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Indicative measurements for the registration procedure of plant protection products in The Netherlands

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De sediment eigenschappen droge bulkdichtheid, organische-stofgehalte en porositeit zijn als functie van de diepte gemeten in vijf sloten, die in akkerbouw- en tuinbouwgebieden verspreid over Nederland liggen. De sediment monsters werden gestoken met Perspex buizen (met een binnendiameter van 59 mm), waarna bovenliggend water voorzichtig werd afgezogen en de buizen werden ingevroren. Op een later tijdstip werden de kolommen met een lintzaag in vijf segmenten (0-1, 1-2, 2-3, 3-5 en 5-10 cm) gezaagd voor nadere analyse. De berekening van de bulkdichtheid en porositeit werd gecorrigeerd voor het uitzetten van water tijdens bevriezing. De bovenste cm van het sediment had een bulkdichtheid van 0.09 tot 0.40 g/ml, in de onderste 5-10 cm was dit 0.37 tot 0.66 g/ml. Voor de porositeit waren de getallen 0.71 tot 0.93 voor de bovenste cm en 0.75 tot 0.84 voor de onderste 5-10 cm, terwijl voor het organische-stofgehalte de getallen 8.9 tot 30.2% en 6.5 tot 22.6% waren voor de genoemde sedimentlagen. Deze waarden verschillen duidelijk van de gebruikte waarden voor sediment in de oppervlaktewater scenario's, die momenteel worden ontwikkeld voor de Nederlandse registratieprocedure voor gewasbeschermingsmiddelen (die zijn overgenomen van de EU-FOCUS scenario's).

The sediment properties dry bulk density, organic matter content and porosity were measured as function of depth in five ditches in areas with arable farming or horticulture across The Netherlands. Sediment sampling was done using Perspex cores (inner diameter 59 mm), removing overlaying water before freezing and sawing the cores into five segments (0-1, 1-2, 2-3, 3-5 and 5-10 cm) for further analysis. Calculation of bulk density and porosity was corrected for the expansion of water during freezing. The upper cm of sediment had a bulk density ranging from 0.09 to 0.40 g/ml, while for the lower 5-10 cm sediment the numbers were 0.37 to 0.66 g/ml. For the porosity the numbers ranged from 0.71 to 0.93 for the upper cm to 0.75 to 0.84 for the 5-10 cm segment and for the organic matter content they ranged from 8.9 to 30.2% to 6.5 to 22.6%. These properties differ considerably from the sediment properties in surface water scenarios that are currently developed for use in the Dutch registration procedure for plant protection products (which have been borrowed from the EU-FOCUS scenarios).

Keywords: sediment physical properties, watercourses in The Netherlands

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Preface

The research project, BO-20-002-012 'Sediment properties of Dutch ditches for use in registration in The Netherlands', was part of the BO-Agro-20-002 'Environment and Pesticides' research plan financed by The Ministry of Economic Affairs. Due to limited resources a preliminary study in a limited number of ditches could be conducted. This preliminary study intends to provide:

a. Improved technique to sample sediment in ditches (see Chapter 5);
b. Frequency distribution of sediment properties in The Netherlands, as a function of depth, space and season in a limited number of representative ditches, geographically distributed across The Netherlands.

In addition to the items mentioned above, this report also includes work from past research, that had not been made available publicly yet, but fitted well within the framework of this research project BO-20-002-012. This concerns Chapter 4 (Definitions of sediment properties and their calculation, including a correction for expansion of water during freezing) and the main part of Chapter 7 (Sediment properties of the experimental ditches of Alterra).

For the sake of simplicity the word 'pesticide' is used in the remainder of this report instead of 'plant protection product'.

Samenvatting

Het gedrag van gewasbeschermingsmiddelen in oppervlaktewater wordt beïnvloed door processen die zich in het onderliggend sediment afspelen. Daarom zijn de sedimenteigenschappen bulkdichtheid, organische-stofgehalte en porositeit van invloed op concentraties in het water. Concentraties in standaard 'realistisch ergste' situaties, i.e. oppervlaktewater scenario's, worden gebruikt om risico's voor het aquatisch ecosysteem te schatten als onderdeel van de registratieprocedure voor gewasbeschermingsmiddelen in Nederland. Daar er onvoldoende data beschikbaar waren over sedimenteigenschappen in Nederland, is een oriënterende studie uitgevoerd naar sedimenteigenschappen voor enkele representatieve waterlopen voor het Nederlands oppervlaktewater scenario voor akkerbouw en tuinbouw, behandeld door neerwaartse bespuiting.

De volgende criteria zijn gebruikt om de bemonsteringslocaties te kiezen:
- De waterloop is direct naast een akkerbouw- of tuinbouwperceel gelegen (geen grasland);
- De waterloop bevat het gehele jaar water, mogelijkerwijs door waterbeheersmaatregelen, zoals stuwen of pompen;
- De populatie waterlopen moet samenvallen met de waterlopen van het Nederlandse scenario voor de akkerbouw en tuinbouw, behandeld door neerwaartse bespuiting (Tiktak *et al.,* 2012);
- De minimale waterdiepte is 20 cm;
- Verschillende bodemsoorten en verschillende akkerbouw- of tuinbouwgewassen zijn aanwezig op de aangrenzende percelen en
- De waterlopen liggen verspreid over heel Nederland.

Er zijn vijf waterlopen geselecteerd, die voldeden aan bovenstaande criteria. Deze waren gelegen in de volgende drie belangrijkste bodemclusters: (i) zware klei, (ii) zavel en lichte klei en (iii) leemarm en zwak lemig zand. Uiteindelijk bleven de data van vier watergangen over en werden de data van één bemonsteringslocatie (MOL) uit de dataset verwijderd, omdat de waterloop niet meer voldeed aan de selectiecriteria: de waterloop stond praktisch droog en er groeide gras op de bodem.

In vergelijking tot voorgaande technieken van Alterra zijn er nu verbeterde bemonsteringstechnieken gebruikt. De bemonsteringsnauwkeurigheid is vergroot door het gebruik van wijdere monsterbuizen (interne diameter van 59 mm in plaats van 39 mm), het bevriezen van de monsters zonder kegelvorming aan de bovenkant en het opdelen van de kolommen in segmenten met een lintzaag in plaats van een beitel. De monsteranalyse is verbeterd door de monstervolumes te corrigeren voor het uitzetten van water tijdens bevriezing, waardoor de bulkdichtheid en porositeit niet worden onderschat. (Het organische-stofgehalte is een massafractie en wordt daardoor niet beïnvloed door bevriezing van de monsters.)

Omdat er maar vijf waterlopen bemonsterd zijn, geven onderstaande resultaten slechts een idee en kunnen deze uitkomsten daarom als indicatief worden beschouwd.

De vier geschikte, over Nederland verspreid liggende waterlopen bevatten sediment met een relatief lage bulkdichtheid en relatief hoog organische-stofgehalte en porositeit. Deze eigenschappen variëren relatief weinig met de diepte. De bovenste cm sediment van de vier waterlopen (excl. MOL) heeft een bulkdichtheid van 0.09 tot 0.40 g/ml, terwijl dit voor de onderste 5-10 cm 0.37 tot 0.66 g/ml is. Voor de porositeit lopen de waarden van 0.71 tot 0.93 voor de bovenste cm en van 0.75 tot 0.84 voor de onderste 5-10 cm, terwijl deze voor het organische-stofgehalte lopen van 8.9 tot 30.2% en 6.5 tot 22.6% (voor de gezamenlijke monsterrondes van juni/juli en september).

De gemeten sedimenteigenschappen bevestigen dat de bemonsteringsnauwkeurigheid en monsteranalyse voldoen, want (i) de standaardafwijkingen waren relatief klein, (ii) de slootvolgorde (wat betreft droge bulkdichtheid en organische-stofgehalte voor de bovenste cm) veranderde niet per seizoen en (iii) in de meeste gevallen nam de bulkdichtheid toe met de diepte en het organische-

stofgehalte af. Dit laatste is als verwacht op basis van lang jaarlijkse neerslag van waterplant resten bovenop het sediment en het feit dat de fasedichtheid van organische stof lager is dan die van minerale stof.

Gevolgen voor de aquatische risicobeoordeling in Nederland
De resultaten van deze studie laten zien dat sediment in geschikte, over Nederland verspreide waterlopen duidelijk losser is dan het sediment uit het akkerbouw en tuinbouw scenario dat wordt ontwikkeld, i.e. het sediment uit deze studie heeft een lagere bulkdichtheid, een hoger organische-stofgehalte en een hogere porositeit in de bovenste cm: 0.09-0.40 vs 0.80 g/ml, 10-30 vs 9% en 0.70-0.90 vs 0.60, respectievelijk. De verschillen met het slootscenario dat het Ctgb momenteel gebruikt zijn kleiner: 0.09-0.40 vs 0.08 g/ml voor bulkdichtheid, 10-30 vs 25% voor het organische-stofgehalte en 0.70-0.90 vs 0.82 voor de porositeit. Omdat sedimenteigenschappen de indringing van stoffen in het sediment in tegenovergestelde richting beïnvloeden, kunnen we niet bij voorbaat voorspellen welk effect de gemeten sedimenteigenschappen uit deze studie hebben op de blootstellingsconcentratie in het bovenliggend water van de Nederlandse scenario's. Daardoor kunnen we niet voorspellen of de Nederlandse scenario's leiden tot een over- of onderschatting van het risico voor het aquatisch ecosysteem. Een beperkte gevoeligheidsanalyse met het TOXSWA model zou kunnen worden uitgevoerd om dit vast te stellen.

Om de wetenschappelijke onderbouwing van de sediment parameterisatie in de toekomstige Nederlandse scenario's te verbeteren, bevelen wij aan om:
- Meer waterlopen dan de huidige vijf te bemonsteren uit het akkerbouw en tuinbouw scenario domein om een deugdelijke frequentieverdeling van de drie sedimenteigenschappen bulkdichtheid, organische-stofgehalte en porositeit op te stellen en
- Waterlopen uit het fruitbomen en laanbomen scenario domein te bemonsteren voor een frequentieverdeling van de drie sedimenteigenschappen, zodat het sediment uit het fruitbomen en laanbomen scenario dat nu ontwikkeld wordt deugdelijk geparameteriseerd kan worden.

Daarnaast bevelen wij aan om, voor een beperkt aantal stoffen, gemeten concentratieprofielen in sediment te vergelijken met door TOXSWA gesimuleerde profielen in situaties die relevant zijn voor de aquatische risicobeoordeling. Dit kan gebeuren door experimenten in bv. twee vereenvoudigde cosms met duidelijk verschillend sediment voor stoffen met lage afbraaksnelheden en duidelijk verschillende sorptiecapaciteiten. Dit is nog niet gebeurd, terwijl het wel belangrijk is om vertrouwen te kweken in het TOXSWA model door het uitvoeren en publiceren van validatiestudies.

Tot slot is het belangrijk om zich te realiseren dat blootstellingsconcentraties in het water niet los staan van blootstellingsconcentraties in het sediment: een hoge blootstelling in het water gaat vaak gepaard met een lage blootstelling in het sediment. Daardoor kan een hoog risico in het water gepaard gaan met een laag risico in het sediment. Daar de EFSA momenteel een richtsnoer ontwikkelt voor risicobeoordeling van sediment-bewonende organismen, is het gebruik van realistische sedimenteigenschappen ook daar van belang.

Summary

The fate of plant protection products in surface water is affected by processes in its underlying sediment. So, the sediment properties bulk density, organic matter content and porosity are relevant for concentrations in water. Concentrations in standard 'realistic worst-case' situations, i.e. surface water scenarios, are used to assess the risk for the aquatic ecosystem as part of the registration procedure for plant protection products in The Netherlands. As insufficient data on sediment properties were available for The Netherlands, an introductory study was undertaken towards sediment properties of ditches, representative for the Dutch surface water scenario for arable farming and horticulture, treated by downward spraying.

Criteria for selection of sample sites were:

- The watercourse is located immediately adjacent to a field with arable farming or horticulture (not grassland);
- The watercourse carries water all the year round, possibly by water management measures, such as a weir or pumping;
- The population of watercourses should coincide with the watercourses of the Dutch scenario for arable farming and horticulture (treated by downward spraying) (Tiktak *et al.*, 2012);
- The minimum water depth is 20 cm;
- Different types of soils and different types of arable or horticultural crops should be present at the adjacent fields and
- The watercourses are distributed across the country of The Netherlands.

Five watercourses that satisfied the selection criteria were selected and these were situated within three major soil clusters: (i) silty clay and clay, (ii) silt loam and silty clay loam and (iii) fine sand. Eventually, data from four watercourses were retained since data from one sample site (MOL) was removed out of the data set, because the watercourse did not fulfil the selection criteria anymore: it was almost dry in September, with grasses growing on the sediment.

Improved sampling techniques were applied compared to the previous techniques used by Alterra. By using wider sampling cores (59 mm inner diameter instead of 39 mm), freezing the sediment cores without cone forming on top and dividing the core into segments with a belt saw instead of a chisel the sampling accuracy has been clearly improved. Analysis of the samples was improved by correcting the sample volumes for the expansion of water during freezing, thus avoiding an underestimation of the bulk density and porosity. (Organic matter content is a mass fraction and therefore not affected by freezing the samples.)

As only five watercourses have been sampled, the results presented below are only indicative.

The four suitable watercourses distributed across the Netherlands have sediment with a relatively low dry bulk density and a high organic matter content and porosity. These properties vary relatively few with depth. The upper cm of sediment of the four watercourses (excl. MOL) has a bulk density ranging from 0.09 to 0.40 g/ml, while for the lower 5-10 cm sediment the numbers are 0.37 to 0.66 g/ml. For the porosity the numbers range from 0.71 to 0.93 for the upper cm and 0.75 to 0.84 for the 5-10 cm segment and for the organic matter content they range from 8.9 to 30.2% and 6.5 to 22.6% (June/July and September sampling rounds combined for all three properties).

The measured sediment properties confirm that the sediment sampling technique and analysis methods are adequate: (i) standard deviations were relatively small, (ii) the ditch ranking order (in size of dry bulk density and organic matter content for the upper cm) did not change with season and (iii) the bulk density increased and the organic matter content decreased with depth in most cases. The latter phenomenon is as expected, in view of the long-yearly settling of water plant debris on top

of the sediment and the fact that the phase density of organic matter is lower than the phase density of mineral matter.

Implications with respect to the aquatic risk assessment in The Netherlands
The results of this study indicate that the sediment in relevant watercourses distributed across The Netherlands is clearly more loose than the one used in the arable farming and horticulture scenario under development, i.e. the sediment of this study has a lower bulk density, higher organic matter content and higher porosity for its upper cm: 0.09-0.40 vs 0.80 g/ml, 10-30 vs 9% and 0.70-0.90 vs 0.60, respectively. Differences with the ditch scenario currently used by the Ctgb are smaller: 0.09-0.40 vs 0.08 g/ml for bulk density, 10-30 vs 25% for organic matter content and 0.70-0.90 vs 0.82 for porosity. As the sediment properties influence penetration into sediment in opposite ways, we cannot predict the effect of the measured sediment properties of this study on the exposure concentration in the overlying water of the Dutch scenarios. So, we cannot predict whether the Dutch scenarios result in an underestimation of overestimation of risks for the aquatic ecosystem. A limited sensitivity analysis using the TOXSWA model may be performed to assess this.

To increase the scientific underpinning of the parameterisation of the sediment in the Dutch scenarios under development we recommend to:

- Sample more than the current five watercourses out of the arable farming and horticulture scenario domain to make a sound frequency distribution of the three sediment properties bulk density, organic matter content and porosity and
- Sample watercourses out of the fruit trees and arboriculture scenario domain to make a frequency distribution of the three sediment properties to parameterise the sediment of the fruit trees and arboriculture scenario under development.

In addition, we recommend to compare measured concentration profiles in sediment of selected compounds to profiles simulated by the TOXSWA model for situations relevant for the aquatic risk assessment. This could be done by experiments in e.g. two simplified cosms with clearly different sediment for a few compounds with low degradation rates and clearly different sorption capacities. This has not yet been done, while it is important to create confidence in the TOXSWA model by executing and publishing validation studies.

Finally, one should realise that exposure concentrations in water are not independent of exposure concentrations in sediment: a high exposure in water is generally associated to a low exposure in sediment. So, a high risk in water may often be associated to a low risk in sediment. As the EFSA is currently developing guidance for risk assessment of sediment-dwelling organisms, using realistic sediment properties is also important for this purpose.

1 Background and aim

During the development of the Dutch exposure scenario (arable farming and horticulture) for the aquatic risk assessment procedure for pesticides (Tiktak *et al.*, 2012) only two studies were found with data on sediment properties (Arts and Smolders, 2008a and b). Moreover, these were not suitable for the selected population of ditches. So, insufficient data on sediment properties are available for The Netherlands, while these are important for the calculation of the penetration of pesticides into the sediment (mainly in the upper few centimeters) by simulation models and therefore, also for the exposure concentrations in the water of the Dutch scenario and thus for the aquatic (including sediment) risk assessment.

Next to the developments in The Netherlands, developments at EU level also play a role. The Guidance Document on Tiered Risk Assessment for Plant Protection Products for aquatic organisms in edge-of-field surface waters (EFSA-PPR Panel, 2013) makes use of the FOCUS Surface Water Scenarios, containing sediment having properties based upon a single data set from the experimental station of Alterra in The Netherlands. In the course of 2013 the EFSA started with the development of a scientific opinion on the risk assessment of sediment-dwelling organisms. To be able to adequately calculate their exposure, a correct parameterisation of the sediment is needed and the Dutch data set may be helpful in this respect.

So, we wanted to know (i) what is the frequency distribution of sediment properties in a limited, but representative number of Dutch ditches and (ii) how do these sediment properties influence the size, timing and duration of the concentration in water and sediment of the exposure scenarios for the Dutch (and EU) registration of pesticides ? The ultimate aim was to improve the exposure scenarios for the risk assessment of the aquatic ecosystem, that play an important role in the registration procedure of pesticides in The Netherlands.

In this study the research questions were:
- What is the bulk density, porosity and organic matter content as a function of depth in sediment ?
- What is the size of the variation in these properties at the relevant spatial scale ?
- What is the size of the variation in these properties at the relevant temporal scale ?

Detailed data on sediment properties exist for the experimental ditches of Alterra at Renkum, NL. The sediment properties of these ditches are compared to the ones measured in this project, i.e. in ditches in the field across The Netherlands. In addition the sediment properties of this study are compared to those used in the Dutch surface water scenarios (currently used by the Ctgb as well as the two scenarios developed by a Dutch working group for future use).

2 Selection of relevant watercourses

2.1 Introduction

There is a lack of data on sediment properties to parameterize exposure scenarios that are used in models for the pesticide registration procedure. At present new exposure scenarios for use in The Netherlands are being developed (e.g. Tiktak *et al.*, 2012), while at EU level the FOCUS Surface Water Scenarios are used to evaluate risks for aquatic organisms. Sediment properties are also relevant for assessing the exposure for sediment-dwelling organisms. Therefore four relevant populations of watercourses exist: (i) the population defined in the Dutch scenario for arable farming and horticulture, treated with pesticides by downward spraying (Tiktak *et al.*, 2012), (ii) the population defined in the Dutch scenario for fruit trees and arboriculture, treated predominantly by sideward and upward spraying (iii) the population defined in the Aquatic Guidance Document mentioned above (EFSA-PPR Panel, 2013) and (iv) the population to be defined in the future EFSA Guidance for sediment-dwelling organisms. This research intends to represent the Dutch situation (arable farming and horticulture), while it does not preclude the possibility that the gathered data may also be useful at EU level, in view of the existing lack of data on sediment properties.

The aim was to select 20-30 watercourses. The following criteria were used to identify the watercourses to study:

- The watercourse is located immediately adjacent to a field with arable farming or horticulture (not grassland);
- The watercourse carries water all the year round, possibly by water management measures, such as a weir or pumping;
- The population of watercourses should coincide with the watercourses of the Dutch scenario for arable farming and horticulture (treated by downward spraying) (Tiktak *et al.*, 2012);
- The minimum water depth is 20 cm;
- Different types of soils and different types of arable or horticultural crops should be present at the adjacent fields and
- The watercourses are distributed across the country of The Netherlands.

Relevant scale in time and space

Pesticides are applied to fight pests, weeds or fungi in crops, so generally, they are applied during the growing period of crops. This implies that pesticide concentrations in surface waters are often higher during the crop growing season, roughly March/April to August/September, than during e.g. winter time. However, when pesticides do not enter the watercourse via spray drift deposition, but via drain flows pesticide concentrations may also be high in autumn or winter time, because of the relatively long travel times that may be associated with the drainage route.

The results of the example calculations for the Dutch standard scenario developed for arable farming and horticulture, demonstrated that the highest concentrations occur from May to September included (Tiktak *et al.*, 2012). Therefore we focus our attention on watercourses during this season, i.e. from May up to September. Watercourse properties vary over the growing season and so, they will be sampled twice, once in May/June and once in August/September. An example of such a property is sediment organic matter e.g. because of dying water plants organic matter may settle on top of the watercourse bottom towards the end of the growing season.

In The Netherlands watercourses are regularly cleaned in order to facilitate the discharge of surplus water. This may be done by mowing the water plants, but also by dredging, which involves scraping a thin layer of mud of the watercourse bottom. Sediment properties will change due to these cleaning activities and therefore, we included the cleaning method and history in our sampling description.

In the Dutch standard scenario developed for arable farming and horticulture, the behaviour of the pesticide is evaluated over a length of 100 m (Tiktak *et al.*, 2012). Therefore we focus our attention on properties of a 100-m long watercourse. To be able to characterise a 100 m watercourse we want to know the variability of its properties within 100 m.

2.2 Cartographic characteristics on watercourses, soil and land use

The criteria for the selection of watercourses mentioned above were applied to select a number of suitable watercourses. As a first step, a number of cartographic characteristics on watercourses and soil types were gathered, namely:

- Watercourse types;
- Soils types and land use and
- Watercourse lengths in soils with relevant land use.

Subsequently, these characteristics were combined to select the final suitable areas. Finally, within these areas watercourses were selected that fulfilled the selection criteria cited above. The criterion that the population of watercourses should be identical to the one used for the Dutch scenario (arable farming and horticulture excluding grassland, downward spraying) implied that primary watercourses (3-6 m wide) and secondary watercourses (0.5-3 m wide) are to be considered.

Watercourses
The primary watercourses (3-6 m wide) and secondary watercourses (0.5-3 m wide) are indicated at the Dutch TOP10 vector map (Fig. 2.1), in which the water board boundaries are indicated.

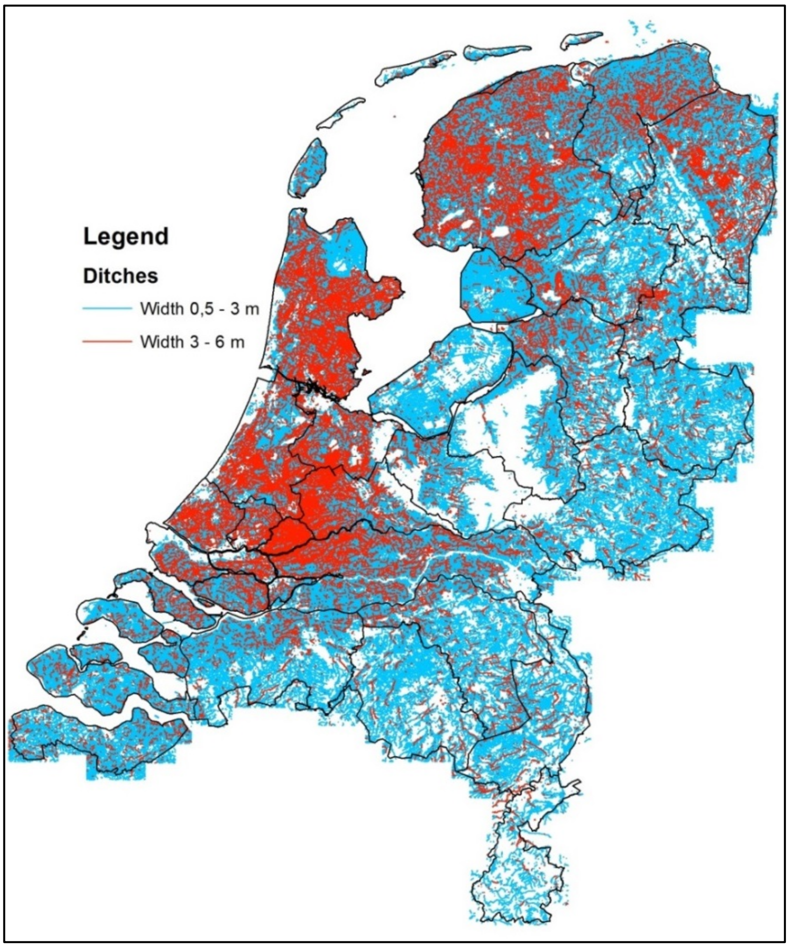

Figure 2.1 *Watercourses 0.5 -3.0 m (blue) and 3-6 m (red) for the Netherlands.*

By leaving out the ditches that fall dry in the summer, the density of ditches on the map strongly decreases in the sandy, eastern parts of the Netherlands. This is illustrated by Figure 2.2 and 2.3. Figure 2.2 is a detail of the map for the entire Netherlands (Fig. 2.1) in Eastern Gelderland.

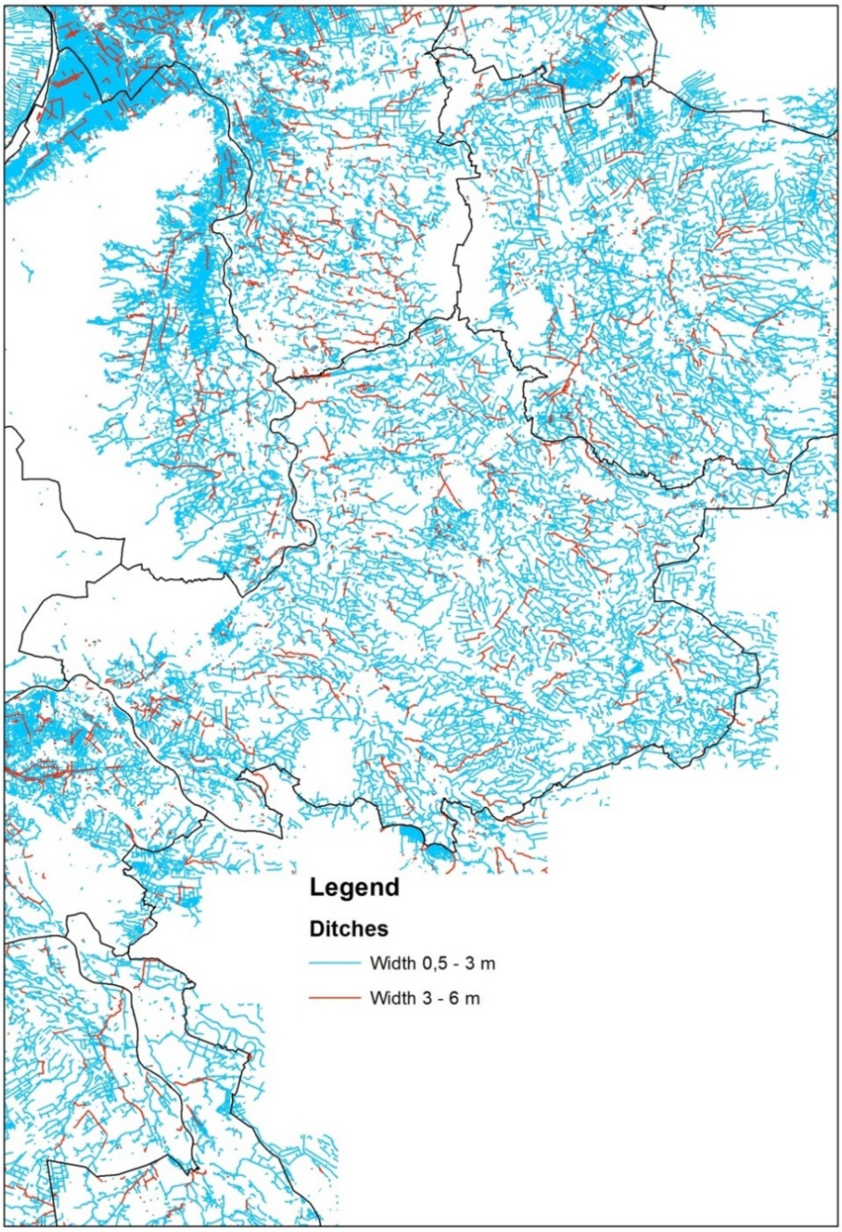

Figure 2.2 *Watercourses 0.5 -3.0 m (blue) and 3-6 m (red) detail for East Gelderland.*

This Top10-vector map of Eastern Gelderland (Fig. 2.2) shows the watercourses that bear water throughout the year. However, the water board 'Rijn and IJssel' made an inventory of the water bearing character of the watercourses and found that part of the watercourses presented on the TOP10-vector map run dry in summer (Fig. 2.3). They used three classes :

- Dry during summer;
- Bearing stagnant water during summer and
- Flowing water during summer.

This map of the water board 'Rijn and IJssel' shows that only a few watercourses in this sandy area hold water throughout the year (i.e. blue or green); these are mainly the larger watercourses.

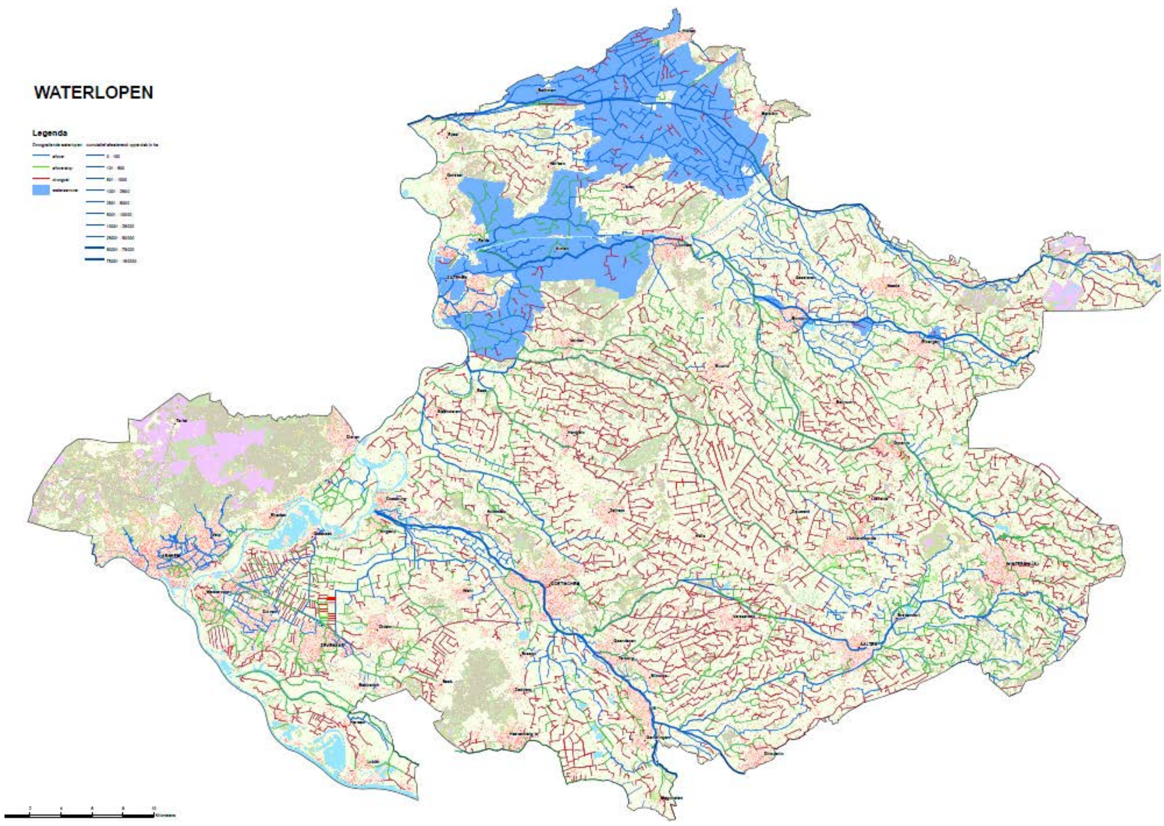

Figure 2.3 *Watercourses within the management area of water board 'Rhine and Ijssel' (red – dry during summer, green – having stagnant water during summer and blue - flowing water during summer).*

The presence of water supply and upward seepage are factors that have a positive impact on the water bearing character of watercourses, mentioned on the TOP10 vector map. Another positive factor is the location near a weir. In the southern part of The Netherlands, for example in water board 'Aa en Maas', large areas are supplied with water from the river Meuse. In the explanatory notes to the TOP10 vector map the presented watercourses are described as water bearing during a greater part of the year. However, in the eastern part of The Netherlands water supply is only possible to a limited extent. Upward seepage may occur in deep ditches that have a ditch bottom below the lowest groundwater level. In conclusion: it seems that the water-bearing character of ditches in the TOP10 vector map may be slightly overrated. Therefore, we checked for each watercourse to be sampled by us, whether it holds water all year round by consulting local experts.

Soils

As most pesticides only penetrate into the upper few centimeters, the top layer of the sediment is the most relevant layer for the pesticide behaviour. The top layer of the ditch bottom is influenced by processes such as decomposition of dead parts of water plants and algae, or other incoming organic material. In addition, its composition may depend on factors such as soil type in which the ditch is located and flow velocity of the ditch water. E.g. surface runoff and wind may supply material from the top soils from the immediate surroundings. Flow velocities vary in edge-of-field ditches and are seldom measured, so, they cannot be easily used as a criterion to select watercourses to be sampled. However, flow velocities depend on incoming drainage or runoff water and geography (bottom slope), which on their turn are related to soil type. So, it seemed defensible to use soil type as one of the selection criteria to select the watercourses to be sampled.

In this study the variation in soil types was reduced to a limited number of clusters. The clustering was based on the Dutch soil map 1: 50 000 with a large amount of soil profiles (300). The Dutch soil map is explored in the period 1960-1989, currently a revision of the peat area is carried out. In a previous study for the spatial schematization of soils, this great number of soil profiles was aggregated into a limited number of 21 profiles. Recently a new schematization became available, resulting in

72 profiles (Wösten *et al.,* 2013). This schematization was not used in this study, because the number of profiles is too large. The 21 profiles mentioned above had been distinguished in order to generalize the soil map 1: 250 000 (Wösten *et al.,* 1988) for the benefit of the PAWN-study. PAWN is the acronym for Policy Analysis of Water management for the Netherlands. In this well-known PAWN study all the interests involved in water management are considered. For the 21 profiles the sequence in soil horizons with their soil physical characteristics is known. In this sediment study the 21 soil profiles were aggregated into six clusters based upon the upper soil horizon. The upper horizons of the 21 soil profiles are characterized by the soil physical parameters of the Staring soil series (Wösten *et al.,* 1987). Table 2.1 gives for each soil profile information of the upper soil horizon in terms of thickness and soil physical properties coded according to the Staring soil series (Annex 1). The six clusters consist of two clusters for sand, two clusters for clay, and one cluster for silt and peat each.

Table 2.1

Upper horizon of the 21 soil profiles in terms of thickness and the Staring soil series code. The 6 colors indicate the 6 clusters.

PAWN Soil profile	Layer name	Code Staring series	Bottom depth (cm)	Cluster
1	A1	B18	-25	Peat (25-70% organic matter
2	A1	B16	-20	Peat (25-100% organic matter
3	A1g	B11	-20	Silty clay (35-50% clay)
4	A1g	B11	-20	Silty clay (35-50% clay))
5	Aanp	B02	-20	Fine sand (10-18% silt)
6	A1	B18	-20	Peat (25-70% organic matter
7	C	O01[1]	-100	Fine sand (0-10% silt)
8	A1	B01	-15	Fine sand (0-10% silt)
9	Ap	B02	-20	Fine sand (10-18% silt)
10	Ap	B02	-20	Fine sand (10-18% silt)
11	Ap	B03	-20	Loamy fine sand (18-33% silt)
12	Aanp	B02	-25	Fine sand (10-18% silt)
13	Ap	B03	-25	Loamy fine sand (18-33% silt)
14	A1	B01	-15	Fine sand (0-10% silt)
15	A1	B08	-25	Silt loam I12-18% clay)
16	A1	B10	-25	Silty clay loam (25-35% clay)
17	A	B12	-25	Clay (50 -100% clay)
18	A	B12	-25	Clay (50 -100% clay)
19	A1	B08	-25	Silt loam I12-18% clay)
20	A1	B08	-25	Silt loam I12-18% clay)
21	A1	O15[1]	-25	Silt (85 -100% silt)

[1] For profile 7 and 21 a subsoil Staring code(O) is allocated to the upper horizon, because of the homogeneity of the profile

The clustering was performed as follows:

- Peat soils consist of the Staring code B16 and B18: profiles 1, 2 and 6 are clustered;
- Silty clay and clay soils consist of the Staring code B11 and B12: profiles 3, 4, 17 and 18 are clustered;
- Silt loam and silty clay loam soils consist of the Staring code B8, B10: profiles 15, 16, 19 and 20 are clustered;
- Silt soils consist of Staring code O15 : they are considered to be a separate group, profile 21, which is almost entirely located in South Limburg;
- Fine sandy soils consist of the Staring code B1 and B2: profiles 5, 7, 8, 9, 10, 12 and 14 are aggregated;
- Loamy fine sandy soils consist of Staring code B3: profiles 11 and 13 are aggregated.

In Figure 2.4 the spatial distribution of the original 21 PAWN-profiles and the resulting six soil clusters are displayed.

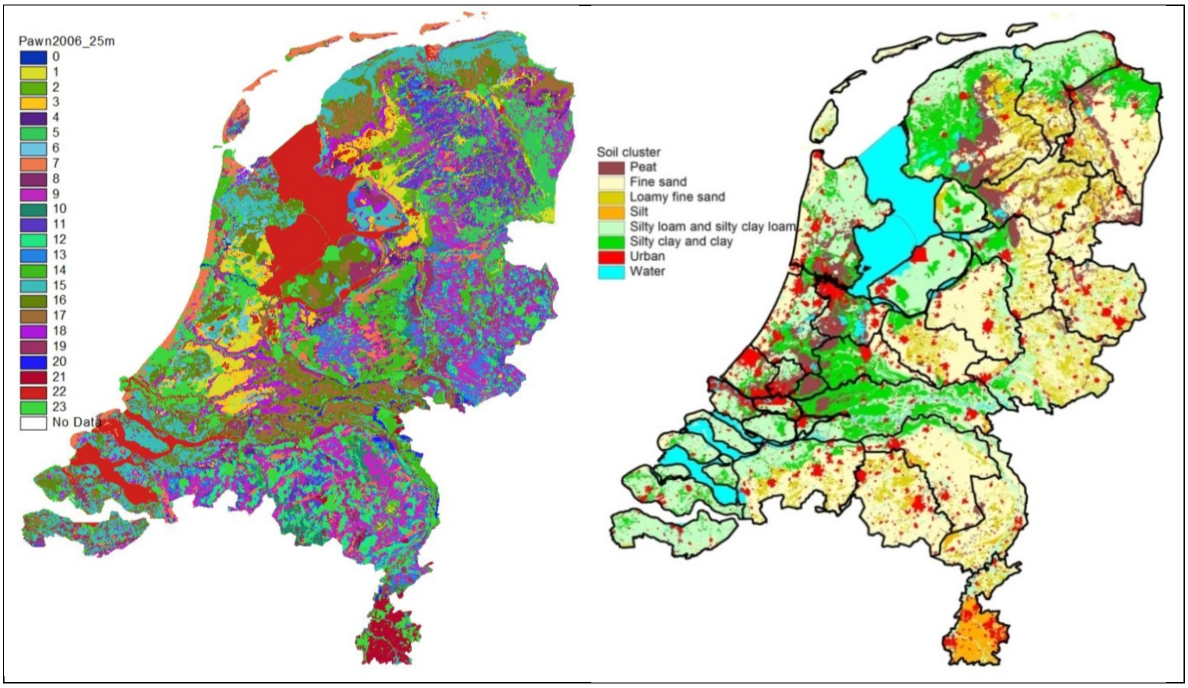

Figure 2.4 *Original 21 PAWN-profiles (left) and six soil clusters used for sediment sampling in this study (right).*

Watercourse lengths in soils with relevant land use

The Top10 vector map was converted into 25 x 25 meter grids, each with its own lengths of watercourse (Van der Gaast *et al.,* 2006). As a first step the watercourse lengths were determined for each soil cluster, irrespective of differences in land use (Table 2.2).

Table 2.2

Watercourse lengths per soil cluster for The Netherlands for primary (3 – 6 m) and secondary (< 3 m) watercourses.

Soil cluster	NL	Primary watercourse width 3 – 6 m	Secondary watercourse width < 3 m	Total	Total
	Area ha	**Length m**	**Length m**	**Length m**	**Length m/ha**
Peat	250265	10445475	25906718	36352193	145.3
Silty clay and clay	425564	10512602	45015064	55527666	130.5
Silt loam and silty clay loam	842506	13031354	47328940	60360294	71.6
Silt	50529	77937	363011	440947	8.7
Fine sand	1186318	8692338	25446226	34138564	28.8
Loamy fine sand	303684	2032175	9365849	11398024	37.5
All clusters	3058866	44791881	153425807.7	198217689	64.8

Table 2.2 shows that watercourse lengths per hectare are largest in peaty areas followed by silty clay and clay areas. The smallest lengths were found in the silt areas. For this study we wanted to sample a number of watercourses that (i) represents the variety of field conditions and (ii) is proportional to their lengths of occurrence in areas with relevant agricultural use. So, next we excluded the

agricultural use of pasture, because in general pesticides are not applied on pasture. Also fruit trees and arboriculture were excluded, because specific Dutch scenarios will be developed for these cultures, treated with pesticides predominantly by upward and sideward spraying. So, the remaining relevant agricultural use considers agricultural crops with downward spraying, for which the new Dutch scenario (arable farming and horticulture, downward spraying) applies. For this remaining agricultural use a new table is created (Table 2.3).

Table 2.3
Watercourse lengths per soil cluster in The Netherlands, excluding pasture, arboriculture and fruit.

Soil cluster	NL excl.	Primary watercourse width 3 – 6 m	Secondary watercourse width < 3 m	Total	Total
	ha	**Length m**	**Length m**	**Length m**	**Length m/ha**
Peat	24182	189514	1514397	1703911	70.5
Silty clay and clay	78087	370456	3348299	3718755	47.6
Silt loam and silty clay loam	331762	1381737	10323193	11704930	35.3
Silt	16384	1454	42500	43954	2.7
Fine sand	272505	1182060	4860332	6042392	22.2
Loamy fine sand	71790	138774	1321672	1460446	20.3
All clusters	794711.6	3263996	21410392	24674387	31.0

The Netherlands has about 2 million hectares of agricultural land. Excluding grassland, arboriculture and fruit trees the remaining area encompasses about 795 000 ha. The watercourse lengths per hectare and per soil cluster in Table 2.3 are much smaller than the ones in Table 2.2. The reason is that in grassland often wetter conditions occur, resulting in higher watercourse lengths per hectare than for arable land.

2.3 Selected watercourses and their characteristics

The watercourse lengths per soil cluster were used to distribute the planned sampling sites proportionally to their length in the soil cluster, i.e. the longer the length, the more sampling sites to be taken. Table 2.4 shows the distribution of the sampling sites per soil cluster for a total of 30 sampling sites.

Table 2.4
Distribution of the sampling sites relative to the watercourse lengths in the soil cluster excluding grassland, arboriculture and fruit trees.

Soil cluster	Primary Water course width 3 – 6 m Length m	Secondary Water course width < 3 m Length m	Total Length m	Primary %	Secondary %	Total %	Primary Number of sampling sites	Secondary Number of sampling sites	Total Total
Peat	189514	1514397	1703911	0.8%	6.1%	6.9%	0	2	2
Silty clay and clay	370456	3348299	3718755	1.5%	13.6%	15.1%	0	4	5
Silt loam and silty clay loam	1381737	10323193	11704930	5.6%	41.8%	47.4%	2	13	14
Silt	1454	42499.52	43953.87	0.0%	0.2%	0.2%	0	0	0
Fine sand	1182060	4860332	6042392	4.8%	19.7%	24.5%	1	6	7
Loamy fine sand	138774	1321672	1460446	0.6%	5.4%	5.9%	0	2	2
All clusters	3263996	21410392	24674387	13.2%	86.8%	100.0%	4	26	30

In Figure 2.5 the suitable area to locate the sampling sites is shown in the color of the soil cluster.

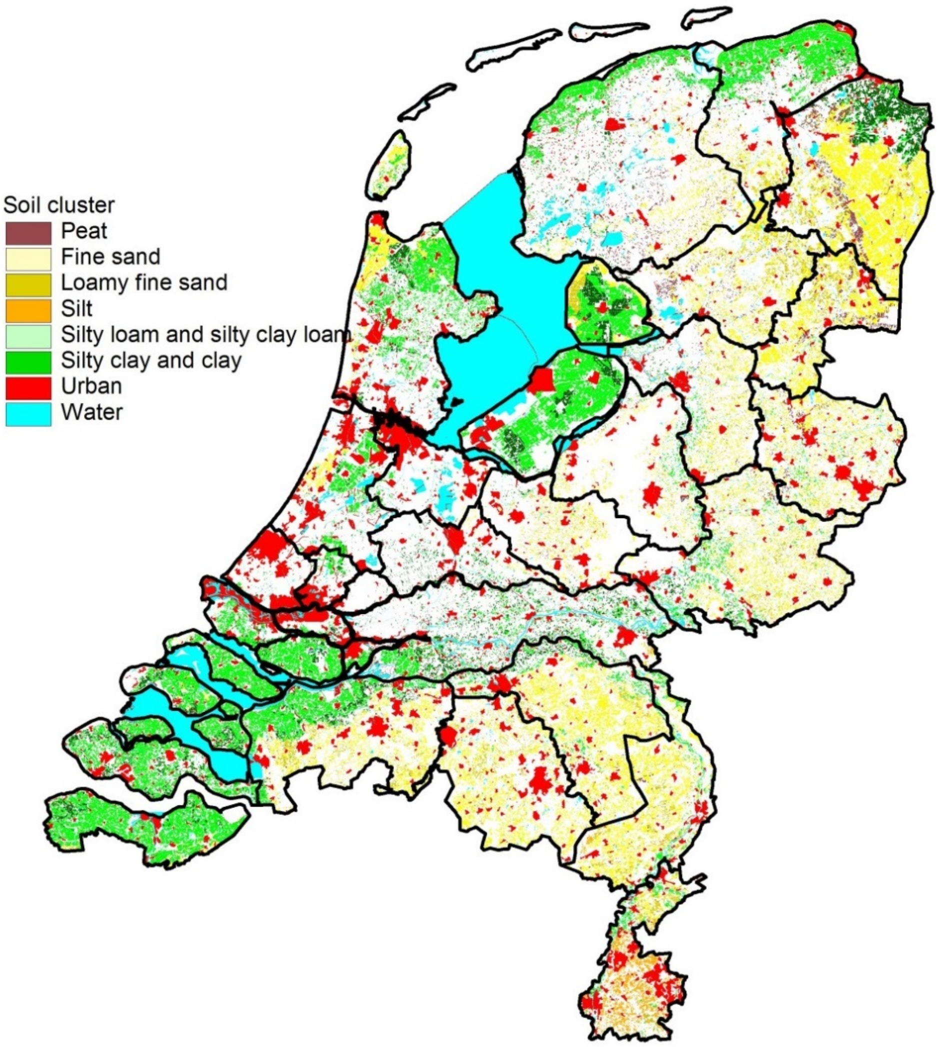

Figure 2.5 *Suitable areas to locate the sampling sites, indicated in the color of the six soil clusters.*

Based on field knowledge and in consultation with hydrologists of the water boards, the first five sampling sites for the year 2013 were selected (Fig. 2.6). These five sites are located in the soil cluster of fine sand (site code KNO), of silty loam and silty clay loam (ZUI, MOL and KAM) and of silty clay and clay (KER). So, the five locations are positioned in the three most important soil clusters and their numbers (1, 3 and 1) are approximately proportional to the length of the watercourses within the specific soil clusters (Table 2.4). The five watercourses consist of two primary and three secondary watercourses, so, the primary watercourses are slightly overrepresented in the sampling set for 2013. The locations of the five watercourses are presented into detail on the maps in Annex 2.

In Chapter 3 the characteristics of the sites are described, including pictures of the watercourses and of an example of the sampled sediment. In addition, an inventory was made of the method and frequency of cleaning and dredging of the sampled watercourses by the responsible water boards (Fig. 2.6) in order to help interpret the obtained results on sediment properties.

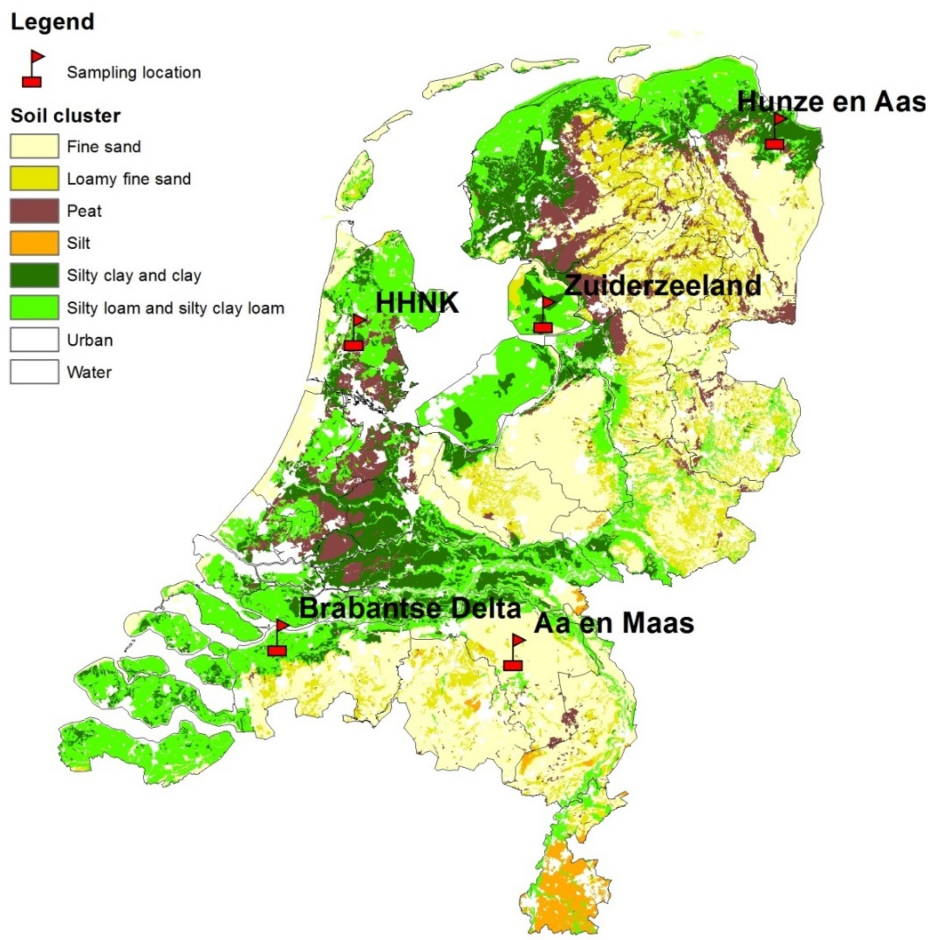

Figure 2.6 *Selected first five sites and their water boards for sediment sampling.*

3 Detailed description of the five sampled watercourses

3.1 Introduction

The five watercourses are described into detail below. The forms detailing the watercourse and the adjacent fields at the day of sampling is presented in Annex 3 (June/July 2013 sampling round) and 4 (September 2013 sampling round). These forms specify e.g. the vegetation at the edge of the watercourse, the top width and water width at water level as well as the total depth and water depth, whether there was visible flow of water, whether a weir was present, the observed crops on the adjacent fields and how the five samples were distributed over the width of the watercourse (in-between distance of 20 m): e.g. in the middle, west or east side.

3.2 Watercourse in Uden (sample code KNO), water board Aa en Maas

The watercourse is located at Knokerweg in Uden. It contained a high iron-oxide concentration and algae, but no macrophytes (Fig. 3.1). On the east side a bicycle road and an area with grasses and trees lies in between the ditch and the agricultural field. On the west side a maize crop is grown. At the date of first sampling (12 June 2013) the width of the watercourse at water level is 1.55 m and the water depth was 21 cm. Cleaning practices are described in Table 3.1. The sediment layer was relatively thick and the sampled sediment was homogeneous and rich in organic matter (Fig. 3.2).

Figure 3.1 *Clockwise starting top-left; view to the east, west, top and south of the ditch KNO (12 June 2013).*

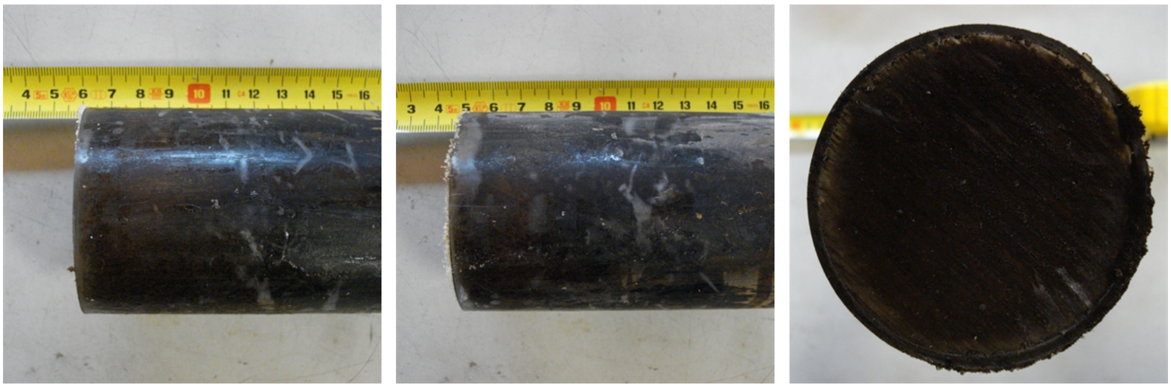

Figure 3.2 *Side views and top view of one of the frozen KNO samples of 12 June 2013.*

3.3 Watercourse in Emmeloord (sample code KAM), water board Zuiderzeeland

The watercourse is located at Kamperweg in Emmeloord. On the east side winter wheat is cultivated, and on the west side sugar beets (Fig. 3.3). The watercourse is a primary waterway with a width of 5.5 m at the water level at the day of sampling (4 July 2013) and its water depth was approximately 80 cm. Further east the canal profile narrows. No macrophytes were present. Due to the width of the watercourse samples could not be taken in the middle. Instead they were taken about 1 m from the side. The waterway was cleaned in 2013 once, a few weeks before the sampling was done. More details on cleaning and dredging practices are listed in Table 3.1. The sediment layer was relatively fluffy and therefore easy to sample (Fig. 3.4).

Figure 3.3 *Clockwise starting top-left; view to the left, right, top and length of the ditch KAM (4 July 2013).*

Figure 3.4 *Side views and top view of one of the frozen samples KAM of 4 July 2013.*

3.4 Watercourse in Stompetoren (sample code MOL), water board Hoogheemraadschap Hollands Noorderkwartier, HHNK

The watercourse is located at Korte Molenweg in Stompetoren. On the east side sugar beets are cultivated, and on the west side winter wheat (Fig. 3.5). At the date of first sampling (4 July 2013) the width of the watercourse at water level is 1.64 m and the water depth was 25 cm. This ditch is a dead end, it drains to and irrigates from a canal on the other side of the unpaved road (behind photographer on the length-picture). The sediment layer was rich in organic matter (Fig. 3.6). At the date of the second sampling (25 September 2013) the ditch was almost dry, grasses were growing on the sediment. More details on cleaning and dredging practices are listed in Table 3.1.

Figure 3.5 *Clockwise starting top-left; view to the left, right, top and length of the ditch MOL (4 July 2013).*

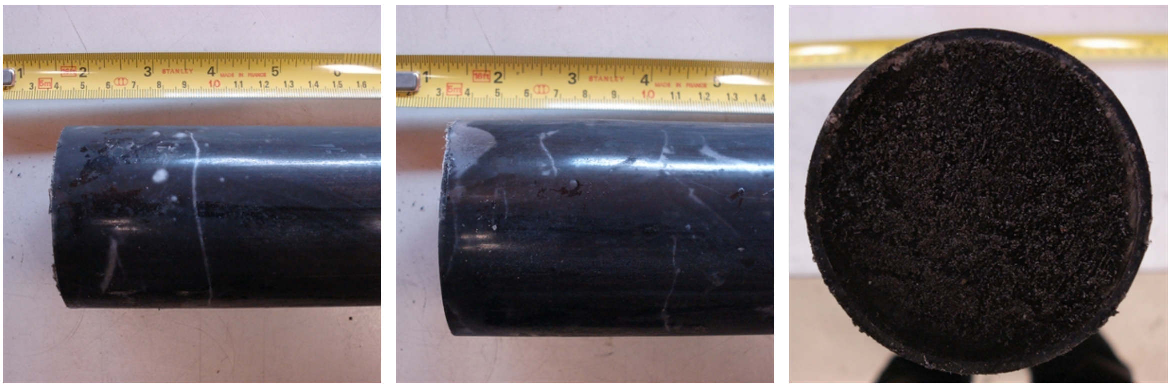

Figure 3.6 *Side views and top view of one of the samples MOL (4 July 2013).*

3.5 Watercourse in Willemstad (sample code ZUI), water board Brabantse Delta

The watercourse is located at Zuidlangeweg, Willemstad. On the east side sugar beets are cultivated, and on the west side maize (Fig. 3.7). At the date of first sampling (4 July 2013) the width of the watercourse at water level is 2.50 m and the water depth was 50 cm. The sediment is shown in Figure 3.8. There was lots of duckweed on the water and reed on the slopes. More details on cleaning and dredging practices are listed in Table 3.1.

Figure 3.7 *Clockwise starting top-left; view to the left, right, top and length of the ditch ZUI (25 July 2013).*

Figure 3.8 *Side views and top view of one of the samples ZUI (25 July 2013).*

3.6 Watercourse in Nieuwolda (sample code KER), water board Hunze en Aas

The watercourse is located at Kerkelaan, Nieuwolda. On both sides winter wheat is cultivated in July (Fig. 3.9). At the end of September, rape was cultivated on one side. At the date of first sampling (25 July 2013) the width of the watercourse at water level is 4.20 m and the water depth was 55 cm. The sediment is shown in Figure 3.10. There was a fair amount of algae in the water and some duckweed. More details on cleaning and dredging practices are listed in Table 3.1. This watercourse is similar in size to the KAM canal but less deep.

Figure.3.9 *Clockwise starting top-left; view to the left, right, top and length of the ditch KER (25 July 2013).*

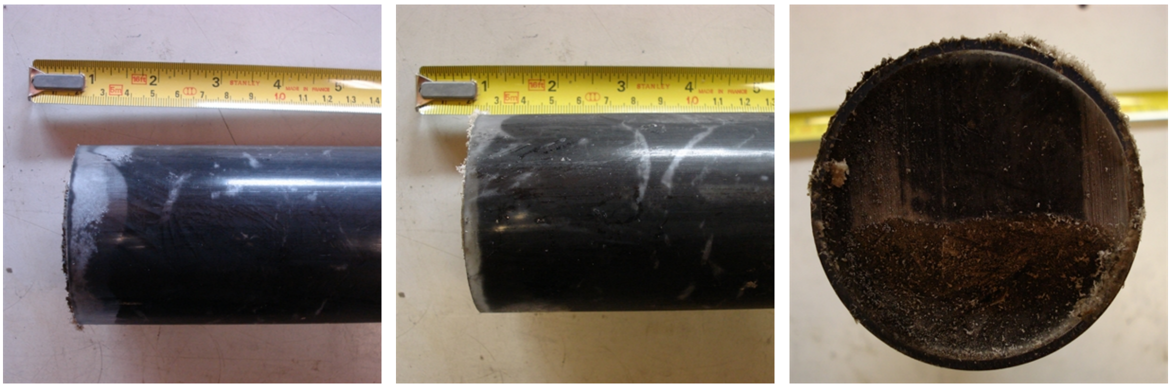

Figure 3.10 *Side views and top view of one of the samples KER (25 July 2013). Air-filled pockets are visible at the top side of the sample.*

3.7 Dredging and cleaning practices

An overview of the cleaning and dredging practices in the five selected watercourse is presented in Table 3.1. An example of a ditch mowing machine and mowing boat is given in Figure 3.11.

Table 3.1
Cleaning and dredging of the selected watercourses.

Sample code + water-board	Frequency (year)	Timing cleaning and sampling date	Method of cleaning	Dredging
KNO Aa en Maas	2 (both slope and bottom)	late June and late October [1] 12 June [2] 24 September	Cutting rake and mini crane with mowing basket for bottom of the ditch. Removing vegetation and fallen leaves. No dredging.	Last time unknown, more than 10 years ago. From 2014 onwards, a seven year maintenance cycle is introduced. Every conduit is checked every 7 year, and dredged, if necessary. If dredging is not required, the watercourse is checked again after 7 years.
ZUI Brabantse Delta	1	between 1 September-15 November [1] 24 July [2] 24 September	Ditch mowing machine. The slope is cut with a ‘klepelmaaier’. The soil profile is cut with a ditch mowing machine. The stubble under water is between 5 and 10 cm.	Dredging cycle once every eight years after measurement dredging growth. The polder Ruigenhil where the sampling site ZUI is located was dredged for the last in winter 2009/2010.
MOL HHNK	1	October [1] 4 July [2] 25 September	Cleaned with the ditch mowing machine by sufficient water. In case of a dry ditch bottom a fixed bucket is used to scrape a thin layer of mud from the bottom.	The ditch is almost never dredged because a little dredging is part of the cleaning.
KER Hunze en Aas	No fixed term. It depends on state of the vegetation. No more than 70% of vegetation present.	This year (2013) at week 26 (end June) and at week 33 (mid August) [1] 25 July [2] 25 September	With a ditch mowing machine. The path and the slope are cut with a ‘klepelmaaier’, the plants are cleaned with a ditch mowing machine.	There is a cycle of 1 every 8 years, but only in case there is too much mud present. Last dredging is not known.
KAM Zuider zeeland	Monthly	First cutting between 1 and 21 June. [1] 4 July [2] 25 September	Cutting boat. Monthly the plants are clipped with mowing boat.	The normal dredging cycle is every seven years. If the growth of dredged material is low, maintenance is sometimes delayed one cycle. The most recent dredging of the Bomentocht (our sampling site) was probably in 2009.

[1] First sampling date in 2013

[2] Second sampling date in 2013

Ditch mowing machine

Mowing boat or lake mower

Figure 3.11 *Ditch mowing machine and mowing boat used for cleaning of watercourses.*

3.8 Overview

Figure 3.12 presents an overview of the five selected watercourses.

Figure 3.12 *The five selected watercourses.*

Location KNO is situated in the south-eastern part of The Netherlands in the province of Noord-Brabant within the water board ‘Aa en Maas’ south of the city of Uden in a fine sand area. The selected watercourse is a secondary watercourse, the adjacent land use is potatoes and other crops according to the LGN6 map (Hazeu *et al.,* 2010), but at the time of sampling the land use was maize.

Location KAM is situated in the central part of The Netherlands in the province of IJsselmeerpolders within the water board ‘Zuiderzeeland’ in the Noordoostpolder south of the city of Emmeloord in a silty loam and silty clay loam area. The selected watercourse is a primary watercourse, the adjacent land use is potatoes according to LGN6, but at the time of sampling the land use was winter wheat and sugar beets.

Location MOL is situated in the north-western part of The Netherlands in the province of Noord-Holland within the water board 'Hoogheemraadschap Hollands Noorderkwartier' in the polder De Schermer east of the city of Alkmaar in a silty loam and silty clay loam area. The selected watercourse is a secondary watercourse, the adjacent land use is cereals and sugar beets according to LGN6, but at the time of sampling the land use was sugar beets and winter wheat.

Location ZUI is situated in the south-western part of The Netherlands in the province of Noord-Brabant within the water board Brabantse Delta in the polder Ruigenhil south of the city of Willemstad in a silty loam and silty clay loam area. The selected watercourse is a secondary watercourse, the adjacent land use is cereals and potatoes according to LGN6, but at the time of sampling the land use was sugar beets and maize.

Location KER is situated in the north-eastern part of The Netherlands in the province of Groningen within the water board 'Hunze en Aa's south of the city of Delfzijl near Nieuwolda in a silty clay and clay area. The selected watercourse is a primary watercourse, the adjacent land use is cereals according LGN6, but at the time of sampling the land use was winter wheat and rape.

Table 3.2 summarises the main characteristics of the sampling sites.

Table 3.2
Main characteristics of the sampling sites.

Sample code	Water board	Soil type (LGN6)	Water course type	Width at water level (m)	Water depth (m) (June/July)	Crops observed
KNO	Aa en Maas	Fine sand	secondary	1.55	0.21	maize
KAM	Zuiderzeeland	Silty loam and silty clay loam	primary	5.5	0.80	winter wheat, sugar beets
MOL	HHNK	Silty loam and silty clay loam	secondary	1.64	0.25	winter wheat, sugar beets
ZUI	Brabantse Delta	Silty loam and silty clay loam	secondary	2.50	0.50	sugar beets, maize
KER	Hunze en Aas	Silty clay and clay	primary	4.20	0.55	winter wheat, rape (Sept)

4 Definition of sediment properties and calculation methods

4.1 Introduction

Before being able to quantify the sediment properties bulk density, porosity and organic matter content we defined them in detail. Next, we explain how we calculated them from the field samples. As the sediment cores were frozen before analysis in the laboratory a correction for expansion of water during freezing was needed.

4.2 Definitions of bulk density, porosity and organic matter content

We define the sediment properties of bulk density, porosity and organic matter content with the aid of definitions of Koorevaar *et al*. (1983) for soil. Sediment is composed of organic matter, mineral matter and water, the water is assumed to be contained in the pores of the sediment.

Before being able to define the bulk density of the sediment we define the general notion of density or volumic mass:

$$\rho = \frac{mass\_of\_matter}{volume\_of\_matter} \qquad \text{eq. 1}$$

with ρ = density, or volumic mass (kg/m^3).

So, phase density, ρ_x, (kg/m^3), is the mass of phase *x*, divided by the volume of phase *x*. The phase density of organic matter is 1200-1500 kg/m^3 (average =1400 kg/m^3). The phase density of mineral matter is 2600-2850 kg/m^3 (average is 2700 kg/m^3).

Bulk density is mass of sediment divided by the total or bulk volume of the sediment, ${}^b\rho_d$, (kg/m^3), where *b* stands for bulk and *d* for dry. So:

$${}^b\rho_d = \frac{mass\_solid}{bulk\_volume} = \frac{mass\_om + mass\_\min}{bulk\_volume} \qquad \text{eq. 2}$$

with ${}^b\rho_d$, is the dry bulk density, (kg/m^3), and the solid mass (kg) is composed of organic matter (om in kg) and minerals (min in kg). The dry bulk density is the bulk density of the sample after drying in an oven at 105°C to a constant mass, based on the original volume. The wet bulk density, ${}^b\rho_w$, (kg/m^3), is defined by

$${}^b\rho_w = \frac{mass\_solid + mass\_liquid}{bulk\_volume} = \frac{mass\_om + mass\_\min + mass\_liquid}{bulk\_volume} \qquad \text{eq. 3}$$

with ${}^b\rho_w$, = wet bulk density (kg/m^3), the bulk density of the original wet sample.

The organic matter content of sediment is defined as

$$m_{om} = \frac{mass\_om}{mass\_om + mass\_\min} \qquad \text{eq. 4}$$

with m_{om} = mass fraction of organic matter to solid phase (-). The organic matter content, m_{om}, is determined from the loss of weight of an oven-dry sample upon complete oxidation of the organic matter at about 900 °C. The solid phase is sieved before entering the oven.

The porosity of the sediment or the volume fraction of pores is defined as

$$\varphi = \frac{total\_volume\_of\_pores}{volume\_of\_sediment} \qquad \text{eq. 5}$$

with φ = porosity, volume fraction of pores in the sediment (-).

In more general terms the volume fraction of phase *a* of the bulk as

$$\varphi_\alpha = \frac{volume\_phase\_\alpha}{bulk\_volume} \qquad \text{eq. 6}$$

with φ_a the volume fraction of phase *a* of the bulk (-).

As the sediment is composed of solid phase (organic matter and mineral matter) and water we can define:

$$\varphi_s = \frac{volume\_solid\_phase}{bulk\_volume} \text{ and} \qquad \text{eq. 7}$$

$$\varphi_l = \frac{volume\_liquid\_phase}{bulk\_volume} \qquad \text{eq. 8}$$

with φ_s = the volume fraction of the solid phase of the sediment bulk (-) and φ_l = the volume fraction of the liquid phase of the sediment bulk (-). As the pores are filled with water $\varphi_l = \varphi$, defined in eq. 5. The volume fraction of the solid phase constitutes the volume fraction of organic matter, together with the volume fraction of mineral matter:

$$\varphi_s = \varphi_{om} + \varphi_{min} \qquad \text{eq. 9}$$

with φ_{om} = volume fraction of sediment organic matter phase (-) and φ_{min} = volume fraction of the sediment mineral phase (-).

On the basis of eq. 7 and 8 we can express the wet and dry bulk densities by (assuming there is no gas phase in the sediment nor stones):

$${}^{b}\rho_w = \varphi_s\rho_s + \varphi_l\rho_l \text{ and} \qquad \text{eq. 10}$$

$${}^{b}\rho_d = \varphi_s\rho_s \qquad \text{eq. 11}$$

with ρ_s = density of the solid phase of the sediment (kg/m^3) and ρ_l = density of liquid phase in the sediment (i.e. water) (kg/m^3).

From eq. 10 and 11 we derive $\varphi_l = \frac{{}^b\rho_w - {}^b\rho_d}{\rho_l}$ eq. 12

So, the volume fraction of liquid equals the difference between the wet and dry bulk density divided by the density of liquid (i.e. water). The volume fraction of liquid are the pores of the sediment, filled with water, so the porosity φ can be determined with the aid of eq. 12.

4.3 Calculation of sediment properties with the aid of frozen sediment cores

Sediment is sampled with the aid of cylindrical cores, which are frozen during storage. Before analysis in the lab the frozen cores are cut into slices, of e.g. 1 cm thick, which are left to melt down before analysing the pesticide concentrations in water and solid sediment matter. Figure 4.1 represents the sequence of handling schematically for a layer of 1 cm sediment from the field to the laboratory.

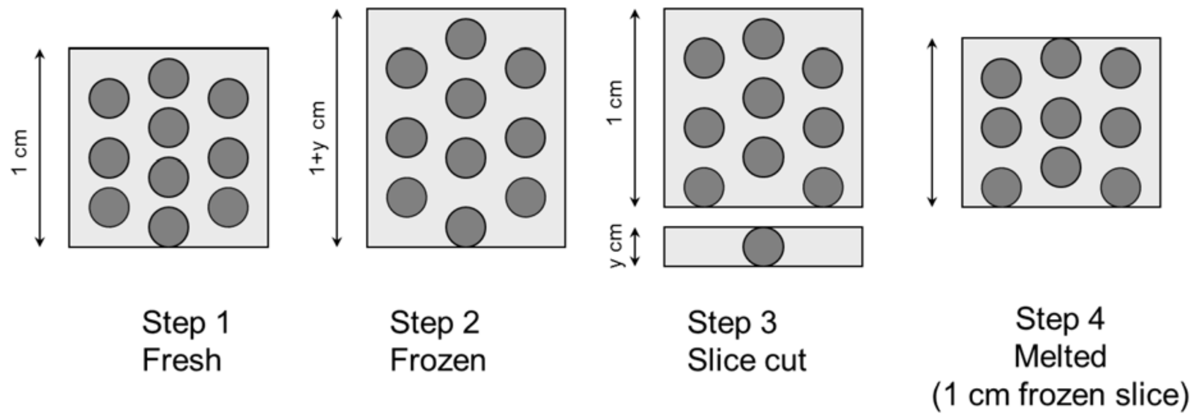

Figure 4.1 *A 1 cm layer of sampled sediment in the field (step 1), frozen in the laboratory (step 2), 1 cm slice cut from frozen core (step 3) and melted 1 cm-frozen slice (step 4).*

The sediment is sampled in the field and transported to the laboratory, where the core is frozen (standing in an upright position in the freezer). During the freezing process water expands and thus the core volume increases. Later on a slice of e.g. 1 cm, is cut from the core and left to melt. During melting the volume of the slice decreases. We assume that
(i) the ratio between solid mass and water remains constant during freezing and melting and
(ii) the volume of the solid mass does not change by freezing, so it remains constant $V_{3,s} = V_{4,s}$.
We now define the following entities:
$M_{x,s}$ = mass of dry sediment in slice of step x (g)
$M_{4,\ water}$ = mass of water in slice of step 4 (g)
$M_{3,\ ice}$ = mass of ice in slice of step 3 (g)
$M_{4,om}$ = mass of organic matter in slice of step 4 (g) and
V_3 = total volume of 1-cm frozen slice of step 3 (cm^3)
V_4 = total volume of defrozen slice of step 4 (cm^3)
V_s = volume of solid matter (cm^3)
$V_{4,\ water}$ = volume of water in step 4 (cm^3) and
$V_{3,\ ice}$ = volume of ice in cut slice of step 3 (cm^3).

So, $V_3 = V_{3,s} + V_{3,ice}$ and $V_4 = V_{4,s} + V_{4,water}$.
As $V_{3,s} = V_{4,s}$ (volume and density of solids do not change during freezing and melting) $V_4 = V_{4,s} + V_{4,water} = V_{3,s} + V_{4,water} = V_3 - V_{3,ice} + V_{4,water}$.
Moreover, $M_{3,ice} = M_{4,water}$ and $M_{3,s} = M_{4,s}$.

In the laboratory the following parameters have been measured:
height and diameter of the frozen cut slice, resulting in V_3, the volume of the 1-cm frozen slice
mass of water in slice of step 4, $M_{4,water}$
mass of solid sediment in slice of step 4, $M_{4,s}$ and
mass of organic matter at step 4, $M_{4,om}$

We now want to determine the organic matter content, m_{om}, the dry bulk density ${}^{b}\rho_d$, and the sediment porosity θ $(= \varphi = \varphi_l)$, based upon the measured parameters V_3, $M_{4,water}$ (=$M_{3,ice}$), $M_{4,s}$ and $M_{4,om}$.

The organic matter content equals the mass fraction of organic matter to solid phase, this corresponds to:

$$m_{om} = \frac{M_{4,om}}{M_{4,s}} , \qquad \text{eq. 13}$$

this is straightforward and always correct, freezing and melting do not influence mass.
The dry bulk density is the mass of sediment divided by the total or bulk volume of the sediment (in the defrosted, melted slice of step 4):

$${}^{b}\rho_d = \frac{M_{4,s}}{V_4} = \frac{M_{4,s}}{V_3 - V_{3,ice} + V_{4,water}} = \frac{M_{4,s}}{V_3 - \dfrac{M_{3,ice}}{\rho_{ice}} + \dfrac{M_{4,water}}{\rho_{water}}} \qquad \text{eq. 14}$$

The volume fraction of liquid is the total volume of liquid divided by the volume of the sediment (in the defrosted, melted slice of step 4):

$$\theta = \frac{V_{4,w}}{V_4} = \frac{\dfrac{M_{4,w}}{\rho_w}}{V_3 - \dfrac{M_{3,ice}}{\rho_{ice}} + \dfrac{M_{4,water}}{\rho_{water}}} \qquad \text{eq. 15}$$

Mark that the calculated sediment properties do not relate to the upper centimetre of sediment, but to a fraction of V_4/V_3 less.

Without correction for the change in volume of water by freezing the dry bulk density and porosity

would be calculated by ${}^{b}\rho_d = \frac{M_{4,s}}{V_3}$ eq. 16

instead of the correct ${}^{b}\rho_d = \frac{M_{4,s}}{V_4}$, and

$$\theta = \frac{V_{4,water}}{V_3} \qquad \text{eq. 17}$$

instead of the correct $\theta = \frac{V_{4,water}}{V_4}$;

thus, the dry bulk density ${}^{b}\rho_d$ and porosity θ as would both be underestimated.

Calculation example:
A slice of 1 cm height in frozen condition has been cut. Its volume V_3 (volume of cut layer) was measured to be 11.9 cm^3 and also measured was: $M_{4,water}$ = 7.5 g; $M_{4,s}$ = 10.0 g and $M_{4,om}$ = 1.6 g. The bulk densities of water and of ice are: ρ_w = 1.0 g/cm^3 and ρ_{ice} = 0.917 g/ cm^3, so $V_{4,water}$ = 7.5 cm^3.

Then:

m_{om} = 1.6 g/10.0 g = 0.16 (eq. 13), so 16 %. This gravimetric % is not influenced by melting and freezing of the sample.

The dry bulk density and the porosity can be calculated with eq. 14 and 15:

$$^{b}\rho_d = \frac{10.0g}{11.9cm^3 - \frac{7.5g}{0.917g/cm^3} + \frac{7.5g}{1.0g/cm^3}} = \frac{10.0g}{11.9cm^3 - 8.18cm^3 + 7.5cm^3} = \frac{10.0g}{11.2cm^3} = 0.89g/cm^3$$

$$\theta = \frac{\frac{7.5g}{1.0g/cm^3}}{11.9cm^3 - \frac{7.5g}{0.917g/cm^3} + \frac{7.5g}{1.0g/cm^3}} = \frac{7.5cm^3}{11.9cm^3 - 8.18cm^3 + 7.5cm^3} = \frac{7.5cm^3}{11.2cm^3} = 0.67$$

The volume fraction of the solid material can also be calculated:

$$\varphi_s = \frac{mass\_of\_solid}{volume\_of\_solid} = \frac{M_{4,s}}{V_{4,s}} = \frac{M_{4,s}}{V_4 - V_{4,w}} = \frac{10.0g}{11.2cm^3 - 7.5cm^3} = \frac{10.0g}{3.7cm^3} = 2.7g/cm^3$$

These properties characterise the upper (V_4/V_3)*1 cm = (11.2 cm^3/11.9 cm^3) * 1 cm = 0.94 cm. (V_4 = V_3 - $V_{3,ice}$ + $V_{4,water}$= 11.9 cm^3 -7.5 g/ ρ_{ice} + 7.5 g / ρ_{water} = 11.9- 8.2 +7.5 = 11.2 cm^3.)

If we would not correct for the expansion of water by freezing we would calculate the dry bulk density and the porosity to be (eq. 16 and 17):

$^{b}\rho_d = \frac{M_{4,s}}{V_3} = \frac{10.0g}{11.9cm^3} = 0.84g/cm^3$, so a lower value than the 0.89 g/cm^3 calculated above.

$\theta = \frac{M_{4,water}}{V_3} = \frac{7.5cm^3}{11.9cm^3} = 0.63$, so also a lower value than the 0.67 above, so these two sediment

properties would indeed be underestimated.

It is also possible to calculate the sediment properties bulk density and porosity by the reasoning presented in Annex 5.

5 Sediment sampling and analysis methods

5.1 Introduction

To be able to answer the research questions considering the size of variation in sediment properties at the relevant spatial and temporal scale, we designed the following sampling strategy. With respect to the spatial scale we considered, first of all, the distribution of the sampled watercourses across The Netherlands (see Chapter 2). In this way we obtain insight in the inter-watercourse variation. Next, we want to consider the variation in sediment properties within a watercourse, i.e. the intra-watercourse variation. As in the current Dutch standard scenario under development (Tiktak *et al.,* 2012) the behaviour of a pesticide is evaluated over a length of 100 m, we also focus our attention on a length of 100 m. In order to limit the costs and in view of the improved sampling technique (see 5.3 below), we opted for taking five samples, distributed proportionally over the chosen sampling length, so separated by approximately 20 m. Two samples were taken from the left half of the ditch, two from the right half and one from the middle (if possible) in order to obtain a width-representative sample.

Pesticide are generally applied during the growing season, so, approximately from March/April to August. So, often pesticide concentrations are higher during the growing season than during autumn and winter time., although drainage entries may continue after the growing season. Example calculation for the current Dutch standard scenario under development (Tiktak *et al.,* 2012) demonstrated that the highest concentrations occur from May to September included. As sediment properties may vary over the growing season, e.g. by decay of algae or water plants resulting in sedimentation of particulate organic matter, we sampled the sediment twice, once in June/July and another time in September.

Because sediment properties are a function of depth and pesticides often penetrate mostly in the top 1 to 2 cm sediment (Adriaanse *et al.,* 2012), we wanted to measure the sediment properties in sediment layers as thin as possible (5-10 mm). To do so, we optimised the sampling technique: we removed the excess water on top of the sediment from the cores, stored them vertically during freezing and thus obtained frozen sediment cores with an almost even (horizontal) sediment surface. Next, we sawed this core into horizontal slices, using a belt saw with a thin saw blade. In this way we could obtain layers with a minimum feasible thickness of 10 mm.

5.2 Sampling technique and sediment analysis

In each watercourse five sediment cores were taken. The cores consisted of transparent PVC tubes with an outer diameter of 63 mm, a wall thickness of 1.8 mm and a length of approximately 80 cm. The tubes were pushed down into the sediment by hand to a depth of at least 30 cm. The upper side of the tube was closed with a rubber stopper. Then they were turned along their axis, once, and next, the tubes were lifted out of the water. After closing off the tubes with rubber stoppers on the bottom side each tube thus contained at least 30 cm sediment plus overlying water. The tubes were stored vertically in a rack and transported to Wageningen.

In the laboratory almost all water above the sediment was removed using a water-jet vacuum pump and the cores were put vertically in a freezer at -25°C until further processing. Using a belt saw the empty part of the tube was cut off, photographs were taken from the top and 2 sides (e.g. Fig. 3.2) and the frozen core was divided into the following segments: 0-1 cm, 1-2 cm, 2-3 cm, 3-5 cm and 5-10 cm. The last millimeter of each sample was lost, because of the thickness of the saw blade. The segments were put in pre-weighed aluminium trays, the remaining PVC rings were removed and the trays were weighed again before putting them in an oven at 105°C. After drying the samples for at least 24 h at 105°C the trays were taken out from the oven and weighed again. Next, part of the dry mass was weighed into a pre-weighed porcelain cup and this was put overnight in an oven at 550°C, where the organic matter was measured by loss of ignition. We thus obtained (i) the volume of the frozen samples (inner surface area of PVC core times segment height) (ii) the mass of water (mass of tray+wet, frozen sample minus mass of tray+dried sample), (iii) the solid phase mass (mass of tray+dried sample minus mass of tray) and (iv) the organic matter mass (mass of cup+dried sample minus mass of cup+ ashed sample). From these four parameters the dry bulk density, porosity and organic matter content were calculated for each segment at the sampling site; average values were calculated for the watercourse for each sampling round.

Bulk densities for all segments were calculated based on the volume of the segments. For some samples the top segment was not completely filled with material, i.e. part was filled with air. For these segments the sample volume and consequently the bulk density was corrected for the volume of air using the pictures taken from the side and top of the sample. See for example the sample pictures for 'Hunze en Aas' (Fig. 3.10). A correction for expansion of the water of the sample due to freezing was applied as well (for details see section 4.3).

5.3 Sampling technique improvements

In previous experiments by Crum and others (Brock *et al.,* 1992, Crum and Brock, 1994, Crum *et al.,* 1998) sediment had already been sampled. When preparing the current study, Crum named several problems with the sampling technique used then: (i) the upper centimeter of sediment was sampled in a crude way (resulting in sediment properties of the upper centimeter having a relative large variation): during freezing cones of sediment material were formed in the cores (due to water freezing proceeding from outside to the inner parts of the core), thus, there was no horizontal interface between water and sediment and a chisel needed to be used to separate the water and sediment, while estimating the amount of sediment material corresponding to the 0-1 cm layer, (ii) the composition of the upper few segments sampled in the laboratory may differ from their composition in the field, because the frozen cones disturb the original structure of the sediment and (iii) sediment material from higher segments sometimes mixed with sediment material from lower segments, probably because, while pushing the frozen core out of the PVC tube, some sediment remained attached to the inner side of the PVC tube, thus 'contaminating' the lower sediment. Crum deducted this from unexpectedly high concentrations of pesticide in lower sediment segments.

To countervail as much as possible the problems, observed by Crum, we implemented the following improvements in our sampling technique:
(i) we used PVC tubes with 59 mm inner diameter instead of 39 mm to sample the sediment: in this way side wall effects are diminished when pushing cores into the sediment or removing the sediment from the core; as larger segment volumes are obtained this also leads to an increased accuracy in the measured water, solid phase and organic matter masses;
(ii) we removed as much overlying water as possible with the water-jet vacuum pump without disturbing the upper sediment: in this way the sediment surface area remained level during freezing and so, the upper cm could be more easily sampled than when the overlying water was not removed and the sediment material formed a cone during freezing and
(iii) we cut the PVC tubes with a belt saw: in this way the segment volumes could be determined in a more accurate way than was done before, when the PVC tubes were kept intact and the frozen samples were pushed outside the tubes and cut into segments with the aid of a chisel.

6 Sediment properties of the five selected watercourses

6.1 Introduction

The five selected watercourses were samples in two rounds, the first in June and July and the second in September 2013. The sediment properties were calculated for each watercourse, their calculation and the results are presented in Annex 6 for the first sampling round (June/July 2013) and in Annex 7 for the second (September 2013).

Section 6.2 summarizes the results for each watercourse in the Tables 6.1 to 6.5. In section 6.3 graphs with the dry bulk density, porosity or organic matter content of the upper cm of sediment for the five selected watercourses are presented and discussed. In section 6.4 an overview table (Table 6.6) is presented in an attempt to analyse, in spite of the low number of sampled watercourses, whether there is a relationship between the measured sediment properties and other characteristics of the watercourses.

6.2 Results as a function of depth per ditch

Table 6.1
Sediment properties of the watercourse near Emmeloord (KAM) in July and September 2013 (water board Zuiderzeeland).

KAM 4 July 2013				**KAM 25 September 2013**		
Averages of bulk density (BD, g/ml), porosity (por, mL/mL) and loss on ignition (om, mass%)						
	BD	por	om	BD	Por	om
0-1 cm	0.23	0.91	17.36	0.23	0.85	17.50
1-2 cm	0.34	0.87	17.75	0.32	0.82	15.70
2-3 cm	0.38	0.89	21.60	0.36	0.82	15.64
3-5 cm	0.40	0.82	18.06	0.38	0.82	16.21
5-10 cm	0.38	0.84	20.85	0.37	0.83	22.57
Standard deviation						
0-1 cm	0.05	0.04	0.78	0.12	0.09	2.72
1-2 cm	0.06	0.02	2.34	0.09	0.03	1.62
2-3 cm	0.10	0.08	5.31	0.09	0.06	1.71
3-5 cm	0.17	0.07	5.93	0.12	0.04	2.66
5-10 cm	0.10	0.04	13.14	0.14	0.04	17.40

KAM is a primary watercourse with a width of 5.5 m at water surface level and a water depth of approximately 80 cm at the date of first sampling. It is located in Emmeloord, in an area with silty loam and silty clay loam soils. No macrophytes were present in the watercourse. At the time of sampling winter wheat and sugar beets were cultivated at the adjacent fields. The most recent cleaning of the watercourse was at least three weeks before the first sampling date (Table 3.1). The (dry) bulk density of its sediment ranges from 0.23 g/ml (0-1 cm) to 0.38-0.40 g/ml in lower segments in July as well as in September. The porosity ranges from 0.91 down to 0.82 and the organic matter content ranges from 17.36 to 22.57%, (values of July and September combined). We expected to find a loose, organic matter-rich upper layer changing into clearly more dense, organic matter-poor lower layers, corresponding to a low bulk density increasing steadily with depth and a porosity and organic matter content decreasing steadily with depth, but the measured properties deviate from these expected trends. In fact, the changes in measured properties with depth are limited, as demonstrated by the cited ranges above. The variability in the measurements is relatively low in most cases, as is shown by the size of the standard deviations, e.g. for the 0-1 cm layer the organic matter content is 17.36 and 17.50%, while the standard deviation is 0.78 and 2.72%, so 4 and 16%. However, the standard deviation in the organic matter content of the 5-10 cm segment of both July and September is markedly high. In both months this is caused by one (of the five) samples having a dark black, peat-like 5-10 cm segment with a 44.2% (July) and 53.6% (September) organic matter content (Annex 6 and 7). This explains also the high organic matter content in the 5-10 cm segment in September. Finally, there is no clear apparent difference between the sediment properties of July and those of September.

Table 6.2

Sediment properties of the watercourse near Nieuwolda, Groningen (KER) in July and September 2013 (water board Hunze en Aas).

KER 25 July 2013				**KER 25 September 2013**		
Averages of bulk density (BD, g/ml), porosity (por, mL/mL) and loss on ignition (om, mass%)						
	BD	Por	om	BD	por	om
0-1 cm	0.40	0.92	8.88	0.30	0.71	10.65
1-2 cm	0.54	0.80	8.52	0.43	0.72	9.91
2-3 cm	0.58	0.80	8.36	0.45	0.68	9.77
3-5 cm	0.59	0.76	7.63	0.52	0.74	8.74
5-10 cm	0.66	0.75	6.45	0.57	0.75	8.32
Standard deviation						
0-1 cm	0.10	0.21	0.48	0.09	0.04	1.63
1-2 cm	0.10	0.04	0.60	0.10	0.05	1.29
2-3 cm	0.09	0.03	0.96	0.09	0.05	1.62
3-5 cm	0.07	0.03	0.16	0.12	0.04	1.11
5-10 cm	0.07	0.02	0.54	0.12	0.04	0.70

KER is a primary watercourse with a width of 4.20 m and a water depth of 55 cm at the date of first sampling. It is located in the province of Groningen, in Nieuwolda near Delfzijl, in an area with silty clay and clay soils. A fair amount of algae and some duckweed was present in the watercourse. At the time of sampling winter wheat and rape were cultivated on the adjacent fields. The most recent cleanings of the watercourse were around four weeks before the first and the second sampling date (Table 3.1). The bulk density of its sediment ranges from 0.40 g/ml (0-1 cm) to 0.66 g/ml (5-10 cm) in July and 0.30 g/ml (0-1 cm) to 0.57 g/ml (5-10 cm) in September. The porosity ranges from 0.92 down to 0.71 and the organic matter content ranges from 10.65 to 6.45% (values of July and September combined). Except for the porosity in September, there are steadily increasing or decreasing trends in the measured sediment properties with depth. Differences between July and September are small; the dry bulk density of September is slightly lower than the one of July, while the organic matter content of September is slightly higher, as one may expect because of decaying macrophytes in the period July-September.

Table 6.3
Sediment properties of the watercourse near Uden, Brabant (KNO) in June and September 2013 (water board Aa en Maas).

KNO 12 June 2013				KNO 24 September 2013		
Averages of bulk density (BD, g/ml), porosity (por, mL/mL) and loss on ignition (om, mass%)						
	BD	Por	om	BD	por	om
0-1 cm	0.19	0.93	22.18	0.09	0.84	30.23
1-2 cm	0.31	0.87	19.51	0.14	0.83	29.21
2-3 cm	0.35	0.90	18.22	0.18	0.82	25.48
3-5 cm	0.44	0.85	14.82	0.34	0.87	15.10
5-10 cm	0.56	0.81	12.35	0.46	0.81	10.46
Standard deviation						
0-1 cm	0.06	0.05	3.80	0.03	0.04	3.60
1-2 cm	0.04	0.06	1.82	0.03	0.06	4.78
2-3 cm	0.07	0.06	2.25	0.04	0.06	6.22
3-5 cm	0.12	0.05	4.18	0.18	0.09	6.46
5-10 cm	0.17	0.07	4.73	0.16	0.05	2.83

KNO is a secondary watercourse with a width of 1.55 m and a water depth of 21 cm at the date of first sampling. It is located in Uden (Brabant) in an area with fine sands. The watercourse contained algae. At the time of sampling maize is grown on one side of the watercourse and a bicycle road and grass plus trees strip is present on the other side. The cleaning of the watercourse was after the first sampling date and around three months before the second sampling date (Table 3.1). The upper cm of its sediment has a dry bulk density of 0.19 g/ml in June and 0.09 g/mL in September, in lower segments the bulk density increased up to 0.56 g/ml (June) and 0.46 (September). Its porosity ranges from 0.93 down to 0.81 (June and September combined) and its organic matter content ranges from 22.18% in June and 30.23% in September down to 12.35% (June) and 10.46% (September). Dry bulk density and organic matter content are steadily increasing, respectively decreasing with depth, both in June and September. Similarly to the KER sediment the dry bulk density of September is slightly lower than the one of June, while the organic matter content of September is slightly higher, as one may expect because of decaying macrophytes in the months of July to September.

Table 6.4
Sediment properties of the watercourse in Stompetoren near Alkmaar, Noord-Holland (MOL) in July and September 2013 (water board 'Hoogheemraadschap Hollands Noorderkwartier').

MOL 4 July 2013				MOL 25 September 2013		
Averages of bulk density (BD, g/ml), porosity (por, mL/mL) and loss on ignition (om, mass%)						
	BD	por	om	BD	por	om
0-1 cm	0.19	0.85	33.58	0.55	0.81	11.53
1-2 cm	0.22	0.89	32.77	0.70	0.73	9.68
2-3 cm	0.22	0.87	30.20	0.84	0.65	7.84
3-5 cm	0.22	0.83	19.92	1.14	0.56	3.96
5-10 cm	0.26	0.85	13.21	1.36	0.47	2.31
Standard deviation						
0-1 cm	0.06	0.02	18.34	0.05	0.07	1.53
1-2 cm	0.06	0.04	17.51	0.08	0.04	2.26
2-3 cm	0.05	0.04	16.61	0.23	0.08	2.92
3-5 cm	0.03	0.03	5.82	0.18	0.07	1.45
5-10 cm	0.03	0.01	1.38	0.07	0.03	0.58

MOL is a secondary watercourse located in Stompetoren near Alkmaar (Noord-Holland) in an area with silty loam and silty clay loam soils. This watercourse is a dead end. At the date of first sampling the watercourse had a width of 1.64 m and a water depth of 25 cm. At the date of the second sampling the watercourse was almost dry and grasses were growing on the sediment. At the time of sampling sugar beets and winter wheat were cultivated at the adjacent fields. The watercourse had not been cleaned before the first and second sampling date (Table 3.1). In the beginning of July the sediment had a bulk density of 0.19 to 0.26 g/ml, a porosity of around 0.85 and an organic matter content of 33.58 down to 13.12%. At the end of September the sediment was more dense and its properties had changed considerably, having a bulk density of 0.55 to 1.36 mg/L, a porosity of 0.81 down to 0.47 and an organic matter content of 11.53 down to 2.31%. So, in this specific case a clear difference exists between the sediment properties in July and those in September, because the ditch sediment had started to dry out in September.

The standard deviations for the organic matter content of the 0-1 cm, 1-2 cm and 2-3 cm segments in July are high: 18.34-16.61% for organic matter contents of 33.58 – 30.21%. This is due to the fact that two (out of five) samples have organic matter contents of 53.6% down to 46.2% in these segments, while the three other samples have contents ranging from 25.6% down to 14.7% for these segments (Annex 6).

As the watercourse was almost dry with grasses growing on the sediment at the second sampling date in September, it does not fulfil the criterion of having a water depth of at least 20 cm. Thus this watercourse does not belong to the population of watercourses, relevant for the Dutch standard scenario (arable farming and horticulture) under development.

Table 6.5

Sediment properties of the watercourse near Willemstad, Noord-Brabant (ZUI) in July and September 2013 (water board 'Brabantse Delta').

ZUI 24 July 2013				**ZUI 24 September 2013**		
Averages of bulk density (BD, g/ml), porosity (por, mL/mL) and loss on ignition (om, mass%)						
	BD	por	om	BD	por	om
0-1 cm	0.38	0.81	10.74	0.25	0.85	14.05
1-2 cm	0.54	0.79	9.66	0.44	0.79	10.19
2-3 cm	0.53	0.78	10.47	0.47	0.78	10.49
3-5 cm	0.50	0.78	9.50	0.46	0.79	10.40
5-10 cm	0.50	0.78	9.49	0.54	0.75	9.73
Standard deviation						
0-1 cm	0.08	0.04	1.08	0.11	0.08	5.10
1-2 cm	0.05	0.04	0.91	0.08	0.02	1.40
2-3 cm	0.03	0.03	0.88	0.09	0.02	1.63
3-5 cm	0.04	0.02	0.72	0.08	0.03	1.06
5-10 cm	0.09	0.03	1.66	0.11	0.06	2.75

ZUI is a secondary watercourse with a width of 2.50 m at water surface level and a water depth of 50 cm. It is located near Willemstad in the Ruigenhil polder in the province of Noord-Brabant in an area with silty loam and silty clay loam soils. A lot of duckweed was floating on the water and there was reed at the side walls. At the time of sampling sugar beets and maize were cultivated on the adjacent fields. The watercourse was not cleaned before the first sampling date. It is not clear whether the watercourse was cleaned before the second sampling date (Table 3.1). The bulk density of its sediment ranges from 0.25 g/ml (0-1 cm) to 0.54 g/ml (5-10 cm) (values of July and September combined). The porosity ranges from 0.85 down to 0.75 and the organic matter content ranges from 14.05 to 9.49% (values of July and September combined). Changes in measured properties with depth seem limited. Similarly to the KER and KNO sediments the dry bulk density of September is slightly lower than the one of July, while the organic matter content of September is slightly higher, as one may expect because of decaying macrophytes in the months of July to September.

6.3 Graphical representation per property of the upper cm

Average values plus standard deviations were calculated and frequency distributions were made for the bulk density (Fig. 6.1 and 6.2), the organic matter content (Fig. 6.3 and 6.4) and the volume fraction of liquid or porosity (Fig. 6.5 and 6.6) of the upper cm of sediment.

The upper cm sediment has a very low (dry) bulk density for all five watercourses in both sampling rounds (Fig. 6.1 and 6.2), compared to soil bulk densities. It ranges from 0.09 g/ml (KNO, Sept) to 0.55 g/ml (MOL, Sept), while soil bulk densities range from 0.9 to 1.8, excluding peat soils ((Wösten *et al.,* 2001). If we leave out watercourse MOL, that was almost dry in September with grasses growing on the sediment, the ranking order of watercourses going from the lowest to the highest average bulk density for the first sampling round of June/July is equal to that of the second sampling round in September. From June/July to September the bulk density appears to have slightly decreased in the KNO, KAM, ZUI and KER watercourses, possibly caused by decay of macrophytes in the months of July to September, resulting in the deposition of detritus and debris on top of the sediment, that have a low phase density.

The fact that all samples show an identical ranking order for bulk density between June/July and September creates confidence that taking five samples over the considered 100 m seems sufficient to characterise the sediment properties of the ditches. Moreover, this implies that also the sampling technique appears to be adequate, even for the 0-1 cm segment, where the interface water-sediment may sometimes be slightly irregular due to e.g. air trapping during water freezing (see e.g. Fig. 3.10 where the sediment material is not fully horizontally spread across the surface area).

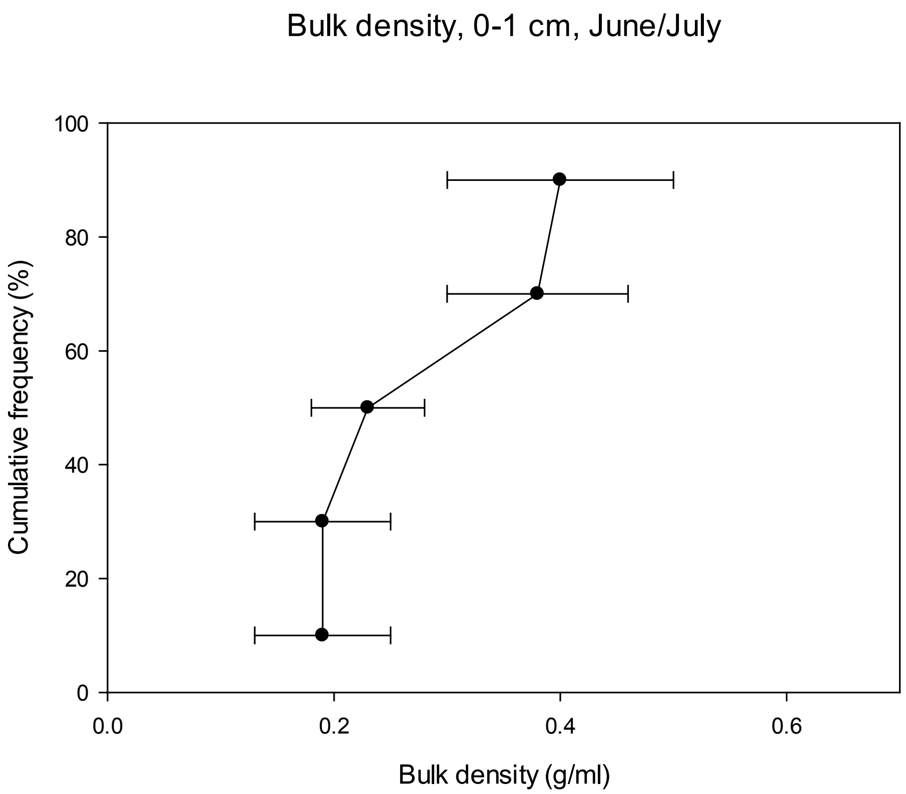

Figure 6.1 *Cumulative frequency distribution of the average dry bulk density (n=5) in the five sampled watercourses of KNO, MOL, KAM, ZUI and KER (in order of increasing dry bulk density) during June/July 2013. N.B. MOL not relevant for NL standard scenarios.*

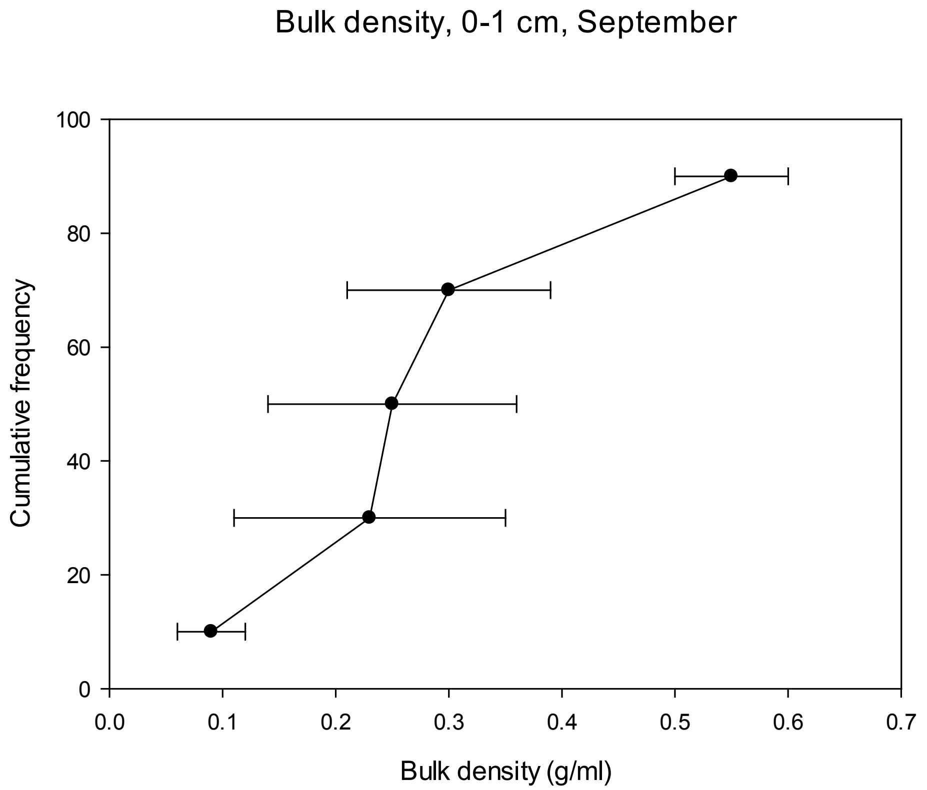

Figure 6.2 *Cumulative frequency distribution of the average dry bulk density (n=5) in the five sampled watercourses of KNO, KAM, ZUI, KER and MOL (in order of increasing dry bulk density) during September 2013. N.B. MOL not relevant for NL standard scenarios.*

The average organic matter content of the upper cm sediment ranges from 8.9% (KER) to 22.2% (KNO) in June/July (Fig. 6.3) and 10.7% (KER) to 30.2% (KNO) in September (leaving out watercourse MOL with its almost dry sediment with grown grasses, Fig. 6.4). The ranking order of sample locations going from the lowest to the highest average organic matter content for the first sampling round of June/July is equal to the ranking order of the second sampling round in September: KER, ZUI, KAM and finally KNO. From June/July to September the average organic matter content of the sediment has increased for all four watercourses, possibly caused by decay of macrophytes in the months of July to September, resulting in the deposition of detritus and debris on top of the sediment.

Comparing this ranking order to the ranking order found for the average dry bulk density (KNO, KAM, ZUI and KER, both for June/July and for September), we notice a correlation between average organic matter content and average dry bulk density: the higher the organic matter content, the lower the bulk density of the considered sediment. This is as expected, because the phase density of organic matter is lower than the phase density of mineral matter (approximately 1.40 kg/L vs 2.65 kg/L) and thus e.g. a high organic matter content results in few mineral matter and thus in a low bulk density.

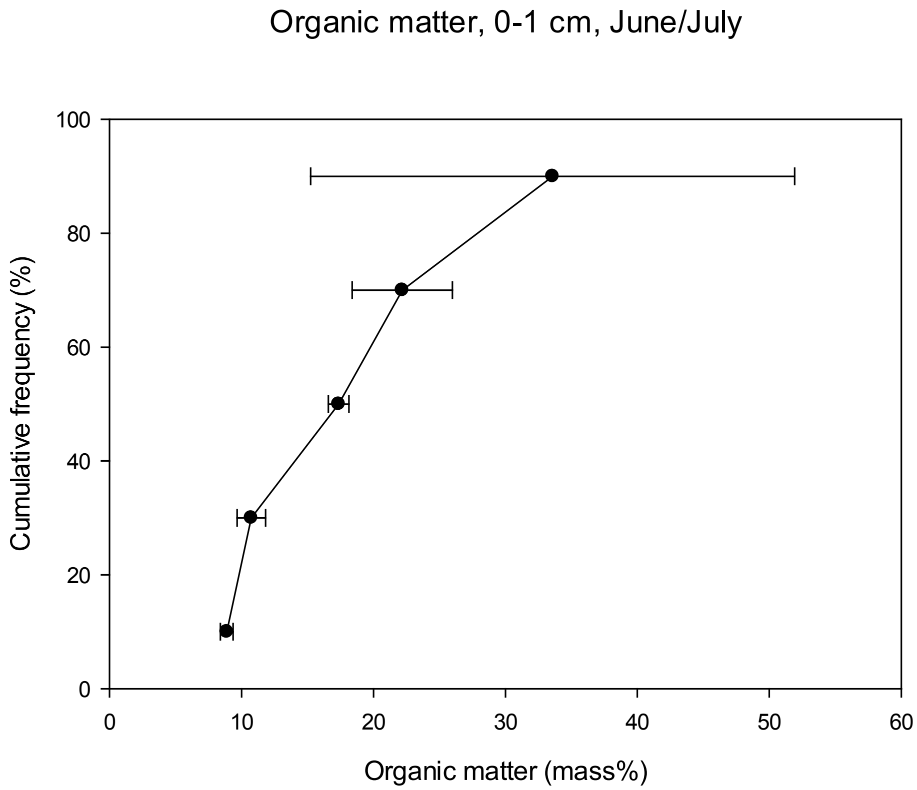

Figure 6.3 *Cumulative frequency distribution of the average organic matter content (n=5) in the five sampled watercourses of KER, ZUI, KAM, KNO and MOL (in order of increasing organic matter content) during June/July 2013. N.B. MOL not relevant for NL standard scenarios.*

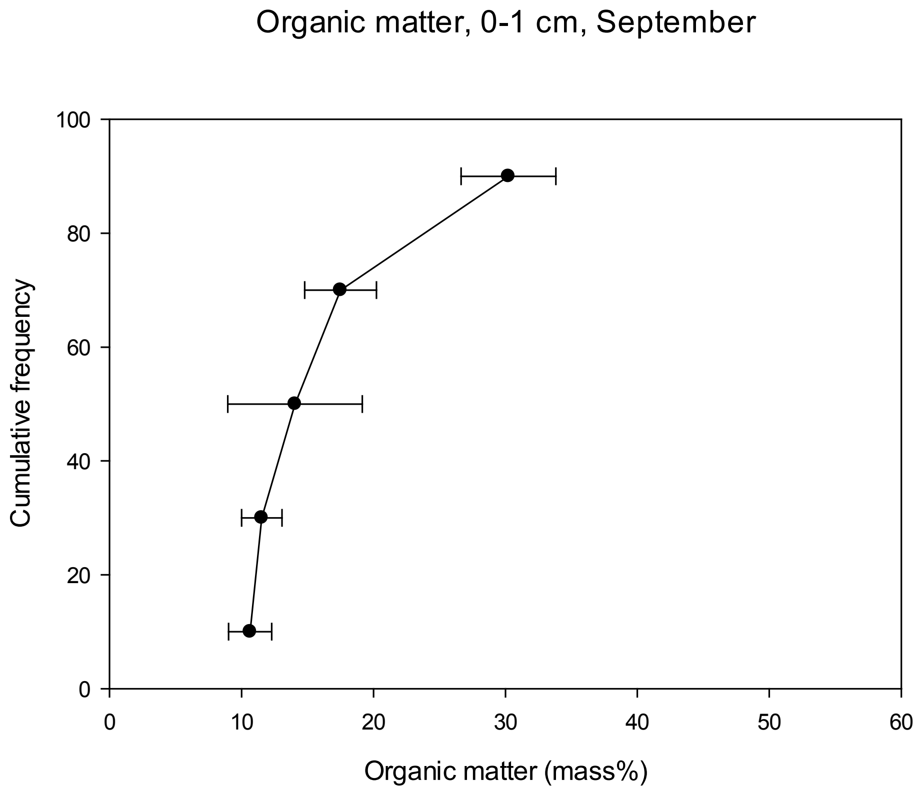

Figure 6.4 *Cumulative frequency distribution of the average organic matter content (n=5) in the five sampled watercourses of KER, MOL, ZUI, KAM and KNO (in order of increasing organic matter content) during September 2013. N.B. MOL not relevant for NL standard scenarios.*

The average porosity of the upper cm sediment ranges from 0.71 (KER, September) to 0.93 (KNO, June). It is relatively high for all five watercourses, compared to soil porosities (0.36 to 0.59, excluding peat soils) or to the porosity of the sediment in the Dutch arable farming and horticulture scenario under development (with downward spraying) or of the sediment in the EU FOCUS surface water scenarios (both 0.6).

Contrary to the bulk density and the organic matter content (MOL not considered), the ranking order of watercourses going from the lowest to the highest average porosity for the first sampling round of June/July is not equal to their ranking order for the second sampling round in September. A reason for this may be that the range of porosities for each sampling round (June/July or September) is narrower than the range of dry bulk densities and organic matter contents. Porosities range from 0.81 (ZUI) to 0.93 (KNO) in June/July and 0.71 (KER) to 0.85 (ZUI) in September, while dry bulk densities range from 0.19 (KNO) to 0.40 (KER) in June/July and 0.09 (KNO) to 0.30 (KER) in September and organic matter contents from 8.88% (KER) to 22.18% (KNO) in June/July and 10.65% (KER) to 30.23% (KNO) in September. This implies that e.g. an error in the value of a porosity is more likely to break the ranking order than an error of the same (relative) size in the value of the dry bulk density or organic matter content.

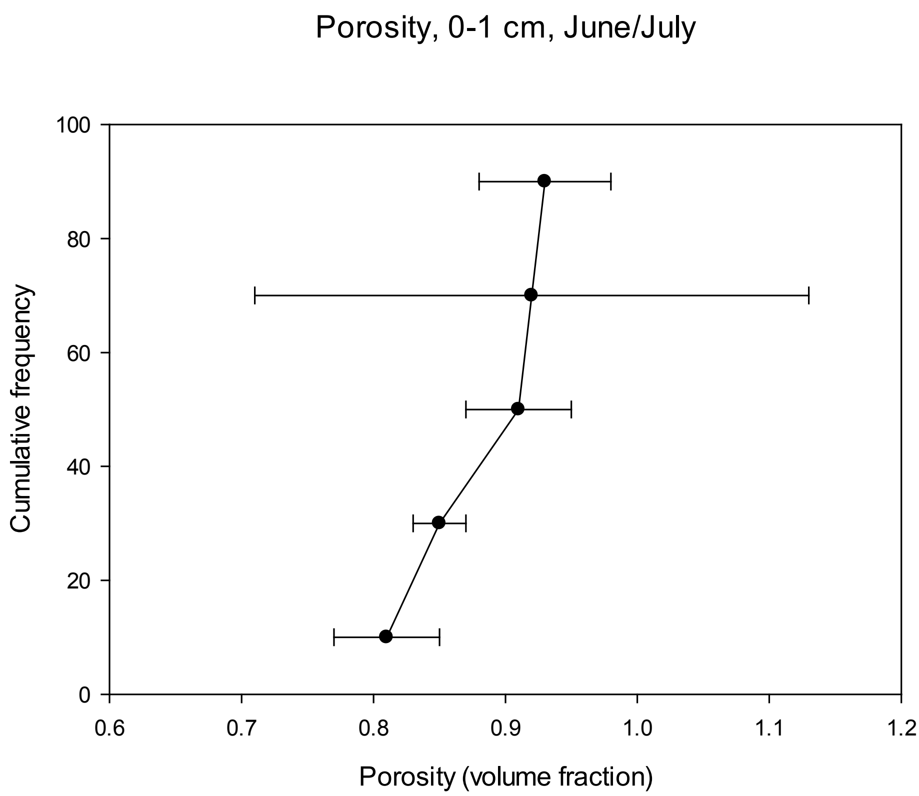

Figure 6.5 *Cumulative frequency distribution of the average porosity (n=5) in the five sampled watercourses of ZUI, MOL, KAM, KER and KNO (in order of increasing porosity) during June/July 2013. N.B. MOL not relevant for NL standard scenarios.*

Porosity, 0-1 cm, September

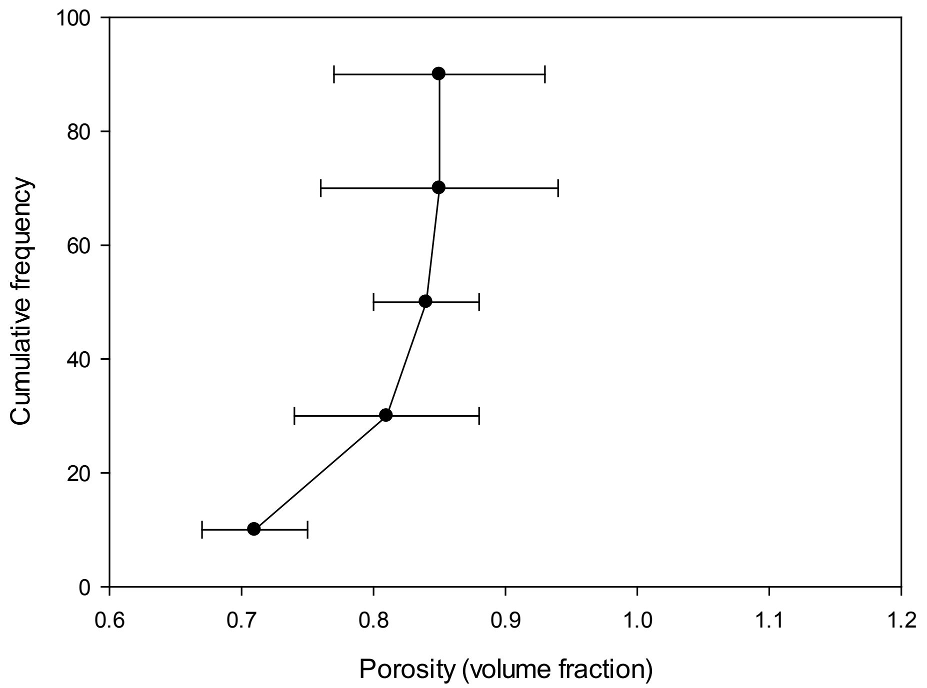

Figure 6.6 *Cumulative frequency distribution of the average porosity (n=5) in the five sampled watercourses of KER, MOL, KNO, KAM and ZUI (in order of increasing porosity) during September 2013. N.B. MOL not relevant for NL standard scenarios.*

6.4 Relation between sediment properties and other ditch characteristics

Table 6.6 presents soil cluster, watercourse type (primary or secondary) and timing of cleaning before the sediment sampling was done. The ranking of the sampling sites (first column of Table 6.6) corresponds (going downwards) to an increasing order of dry bulk density and a decreasing order of organic matter content. In spite of the low number of sampled watercourses, we analyse below whether there is an apparent relationship between the measured sediment properties of the sampled watercourses and other characteristics of these watercourses.

Table 6.6
Soil cluster, watercourse type and timing of cleaning for the five selected ditches.

Sampling site (in order of increasing bulk density)	Soil cluster (province)	Watercourse type primary: 3-6 m wide; secondary: 0.5-3 m wide	Timing of cleaning before June/July + September sampling round
KNO	Fine sand (NB)	Secondary	No + 3 months
MOL*	Silty loam & silty clay loam (NH)	Secondary	No + No
KAM	Silty loam & silty clay loam (IJss)	Primary	Approx. 3 weeks
ZUI	Silty loam & silty clay loam (NB)	Secondary	No + No ?
KER	Silty clay & clay (Gr)	Primary	4 weeks + 5 weeks

* ditch not fulfilling the criterion of carrying water all year round, so this ditch does not qualify for the population of ditches for NL standard scenarios.

Table 6.6 shows that increasing sediment dry bulk density corresponds to the ranking order in soil cluster Fine sand – Silty loam & silty clay loam – Silty clay and clay. However, this ranking order in soil cluster does not correspond to a ranking order in soil bulk density (Wösten *et al.,* 2001, compare bulk densities of Fine sand [Staring code B01 and B02], Silty loam & silty clay loam [Staring code B8 and B10] and Silty clay and clay [Staring code B11 and B12]), so we cannot state that the soil type of the area in which the watercourse is located influences the size of the dry bulk density.

In all watercourses cleaning is done by mowing or cutting/clipping the vegetation from the bottom and side walls (Table 3.1). So, there is no essential difference between the cleaning methods of the watercourses and the only important difference in cleaning between the watercourses is the timing. Table 6.6 shows that there is no apparent relation between timing and dry bulk density (or organic matter content) of the sampled watercourses.

7 Sediment properties of the experimental ditches in Renkum, The Netherlands

7.1 Introduction

In addition to the sediment properties of the five watercourses described in this study and located across The Netherlands there are data available from the experimental ditches at the experimental station De Sinderhoeve of Alterra, located in Renkum, The Netherlands. Their measured bulk density, organic matter content and porosity formed the basis for the parameterisation of the sediment properties in the scenarios that are currently used or under development in registration procedures in The Netherlands (and at EU level) (Beltman & Adriaanse, 1999; FOCUS, 2001; Tiktak *et al.,* 2012). Therefore, we here present these data and compare them to what we measured in this study.

Sediment properties were measured in a number of experimental ditches of the Sinderhoeve during two former experiments. These ditches are 40 m long, they have a water depth of 0.50 m, a bottom width of 1.65 m, a sediment layer of 0.25 m and the side slope is 3:2 (hor:vert). They intend to mimic Dutch drainage ditches with no or low flow. There is extensive growth of macrophytes in summer.

Sediment samples were taken in macrophyte-free sections of the ditches. Sampling and analysis was done as described in Chapter 5, except that (i) the Perspex sampling tubes had an inner diameter of 39 mm (instead of 59 mm), (ii) excess water on top of the sediment was not removed before freezing the cores, resulting in sediment frozen in the form of a cone, and (iii) the segments were cut by hand with the aid of a chisel from the frozen sediment cores pushed out of the tubes (instead of sawing the PVC tubes containing the sediment into segments). Below relevant experimental details are described and the main measured sediment properties are briefly presented. These properties are compared to the sediment properties found in the five sampled watercourses across The Netherlands of this research.

7.2 Results for 1990 during the chlorpyrifos experiment

After construction of the experimental ditches at the experimental station De Sinderhoeve (1988) the first experiment was done in 1990, with the compound chlorpyrifos, applied at 8 May. The sediment properties bulk density, organic matter content and porosity were measured in four ditches (Crum, S.J.H. pers. comm., 1999). The sediment was sampled at two locations in each ditch (at 6 and 34 m from the water inlet) at seven points in time (2, 7, 14 (in duplicate), 29, 56, 129 and 246 d post-application). The frozen sediment was cut into four segments: 0-1 cm, 1-3 cm, 3-6 cm and > 6 cm. For each segment the sediment properties were measured in each of the four ditches (Table 7.1).

Table 7.1
Bulk density, organic matter content and porosity in sediment segments. Values are averages of 16 measurements over time, with their standard deviations (uncorrected for expansion of water by freezing the samples before analysis).

Ditch No.	Segment (cm)	Bulk density ($g.ml^{-1}$)	Organic matter content (%)	Porosity (-)
6	0-1	0.68 ± 0.35	4.1 ± 2.8	0.64 ± 0.14
	1-3	1.44 ± 0.24	1.5 ± 0.5	0.39 ± 0.08
	3-6	1.55 ± 0.12	1.9 ± 1.0	0.36 ± 0.05
	below 6	1.52 ± 0.12	1.9 ± 0.5	0.35 ± 0.06
9	0-1	0.74 ± 0.34	3.9 ± 3.2	0.65 ± 0.11
	1-3	1.46 ± 0.23	1.8 ± 0.7	0.41 ± 0.07
	3-6	1.56 ± 0.09	1.8 ± 0.6	0.37 ± 0.05
	below 6	1.53 ± 0.08	2.0 ± 0.5	0.37 ± 0.04
4	0-1	0.55 ± 0.23	5.5 ± 2.8	0.69 ± 0.07
	1-3	1.47 ± 0.14	1.6 ± 0.5	0.39 ± 0.05
	3-6	1.57 ± 0.07	1.8 ± 0.3	0.36 ± 0.04
	below 6	1.58 ± 0.08	1.7 ± 0.3	0.34 ± 0.03
10	0-1	0.63 ± 0.27	3.7 ± 2.2	0.67 ± 0.12
	1-3	1.46 ± 0.10	1.5 ± 0.4	0.40 ± 0.05
	3-6	1.55 ± 0.12	1.8 ± 0.7	0.36 ± 0.06
	below 6	1.54 ± 0.11	1.8 ± 0.6	0.37 ± 0.05

For all four ditches there is an upper segment of 1 cm, with relatively loose material, where the bulk density ranges from 0.55 to 0.74 g/ml, the organic matter from 3.7 to 5.5% and the porosity from 0.64 to 0.69. The lower segments are more dense, having a bulk density ranging from 1.44 to 1.58 g/ml, an organic matter content of 1.5 to 2.0% and a porosity from 0.34 to 0.41.

7.3 Results for 1995 during the linuron experiment

In 1995 an experiment with linuron was performed during which the sediment properties bulk density, organic matter content and porosity were measured in two ditches at the experimental station De Sinderhoeve (Crum *et al.,* 1998). After applications on 9 May, 6 June and 4 July the ditches were kept stagnant for one week and thereafter fresh water was introduced at a velocity of approximately 5 m/d during three weeks. The sediment was sampled at five locations in each ditch (7, 13, 18, 26 and 35 m from the inlet) at 21 points in time (9, 10, 12, 15, 18, 22 and 29 May, 5, 6, 7, 9, 12, 15 and 22 June and 3, 5, 7, 10, 17, 24 and 31 July). The sediment cores were frozen and next divided into four segments (0-1 cm, 1-2 cm, 2-4 cm and >4 cm). For each segment the sediment properties were measured (Table 7.2).

Table 7.2
Bulk density, organic matter content and porosity in sediment segments. Values are averages of measurements over time (not corrected for freezing).

Sediment segment (cm)	Dry bulk density (g/ml)	Organic matter (mass %)	Porosity (-)
0-1	0.1	26	0.9
1-2	0.2	19	0.8
2-4	0.7	6	0.7
4-10	1.6	2	0.4

In the two sampled ditches the upper 2 cm form a loose layer, with bulk densities of 0.1 and 0.2 g/ml, organic matter contents of 26 and 19%, and porosities of 0.9 and 0.8. Below 2 cm the sediment is more dense, the bulk density increases to 0.7 and 1.6 g/ml, the organic matter content is 6% or lower and the porosities are 0.7 and 0.4. So, compared to the situation in the experimental ditches in 1990, the loose upper layer has grown thicker and contains significantly more organic matter.

7.4 Comparison between the experimental ditches and the four suitable watercourses

The sediment in the experimental ditches of 1990 is considerably more dense than the sediment found in the five watercourses across the Netherlands: their organic matter content is clearly lower, the bulk density is higher and the porosity somewhat lower, for the upper cm and especially for the lower segments (Table 7.3). The experimental ditches were constructed in 1987-1988 and thus, in 1990 the sediment had developed during two years. In 1988 a silty clay sediment was dredged from a mesotrophic pond and this was brought into the experimental ditches (Drent & Kersting, 1993). In 1989 macrophytes were present and their decay and deposition had probably increased the organic matter content of the upper cm of the sediment material brought from the pond in 1988.

In 1995 the properties of the upper 2 cm of the sediment of the two experimental ditches are within the range found for the upper 10 cm of the sediment of the five watercourses sampled in this study (Table 7.3). An additional five years had passed by since the chlorpyrifos experiment of 1990, during which macrophytes had developed in spring/summer and decayed in autumn/winter, resulting in plant debris and particulate organic matter deposited on top of the sediment; No dredging had taken palce (i.e. no sediment had been taken out in the period 1990-1995) and thus a thicker loose sediment layer was formed, in which the organic matter content had considerably increased. This indicates that probably the sampled watercourses of this study have also accumulated organic matter during a series of years, corresponding to what is stated in Table 3.1 in the column headed ‘Dredging’.

Table 7.3
Sediment properties for the five sampled watercourses (excl. MOL) and the experimental ditches in 1990 and 1995 for the segments indicated.

Ditches + segments	**Bulk density (g/ml)**	**Organic matter (mass %)**	**Porosity (-)**
Sampled this study (excl. MOL)			
0-1 cm	0.09-0.40	10-30	0.70-0.90
1-2	0.14-0.54	8.5-29.2	0.72-0.87
2-3	0.18-0.58	8.4-25.5	0.68-0.90
4 experimental ditches 1990			
0-1 cm	0.55-0.74	3.7-5.5	0.64-0.69
1-3	1.44-1.47	1.5-1.8	0.39-0.41
2 experimental ditches 1995			
0-1 cm	0.1	26	0.9
1-2	0.2	19	0.8

The properties of the sediment of the experimental ditches in 1990 and 1995 had not been corrected for the effect of freezing the samples before cutting them into segments. This will affect the calculated bulk density and porosity, but not the organic matter content (being a mass fraction). By not correcting for freezing, the volumes of the segments are overestimated, resulting in an underestimation of the calculated bulk density and porosity. The bulk densities of water and of ice are:

ρ_w = 1.0 g/cm^3 and ρ_{ice} = 0.917 g/ cm^3, resulting in a correction of volume ice to volume water in the segments by a factor of 0.917. So, we expect the underestimation of the bulk density and porosity to be maximally 8 to 9%. The exact size of underestimation depends on the ratio water to sediment material in the samples in the field. The exact values of the bulk density and porosity for all segments can be calculated with the aid of eqns 16 and 17 of section 4.2.

In addition to the effect of freezing the samples, we expect a considerable influence of the sampling technique used in the nineties on the reliability of the sediment properties calculated for the experimental ditches in Renkum. The formation of a cone in the frozen sediment samples makes it virtually impossible to cut the sample in horizontal slices, especially for the upper 0-1 cm and 1-3 segments. Moreover, cutting slices by hand with the aid of a chisel is not a very accurate way of subdividing the sediment core. We can try to obtain a quantitative assessment of the confidence in the results by considering the calculated standard deviations for the experimental ditches during the chlorpyrifos experiment. E.g. for the porosity of the 0-1 cm segment the standard deviations range from 0.07 to 0.14 for the ditches during the chlorpyrifos experiment, while they range between 0.04 to 0.09 for the four ditches of this study (excl. MOL and with one outlier of 0.21). One would expect the contrary, that is, the standard deviations for the ditches during the chlorpyrifos experiment would be considerably smaller, instead of larger, than those for the four ditches of this study, given the facts that (i) the number of replicates during the chlorpyrifos experiment are higher than during this study (n=16 vs n=5 in both sampling rounds), and (ii) the absolute values for the porosity are lower for the ditches during the chlorpyrifos experiment than for the four ditches of this study: 0.64-0.67 (chlorpyrifos experiment) vs 0.71-0.93 (this study). Note that point (i) alone would already result in standard deviations of a factor 2 lower for the chlorpyrifos experiment than those for this study (namely 0.50/0.26 ≈ 2, corresponding to $1/\sqrt{(5-1)}$ divided by $1/\sqrt{(16-1)}$, assuming the standard deviations have a normal distribution). In conclusion: as shown by the relatively large standard deviations (chlorpyrifos experiment) the sediment properties of the experimental ditches of 1991 and 1995 are clearly less reliable (especially for the 0-1 cm segment) than those obtained in the current study with the improved sampling technique, notwithstanding the lower number of replicates of the latter study.

8 Sediment properties in Dutch scenarios

8.1 Introduction

At present various scenarios are relevant for the aquatic risk assessment in the registration procedure of plant protection products in The Netherlands. Scenarios may be defined as 'unique combinations of agronomic and environmental conditions, that realistically represent significant areas within which conditions are relatively homogeneous with respect to modelling input parameters' (FOCUS, 1996). Since the end of the nineties two simple ditch scenarios are used by the Ctgb to estimate the exposure concentration in water. Currently, more realistic scenarios are defined by a Dutch Working Group, distinguishing between arable farming and horticulture (treated by downward spraying) and fruit trees and arboriculture (predominantly sideward and upward spraying). In this chapter the scenarios are briefly presented and their sediment composition is presented. Next, we present the process descriptions of the TOXSWA model (that is used in the Dutch aquatic risk assessment) and explain why it is not straightforward to predict how sediment properties influence the exposure concentration in the water of scenarios. Finally, we indicate what are the consequences of the differences in sediment between the Dutch scenarios and this study for registration purposes and we suggest further actions to develop scenarios with realistic sediment properties.

8.2 Dutch scenarios and comparison to the four suitable watercourses

In the current aquatic risk assessment of the registration procedure in The Netherlands two simple ditch scenarios are used by the Ctgb: a spring/summer scenario with a constant water flow of 10 m/d and an autumn scenario with a constant water flow of 100 m/d in the 300 m ditch, both with pesticides entering by spray drift deposition only. According to Beltman and Adriaanse (1999) the sediment properties of these current scenarios are based upon the sediment of the experimental ditches in Renkum, six years after finalisation of their construction and exposure to natural conditions, i.e. as measured during the linuron experiment. Table 8.1 below presents the sediment properties used in these scenarios as a function of depth.

Table 8.1
Sediment properties of the two simple ditch scenarios, currently used by the Ctgb.

Segment (cm)	Bulk density (g/ml)	Organic matter (mass %)	Porosity (-)
0-1	0.080	25	0.82
1-2	0.220	19	0.77
2-4	0.670	6	0.62
4-10	1.500	2	0.36

At present new, more realistic scenarios for the aquatic risk assessment are being developed by a Working Group with representatives of various Dutch ministries and the Ctgb. One of the main reasons for this is that the current scenarios have been developed more than ten years ago and do not incorporate the most recent developments, e.g. the evaluation of a drainage or runoff/erosion entry route into the watercourse, as do the FOCUS Surface Water Scenarios used at EU level for pesticide registration.

The scenario for evaluation of arable farming and horticulture, treated predominantly by downward spraying, has been described in Tiktak *et al.* (2012). Due to lack of data on sediment properties, the sediment in this scenario has been parameterised in the same way as the sediment of the FOCUS Surface Water Scenarios of the EU. This sediment has properties that have been based on the sediment of the experimental ditches of Alterra in Renkum during the linuron experiment (1995), but it was simplified into sediment with properties that are constant with depth. Table 8.2 presents these data.

Table 8.2
Sediment properties of the Dutch scenario under development (arable farming and horticulture, downward spraying; Tiktak et al., 2012).

Sediment segment (cm)	Bulk density (g/ml)	Organic matter (mass %)	Porosity (-)
0-10	0.800	9	0.60

Currently, the Working Group develops a scenario for fruit trees and arboriculture, treated predominantly by sideward and upward spraying. The Working Group has not yet decided upon the definition of the watercourse, including its sediment.

Table 8.3 summarizes the sediment properties of the sampled five watercourses (excl. MOL) and the scenarios for the 0-1 cm layer. The values show that the differences between the three cases are considerable, especially for the bulk density: between 0.09-0.40 g/ml for the sampled watercourses, 0.08 g/ml for the current Dutch scenarios and 0.800 g/ml. The organic matter content and porosity of the scenarios under development also differ considerably from those of the sampled watercourses (excl. MOL) of this study: 9% vs 10-30% for the organic matter content and 0.60 vs 0.70-0.90 for the porosity.

Table 8.3
Sediment properties for the five sampled watercourses (excl. MOL) and the Dutch scenarios, 0-1 cm depth.

Ditches	Bulk density (g/ml)	Organic matter (mass %)	Porosity (-)
Sampled (excl. MOL)	0.09-0.40	10-30	0.70-0.90
$NL_{current}$	0.08	25	0.82
NL_{devt}=EU	0.800	9	0.60

8.3 Influence of sediment properties on exposure in water as described by the TOXSWA model

The TOXSWA model (Adriaanse, 1996; Adriaanse, 1997) is applied to calculate exposure concentrations in water for the aquatic risk assessment in The Netherlands. Below we describe how the used process descriptions of TOXSWA influence the concentration in water.

In the TOXSWA model pesticide mass leaves the water layer and enters the sediment by diffusion described by eq. 18, in the absence of upward or downward seepage of water (Adriaanse, 1996):

$$J_{lb} = -\varepsilon D_{lb} \left(\frac{\delta c_{lb}}{\delta z}\right) \qquad \text{eq. 18}$$

with

J_{lb} = areic mass flux of substance in the liquid phase of the sediment by diffusion (g/(m^2.d)),
ε = porosity of sediment, i.e. volume of liquid divided by volume of sediment material (-),
D_{lb} = diffusion coefficient of substance in the liquid phase of the sediment (m^2/d),
c_{lb} = mass concentration of substance in the liquid phase of the sediment (g/m^3),
z = depth below the water-sediment interface (m).

Eq. 18 implies that the diffusion flux increases for increasing porosity ε. So, for increasing porosity an increasing pesticide mass will leave the water and enter the sediment and thus, the concentration in water will lower.

The concentration in sediment is described by eq. 19:

$$c*_b = \varepsilon c_{lb} + \rho_b X_b \qquad \text{eq.19}$$

For instantaneous sorption according to a linear isotherm eq. 19 equals

$$c*_b = \varepsilon c_{lb} + \rho_b m_{om,b} K_{om,b} c_{lb} \qquad \text{eq. 20}$$

With

c^*_b = mass concentration of substance in sediment (g/m^3),
ρ_b = bulk density of dry sediment material, i.e. volumic mass of dry sediment material (g/m^3),
$m_{om,b}$ = mass fraction of organic matter of the sediment material (g/g),
$K_{om,b}$ = slope of sorption isotherm, based on the organic matter content (m^3/g).

Eq. 20 implies that the pesticide mass sorbed onto the sediment matrix decreases for a decreasing product of bulk density and organic matter content, $\rho_b * m_{om,b}$, thus increasing the mass dissolved in the pores, εc_{lb} and thus decreasing the diffusion flux into the sediment. So, a decreasing product of bulk density times organic matter content, $\rho_b * m_{om,b}$, is associated with a decreasing diffusion flux into the sediment and thus, a decreasing mass leaving the water and a higher remaining concentration in water.

For the high porosities ε measured for the five watercourses (excl. MOL) that are associated to the measured relatively low bulk densities ρ_b (Table 8.3), eqns 18 and 20 imply that two opposing trends occur. Thus, it is not possible to simply predict the effect of the sediment properties as measured in the five watercourses (excl. MOL) of this study on the exposure concentration in water of the Dutch scenarios under development. For the Dutch scenarios currently used by the Ctgb we expect relatively small differences, as their organic matter content and porosity lie within the range measured in this study (25 vs 10-30% and 0.82 vs 0.70-0.90) and their bulk densities are close the values measured in this study (0.08 vs 0.09-0.40 g/ml, Table 8.3).

8.4 Consequences for registration

As explained above it is not possible to predict the effect of the sediment properties as measured in the five watercourses (excl. MOL) of this study on the exposure concentration in the overlying water layer of the Dutch scenarios under development and, to a lesser extent, of the scenarios currently used by the Ctgb. So, we do not know whether the Dutch scenarios result in realistic exposure concentrations.

TOXSWA model calculations provide insight into the quantitative effect of sediment properties on the exposure concentration in water and thus, the calculations can indicate whether the exposure concentrations in the Dutch scenarios are underestimated or overestimated. Therefore, we propose to perform a limited sensitivity analysis to quantify the effect of sediment properties on the selected target concentration in water and/or sediment. Next to the three sediment properties, other factors need to be considered in this analysis, such as the sorption coefficient, K_{om}, the degradation rate in water and the number of applications, as they all influence the penetration into sediment and thus the effect on the concentration in water.

9 General discussion, conclusions and recommendations

9.1 Discussion and conclusions

Selection of watercourses
In this study one of the main criteria to select watercourses within the arable farming and horticulture scenario domain across The Netherlands has been soil type, clustered into a limited number. Although flow velocity of water in the watercourse may also be a relevant criterion, this has not been considered, firstly, because flow velocity is a difficult parameter to operationalise, while it varies strongly in time and is not routinely measured in the small watercourses we focus on, and secondly, because it is too costly and time-consuming to measure in the framework of this study.

Only five watercourses have been selected. Because of this limited number of watercourses this study should be seen as giving an indication of sediment properties in watercourses of the arable farming and horticulture scenario domain across The Netherlands, rather than a comprehensive overview.

Sediment sampling technique and analysis methods
The sediment sampling technique was considerably improved compared to the former technique used by Alterra. By using wider sampling cores (59 mm inner diameter instead of 39 mm), freezing the sediment cores without cone forming on top and dividing the core into segments with a belt saw instead of a chisel the sampling accuracy has been clearly improved (see Chapters 5 and 7.4 for more details).

The sediment samples contain 50% water or more. Water expands during freezing and therefore we corrected the volumes of the sediment segments. In this way we avoided an underestimation of the bulk density and porosity of up to 8-9% (organic matter content is a mass fraction, thus not affected). This improvement in sediment analysis is applied by the authors' Alterra team from now on (see Chapter 7.4 for more details).

Because the lowest 1 mm of the 1 cm segments is lost by sawing, we obtain sediment properties for the upper 9 mm only (e.g. from 0-9 mm instead of 0-10 mm depth and 10-19 mm instead of 10-20 mm). As the sediment properties are a function of depth this means that the obtained results will not truly reflect the sediment properties of the indicated segment sizes. The effect is greater for smaller segments.

Sediment properties
As stated above only five watercourses have been sampled and therefore the results presented below are only indicative.

The four suitable watercourses (so, excl. MOL) distributed across the Netherlands have sediment with a relatively low dry bulk density and a high organic matter content and porosity. These properties vary relatively little with depth. The upper cm of sediment of the four watercourses (MOL excluded, because it had almost run dry in September) has a bulk density ranging from 0.09 to 0.40 g/ml, while for the lower 5-10 cm sediment the numbers are 0.37 to 0.66 g/ml. For the porosity the numbers range from 0.71 to 0.93 for the upper cm and 0.75 to 0.84 for the 5-10 cm segment and for the organic matter content they range from 8.9 to 30.2% and 6.5 to 22.6% (June/July and September sampling rounds combined for all three properties).

The measured sediment properties confirm that the sediment sampling technique and analysis methods are adequate: (i) standard deviations are relatively small (Tables 6.1-6.5 and Chapter 7.4), (ii) the ditch ranking order (in size of dry bulk density and organic matter content for the upper cm) does not change with season and (iii) the bulk density increases and the organic matter content decreases with depth in most cases. The latter phenomenon is as expected, in view of the long-yearly settling of water plant debris on top of the sediment and the fact that the phase density of organic matter is smaller than the phase density of mineral matter, $\rho_{om} < \rho_{min}$.

In some cases the sediment properties vary greatly between the individual samples in the watercourse. This is observed to be caused by local changes in composition of the sediment, e.g. visible plant debris in the KAM watercourse (Table 6.1) where one of the five sediment cores had in its deeper segment (5-10 cm) an organic matter content of 44.2% (July) and 53.6% (September), while the four other segments had organic matter contents of approximately 13-17% (July) and 14-16% (September) (Annex 6 and 7). This is the reason that the standard deviations are extremely high for the 5-10 cm segment of the KAM watercourse (13.1% in July and 17.4% in September).

For the four suitable watercourses dry bulk densities of the upper cm of sediment slightly decreased and the organic matter content increased from June/July to September. Dry bulk densities decreased from 0.19 – 0.40 g/ml down to 0.09 – 0.30 g/ml, while the measured organic matter content in this 0-1 cm segment increased from 8.9 – 22.2% in June/July to 10.7 to 30.2% in September. This is probably caused by deposition of water plants debris on top of the sediment. There was no apparent relationship between timing of cleaning of the watercourse and the sediment properties.

In 1990 the sediment in the experimental ditches in Renkum is considerably more dense than the sediment found in the four suitable watercourses of this study. In 1995 the properties of the upper 2 cm of the sediment of two experimental ditches are within the range found for the upper 10 cm of the sediment of the four suitable watercourses of this study, probably due to long-yearly accumulation of plant debris and particulate organic matter on top of the sediment, that happened both in the experimental ditches as in the watercourses of this study.

The results for the experimental ditches were not corrected for the effect of expansion of water during freezing, therefore, we expect an underestimation of their bulk density and porosity of maximally 8 to 9%. Way of freezing and cutting the frozen sediment cores into segments (with a chisel) resulted in higher standard deviations for sediment properties of the experimental ditches (chlorpyrifos experiment of 1990) compared to those of this study, while in view of the sampling numbers the standard deviations of the experimental ditches in 1990 are expected to be at least a factor 2 smaller. (For more details, see Chapter 7.4.).

In literature we found sediment dry bulk density and organic matter content in ponds used for aquaculture. Munsiri *et al.* (1995) proposed to subdivide pond sediment into horizons, of which he defined the upper three as: the F-horizon (Flocculent layer, often lost while pushing (unfrozen) sediment out of the sampling core from below), the S-horizon (Stirred or well-mixed layer of sediment with a bulk density of 0.3 g/ml or less) and a M-horizon (Mature, bulk, unmixed, deeper sediment layer). He reported dry bulk densities of 0.26-0.31 g/ml for the S-horizon and 0.40-0.52 for the M-horizon of fishpond bottom soils in Auburn, Alabama (USA), which corresponds well to the magnitude we found for the upper 3 to 5 cm sediment in our samples.

In Thailand, Wudtisin & Boyd (2006) studied three types of fishponds. These ponds are allowed to dry at about 2-yearly intervals, with sediment being removed manually. They found means and standard deviations of 0.17 ± 0.10 g/ml in 42 catfish ponds, 0.18 ± 0.06 g/ml for 40 freshwater prawn ponds and 0.28 ± 0.07 g/ml for 18 carp ponds for the S-horizon being 19.9 ± 18.5 cm, 11.9 ± 9.7 cm and 33.4 ± 16.6 cm thick, respectively. So, these values correspond well with the values found by us in the Dutch ditches. They found organic carbon contents (multiply by 1.724 to obtain organic matter contents) of 1.20 ± 0.66%, 1.07 ± 0.36% and 2.08 ± 1.06% for the same ponds. In view of our results it is astonishing that such low organic matter contents are associated to the reported, low bulk densities in these ponds.

Implications for aquatic risk assessment procedure in The Netherlands
The results of this study indicate that the sediment in relevant watercourses distributed across The Netherlands is more loose than the one used in the arable farming and horticulture scenario under development, i.e. the sediment of this study has a lower bulk density, higher organic matter content and higher porosity for its upper cm: 0.09-0.40 vs 0.80 g/ml, 10-30 vs 9% and 0.70-0.90 vs 0.60,

respectively. Differences with the ditch scenario currently used by the Ctgb are smaller: 0.09-0.40 vs 0.08 g/ml for bulk density, 10-30 vs 25% for organic matter content and 0.70-0.90 vs 0.82 for porosity. As the sediment properties influence penetration into sediment in opposite ways (Chapter 7.3), we cannot predict the effect of the measured sediment properties of this study on the exposure concentration in the overlying water of the Dutch scenarios. So, we cannot predict whether the Dutch scenarios result in an underestimation of overestimation of risks for the aquatic ecosystem.

Finally, one should realise that exposure concentrations in water are not independent of exposure concentrations in sediment: a high exposure in water is generally associated to a low exposure in sediment. So, a low risk in water may often be associated to a high risk in sediment. As the EFSA is currently developing guidance for risk assessment of sediment-dwelling organisms, using realistic sediment properties is also important for this purpose.

9.2 Recommendations

Follow up of this study

To increase the scientific underpinning of the parameterisation of the sediment in the Dutch scenarios under development we recommend to:

- Sample more than the current five watercourses out of the arable farming and horticulture scenario domain to make a sound frequency distribution of the three sediment properties bulk density, organic matter content and porosity and
- Sample watercourses out of the fruit trees and arboriculture scenario domain to make a frequency distribution of the three sediment properties to parameterise the sediment of the fruit trees and arboriculture scenario under development.

In addition we recommend to perform a limited sensitivity analysis to assess whether the current sediment parameterisation of the Dutch scenarios result in an underestimation or overestimation of the exposure concentration in water and/or sediment.

Selection of watercourses

We recommend not to select dead-end watercourses in any future study, as these are liable to run (almost) dry in the course of the growing season, as did the MOL watercourse in this study.

Sediment sampling technique and analysis methods

We have no recommendations, as sampling techniques and analysis methods were explicitly studied before starting the work, resulting in considerable improvements with respect to former practices at Alterra (for more details see Chapter 5 and 7.4).

Sediment properties

We recommend to maintain two sampling rounds in the watercourses, one early in the growing season (around April) and one late (around September) to obtain insight in changes of sediment properties during the most important period of use of pesticides.

We recommend to sample a limited number of watercourses during winter and spring, in order to obtain insight in the dynamics of sediment properties before and after the main growing season, including the influence of cleaning practices and flow velocities.

Implications for registration procedure in The Netherlands

The present situation is that measured sediment properties of four suitable watercourses of this study differ considerably from those used in the Dutch surface water scenarios (used currently in the registration procedure, as well as scenarios under development). Therefore we recommend to perform TOXSWA model calculations to assess whether the exposure concentrations in water of the Dutch scenarios are underestimated or overestimated on the basis of their present sediment properties.

Only four watercourses within the arable farming and horticulture scenario domain have been sampled and no watercourses have been sampled within the fruit trees and arboriculture scenario domain. To enhance the scientific underpinning of the sediment parameterisation in the Dutch scenarios, we recommend to sample more watercourses within the arable farming and horticulture scenario domain and to also sample watercourses within the fruit trees and arboriculture scenario domain. This will result in frequency distributions of the three sediment properties which will enable a well-founded parameterisation of the sediment in the Dutch scenarios under development.

Finally, we recommend to compare measured concentration profiles in sediment of selected pesticides to profiles simulated by the TOXSWA model for situations relevant for the aquatic risk assessment. This could be done by experiments in e.g. two simplified cosms with clearly different sediment for a few pesticides with low degradation rates and clearly different sorption capacities. This has not yet been done, while it is important to create confidence in TOXSWA's results by published studies.

In view of the current EFSA activities with regard to designing guidance for risk assessment of sediment-dwelling organisms, the recommendations made above are also useful for a future sediment risk assessment in The Netherlands.

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Annex 1 Description of the Staring soil series: upper horizons and lower horizons

Classification according to texture (in % of mineral parts), organic matter content (in % of soil) and median of the fraction sand (M50) of the Staring Soil Series according to the texture terminology of the soil classification system of The Netherlands plus the number of measured relationships on which the average values have been based.

BOVENGRONDEN

Bouwsteen		Leem (%)	Lutum (%)	Organische stof (%)	M50 (μm)	Aantal (-)
Zand						
B1	leemarm, zeer fijn tot matig fijn zand	0- 10		0- 15	105- 210	32
B2	zwak lemig, zeer fijn tot matig fijn zand	10- 18		0- 15	105- 210	27
B3	sterk lemig, zeer fijn tot matig fijn zand	18- 33		0- 15	105- 210	14
B4	zeer sterk lemig, zeer fijn tot matig fijn zand	33- 50		0- 15	105- 210	9
B5	grof zand			0- 15	210-2000	26
B6	keileem	0- 50		0- 15	50-2000	8
Zavel						
B7	zeer lichte zavel		8- 12	0- 15		6
B8	matig lichte zavel		12- 18	0- 15		43
B9	zware zavel		18- 25	0- 15		29
Klei						
B10	lichte klei		25- 35	0- 15		12
B11	matig zware klei		35- 50	0- 15		13
B12	zeer zware klei		50- 100	0- 15		9
Leem						
B13	zandige leem	50- 85		0- 15		10
B14	siltige leem	85- 100		0- 15		67
Moerig						
B15	venig zand		0- 8	15- 25		15
B16	zandig veen en veen		0- 8	25- 100		20
B17	venige klei		8- 100	16- 45		25
B18	kleiig veen		8- 100	25- 70		20

ONDERGRONDEN

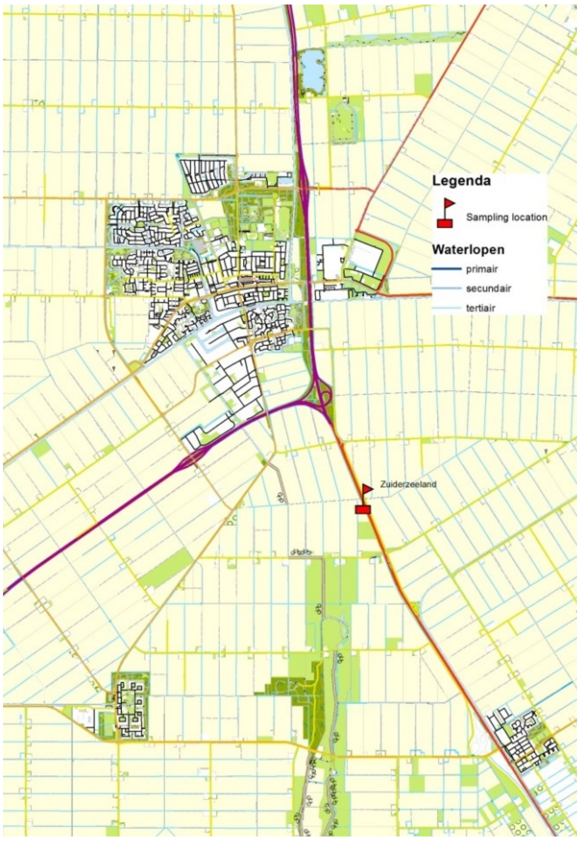
Bouwsteen		Leem (%)	Lutum (%)	Organische stof (%)	M50 (µm)	Aantal (-)
Zand						
01	leemarm, zeer fijn tot matig fijn zand	0- 10		0- 3	105- 210	109
02	zwak lemig, zeer fijn tot matig fijn zand	10- 18		0- 3	105- 210	14
03	sterk lemig, zeer fijn tot matig fijn zand	18- 33		0- 3	105- 210	23
04	zeer sterk lemig, zeer fijn tot matig fijn zand	33- 50		0- 3	105- 210	9
05	grof zand			0- 3	210-2000	17
06	keileem	0- 50		0- 3	50-2000	15
07	beekleem	33- 50		0- 3	50- 150	15
Zavel						
08	zeer lichte zavel		8- 12	0- 3		14
09	matig lichte zavel		12- 18	0- 3		30
010	zware zavel		18- 25	0- 3		25
Klei						
011	lichte klei		25- 35	0- 3		11
012	matig zware klei		35- 50	0- 3		25
013	zeer zware klei		50- 100	0- 3		19
Leem						
014	zandige leem	50- 85		0- 3		9
015	siltige leem	85- 100		0- 3		53
Veen						
016	oligotroof veen			35- 100		16
017	mesotroof en eutroof veen			35- 100		36
018	moerige tussenlaag			15- 35		7

Annex 2 The selected five sampling sites: overview of sampled soil clusters and location of sampling sites

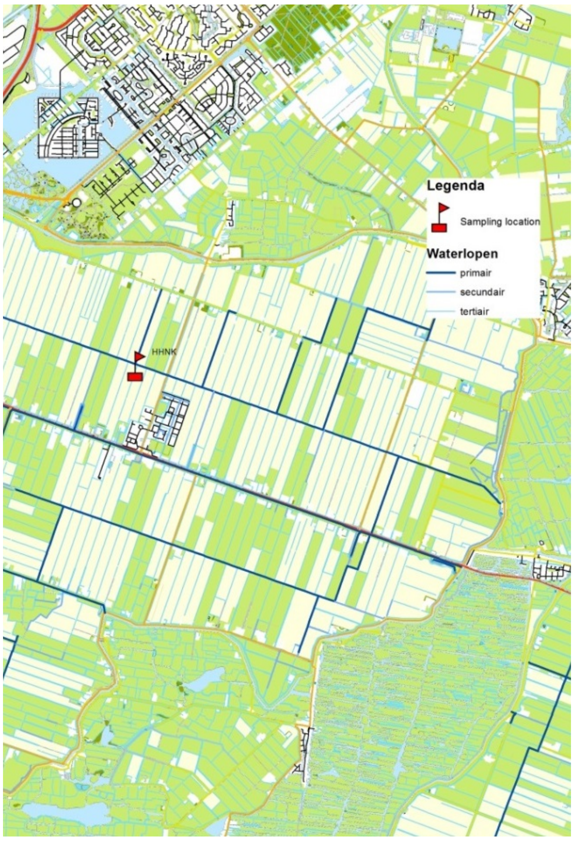
Location	Waterboard	Soiltype	X_Coor-dinate	Y_Coor-dinate	Town	Sample code	Hydrotype	Width m	Water-board
1	Aa en Maas	**Fine sand**	171551	404524	Uden	KNO	Nuenengroep	0,5 -3	yes
2	Zuiderzeeland	**Silt loam and silty clay loam**	181975	521125	Emmeloord	KAM	Westland-DH	>6	yes
3	HHNK	**Silt loam and silty clay loam**	116537	514985	Stompetoren	MOL	Westland-C	0,5 -3	no
4	Brabantse Delta	**Silt loam and silty clay loam**	90142	409629	Willemstad	ZUI	Westland-DHC	0,5 -3	yes
5	Hunze en Aas	**Heavy clay**	261801	584506	Niewolda	KER	Westland-DH	3-6	yes

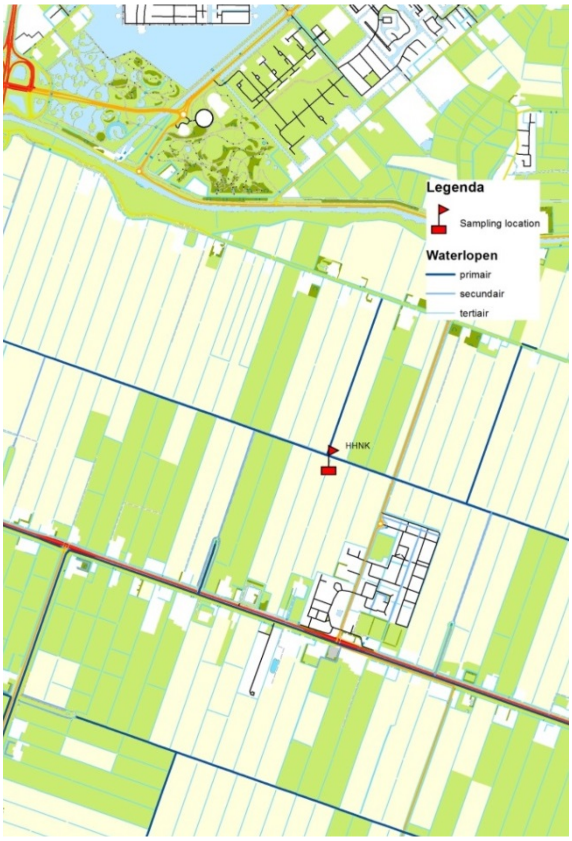
1 Aa en Maas (sampling site code KNO)

2 Zuiderzeeland (sampling site code KAM)



3 HHNK (sampling site code MOL)





4 Brabantse Delta (sampling site code ZUI)

5 Hunze en Aa's (sampling site code KER)

Annex 3 Forms describing the sediment sample sites during the first sampling round (June/July 2013)

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	12 jun 2013	Time (local)	14 00
Latitude	51° 37.760'	Longitude	5° 37.575'
Crop N/E side	maize	Crop S/W side	maize
At distance (m)	27.7	At distance (m)	1.82
Edge vegetation	grass+road+trees	Edge vegetation	grass
Location code	KNO	number of samples	5
Location name	Knokerweg	Distance between samples (m)	20
Owner		Waterboard contact	Aa en Maas

Characteristics ditch

Top width (m)	3.77	Total Depth (m)	± 1.0
Width at water level (m)	1.55	Water depth (m)	0.21
Slope width N/E (m)	1.12	Slope width S/W (m)	1.07
Cleaned when		Flowing (y/n)	slow, south
Cleaning method		Weir present (y/n)	N
pH (2x)	6.36 5.78	T (2x)	13.7 13.6
Sample 1*	East geen macrofyten, algen, ijzer		
Sample 2*	Midde "		
Sample 3*	West "		
Sample 4*	Middle "		
Sample 5*	East "		

* which side, presence/type macrophytes, other remarks

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	4/7/13	Time (local)	14:30
Latitude	52° 40.614'	Longitude	5° 47.163'
Crop N/E side	winterwheat	Crop S/W side	? see picture
At distance (m)	0.8	At distance (m)	2.90
Edge vegetation	grass / riet	Edge vegetation	grass / riet
Location code	KAM	number of samples	5
Location name	Kamperweg	Distance between samples (m)	20
Owner	waterboard	Waterboard contact	

Characteristics ditch

Top width (m)	13.65	Total Depth (m)	± 2.20
Width at water level (m)	5.5	Water depth (m)	± 0.80
Slope width N/E (m)	3.80	Slope width S/W (m)	3.80
Cleaned when		Flowing (y/n)	N
Cleaning method		Weir present (y/n)	Y
pH (2x)	—	T (2x)	—
Sample 1*	E 1 m from side		
Sample 2*	E some lovoos on side		
Sample 3*	E samples taken in wider part		
Sample 4*	W of ditch		
Sample 5*	W		

(all samples)

* which side, presence/type macrophytes, other remarks

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	25/7/2013	Time (local)	14 30
Latitude	53. 14.188	Longitude	6 59.211
Crop N/E side	wintertarwe	Crop S/W side	wintertarwe
At distance (m)	1.20	At distance (m)	1.50
Edge vegetation	gras	Edge vegetation	gras
Location code	KER	number of samples	5
Location name	Kerkelaan	Distance between samples (m)	20
Owner	waterschap	Waterboard contact	

Characteristics ditch

Top width (m)	8.30	Total Depth (m)	± 2.0 to water level
Width at water level (m)	4.20	Water depth (m)	± 0.55
Slope width N/E (m)	2.00	Slope width S/W (m)	1.95
Cleaned when	–	Flowing (y/n)	N
Cleaning method	–	Weir present (y/n)	N
pH (2x)	8.90 8.88 9.20 8.76	T (2x)	20.0 x4 ?
Sample 1*	N algen en beetje kroos		
Sample 2*	M		
Sample 3*	N		
Sample 4*	S		
Sample 5*	S		

* which side, presence/type macrophytes, other remarks

calibration temperature?

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	4/7/13	Time (local)	11:30
Latitude	52° 37.262'	Longitude	4° 49.153
Crop N/E side	sugarbeets	Crop S/W side	winter wheat
At distance (m)	0.5	At distance (m)	± 1.0
Edge vegetation	grass	Edge vegetation	grass
Location code	MOL	number of samples	5
Location name	Korte Molenweg	Distance between samples (m)	20
Owner		Waterboard contact	Jos Schilder HHNK

Characteristics ditch

Top width (m)	5.60	Total Depth (m)	± 1.60
Width at water level (m)	1.64	Water depth (m)	± 0.25
Slope width N/E (m)	2.02	Slope width S/W (m)	1.80
Cleaned when	autumn 2012	Flowing (y/n)	N
Cleaning method	maaikorf	Weir present (y/n)	N
pH (2x)	—	T (2x)	—
Sample 1*	E wat zegge en lis	all samples	
Sample 2*	M miniem kroos		
Sample 3*	W aanvoer vanuit tocht		
Sample 4*	M loopt dood		
Sample 5*	E		

*which side, presence/type macrophytes, other remarks

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	24/7/2013	Time (local)	1445
Latitude	51 40. ~~007~~ 030 38	Longitude	4 26. ~~671~~ 965
Crop N/E side	bieten	Crop S/W side	mais
At distance (m)	0.70	At distance (m)	0.80
Edge vegetation	grass	Edge vegetation	grass
Location code	2W1	number of samples	5
Location name	Zuidlangeweg	Distance between samples (m)	20
Owner	waterschap	Waterboard contact	

Characteristics ditch

Top width (m)	5.94	Total Depth (m)	1.30 to water level
Width at water level (m)	2.50	Water depth (m)	0.50
Slope width N/E (m)	1.35	Slope width S/W (m)	2.04
Cleaned when	–	Flowing (y/n)	N
Cleaning method	–	Weir present (y/n)	N
pH (2x)	7.32 7.27 7.31	T (2x)	20.0 20.0 20.0
Sample 1*	E niet op oever		
Sample 2*	W kroos in water		
Sample 3*	M		
Sample 4*	W		
Sample 5*	E		

* which side, presence/type macrophytes, other remarks

Annex 4 Forms describing the sediment sample sites during the second sampling round (September 2013)

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	24/9/2013	Time (local)	14^00
Latitude		Longitude	
Crop N/E side	maize	Crop S/W side	maize
At distance (m)		At distance (m)	
Edge vegetation		Edge vegetation	
Location code	KNO	number of samples	5
Location name	Knoherdweg	Distance between samples (m)	20
Owner		Waterboard contact	

Characteristics ditch

Top width (m)		Total Depth (m)	
Width at water level (m)		Water depth (m)	
Slope width N/E (m)		Slope width S/W (m)	
Cleaned when	not yet	Flowing (y/n)	Yes, south
Cleaning method		Weir present (y/n)	
pH (2x)		T (2x)	
Sample 1*	E		
Sample 2*	M		
Sample 3*	W		
Sample 4*	M		
Sample 5*	E		

* which side, presence/type macrophytes, other remarks

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	25/9/2013	Time (local)	15[20]
Latitude		Longitude	
Crop N/E side	—	Crop S/W side	sugar beets
At distance (m)		At distance (m)	
Edge vegetation		Edge vegetation	
Location code	KAM	number of samples	5
Location name	Kamperweg	Distance between samples (m)	20
Owner		Waterboard contact	

Characteristics ditch

Top width (m)		Total Depth (m)	
Width at water level (m)		Water depth (m)	~~almost dry~~
Slope width N/E (m)		Slope width S/W (m)	
Cleaned when	no	Flowing (y/n)	N
Cleaning method		Weir present (y/n)	
pH (2x)		T (2x)	
Sample 1*	E		
Sample 2*	E		
Sample 3*	E		
Sample 4*	W		
Sample 5*	W		

* which side, presence/type macrophytes, other remarks

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	25/9/2013	Time (local)	18⁰⁰
Latitude		Longitude	
Crop N/E side	sugar beets	Crop S/W side	—
At distance (m)		At distance (m)	
Edge vegetation		Edge vegetation	
Location code	MOL	number of samples	5
Location name	Korte Molenweg	Distance between samples (m)	20
Owner		Waterboard contact	

Characteristics ditch

Top width (m)		Total Depth (m)	
Width at water level (m)		Water depth (m)	Almost dry
Slope width N/E (m)		Slope width S/W (m)	
Cleaned when	not yet	Flowing (y/n)	N
Cleaning method		Weir present (y/n)	
pH (2x)		T (2x)	
Sample 1*	E		
Sample 2*	M		
Sample 3*	W		
Sample 4*	M		
Sample 5*	E		

* which side, presence/type macrophytes, other remarks

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	24/9/2013	Time (local)	16 30
Latitude		Longitude	
Crop N/E side	sugar beets	Crop S/W side	maize
At distance (m)		At distance (m)	
Edge vegetation		Edge vegetation	
Location code	ZWi	number of samples	5
Location name	Zuidlangeweg	Distance between samples (m)	20
Owner		Waterboard contact	

Characteristics ditch

Top width (m)		Total Depth (m)	
Width at water level (m)		Water depth (m)	
Slope width N/E (m)		Slope width S/W (m)	
Cleaned when	not yet	Flowing (y/n)	N
Cleaning method		Weir present (y/n)	
pH (2x)		T (2x)	
Sample 1*	E		
Sample 2*	W		
Sample 3*	M		
Sample 4*	W		
Sample 5*	E		

* which side, presence/type macrophytes, other remarks

Description sample location sediment sampling **Alterra project 5240375**

Location

Date	25/9/2013	Time (local)	11 30
Latitude		Longitude	
Crop N/E side	koolzaad	Crop S/W side	—
At distance (m)		At distance (m)	
Edge vegetation		Edge vegetation	
Location code	KER	number of samples	5
Location name	Kerkelaan	Distance between samples (m)	20
Owner		Waterboard contact	

Characteristics ditch

Top width (m)		Total Depth (m)	
Width at water level (m)		Water depth (m)	
Slope width N/E (m)		Slope width S/W (m)	
Cleaned when	not yet	Flowing (y/n)	N
Cleaning method		Weir present (y/n)	
pH (2x)		T (2x)	
Sample 1*	N		
Sample 2*	M		
Sample 3*	N		
Sample 4*	S		
Sample 5*	S		

* which side, presence/type macrophytes, other remarks

Annex 5 Calculation example of dry bulk density and porosity of sediment samples, corrected for freezing after sampling

In the laboratory slices of 1 cm frozen sediment were cut and next defrozen. The volume of the frozen sediment was 11.9 cm^3. In the melted sediment sample 7.5 g of water and 10.0 g solid phase had been measured. We know that ρ_{water} and ρ_{ice} are 1.0 and 0.917 g/cm^3, respectively.

The volume of the 7.5 g water equals 7.5 cm^3 of water and 7.5/ρ_{ice} = 7.5 g/0.917 g/cm^3 = 8.2 cm^3 in the frozen sample. So, the total volume of the sample in the field was 8.2-7.5=0.7 cm^3 smaller than the volume of the frozen sample. So, in the field we had 11.9-0.7=11.2 cm^3, which consisted of 7.5 g water and 10.0 g solid phase.

Therefore, the porosity in the field was 7.5 cm^3/11.2 cm^3 = 0.67, so a volumic % of 67. The dry bulk density in the field was 10.0 g/11.2 cm^3 = 0.89 g/cm^3. In addition we can calculate the bulk density of the solid phase: 10.0 g was contained in 11.9-8.2= 3.7 cm^3, so ρ_s = 2.7 g/cm^3. Mark that these values are not related to the upper centimeter in the field, but to a smaller slice: the 11.9 cm^3 frozen sample was 11.2 cm^3 in the field, so the height of the sampled slice in the field was 11.2/11.9 times the 1 cm, i.e. 0.94 cm.

Annex 6 Results of laboratory analysis and calculation of dry bulk density, porosity and organic matter content for five locations in June/July 2013

(Analysis by Crum and Elbers. Results corrected for freezing. Inner diameter of sampling core is 59.4 mm. N.B. Sampling site first form below is KAM and not KNO as stated.)

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datum	10-jul-13			
project nummer	5240375			
soort monsters	KAM			
naam uitvoerder	Elbers / Crum			

Average	0.23	0.91	17.36
	0.34	0.87	17.75
	0.38	0.89	21.60
	0.40	0.82	18.06
	0.38	0.84	20.85
SD	0.05	0.04	0.78
	0.06	0.02	2.34
	0.10	0.08	5.31
	0.17	0.07	5.93
	0.10	0.04	13.14

sample	depth (cm)	volume	volume	volume	mass (g)	mass (g)	mass (g)	mass (g)	mass (g)	number	mass (g)	mass (g)	mass (g)	bulk	volume	ignition
code		layer (ml)	water	sample	alu tray	alutray + wet sample	alutray + dry sample	dry matter	water	cup	cup	cup+sample	cup+sample	density	fraction	loss
			frozen (ml)	defrozen (ml)	empty		after drying 105°C				empty	after drying 105°C	after ignition 550°C	(g/ml)	water (ml/ml)	(%)
KNO 1-1	0-1 cm	24.94	23.58	22.98	4.04	30.38	8.76	4.72	21.62	108	26.40	31.02	30.17	0.21	0.94	18.4
KNO 1-2	1-2 cm	24.94	21.77	23.13	4.03	33.82	13.86	9.83	19.96	100	24.15	33.43	31.97	0.42	0.86	15.7
KNO 1-3	2-3 cm	24.94	19.31	23.34	4.03	34.49	16.78	12.75	17.71	106	23.50	30.66	28.69	0.55	0.76	27.5
KNO 1-4	3-5 cm	52.65	38.09	49.49	3.98	73.67	38.74	34.76	34.93	22	49.78	83.42	78.10	0.70	0.71	15.8
KNO 1-5	5-9.4 cm	121.93	101.77	113.48	3.99	142.20	48.88	44.89	93.32	10	48.86	76.20	71.81	0.40	0.82	16.1
KNO 2-1	0-1 cm	24.94	22.70	23.06	4.06	30.37	9.55	5.49	20.82	4	25.24	30.17	29.32	0.24	0.90	17.2
KNO 2-2	1-2 cm	24.94	21.67	23.14	4.04	31.13	11.26	7.22	19.87	50	26.31	33.28	31.77	0.31	0.86	21.7
KNO 2-3	2-3 cm	24.94	23.84	22.96	4.00	33.47	11.61	7.61	21.86	1 (44)	26.95	33.40	31.64	0.33	0.95	27.3
KNO 2-4	3-5 cm	52.65	46.27	48.81	4.03	59.62	17.19	13.16	42.43	9	47.28	60.26	56.56	0.27	0.87	28.5
KNO 2-5	5-10 cm	135.79	122.33	125.63	4.08	143.74	31.56	27.48	112.18	13	47.98	60.53	54.98	0.22	0.89	44.2
KNO 3-1	0-1 cm	24.94	22.78	23.05	4.04	28.56	7.67	3.63	20.89	10	26.14	29.67	29.04	0.16	0.91	17.8
KNO 3-2	1-2 cm	24.94	22.68	23.06	4.07	31.05	10.25	6.18	20.80	1 (19)	25.89	31.89	30.86	0.27	0.90	17.2
KNO 3-3	2-3 cm	24.94	23.60	22.98	4.05	31.89	10.25	6.20	21.64	112	24.85	30.81	29.74	0.27	0.94	18.0
KNO 3-4	3-5 cm	52.65	45.95	48.84	4.05	61.25	19.11	15.06	42.14	27	47.08	61.92	59.79	0.31	0.86	14.4
KNO 3-5	5-10 cm	135.79	113.18	126.39	4.04	159.66	55.87	51.83	103.79	1 (17)	103.86	155.37	148.51	0.41	0.82	13.3
KNO 4-1	0-1 cm	24.94	21.48	23.16	4.04	30.15	10.45	6.41	19.70	19	22.63	28.41	27.46	0.28	0.85	16.4
KNO 4-2	1-2 cm	24.94	21.94	23.12	4.03	32.80	12.68	8.65	20.12	114	24.72	30.31	29.31	0.37	0.87	17.9
KNO 4-3	2-3 cm	24.94	22.39	23.08	4.00	33.43	12.90	8.90	20.53	1 (49)	25.17	31.18	30.09	0.39	0.89	18.1
KNO 4-4	3-5 cm	52.65	45.05	48.91	3.98	64.70	23.39	19.41	41.31	54	47.03	66.21	62.97	0.40	0.84	16.9
KNO 4-5	5-10 cm	135.79	110.34	126.63	4.05	168.79	67.61	63.56	101.18	3 (16)	106.87	140.65	135.95	0.50	0.80	13.9
KNO 5-1	0-1 cm	24.94	23.42	23.00	3.96	31.69	10.21	6.25	21.48	17	23.93	29.91	28.90	0.27	0.93	16.9
KNO 5-2	1-2 cm	24.94	21.80	23.13	3.95	31.28	11.29	7.34	19.99	111	21.89	26.92	26.10	0.32	0.86	16.3
KNO 5-3	2-3 cm	24.94	23.15	23.02	3.93	33.17	11.94	8.01	21.23	118	22.91	28.06	27.18	0.35	0.92	17.1
KNO 5-4	3-5 cm	52.65	44.77	48.94	3.97	61.22	20.17	16.20	41.05	11	49.22	64.92	62.61	0.33	0.84	14.7
KNO 5-5	5-10 cm	135.79	116.34	126.13	3.96	156.79	50.11	46.15	106.68	14	49.58	70.61	67.09	0.37	0.85	16.7

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	Average	0.40	0.92	8.88
		0.54	0.80	8.52
		0.58	0.80	8.36
datum 25-jul-13		0.59	0.76	7.63
		0.66	0.75	6.45
project nummer 5240375				
	SD	0.10	0.21	0.48
soort monsters KER		0.10	0.04	0.60
		0.09	0.03	0.96
naam uitvoerder Elbers / Crum		0.07	0.03	0.16
		0.07	0.02	0.54

sample	depth (cm)	volume	volume	volume	mass (g)	mass (g)	mass (g)	mass (g)	mass (g)	number	mass (g)	mass (g)	mass (g)	bulk	volume	ignition
code		layer (ml)	water	sample	alu tray	alutray + wet sample	alutray + dry sample	dry matter	water	cup	cup	cup+sample	cup+sample	density	fraction	loss
			frozen (ml)	defrozen (ml)	empty		after drying 105°C				empty	after drying 105°C	after ignition 550°C	(g/ml)	water (ml/ml)	(%)
KER 1-1	0-1 cm	19.40	18.64	17.85	3.95	30.55	13.46	9.51	17.09	17	23.94	32.41	31.70	0.53	0.96	8.4
KER 1-2	1-2 cm	24.94	19.11	23.35	4.01	36.70	19.18	15.17	17.52	44	26.94	37.17	36.34	0.65	0.75	8.1
KER 1-3	2-3 cm	24.94	19.26	23.34	4.01	36.57	18.91	14.90	17.66	108	26.37	36.83	35.93	0.64	0.76	8.6
KER 1-4	3-5 cm	52.65	39.30	49.39	4.07	72.06	36.02	31.95	36.04	11	49.20	80.26	77.86	0.65	0.73	7.7
KER 1-5	5-10 cm	135.79	104.89	127.08	4.07	182.67	86.49	82.42	96.18	3	106.88	188.14	183.01	0.65	0.76	6.3
KER 2-1	0-1 cm	24.94	18.63	23.39	4.08	27.40	10.32	6.24	17.08	19	25.89	31.89	31.33	0.27	0.73	9.3
KER 2-2	1-2 cm	24.94	19.80	23.30	4.06	31.53	13.37	9.31	18.16	4	25.23	31.88	31.25	0.40	0.78	9.5
KER 2-3	2-3 cm	24.94	20.46	23.24	4.04	34.17	15.41	11.37	18.76	112	24.84	32.86	32.14	0.49	0.81	9.0
KER 2-4	3-5 cm	52.65	42.17	49.15	4.01	67.75	29.08	25.07	38.67	14	49.60	74.09	72.17	0.51	0.79	7.8
KER 2-5	5-10 cm	135.79	106.46	126.95	4.04	175.61	77.99	73.95	97.62	22	49.77	122.79	118.02	0.58	0.77	6.5
KER 3-1	0-1 cm	16.07	19.61	14.45	3.99	28.74	10.76	6.77	17.98	50	26.30	32.38	31.86	0.47	1.24	8.6
KER 3-2	1-2 cm	24.94	20.20	23.26	4.01	36.67	18.15	14.14	18.52	111	21.91	29.85	29.22	0.61	0.80	7.9
KER 3-3	2-3 cm	24.94	20.04	23.28	3.98	38.75	20.37	16.39	18.38	100	24.16	36.59	35.76	0.70	0.79	6.7
KER 3-4	3-5 cm	52.65	39.54	49.37	4.09	72.23	35.97	31.88	36.26	27	47.06	75.03	72.93	0.65	0.73	7.5
KER 3-5	5-10 cm	135.79	101.76	127.34	4.08	187.29	93.98	89.90	93.31	17	103.86	192.44	186.24	0.71	0.73	7.0
KER 4-1	0-1 cm	24.94	19.41	23.33	4.14	30.85	13.05	8.91	17.80	19	22.63	30.59	29.90	0.38	0.76	8.7
KER 4-2	1-2 cm	24.94	20.55	23.24	4.07	35.74	16.90	12.83	18.84	49	25.21	33.82	33.09	0.55	0.81	8.5
KER 4-3	2-3 cm	24.94	19.95	23.29	4.04	35.27	16.98	12.94	18.29	106	23.49	33.42	32.57	0.56	0.79	8.6
KER 4-4	3-5 cm	52.65	40.35	49.30	3.95	72.12	35.12	31.17	37.00	10	48.86	77.97	75.80	0.63	0.75	7.5
KER 4-5	5-10 cm	135.79	100.57	127.44	4.03	193.00	100.78	96.75	92.22	54	47.04	142.89	137.51	0.76	0.72	5.6
KER 5-1	0-1 cm	20.78	18.62	19.24	4.06	28.00	10.93	6.87	17.07	118	22.90	29.35	28.74	0.36	0.89	9.5
KER 5-2	1-2 cm	24.94	21.66	23.14	4.00	34.75	14.89	10.89	19.86	10	26.13	36.23	35.36	0.47	0.86	8.6
KER 5-3	2-3 cm	24.94	21.15	23.19	3.91	34.82	15.43	11.52	19.39	114	24.72	33.42	32.64	0.50	0.84	9.0
KER 5-4	3-5 cm	52.65	41.76	49.19	4.07	68.80	30.51	26.44	38.29	9	47.29	72.96	71.00	0.54	0.78	7.6
KER 5-5	5-10 cm	135.79	106.25	126.97	4.11	179.93	82.50	78.39	97.43	13	48.00	125.38	120.12	0.62	0.77	6.8

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datum	25-jul-13
project nummer	5240375
soort monsters	KNO
naam uitvoerder	Elbers / Crum

Average	0.19	0.93	22.18
	0.31	0.87	19.51
	0.35	0.90	18.22
	0.44	0.85	14.82
	0.56	0.81	12.35
SD	0.06	0.05	3.80
	0.04	0.06	1.82
	0.07	0.06	2.25
	0.12	0.05	4.18
	0.17	0.07	4.73

sample	depth (cm)	volume	volume	volume	mass (g)	mass (g)	mass (g)	mass (g)	mass (g)	number	mass (g)	mass (g)	mass (g)	bulk	volume	ignition
code		layer (ml)	water	sample	alu tray	alutray + wet sample	alutray + dry sample	dry matter	water	cup	cup	cup+sample	cup+sample	density	fraction	loss
			frozen (ml)	defrozen (ml)	empty		after drying 105°C				empty	after drying 105°C	after ignition 550°C	(g/ml)	water (ml/ml)	(%)
KNO 1-1	0-1 cm	24.94	21.40	23.16	4.05	27.24	7.62	3.57	19.62	49	25.16	28.65	27.92	0.15	0.85	20.9
KNO 1-2	1-2 cm	24.94	20.22	23.26	4.05	28.51	9.97	5.92	18.54	118	22.91	28.76	27.61	0.25	0.80	19.7
KNO 1-3	2-3 cm	24.94	21.53	23.15	4.07	30.02	10.28	6.21	19.74	10	26.14	32.26	30.95	0.27	0.85	21.4
KNO 1-4	3-5 cm	52.65	45.76	48.85	4.06	63.68	21.72	17.66	41.96	27	47.05	64.63	61.87	0.36	0.86	15.7
KNO 1-5	5-10 cm	135.79	110.03	126.65	4.01	177.32	76.42	72.41	100.90	11	49.18	65.73	64.20	0.57	0.80	9.2
KNO 2-1	0-1 cm	24.94	23.00	23.03	3.97	28.72	7.63	3.66	21.09	108	26.39	30.04	29.36	0.16	0.92	18.6
KNO 2-2	1-2 cm	24.94	21.24	23.18	3.98	31.08	11.60	7.62	19.48	13	23.48	31.13	29.80	0.33	0.84	17.4
KNO 2-3	2-3 cm	24.94	21.04	23.19	4.00	31.31	12.02	8.02	19.29	19	22.62	30.55	29.21	0.35	0.83	16.9
KNO 2-4	3-5 cm	52.65	45.22	48.90	4.02	61.25	19.78	15.76	41.47	10	48.88	64.48	61.67	0.32	0.85	18.0
KNO 2-5	5-10 cm	135.79	120.08	125.82	4.05	158.44	48.33	44.28	110.11	22	49.74	62.30	60.10	0.35	0.88	17.5
KNO 3-1	0-1 cm	24.94	24.22	22.93	4.02	29.46	7.25	3.23	22.21	19	25.87	29.01	28.11	0.14	0.97	28.7
KNO 3-2	1-2 cm	24.94	23.86	22.96	4.06	32.32	10.44	6.38	21.88	17	23.93	30.34	28.91	0.28	0.95	22.3
KNO 3-3	2-3 cm	24.94	24.39	22.92	4.05	33.67	11.30	7.25	22.37	4	25.22	32.33	30.95	0.32	0.98	19.4
KNO 3-4	3-5 cm	52.65	49.24	48.57	4.00	68.29	23.14	19.14	45.15	14	49.59	68.55	64.87	0.39	0.93	19.4
KNO 3-5	5-10 cm	135.79	120.11	125.82	4.02	167.94	57.80	53.78	110.14	17	103.84	118.62	116.04	0.43	0.88	17.5
KNO 4-1	0-1 cm	24.94	23.65	22.98	4.00	30.00	8.31	4.31	21.69	111	21.89	26.17	25.26	0.19	0.94	21.3
KNO 4-2	1-2 cm	24.94	23.01	23.03	3.97	33.17	12.07	8.10	21.10	100	24.14	32.17	30.68	0.35	0.92	18.6
KNO 4-3	2-3 cm	24.94	23.47	22.99	4.06	36.12	14.60	10.54	21.52	112	24.83	35.32	33.68	0.46	0.94	15.6
KNO 4-4	3-5 cm	52.65	43.76	49.02	4.07	70.22	30.09	26.02	40.13	13	47.96	63.40	61.70	0.53	0.82	11.0
KNO 4-5	5-10 cm	135.79	99.25	127.55	4.02	193.54	102.53	98.51	91.01	16	106.86	132.44	130.40	0.77	0.71	8.0
KNO 5-1	0-1 cm	24.94	23.87	22.96	3.95	32.55	10.66	6.71	21.89	114	24.71	31.38	29.95	0.29	0.95	21.4
KNO 5-2	1-2 cm	24.94	21.83	23.13	4.02	31.52	11.50	7.48	20.02	44	26.95	32.14	31.12	0.32	0.87	19.7
KNO 5-3	2-3 cm	24.94	22.40	23.08	4.03	33.12	12.58	8.55	20.54	50	26.31	34.81	33.30	0.37	0.89	17.8
KNO 5-4	3-5 cm	52.65	42.22	49.15	4.01	72.97	34.25	30.24	38.72	54	47.05	77.23	74.22	0.62	0.79	10.0
KNO 5-5	5-10 cm	135.79	106.96	126.91	4.00	185.84	87.76	83.76	98.08	9	47.26	65.72	63.96	0.66	0.77	9.5

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datum	4-jul-13	Average	0.19	0.85	33.58
			0.22	0.89	32.77
			0.22	0.87	30.20
			0.22	0.83	19.92
project nummer	5240375		0.26	0.85	13.21
soort monsters	MOL	SD	0.06	0.02	18.34
			0.06	0.04	17.51
			0.05	0.04	16.61
naam uitvoerder	Elbers / Crum		0.03	0.03	5.82
			0.03	0.01	1.38

sample code	depth (cm)	volume layer (ml)	volume water frozen (ml)	volume sample defrozen (ml)	mass (g) alu tray empty	mass (g) alutray + wet	mass (g) alutray + after drying	mass (g) dry matter	mass (g) water	number cup	mass (g) cup empty	mass (g) cup+sample after drying 105°C	mass (g) cup+sample after ignition 550°C	bulk density (g/ml)	volume fraction water (ml/ml)	ignition loss (%)
MOL 1-1	0-1 cm	24.94	21.54	23.15	4.08	27.73	7.98	3.90	19.75	44	26.94	30.78	29.90	0.17	0.85	22.9
MOL 1-2	1-2 cm	24.94	21.81	23.13	4.06	28.61	8.61	4.55	20.00	50	26.31	30.73	29.60	0.20	0.86	25.6
MOL 1-3	2-3 cm	24.94	21.26	23.18	4.08	28.45	8.95	4.87	19.50	19	25.91	30.71	29.65	0.21	0.84	22.1
MOL 1-4	3-5 cm	52.65	45.46	48.88	4.13	56.61	14.92	10.79	41.69	22	49.76	60.34	58.60	0.22	0.85	16.4
MOL 1-5	5-10 cm	135.79	116.91	126.08	4.17	144.44	37.23	33.06	107.21	10	48.87	69.40	66.94	0.26	0.85	12.0
MOL 2-1	0-1 cm	24.94	20.71	23.22	4.05	29.37	10.38	6.33	18.99	100	24.15	30.24	29.25	0.27	0.82	16.3
MOL 2-2	1-2 cm	24.94	20.80	23.21	4.09	30.05	10.98	6.89	19.07	4	25.22	31.97	30.91	0.30	0.82	15.7
MOL 2-3	2-3 cm	24.94	20.47	23.24	4.11	29.68	10.91	6.80	18.77	49	25.18	31.56	30.62	0.29	0.81	14.7
MOL 2-4	3-5 cm	52.65	42.43	49.13	4.16	56.17	17.26	13.10	38.91	9	47.28	60.19	58.39	0.27	0.79	13.9
MOL 2-5	5-10 cm	135.79	115.56	126.20	4.16	147.39	41.42	37.26	105.97	16	106.87	144.03	139.72	0.30	0.84	11.6
MOL 3-1	0-1 cm	24.94	21.53	23.15	4.08	29.11	9.37	5.29	19.74	19	22.65	27.75	26.64	0.23	0.85	21.8
MOL 3-2	1-2 cm	24.94	22.70	23.06	4.01	30.67	9.85	5.84	20.82	17	23.92	29.61	28.50	0.25	0.90	19.5
MOL 3-3	2-3 cm	24.94	22.72	23.06	4.06	30.90	10.07	6.01	20.83	118	22.90	28.69	27.65	0.26	0.90	18.0
MOL 3-4	3-5 cm	52.65	44.17	48.99	4.00	56.00	15.50	11.50	40.50	27	47.08	58.52	56.56	0.23	0.83	17.1
MOL 3-5	5-10 cm	135.79	117.76	126.01	4.04	143.38	35.39	31.35	107.99	14	49.58	67.97	65.39	0.25	0.86	14.0
MOL 4-1	0-1 cm	24.94	21.89	23.12	3.99	27.19	7.12	3.13	20.07	108	26.40	29.40	27.80	0.14	0.87	53.3
MOL 4-2	1-2 cm	24.94	22.90	23.04	4.10	28.60	7.60	3.50	21.00	106	23.48	26.68	24.99	0.15	0.91	52.8
MOL 4-3	2-3 cm	24.94	22.91	23.04	4.11	28.86	7.85	3.74	21.01	114	24.70	28.30	26.50	0.16	0.91	50.0
MOL 4-4	3-5 cm	52.65	43.56	49.04	4.06	52.69	12.75	8.69	39.94	54	47.06	55.46	53.40	0.18	0.81	24.5
MOL 4-5	5-10 cm	135.79	120.29	125.80	4.04	140.69	30.38	26.34	110.31	13	48.00	65.57	62.96	0.21	0.88	14.9
MOL 5-1	0-1 cm	24.94	22.00	23.11	4.03	28.00	7.83	3.80	20.17	10	26.15	29.06	27.50	0.16	0.87	53.6
MOL 5-2	1-2 cm	24.94	23.22	23.01	4.08	29.58	8.29	4.21	21.29	111	21.89	25.57	23.72	0.18	0.93	50.3
MOL 5-3	2-3 cm	24.94	22.37	23.08	4.07	28.91	8.40	4.33	20.51	112	24.84	28.02	26.55	0.19	0.89	46.2
MOL 5-4	3-5 cm	52.65	45.35	48.89	4.08	55.99	14.40	10.32	41.59	11	49.20	59.39	56.58	0.21	0.85	27.6
MOL 5-5	5-10 cm	135.79	116.47	126.12	4.02	144.59	37.79	33.77	106.80	17	103.85	137.53	132.96	0.27	0.85	13.6

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datum	24-jul-13
project nummer	5240375
soort monsters	ZUI
naam uitvoerder	Elbers / Crum

Average	0.38	0.81	10.74
	0.54	0.79	9.66
	0.53	0.78	10.47
	0.50	0.78	9.50
	0.50	0.78	9.49
SD	0.08	0.04	1.08
	0.05	0.04	0.91
	0.03	0.03	0.88
	0.04	0.02	0.72
	0.09	0.03	1.66

sample code	depth (cm)	volume layer (ml)	volume water frozen (ml)	volume sample defrozen (ml)	mass (g) alu tray empty	mass (g) alutray + wet	mass (g) alutray + after drying	mass (g) dry matter	mass (g) water	number cup	mass (g) cup empty	mass (g) cup+sample after drying 105°C	mass (g) cup+sample after ignition 550°C	bulk density (g/ml)	volume fraction water (ml/ml)	ignition loss (%)
ZUI 1-1	0-1 cm	24.94	21.70	23.14	4.01	30.45	10.55	6.54	19.90	100	24.17	30.23	29.51	0.28	0.86	11.9
ZUI 1-2	1-2 cm	24.94	20.83	23.21	4.04	34.12	15.02	10.98	19.10	49	25.18	33.21	32.35	0.47	0.82	10.7
ZUI 1-3	2-3 cm	24.94	20.21	23.26	4.11	34.22	15.69	11.58	18.53	112	24.85	33.04	32.10	0.50	0.80	11.5
ZUI 1-4	3-5 cm	52.65	43.66	49.03	4.13	66.83	26.79	22.66	40.04	26	48.51	70.93	68.56	0.46	0.82	10.6
ZUI 1-5	5-10 cm	135.79	110.15	126.64	4.05	159.97	58.96	54.91	101.01	17	103.84	156.02	150.28	0.43	0.80	11.0
ZUI 2-1	0-1 cm	24.94	19.45	23.33	4.05	31.96	14.12	10.07	17.84	19	25.90	32.86	32.10	0.43	0.76	10.9
ZUI 2-2	1-2 cm	24.94	20.02	23.28	4.02	34.77	16.41	12.39	18.36	50	26.29	36.82	35.79	0.53	0.79	9.8
ZUI 2-3	2-3 cm	24.94	19.72	23.30	4.01	34.82	16.74	12.73	18.08	17	23.93	33.22	32.31	0.55	0.78	9.8
ZUI 2-4	3-5 cm	52.65	41.06	49.24	4.08	65.81	28.16	24.08	37.65	27	47.04	70.83	68.54	0.49	0.76	9.6
ZUI 2-5	5-10 cm	135.79	105.74	127.01	4.06	160.64	63.68	59.62	96.96	54	47.05	74.53	71.85	0.47	0.76	9.8
ZUI 3-1	0-1 cm	24.94	19.69	23.31	4.09	32.58	14.52	10.43	18.06	10	26.12	34.32	33.48	0.45	0.77	10.2
ZUI 3-2	1-2 cm	24.94	20.49	23.24	3.97	36.13	17.34	13.37	18.79	111	21.89	31.48	30.55	0.58	0.81	9.7
ZUI 3-3	2-3 cm	24.94	19.45	23.33	3.93	34.80	16.96	13.03	17.84	19	22.62	31.44	30.61	0.56	0.76	9.4
ZUI 3-4	3-5 cm	52.65	41.26	49.23	3.97	65.93	28.09	24.12	37.84	9	47.27	70.76	68.54	0.49	0.77	9.5
ZUI 3-5	5-10 cm	135.79	108.14	126.81	4.00	166.82	67.66	63.66	99.16	8	49.59	81.08	78.20	0.50	0.78	9.1
ZUI 4-1	0-1 cm	24.94	21.35	23.17	4.01	30.64	11.06	7.05	19.58	108	26.40	33.10	32.33	0.30	0.85	11.5
ZUI 4-2	1-2 cm	24.94	20.61	23.23	4.01	34.68	15.78	11.77	18.90	118	22.92	30.69	29.92	0.51	0.81	9.9
ZUI 4-3	2-3 cm	24.94	20.64	23.23	3.99	34.50	15.57	11.58	18.93	106	23.49	31.88	31.00	0.50	0.81	10.5
ZUI 4-4	3-5 cm	52.65	40.74	49.27	3.96	66.34	28.98	25.02	37.36	16	49.74	74.35	72.24	0.51	0.76	8.6
ZUI 4-5	5-10 cm	135.79	111.03	126.57	3.95	159.79	57.98	54.03	101.81	14	49.57	75.83	73.02	0.43	0.80	10.7
ZUI 5-1	0-1 cm	24.94	20.39	23.25	3.99	33.17	14.47	10.48	18.70	114	24.72	34.66	33.75	0.45	0.80	9.2
ZUI 5-2	1-2 cm	24.94	18.62	23.40	3.99	35.03	17.96	13.97	17.07	4	25.22	35.22	34.40	0.60	0.73	8.2
ZUI 5-3	2-3 cm	24.94	19.15	23.35	3.98	34.11	16.55	12.57	17.56	44	26.95	35.37	34.43	0.54	0.75	11.2
ZUI 5-4	3-5 cm	52.65	41.66	49.19	3.95	69.58	31.38	27.43	38.20	10	48.86	75.73	73.24	0.56	0.78	9.3
ZUI 5-5	5-10 cm	135.79	101.56	127.36	3.96	180.58	87.45	83.49	93.13	22	49.75	87.83	85.23	0.66	0.73	6.8

Crum: Bij deze monsters was het vrij opvallend dat in diepere lagen ook relatief veel organisch materiaal aanwezig was zoals rietstengels en andere planten delen

Annex 7 Results of laboratory analysis and calculation of dry bulk density, porosity and organic matter content for five locations in September 2013

(Analysis by Crum and Elbers. Results corrected for freezing. Inner diameter of sampling core is 59.4 mm.)

invulformulier drogestof- en organischestofbepaling Sedimentkarakterisering

datum	15-sep-13	
project nummer	5240375	
soort monsters	KAM	
naam uitvoerder	Elbers / Crum	

	bulk density	volume fraction	ignition loss
Average	0.23	0.85	17.50
	0.32	0.82	15.70
	0.36	0.82	15.64
	0.38	0.82	16.21
	0.37	0.83	22.57
SD	0.12	0.09	2.72
	0.09	0.03	1.62
	0.09	0.06	1.71
	0.12	0.04	2.66
	0.14	0.04	17.40

sample	depth (cm)	volume	volume	volume	mass (g)	mass (g)	mass (g)	mass (g)	mass (g)	number	mass (g)	mass (g)	mass (g)	bulk	volume	ignition
code		layer (ml)	water	sample	alu tray	alutray + wet sample	alutray + dry sample	dry matter	water	cup	cup	cup+sample	cup+sample	density	fraction	loss
			frozen (ml)	defrozen (ml)	empty		after drying 105°C				empty	after drying 105°C	after ignition 550°C	(g/ml)	water (ml/ml)	(%)
KAM 1-1	0-1 cm	24.94	20.20	23.26	3.81	25.43	6.91	3.10	18.52	44	26.93	29.96	29.41	0.13	0.80	18.2
KAM 1-2	1-2 cm	24.94	21.26	23.18	3.82	28.70	9.20	5.38	19.50	114	24.70	29.99	29.13	0.23	0.84	16.3
KAM 1-3	2-3 cm	24.94	22.26	23.09	3.84	30.41	10.00	6.16	20.41	112	24.85	29.97	29.13	0.27	0.88	16.4
KAM 1-4	3-5 cm	52.65	45.32	48.89	3.80	59.69	18.13	14.33	41.56	10	48.86	62.93	60.62	0.29	0.85	16.4
KAM 1-5	5-9.4 cm	135.79	113.83	126.34	3.77	159.17	54.79	51.02	104.38	8	49.60	99.49	92.45	0.40	0.83	14.1
KAM 2-1	0-1 cm	24.94	20.24	23.26	3.72	24.62	6.06	2.34	18.56	10	26.14	28.44	27.94	0.10	0.80	21.7
KAM 2-2	1-2 cm	24.94	20.65	23.23	3.78	29.28	10.34	6.56	18.94	49	25.16	31.01	30.13	0.28	0.82	15.0
KAM 2-3	2-3 cm	24.94	21.19	23.18	3.73	31.45	12.02	8.29	19.43	19	25.88	32.71	31.71	0.36	0.84	14.6
KAM 2-4	3-5 cm	52.65	45.10	48.91	3.78	59.88	18.52	14.74	41.36	14	49.60	64.09	61.18	0.30	0.85	20.1
KAM 2-5	5-10 cm	135.79	121.47	125.71	3.75	133.76	22.37	18.62	111.39	16	49.74	62.64	55.72	0.15	0.89	53.6
KAM 3-1	0-1 cm	24.94	20.31	23.26	3.76	28.43	9.81	6.05	18.62	4	25.21	31.07	30.09	0.26	0.80	16.7
KAM 3-2	1-2 cm	24.94	20.70	23.22	3.76	29.94	10.96	7.20	18.98	106	23.50	30.43	29.26	0.31	0.82	16.9
KAM 3-3	2-3 cm	24.94	21.12	23.19	3.79	31.68	12.31	8.52	19.37	111	21.90	29.81	28.50	0.37	0.84	16.6
KAM 3-4	3-5 cm	52.65	43.38	49.05	3.77	65.25	25.47	21.70	39.78	9	47.29	68.69	65.65	0.44	0.81	14.2
KAM 3-5	5-10 cm	135.79	113.68	126.35	3.80	160.30	56.06	52.26	104.24	22	49.75	78.28	73.77	0.41	0.82	15.8
KAM 4-1	0-1 cm	24.94	21.31	23.17	3.76	29.12	9.58	5.82	19.54	19	22.63	28.03	27.14	0.25	0.84	16.5
KAM 4-2	1-2 cm	24.94	21.15	23.19	3.73	30.08	10.69	6.96	19.39	118	22.91	29.28	28.19	0.30	0.84	17.1
KAM 4-3	2-3 cm	24.94	20.87	23.21	3.72	29.80	10.66	6.94	19.14	100	24.15	30.75	29.60	0.30	0.82	17.4
KAM 4-4	3-5 cm	52.65	44.66	48.95	3.75	59.75	18.80	15.05	40.95	27	47.06	61.90	59.37	0.31	0.84	17.0
KAM 4-5	5-10 cm	135.79	115.85	126.17	3.79	154.84	48.61	44.82	106.23	26	48.52	91.91	85.09	0.36	0.84	15.7
KAM 5-1	0-1 cm	20.78	20.69	19.07	3.76	30.68	11.71	7.95	18.97	108	26.41	34.11	33.00	0.42	0.99	14.4
KAM 5-2	1-2 cm	24.94	19.75	23.30	3.75	32.69	14.58	10.83	18.11	17	23.95	34.57	33.17	0.46	0.78	13.2
KAM 5-3	2-3 cm	24.94	18.51	23.40	3.82	32.26	15.29	11.47	16.97	50	26.33	36.65	35.29	0.49	0.73	13.2
KAM 5-4	3-5 cm	52.65	40.57	49.29	3.75	68.54	31.34	27.59	37.20	54	47.09	74.57	70.92	0.56	0.75	13.3
KAM 5-5	5-10 cm	135.79	106.23	126.97	3.75	170.12	72.71	68.96	97.41	17	103.86	172.23	162.96	0.54	0.77	13.6

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datum	25-sep-13	Average	0.30	0.71	10.65
			0.43	0.72	9.91
			0.45	0.68	9.77
			0.52	0.74	8.74
			0.57	0.75	8.32
project nummer	5240375				
		SD	0.09	0.04	1.63
soort monsters	KER		0.10	0.05	1.29
			0.09	0.05	1.62
naam uitvoerder	Elbers / Crum		0.12	0.04	1.11
			0.12	0.04	0.70

sample code	depth (cm)	volume layer (ml)	volume water frozen (ml)	volume sample defrozen (ml)	mass (g) alu tray empty	mass (g) alutray + wet	mass (g) alutray + dry after drying	mass (g) dry matter	mass (g) water	number cup	mass (g) cup empty	mass (g) cup+sample after drying 105°C	mass (g) cup+sample after ignition 550°C	bulk density (g/ml)	volume fraction water (ml/ml)	ignition loss (%)
KER 1-1	0-1 cm	24.94	16.97	23.53	3.73	22.99	7.43	3.70	15.56	118	22.87	26.49	26.04	0.16	0.66	12.4
KER 1-2	1-2 cm	24.94	19.52	23.32	3.78	29.39	11.49	7.71	17.90	112	24.84	32.46	31.56	0.33	0.77	11.8
KER 1-3	2-3 cm	24.94	18.80	23.38	3.77	29.05	11.81	8.04	17.24	19	22.65	30.27	29.34	0.34	0.74	12.2
KER 1-4	3-5 cm	52.65	41.90	49.17	3.76	60.83	22.41	18.65	38.42	27	47.10	64.88	63.01	0.38	0.78	10.5
KER 1-5	5-10 cm	135.79	109.95	126.66	3.79	159.26	58.44	54.65	100.82	10	48.88	69.24	67.40	0.43	0.80	9.0
KER 2-1	0-1 cm	24.94	17.83	23.46	3.77	28.82	12.47	8.70	16.35	111	21.89	30.06	29.31	0.37	0.70	9.2
KER 2-2	1-2 cm	24.94	16.83	23.54	3.76	31.95	16.52	12.76	15.43	114	24.70	37.13	36.01	0.54	0.66	9.0
KER 2-3	2-3 cm	24.94	15.35	23.67	3.76	31.50	17.42	13.66	14.08	10	26.13	36.99	36.06	0.58	0.59	8.6
KER 2-4	3-5 cm	52.65	36.14	49.65	3.76	70.59	37.45	33.69	33.14	26	48.50	82.05	79.41	0.68	0.67	7.9
KER 2-5	5-10 cm	135.79	99.02	127.57	3.75	183.09	92.29	88.54	90.80	17	103.86	192.11	184.59	0.69	0.71	8.5
KER 3-1	0-1 cm	24.94	19.44	23.33	3.76	29.60	11.77	8.01	17.83	50	26.30	33.88	33.15	0.34	0.76	9.6
KER 3-2	1-2 cm	24.94	17.91	23.45	3.75	28.93	12.51	8.76	16.42	17	23.93	32.44	31.59	0.37	0.70	10.0
KER 3-3	2-3 cm	24.94	18.23	23.43	4.11	29.67	12.95	8.84	16.72	108	26.41	35.02	34.11	0.38	0.71	10.6
KER 3-4	3-5 cm	52.65	39.81	49.35	4.12	61.54	25.03	20.91	36.51	16	49.74	70.08	68.30	0.42	0.74	8.8
KER 3-5	5-10 cm	135.79	107.99	126.82	4.05	164.38	65.35	61.30	99.03	9	47.27	106.70	101.66	0.48	0.78	8.5
KER 4-1	0-1 cm	24.94	18.28	23.42	4.02	27.07	10.31	6.29	16.76	19	25.87	31.74	31.01	0.27	0.72	12.4
KER 4-2	1-2 cm	24.94	19.43	23.33	4.03	30.53	12.71	8.68	17.82	49	25.17	32.95	32.15	0.37	0.76	10.3
KER 4-3	2-3 cm	24.94	17.73	23.47	4.03	31.06	14.80	10.77	16.26	100	24.15	34.60	33.64	0.46	0.69	9.2
KER 4-4	3-5 cm	52.65	40.64	49.28	4.08	67.47	30.20	26.12	37.27	54	47.06	72.68	70.42	0.53	0.76	8.8
KER 4-5	5-10 cm	135.79	103.77	127.17	4.04	170.52	75.36	71.32	95.16	14	49.59	81.76	79.05	0.56	0.75	8.4
KER 5-1	0-1 cm	24.94	18.76	23.38	4.08	30.26	13.06	8.98	17.20	106	23.47	31.71	30.92	0.38	0.74	9.6
KER 5-2	1-2 cm	24.94	17.96	23.45	4.10	33.02	16.55	12.45	16.47	44	26.93	37.57	36.67	0.53	0.70	8.5
KER 5-3	2-3 cm	24.94	17.40	23.50	4.12	32.00	16.04	11.92	15.96	4	25.22	35.32	34.48	0.51	0.68	8.3
KER 5-4	3-5 cm	52.65	39.37	49.38	4.05	69.78	33.68	29.63	36.10	22	49.78	79.05	76.78	0.60	0.73	7.8
KER 5-5	5-10 cm	135.79	98.53	127.61	4.03	181.90	91.55	87.52	90.35	8	49.59	135.10	128.99	0.69	0.71	7.1

invulformulier drogestof- en organischestofbepaling Sedimentkarakterisering

datum 25-sep-13

project nummer 5240375

soort monsters KNO

naam uitvoerder Elbers / Crum

	bulk density	volume fraction water	ignition loss
Average	0.09	0.84	30.23
	0.14	0.83	29.21
	0.18	0.82	25.48
	0.34	0.87	15.10
	0.46	0.81	10.46
SD	0.03	0.04	3.60
	0.03	0.06	4.78
	0.04	0.06	6.22
	0.18	0.09	6.46
	0.16	0.05	2.83

sample code	depth (cm)	volume layer (ml)	volume water frozen (ml)	volume sample defrozen (ml)	mass (g) alu tray empty	mass (g) alutray +	mass (g) alutray + after	mass (g) dry matter	mass (g) water	number cup	mass (g) cup empty	mass (g) cup+sample after drying	mass (g) cup+sample after ignition	bulk density (g/ml)	volume fraction water (ml/ml)	ignition loss (%)
KNO 1-1	0-1 cm	22.17	19.57	20.54	4.08	23.60	5.65	1.57	17.95	106	23.49	25.00	24.54	0.08	0.87	30.5
KNO 1-2	1-2 cm	20.78	18.02	19.29	4.03	22.78	6.26	2.23	16.52	19	22.66	24.75	24.06	0.12	0.86	33.0
KNO 1-3	2-3 cm	24.94	21.24	23.18	4.07	27.59	8.11	4.04	19.48	100	24.14	28.07	27.15	0.17	0.84	23.4
KNO 1-4	3-5 cm	52.65	39.11	49.41	4.06	71.18	35.32	31.26	35.86	9	47.27	78.30	76.50	0.63	0.73	5.8
KNO 1-5	5-10 cm	135.79	104.70	127.10	4.06	181.89	85.88	81.82	96.01	18	49.60	105.77	101.00	0.64	0.76	8.5
KNO 2-1	0-1 cm	24.94	19.84	23.29	4.02	25.44	7.25	3.23	18.19	10	26.17	29.29	28.47	0.14	0.78	26.3
KNO 2-2	1-2 cm	24.94	18.27	23.42	4.11	24.29	7.54	3.43	16.75	49	25.16	28.51	27.64	0.15	0.72	26.0
KNO 2-3	2-3 cm	24.94	19.20	23.35	4.07	26.53	8.92	4.85	17.61	118	22.90	27.62	26.62	0.21	0.75	21.2
KNO 2-4	3-5 cm	52.65	45.41	48.88	4.16	64.20	22.56	18.40	41.64	54	47.06	65.27	63.08	0.38	0.85	12.0
KNO 2-5	5-10 cm	135.79	103.75	127.18	4.16	177.11	81.97	77.81	95.14	17	103.84	180.55	174.80	0.61	0.75	7.5
KNO 3-1	0-1 cm	24.94	21.29	23.17	4.09	25.22	5.70	1.61	19.52	112	24.84	26.31	25.83	0.07	0.84	32.7
KNO 3-2	1-2 cm	24.94	21.19	23.18	4.11	26.90	7.47	3.36	19.43	114	24.74	27.99	27.13	0.14	0.84	26.5
KNO 3-3	2-3 cm	24.94	20.12	23.27	4.07	26.98	8.53	4.46	18.45	17	23.92	27.27	26.37	0.19	0.79	26.9
KNO 3-4	3-5 cm	52.65	49.50	48.54	4.11	59.61	14.22	10.11	45.39	26	48.50	58.42	56.41	0.21	0.94	20.3
KNO 3-5	5-10 cm	135.79	116.30	126.13	4.03	151.53	44.88	40.85	106.65	22	49.74	74.94	71.91	0.32	0.85	12.0
KNO 4-1	0-1 cm	24.94	21.00	23.20	4.05	25.73	6.47	2.42	19.26	44	26.96	29.29	28.66	0.10	0.83	27.0
KNO 4-2	1-2 cm	24.94	21.18	23.18	4.04	27.50	8.08	4.04	19.42	19	25.90	29.82	28.84	0.17	0.84	25.0
KNO 4-3	2-3 cm	24.94	20.61	23.23	4.04	27.85	8.95	4.91	18.90	4	25.23	30.01	29.04	0.21	0.81	20.3
KNO 4-4	3-5 cm	52.65	48.04	48.67	4.05	60.95	16.90	12.85	44.05	10	48.86	61.57	59.58	0.26	0.91	15.7
KNO 4-5	5-10 cm	135.79	114.14	126.31	4.11	161.97	57.30	53.19	104.67	14	49.56	79.25	76.35	0.42	0.83	9.8
KNO 5-1	0-1 cm	24.94	21.77	23.13	4.10	25.84	5.88	1.78	19.96	108	26.40	28.07	27.49	0.08	0.86	34.7
KNO 5-2	1-2 cm	24.94	22.15	23.10	4.06	26.81	6.50	2.44	20.31	111	21.88	24.21	23.38	0.11	0.88	35.6
KNO 5-3	2-3 cm	24.94	22.77	23.05	4.13	27.81	6.93	2.80	20.88	50	26.31	29.06	28.08	0.12	0.91	35.6
KNO 5-4	3-5 cm	52.65	48.90	48.59	4.09	58.48	13.64	9.55	44.84	27	47.06	56.44	54.40	0.20	0.92	21.7
KNO 5-5	5-10 cm	135.79	117.30	126.05	4.06	149.71	42.15	38.09	107.56	16	49.73	68.13	65.46	0.30	0.85	14.5

invulformulier drogestof- en organischestofbepaling Sedimentkarakterisering

datum	25-sep-13
project nummer	5240375
soort monsters	MOL
naam uitvoerder	Elbers / Crum

	bulk density	volume fraction water	ignition loss
Average	0.55	0.81	11.53
	0.70	0.73	9.68
	0.84	0.65	7.84
	1.14	0.56	3.96
	1.36	0.47	2.31
SD	0.05	0.07	1.53
	0.08	0.04	2.26
	0.23	0.08	2.92
	0.18	0.07	1.45
	0.07	0.03	0.58

sample code	depth (cm)	volume layer (ml)	volume water frozen (ml)	volume sample defrozen (ml)	mass (g) alu tray empty	mass (g) alutray + wet	mass (g) alutray + after drying	mass (g) dry matter	mass (g) water	number cup	mass (g) cup empty	mass (g) cup+sample after drying 105°C	mass (g) cup+sample after ignition 550°C	bulk density (g/ml)	volume fraction water (ml/ml)	ignition loss (%)
MOL 1-1	0-1 cm	22.86	19.24	21.27	3.72	34.43	16.79	13.07	17.64	100	24.13	35.60	34.33	0.61	0.83	11.1
MOL 1-2	1-2 cm	24.94	18.42	23.41	3.70	38.21	21.32	17.62	16.89	118	22.93	33.66	32.51	0.75	0.72	10.7
MOL 1-3	2-3 cm	24.94	15.02	23.69	3.83	44.43	30.66	26.83	13.77	10	26.13	39.55	38.92	1.13	0.58	4.7
MOL 1-4	3-5 cm	52.65	25.80	50.51	3.83	97.39	73.73	69.90	23.66	16	49.77	108.23	106.83	1.38	0.47	2.4
MOL 1-5	5-10 cm	135.79	62.66	130.59	3.81	250.32	192.86	189.05	57.46	17	103.86	289.75	286.52	1.45	0.44	1.7
MOL 2-1	0-1 cm	23.55	16.61	22.18	3.80	32.08	16.85	13.05	15.23	44	26.95	36.02	35.13	0.59	0.69	9.8
MOL 2-2	1-2 cm	24.94	17.21	23.51	3.76	38.28	22.50	18.74	15.78	106	23.49	36.78	36.00	0.80	0.67	5.9
MOL 2-3	2-3 cm	24.94	16.19	23.60	4.04	43.95	29.10	25.06	14.85	112	24.88	37.93	37.22	1.06	0.63	5.4
MOL 2-4	3-5 cm	52.65	30.88	50.09	4.02	86.19	57.87	53.85	28.32	8	49.57	83.17	81.99	1.08	0.57	3.5
MOL 2-5	5-10 cm	135.79	71.06	129.89	3.87	236.38	171.22	167.35	65.16	22	49.78	100.07	98.85	1.29	0.50	2.4
MOL 3-1	0-1 cm	22.86	18.24	21.35	3.97	32.34	15.61	11.64	16.73	17	23.92	34.21	33.09	0.55	0.78	10.9
MOL 3-2	1-2 cm	24.94	19.63	23.31	3.94	37.52	19.52	15.58	18.00	19	22.62	33.25	32.17	0.67	0.77	10.2
MOL 3-3	2-3 cm	24.94	17.72	23.47	3.94	35.95	19.70	15.76	16.25	108	26.40	38.52	37.36	0.67	0.69	9.6
MOL 3-4	3-5 cm	52.65	33.68	49.86	3.91	83.62	52.74	48.83	30.88	54	47.06	92.04	89.68	0.98	0.62	5.2
MOL 3-5	5-10 cm	135.79	71.10	129.89	3.86	235.86	170.66	166.80	65.20	9	47.30	94.69	93.16	1.28	0.50	3.2
MOL 4-1	0-1 cm	21.62	19.02	20.04	3.93	31.54	14.10	10.17	17.44	111	21.88	28.86	27.89	0.51	0.87	13.9
MOL 4-2	1-2 cm	24.94	18.91	23.37	3.93	34.77	17.43	13.50	17.34	50	26.32	35.21	34.16	0.58	0.74	11.8
MOL 4-3	2-3 cm	24.94	19.61	23.31	3.96	36.95	18.97	15.01	17.98	49	25.16	33.32	32.36	0.64	0.77	11.8
MOL 4-4	3-5 cm	52.65	34.21	49.81	3.95	83.94	52.57	48.62	31.37	27	47.06	93.85	91.18	0.98	0.63	5.7
MOL 4-5	5-10 cm	135.79	64.61	130.42	3.96	244.84	185.59	181.63	59.25	14	49.58	126.60	125.11	1.39	0.45	1.9
MOL 5-1	0-1 cm	22.17	19.20	20.58	3.98	31.80	14.19	10.21	17.61	4	25.22	32.72	31.82	0.50	0.86	12.0
MOL 5-2	1-2 cm	24.94	18.76	23.38	4.02	37.19	19.99	15.97	17.20	19	25.90	35.13	34.22	0.68	0.74	9.9
MOL 5-3	2-3 cm	24.94	15.18	23.68	4.05	34.66	20.74	16.69	13.92	114	24.71	36.49	35.58	0.70	0.59	7.7
MOL 5-4	3-5 cm	52.65	27.39	50.38	4.02	93.54	68.42	64.40	25.12	26	48.48	95.09	93.72	1.28	0.50	2.9
MOL 5-5	5-10 cm	135.79	65.30	130.37	4.05	241.59	181.71	177.66	59.88	10	48.85	101.30	100.13	1.36	0.46	2.2

invulformulier drogestof- en organischestofbepaling Sedimentkarakterisering

datum: 12-nov-13

project nummer: 5240375

soort monsters: ZUI

naam uitvoerder: Elbers / Crum

	bulk density	volume fraction water	ignition loss
Average	0.25	0.85	14.05
	0.44	0.79	10.19
	0.47	0.78	10.49
	0.46	0.79	10.40
	0.54	0.75	9.73
SD	0.11	0.08	5.10
	0.08	0.02	1.40
	0.09	0.02	1.63
	0.08	0.03	1.06
	0.11	0.06	2.75

sample code	depth (cm)	volume layer (ml)	volume water frozen (ml)	volume sample defrozen (ml)	mass (g) alu tray empty	mass (g) alutray + wet	mass (g) alutray + after drying	mass (g) dry matter	mass (g) water	number cup	mass (g) cup empty	mass (g) cup+sample after drying 105°C	mass (g) cup+sample after ignition 550°C	bulk density (g/ml)	volume fraction water (ml/ml)	ignition loss (%)
ZUI 1-1	0-1 cm	26.33	20.39	24.63	4.05	28.70	10.00	5.95	18.70	106	23.47	29.26	28.51	0.24	0.76	13.0
ZUI 1-2	1-2 cm	26.33	21.81	24.52	4.00	32.93	12.93	8.93	20.00	17	23.92	32.43	31.41	0.36	0.82	12.0
ZUI 1-3	2-3 cm	26.33	20.87	24.59	4.03	32.00	12.86	8.83	19.14	111	21.89	29.46	28.56	0.36	0.78	11.9
ZUI 1-4	3-5 cm	52.65	43.83	49.01	4.05	60.49	20.30	16.25	40.19	16	49.75	65.65	63.75	0.33	0.82	11.9
ZUI 1-5	5-10 cm	135.79	112.97	126.41	4.02	157.83	54.24	50.22	103.59	22	49.72	79.39	75.21	0.40	0.82	14.1
ZUI 2-1	0-1 cm	26.33	22.64	24.45	4.10	30.04	9.28	5.18	20.76	50	26.30	31.25	30.55	0.21	0.85	14.1
ZUI 2-2	1-2 cm	26.33	20.99	24.58	4.07	33.09	13.84	9.77	19.25	19	25.88	35.36	34.37	0.40	0.78	10.4
ZUI 2-3	2-3 cm	26.33	20.94	24.59	4.09	34.93	15.73	11.64	19.20	44	26.94	35.91	35.05	0.47	0.78	9.6
ZUI 2-4	3-5 cm	52.65	42.70	49.11	4.08	66.87	27.71	23.63	39.16	9	47.27	70.39	68.17	0.48	0.80	9.6
ZUI 2-5	5-10 cm	135.79	106.56	126.94	4.09	169.44	71.72	67.63	97.72	1	103.82	169.82	163.95	0.53	0.77	8.9
ZUI 3-1	0-1 cm	26.33	22.58	24.45	4.07	32.23	11.52	7.45	20.71	118	22.90	29.91	29.12	0.30	0.85	11.3
ZUI 3-2	1-2 cm	26.33	20.96	24.59	4.04	34.82	15.60	11.56	19.22	112	24.84	34.62	33.75	0.47	0.78	8.9
ZUI 3-3	2-3 cm	26.33	21.32	24.56	4.10	35.51	15.96	11.86	19.55	114	24.72	33.77	32.86	0.48	0.80	10.1
ZUI 3-4	3-5 cm	52.65	43.71	49.02	4.16	65.55	25.47	21.31	40.08	26	48.50	69.38	67.23	0.43	0.82	10.3
ZUI 3-5	5-10 cm	135.79	107.78	126.84	4.20	164.41	65.58	61.38	98.83	14	49.57	83.00	79.84	0.48	0.78	9.5
ZUI 4-1	0-1 cm	24.25	23.70	22.28	4.12	27.86	6.13	2.01	21.73	19	22.64	24.50	24.08	0.09	0.98	22.6
ZUI 4-2	1-2 cm	26.33	21.24	24.56	4.14	33.25	13.77	9.63	19.48	100	24.15	33.19	32.20	0.39	0.79	11.0
ZUI 4-3	2-3 cm	26.33	21.53	24.54	4.14	33.88	14.14	10.00	19.74	4	25.21	34.88	33.68	0.41	0.80	12.4
ZUI 4-4	3-5 cm	52.65	41.30	49.22	4.13	65.51	27.64	23.51	37.87	54	47.04	70.30	67.78	0.48	0.77	10.8
ZUI 4-5	5-10 cm	108.08	73.79	101.95	4.18	143.41	75.74	71.56	67.67	27	47.06	83.80	81.42	0.70	0.66	6.5
ZUI 5-1	0-1 cm	26.33	21.48	24.54	5.15	34.65	14.95	9.80	19.70	108	26.41	36.72	35.76	0.40	0.80	9.3
ZUI 5-2	1-2 cm	26.33	20.46	24.63	4.18	37.00	18.24	14.06	18.76	49	25.17	38.90	37.71	0.57	0.76	8.7
ZUI 5-3	2-3 cm	26.33	20.20	24.65	4.13	37.65	19.13	15.00	18.52	10	26.13	36.37	35.50	0.61	0.75	8.5
ZUI 5-4	3-5 cm	52.65	41.23	49.23	4.09	69.05	31.24	27.15	37.81	18	49.59	76.17	73.70	0.55	0.77	9.3
ZUI 5-5	5-10 cm	135.79	102.75	127.26	4.07	170.17	75.95	71.88	94.22	10	48.86	82.53	79.25	0.56	0.74	9.7

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Alterra Wageningen UR is the research institute for our green living environment. We offer a combination of practical and scientific research in a multitude of disciplines related to the green world around us and the sustainable use of our living environment, such as flora and fauna, soil, water, the environment, geo-information and remote sensing, landscape and spatial planning, man and society.

The mission of Wageningen UR (University & Research centre) is 'To explore the potential of nature to improve the quality of life'. Within Wageningen UR, nine specialised research institutes of the DLO Foundation have joined forces with Wageningen University to help answer the most important questions in the domain of healthy food and living environment. With approximately 30 locations, 6,000 members of staff and 9,000 students, Wageningen UR is one of the leading organisations in its domain worldwide. The integral approach to problems and the cooperation between the various disciplines are at the heart of the unique Wageningen Approach.