How to comply with the EU Nitrate Directive: Insights from data analysis and modelling

Jan Diels[1], Koen Van Overveld[1], Mia Tits[3], Davy Vandervelpen[3], Jan Vanderborght[1&4], Okke Batelaan[2], Luk Peeters[2], Philippe Van De Vreken[5], Jan Bries[3] en Hilde Vandendriessche[3]

[1] Afdeling Bodem- en Waterbeheer, Departement Aard- en Omgevingswetenschappen, K.U.Leuven
[2] Afdeling Geologie, Departement Aard- en Omgevingswetenschappen, K.U.Leuven
[3] Bodemkundige Dienst Van België, vzw
[4] Agrosphere Institute, Forschungszentrum Jülich, Duitsland
[5] LRD Divisie Ruimtelijke Informatieverwerking (SADL), Departement Aard- en Omgevings-wetenschappen, K.U.Leuven

Workshop 'Analysing Natural and Anthropogenic Influences on Groundwater Quality'
Leuven, 19 January 2010

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

Background

- 1991: European Nitrate Directive: Threshold 50 mg NO_3 L^{-1} in ground and surface water
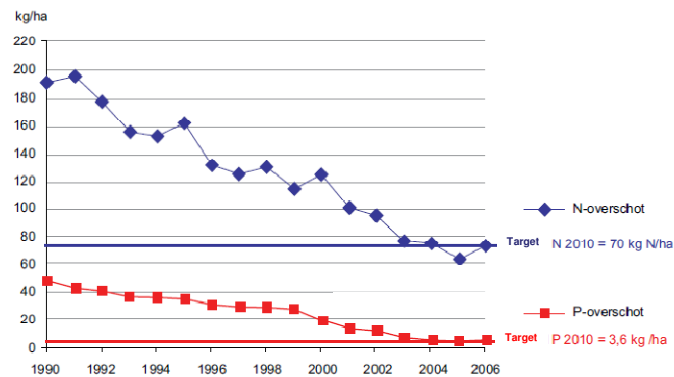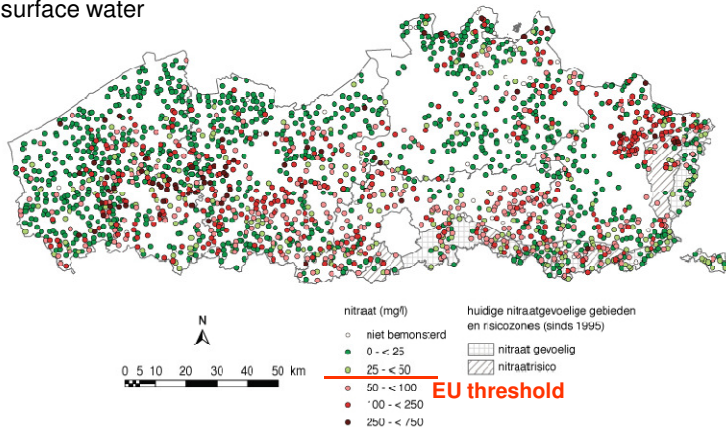

Evolution of N and P surplus on soil balance for Flanders
(Source: MIRA Achtergronddocument Vermesting)

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

2

1

Background

- 1991: European Nitrate Directive: Threshold 50 mg NO_3 L^{-1} in ground and surface water

nitraat (mg/l)
- niet bemonsterd
- 0 - < 25
- 25 - < 50
- 50 - < 100
- 100 - < 250
- 250 - < 750

EU threshold

huidige nitraatgevoelige gebieden en risicozones (sinds 1995)
- nitraat gevoelig
- nitraatrisico

NO3 concentrations in phreatic groundwater in Flanders during spring 2006
(source: VMM, MIRA-T 2006 Achtergronddocument Vermesting)

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

3

Background

- 1991: European Nitrate Directive: Threshold 50 mg NO_3 L^{-1} in ground and surface water

38.000 samples taken in groundwater by VMM since 2004
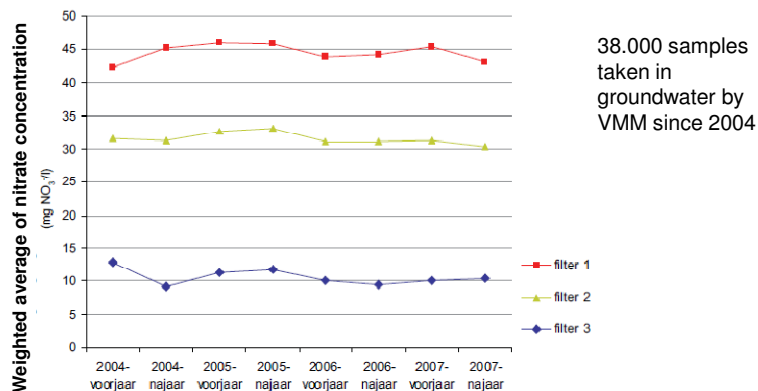
Evolution of average nitrate concentration in phreatic groundwater (MAP monitoring programme) (Source: VMM, Voortgangsrapport Mestbank 2008)
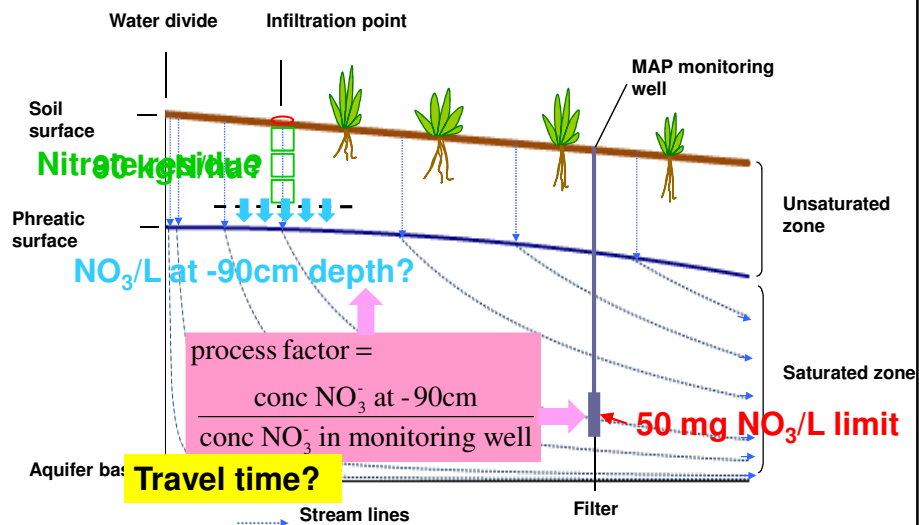
Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

4

Background

- 1991: European Nitrate Directive: Threshold 50 mg NO_3 L^{-1} in ground and surface water

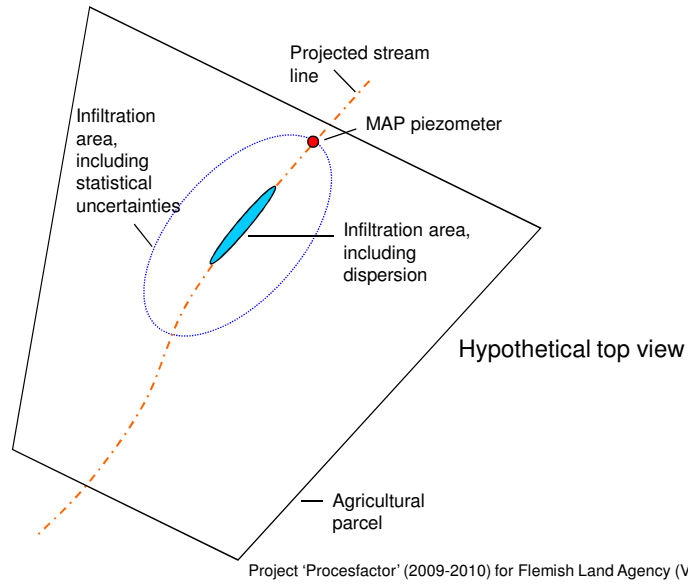- 1999 (MAP2): Introduction of nitrate residue limit of 90 kgN/ha in 0-90cm (1 October – 15 November)

Nitrate residue:
+/- 200.000 samples
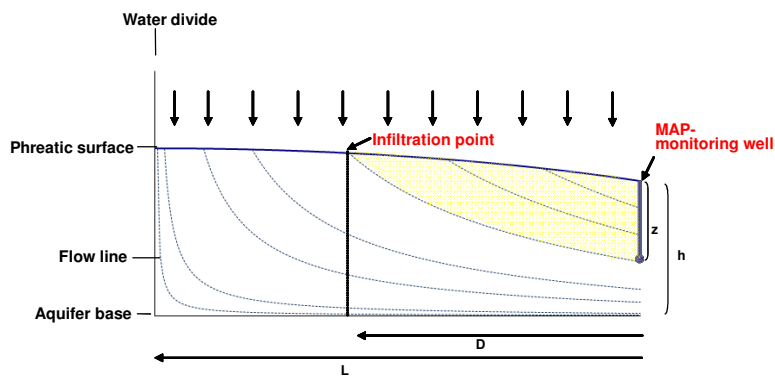taken since 2000

(Photo: Bodemkundige Dienst van België vzw)

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

5

"Process factor" approach ….

Water divide   Infiltration point

MAP monitoring well

Soil surface

Nitrate residue   90 kgN/ha

Unsaturated zone

Phreatic surface

NO_3/L at -90cm depth?

Saturated zone

process factor =

$$\frac{\text{conc } NO_3^- \text{ at } -90\text{cm}}{\text{conc } NO_3^- \text{ in monitoring well}}$$

50 mg NO_3/L limit

Aquifer base   **Travel time?**

Filter

········▸ Stream lines

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

6

3

Determination of capture zone (infiltration area) of MAP monitoring wells

Projected stream line

Infiltration area, including statistical uncertainties

MAP piezometer

Infiltration area, including dispersion

Hypothetical top view

Agricultural parcel

Project 'Procesfactor' (2009-2010) for Flemish Land Agency (VLM)

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

7

Identification of infiltration point of monitoring well

Water divide

Phreatic surface

Infiltration point

MAP-monitoring well

Flow line

z

h

Aquifer base

D

L

Position infiltration point: $D = \dfrac{z}{h} \cdot L$
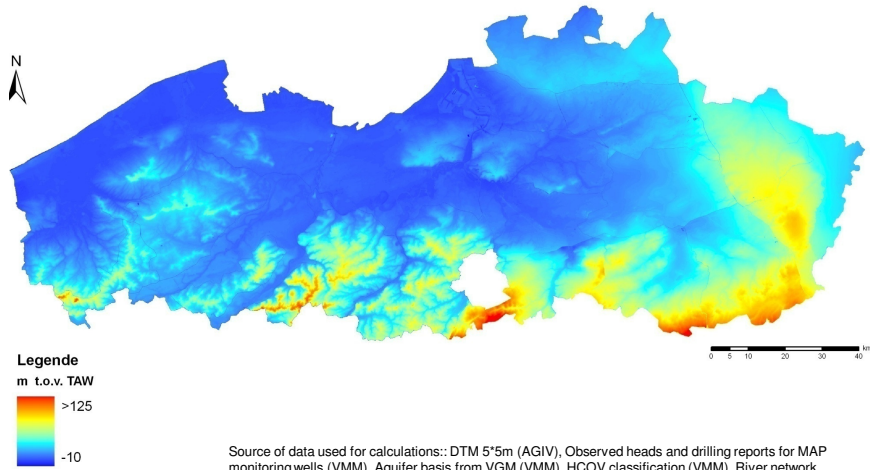
Infiltration zone derived from: flow line, depth of filter, depth of aquifer basis
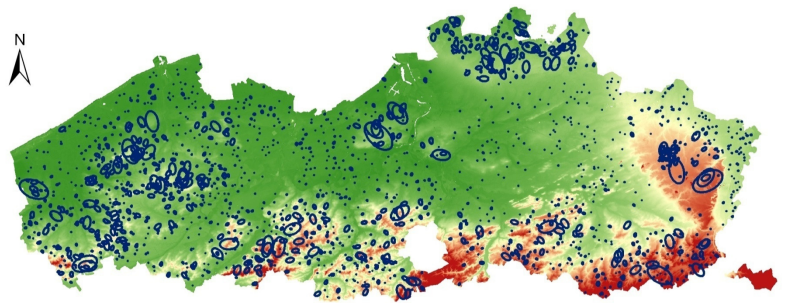
Water table map

Drilling report

VGM

Project 'Procesfactor' (2009-2010) for Flemish Land Agency (VLM)

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

8

Water table map obtained by Bayesian Data Fusion

N

Legende

m t.o.v. TAW

>125

-10

0 5 10 20 30 40 km

Source of data used for calculations:: DTM 5*5m (AGIV), Observed heads and drilling reports for MAP monitoring wells (VMM), Aquifer basis from VGM (VMM), HCOV classification (VMM), River network from VHA (VMM), Groundwater recharge from WETSPASS (VMM)
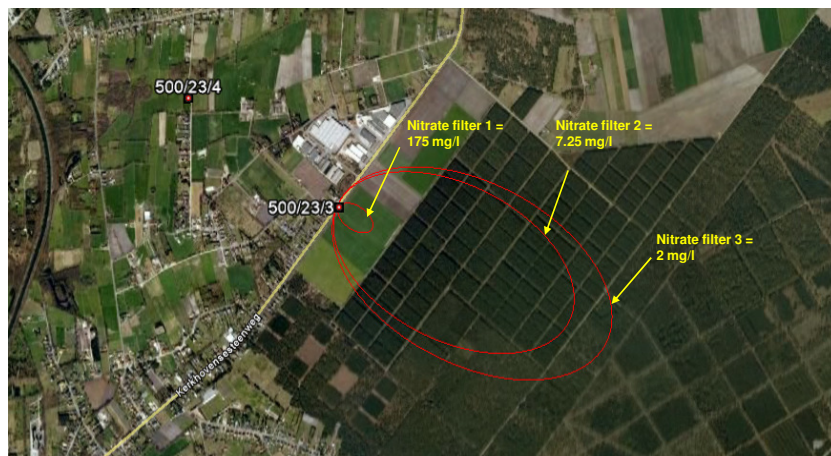
Project 'Procesfactor' (2009-2010) for Flemish Land Agency (VLM)

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

9

Delineation of capture zones of MAP monitoring wells

N

Source of data used for calculations: DTM 5*5m (AGIV), Observed heads and drilling reports for MAP monitoring wells (VMM), Aquifer basis from VGM (VMM), HCOV classification (VMM), River network from VHA (VMM), Groundwater recharge from WETSPASS (VMM)
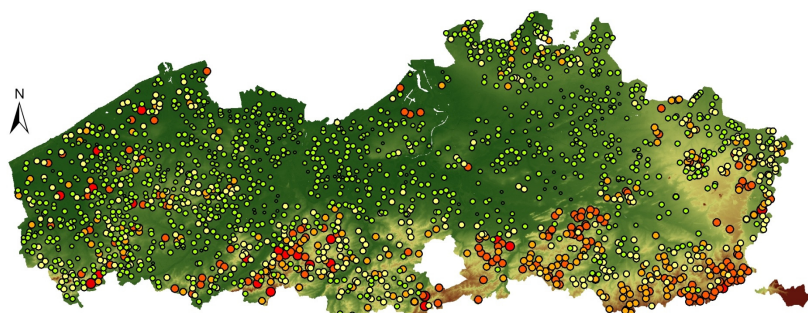
0 5 10 20 30 40 km

Project 'Procesfactor' (2009-2010) for Flemish Land Agency (VLM)

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

10
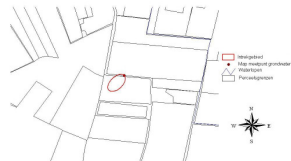
How to validate the procedure?

Kerkhoven near Leopoldsburg (HHZ 23)

Groundwater age (=travel time from surface to filter)

Legende
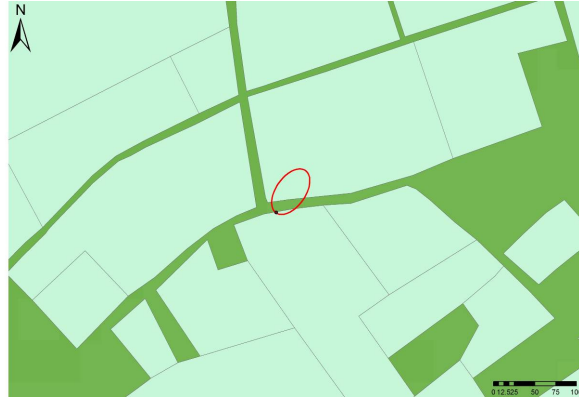**MAP meetpunten grondwater**
Leeftijd water in filter 1

0 - 1		11 - 20
1 - 2		21 - 50
3 - 5		51 - 100
6 - 10		101 - 200

Source of data used for calculations:: DTM 5*5m (AGIV), Observed heads and drilling reports for MAP monitoring wells (VMM), Aquifer basis from VGM (VMM), HCOV classification (VMM), River network from VHA (VMM), Groundwater recharge from WETSPASS (VMM)
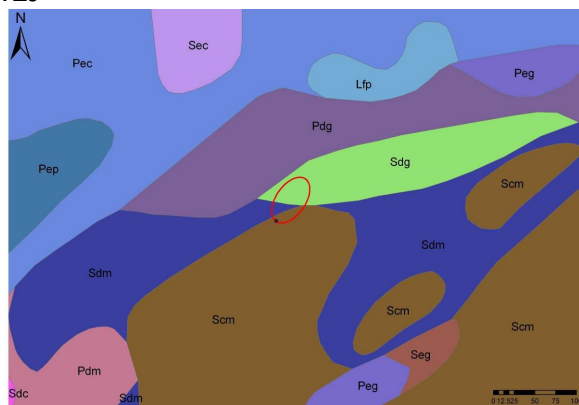
Data base on agricultural fields and 'Mestbank' data from Flemish Land Agency provide information on nitrate residue before winter

- Nitrate residue (0-30, 30-60 and 60-90) is either measured or estimated for each field in capture zone (ellips)

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

13

Soil (and sub-soil) hydaulic properties:

- Soil map (1:20,000) in combination with soil profile database 'Aardewerk' and drilling report provides information on soil profile, texture, %C.

- Estimation hydraulic properties with pedotransfer function Weynants *et al.*, 2009, VZJ

Bodemkundige Dienst van België vzw

DEPARTEMENT
AARD- EN OMGEVINGSWETENSCHAPPEN
K.U.LEUVEN

JÜLICH
FORSCHUNGSZENTRUM

14

7

Calculation of moisture profile under steady state vertical flow during winter (integral form of Darcy equation)

Soil surface

Phreatic surface
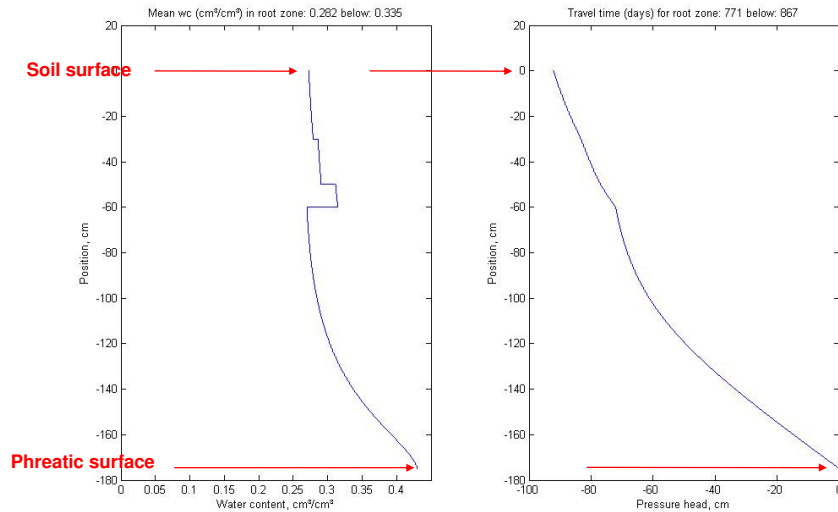
Calculation of average nitrate concentration at -90cm

- Analytical solution (Toride *et al.*, 1993) of convection-dispersion equation (Initial value problem)
- Concentration C(I) is integrated over rainfall excess I
- Calculated for each polygon within capture zone

$$\overline{C_{f,-90\,cm}} = \frac{1}{I_{tot}} \int_0^{I_{tot}} C_{f,-90}(I; N_{0-30}, N_{30-60}, N_{60-90}, \theta, \lambda)\,dI$$
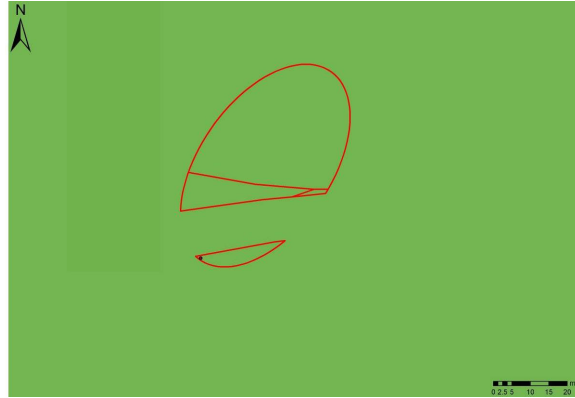
Rainfall excess

Nitrate residue

Soil water content

Dispersivity

Calculation of nitrate concentration at -90cm for each polygon within capture zone
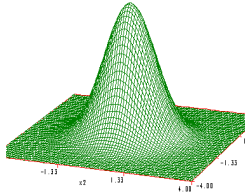
- Polygons differ in soil hydraulic properties and/or nitrate residue > estimated nitrate concentration also different

---

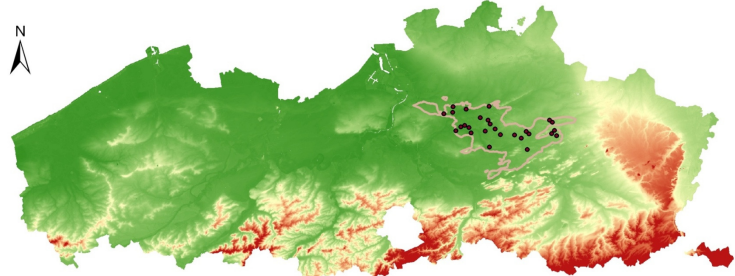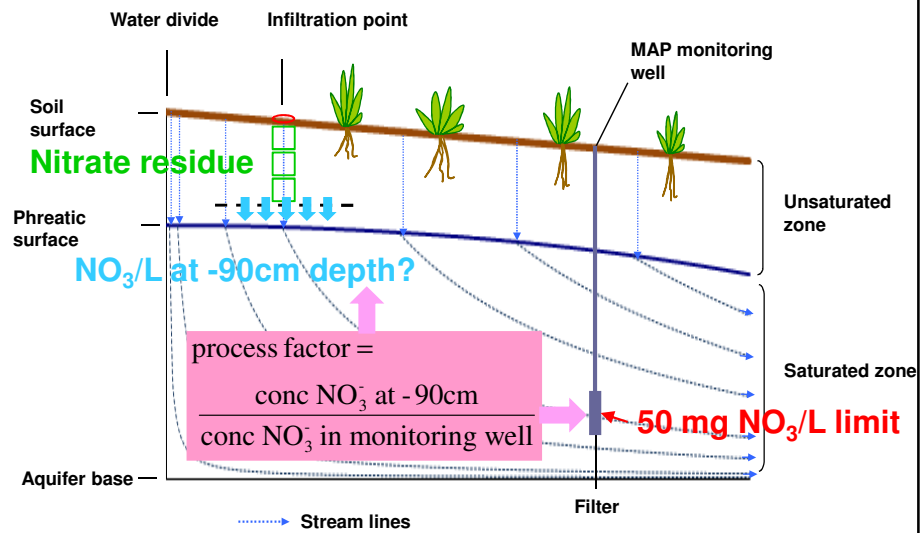## Weighted average concentration over capture zone (ellips)

$$E(\overline{C_f}) = \frac{\iint\limits_{S} \overline{C}_f(x,y)\,f(x,y)\,dxdy}{\iint\limits_{S} f(x,y)\,dxdy} = \frac{\iint\limits_{S} \overline{C}_f(x,y)\,f(x,y)\,dxdy}{0.75}$$

Integration over ellips S

"Process factor" approach ....

Water divide   Infiltration point

MAP monitoring well

Soil surface

Nitrate residue

Phreatic surface

NO_3/L at -90cm depth?

Unsaturated zone

$$process\ factor = \frac{conc\ NO_3^-\ at\ -90cm}{conc\ NO_3^-\ in\ monitoring\ well}$$

Saturated zone

50 mg NO_3/L limit

Aquifer base

Filter

Stream lines

19

$$process\ factor = \frac{conc\ NO_3^-\ at\ -90cm}{conc\ NO_3^-\ in\ monitoring\ well}$$

20

process factor =

$$\frac{\text{conc } NO_3^- \text{ at } -90cm}{\text{conc } NO_3^- \text{ in monitoring well}}$$

Next …

- Testing of analytical steady-state approach vs numerical model
- Calculations for monitoring wells in 9 HHZ zones across Flanders
- Statistical analysis

- Also calculation of process factor for surface water + WEKU modelling (Jülich)

Legende

geselecteerd afstroomgebied

rivierbekken