises, crop production dominated, whereas 38% focused on livestock production and 9% on a combination of the two. The rest of the enterprises fell into the category small enterprises. Although all types of enterprises can be found in all parts of the country, there is a difference between regions as regards the dominating type. In the north of Sweden and in forest areas of southern Sweden, livestock production is the dominating form, and there is also a large share of small enterprises there. In the Mälaren-Hjälmaren region, there are many crop production enterprises and few small ones. In the agricultural areas south of lake Vänern and in the southernmost part of Sweden, production focuses on both crops and livestock.

In 2001, 207,000 tonnes of plant-available nitrogen were supplied via manure and fertilisers to the cultivated land (Statistics Sweden, 2002). Of this total amount, 85% came from fertilisers. In addition to plant-available nitrogen, 42,000 tonnes of organically bound nitrogen were supplied via manure. Plant-available nitrogen in manure here refers to nitrogen in ammonium form after ammonia losses.

In total, 19.9 million tonnes of manure were spread on arable land in 2001. Most of it (85%) came from cattle manure. 70% of this was liquid manure, and the rest was solid or deep litter manure. Manure was spread on one-third of arable land. An average of 90-98 kg total nitrogen per hectare was spread to this area, 37-44 kg ha^{-1} of which was plant-available.

Fertiliser sales have declined since the mid-1980s. Figure 5 shows the sale of fertiliser nitrogen between 1993 and 2002. An environmental tax is charged on such nitrogen. At the moment, this tax is SEK 1.80 kg^{-1} N (about € 0.2).

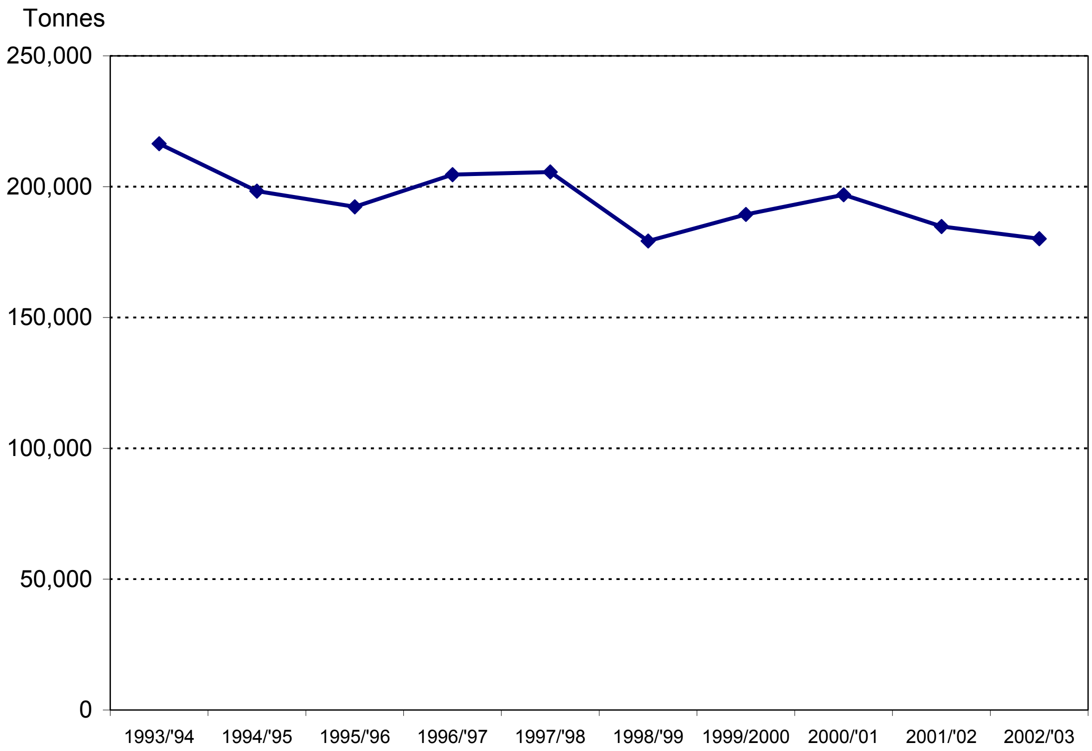

Fig. 5 Consumption of mineral fertiliser 1993/94-2001/02, tonnes N (Source: Statistics Sweden 1999 and 2003c).

In 2001, 72% of arable land received nitrogen from fertilisers. For approximately half (49%) of the arable land, only fertilisers were used for supplying nitrogen. Nitrogen from both fertilisers and manure was spread to 23% of arable land. Since the mid-1990s, there has been a slight decline in the area on which fertilisers are used. For 11% of the arable land, only manure was added. In all of Sweden, neither fertilisers nor manure were used on 17% of the area. Fertilisers are spread to almost 90% of the cereals area. For leys, the corresponding share is smaller, slightly more than 60%.

Figure 6 shows average supply of plant-available nitrogen per hectare in 2001 for various crops that were given: (1) fertilisers only, (2) fertilisers and manure, and (3) manure only.

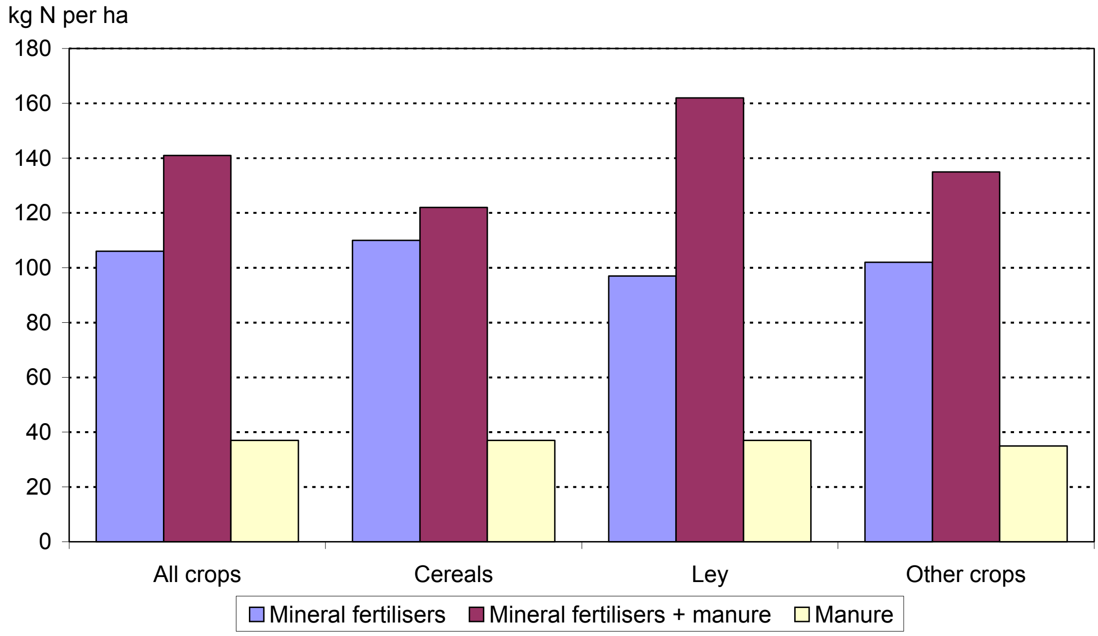

Fig. 6 Average supply of nitrogen per hectare (plant-available nitrogen), kg N ha-1, 2001 for crops grown using only fertilisers, fertilisers and manure, and only manure (Source: Statistics Sweden).

The OECD has calculated nitrogen balances on arable land for the periods 1985/87 and 1995/97. For Sweden, the estimated excess was slightly more than 30 kg N ha^{-1} in the latter period. The EU average was not quite 60 kg N ha^{-1}. Statistics Sweden has calculated nutrient balances for arable land using the soil surface method, and for the Swedish farm sector using the farm gate method, in accordance with guidelines of the OSPAR convention [The Convention for the Protection of the Marine Environment of the North-East Atlantic Please]. Table 2 presents nitrogen and phosphorus efficiency in 1985-2001, according to the farm gate method.

Table 2 Nitrogen and phosphorus efficiency according to the farm gate method, 1985-2001 (Source: Statistics Sweden, 2003b).

	Efficiency, %					
	1985	1991	1995	1997	1999	2001
Nitrogen	32	35	32	35	33	37
Phosphorus	34	54	48	56	50	63

In this context, “efficiency” refers to the share of nutrients removed from agriculture out of the total amount supplied during one year. Products that circulate within agriculture, like ley forage and feed grain, are thus not included. In addition to emissions to air and water that affect the environment, the difference between input and removal can consist of a build-up of the soil’s organic store, i.e. an increase in humus content, or of emissions of pure nitrogen to the air via denitrification. The phosphorus efficiency clearly improved during the period 1985-2001. The nitrogen efficiency has improved somewhat during the same period, but the trend is more uncertain.

1.4 Overview of monitoring networks

Sweden has developed extensive networks to document the state of the environment and its changes. The environmental monitoring is carried out within different programme areas on a national and regional level. The national monitoring gives information on the state of the environment in Sweden and forms the basis for international reporting and evaluation of environmental goals. The Swedish Environmental Protection Agency is responsible for and co-ordinates the national environmental monitoring. Regional monitoring provides information on regional conditions and in many cases supplement the national monitoring. The County Administrative Boards are responsible for the co-ordination of regional activities as well as parts of the implementation. In Sweden the ordinary monitoring networks, within the programme areas of Freshwater and Seas and coastal areas, are used to identify waters for the purpose of designating vulnerable zones.

In the programme area Freshwater monitoring of lakes, watercourses and groundwater is performed. Groundwater monitoring is also carried out within the Swedish National Groundwater Network by The Geological Survey of Sweden (SGU), with the objective to study the long-term variation in the quantity and quality of groundwater. The main national sub-programmes of the programme area Freshwater are described below.

Reference stations – groundwater. At approximately 100 stations samples are taken four times a year for chemical analyses. The aim of the programme is, together with other data, to provide a nationwide description of the status of Swedish groundwater.

River mouths. The aim of the programme is to study the transport of nutrients and other substances by rivers to the seas surrounding Sweden. It includes all the large rivers and some typical small rivers. Together they represent about 85% of the Swedish surface runoff. Water chemistry is measured monthly at approximately 50 sites.

Reference stations-lakes. Physical and chemical parameters are measured every year in about 80 lakes.

Reference stations-watercourses. The sub-programme includes 50 watercourses of medium size. Samples are taken every month for analyses of water chemistry. In these two sub-programmes the impact and large-scale effects are studied in lakes and watercourses that are relatively unaffected by land use and discharge from point sources.

The large lakes. The sub-programme aims at describing the biological and chemical state of the three largest lakes in Sweden, Vänern, Vättern and Mälaren. The biological and chemical state of the fourth large lake, Hjälmaren, is monitored in a regional program.

Nationwide inventory of lakes and watercourses. The sub-programme shall provide an overview of the state of all Swedish lakes and watercourses with respect to eutrophication, acidification and content of metals. National inventories of lakes have been carried out every fifth year since 1975. The first national inventory of watercourses was made in 1995. During the last inventory in 2000, measurements of chemical and biological parameters were carried out in over 3000 lakes and 1500 rivers all over the country.

The programme area of Seas and Coastal areas aims at describing the impact and large-scale trends with respect to eutrophication and toxic substances. The marine programme covers both the Swedish as well as parts of international requirements of information and the programme is co-ordinated with the international programmes in other countries. Today the national programme only has a limited geographical covering in coastal areas, and monitoring in these areas is mainly carried out through regional efforts. Some examples of sub-programmes are mentioned below.

The phytobenthic communities in coastal areas in the Baltic proper and in the Skagerrak are examined to indicate long-term changes caused primarily by eutrophication.

Monitoring of the free water mass is performed at a large number of stations in all Swedish sea areas. The objectives are to obtain information on stratification and water mass distribution to estimate exchanges between the various basins as well as with the North Sea, and to observe the inter-annual and annual cycles of chemical and biological variables as indicators of the environmental conditions.

County Administrative Boards, Water Conservation Associations and others accomplish the regional water monitoring with regard to lakes, rivers and coastal areas. The Water Conservation Associations were founded in the 1950's by municipal authorities and industries as a response to increasing environmental problems. Their task is *inter alia* to monitor the environmental state in areas affected by pollution. Most of them publish annual reports and compilations and evaluations of results for longer periods.

To monitor the effects of action programmes environmental monitoring, simulation models, statistical surveys and nutrient balances are used. Effect monitoring is further described in the section 2.2.

1.5 Environmental goals

In the end of the 1980's, a national environmental goal aiming at reducing nitrogen emissions by 50% was approved *inter alia* as a consequence of Swedish commitments within the OSPAR and HELCOM conventions. In 1988, the Swedish Parliament also accepted an action programme with the objective to halve nitrogen leaching from agriculture until the end of the century. The programme consisted of directed measures in intensively farmed and coastal areas, for example restrictions for applications of manure, manure storage requirements and increased share of vegetation cover during autumn and winter. In coastal areas and the southern parts of Sweden special vulnerable zones were introduced. Nationwide measures, such as restrictions of livestock density and an environmental fee on the usage of fertilisers, aiming at decreasing the intensity in agriculture were also introduced. An evaluation performed in the middle of the 1990's by the Swedish Environmental Protection Agency showed that nitrogen leaching from agriculture had decreased by 25% until 1995.

When Sweden joined the European union in 1995, Swedish authorities judged that the measures already implemented were sufficient to fulfil and well corresponded to the requirements for vulnerable zones and the measures according to the Nitrates Directive. In 1995, Sweden therefore designated the existing vulnerable zones as Nitrate Vulnerable Zones according to the Nitrates Directive. The measures already implemented in the south of Sweden and in the coastal areas formed the Action Programme in accordance with the Nitrates Directive. However, some supplementary measures have later been introduced. Lately, also additional Nitrate Vulnerable Zones have been designated, see Fig. 7. Sweden has not considered notifying a derogation on the maximum amount of manure applied to the land each year.

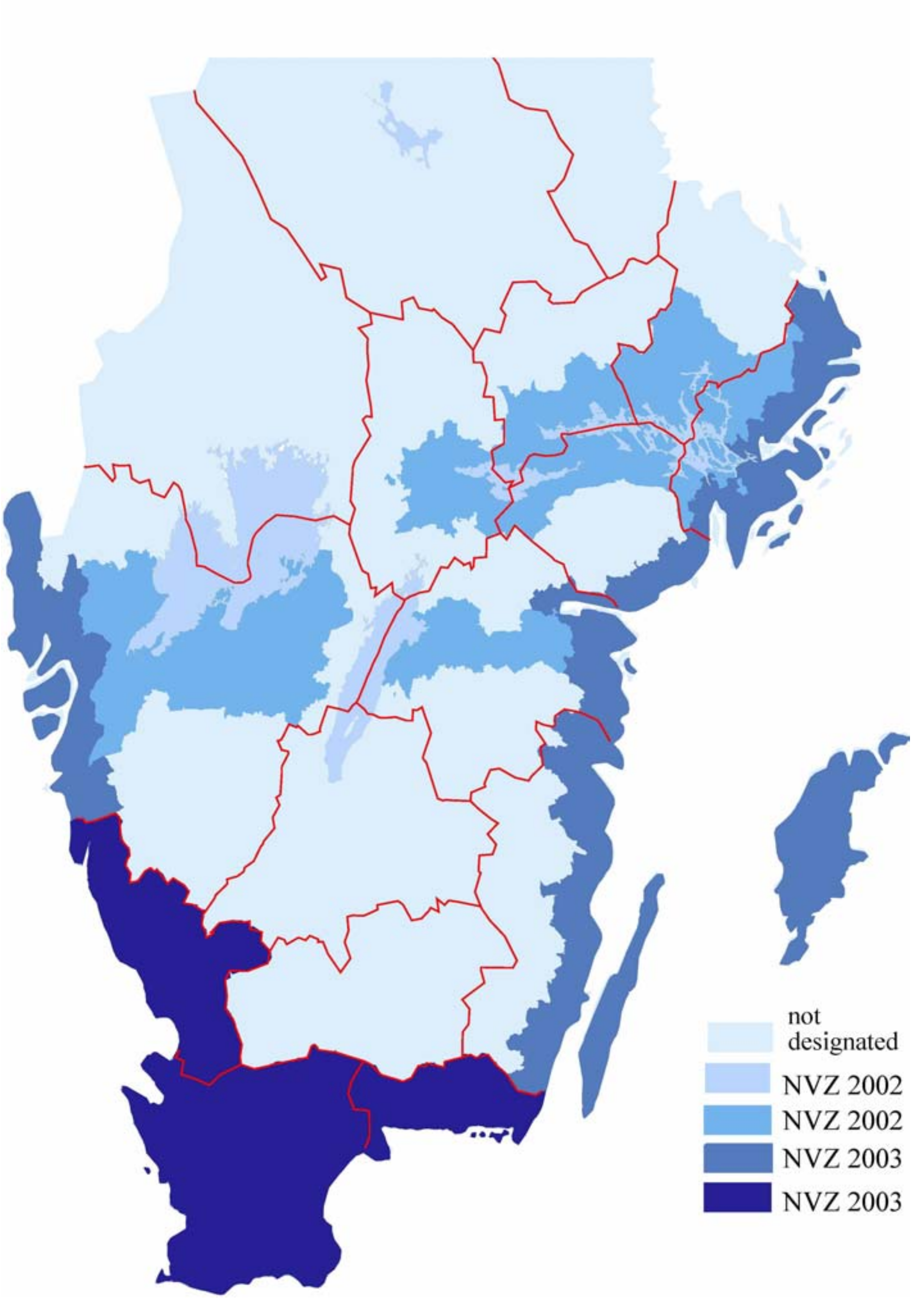

Fig. 7 Vulnerable zones in Sweden. The two areas (three counties in the southernmost Sweden and coastal areas) with the darkest nuances of blue were introduced in 1995 and the areas with lightest nuance were introduced in 2002 (2003).

In the late 1990's, the previous environmental goals were revised into fifteen so-called environmental quality objectives, which comprise all activities affecting the environment. The environmental quality objectives were decided by the Swedish

Parliament after a proposal from the Swedish Government (Swedish Government, 2001). They describe the environmental state that shall be achieved until 2020. Interim targets have also been formulated. They shall be reached until 2010 and are to a higher degree measurable and quantifiable. Eutrophication of water and air is mainly comprised by the environmental quality objective “Zero Eutrophication”, see text box. One interim target concerns discharge of nitrogen compounds to seas and coastal areas. That interim target stipulates that by 2010 waterborne anthropogenic emissions in Sweden into the sea south of Åland Sea will have to be reduced by 30% compared to 1995 levels, i.e. to 38,500 tonnes. Other environmental quality objectives regarding water quality are “Good-quality groundwater” and “A Balanced Marine Environment”.

The environmental quality goal “Zero Eutrophication”

“Nutrient levels in soil and water must not cause adverse effects on human health, the prerequisites for biological diversity or versatile land and water use”.

The outcome within a generation (until 2020) for this environmental quality objective should for example include the following:

- Groundwater does not contribute to eutrophication of surface water.
- The nutrient status of lakes and streams in forest and mountain areas is the same as in nature.
- The nutrient status of lakes and streams in agricultural areas does not exceed natural concentrations, which means that the water may at most be nutrient-rich or moderately nutrient-rich.
- Nutrient concentrations in coastal waters and seas are essentially the same as in the 1940s, and nutrient inputs into the sea do not cause eutrophication.

Example of an interim target for Zero Eutrophication decided by the Parliament:

> By 2010 waterborne anthropogenic nitrogen emissions in Sweden into the sea south of Åland Sea will have been reduced by 30% compared with 1995 levels, i.e. to 38,500 tonnes.

When the environmental objective was revised in the late 1990’s, the national action programme to reduce nutrient losses from agriculture was also evaluated and additional measures were introduced. The complementary measures comprise further restrictions for the application of manure, a campaign to provide training and advice and the introduction of environmental support for the cultivation of catch crops, postponed autumn tillage and the establishment of wetlands.

2. EFFECT MONITORING

2.1 Strategy for effect monitoring

The national and regional environmental monitoring is used to follow the biological and chemical state in different waters. The interpretation is facilitated by the Swedish EPA’s Criteria for Assessments which is a system for classification of environmental data.

Natural factors such as run-off and other meteorological factors have a significant influence on nitrogen leaching. Measurements over longer periods of time are therefore required to confirm trends in waters as a result of action programmes.

To assess the outcome of the interim target concerning nitrogen emission to the sea, a model approach is used.

Measurements in small catchments and on fields are performed in two sub-programmes within the programme area of Agriculture. The aim is to study and quantify the influence of agriculture on surface and groundwater quality. The sub-programmes shall also demonstrate if the measures taken have had the expected effect and if they contribute to the achievement of the environmental goals. Research and development activities are also carried out in order to develop measures aiming at reducing nitrogen leaching and to demonstrate the effect of such measures. In long-lasting field experiments on several locations the short and long-term effects of counter-measures are studied.

Nutrient balances indicate the potential risks for emissions of nitrogen. Changes in surplus between different years can be followed. Balances are calculated on a national and on a regional level by Statistics Sweden as well as on farm level, for instance in the advisory services. A statistical survey on usage of mineral fertilisers and manure in agriculture is carried out every two years by Statistics Sweden. Information from the survey is used when national and regional nutrient balances are calculated. It also provides information on the fulfilment of measures to be implemented, such as manure storage requirements and restrictions for applications of manure. The municipality authorities are responsible for the supervision of mandatory measures according to the Nitrates Directive and other mandatory measures aiming at reducing nitrogen leaching.

2.2 Detailed technical description of networks used for effect monitoring

An overview of different monitoring programmes was given in the section “Overview of monitoring networks”. In this section the sub-programmes of the programme area of Agriculture will be described in detail, since they are directly intended to monitor the effects of measures in agriculture. Other measures to assess the effects of measures are briefly described.

The Swedish Environmental Protection Agency has an overall responsibility for the environmental monitoring and the programme area of Agriculture. The Swedish University of Agricultural Sciences (Division of Water Quality Management) is responsible for co-ordination, measurements in some catchments, national compilations and is the so-called data host. Some of the County Administrative Boards are responsible for carrying out the monitoring activities in their respective county.

In one sub-programme measurements are made in small catchments (200-1500 ha) dominated by agriculture. Most of them are situated in typical agricultural districts and within the designated vulnerable zones. A few catchments are situated in the north of Sweden or in forested areas in order to obtain a nationwide covering. The sub-programme started in the 1970’s. Until recently there were 35 catchments in the programme. In 2002, a revision was made and the programme now comprises eight “intensive areas” and about 15 “extensive areas”. In the other sub-programme measurements are made in drainage water from 13 agricultural fields (“observation fields”). The fields are part of the ordinary cultivation on private farms and are not treated separately. They have an ordinary crop rotation and a size between 4 and 34 ha. Most of them are situated within the designated vulnerable zones.

In the catchments surface water is measured regularly and water discharge is continuously registered at measurement-stations to make it possible to assess the transport of nutrients. In the “intensive areas” measurements are made more frequently and groundwater chemistry is also analysed. Drainage from the “observations fields” is registered continuously. Surface water and groundwater is measured regularly.

Within the so-called TRK project (Transport–Retention-Källfördelning) the load of nitrogen originating from land use and point sources during year 2000 was calculated, *inter alia* to assess the outcome of interim target concerning nitrogen emission to the sea (Brandt & Ejhed, 2002). Within this project Sweden has been divided into a large number (approx. 1000) of smaller catchments and the nitrogen load for each of them has been calculated. Nitrogen leaching from agriculture was calculated with the simulation-tool SOILNDB, see Fig. 8. The model (SOILN/HBVN) that was used in the TRK project is one of the quantification tools that are being evaluated within the Euroharp project (www.euroharp.org).

A statistical survey on usage of mineral fertilisers and manure in agriculture is carried out every two years by Statistics Sweden. Approximately 4000 farmers are interviewed. Other topics with connection to manure are treated in the survey such as techniques applied for storing and spreading manure. Information from the surveys is used when national and regional nutrient balances are calculated. These nutrient balances are calculated every two years by Statistics Sweden. Both soil surface and farm gate balances are calculated.

Since the mid 1980’s, the County Administrative Boards offer advice on environmental matters to farmers, free of charge. The advisory services became a part of the Environmental and Rural Development plan in 1995. In 2001, a project called “Focus on nutrients” started in the southern parts of Sweden. It is one of the largest single undertakings in Sweden to reduce losses of nutrients to air and water. The project takes the form of a campaign intended to provide training and advice and its name reflects the project’s aim to encompass the entire flow of nutrients on the farm. The advice offered has been divided into 24 different modules. Some of these are basic for all farms, e.g. nutrient balances. The service is based not on a single farm visit but relies on the adviser’s returning to follow up the advice given. To facilitate this process, different environmental key indicators are calculated. These are documented so that improvements can be traced.

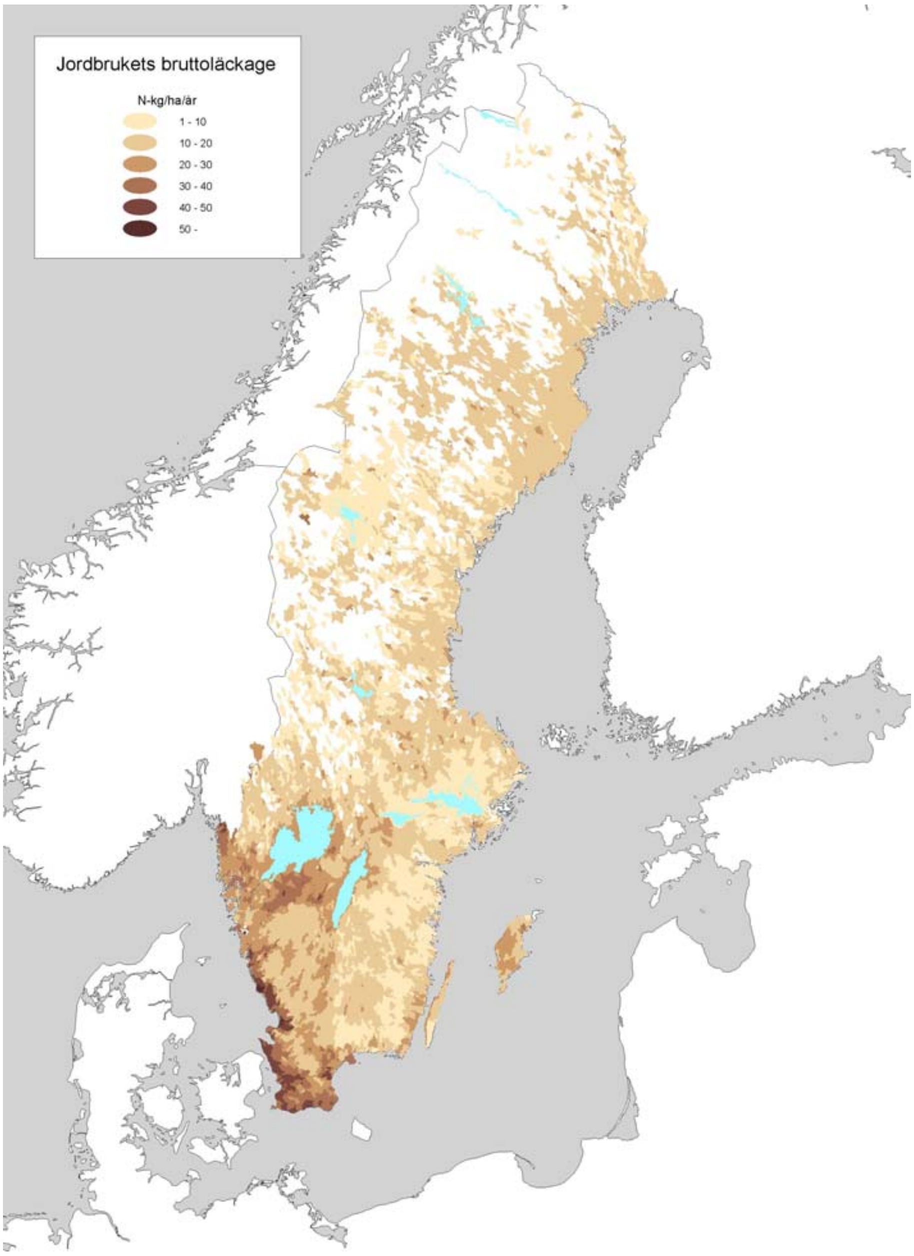

Fig. 8 Average nitrogen leaching (kg ha^{-1} $year^{-1}$) from arable land in smaller catchments for 1999, calculated with the simulation tool SOILNDB. (Source: Swedish Board of Agriculture, 2002).

2.3 Data interpretation

Annual results with regard to the two sub-programmes of the programme area of Agriculture are reported in the period of agro-hydrological year. The results from the observations are evaluated approximately every two or three years. Agriculture's impact on water quality is quantified for the catchments, taking into account changes in cropping among other factors. The effects of climate and cropping measures on nutrient loss also need to be kept separate. Statistical analyses have been made regarding the trends of nitrogen transport to waters from the catchments and observations fields. The analyses have been based on flow-adjusted nitrogen transports in order to reduce variations between different years due to changes in run-off. Long time series have been used for the trend analyses, as short time series are not suitable considering that weather factors other than flow variations, for example winter temperature, may have an important impact. Natural factors such as soil and climate may be important to what the effects will be of implemented measures as well as to how soon effects may be observed. In areas with for example sandy soils, changes in cropping measures may have more rapid effects on water quality. For example, several downward trends have been confirmed in some parts in the south of Sweden with sandy soils and a high discharge.

National calculations of nitrogen load (the TRK project) may show changes in nitrogen load on a national and a regional level as well as on a catchment level. As regards nitrogen leaching, the calculations show the aggregate effects that result due to various factors, but the effects of specific factors are not quantified. This will have to be assessed using detailed data of for example crop areas and changes in manure doses and in application periods. The simulation tool SOILNDB has previously been used to estimate the effects of single factors, such as the effect of changes in crop distribution from one year to another and the expected effect of proposed or implemented measures, for example growing catch crops or changed periods for application of manure.

Evaluations of implemented nutrient balances may indicate whether improvements have been made in, for example manure handling. Statistics may show how various measures have been applied, for example manure storage requirements or restrictions for applications of manure.

3. DISCUSSION

For the Nitrates Directive Action Programme to be demonstrably effective, two factors must occur. To begin with, changes in nitrate levels in water must be verified and, secondly, those changes must be associated with the measures taken. From year to year there is a natural variation in nitrate levels and other parameters that indicate the nutritive status of water. Therefore, long-term series of measurements are required in order to establish whether the environmental situation has changed, and whether there is any changing trend as regards nitrate levels in water.

The Nitrates Directive Action Programme is intended to reduce nitrogen supply to the identified waters. Nitrate leaching from arable land is, to a large extent, guided by natural factors, such as discharge and other meteorological factors that affect for instance the nitrogen mineralization. This means that also long-term series of measurements are needed for deciding whether or not the measures have any effect on the nitrate levels in the water that is discharged from arable land, or on total transport of nitrogen from arable land.

In Sweden, almost half of the anthropogenous nitrogen input are believed to come from arable land. Action programmes aimed at reducing nitrogen load are carried out also in other sectors than agriculture, mostly as regards the sewage-works, which have an effect on the nitrogen input to the identified waters. In addition to measuring changes in nitrate levels in the identified waters, and changes in nitrogen transport from arable land, it is also important to estimate the total input of nitrogen compounds to these waters, and determine what the sources are of such compounds.

It can be assumed that total nitrogen input must be reduced to a certain level in order to achieve the stated objective and the desired environmental state. The development of nitrogen input in all sectors is important. This is why Sweden uses inter alia the model calculations mentioned above for estimating nitrogen input (to coastal waters/seas) from agriculture and from other sectors. Estimating the effects of measures in different sectors is also important, so that the measures that are most cost-effective are carried out.

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Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Netherlands

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Abstract This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the Netherlands. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5(6). The Netherlands applies their Nitrates Directive Action Programmes to the entire territory, nevertheless legislation distinguishes between soil types and the measures are based on soil vulnerability to nitrate leaching. The effect monitoring programmes therefore focus on the level of the main soil-type regions in the Netherlands, i.e. sand, loess, clay and peat regions. The monitoring of the effects of the Action Programmes consists of the regular agricultural, groundwater, and surface-water monitoring programmes and a specialised monitoring programme, the National Monitoring Programme for the effectiveness of the Minerals Policy (LMM). The LMM monitors both water quality and farm management, i.e. agricultural practice. Policy measures aim at changing farm management in such a way that water quality will improve. To be able to distinguish between the effects of measures on water quality and the effects of confounding factor, such as weather, these confounding factors are monitored as well. A statistical model approach was developed to account for variation in precipitation excess and other confounding factors. Further improvements of monitoring and model approaches are discussed. They will be implemented in near future.

1. INTRODUCTION

1.1 General

The Netherlands, with its 16 million inhabitants on a total land-surface area of about 34,000 km^2, is a densely populated country located in Western Europe, with the North Sea to the west and north, Germany to the east and Belgium to the south. The Netherlands' intensive agriculture is responsible for large surpluses of nitrogen, representing the largest (per unit area) for nitrogen of all the member states in the European Union, and the second largest phosphorus surplus (De Walle & Sevenster, 1998).

1.2 Description of natural factors influencing nitrate occurrence

The major natural factors influencing nitrate occurrence in shallow groundwater are weather, especially precipitation excess, soil type and the average fluctuation of the groundwater table within a year, the latter expressed in so-called groundwater regime classes. In addition, nitrate concentrations decrease with depth below the groundwater table.

Climate

The Netherlands has a cool marine to cool temperate climate. The soil moisture regime is udic and the soil temperature regime, mesic. The average annual precipitation between 1971 and 2000 was about 780 mm and varies between 675–950 mm (see Fig. 1, left). The average annual precipitation was 820 mm over the last 15 years. The amount of precipitation differs clearly between years, but does not differ much between summer and winter periods, see Fig. 2. In the summer months, the potential evapotranspiration exceeds the precipitation. In winter, the storage of water is replenished and an average of 290 mm of the precipitation percolates into the soil (300 mm for the last 15 years). The average precipitation surplus varies in the Netherlands between 120 and 440 mm in the 1971-2000 period, see Fig. 1, right. After years with high precipitation excess, nitrate concentrations in shallow groundwater are relatively lower than the concentration after dry years (Fraters *et al.*, 1998); see Fig. 15.

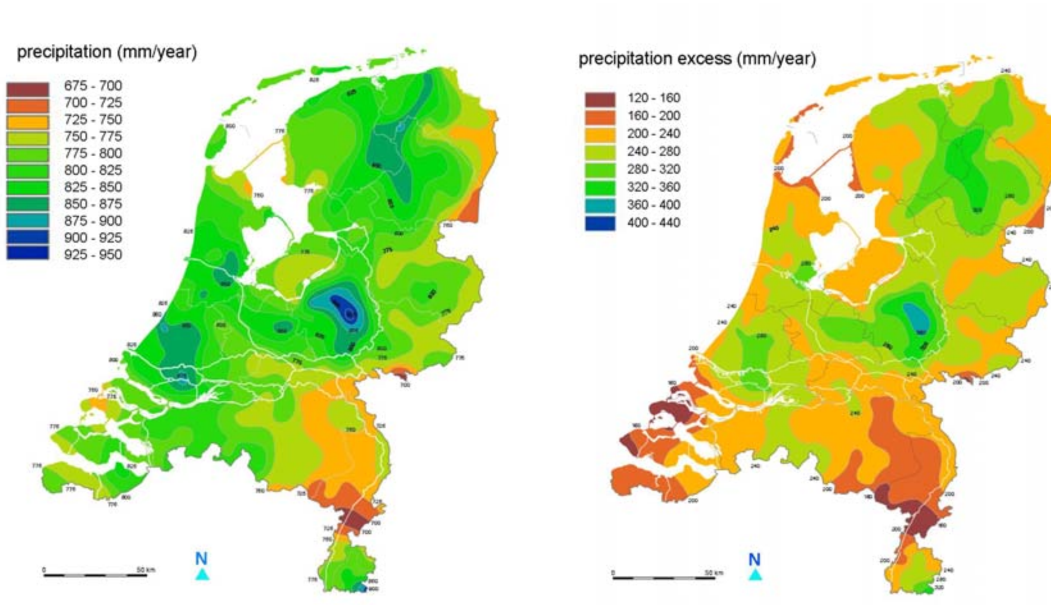

Fig. 1 Average annual precipitation (left) and precipitation excess (right) in the Netherlands for the 1971–2000 period. Source: Royal Meteorological Institute (KNMI, 2001).

Geology

The Netherlands is a delta formed by the Rhine-Meuse river system and a northern Germany river system. Ever since the Cambrian period (570 million years ago), the Netherlands has formed part of different sedimentation basins. Thousands of metres of sedimentary deposits occur in the central part of the country. Depending on the ratio between the rate of decrease in the land level and the sedimentation sometimes marine deposits filled the basin and at other times terrestrial deposits. The present day outcroppings are mainly Quaternary deposits, see Fig. 3. In the eastern and southern part of the country Pleistocene wind-born sand deposits occur of Weichsel pleni-glacial and late glacial age (10,000-50,000 BP) with loess deposits in the most southern part. In the western and northern part Holocene marine clay deposits occur that are alternated with peat. Most clay outcrops are younger than 3500 years.

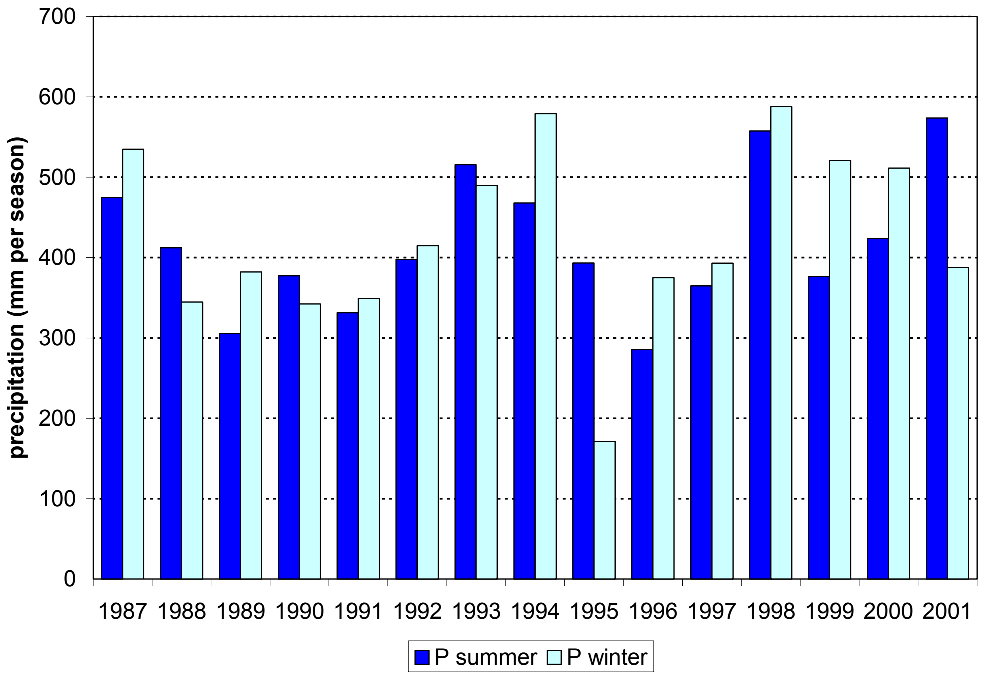

Fig. 2 Total precipitation (mm) in summer (day 91–270) and winter (day 271–90) in the 1987-2001 period; average of all weather stations. Source: Royal Meteorological Institute (KNMI).

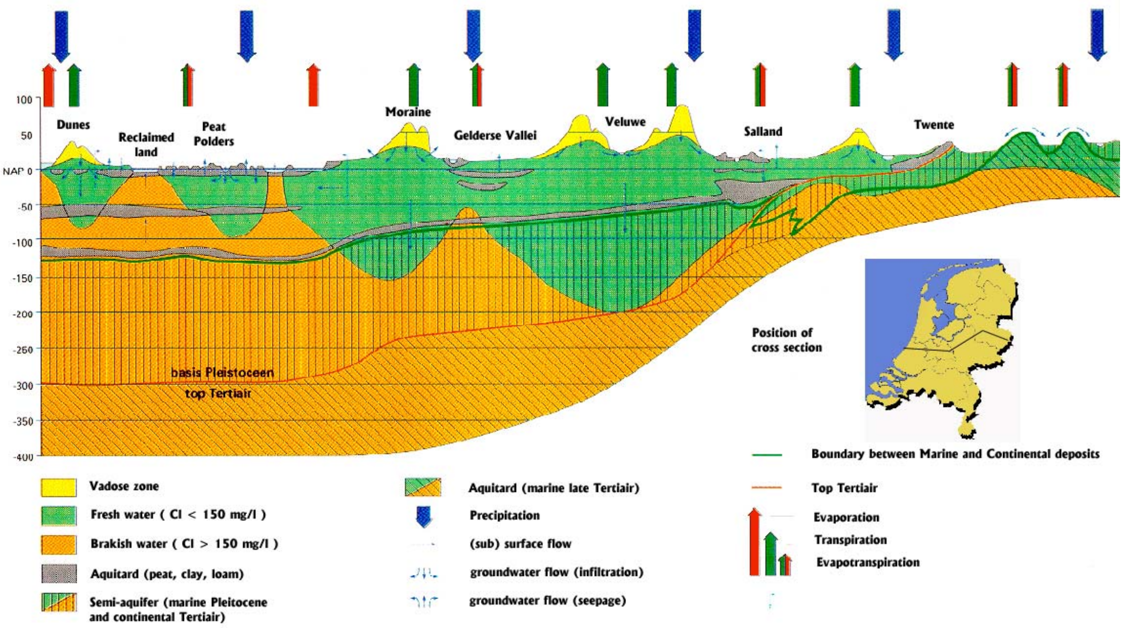

Fig. 3 Schematic East-West cross section of the subsoil of the Netherlands. The subsoil is characterised by marine and continental deposits of mainly Pleistocene and late Tertiary origin (Source: Dufour, 1998).

Soil types

Four major soil type regions can be distinguished: clay and peat regions in the northern and western part of the Netherlands, and sand and loess regions in the centre, east and south, see Fig. 4.

In clay regions in the north and south-west of the Netherlands sedimentation has occurred in tidal marshes. Surface level ranges from 1 m below sea level to 1.5 m above sea level. Half the soils are Gleyo-Calcaric Fluvisols (near the coast) and half are Gleyo-Eutric Fluvisols (inland). Two types of clay soils occur in the central clay region. Firstly, there are soils reclaimed from the sea with an age of less than 200 years, the surface level ranging between 3 and 4 m below sea level (mainly Gleyo-Calcaric Fluvisols). Secondly, there are reclaimed (former) peat soils with a surface level ranging from 4 to 6 m below sea level (mainly Mollic Gleysols). Finally there is a river clay region that is characterised by Holocene, and late Pleistocene Rhine and Meuse river deposits. Surface levels range from an average of 13 m above sea level in the eastern part to 1.5 m above sea level in the western part. Soil types are Gleyo-Eutric Fluvisols and Fluvi-Calcic Cambisols.

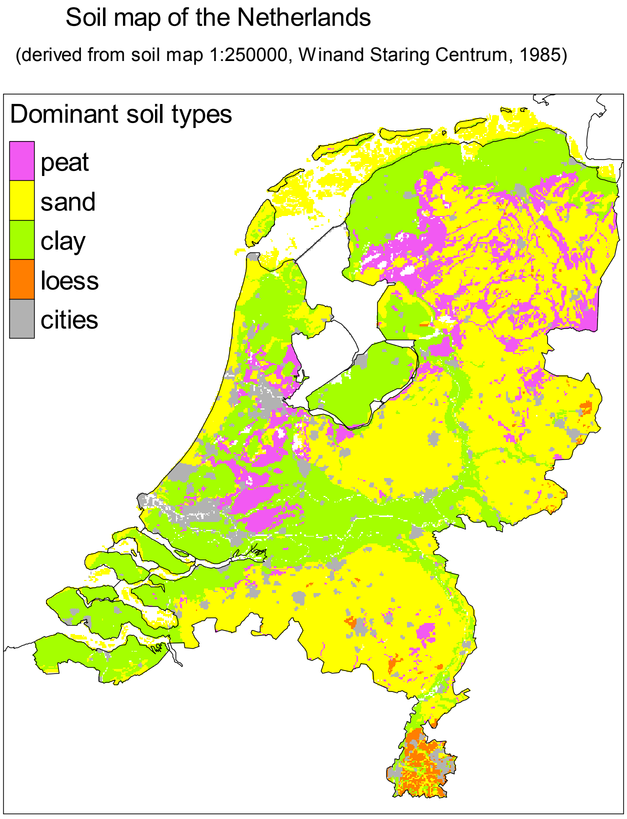

Fig. 4 Soil map of the Netherlands with dominant soil types (Source: Alterra, Wageningen).

The soils in the peat regions are strongly influenced by human activities. They were reclaimed in a period between the 9th and 14th century (Schothorst, 1977). Currently the surface level ranges from 1 to 2 m below sea level. One region occurs in the west and one in the north-east of the country. Soils in the western peat region are mainly Eutric Histosols, while in the north-east peat region both Eutric and Dystric Histosols occur. The former peat soils and their remainder east of the north-east peat region, mainly Dystric Histosols formed on sandy soils and originally 1-40 m above sea level, are now considered part of the sand regions because most of the peat has been removed to produce turf for house hold heating.

The sand regions occur mainly in the eastern and southern part of the Netherlands. The sand region in the western part of the country consists of dunes. In the eastern and southern regions surface level ranges from around sea level to just above 100 m above sea level, but commonly levels are between 2.5 and 30 m above sea level. Most of the soils are Gleyic Podzols. Only on the lateral moraines in the middle of the country do larger areas with Humic and Orthic Podzols occur, along with Dystric Regosol in former drifting sands. Calcaric Regosols are found in the dunes in the western part and Eutric Regosols in the north-western part.

Loess occurs mainly in the most southern part of the Netherlands. Surface levels range from around 200 m above sea level in the south-east to about 40 m in the western and northern part of the region. Soils are mainly Orthic Luvisols.

Hydrology and groundwater depths

Groundwater in the Netherlands usually occurs within 1 to 2 m from the surface. Groundwater depth and regime (average fluctuation within a year) in the clay and peat regions are mainly determined by polder-water level in the ditch system, in combination with soil physical characteristics. In the clay regions with marine clay, soils are usually drained with tile drains (depth about 1 m) and ditches, while in the region with river clay, tile drainage occurs to a lesser extent. Soils are sometimes drained by gully drains and sometimes by natural drainage (a sandy well draining subsoil) in combination with ditches. Peat soils are usually drained by gully drains and ditches. Groundwater depth usually fluctuate within 1 m below surface level. In the sand regions there are larger differences between average groundwater depth and fluctuations in depth in time. On average groundwater level is at 1.5 m below surface level, but in the loess region, on the lateral moraines and some smaller areas in the eastern part of the Netherlands groundwater levels deeper than 5 m below surface level occur.

Seven main groundwater regime classes (GRC) and four subclasses are distinguished on the basis of average highest and lowest groundwater depth (see text box). Due to artificial drainage (tile drains, gully drains and ditches) of wet soils for agricultural use, actual groundwater depth will be lower than natural groundwater depth. Nevertheless, nitrate concentrations in upper groundwater still show a strong correlation with GRC. Soils with shallow groundwater tables (GRC I to III) have on average lower nitrate concentrations than soils with deep groundwater tables (GRC VI to VII). Soils with intermediate groundwater tables (GRC IV to V) usually have nitrate concentration levels lower than those at GRC VI to VII but higher than those at GRC I to III.

Nitrate concentrations in shallow groundwater are the highest in sandy and loess soils and the lowest in peat soils, concentrations in clay soils are intermediate (Fraters *et al.*, 2002b); see Fig. 15. Shallow groundwater in sandy soils is usually aerobic, as is the upper groundwater in clay soil draining during the winter period to surface waters. However, shallow groundwater in peat and clay regions are, in the summer, usually anaerobic due to the presence of organic matter. Almost all nitrate in groundwater is denitrified in peat and clay regions.

Deeper groundwater in clay and peat regions is anaerobic and often brackish or even saline. In the sand regions both aerobic and anaerobic groundwater occur at greater depth depending on the presence or absence of organic layers or pyrite-like compounds. If such layers occur almost all nitrate is denitrified (see Fig. 11).

Four river basin districts, the Meuse (Maas), Rhine (Rijn), Eems and Scheldt (Schelde), have been assigned for the Water Framework Directive (see Fig. 5). The Rhine system is by far the largest of these four. Two water types are distinguished: the main water system, consisting of the large rivers, canals and lakes, on one hand, and regional water systems, consisting of ditches, brooks, smaller rivers and lakes, on the other.

Fig. 5 River basin districts in the Netherlands, provisional assignment for the Water Framework Directive.

Water quality of the main water systems is strongly influenced by activities in neighbouring countries. Water quality of regional waters in the eastern and southern parts of the Netherlands is mainly influenced by local activities. Regional waters in polder areas (mainly in the western part) are strongly influenced by local emissions and discharges. During dry periods in the summer, however, substantial amounts of water from the main systems are usually let in. These will also influence the water quality. In dry summer 2003 brackish water was let in the polders of the west of the Netherlands to counteract the decrease of groundwater table and thus to ensure that wooden foundations of buildings were not damaged and peat dikes were not weakened (see Fig. 6).

Fig. 6 Area in the Netherlands where brackish water was used to fill ditches to keep groundwater levels high in the dry summer of 2003. Source: NOS (2003).

Groundwater Regime Classes (GRC)

In total, 11 groundwater regime classes are distinguished on the basis of average highest groundwater level (AHG) and average lowest groundwater level (ALG) in a hydrological year (April–April). The three highest (lowest) values in a hydrological year are averaged. Subsequently, the average of a succession of years is calculated. Mapping the GRC was largely based on field estimations using soil characteristics in combination with measurements (Locher & De Bakker, 1993).
The influence of GRC on nitrate concentration in the upper metre of groundwater was studied by Boumans *et al.* (1989), who expressed this influence in a 'Relative Nitrate Concentration' factor (RNC), where the nitrate concentration found in soil with GWR VII* has an RNC of 1.
Groundwater depth (cm below surface level) is shown in the table below (Locher & De Bakker, 1993; Boumans *et al.*, 1989).

Regime	AHG (limit)	ALG (border)	AHG (measured)	ALG (measured)	AHG – ALG (measured)	RNC
I	-	< 50	-5 ± 4	38 ± 7	43 ± 5	-
II	-	50-80	7 ± 3	66 ± 4	60 ± 3	0.05 ±0.09
II* a)	-	50-80	32 ± 7	67 ±11	36 ± 10	-
III	< 40	80-120	17 ± 1	103 ± 3	86 ± 10	0.08 ±0.07
III* a)	< 40	80-120	32 ± 3	102 ± 4	70 ± 3	0.31 ±0.06
IV	> 40	80-120	56 ± 3	104 ± 4	49 ± 3	0.43 ±0.06
V	< 40	> 120	17 ± 3	135 ± 5	118 ± 4	0.50 ±0.06
V* a)	< 40	> 120	32 ± 3	142 ± 4	110 ± 3	0.48 ±0.06
VI	40-80	> 120	61 ± 1	155 ± 2	94 ± 2	0.65 ±0.04
VII	>80	> 120	101 ± 2	190 ± 3	90 ± 2	0.83 ±0.07
VII* b)	>80	> 120	185 ± 3	281 ± 4	97 ± 3	1.00 ±0.09

a) Drier part of GWR II, III or V, groundwater table level less than 1 month shallower than 25 cm below surface level

b) Drier part of GWR VII, groundwater table level less than 1 month shallower than 120 cm below surface level

1.3 Description of human factors influencing nitrate occurrence

1.3.1 Global information on land use.

Accounting for 70% of land use, agriculture is by far the most important form of land use in the Netherlands, see Fig. 7 (left) and Table A1 (Appendix). Almost 14% of the land is covered by nature. About 70% of the nature areas are taken up woodlands, 18% consist of dry nature areas like heathlands and dunes and 12% of wet nature areas like peat areas and tidal marshes. The general trend is a decrease in the agricultural land area.

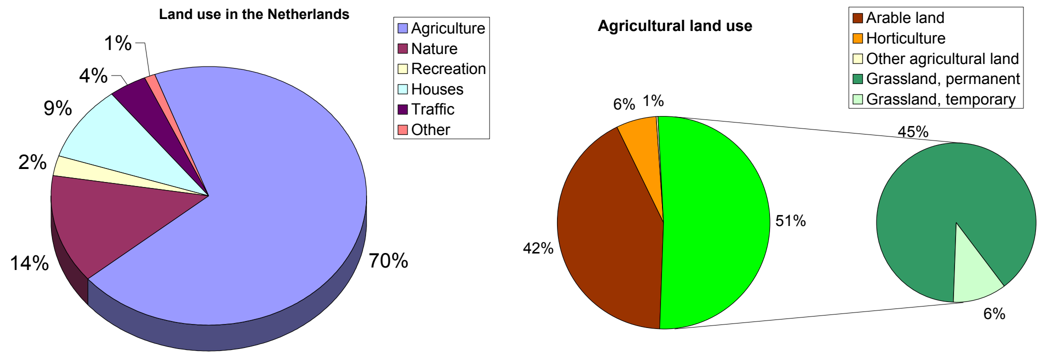

Fig. 7 Land use in the Netherlands in 1996 (left) and agricultural land use in 2002 (right), in percentage. Source: CBS Statline (2003).

1.3.2 Main crops

The total area of cultivated land is a little less than 2 million ha. Grassland is the major agricultural land use and most of it is permanent grassland, see Fig. 7 (right). The acreage of agricultural land has decreased the last 10 years by almost 2%. There has been a small shift from grassland to arable land and from permanent grassland to temporary grassland (see Table A2 in Appendix).

1.3.3 Characteristics of agriculture

In 2002 there were about 90,000 farms, more than half are dairy farms. Since 1985 the number of farms has decreased with about 35%, see Fig 8.

The number of livestock for 1980-2002 is shown in Table 1. The number of dairy cattle increased up to 1984. After the introduction of the “Super Levy” for milk in 1984 the number of cattle steadily decreased, from 4.5 million units in 1984 to 2.8 million in 2002. The number of pigs increased up to 1997. The combination of Swine fever in the first month of 1998 and implementation of policy measures led to a strong decrease in that year, followed by a moderate decrease in the years thereafter. The number of poultry is still increasing, although this number showed a large annual variation. The numbers strongly decreased for 2003 due to chicken fever. Other farm animal types are not very important.

In the 1992-2002 period the number of livestock units has decreased with 18%. There is a general decrease in number of livestock per hectare as is shown in Table 2. For example, in 1992 9.6% of the livestock units (LU) was housed on farms with less than

2 LU ha^{-1}, while in 2002 18.2% of the livestock units was housed on farms with this density of less than 2 LU ha^{-1}.

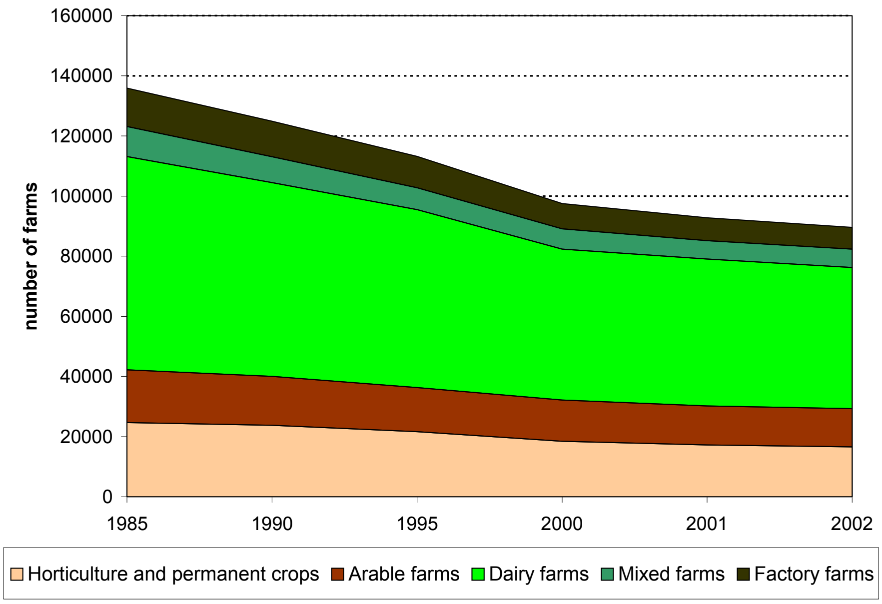

Fig. 8 Development of number of farms per farm type in the Netherlands in 1985-2002 period. Source: CBS Statline (2003).

Table 1 Number of livestock in 1980-2002 period (Source: CBS Statline, 2003).

	1980	1984	1987	1992	1997	2002
Dairy cattle	4.3	4.5	3.7	3.5	3.2	2.8
Other cattle	0.9	1.0	1.2	1.4	1.3	1.1
Pigs	10.1	11.1	14.3	14.2	15.2	11.6
Sheep	0.9	0.8	1.0	2.0	1.5	1.2
Goats	-	0.0	0.0	0.1	0.1	0.1
Horses	0.1	0.1	0.1	0.1	0.1	0.1
Poultry	81	83	97	99	93	101
Rabbits	-	-	-	0.8	0.5	0.4

Table 2 Number of livestock units and livestock density (percentage of livestock units on farms expressed in LU ha^{-1}) for 1992-2002 period (Source: CBS Statline, 2003).

	1992	1997	2002
Total number of livestock units (in millions)	6.01	5.70	4.94
% on farms with less than 2 LU ha^{-1}	9.6	12.9	18.2
% on farms with 2 to 3 LU ha^{-1}	20.0	18.8	21.3
% on farms with 3 to 6 LU ha^{-1}	18.5	15.2	11.8
% on farms with 6 to 15 LU ha^{-1}	14.8	13.2	10.2
% on farms with 15 or more LU ha^{-1}	32.7	35.4	33.7
% on farms without land	4.5	4.5	4.8

1.3.4 Manure production and fertiliser use

The manure production, expressed as nitrogen, decreased in the 1990-2000 period from 657 to 542 million kg. Cattle was the main contributor to this production, see Fig. 9. Manure and fertiliser nitrogen use decreased in this period as well, see Table 3.

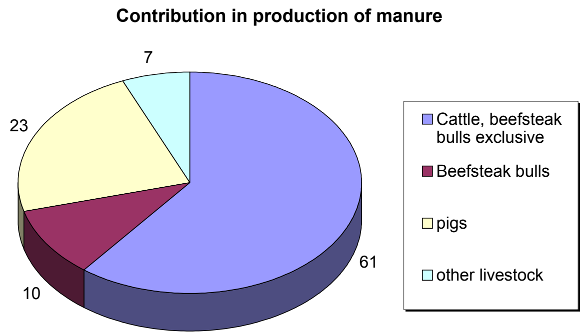

Fig. 9 Contribution to manure production, expressed as nitrogen, in the Netherlands for major livestock types in 2001.

Table 3 Soil surface balance for nitrogen in kg ha^{-1} for the 1990-2000 period (Source: CBS Statline, 2003).

Soil balance item	1990	1995	2000
Manure	233	243	206
Chemical fertiliser	204	202	168
Atmospheric deposition	41	39	39
Other	19	19	20
Total input	497	502	432
Crop removal	251	229	221
Net load	246	273	211

1.4 Overview of monitoring networks

There are national monitoring networks for agriculture, surface water, soil, groundwater and drinking water in the Netherlands. In addition, there is a special network for monitoring the effectiveness of the mineral policy. These networks will be briefly discussed in this section.

1.4.1 The agriculture monitoring networks

Agricultural Census

Statistics Netherlands collects general information on such topics as acreage and number of farm animals for all farms larger than three "Dutch Magnitude Units" (NGEs) (CBS Statline, 2003). These NGEs represent units of gross balance corrected for price fluctuations; NGEs are also used as the basis of levies and issuing rules. The annual data collection is called the "Agricultural Census".

Farm Accountancy Data Network

The Dutch Agricultural Economics Research Institute (LEI) collects more specific information on farm economics and technical management through the Farm Accountancy Data Network (FADN) (Vrolijk, 2002; Poppe, 1993). This farm management information includes environmental relevant data such as mineral balances (inputs and outputs of minerals), the use of pesticides, water and energy consumption, fertiliser, import and export of minerals, and grazing frequency. FADN represents 1500 farms from the Agricultural Census, selected through stratified random sampling, and so forming a representative sample of Dutch agriculture. The FADN network is a participant in the EU networks (EU, 1965). Farms participate for a 5 to 6 year period and are visited annually. Since about 15-20% of the farms are replaced every year, the FADN network can remain representative of Dutch agriculture. FADN represents about 60% of the total number of farms and about 86% (in NGEs) of registered agricultural production in the Netherlands. For reasons of representiveness farms less than 16 NGEs, on which farming generally is not the main occupation of the farmer, are excluded in FADN. Farms (mostly nurseries under glass) greater than 800 NGEs are less appropriate for data-collection and therefore also excluded from the field survey.

1.4.2 Surface-water monitoring networks

Monitoring Water Status of the Country (MWTL)

The Department of Public Works of the Ministry of Transport, Public Works and Water Management collects data at 39 stations in marine waters (including the estuary) and at around 30 stations in main (national) fresh surface waters. These are larger rivers, canals and lakes. The frequency of sampling in marine waters is once a month in winter and once every two weeks in summer. The sampling depth for marine waters is about 1.5 m below water level, and for North Sea locations, 3.5 m below the water level. For most locations (23), nutrients, common parameters (temperature, oxygen, etceteras) and phytoplankton (species composition and chlorophyll) are determined, while for the other marine stations only nutrients and common parameters are determined. The frequency of sampling at most main freshwater stations is once every four weeks, for stations bordering on Germany and Belgium it is once every two weeks. The sampling depth is about 0.5-1.0 m below the water level. Samples are analysed for nutrients, common parameters and chlorophyll.

The National Institute for Coastal and Marine Waters (RIKZ) is responsible for the interpretation of the marine water data. The Institute for Inland Water Management and Wastewater Treatment (RIZA) is responsible for the fresh surface-water data.

Regional Water Status Networks

The 27 regional Water Boards and some of the regional departments of public works all have their own Regional Water Status Networks (RWSNs). These RWSNs comprise several thousands of freshwater monitoring stations in regional waters. The frequency of sampling varies but is usually once every four weeks. Depth of sampling depends on local conditions but is normally about 0.5-1.0 m below the water level.

The Commission for Integral Water Management (CIW) conducts an annual survey of water quality data of the main RWSN stations. In 2002 this survey comprised about 350 freshwater stations (CIW main stations), representative for the larger regional water systems, while in 1992 the number was around 250. The water quality of these CIW main stations is not only influenced by agriculture but also by other sources, and in summer also by water inlets from the main water system. Therefore an additional

survey was performed by CIW to collect data for smaller regional waters. These water stations should meet the following requirements:
1) water quality to be mainly influenced by agriculture;
2) station representative of a larger area than a field or farm;
3) station representative of soil types in the region;
4) data available for all years since 1992 with continuing data collection.

These water stations, about 200, are called CIW agricultural stations. Nevertheless, the number of monitored agricultural-influenced, regional water stations for which data are available increased to 280 in 2002. There are some indications that water quality of at least some of the stations is influenced by other sources than agriculture. The CIW main stations are called 'other regional water stations'.

The fluctuation in numbers of regional water stations in time is due to:
- changes in number of locations in the RWSNs of the Regional Water Boards;
- additional information provided by the Regional Water Boards in the next survey on request of the CIW.

1.4.3 Groundwater monitoring networks

National Groundwater Quality Monitoring Network (LMG)

The LMG, established between 1979 and 1984, comprises about 360 locations divided over the whole country (Van Duijvenbooden, 1987). Main criteria for site selection were type of soil, land use and hydro-geological state. At each location groundwater is sampled at a depth of approximately 10 and 25 m below surface level.

From 1984 to 1998 locations were sampled annually, results have been published by Reijnders *et al.,* (1998) and by Pebesma & De Kwaadsteniet (1997). After an evaluation in 1998 (Wever & Bronswijk, 1998), the frequency of sampling was decreased for certain combinations of soil type and depth. Shallow filters in sand regions are still sampled every year; shallow filters in other regions (clay and peat) are sampled every two years; deep filters are sampled every four years; shallow filters with high chloride concentrations (more than 1000 mg l^{-1} due to marine influence) are also measured every four years. Finally, filters dominated by local conditions (e.g. nearby rivers and local sources of pollution) have been eliminated. In this way, the number of filters to be sampled every year has been reduced from 756 to about 350. The National Institute for Public Health and the Environment (RIVM) is responsible for the network and data interpretation and reporting. Average nitrate concentration in wells at agricultural sites shows a large differences between soil type regions and depth of sampling, see Fig. 10.

Provincial Groundwater Quality Monitoring Networks (PMGs)

Most of the 12 provinces of the Netherlands have groundwater quality networks comparable to the national network (LMG). Slight differences with respect to sampling depth and site selection occur due to provincial specific goals.

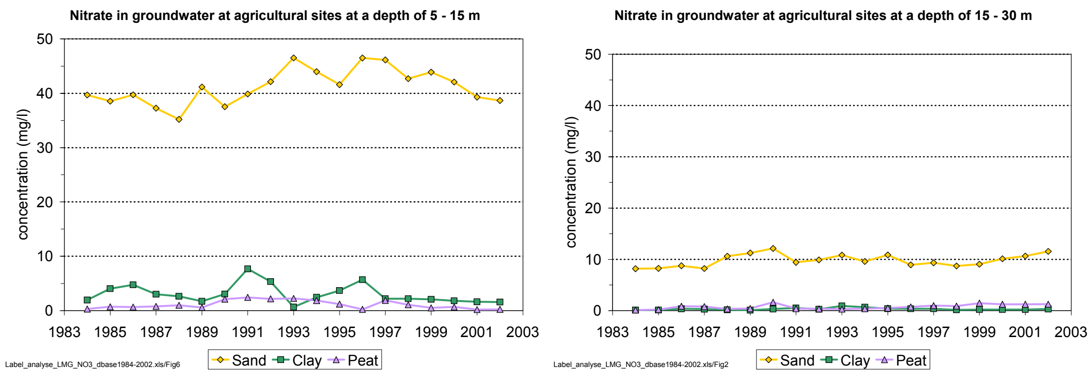

Fig. 10 Average nitrate concentration (mg l^{-1}) in groundwater in the Netherlands at a depth of 5-15 m (left) and at a depth of 15-30 m below the surface level (right).

1.4.5 Drinking-water monitoring network

About 30 production companies cover drinking-water production in the Netherlands. About 65% of the drinking water originates from groundwater (Joosten *et al.*, 1998). There are about 200 groundwater production sites, of which 120 deliver from unconfined groundwater, and 80 from confined groundwater. There are about another 30 sites where drinking water is produced from riverbank groundwater, dune infiltration groundwater and surface water (Willems *et al.*, 2002; Fraters *et al.*, 2004). The average depth of the groundwater used for drinking-water production for unconfined aquifers is 45 m, with an average depth for the upper part of the well screen of 30 m and for the lower part, 65 m.

Water production companies carry out monitoring programmes focusing on quality control of the water resource, the production process and the end product. Companies report results annually to the national Inspectorate for the Environment of the Ministry of Housing, Spatial Planning and the Environment, which is an statutory obligation. Data management and reporting are carried out by RIVM.

1.4.6 Effect monitoring networks

Three networks have been set up to monitor the effects of the Dutch policies more specifically. These are the National Soil Monitoring Network (LMB), the Upper Groundwater Acidification Network (TMV) and the National Monitoring Programme for Effectiveness of the Minerals Policy (LMM). These networks in combination with the FADN and the network of CIW agricultural stations, discussed above, cover the effect monitoring of the policy measures. The LMB, TMV and LMM will be discussed in short below; LMM, the most relevant programme for the Nitrates Directive effect monitor, will be discussed in more detail in the next section.

National Soil Monitoring Network (LMB)

The National Soil Monitoring Network has the following objectives:
- to determine whether changes occur in soil quality;
- to describe and explain current soil quality in relation to environmental pressure and policy measures.

The monitoring network was set up in phases for practical reasons. Over a period of five years, 40 locations were to be sampled every year in two land use / soil-type combinations (see Table 4).
The LMB comprises a total of 200 locations, primarily farms. As farms were (or still are) participating in the Farms Accountancy Data Network of the Agricultural Economics Research Institute, data about inputs and outputs of heavy metals can be obtained for analysing differences in soil quality between farms. After a full 5-yearly monitoring round has been completed, all locations are sampled again in a new monitoring round. The first sampling round was started in 1993 and ended in 1997 (Bronswijk et al., 2003). The second sampling round started in 1999. The third round will start in 2005.

Table 4 National Soil Monitoring Network (LMB) phasing.

Year[1]	Group	Land use	Soil type
1993, 1999	1	Dairy farm, low cattle density	Sand
	2	Dairy farm, high cattle density	
1994, 2000	3	Dairy farm with factory farming	Sand
	4	Forest	
1995, 2001	5	Arable farm	Sand
	6	Dairy farm	Peat
1996, 2002	7	Arable farm	Marine clay
	8	Dairy farm	River clay
1997, 2003	9	Dairy farm	Marine clay
1997	10	Horticulture: vegetable growing and flower bulbs cultivation	Clay / Sand
2003	11	Arable and dairy farming	Loess

[1] first year and second year of sampling.

Both the top and deeper layers of the soil are sampled. The samples from the top layer are taken 0-10 cm below ground level at 320 individual samples per location, divided over four combined samples). In the deeper soil layer, samples are taken 30-50 cm below ground level at 16 individual samples per location, divided over 1 combined sample. In addition, upper groundwater was sampled in the first round (16 holes per location, divided over four combined samples). Profile descriptions of the upper 120 cm of the soil were made.

A large number of analyses are carried out in which a distinction is made between soil and groundwater. The following parameters are analysed in the soil samples: physical soil parameters (pH, lutum, organic matter and CEC), heavy metals, Polycyclic-Aromatic Hydrocarbons (PAH), organochloric pesticides (including lindane, drins, DDT), triazines and phosphate saturation. Groundwater samples are analysed for pH and DOC, heavy metals, other metals, eutrophication parameters.

A specific programme with respect to minerals was performed in the second round. On each location two soil layers were sampled up to 60 cm below the surface (0-30 and 30-60 cm, 80 individual samples per location, divided over one combined sample per layer). Parameters analysed are total N and P.

Upper Groundwater Acidification Monitoring Network (TMV)

The Upper Groundwater Acidification Monitoring Network has the following objectives:
- to determine the changes in the groundwater quality of nature areas on sandy soil;
- to describe and explain the quality and the changes in relation to environmental pressure (atmospheric emissions) and policy measures (emission-reducing measures).

This mainly concentrates on nitrate in the groundwater of nature areas on sandy soils. The TMV comprises 155 locations spread over forest and heathland on sandy soils in the Netherlands. A TMV sample location is the largest continuous surface area of forest and heath in a grid cell of 500 x 500 metres.

The first sampling round took place in the winter months of 1989-1990 (Boumans *et al.*, 2004). The second round was carried out from 2000 to 2004. A few locations (11) were more intensively researched between 1992 and 1996. Ten groundwater samples are taken across the longest possible transect of the location and added up to form a combined sample. The individual distance between the sample points is 50 m. If the transect is not long enough, samples are taken along the central perpendicular line on the transect. The distance to the edge of the nature area is at least 20 m.
A large number of analyses are carried out on the collected combined sample: e.g. pH, EC and DOC, heavy metals (cadmium, lead, chrome, copper, zinc and arsenic), other metals (aluminium, barium, calcium, magnesium, manganese, sodium and strontium) and eutrophication parameters (total-phosphate, inorganic phosphate, ammonium, chloride, nitrate, sulphate and potassium).

National Monitoring Programme for Effectiveness of the Minerals Policy (LMM)

The National Monitoring Programme for Effectiveness of the Minerals Policy (LMM) has the following objectives:
- to describe and explain the current quality of the recently formed groundwater and surface water in relation to the environmental pressure;
- to relate changes in the quality of the recently formed groundwater and surface water to changes in the agricultural practices and policy measures.

The LMM monitors farm management and water quality, concentrating on nutrients. The LMM comprises about 160 farms, spread over the three main soil-type regions of Netherlands: the sand and loess regions, clay regions and peat regions. In Chapter 2 details of the LMM are discussed.

1.5 Environmental goals

The Dutch government first introduced policy to combat the problem of mineral surpluses in the 1980’s. In 1998 a new minerals policy was implemented. The Minerals accounting system (MINAS) forms the core of the Dutch minerals policy. It sets levies on phosphorus and nitrogen surpluses above a certain maximum allowed per hectare. Dutch standards were tightened considerably in 1999 (LNV, 2001). In 2002 a system of Manure transfer contracts was introduced to complement MINAS. This system obliges farmers to enter into manure transfer contracts before it is produced. Farmers don not have to enter into such contracts provided that they do not exceed the 170 kg ha^{-1} for arable land and 250 kg ha^{-1} for grassland. In October 2003, the European Court of Justice considered that the action programme of the Netherlands suffered from several shortcomings. It rejected the use of the loss-based system (MINAS), to control nitrate pollution under the Nitrates Directive (EU, 1991). Therefore a new system will be developed based on application standards.

A brief outline of the environmental target and limit values for nutrients in groundwater and surface waters is given in Table 5. Limit values state the water quality that should not be exceeded; this is a maximum acceptable risk level. Target values indicate the water quality level that should eventually be realised; this is the level of negligible risk. Both limit and target values for nutrients are non-statutory standards. This means that the only obligation is to make an effort.

The limit values for surface waters are derived from empirical relationships between summer average concentrations of nutrients and chlorophyll-a in shallow Dutch lakes and a maximum chlorophyll-a concentration of 100 $\mu g\ l^{-1}$. The target concentrations are derived from experiences from lake restoration programmes. Below these concentrations, shallow lakes are almost always in the desired clear water state.

There are no limit values for marine waters. Instead, there is a target of reduction for the loading of both N and P to the Dutch marine waters of 50% relative to the 1985 loading.

Table 5 Target and limit values for nutrients in groundwater and fresh surface waters. Concentrations in mg l^{-1}. Source: Willems *et al.* (2002).

Parameter	Groundwater		Surface water (fresh)	
	Limit value	Target value	Limit value	Target value
Nitrate-N	11.3 [a]	5.6 [b]	-	-
Ammonium-N	-	2 / 10 [c]	-	-
Total-N	-	-	2.2 [d]	1 [d]
Total-P	-	0.4 / 3 [c]	0.15 [d]	0.05 [d]

[a] Value applies to all groundwater.
[b] Value applies to deep groundwater in drinking-water production areas and groundwater protection areas.
[c] Low value applies to sandy soils, high value to peat and clay soils. In areas with brackish or saline groundwater, higher ammonium concentration may occur.
[d] Value applies to stagnant eutrophication sensitive fresh surface waters (summer average value), and are also directives for other fresh surface waters.

Formally, the level of spatial and time scale for which the environmental quality standards apply are not regulated. Therefore it is not clear whether these standards should be realised for each sample at each moment in time or on average, for example, for each field, farm, catchment or region over a time scale of a year or several years.

It is often reported that there is a large variation of the nitrate concentration in time, especially for shallow groundwater and surface waters. This variation exists both within years and between years mainly due to variation in precipitation excess. The EU Nitrates Directive guidelines on reporting (EU, 2002) and monitoring (EU, 2003, 1999) indicate, in our view, that for nitrate in groundwater a long-term year average or average weather year can be used, and for nitrate in surface water a long-term winter average.

With respect to the validity of the environmental quality standards for groundwater: the limit value for nitrate applies formally applies to all groundwater in the Netherlands, see Fig. 11.

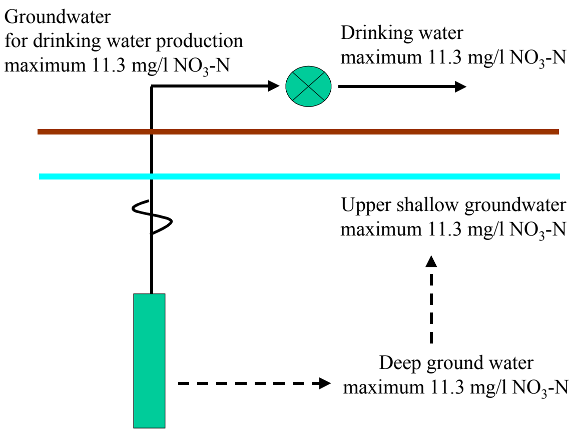

Fig. 11 Background of nitrate limit value for groundwater in relation to the implementation of the EU Nitrates Directive (Source: Willems *et al.*, 2002).

2. EFFECT MONITORING

2.1 Strategy for effect monitoring

The monitoring of the effects of the Action Programme consists of the regular agricultural, groundwater, and surface-water monitoring programmes and a specialised monitoring programme, the National Monitoring Programme for the effectiveness of the Minerals Policy (LMM). The LMM was developed to assess the contribution of nitrate from agriculture to receiving waters and the effects of changing agricultural practice on these losses. It would thus monitor the effect of policy measures on water quality.

The LMM monitors both water quality and farm management, i.e. agricultural practice. Policy measures aim at changing farm management in such a way that water quality will improve. Water quality of groundwater and surface waters is generally not only influenced by farm practice, but also by other sources of pollution and environmental factors such as weather. To exclude other sources of pollution water quality as far as possible, on-farm waters, such as the upper metre of groundwater or soil moisture within 5 metres of the soil surface, tile drain water, or ditch water are monitored. This type of water also reflects the effect of recent management (less than 4 years ago). To be able to distinguish between the effects of measures on water quality and the effects of confounding factor, such as weather, these confounding factors are monitored as well.

LMM and FADN

When the LMM monitoring programme started up in the sand regions in 1992, it has been decided that linking LMM and FADN (Farm Accountancy Data Network) would have many advantages. Linking these two would make both farm management and water quality data available to all farms. In 1996, after the evaluation of the first 4-year period, it was decided to continue this co-operation. Because of the characteristics of

Dutch agriculture, a high level of dynamics, the advantages of linking the FADN and the LMM were obvious. The choice for use of a changing group for the FADN was made in the second half of the 1960s. Monitoring a fixed group independent from FADN would implicate duplication of activities of the FADN, while regular replacement of farms would still occur due to the high level of dynamics (see below for detailed discussion). It should be marked that both FADN and LMM exclude farms from participation. For reasons of representiveness farms less than 16 "Dutch Magnitude Units" (NGEs) and greater than 800 NGEs are excluded in FADN. Above these thresholds of FADN, in LMM also a minimum of 10 hectares of land is used as criteria for participation.

Main soil type areas

The Netherlands applies their Nitrates Directive Action Programme to the entire territory, nevertheless legislation distinguishes between soil types and the measures are based on soil vulnerability to nitrate leaching. The effect monitoring programmes therefore focus on the level of the main soil-type regions in the Netherlands, i.e. sand and loess, clay and peat regions. Within the sand and loess regions the different situation in vulnerability between dry and wet soils (Groundwater Regime Class, GRC, see text box in Introduction) is taken into account. Each of these regions can be considered as a group of similar groundwater bodies. The state of affairs with respect to the aquatic environment on farms is described for each main soil-type region.

Main farm types

Within each main soil-type area, the LMM focuses on the main farm types with respect to acreage (i.e. arable farms and dairy farms) and sometimes includes a group of other farm types. The reason for this restriction of the sample population is to decrease the variation in farm practice and water quality within the sample and, in this way, increase the ability to observe a change in farm practice and water quality.

Sampling and other data collection

The water quality on farms is monitored by sampling soil water in the unsaturated zone below the root zone, shallow phreatic groundwater (within 5 m of the soil surface), tile-drain water and/or ditch water. Environmental data, e.g. precipitation and evapotranspiration, fraction of soil types and GRCs, are collected, and the influence of the data on the monitoring results is accounted for using modelling approaches, see Fraters *et al.* (2004) for details.

Sampling unit

The unit used for the sample location in the LMM is the farm. This is because Dutch legislation regulates agricultural practices on farm scale and because farm management can be monitored easier at farm level than at any other scale level: e.g. parcel, and farm management was already monitored on farm level in FADN.

Fix or changing sample group

The choice between monitoring a fixed group of farms and monitoring a changing group of farms is a difficult one. The merits and demerits of both will be discussed briefly. But to start with, the difference between the options will be largely theoretical. In practice, a fixed group also changes during the period of monitoring. Participants will stop attending for all kinds of reasons and new participants will have to be selected to replace those leaving. Keeping this in mind, we have summarised advantages of both below, where an advantage for one is a disadvantage for the other.

The advantages of monitoring a fixed group of farms compared with a changing group:
(a) There is less variation within a fixed group; changes in nitrate concentration, for example, can be detected earlier.
(b) When there is a low level of dynamics in agriculture, costs with a fixed group are lower because fewer farms have to be selected and incorporated into the network.

The advantages of monitoring a changing group of farms compared with a fixed group:
(a) The sample group will be more representative using a changing group, because the group can be adapted to the large extent of dynamics in agriculture.
(b) Farms will shows less adaptation in farm management using a changing group - influenced by the fact that they are participants - which introduces bias.

<u>*Sampling frequency*</u>

The sampling frequency varies between sub-programmes and main soil-type areas. The sampling frequency is the key to the expected change in quality in time, and the variation in quality in time and space. For groundwater and surface waters, changes in nitrate concentrations in time should be relatively large if target values are to be reached. The current design of the LMM, i.e. the sampling strategy, is based on statistical analysis of the results of the research performed in the 1992-2002 period. This comprises research in the sand regions in the 1992-1995 period (Fraters *et al.*, 1998), and in the clay (Fraters *et al.*, 2001) and peat regions (Fraters *et al.*, 2002a) in the 1995-2002 period. Farms were sampled each year in these periods.

This research showed three major sources of variation in nitrate concentration (in decreasing order of magnitude):
1) differences in nitrate concentration between individual farms of the same farm type;
2) differences in nitrate concentrations between years on a single farm;
3) differences in nitrate concentrations between sampling points on a farm in a certain year.

Differences in nitrate concentration between farm types were to a lesser extent a source of variation as well. The statistical analysis of the data pointed to more effectiveness by sampling more farms (and each farm) only a limited number of times in the FADN participation period than by sampling a smaller number of farms each year. The difference in nitrate concentration between farms as the most important source of variation justifies this approach.

The sampling strategy during the participation period of the farms is determined by both the importance of the sources of variation, and the organisational and financial aspects of sampling, e.g. travel time between farms and number of samples that could be taken on a farm in a day. On the basis of the importance of the sources of variation for nitrate concentration, one should first strive to maximise the number of farms in the sample population. This should be followed by maximising the number of years of monitoring on a certain farm and, finally, the number of sampling points per farm.

The potential number of farms in FADN that are eligible for participation in the LMM evaluation-monitoring programme is large. For this reason, the most cost-effective method is to sample farms in the sand and peat regions, where the upper metre of groundwater is sampled, but only in years 1, 4 and 7. However, in the clay regions, where tile drains artificially drain most of the farms and tile drain water is sampled, it is more cost-effective to sample farms each year.

Relevant farming practice information, an essential part of the FADN, is recorded each year on all participating farms in the LMM evaluation-monitoring programme. In general, data are available from 1 years before the first sampling to one year before the last sampling.

<u>Loess region</u>

For the loess region in the very southernmost part of the Netherlands, only data from the Provincial Soil Moisture Network of Limburg are currently available. The design for the sampling unit, the parcel instead of the farm, differs from the LMM (IWACO, 1999; Voortman *et al.*, 1994).

2.2 Detailed technical description of networks used for effect monitoring

The LMM has been jointly developed and managed by the RIVM and the LEI (Agricultural Economics Research Institute). In addition, some parts of the network are managed in collaboration with other organisations. The monitoring programme is made up of an evaluative and an investigative part. The evaluative part (LMM-EM) determines the changes in agriculture that take place over time as a result of the implemented policies. The investigative part (LMM-VM) concentrates on the impact of intended policy measures.

The LMM-EM consists of a sub-programme for each of the three main soil-type regions in the Netherlands, that is, the sand and loess, and clay and peat regions. Each sub-programme was realised in phases. Following an introductory research programme (scouting), an initial monitoring programme (scanning) is carried out, see Fig. 12, using a fixed group of farms. This is the basis on which a more efficient long-term monitoring programme is then realised using a changing group of farms. The farms for the LMM-EM are selected from the Farm Accountancy Data Network (FADN) of the LEI.

In the sand regions, a scouting programme was carried out on about 12 dairy farms and five arable farms in the 1987-1991 period (a/o Boumans, 1990). Farms were monitored for two or more years. In the 1992-1995 period a scanning programme was performed on 80 dairy farms and 20 arable farms (Fraters *et al.*, 1998). Farms were monitored for 3-4 years. The implementation of a long-term monitoring programme started in 1997 (Fraters *et al.*, 2002b). As soon as the monitoring programme is completely operational (expected in 2003), approximately 90 farms will be sampled annually. Each farm is sampled three times over a 7-year period. Every year 29 new farms are included in the monitoring programme. A further 29 farms have been sampled for the second time and 29 farms for the third and last time. Each new group will consist of 16 dairy farms, five arable farms, four factory farms and four arable-livestock combination farms. Two farms will be in the loess region and 27 in the sand regions.

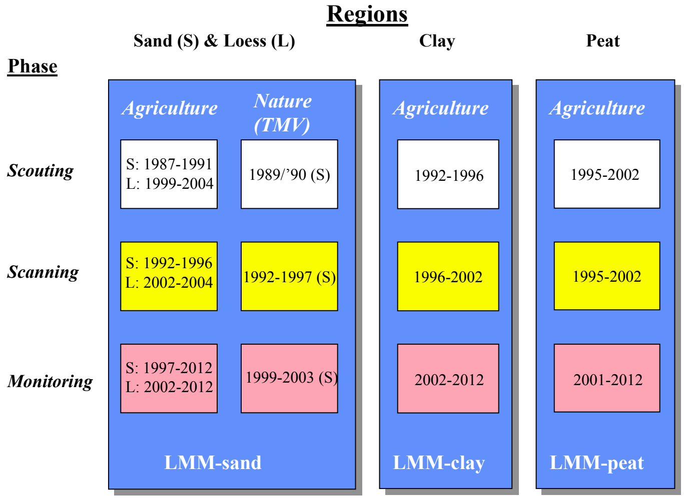

Fig. 12 Phase of development of the LMM-EM (Agriculture) and TMV (Nature) for all regions.

In the clay regions, a scouting programme was carried out in the 1992-1995 period on about 16 different farms that were monitored for two years (Meinardi & Van den Eertwegh, 1997, 1995); see Table 6. Approximately 55 farms per year took part in the scanning programme in the 1996-2002 period (Fraters *et al.*, 2001). Farms were monitored each year. A long-term monitoring programme started in 2002 and eventually 60 farms will be monitored each year. Every year a new group of 10-12 farms will be selected and monitored for six consecutive years. Five clay regions were and are distinguished, along with four marine clay regions and one river clay region (Fraters *et al.*, 2002b). Both dairy and arable farms are selected. The number per region and per farm type depends on the ratio of acreage per farm type and per region.

In the peat regions scouting and scanning programmes were started in winter 1995-1996; these were based on the experiences acquired in the programmes in the sand and clay regions (Fraters *et al.,* 2002a). These programmes finished in winter 2002-2003. A long-term monitoring programme was planned to start in the winter of 2000-2001, but due to Foot & Mouth Disease this programme only actually started in winter 2001-2002. The set-up of the monitor programme is similar to that for the sand regions. A total of 12 farms are sampled per year. The number of farms monitored in the 1992-2002 period is given for each region in Table 6.

The LMM-VM, the investigative part of the LMM, consists of research into farms, which obviously use fewer than average nutrients in the agricultural sector. Most of the farms in this research also take part in projects for other research institutes. More information is available on the RIVM web site (www.rivm.nl/en/).

The type of water sampled on the farms in the EM monitoring programmes differs among the soil-type regions distinguished. In the sand and loess regions the upper metre of groundwater up to 5 m below the soil surface is sampled, see Fig. 13 (left). If the groundwater table depth is below 5 m of the soil surface, soil samples are taken at a depth of 1.5-3.0 m below the soil surface and soil moisture is extracted. In the clay regions, where tile drains artificially drain most fields, tile drain water is sampled, see

Fig. 13 (right). Since winter 2002/2003 ditch water is sampled as well, and where tile drains drain less than 25% of the farm area, the upper metre of groundwater is sampled in combination with ditch water. The upper metre of groundwater and ditch water is sampled in the peat regions.

Table 6 Number of farms taking part in the National Monitoring Programme for Effectiveness of the Minerals Policy (LMM) according to type of farm and soil type in the area.

Region	Type of farm	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Sand	Arable [b]	18	19	-	18	-	16	18	16	13	13	19
	Dairy [a, d]	75	70	35	66	-	11[c]	26	24	30	37	37
Clay [e]	Arable	-	10	11	3	-	4	11	29	30	28	27
	Dairy [a]	-	-	5	4	-	2	16	23	27	26	24
Peat [f]	Dairy [a]	-	-	-	-	18	-	-	19	5	14	25

a) Dairy farms, with and without factory farming.
b) Including mixed arable – cattle farms from 1997 onwards.
c) Farms with pigs could not be visited due to swine fever.
d) Including factory farms from 1998 onwards.
e) Farms where tile drain water was sampled, October - April (year in which April falls is given).
f) Sampling period of November – May (year in which May falls is given), including 5 survey farms from 1999 onwards.

Fig. 13 Sampling of upper meter of groundwater in the sand regions (left) and of tile-drain water in the clay regions (right).

The number of sample points per farm in the monitoring programmes is 16 for upper groundwater, soil moisture and tile drain water, and eight for ditch water. Sampling points are proportionally distributed per field on the basis of the acreage, and randomly distributed in the field using a random generator. Ditch water points are classified on the basis of origin of the water. Three types are distinguished:

(a) farm ditch water, water that originates from the farm only;
(b) local ditch upstream water, water that originates from the surrounding area sampled just before entering the farm;
(c) local ditch downstream upstream water, water that originates from farm and surrounding area sampled at a point where it leaves the farm.

A combination is sampled of either (a) and (c) ditches or (b) and (c) ditches, taking samples per ditch type.

Sampling of upper groundwater slightly differs between soil types. The general procedure is that a vertical hole of 0.07–0.10 m diameter is made with an auger of up to 0.8-1.0 m below the groundwater table. After placement, the borehole is pre-empted. Next groundwater is sampled directly (sand), or after a few days (clay and peat). Samples are directly filtered, acidified and stored in the dark at about 4°C till further treatment. In the laboratory two mixed sampled are made at random from each eight individual samples. Tile drains are sampled four times during winter, usually using a measuring jug. Samples are cooled and transported to the laboratory within 24 hours and then mixed as for groundwater samples, filtered, acidified and stored in the dark at about 4°C till analysis. Ditch water is sampled once (in combination with upper groundwater sampling) or four times (in combination with tile drain water sampling). Treatment is similar to that of groundwater or tile drain water. Two mixed samples are made on the basis of ditch type. Soil moisture is extracted from individual samples by centrifuging. In addition two mixed samples are made at random from each eight individual samples. These samples are extracted by a dilution method, adding milli-Q water in a ratio of 1 : 1 and then separating soil and water. This way enough water is available for additional analysis.

All samples, except individual soil moisture samples, are analysed for nitrogen compounds (kjeldalh-N, nitrate and ammonium), phosphorus compounds (total-P, ortho-P), potassium, chloride, and DOC. Usually, other macro components (calcium, magnesium, sodium, sulphate) and metals (cadmium, chromium, copper, nickel and zinc) are analysed as well. Individual soil moisture samples are analysed for nitrate, ammonium, chloride and sulphate. Individual upper groundwater samples, tile drain water samples and ditch water samples are analysed for pH, electric conductivity (EC) and nitrate (Nitrachek, colour method) in the field or directly after arrival in the laboratory. At the groundwater sampling point an indicative depth of the groundwater table is determined. Recently, brief soil-profile descriptions are made as well.

Additional geographical information on soil type and groundwater regime class (50 x 50 m^2 grid cell; De Vries & Denneboom, 1992) is collected, as well as precipitation and evaporation data of the Royal Dutch Meteorological Institute (KNMI) are also collected (10-day average values for 15 weather districts).

FADN data are collected in addition to socio-economic data, including all farm-gate mineral balance items, MINAS balance items, crop rotation, amount of chemical fertiliser and manure applied, grazing regime of livestock, state of soil fertility for potassium and phosphorus, indications for acreage with tile drainage and use of irrigation waters. The LEI also calculates atmospheric nitrogen deposition and nitrogen mineralisation per farm per year.

2.3 Data interpretation

Though both regulations and monitoring distinguish between soil-type regions and farm type or main crops, it should be realised that on farms, other soil types and crops will occur in addition to the main soil type and main crop. For example, in the LMM monitoring programme in the sand region, an average of 25% of the soils were peat or peat-like soils and an average of 2% were clay soils in the 1992-2001 period (Fraters *et al.*, 2005). On dairy farms 80% of the acreage consist of grassland, while on about 20% of the acreage, fodder maize was grown.

To evaluate the effectiveness of the mineral policy, measures are evaluated for each of the main soil-type regions. For example, Willems *et al.* (2002) showed that in the sand regions comparing two 4-year periods a decrease in nitrate concentration on dairy farms of 25-30% was detected with a 90-95% significance. Differences in sample group and environmental conditions in time had to be taken into account in the analysis and interpretation of the data. The LMM sample group changes in time. Therefore differences occur in the ratio between farm types, soil type acreage, GRC, etcetera. The variation in precipitation excess strongly influences measured nitrate concentration and has to be taken into account as well. Boumans *et al.* (2001) developed a statistical approach to account for variation in precipitation excess and other confounding factors for the sand regions. In general, to evaluate the effectiveness, standardised nitrate concentrations are calculated on the basis of measured nitrate concentrations, and circumstances and average circumstances. Recently, this procedure has been improved and is now available for both the sand and clay regions, see Fig. 14 (Fraters *et al.,* 2004).

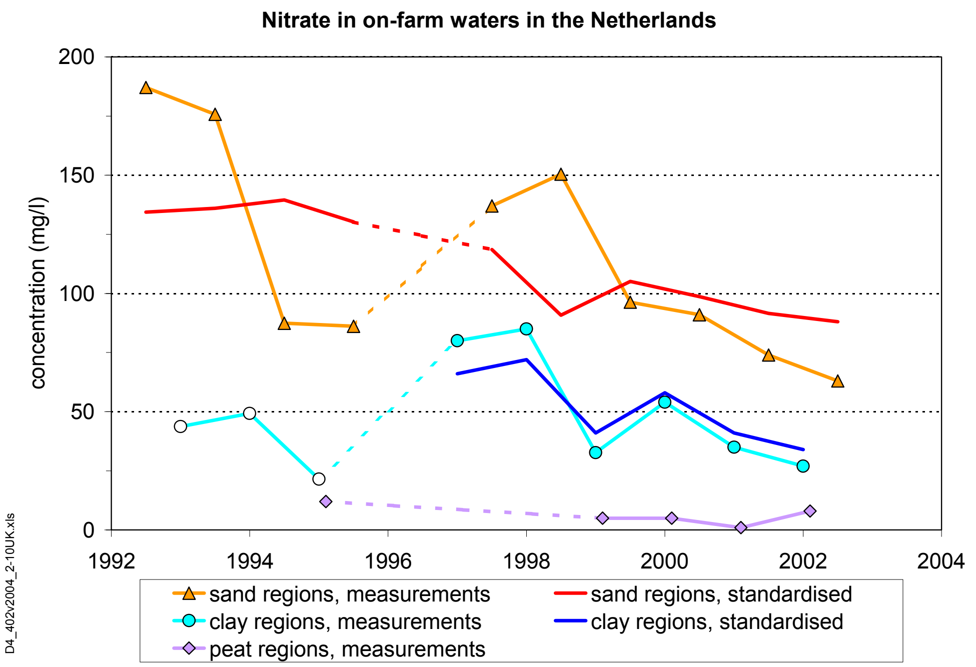

Fig. 14 Average measured nitrate concentration per soil-type region per year in the upper metre of groundwater (sand and peat) and tile-drain water (clay), as well as average standardised nitrate concentration for sand regions (Fraters *et al.*, 2004).

Comparison of measured nitrate concentration with environmental quality standards is usually done per main soil-type region and farm type, see Fig. 15.

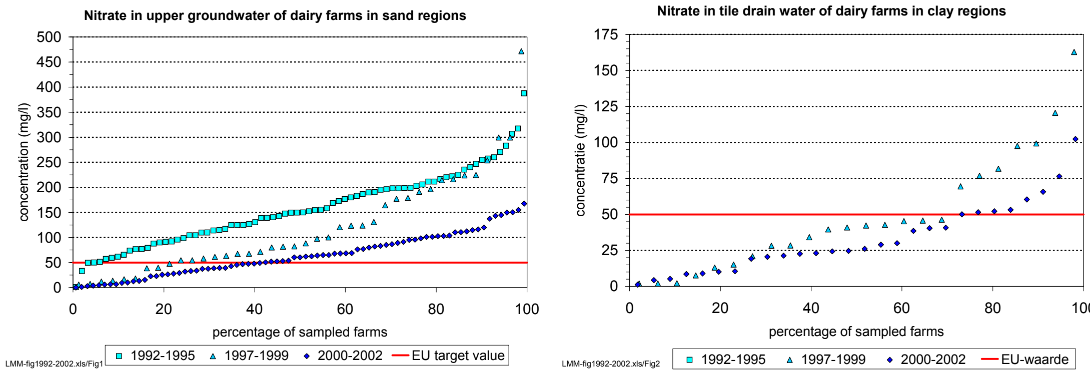

Fig. 15 Cumulative frequency diagram of measured farm average nitrate concentrations on Dutch dairy farms in the upper metre of groundwater in the sand regions (left) and in tile drain water in the clay regions (right).

3. DISCUSSION

Evaluating the effectiveness of the Action Programme is performed for each of the main soil-type regions. Though these regions are considered as a group of similar groundwater bodies, this approach might be conflicting to some extent with the catchment approach recommended in the Nitrates Directive monitoring guidelines and required for the Water Framework Directive. To date, the catchment approach has not been considered useful in a flat delta area of several rivers, because a watershed is difficult to distinguish, especially for groundwater.

A recent evaluation of the results of the LMM (RIVM/LEI, 2002) showed that the LMM is sufficiently equipped to determined trends in nitrate concentration in shallow groundwater per main soil type region. However, in order to be able to show the effect of the specific policy measures for vulnerable (dry) sandy and loess soils the number of (dairy) farms should be increased. These soils are the most prone to nitrate leaching and standard loss for these soils are therefore lower than for other soil types. Effects of policy measures on surface water quality on farms in the sand regions can not be detected in a similar way as for shallow groundwater, because neither ditch water nor tile drain water is monitored yet.

With respect to the LMM programme in the clay regions the question of how to monitor effects and compared measured values with target values is still not answered once and for all. For example, should tile drain water be considered as shallow groundwater or as ditch water, i.e. should concentrations in tile drain water be compared with target values for groundwater of for surface water.

With respect to the peat regions, a recent study (Van Beek *et al.*, 2003) shows that surface run off contributed for 10% of the total nitrogen load to the surface water. In the LMM surface runoff is not yet measured.

In the fall of 2003 an action plan has been made to cope with the above mentioned weaknesses in the LMM. From 2004 onwards the LMM will be extended with a programme that specifically monitors farms on vulnerable (dry) sand and loess soils (about 55 farms per year), a programme to monitor tile drain and ditch water on farms in the sand regions (about 30 farms per year), and a programme to study and monitor the surface runoff on farms in especially peat regions. In addition the number of monitored farms in the peat regions will be doubled to about 24 farms per year.

For estimating the effect of the Action Programme on surface waters, especially with respect to eutrophication, some improvement of the existing programmes might be necessary. The LMM focuses on nutrient concentrations in ditch water on farms in the winter period. No information has been collected on eutrophication phenomena in ditch waters in the summer months. The network of CIW agricultural surface water stations is better equipped, since more parameters have been determined and measurements taken during the entire year. However, one should realise that the water quality of regional surface waters in clay and peat regions in summer is strongly influenced by the quality of larger rivers due to letting fresh water into polders in the summer. In some regions the surface water quality is also influenced by the up-welling nutrient rich groundwater.

There are several drawbacks in this network (Portielje *et al.*, 2002). Some are due to the fact that it has only been recently developed. There are specific areas where there is a lack of monitoring stations. There are also indications that not all selected stations are representative for agriculturally influenced water. Stations are located at easily accessible locations and are therefore usually larger waters in comparison with the ditch water monitored in the LMM. The responsible water boards have selected the monitoring stations. A quality control has not yet been performed on consistency of choices between water boards.

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APPENDIX

Table A1 Land use in the Netherlands 1989–1996 (Source: CBS Statline, 2003).

Land use	1989	1993	1996
Total land area (million of ha)	3.4	3.4	3.4
% Agriculture [1]	70.8	70.1	69.4
% Nature (forest, heath, grass)	13.3	13.3	13.6
% Houses	8.8	9.1	9.4
% Roads and railway	3.9	3.9	4.0
% Industry	1.0	1.1	1.1
% Recreation	2.2	2.4	2.4
Total inland surface water area (million of ha)	0.76	0.76	0.77
% Lake IJssel	24.0	24.0	24.0
% Reservoirs and recreational waters	0.7	0.8	0.8
% Other inland waters > 6 m	20.6	20.6	20.7
% Estuary and marine waters	54.7	54.6	54.5

[1] Including non-paved roads, strips of woodland and waterways narrower than 6 m, and scattered agricultural and non-agricultural buildings.

Table A2 Areas (million of ha) of major forms of agricultural land use in the 1992-2002 period. (Source: CBS Statline, 2003).

	1992		1997		2002	
	Area	%	area	%	Area	%
Total area cultivated land	1.98		1.97		1.95	
Grassland	*1.06*	*53.6*	*1.03*	*52.4*	*1.00*	*51.3*
Permanent	1.03	51.9	0.96	48.8	0.89	45.8
Temporary	0.03	1.7	0.07	3.7	0.11	5.5
Arable land	*0.80*	*40.5*	*0.81*	*41.2*	*0.82*	*42.3*
Fodder crops	0.22	11.3	0.24	12.1	0.22	11.3
Cereals	0.17	8.7	0.19	9.6	0.20	10.5
Potatoes & beets	0.31	15.7	0.30	15.0	0.27	14.1
Other crops	0.09	4.6	0.09	4.4	0.13	6.4
Horticulture	*0.11*	*5.6*	*0.11*	*5.7*	*0.12*	*5.9*
Open	0.10	5.1	0.10	5.2	0.11	5.4
Glass	0.01	0.5	0.01	0.5	0.01	0.5
Other use	*0.006*	*0.03*	*0.014*	*0.7*	*0.010*	*0.5*
Fallow land	0.006	0.03	0.011	0.6	0.006	0.3
Other	-	-	0.003	0.1	0.004	0.2

Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the United Kingdom

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Abstract This contribution describes the methodology for monitoring the effectiveness of the EU Nitrates Directive Action Programmes in the United Kingdom, including England, Wales, Scotland and Northern Ireland. The legal requirements for this type of monitoring are set down in the Nitrates Directive, Article 5(6) (EC, 1991). In 1999 the European Commission published the Draft Monitoring Guidelines (EC, 1999). The UK has well-developed networks for measuring nitrate concentrations in surface waters and groundwaters. The groundwater monitoring networks are supplemented with additional modelling techniques to interpolate between sites and identify groundwater areas vulnerable to nitrate leaching from agricultural land. Following the significant extension of Nitrate Vulnerable Zones in the UK during 2002 and 2003, we have developed a new effectiveness monitoring strategy in England, details of which are provided in this paper. Scotland, Wales and Northern Ireland are developing similar strategies in relation to their own territories. The overall aim is to combine farm practice data, small-scale catchment studies and modelling techniques to build up a picture of the impact of Action Programme measures on nitrate concentrations over time. The UK has particular experience of several aspects of effectiveness monitoring which are explained in this paper. These include porous pot monitoring on freely-draining soils, developing models to predict nitrate losses from agricultural land and identifying trends in groundwater using residence time indicators.

1. INTRODUCTION

1.1 Description of natural factors influencing nitrate occurrence

1.1.1 Climate

The United Kingdom (UK) has a temperate climate with most rainfall and recharge occurring in winter months. The concentration of nitrate in water draining from land is dependent on both the amount of nitrate leached and the degree of dilution. In the wetter west of the UK, the excess winter rainfall (hydrologically effective rainfall) is typically >400 mm. Because of dilution, quite large amounts of nitrate can be leached in these areas (50 kg N ha^{-1} $year^{-1}$) without the average concentration exceeding the Nitrates Directive limit. In the drier southern and eastern parts of the UK the long-term excess winter rainfall is as little as 150 mm and so the leaching of as little as 15 kg N ha^{-1} $year^{-1}$ results in an average concentration of nitrate in breach of the Nitrates Directive limit (Davies, 2000).

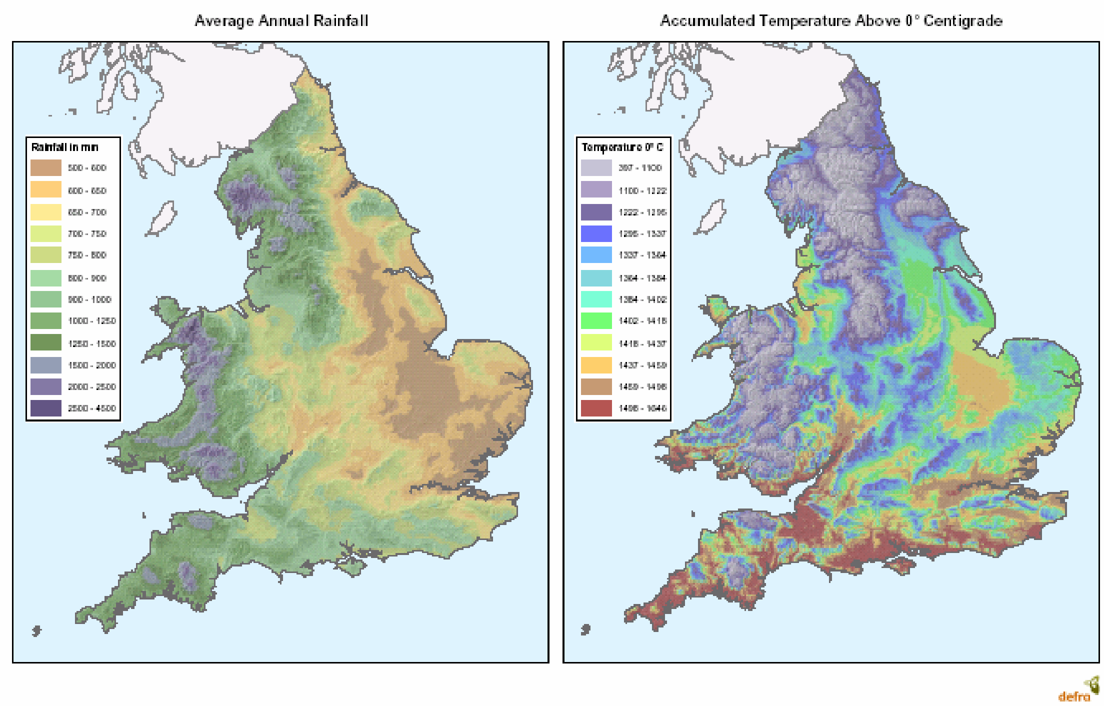


Fig. 1 Average Annual Rainfall (left) and Accumulated Temperature (°C) (right) in England and Wales.

1.1.2 Soil type

Much of the UK is covered by clay soils (Fig. 2). Soils in some areas, particularly in the south and east, have low clay content and are free draining, for example over Cretaceous chalks and Jurassic limestones *(ibid.)*. These areas are particularly susceptible to leaching of soluble nutrients.

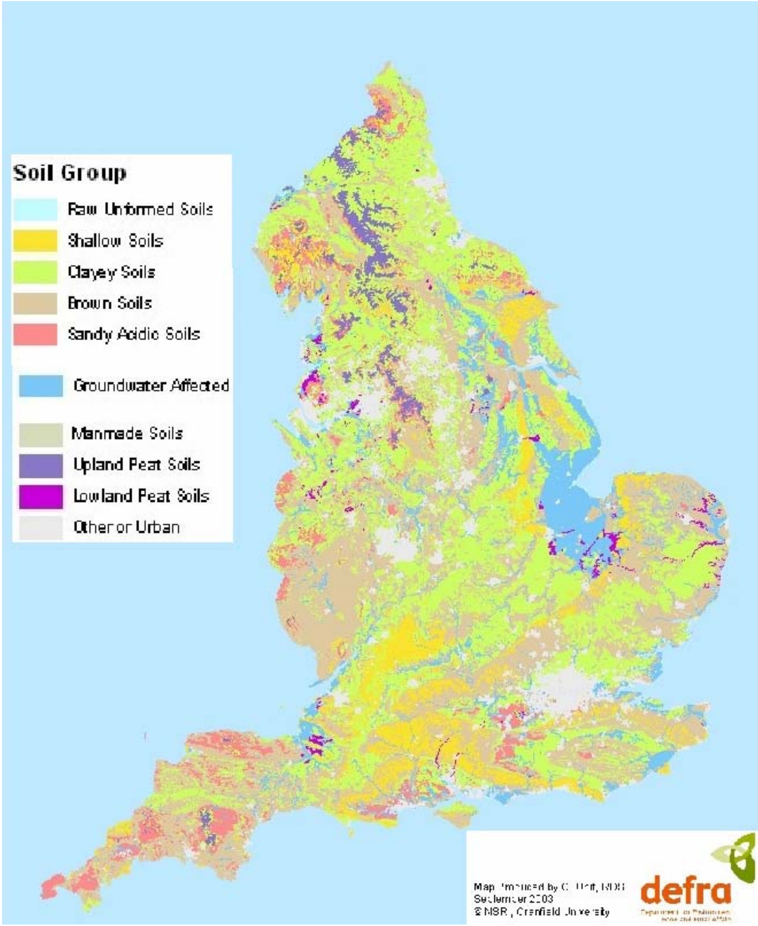


Fig. 2 Soil type in England.

1.1.3 Topography

The flattest land in the UK is towards the south east – East Anglia in particular. Most steep slopes occur towards the north and west of the UK in northern England, Wales and Scotland. In Northern Ireland steeper slopes occur to the west and south-east.

1.1.4 Hydrogeology and groundwater depth

The principal water supply aquifers of the UK are found in the lowlands of England (see Fig. 3). Considerable areas of these aquifers are unconfined and because of their location coincide with areas of high population density and intensive agricultural activity. They are therefore in many places extremely vulnerable to pollution.

The depth of the water table (top of the saturated aquifer) is extremely variable across the UK due to complex geology and topography. The water table will generally be deepest in aquifer recharge areas and shallowest in areas of discharge. Groundwater contribution to surface water flows can be extremely significant and in some areas at certain times of the year all surface water flow is groundwater derived (e.g. the Chalk streams of southern England). Annual variations in groundwater level range from less than a metre in some aquifers (e.g. Triassic sandstone) to tens of metres in others (e.g. chalk and limestone aquifers).

Groundwater depth in Scotland is highly variable, from 10 to 30 metres below ground surface in the major aquifers, and several meters in the alluvium and gravels along the river valleys. Much of Scotland is Precambrian crystalline rocks and groundwater is found in widely spaced fractures at variable depths.

Groundwater levels are generally relatively shallow within Northern Ireland with only modest seasonal variation.

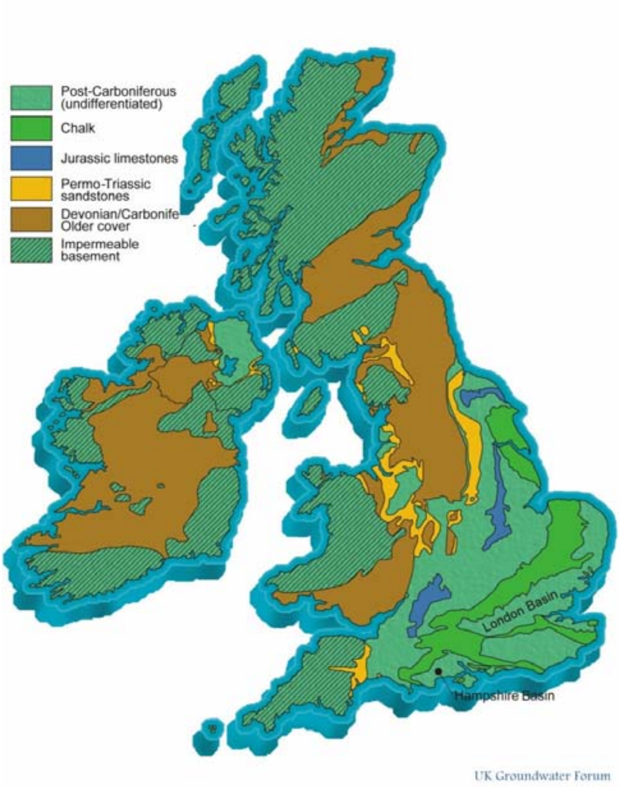


Fig. 3 Distribution of the principal aquifers in the British Isles (Source: UK Groundwater Forum).

1.1.5 Surface waters

The main watershed in the UK runs from north to south. Westward flowing rivers empty into the Atlantic within relatively short distances, whereas the eastward flowing rivers are generally longer in length. The eastern rivers in Scotland are generally fast-flowing over impermeable rocks and respond quickly to rainfall events. A group of rivers drain into the Wash after slowly draining the flat countryside of East Anglia. The Thames dominates drainage in the southeast of England with a drainage area of about 10,000 km^2 (Encyclopedia Britannica, 1993).

Broadly speaking, higher concentrations of nitrate are found in the south and east of the UK. Figure 4 shows the average nitrate concentrations of the main river networks in England and Wales. Table 1 defines the categories by which a river is classified according to its nitrate concentration.

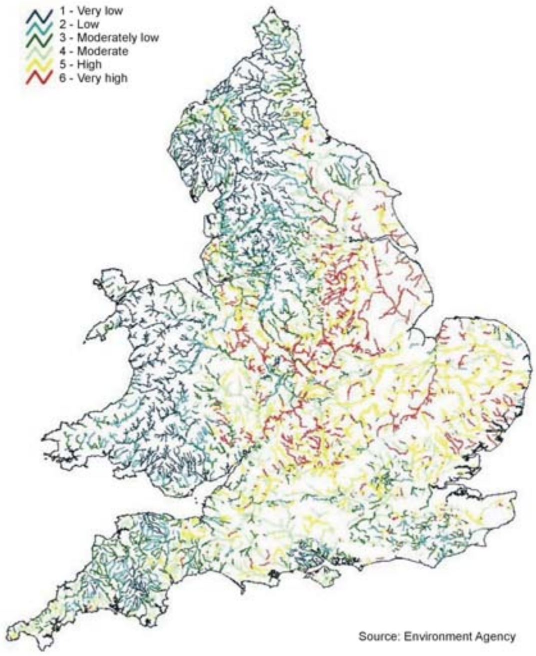


Fig. 4 Nitrate concentrations in rivers in England and Wales, 2001. See Table 1 for the definition of the six classifications according to river nitrate concentrations.

Table 1 River classification according to average nitrate concentration.

Classification for nitrate Grade	*Grade limit (mg NO_3 l^{-1}) Average*	*Description*
1	<5	Very low
2	>5 to 10	Low
3	>10 to 20	Moderately low
4	>20 to30	Moderate
5	>30 to 40	High
6	>40	Very high

1.2 Description of human factors influencing nitrate occurrence

1.2.1 Global information on land use

More than half of the UK is either used for intensive agriculture or is developed. The remainder is largely semi-natural. Woodlands occupy about a quarter of UK semi-natural land, with broadleaved and coniferous types about equal in extent. Heaths and bogs cover a third of the low intensity land; semi-natural swards form over a quarter. Montane and coastal habitats, while important, are small in extent.

The four countries of the UK differ markedly from each other in terms of land use. Intensive uses affect over three-quarters of England, about two-thirds of Northern Ireland and about half of Wales. In Scotland, less than a quarter is intensively farmed or developed.

The semi-natural land of England is evenly split between woodlands and “mountain, moor, heath and down”. The situation in Wales is similar, but with the semi-natural area being a larger proportion of its land area. Scotland is dominated by “mountain, moor, heath and down” which make up more than half of all its semi-natural land.

Northern Ireland also has reasonably extensive “mountain, moor, heath and down” and neutral grass but is notably short of woodland cover.

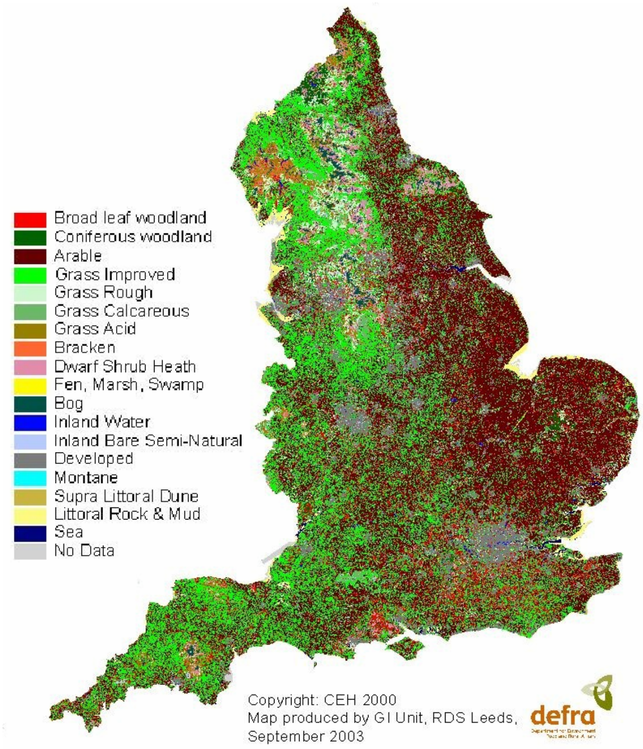


Fig. 5 Map of land use in England.

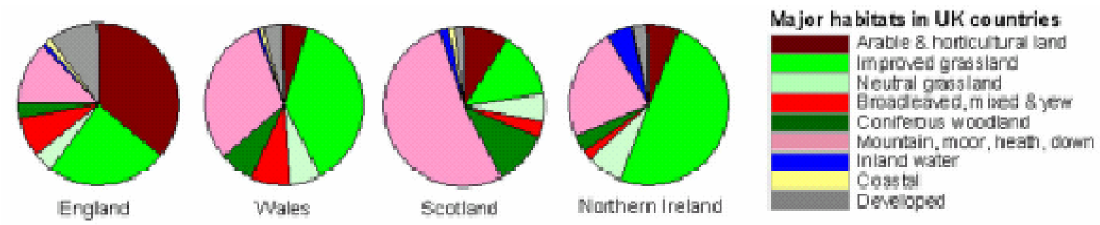


Fig. 6 Major habitats in UK countries (Source: Landcover Maps, 2000).

1.2.2 Main crops and characteristics of agriculture

Total cropping areas in the UK are shown below in Table 2**.** The figures show some large changes in cropping over the past five years. This change is not necessarily representative of overall trends. The figures below reflect unusually high autumn rainfall which resulted in shifts from autumn-sown to spring sown crops in some cases e.g. from winter barley to spring barley.

Table 2 Main crop types in the United Kingdom (Source: Defra June agricultural census data).

Crops	Area ('000s hectares)	% change over last 5 years	% of total tillage area
Wheat	1632	-17.1	36.7
Winter barley	459	-38.1	10.3
Spring barley	752	+52.7	16.9
Total cereals	**2974**	**-10.3**	**66.9**
Oilseed rape	403	+13.1	9.1
Sugar beet	177	-11.0	4.0
Potatoes	144	-14.8	3.2
Linseed	30	-38.5	0.7
Peas/beans	276	+54.8	6.2
Maize/other fodder	188	+5.1	4.2
Vegetables	118	-9.8	2.7
Total tillage	**4443**	**-5.5**	**100.0**
Set-aside	797	+57.1	17.9
Grassland	**Area ('000s hectares)**	**% change over last 5 years**	**% of total grass area**
Less than 5 years old	1065	-11.6	17.9
5 years and older	4884	+3.4	82.1
Total grass	**5949**	**+0.3**	**100**
Total crops and grass	**10392**	**-2.2**	**-**

Defra's annual June agricultural census for England provides data on cropping and stocking rates. The online search facility can produces maps showing the distribution of main crop types and livestock numbers across England. The facility also provides animated series which show trends in how distributions have changed over time. The link is: http://farmstats.defra.gov.uk/cs/farmstats_data/MAPS/agricultural_atlas/map_select.asp.

Grassland agriculture covers the major proportion of the land surface of the UK. About 5 million hectares are in leys or permanent grassland (excluding rough grazing). The distribution of grassland is largely determined by soil, geographic/topographic and climatic conditions as indicated above and all of which encourage its concentration in the western half of the UK (Jarvis, 1999). This is the main livestock area.

Most arable land lies in the south and east of England. Most intensive arable production and pig production is located in the flatter, drier east of England. Most dairy farms are located in the west of England, especially the south-west and Cheshire. Much of the north and west of England is dominated by extensive grazing on unimproved pastures.

In Scotland only 16% of the 5.5 million hectares of agricultural land in Scotland is arable. Much of the arable land is in the east of the country where the land is flatter and the climate drier. Much of the north and west of Scotland is rough grazing.

The latest available UK-wide census data show there were 10,381,000 cattle, 5,330,000 pigs, 24,898,000 sheep and 870,000,000 numbers of poultry in 2002 (National Statistics, 2003).

1.2.3 Manure production and fertiliser use

The 2001 Farm Practices Survey for England (Defra, 2002) is available to download from http://www.defra.gov.uk/esg/work_htm/publications/cs/fps/fpsfinalreport.pdf and contains much detailed information about manure production and application in England.

The quantity of livestock manures in England and Wales collected annually from farm buildings and yards and requiring handling storage and subsequent land application is estimated at approximately 67 million tonnes. Additionally around 45 million tonnes of excreta are deposited directly in fields by grazing cattle, sheep and pigs. The nitrogen content of the manures and excreta are estimated at around 560,000 tonnes, which is equivalent to an average loading rate on agricultural land (crops plus grassland) of 65 kg N ha^{-1}.

Fuller analysis of 1995 data for England indicated that the average loading of excreted nitrogen was 75 kg N ha^{-1} with 37% derived from dairy cattle, 42% from beef cattle and sheep, 9% from pigs and 12% from poultry.

The British Survey of Fertiliser Practice (BSFP) is an annual survey which has been collecting aggregated data on agricultural use of fertilisers across the whole of the UK since 1983 (BSFP Authority, 2002). Total nitrogen use on all crops and grassland decreased by 7 kg ha^{-1} in 2001 to 116 kg ha^{-1}. This overall rate of total nitrogen was the lowest recorded since the British survey started in 1983. The decline in total nitrogen use during 1997 to 2001 was mainly associated with a drop in the overall application rate of straight nitrogen especially on grassland. Table 3 shows total nitrogen use on main crop types in the UK during 2001.

Table 3 Average total nitrogen fertiliser use for main crops in the UK in 2001 (Source: BSFP Authority, 2002).

Crop	**Total N kg ha^{-1}**	**Crop**	**Total N kg ha^{-1}**
Winter wheat	185	Oilseed rape	193
Spring barley	111	Sugar beet	103
Winter barley	145	Grassland	94
Maincrop potatoes	151		

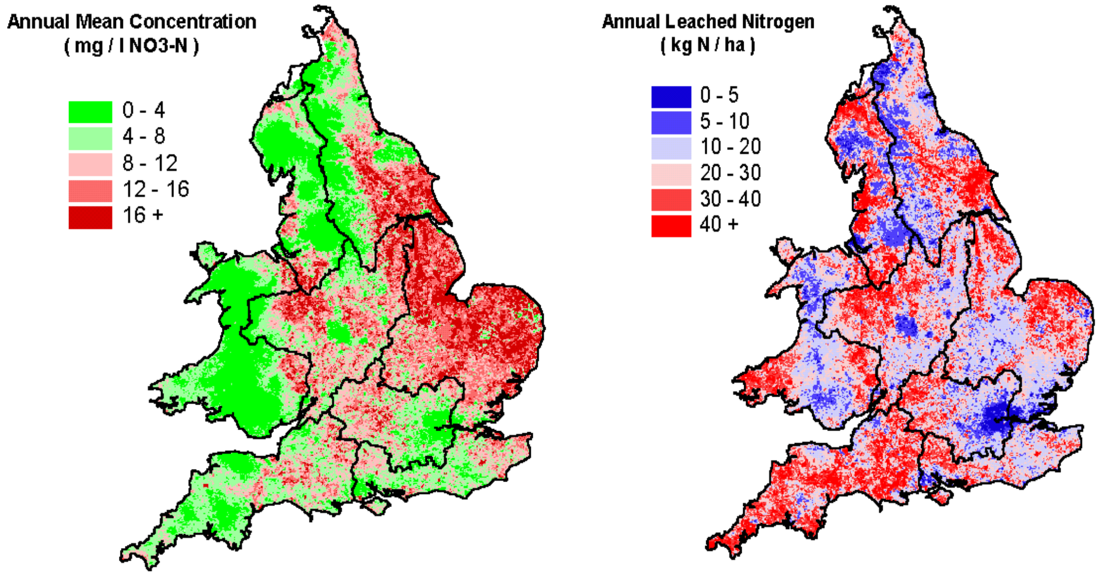


Fig. 7 Annual leached nitrogen from agricultural land (left) and resultant nitrate concentration (right) in England and Wales (Source: MAGPIE, National Nitrate Leaching Simulation: Modelling Agricultural Pollution and Interactions with the Environment).

1.3 Overview of monitoring networks

The UK has taken the approach of designating Nitrate Vulnerable Zones for the protection of waters against pollution caused by nitrates from agricultural sources. Therefore the UK is required to establish two monitoring networks; one for the identification of nitrate-polluted waters, and one to assess the effectiveness of the Action Programme measures (which incorporates the aforementioned monitoring network).

1.3.1 Monitoring for the identification of nitrate-polluted waters

During 2002 and 2003, new NVZ areas were designated throughout the UK. In England coverage has increased from 8% to 55% of total land (see Fig. 8). The reasons for designation are as follows, given as proportions of England's total land area: protection of nitrate-polluted surface waters 41%, groundwaters 14%, protection of eutrophic waters 2%. More detail is available at http://nvz.adasis.co.uk/maps/regional.html which is part of the NVZ Interactive Mapping Service developed by ADAS Consulting Ltd on behalf of Defra.

In Scotland a total of 14.3% of land is now designated for the protection of groundwaters (smaller surface water NVZs have been subsumed within these groundwater NVZs). See Fig. 17.

In Wales 3% of land is now designated, some for the protection of groundwaters and some for surface waters.

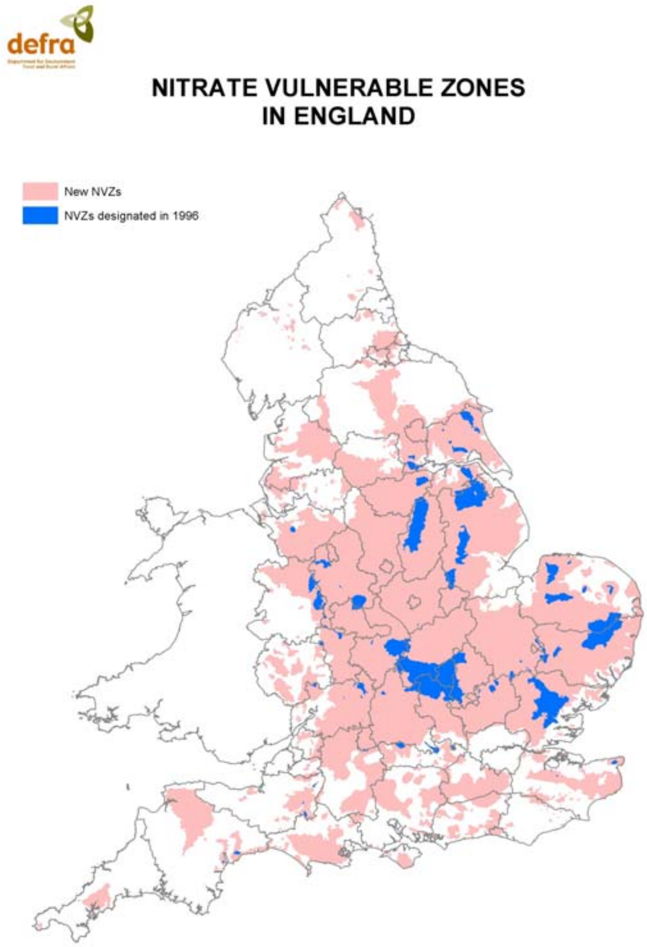


Fig. 8 Nitrate Vulnerable Zones in England, 2002.

In Northern Ireland seven small NVZ areas (<0.14%) have been designated for the protection of groundwaters (Northern Ireland does not have high levels of nitrate in its surface waters). See Fig. 19.

A detailed explanation of the monitoring networks and the methodology applied in identifying new Nitrate Vulnerable Zones in England is in the Defra methodology document published in October 2002 at http://www.defra.gov.uk/environment/water/quality/nitrate/method.htm (Defra, 2002a). The principles described in this document are virtually identical to those used to identify the new NVZs in Wales.

There are also similar documents available describing the methodology applied in Scotland (Lilly *et al.*, 2001; Ball & MacDonald, 2001, 2002) and Northern Ireland (GSNI, 2002).

The methods described below are for England and Wales but, other than where indicated, the approaches in Scotland and Northern Ireland are very similar. More detail is provided in relation to groundwater monitoring than surface water or eutrophication, because we have developed some complex modelling techniques for groundwater which we hope will be of interest.

Surface water monitoring networks

England and Wales

The Environment Agency monitors nitrate levels in surface waters through its General Quality Assessment (GQA) network, which covers over 7000 sites in England and Wales. Data from additional Surface Water Abstraction Directive (SWAD) network water quality monitoring points are also used. The location of these monitoring points is shown below in Fig. 9.

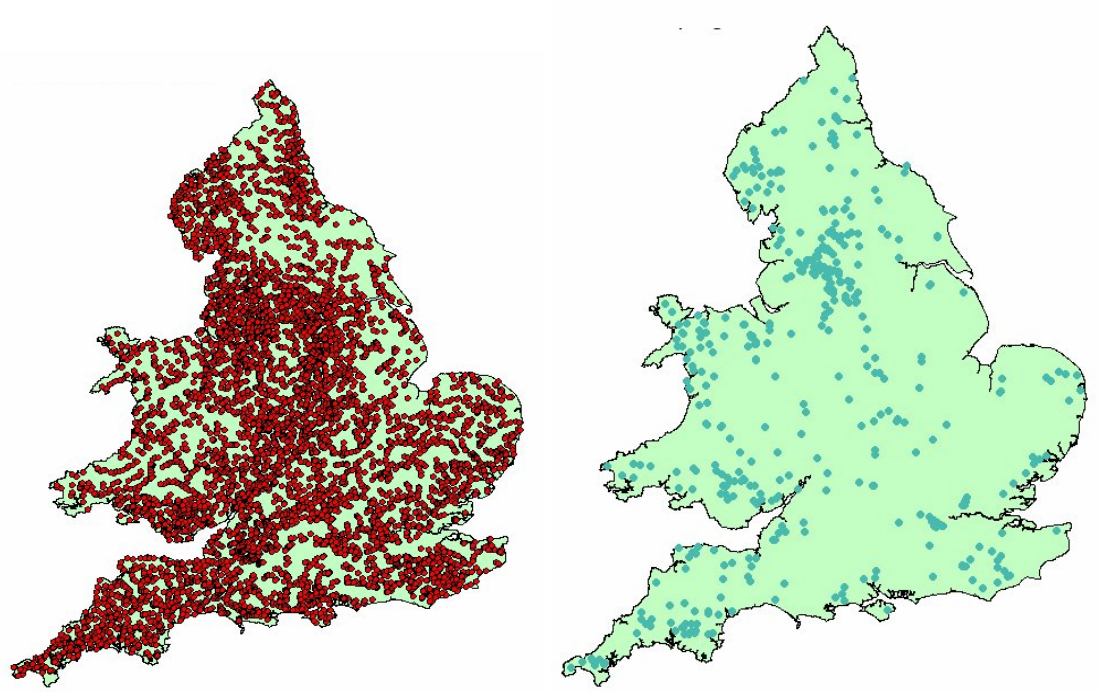


Fig. 9 The GQA network (left) and SWAD network (right) (Source: Environment Agency).

At each sampling site, water samples are normally taken on a monthly basis and the nitrate concentration is recorded as total oxidised nitrogen (mg NO_3 l^{-1}). Only results from routine, pre-planned sampling programmes with samples analysed at accredited laboratories are used. To avoid bias all extra data collected from special surveys or pollution incidents are ignored.

To identify surface waters with nitrate concentrations exceeding 50 mg l^{-1}, or which could exceed 50 mg l^{-1}, the following steps were undertaken for the 2002 designations:

a) Sampling nitrate concentrations between 1996 and 2000 at water quality monitoring points representative of all major surface waters in England;
b) Analysing the monitoring data over the 1996 to 2000 period to identify those points where there is 95% statistical certainty that the level of 50 mg l^{-1} of nitrate has been exceeded at least 5% of the time. This is done by calculating a 95th percentile from the dataset and constructing a 90% confidence interval around this. If the lower confidence interval on the calculated 95th percentile exceeds the

50 mg l^{-1} nitrate level, then the sample point is judged, with 95% certainty, to be affected by nitrate pollution;

c) Trend analysis to identify any additional points which could exceed 50 mg l^{-1} nitrate in the future if action is not taken. This work uses a ten-year dataset from 1991 to 2000 to extrapolate future trends. Points predicted with 95% confidence to exceed the level of 50 mg l^{-1} at least 5% of the time by 2004, which is the year of the next monitoring review required under the Nitrates Directive, are judged to be waters that could be affected by pollution if no action is taken.

Scotland

SEPA operates a representative network of 233 surface water monitoring sites for the purposes of the Nitrates Directive. The aim is to sample at these sites on a monthly basis. The sites are shown below in Fig. 10.

There are 8 surface water catchments in Scotland which have been identified as Nitrate Vulnerable Zones. These comprise six Angus coastal burns (Lunan Water, Brothock Water, Elliott Water, Barry Burn, Dighty Water, Buddon Burn), a tributary of the Tweed (Leet Water) and the River Ythan in NE Scotland. They are shown in Fig. 10. These areas have been subsumed into the larger groundwater NVZs. The assessment of the nitrate concentrations in surface waters to determine whether they are nitrate-polluted has followed a similar process to that in England and Wales.

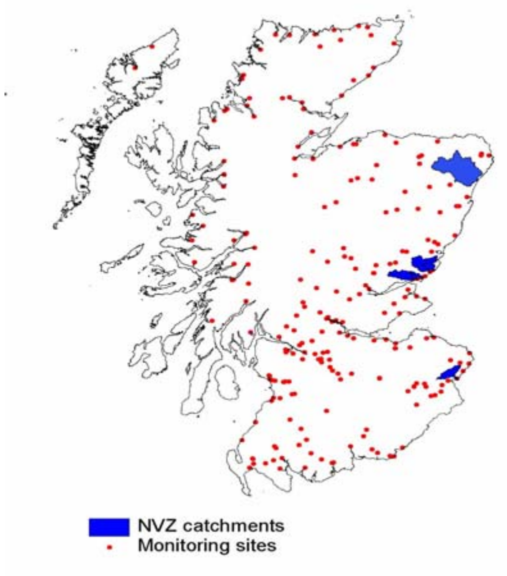


Fig. 10 Surface water NVZ catchments and monitoring network in Scotland, 2003.

Northern Ireland

The Environment and Heritage Service (EHS) in Northern Ireland monitors nitrate levels in surface waters through its non-drinking and drinking water monitoring network. In Northern Ireland non-drinking water nitrate monitoring is routinely carried out at 262 river and lake sites. Nitrate monitoring is also carried out at 53 drinking water supply abstraction points. At each site, water samples are normally taken on a monthly basis. The location of these monitoring sites is shown in Fig. 11 below.

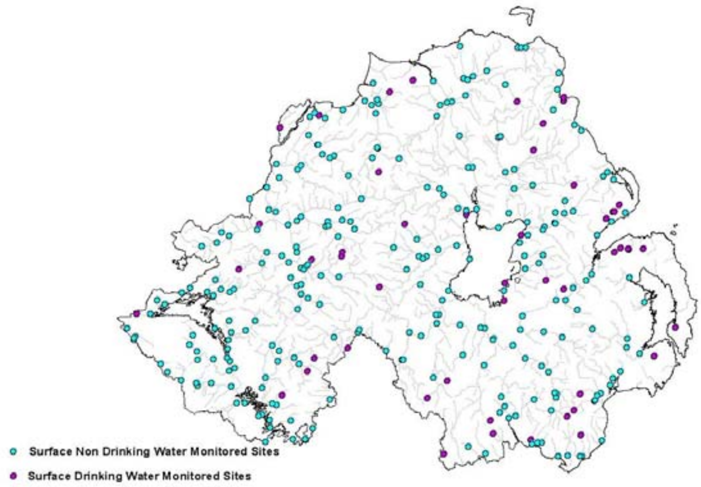


Fig. 11 Surface Non-drinking, and Surface Drinking Water Monitoring Network in Northern Ireland, 2003.

The methodology used by Northern Ireland to identify surface waters with nitrate concentrations exceeding or which could exceed 50 mg l^{-1} was similar to that used by England and Wales.

The statistical analysis and trend analysis carried out showed that no surface non-drinking water in Northern Ireland contains or could contain more than 50 mg l^{-1} nitrate. An analysis of the surface drinking water was not undertaken as no single result from any site in this network in the period 1996–2000 exceeded 40 mg l^{-1}. No trend analysis was carried out for surface drinking water.

Groundwater monitoring networks

England and Wales

The 2002 designations have resulted in a significant increase in the area of groundwater NVZs as the methodology has shifted from protecting only the groundwater catchments of affected Public Water Supplies, to the protection of all groundwaters from agriculturally derived nitrates where concentrations exceed, or could exceed, 50 mg l^{-1} nitrate.

The first stage collated and statistically examined groundwater quality data from all available monitoring points to identify groundwaters which are nitrate-polluted, or which could become polluted. In the second stage, the theoretical risk to groundwater from nitrate leaching was modelled and mapped based on land use, rainfall, soil and (solid and drift) geological characteristics. The spatial distribution of nitrate values from the monitoring network were then used in conjunction with the vulnerability map to propose groundwater NVZs.

Identification of groundwaters which are nitrate-polluted, or which could become polluted

A method of interpolation was used to estimate nitrate concentrations in groundwater throughout England and Wales and the confidence of these estimates. The method used was based on estimating a predicted average nitrate concentration in 2017 and a geostatistical analysis technique (disjunctive kriging) that enables local estimates of nitrate concentration to be determined at any point and the probability of a value exceeding the 50 mg l^{-1} nitrate threshold value. The use of 2017 as the year for prediction reflects the time lag associated with the downward movement of nitrate through the soil and unsaturated zones to the underlying aquifer and is consistent with the prediction periods used in the previous 1996 designation and 1997 review.

In determining the spatial estimates of nitrate concentrations in groundwater, all available groundwater nitrate concentration data for 3714 monitoring sites in England from 1990 to 2000, which were held by the Environment Agency and water companies, were used (see Fig. 12). Trend lines were estimated manually to predict a value of nitrate in groundwater for the year 2017. Measured 50 mg l^{-1} nitrate exceedences were also recorded. This method was selected because the variability in nitrate concentrations over time in UK aquifers as a result of the numerous influencing factors, e.g. seasonal variations, drought/wet periods, aquifer characteristics and response, sampling frequency and timing, etceteras, could not be accommodated adequately by automated statistical trend estimation techniques.

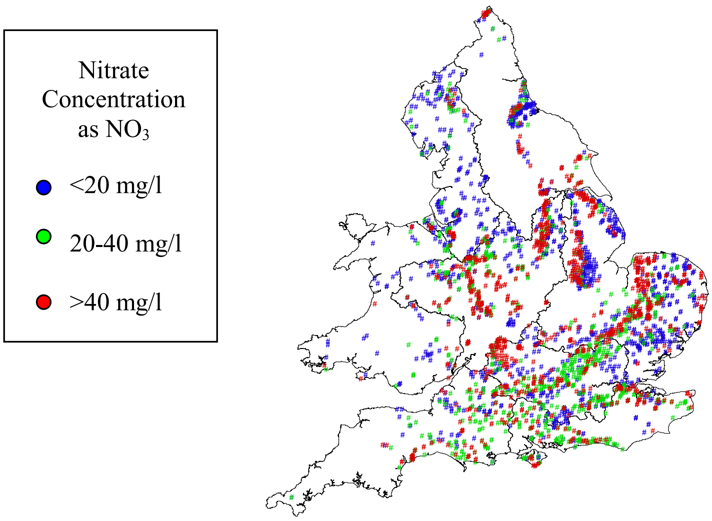


Fig. 12 England and Wales groundwater nitrate monitoring network: estimated mean nitrate concentrations in 2017.

Disjunctive kriging was used to provide both local estimates of the nitrate concentrations and the probabilities that the actual values exceed the 50 mg l^{-1} nitrate limit. These data were used to produce maps of estimated nitrate concentrations and probabilities of exceeding 50 mg l^{-1}, together with maps of the estimation variance.

The threshold probability of exceeding the 50 mg l^{-1} nitrate limit was set to 0.2 to minimise the likelihood of excluding an area that is potentially at risk from nitrate leaching. This value has been validated by hydrogeological knowledge combined with calibration using the existing NVZs (designated in 1996) and other catchment based zones, which were defined by the Environment Agency during a review in 1997. The calculated values of estimation variance identify the confidence in the predicted nitrate concentrations, with higher variance values indicating reduced confidence. Areas with an estimation variance value greater than 500 (mg $l^{-1})^2$, resulted in the predictions in these areas being rejected. These data were then used to generate a map (Fig. 13) showing those areas of England and Wales in which the probability of exceeding 50 mg l^{-1} nitrate was ≥ 0.2 and there was adequate confidence in the monitoring results and predictions.

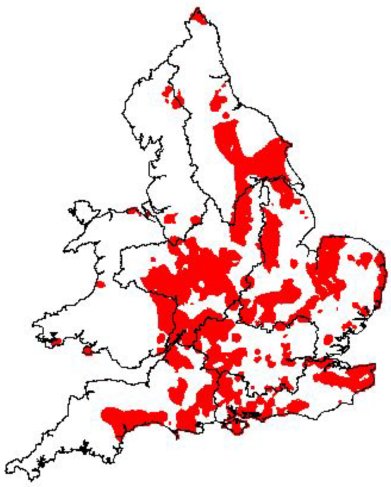


Fig. 13 Areas of England and Wales in which the probability of exceeding 50 mg l^{-1} nitrate was ≥0.2 and with adequate confidence in the monitoring results and predictions.

Identification of groundwaters vulnerable to nitrate leaching

In this stage a model was produced to define areas vulnerable to nitrate leaching (Lovett *et al.*, 2001). All the variables affecting nitrate leaching to groundwater were represented in the model, i.e. climate, agricultural nitrate loading, soil attributes, the presence of low permeability superficial deposits (Drift) and the hydrogeological properties of the rocks (Fig. 14). The model was developed in GIS using digital data sets and layers from the ADAS MAGPIE (Modelling Agricultural Pollution and Interactions with the Environment) system, and the Environment Agency's published Groundwater Vulnerability Maps. The ADAS MAGPIE system (Lord, 1999; Lord & Anthony, 2000) was used to calculate soil drainage and nitrate losses in leachate from land under a number of standard scenarios. The output is simulated mean nitrate-nitrogen concentrations in land drainage (mg l^{-1} nitrate-N).

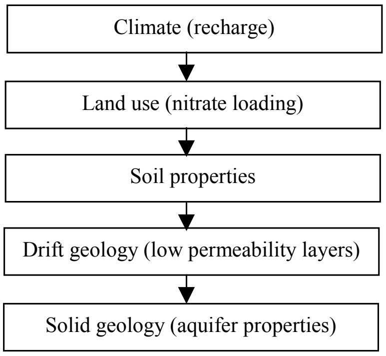


Fig. 14 Conceptual diagram indicating key factors influencing groundwater vulnerability.

The Environment Agency's Groundwater Vulnerability (GWV) maps (at a scale of 1:100,000) classify geological formations (rocks) as either Major, Minor or Non-Aquifer, based on the dominant flow characteristics and resource potential of the rocks. The aquifer categories are subdivided on the basis of the overlying soil's leaching potential, which is classified as high (H), intermediate (I) and low (L) according to the properties affecting the downward passage of water and contaminants. Low permeability Drift is also mapped where it exceeds 5 m in thickness.

The four spatial data layers of the GWV maps were combined within the GIS and each input layer is ranked according to impact on groundwater vulnerability. The different combinations of aquifer, low permeability Drift and soil attributes were converted into a relative vulnerability scheme (i.e. ranking from highest to lowest) with each allocated a vulnerability index or score. The leaching layer (MAGPIE output) was also divided into vulnerability classes each with a vulnerability score. The two vulnerability scores were then weighted and combined.

To establish the high vulnerability threshold for the vulnerability model, which encompassed a large proportion of the monitoring sites with historical or predicted values above the 50 mg l^{-1} the variation of nitrate concentrations within the aquifer area was investigated. On the basis of these investigations, a high vulnerability threshold was set. A map (Fig. 15) was then produced to identify the areas in which groundwater vulnerability exceeded this threshold.

Defining groundwater NVZs

The map of the areas where nitrate levels in groundwater are high or expected to become high (Fig. 13) is overlain with the highly vulnerable areas of the vulnerability map (Fig. 15). The coincident areas were then extracted. A buffer was added to these resulting areas, extending either 707.1 m or to the edge of the high nitrate area (i.e. the areas identified in Fig 13), whichever is less. This buffer was intended to allow for uncertainties in the vulnerability map, i.e. to include areas that could have high vulnerability to nitrate leaching even though they are not included in the vulnerability map.

The resultant areas were those that have a high probability of exceeding the 50 mg l^{-1} threshold, that have a sufficiently dense monitoring network to give confidence in the estimates, and high groundwater vulnerability to nitrate leaching. All known areas of land draining into groundwaters which are affected by nitrate pollution, or which could become so affected, were therefore identified.

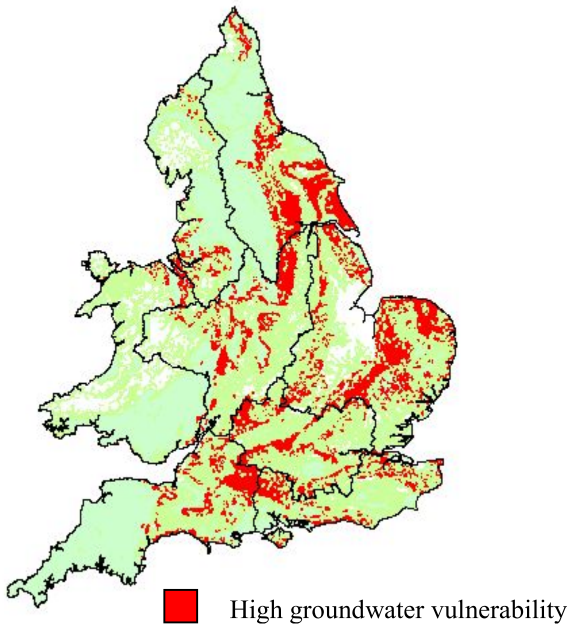


Fig. 15 Groundwater Vulnerability. Areas exceeding threshold in red.

Revising the groundwater monitoring network in England and Wales

The Environment Agency is responsible for monitoring the quality of groundwater in England and Wales to protect and manage groundwater resources effectively, to gain a better understanding of the impact of pressures on groundwater quality and to comply with domestic and European legislation and obligations, including the Nitrates Directive.

Although there is already a substantial groundwater monitoring network, recent changes in legislation has meant that the way we need to monitor groundwater needs to be improved. Any improvements must also take into account the information needs of other stakeholders. A new national framework has been developed that identifies the prioritised requirements for groundwater quality monitoring throughout England and Wales. This framework is summarised in Groundwater Quality: A Framework for Improved Monitoring (Environment Agency, 2002). The role and relationship of groundwater quality monitoring to other environmental monitoring, objectives and legislation is shown in Fig. 16.

In implementing the strategy, a groundwater monitoring network will be established that comprises approximately 3500-4000 monitoring sites across England and Wales. The network is being developed on the basis of identifying groundwater bodies, developing a conceptual model for each that includes a description of the geology and hydrogeology, existing knowledge of groundwater quality, information on land use and pressures, interactions between groundwater and surface water and aquatic ecosystems and resource potential. This information is being used to identify detailed monitoring requirements, such as the location, number and density of monitoring points, the chemical parameters to be measured and the frequency of measurement.

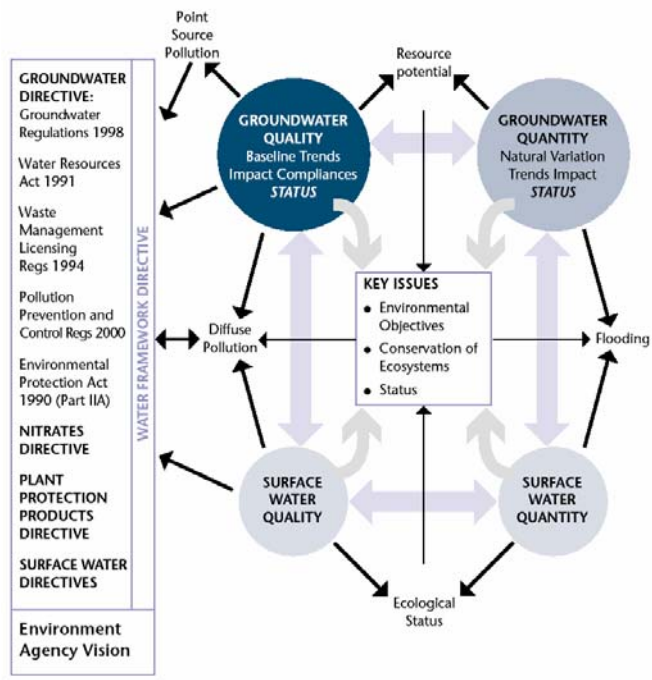


Fig. 16 Relationship of groundwater quality monitoring to other environmental monitoring, objectives and legislation.

Implementation of the strategy is building on the existing monitoring network and will lead to a much improved and optimised monitoring programme that can meet future needs, in particular the Water Framework Directive, and contribute to effectiveness monitoring for the Nitrates Directive.

<u>*Scotland*</u>

The Scottish Environment Protection Agency (SEPA) is responsible for monitoring groundwater in Scotland. The groundwater monitoring network was established in 2000 with 150 sites across Scotland. The sites were chosen using a biophysical framework based on the risk of contamination from various land use practices and on the ability of the soil to protect the groundwater (Lilly *et al.*, 1999). A total of 39 biophysical classes were identified which included highly and moderately permeable aquifers as well as the largely superficial aquifers in weakly permeable bedrock. Existing groundwater sources in each of these classes were then chosen to monitor. These sources include boreholes, shallow wells and springs from private, industrial and public water supplies.

When designating additional NVZs in Scotland in 2001 it became apparent that the original 150 sites were insufficient to monitor nitrate effectively. An additional 70 sites within the NVZ areas were identified by BGS (Ball & MacDonald, 2002). The sites were identified from BGS datasets and subjected to a rigorous assessment procedure to ensure that they were suitable for measuring groundwater in agricultural areas. Most of these sources are boreholes greater than 30 m deep and all have adequate wellhead protection to stop surface contamination. These 70 sites have been added to the SEPA monitoring network and have been monitored since early 2002. The location of these sites and the 150 original SEPA sites are shown in Fig. 17. All sites are sampled four times per year.

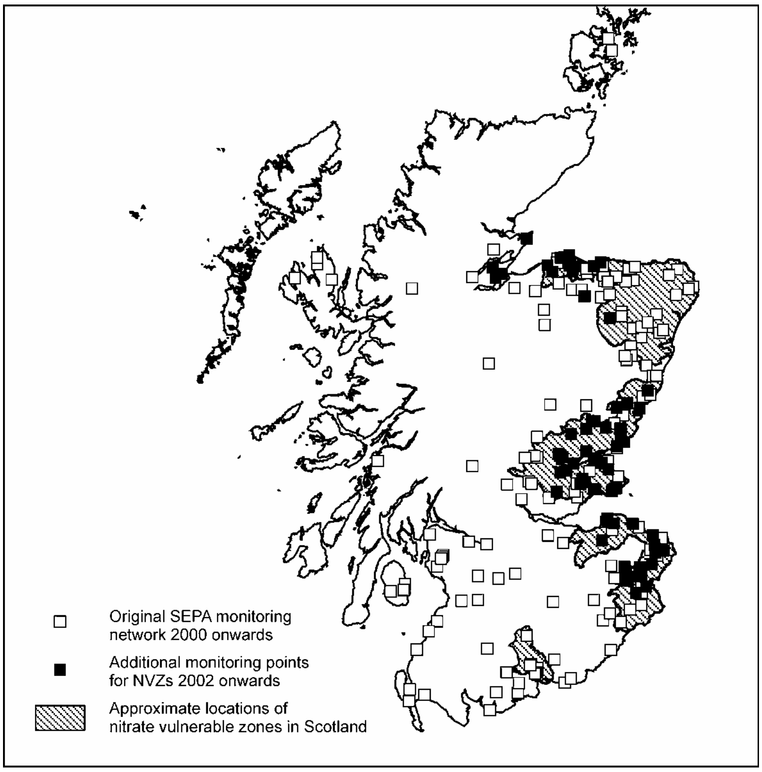


Fig. 17 Groundwater monitoring sites and NVZs for Scotland.

An approach for identifying additional nitrate vulnerable zones for Scotland was developed during 2001. Due to a lack of long term monitoring data for Scotland a combined risk and vulnerability approach was used (see Fig. 18). The approach is described in detail in Ball & MacDonald (2001). Digital solid and superficial geology data (at 1:50,000) for the country were interpreted to give an indication of aquifer vulnerability. This was combined with modelling information on the risk of nitrate leaching from crops and soils developed by the Macaulay Institute in Aberdeen (Lilly *et al.*, 2001). The final zones were then calculated by identifying local water catchments associated with areas of highest risk and vulnerability. The location of the NVZs are shown in Fig. 17. The groundwater NVZs encompass several smaller surface water zones.

The results of the vulnerability/risk analysis were consistent with the available nitrate data for much of Scotland. To aid designation several data sources were used: (1) the SEPA monitoring network; (2) additional monitoring sites identified by BGS; (3) water authority data; (4) data from BGS studies; and (5) private water supply data. Within the NVZs 25% of all sites (approximately 2000) exceed 50 mg l^{-1}. Throughout the rest of Scotland, where arable agriculture is rarely present, less than 5% of approximately 1000 sites exceed 50 mg l^{-1}. Two minor exceptions, where nitrate concentrations were high, but not identified using the risk/vulnerability methodology, are associated with intensive livestock rearing and dairy farms. These areas were designated on the basis of the data alone.

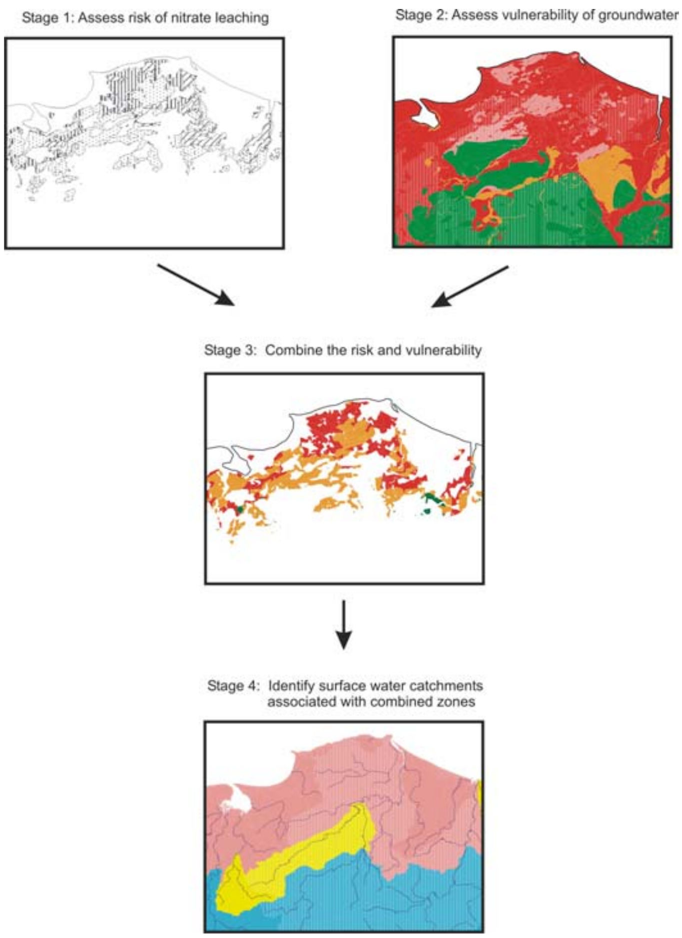


Fig. 18 A summary of the methodology used to identify groundwater NVZs in Scotland.

Northern Ireland

The Environment and Heritage Service (EHS) - an Agency within the Department of the Environment, Northern Ireland - have regulatory responsibility for the general management and protection of water resources in Northern Ireland. The EHS regional groundwater quality monitoring network was established in 2000 (Fig. 19). Currently 80 sources are monitored quarterly. Most of the sources are agricultural boreholes greater than 50 m deep although several shallower boreholes are also included. These boreholes were chosen from a much larger survey of 759 boreholes undertaken by BGS in the early 1990s (Robins *et al.*, 1994). The monitoring boreholes were selected for their isolation from obvious point sources of contamination, good access and aerial distribution. Additional monitoring is also carried out within designated groundwater NVZs.

Following a review of available monitoring data in Northern Ireland, three NVZs, one located at Clogh Mills, County Antrim and two near Comber, County Down, were designated in Northern Ireland (NI) in 1999. All three NVZs were created based upon nitrate exceedences in groundwater. The "soft" boundaries of the NVZs were identified as groundwater catchments, derived using a groundwater modelling package (Flowpath). Analysis of data from the monitoring network established in 2000, supplemented by further hydrogeological investigation has resulted in four new groundwater NVZs being designated for Northern Ireland in June 2003. These are located at Knockcloghrim and Kilrea, County Londonderry, Whitehead, County Antrim and Dromara, and County Down. Within the designated NVZs, key abstraction boreholes are monitored on a monthly basis. The locations of the NVZs are shown in Fig. 19.

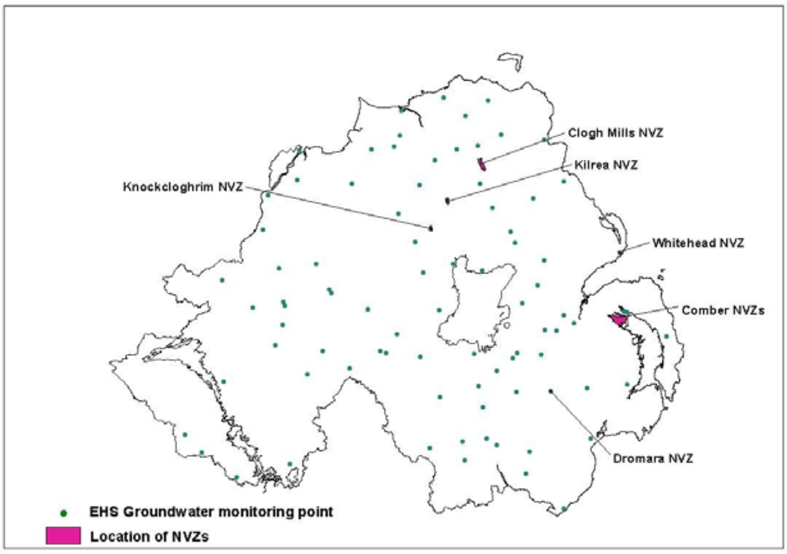


Fig. 19 The location of groundwater sites in Northern Ireland, monitored since 2000. The locations of the current NVZs are also shown.

Monitoring of eutrophication

In England and Wales, the Environment Agency undertake a *basic screening* programme of all waters, using GQA (see Fig. 9) and other water quality monitoring points. Any observations of undesirable disturbances, for example exceptional nuisance algal blooms or excessive macro-algal growth, are recorded. Chlorophyll-*a* analysis is also undertaken.

For waters where algal blooms or excessive macro-algal growth is significant, more detailed *purposeful monitoring* is also undertaken. This includes sampling the waters from boats, jetties, marinas, headlands or bridges as appropriate, together with remote sensing data. Nutrient budget modelling is undertaken to assess the relative contribution of agriculture to the pollution. Winter and summer nutrient concentration data are recorded. Reports of further undesirable disturbances attributable to algal blooms are investigated and recorded.

For waters where macro-algal growth is significant, summer monitoring is undertaken for excessive macro-algal growth. False colour aerial surveys and other observations are used to give quantitative information on percentage cover. Winter nutrient concentrations are recorded and modelling is used to provide supporting evidence.

Parameters which are measured include nitrogen, chlorophyll-*a*, algal biomass, dissolved oxygen, benthic biomass, fish species composition, macrofauna, microfauna, extensions of natural area and duration of paralytic shellfish poisoning.

Monitoring of eutrophication in Northern Ireland is carried out by the Environment and Heritage Service through routine GQA and marine monitoring programmes. Parameters measured are similar to those monitored by England and Wales.

1.3.2 Monitoring to assess the effectiveness of the Action Programme measures

Nitrate Vulnerable Zone designations have just recently been extended across the whole of the UK during 2002 and early 2003. As a result, new comprehensive programmes of effectiveness monitoring are currently in the first stages of development. A vision of such a strategy is presented in the section below. The UK does have experience of some types of effectiveness monitoring. Some of the following are described in more detail in chapter 2 below:

- existing surveys of agricultural practices in the UK;
- baseline surveys of good agricultural practices and implications for nitrate loss in NVZ areas;
- monitoring nitrate losses from agriculture on freely draining soils – experience from porous pot monitoring in Nitrate Sensitive Areas since the early 1990s;
- catchment monitoring projects on clay soils;
- MEASURES project;
- MAGPIE – modelling nitrate losses from agricultural land;
- repeated measurements of nitrate depth profiles through the unsaturated zone (Foster *et al.*, 1986);
- using residence time indicators to identify trends in groundwater quality.

1.4 Environmental goals

National environmental goals with respect to nitrate and eutrophication are focused on meeting the requirements of the Nitrates Directive and other European legislation (i.e. the 50 mg l^{-1} nitrate limit and the trophic status of the water body). The use of these targets in the UK is largely a consequence of our decision to pursue targeted approach of designating specific NVZs, as this approach focuses our attention on the end quality of our water rather than the loss pathways. If we had pursued the whole territory approach it is likely that different environmental targets would have been set.

The details of how nitrate concentrations are measured spatially and temporally in England under the Nitrates Directive are described in the Defra NVZ designation methodology document http://www.defra.gov.uk/environment/water/quality/nitrate/method.htm. (Defra, 2002a). The principles are very similar for the rest of the UK.

In the future these targets will be built into UK implementation of the Water Framework Directive.

As our effectiveness monitoring programmes develop and we begin to see the impact of the new NVZ areas designated in 2002 and 2003, we may be able to set different environmental targets in the future (i.e. reduce nitrate leaching by 50%).

2. EFFECT MONITORING

2.1 Action Programme measures and derogation

The Nitrates Directive requires that a set of rules is put in place in NVZs to reduce existing nitrate pollution from agricultural land and to prevent further pollution from arising. A common set of Action Programme measures are followed in England, Wales and Northern Ireland (Defra, 2002) but there are small differences in the Action Programme measures defined for Scotland (SERAD, 2003).

There are both farm and field limits to the loading of organic manure nitrogen permitted within NVZs. The limits are those prescribed in the Directive except for grassland where a derogation for a higher limit of 250 kg ha^{-1} of total nitrogen has been assumed. This derogation has not yet been agreed with the European Commission. There are autumn closed periods for the application of manures with a high available nitrogen content (i.e. slurries and poultry manures) on sandy and shallow soils.

The principle rule for nitrogen fertiliser is to avoid exceeding the crop requirement for nitrogen having taken account of the supply of nitrogen from the soil, crop residues and organic manures. Closed periods are defined during which nitrogen fertilisers must not be applied.

There are spreading controls for both nitrogen fertilisers and organic manures. These must not be applied to steeply sloping field or when the soil is waterlogged, flooded, frozen hard or snow covered. Organic manures must not be applied within 10 m of water courses.

There must be sufficient storage capacity for slurry to meet the autumn closed period. Any new or modified stores must comply with existing national legislation.

The farmer must keep adequate farm and field records to demonstrate compliance with the rules for a period of at least five years. The records must available for inspection by Environment Agency staff who are responsible for enforcing the legislation.

Support programmes including workshops and free advisory visits are available to assist farmers understand and comply with the rules. In England and Scotland grant aid of 40% is available for farmers who need to construct or upgrade their manure handling and storage facilities to meet the requirements of the Action Programme measures.

2.2 Strategy for effect monitoring

The Nitrates Directive requires Member States to review and if necessary revise their Action Programme measures. The Commission has provided guidelines for the monitoring required to assist Member States in reviewing the effectiveness of their Action Programme measures (often referred to as "Effect Monitoring").

Now that new NVZs have been designated across the UK, we are beginning to develop our effect monitoring strategy for these new areas. The strategies will be separate, but co-ordinated, across England, Wales, Scotland and Northern Ireland. Effect monitoring is already underway in England, whilst Wales, Scotland and Northern Ireland are developing similar strategies in relation to their own territories. Figure 20 illustrates in general terms the key elements of effect monitoring in the UK.

Overview of approach to effect monitoring in England

Modelling is at the heart of our effect monitoring strategy. Only modelling can deal with the scale of national NVZs and provide historic, current and future assessments, taking account of the key issues of time lags, annual variations in weather and non-NVZ driven land management changes.

Other components of our strategy explicitly support the modelling – namely, to provide input data and validation of the models.
1) The input land management data is collected from existing agricultural surveys. Such surveys are repeated over time and provide useful information about changes in farm practice.
2) The water quality monitoring networks, as used for the identification of NVZs, do not pick up small variations in river quality on a very local scale and are susceptible to considerable lag times due to the distance between source and the point of sampling. Therefore, this identification network has been supplemented by study micro-catchments, which are located to cover the geographic range of NVZs and target the key manure related aspects of the Action Programme, especially those that are known to be poorly modelled. The field and catchment measurements provide confidence in, and validation of, the model outputs.

On farm validation is based on study micro-catchments, in surface water, groundwater and eutrophic NVZs, that are representative of the main types of agriculture, soils and climatic regions. Measurements focus upon N loss from the “agricultural zone”, generally the top 1 metre of soil. This has the advantage of acting as an “early warning” of nitrate loss before reaching watercourses. Also, measurements at this point are more sensitive to changes in management practices, so that a more accurate assessment of Action Programme measures can be made.

The selected micro-catchments do not demonstrate unequivocal trends in N losses as it is not possible to monitor enough fields to give a statistically representative coverage of all management and environmental conditions; there is no baseline dataset; and site/year variation will be large. The approach is therefore to use farm practice survey data (covering a much greater area) to define changes in management. Appropriate field-scale models (e.g. NITCAT, MANNER) are used to calculate the resulting change in N flux, for a range of conditions. These predictions are tested against observations from the monitoring micro-catchments; and are scaled-up to macro-catchment, regional and national N loss calculation by using the MAGPIE GIS agri-environmental database (described in more detail below) linked to catchment-scale models (NEAP-N, EvenFlow). Time course of response, the agricultural change in the context of other N inputs, and potential impacts on eutrophication is then assessed. This is the approach recommended in the EC Reporting and Monitoring Guidelines.

The approach to field and catchment monitoring is dependent upon NVZ type and soil type. We use porous pots on appropriate soil-types in groundwater catchments and utilise some of the existing “NSA sites” (more detail provided below). We use different techniques in surface water catchments, specifically monitoring systems comprising flow monitors and water samplers that take into account the specific hydrological characteristics of each micro-catchment. Sampling for, and analysis of, autumn soil mineral N (as an indicator of potential N loss) in additional fields within the micro-catchments supports water sampling.

Effect monitoring can be resource intensive and so the UK makes maximum use of existing monitoring projects and catchment studies, and has designed its effect monitoring strategy to help meet wider objectives than just compliance with the Nitrates Directive e.g. links with Water Framework Directive, wider diffuse pollution issues, HARP monitoring, etcetera.

OVERVIEW VISION OF UK EFFECTIVENESS MONITORING STRATEGY

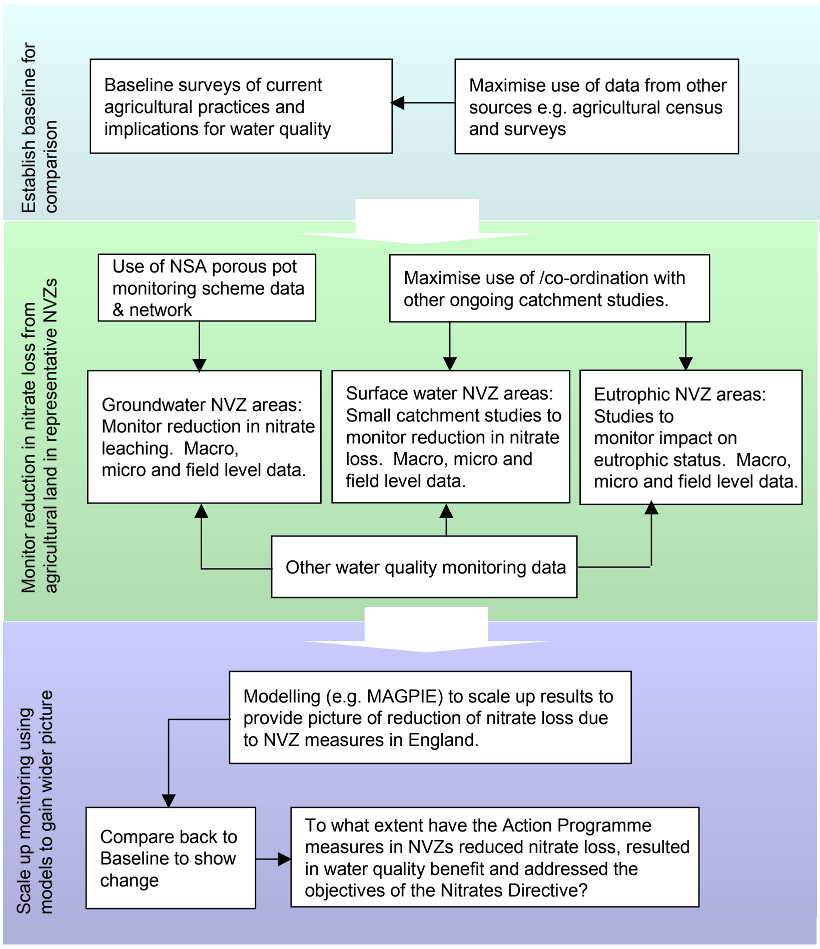


Fig. 20 An overview of effect monitoring in the UK.

2.3 Detailed technical description of networks used for effect monitoring

2.3.1 Baseline surveys of agricultural practice

These surveys can be repeated regularly to assess changes in agricultural practices as a result of Action Programme measures. They also act as important source of input data in support of the modelling.

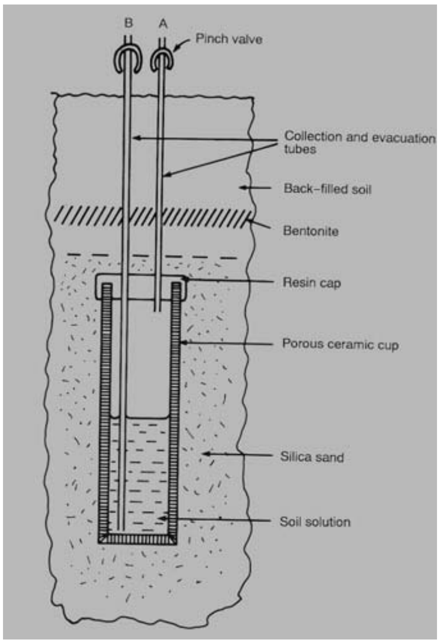
The surveys use a combination of existing sources of data, all of which are listed in the References section below, and new information. There are detailed data available about cropping and stocking rates from the annual *June agricultural census*. Information about inorganic fertiliser applications is available from the *British Survey of Fertiliser Practice*. Some further details about trends in manure applications and slurry storage are available from the *Farm Practices Survey*. In addition to these, we complete *questionnaires* for a representative sample of farms. These questionnaires ask NVZ-specific questions about livestock housing, manure storage, record keeping, planning fertiliser applications and details of all applications of manures and fertilisers to agricultural land on a field-by-field basis. Each of these sources of data involves its own sampling techniques. All this information is then scaled up and fed into the MAGPIE model to assess the likely impact on nitrate leaching and the resulting nitrate concentrations in waters.

Throughout this process we recognise that other factors may influence changes in agricultural practice, for example climate, economic conditions and market trends. It is also likely that many other factors influence changes in water quality. The MAGPIE model takes account of weather conditions but nevertheless we recognise that there is not always a direct cause and effect relationship between changes in agricultural practice and changes in water quality, and that trends can fluctuate over time for many reasons.

2.3.2 Porous pot monitoring

The porous pot is the most widely used UK method for measuring nitrate concentrations in light to medium textured soils typical of those over groundwaters – see Fig. 21. Soil water samples are taken from 90 cm depth (60 cm in some shallow limestone areas) using porous pots connected to the soil surface using capillary tubes. These tubes are used to apply a suction in the pots, which extract a sample of soil solution from the region of soil in contact with the buried ceramic pots. Typically, ten porous pots are installed per field site according to standard methods that do not restrict standard farming practice. The installed pots are used to collect samples of soil water leaving the base of the root zone at approximately fortnightly intervals from the return to soil field capacity in the autumn until the end of winter drainage the following spring. The total flux of nitrate from the root zone is calculated for each field from nitrate concentrations measured in the replicated soil water samples and estimates of drainage volume between sampling occasions predicted using a water balance model such as IRRIGUIDE. This is a field-scale model based on the UK Meteorological Office’s MORECS model version 2, but with greater flexibility in taking account of crop management, soil types, and local rainfall.

The integral of measured nitrate concentration against modelled drainage volume gives the estimated nitrate flux from the root zone. The impact on water quality at the point of abstraction (i.e. the borehole) may not be detected for many decades, depending on hydrogeological conditions, due to the time taken for the percolating water and nitrate to travel through the rock to the underlying aquifer, together with the mixing and dilution of the new percolating water with “older” water already present in the aquifer.



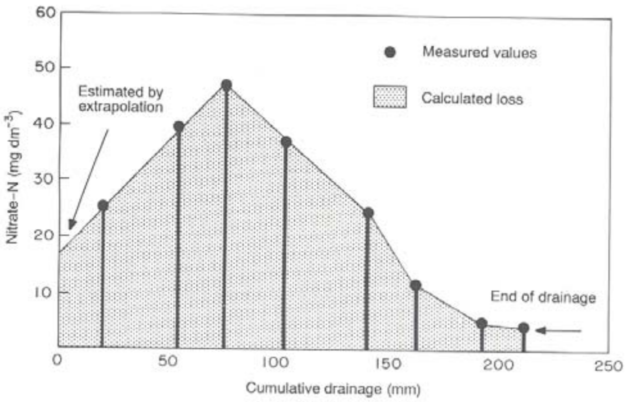


Fig. 21 Left: Schematic representation of a porous ceramic pot sampler and its installation to ensure good contact with the surrounding soil. Above: Calculation of N flux from measured N concentrations and modelled cumulative drainage, using the trapezoidal method.

Nitrate leaching from these soils, for a given site, year and system, is closely correlated with soil mineral nitrogen (SMN) in late autumn. The models used estimate soil nitrate as an input to the autumn crop offtake and leaching subroutines. Measurement of autumn SMN therefore provides a less absolute measure of nitrate leaching than use of porous cups, but can be used to reflect effects of management practice and site history on N a risk of leaching.

Previous experience of Porous pot monitoring in Nitrate Sensitive Areas

The Nitrate Sensitive Area (NSA) Scheme was an agri-environment scheme in 32 small areas where groundwater was highly vulnerable to continued nitrate leaching from agricultural land. The scheme was established after a pilot in 1992 and compensated farmers for significantly changing arable farming practices to help reduce nitrate leaching. Options included a spectrum of land use conversions from intensively-farmed arable to extensive permanent grassland and woodland. The Scheme was closed to new entrants in 1998 following the Government's Comprehensive Spending Review, but existing five-year agreements continued for their full term. The last land comes out of the NSA scheme in 2003 but all the areas are now located in NVZs. At its peak, the NSA scheme had 80% uptake. Further details of the scheme are available via http://www.defra.gov.uk/erdp/schemes/pre_erdp/nitrate.htm.

The environmental benefits of the NSA Scheme have been monitored on an annual basis under contract to Defra as follows:

- by collecting data on cropping and husbandry practices for each field and, using a computer model (MAGPIE, see below), estimating nitrate leaching losses;
- by measuring actual nitrate leaching from the soil zone from a representative sample of fields (by means of porous pots), and taking soil and water samples;
- by measuring nitrate levels in water pumped from the boreholes within the NSAs.

The impact of the NSA Scheme on nitrate concentrations in abstracted groundwater was not expected to be expressed for several decades because of the depth of the aquifers. Therefore best estimates of the changes in nitrate loss from the soil (90 cm depth) were sought as indicators of Scheme impact. For each arable crop, a “baseline” nitrate loss was defined based on experimental data. This value referred to a correctly fertilised crop followed by bare ground over winter, with sufficient winter rainfall to purge the soil profile. The value was then modified within the model to allow for variation in fertiliser input, yield, applications of fertiliser or livestock manures during the subsequent autumn and winter period, and date of establishment of cover crops and autumn-sown crops. Nitrates loss from non-agricultural land was set to 10 kg N ha^{-1}. For each field, the estimate of loss was adjusted for hydrologically effective rainfall (Lord *et al.,* 1999).

Nitrate leaching from the soil was also measured directly on a subset of fields. Within NSA, 10 or more fields were selected to represent the main types of land use. On each site, 10 porous ceramic cups were installed to 90 cm (less on some shallow limestone soils) in autumn 1990. Cups were left in place throughout the duration of the Scheme, the access tubes being buried prior to cultivations. Samples were taken about every two weeks during the winter months. The total quantity of nitrate lost was calculated as the integral of concentration and hydrologically effective rainfall *(ibid.)*.

The monitoring programme has demonstrated that the changes from previous agricultural practice made under the scheme have been successful in reducing nitrate leaching losses. Average groundwater nitrate concentrations have declined. However this is not all attributable to the NSA measures alone – fluctuating groundwater levels play an important role in changing nitrate concentrations.

2.3.3 Surface water monitoring

A different approach to porous pots has to be used for monitoring water quality in surface water catchments. Data on both chemical monitoring and flow monitoring needs to be collected. Whilst nitrate leaching (concentrations) can be monitored for numerous fields, flow monitoring is limited by the availability of a suitable drain or ditch for weir/flume location. It is likely that monitored flow will reflect the drainage from several fields. At the flow monitoring location, nitrate concentrations can also be measured.

Experience has shown that the number of monitoring positions required to characterise surface water draining from a particular micro-catchment varies considerably depending on the configuration of the underdrainage systems, complexity of aspect (underlying slope), distribution of the drainage outfalls and origin/outlet of the receiving waters. The particular configuration of the monitoring station will also depend on these and other factors including catchment area of land represented.

However, it is considered that each catchment will require, on average, 5 monitoring positions - 2 ditch/stream stations at the inflow and outflow of the catchment, and up to 3 stations characterising individual fields/groups of fields. The latter are located at either drainage outfalls, or in the receiving ditch/stream depending on local conditions.

In order to provide data on nitrate loading (flux) as well as concentrations, monitoring stations need to contain both flow recording and water quality instrumentation. The actual techniques used are best established following site identification and subsequent survey, but should be based on a combination of the following range of solutions:

Flow recording:

- A weir or flume system pre-calibrated to relate water level flowing through the instrument to derive flow rate. This provides a high level of accuracy as the whole flow volume is measured.
- A simpler solid state velocity gauge which has lower capital/installation costs, but relies on accurate assessment of the channel cross sectional area to derive flow rates could be used but may require a fixed “control section” in irregular channels.

Determination of nitrate concentration:

- Programmable automatic water samplers with laboratory analysis. The samplers (e.g. ISCO Ltd) are controlled by the datalogger programme and can be configured to take samples proportional to the rate of stream/drainflow such that sampling frequency increases during events where solute transport is likely to be greatest.
- On line direct reading sensors (ion specific electrodes). Although use of the on-line method offers considerable capital and running cost savings over the water sampling approach, there are some drawbacks. These relate to the possibility of interference from other ionic compounds (most importantly, chloride), and the potential for the stability of output to “drift” over time.

2.3.4 MAGPIE: Modelling agricultural pollution and interactions with the environment

A national agri-environment database and nitrate modelling system has been developed (Lord, 1999; Lord & Anthony, 2000) to support the UK government’s nitrate policy. The framework consists of a database and models linked within a Geographical Information System and provides a user interface which allows detailed spatial and statistical investigation of the current state (data and model output) and the impact of changes in conditions or agricultural practice. Data on crops and livestock numbers taken from the annual agricultural census are modified in relation to land cover data derived from remote sensing and other sources. These data and data on climate, soils and altitude are interpolated to a 1-km grid as shown in Fig. 22. The models of nitrate loss are adapted to work with this data set whilst retaining as far as possible the salient features of the more detailed models and data from which they were derived. The resulting policy decision support system gives estimates of mean annual flow and nitrate load from agricultural catchments which closely match measured data (Lord & Anthony, 2000). Figure 7 is an example of the outputs that MAGPIE can produce.

2.3.5 Identifying trends in groundwater quality using residence time indicators

Understanding past and current trends in groundwater quality is fundamental to Nitrates Directive effectiveness monitoring and a wider range of legislative and environmental reasons. However, for many aquifers, the information required to identify trends is not available. Groundwater flow within the aquifer may be poorly understood and there may be no long term monitoring data of groundwater quality.

Where historical data are absent, groundwater residence time indicators can offer a simple method of identifying likely trends in groundwater quality. They can also help interpret nitrate data from monitoring boreholes where the samples are a mixture of different groundwaters. Since most changes in groundwater quality are attributable to anthropogenic pollution commencing in the 20th century, clearly shorter-term residence indicators are the most appropriate. There are several indicators available including ^3H (tritium), ^{36}Cl, ^{85}Kr, chlorofluorocarbons (CFCs) and SF_6 (sulphur hexafluoride).

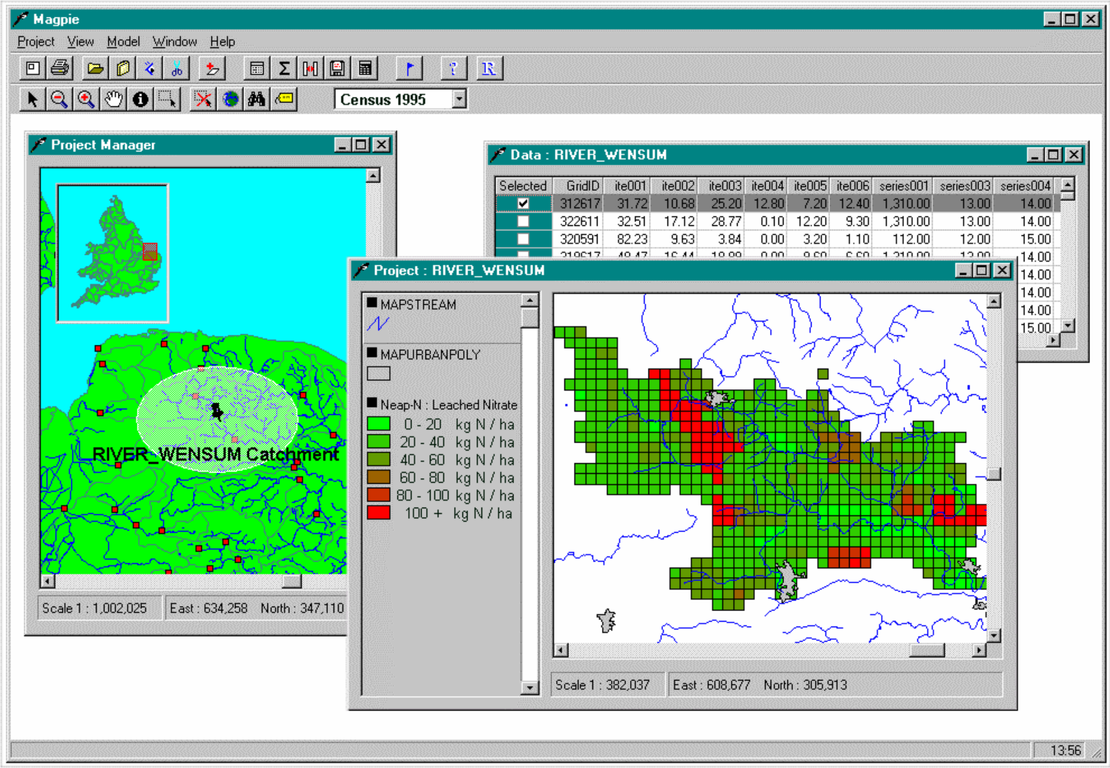


Fig. 22 The MAGPIE interface.

A combined groundwater residence time and chemistry study has been undertaken in the Permian aquifer of the Dumfries basin in Scotland. CFCs were used as an investigation tool. The study demonstrates how residence time indicators help to increase knowledge of likely nitrate trends and improve the conceptual model of groundwater flow in the aquifer (MacDonald *et al.,* 2003).

In the Scottish study *(ibid.)*, time indicators showed the proportions of old (more than 50 years) and modern water resident in the aquifer. There was a significant correlation between nitrate concentration and the proportion of modern water in the sample as shown in Fig. 23. This can be used to calculate the nitrate concentration of current recharge water and to predict how groundwater concentrations may change in the future if current agricultural practices continue.

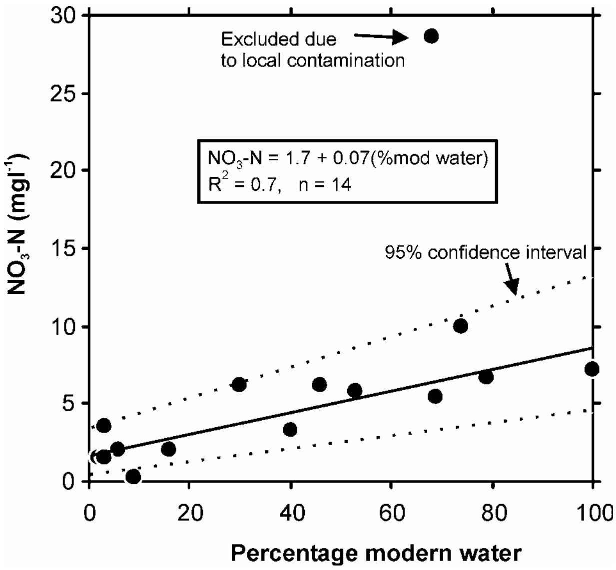


Fig. 23 The relation between nitrate concentrations and the percentage of modern water in each sample. Modern groundwater in the basin is recharge with average concentrations of 9 mg l^{-1} NO_3-N (40 mg l^{-1} NO_3).

3. DISCUSSION

One particular issue that the UK is acutely aware of is the need to develop accurate models of nitrate loss from agriculture and the impact on water quality to interpolate in between water quality monitoring sites. A monitoring network can never be entirely comprehensive, particularly at the local level – the impact of results from a monitoring network are highly dependent on the precise location chosen for each monitoring point.

With the recent extension of NVZs in the UK, designations now cover large areas of clay soils for the protection of surface waters. In the UK, agricultural clay soils are drained using draining or ditch systems, or by direct surface water runoff into streams. Within such surface water catchments, much of the winter flow reaches the river within a few days – it travels laterally within the soil to ditches. During periods of high flow the water does not equilibrate fully with nitrate already in the soil matrix and river nitrate concentrations tend to be diluted relative to those during low-flow periods. Therefore changes in nitrate loss as a result of Action Programme measures are very difficult to discern against substantial background "noise" due to fluctuations in river nitrate concentrations.

Another important issue when setting up the effect monitoring network and interpreting the results, is the consideration of other influences on nitrate concentrations and how these vary over time e.g. natural fluctuations from year to year in rainfall, changes in the economic conditions of agriculture, other sources of nitrate in the catchment. These factors can be accounted for by the models to some extent, but there may be some changes to nitrate loss figures which cannot be accounted for.

The UK is under pressure to integrate Nitrates Directive effect monitoring with other monitoring requirements, in particular looking towards the future and the Water Framework Directive (WFD). We need to consider how to integrate with the WFD and how to monitor a range of pollutants other than just nitrate through the same/adapted monitoring network.

It is difficult to determine whether the source of the nitrate is agricultural or non-agricultural (i.e. industry, sewage treatment works). If the inputs of nitrate are predominantly non-agricultural in a catchment, then it is unlikely that the Action Programme measures will have a substantial effect on the nitrate concentration – subsequent tightening of the Action Programme measures to try and reduce nitrate losses in these catchments would be ineffectual and unnecessarily burdensome to farmers. The UK needs to consider how it is to assess the contribution of agriculture to the measured nitrate concentrations –by modelling the expected contributions, by additional monitoring upstream from any point discharges, or by measuring N-isotopes, etcetera.

The lag time between changes in agricultural practice and changes in water quality is often substantial, especially in the case of groundwaters. To accurately assess the effectiveness of the Action Programme measures it is necessary to account for this lag time, and if possible estimate the expected effect of the Action Programme measures. The UK needs to consider the use of models and techniques such as CFC analysis described above to measure and account for the lag time.

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APPENDIX 1: LIST OF WORKSHOP PARTICIPANTS

Overview

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Belgium	Arnaud	Dewez	Nitrate Association of Wallonia (NITRAWAL)
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Belgium	Ralf	Eppinger	Ministry of the Flemish Community - Water Division
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Belgium	Christop he	Vandenberghe	University of Gembloux, Faculty of Agriculture, Laboratory of Soil Science
Czech Rep.	Pavel	Rosendorf	T.G. Masaryk Water Research Institute
Denmark	Ruth	Grant	National Environmental Research Institute
Denmark	Uffe	Jørgensen	Danish Institute of Agricultural Sciences
Denmark	Jens	Stockmarr	Geological Survey of Denmark and Greenland
Germany	Horst	Gömann	Research Association for Agricultural Policy and Agricultural Sociology
Germany	Hubertus	Schültken	Lower Saxony State Agency for Ecology
Germany	Rüdiger	Wolter	The Federal Environmental Agency
Ireland	Pat	Duggan	Department of the environment and Local Government
Ireland	Micheál	Mac Cárthaigh	Environmental Protection Agency
Poland	Jan	Mitręga	Polish Geological Institute
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Sweden	Holger	Johnsson	Swedish University of griculutral Science - Division of Water Quality Management
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The Netherlands	Leo	Boumans	National Institute for Public Health and the Environment
The Netherlands	Dico	Fraters	National Institute for Public Health and the Environment
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United Kingdom	Simon	Gardner	Environmental Agency
United Kingdom	Mark	Hallard	Scottish Environment Protection Agency
United Kingdom	Alan	MacDonald	British Geological Survey
United Kingdom	Orla	Ruddle	Department of Environment for Northern Ireland, Environment and Heritage Service
United Kingdom	Rob	Ward	National Groundwater and Contaminated Land Center

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APPENDIX 2: WORKSHOP PROGRAMME

MonNO$_3$ Workshop, The Hague (Scheveningen), 11-12 June 2003
Programme for the period 10-13 June 2003

Tuesday, 10 June 2003

14.00-17.00	Check-in of participants at the Bilderberg Europe Hotel, Scheveningen
15.00-17.00	Meeting of Organising Committee, Workshop Chairman, and Discussion Leaders
17.00-18.00	Welcome at the Europe Bar
18.00-20.00	Welcome dinner

Wednesday, 11 June 2003 (plenary, session A, B, C and D)

07.00-08.30	Breakfast
08.15-08.30	Meeting of session A presenters (DK & UK)
08.30-09.15	Opening session: - welcome on behalf of RIVM (NL) - welcome on behalf of GEUS (DK) - Scope and objectives of workshop (RIVM)
09.15-10.30	Plenary session A *: DK (25 min); UK (40 min)
10.30-11.00	Coffee/tea break Meeting of session B presenters (Sweden, B/Flanders, B/Wallonia)
11.00-12.30	Plenary session B *: Sweden (25 min); B/Flanders (25 min); B/Wallonia (25 min)
12.30-14.00	Lunch
13.30-14.00	Meeting of session C presenters (Germany, Austria)
14.00-15.00	Plenary session C *: Germany (25 min); Austria (25 min)
15.00-15.30	Coffee/tea break Meeting of session D presenters (Ireland, NL)
15:30-16:30	Plenary session D *: Ireland (25 min); NL (25 min)
17:00-18:00	Plenary visit/discussion of posters (with drinks and snacks)
19:00-22:00	Barbecue at the 'Motta Beach Company'

***** *After each presentation there will be 5 minutes for questions*

Thursday, 12 June 2003 (combination of plenary and parallel)

07.00-08.30	Breakfast
08.45-09.00	General information
09.00-09.15	Plenary introduction for Discussion Session 1
09.15-10.30	Discussion Session 1 (parallel, 4 subgroups)
10.30-11.00	Coffee/tea break
11.00-12.30	Plenary part (evaluation, conclusions) of Discussion Session 1
12.30-14.00	Lunch
14.00-14.15	Plenary introduction for Discussion Session 2
14.15-15.30	Discussion Session 2 (parallel, 4 subgroups)
15.30-16.00	Coffee/tea break
16:00-17:00	Plenary part (evaluation, conclusions) of Discussion session 2
17:00-17:30	Closing session
18.00-20.00	Dinner

Friday, 13 June 2003

07.00-08.30	Breakfast
08.30-12.00	Check-out
09.00-11.00	Meeting of Organising Committee, Workshop Chairman, and Discussion Leaders