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ANTWERPEN

ECOSYSTEM MANAGEMENT
RESEARCH GROUP

Onderzoek naar de gevolgen van het Sigmaplan, baggeractiviteiten en havenuitbreiding in de Zeeschelde op het milieu

Geïntegreerd eindverslag van het onderzoek verricht in 2004

Tom Maris, Stefan Van Damme & Patrick Meire [Red.]

Onderzoeksgroep Ecosyteembeheer
Departement Biologie
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Hoofdstuk 1. Inleiding

1.1. Situering Omes

De stormvloed van 3 januari 1976 en de eropvolgende overstromingen gaven aanleiding tot de uitvoering van een omvangrijk plan dat het gehele Zeescheldebekken moet beschermen tegen overstromingen: het Sigmaplan. Na een nieuwe storm in 1994, met de hoogste waterstanden ooit gemeten op de Zeeschelde, werd hiertoe een nood- en urgentieprogramma goedgekeurd. De uitvoering hiervan diende wel te passen binnen een integrale visie op het beheer van de waterlopen. Dit leidde tot een Algemene Milieu-Impact studie voor het Sigmaplan en aansluitend tot een Onderzoek Milieu-Effecten Sigmaplan, OMES genaamd (Meire *et al.*, 1997; Van Damme *et al.*, 2001). Het OMES-project had tot doel de biogeochemische kennis van de Zeeschelde te actualiseren en in belangrijke mate uit te breiden. Als vervolg hierop werd een uitgebreid monitoringprogramma opgestart: "Onderzoek naar de gevolgen van het Sigmaplan, baggeractiviteiten en havenuitbreiding in de Zeeschelde op het milieu", meestal ook kortweg Omes genaamd. Dit OMES project werd opgericht om de biogeochemische kennis van de Zeeschelde te actualiseren en in belangrijke mate uit te breiden, in het kader van het Sigmaplan. In de nieuwe visie waarbij veiligheid, toegankelijkheid en natuurlijkheid tesamen worden aangepakt, is een goede kennis van het estuarine ecosysteem van de Schelde onontbeerlijk. De voorzetting van deze monitoring is een belangrijk instrument geworden bij het wetenschappelijk onderzoek in het estuarium. De kennis die voortvloeit uit dit onderzoek is een onmisbaar instrument bij de verdere planning en uitvoering van het vernieuwde Sigmaplan.

1.2. Inhoud van dit rapport

Dit rapport bundelt de resultaten van de monitoringscampagne van het monitoringsjaar 2004. De monitoring werd verzorgd door verschillende partners (vermeld als de verschillende percelen in bestek 16EI/01/37) die elk een deelaspect van het estuariene systeem bestudeerden. De conclusies van de verschillende deelstudies staan geïntegreerd in dit eindrapport. Het eerste hoofdstuk is gewijd aan de practische organisatie en coördinatie van de monitoring. Hoofdstuk 2 geeft een beknopte synthese van de verschillende onderzoeksresultaten. De volgende hoofdstukken geven telkens de integrale deelverslagen van de verschillende deelonderzoeken (percelen).

1.3. Organisatie en coördinatie

1.3.1. Monitoring 2004

Organisatie en coördinatie behoort, naast de monitoring van de basiswaterkwaliteit, tot de kerntaken van de deelopdracht 1 (Van Damme & Meire, 2002). De activiteiten worden zowel logistiek als op wetenschappelijke inhoud gecoördineerd. De monitoring in 2004 vormt een voortzetting van de monitoring uit 2003 (Maris et al, 2004). Voor de uniformiteit van de dataset werd maandelijks op dezelfde plaatsen op dezelfde methode gemonsterd. De vaartochten werden in overleg met het Nederlandse Instituut voor Oecologisch Onderzoek (NIOO) georganiseerd zodat er zoveel mogelijk aansluiting bestaat tussen de OMES en de NIOO dataset. In 2004 werden ook afspraken gemaakt met het NIOO voor staalname op de Westerschelde. Het betreft de lokaties Hansweert, Baalhoek en Bath, die nu toegevoegd zijn aan het Omes monitoringsprogramma (tabel 1.1). De stalen zullen op de dag van monstername zelf overhandigd worden aan de Omes partners op de Veremans, en zullen verder behandeld worden zoals de boundary stations. In de maanden waar er geen overlap is van de Omes en de NIOO vaartochten, zal de coördinator de stalen ophalen.

Concreet werd de monitoring in 12 maandelijkse campagnes georganiseerd voor het opnemen van het longitudinale profiel en zes 13-uurscampagnes voor een tidaal profiel (tabel 1.2 en 1.3). De monstername door de verschillende percelen gebeurde steeds simultaan op aangeven van de coördinator. Bemonstering van de zijrivieren werd door perceel 1 verzorgd. De stalen werden steeds op de dag van de monstername bezorgd aan de verschillende Omes partners.

De 13-uursmetingen werden georganiseerd in twee grote campagnes van telkens drie opeenvolgende dagen. Op deze wijze kon een meting in het zoete en op twee lokaties in de brakke saliniteitsgradiënt onder vergelijkbare meteorologische omstandigheden uitgevoerd worden. Omwille van de lichtmetingen (perceel 5), werden tijcycli met kentering in de vroege voormiddag gekozen. De drie opeenvolgende dagen werden bovendien gekozen kort voor of na de maandelijkse campagne, om de 13-uursdata te kunnen kaderen in een longitudinal profile. Dat resulteerde in juni in 3 meetdagen van eb tot eb, in september van vloed tot vloed.

Tabel 1.1: Omes monitoringsstations in 2004

station		staalname
Hansweert	Westerschelde	NIOO, met MS Luctor
Baalhoek	Westerschelde	NIOO, met MS Luctor
Bath	Westerschelde	NIOO, met MS Luctor
Boei 87	Zeeschelde	OMES, met MS Veremans
Boei 92	Zeeschelde	OMES, met MS Veremans
Boei 105	Zeeschelde	OMES, met MS Veremans
Antwerpen	Zeeschelde	OMES, met MS Veremans
Kruibeke	Zeeschelde	OMES, met MS Veremans
Bazel	Zeeschelde	OMES, met MS Veremans
Steendorp	Zeeschelde	OMES, met MS Veremans
Temse	Zeeschelde	OMES, met MS Veremans
Mariekerke	Zeeschelde	OMES, met MS Veremans
Vlassenbroek	Zeeschelde	OMES, met MS Scaldis I
Dendermonde	Zeeschelde	OMES, met MS Scaldis I
St. Onolfs	Zeeschelde	OMES, met MS Scaldis I
Appels	Zeeschelde	OMES, met MS Scaldis I
Uitbergen	Zeeschelde	OMES, met MS Scaldis I
Wetteren	Zeeschelde	OMES, met MS Scaldis I
Melle	Zeeschelde	OMES, met MS Scaldis I
Bovenschelde	Boundary	OMES, door perceel 1 (UA)
Durme	Boundary	OMES, door perceel 1 (UA)
Dender	Boundary	OMES, door perceel 1 (UA)
Rupel	Boundary	OMES, door perceel 1 (UA)
Zandvliet, dokzijde	Boundary	OMES, door perceel 1 (UA)

Tabel 1.2: Data van de maandelijkse monitoring 2004

Maand	Veremans	Scaldis I	Luctor (NL)
januari	27/1	28/1	27/1
februari	24/2	25/2	24/2
maart	23/3	24/3	23/3
april	20/4	21/4	20/4
mei	11/5	12/5	18/5
juni	15/6	16/6	15/6
juli	13/7	14/7	13/7
augustus	17/8	18/8	17/8
september	14/9	15/9	14/9
oktober	12/10	13/10	12/10
november	16/11	17/11	9/11
december	7/12	8/12	7/12

Tabel 1.3: Data van de 13-uurscampagnes

datum	lokatie	tij
28 juni '04	Lippenbroek (nabij Driegoten)	eb -vloed - eb
29 juni '04	Kruibeke	eb -vloed - eb
30 juni '04	Pas van Rilland (NL)	eb -vloed - eb
20 sept '04	Lippenbroek (nabij Driegoten)	vloed - eb - vloed
21 sept '04	Kruibeke	vloed - eb - vloed
22 sept '04	Pas van Rilland (NL)	vloed - eb - vloed

Zoals aangegeven in het voorgaande Omes rapport (Maris et al, 2004) werd ook aan de boundary stations een nieuwe lokatie toegevoegd: Zandvliet (tabel 1.1). Uit de monitoring van de voorbije jaren blijkt immers dat via deze sluis een groot debiet aan water zijn weg vindt naar de Schelde; een reden dus om deze stroom mee te behandelen met de andere zijzrivieren.

1.3.2. Planning Omes 2005

In overleg met alle partners werd reeds de planning voor 2005 uitgezet. Het betreft in grote mate een voortzetting van de huidige monitoring. Toch zullen er een aantal grote veranderingen worden doorgevoerd in 2005. De rol van de Rupel, en zijn invloed op de Schelde is nog onvoldoende gekend. Met het oog op een verandering van de waterkwaliteit van deze rivier, wanneer in 2007 de bouw van een waterzuivering op de Zenne voltooid zal zijn, is monitoring van de Rupel binnen Omes meer dan nuttig. Er wordt dan ook voorgesteld om met de MS Veremans de Rupel op te varen, en het boundarystation Rupel (te Klein Willebroek) voortaan te bemonsteren als een volwaardig estuarien meetstation. Indien mogelijk wordt nog een tweede punt, meer stroomopwaarts (Rumst) bemonsterd.

Om te vermijden dat deze uitbreiding van het vaarprogramma een te grote belasting wordt op het vaarschema van de Veremans, zullen een aantal meetstations gewijzigd worden. Het station Bazel, dat toch vrij dicht bij Kruibeke ligt, wordt opgeheven. De vrijgekomen tijd en analysecapacitiet wordt aangewend voor de twee extra Rupelstations. Het station Mariekerke, het laatste station van de Veremans vaartocht, wordt verschoven naar Lippenbroek, nabij Driegoten. Dit is een tijdswinst, en bovendien is een staalname ter hoogte van Lippenbroek veel relevanter voor het Omes onderzoek. Te Lippenbroek zal immers het eerste gecontroleerd overstromingsgebied met gecontroleerd gereduceerd getij (GOG-GGG) in werking treden. Meer gedetailleerde monitoringsdata in het estuarium pal voor dit testgebied zullen een belangrijke bijdrage spelen in het onderzoek van dit GOG-GGG.

Door de stroomafwaartse verschuiving van het station Mariekerke, ontstaat er wel een groter hiaat tussen de monitoring met Veremans en de monitoring met Scaldis, die pas start vanaf Vlassenbroek. Daarom wordt het eerste meetpunt van de Scaldis vaartocht stroomafwaarts verschoven tot Baasrode (tabel 1.4).

Tabel 1.4: voorgestelde monitoring 2005 (in vet de wijzigingen ten opzichte van 2004)

station		staalname
Hansweert	Westerschelde	NIOO, met MS Luctor
Baalhoek	Westerschelde	NIOO, met MS Luctor
Bath	Westerschelde	NIOO, met MS Luctor
Boei 87	Zeeschelde	OMES, met MS Veremans
Boei 92	Zeeschelde	OMES, met MS Veremans
Boei 105	Zeeschelde	OMES, met MS Veremans
Antwerpen	Zeeschelde	OMES, met MS Veremans
Kruibeke	Zeeschelde	OMES, met MS Veremans
~~Bazel~~	**opgeheven**	
Rupel (Kl. Willebroek)	**Rupel**	**OMES, met MS Veremans**
Rupel (Rumst)	**Rupel**	**OMES, met MS Veremans**
Steendorp	Zeeschelde	OMES, met MS Veremans
Temse	Zeeschelde	OMES, met MS Veremans
Lippenbroek	**Zeeschelde**	**OMES, met MS Veremans**
~~Mariekerke~~	**vervangen door Lippenbroek**	
Baasrode	**Zeeschelde**	**OMES, met MS Scaldis I**
~~Vlassenbroek~~	**vervangen door Baasrode**	
Dendermonde	Zeeschelde	OMES, met MS Scaldis I
St. Onolfs	Zeeschelde	OMES, met MS Scaldis I
Appels	Zeeschelde	OMES, met MS Scaldis I
Uitbergen	Zeeschelde	OMES, met MS Scaldis I
Wetteren	Zeeschelde	OMES, met MS Scaldis I
Melle	Zeeschelde	OMES, met MS Scaldis I
Bovenschelde	Boundary	OMES, door perceel 1 (UA)
Durme	Boundary	OMES, door perceel 1 (UA)
Dender	Boundary	OMES, door perceel 1 (UA)
~~Rupel~~	**~~Boundary~~ nu als estuarien station**	
Zandvliet, dokzijde	Boundary	OMES, door perceel 1 (UA)

Hoofdstuk 2. Omes synthese

2.1. Beknopt overzicht van de voornaamste resultaten per deelstudie

Dit overzicht van de resulaten werd door perceel 1 (Universiteit Antwerpen) opgesteld. Voor integrale conclusies per deelstudie (perceel) wordt naar de afzonderlijke deelstudies verwezen (Hoofdstukken 3-9).

2.1.1. Deelstudie 1: Basiswaterkwaliteit

Ondanks de hoge regenval, was 2004 een jaar met lage afvoerdebieten. Deze lage afvoerdebieten vertalen zich in een toegenomen saliniteit, en in een afname van de verdunning van de vuilvracht. Toch stijgen de meeste parameters niet, wat leidt tot een sterke daling van de totale vracht. De totale stikstofexport naar de Noordzee daalt terug tot het niveau van de jaren 1996-1997, een periode met vergelijkbare debieten. Tussen 1996 en 2004 is er dus niet veel verbetering geboekt wat betreft stikstofexport. De grootste stikstofbron voor het estuarium is misschien niet de Rupel, maar wel de Bovenschelde. Naar Gent toe worden de hoogste concentraties aan stikstof waargenomen.

2004 kenmerkt zich ook door hoge chlorofylwaarden in het zoete deel van de Zeeschelde. De sterke primaire productie geeft in deze zone aanleiding tot hoge zuurstofwaarden, ondanks de hoge belasting. De siliciumpoel geraakt wel quasi volledig uitgeput naar het einde van de zomer; de export naar zee is de laagste sinds de start van de omes monitoring.

2.1.2. Deelstudie 2: Koolstofcyclus

Net als vorig jaar, wordt in 2004 een duidelijke relatie gevonden tussen POC (particulair organsiche koolstof en zwevende stof, tussen $\delta^{13}C_{DIC}$ en de watertemperatuur en tussen $\delta^{13}C_{DIC}$ en de koolstof-stikstofverhouding in de zwevende stof. De laatste twee relaties illustreren fotosynthese en respiratie. Door preferentiële opname van ^{12}C tijdens fotosynthese, wordt de anorganische stikstofpoel in het water relatief rijker aan ^{13}C tijdens planktonbloei. Uit de analyses blijkt dat in 2004 de respiratie in het estuarium steeds belangrijker blijft dan de fotosynthese. Vooral in de winter, wanneer er quasi geen fotosynthese is, daalt hierdoor de $\delta^{13}C_{DIC}$. In de zomer stijgt de $\delta^{13}C_{DIC}$, vooral in de zone stroomafwaarts Kruibeke. De laagste waarden terft men aan in de Rupel tijdens de wintermaanden.

In het zoete deel van het estuarium worden in de zomer van 2004 hoge concentraties SPM en POC waargenomen, waarschijnlijk een gevolg van een hoge fytoplankton biomassa.

Vergeleken met 2003, liggen de $\delta^{13}C_{DIC}$ waarden in 2004 hoger, vooral in de winter. Er is een stijgende trend waarneembaar. De TAlk vertoont een dalende trend sinds 1995. Dit kan een gevolg zijn van teogenomen nitrificatie, als gevolg van betere zuurstofomstandigheden. De toegenomen debieten spelen wellicht ook een rol in de periode 1995-1999.

2.1.3. Deelstudie 3: Sedimentologie

Omdat de maandelijkse monitoring slechts een momentopname is uit een gehele tijcyclus, kunnen de maandelijkse waarden voor SPM moeilijk vergeleken worden. Om dit probleem te herhelpen, wordt ofwel met jaarlijkse gemiddelden gewerkt, ofwel wordt de conecntratie zwevende stofuitgedrukt in functie van de stroomsnelheid. Gemiddeld worden steeds de hoogste concentraties aan zwevende stof waargenomen nabij de bodem. Tussen de Nederlandse grens en Antwerpen zijn de concentraties de hoogste, tussen Temse en St. Onolfs komen geen hoge pieken van zwevende stof voor nabij de bodem. Nochtans kent de concentratie zwevende stof in de bovendste 10% van de waterkolom een maximum tussen Temse en Mariekerke, en een minimum nabij de Nederlandse grens. Een analyse van zwevende stof versus stroomsnelheid toont duidelijk dat perioden van hoge SPM concentraties samengaan met hoge stroomsnelheden. Echter een systematische correlatie tussen beide werd niet gevonden. Bovendien worden bij zeer lage stroomsnelheden soms ook hoge concentraties SPM waargenomen, ten gevolge van een vertraagde sedimentatie bij kentering.

Op de nieuwe stations in de Westerschelde wordt gemiddeld een stijging van SPM waargenomen van Waarde naar Bath.

Binnen deze studie werdook een inschatting gemaakt van de totale vracht aan zwevende stof in het estuarium. Deze berekening werd zowel voor de maandelijkse stations als voor de 13-uurscampagnes uitgevoerd. De totale vracht blijkt exponentieel toe te nemen met een diepte gemiddelde stroomsnelheid.

2.1.4. Deelstudie 4: fytoplankton

Net zoals in 2003, werd in 2004 de fytoplanktonbiomassa in het Schelde-estuarium gedomineerd door diatomeeën. Echter, in tegenstelling tot 2003, waar groenalgen enkel in de zomer van enig belang waren, komen in 2004 wel belangrijke hoeveelheden chlorofyten voor. Ze werden het ganse jaar waargenomen, maar vooral tijdens de lente in het zoete deel van de zeeschelde. Cyanobacteria, cryptofyten, euglenofyten en dinofyten werden ook waargenomen, maar bereikten nooit hoge biomassa's. In de Bovenschelde zijn diatomeeën duidelijk dominant tot het vroege voorjaar, maar in juni is er grote bloei van chlorofyten. In Dender en Rupel zijn chlorofyten ook de dominante groep in de lente.

In 2002 en 2003 was er een duidelijk te onderscheiden lente- en zomerbloei in het estuarium. In 2004 is er een geleidelijke overgang van lente naar zomerbloei, een bloei die vroeger begint en langer aanhoudt. Het warme en zonnige weer, gecombineerd met lage afvoerdebieten, ligt wellicht aan de basis van deze sterke bloeiperiode.

In de Ketenisse polder werd de ontwikkeling van microfythobenthos op de recent gecreeërde slikken opgevolgd. De chlorofylconcentraties op dit jonge slikke waren vergelijkbaar met de concentraties op de slikken van het Groot Buitenschoor, wat erop wijst dat kolonisatie door microfytobenthos zeer snel kan gaan. Bovendien werd in Ketenisse polder een geode relatie tussen de sedimentatie-ersoiesnelheid en chlorofyl a concentratie gevonden. Microfythobenthos is dan ook een belangrijke factor bij het vastleggen van intergetijdesedimenten, chlorofyl a kan misschien gebruikt worden als een indicator voor sedimentatie en erosie in nieuwe slik- en schorgebieden.

2.1.5. Deelstudie 5: Primaire productie

Net als tijdens de voorbije jaren werd in deze studie gefocust op het lichtklimaat in de waterkolom en de relatie met zwevende stof enerzijds, en de kwantificatie van fotosyntheseparameters voor estuarine fytoplanktonpopulaties anderzijds.
De lichtextinctie in het estuarium vertoont dezelfde patronen als voorgaande jaren. Ook de eufotische diepte, dit is de diepte waar nog slechts 1% van het licht aan de wateroppervlakte kan doordringen, kent gelijkaardige waarden, variërend tussen 2.3 en 0.27 meter. Deze eufotische diepte is sterk tijafhankelijk. Gemiddeld wordt de grootste diepte gevonden naij de grens (1.24 m), deze daalt dan tot een minimum rond km 110 (nabij Lippenbroek) om vanaf daar quasi constant rond 0.65 m te blijven tot Gent. In 2004 werd een duidelijke relatie waargenomen tussen fotische diepte en zwevende stof, een relatie die bijna identiek is aan die van de voorbije 2 jaren. Tijdens de 13-uurscampagnes wordt nogmaals de sterke afhankelijkheid van de lichtextinctie van zwevende stof, en bijgevolg van stroomsnelheid, bevestigd.

De fotosyntheseparameters die in 2004 bepaald werden, benaderen sterk de waarden van 2003.

Dankzij de herhaalde observatie van zwevende stof , werd een zero-dimensionaal model opgesteld voor fytoplanktonproductie in een troebel, sterk tijafhankelijk en goed gemengd estuarium zoals de Schelde. Dit model toont aan dat in stroomopwaartse, ondiepe lokaties zoals Dendermonde een netto fytoplanktonproductie mogelijk is, ondanks de hoge turbiditeit. In Antwerpen daarentegen, leidt de grotere waterdiepte tot een netto negatieve productie, ondanks de lagere turbiditeit. Dit stemt overeen met de afname van fytoplankton tussen Gent en Antwerpen, die wordt waargenomen tijdens de monitoring.

2.1.6. Deelstudie 6: Micro- en mesozoöplankton

De monitoring van het micro- en mesozoöplankton in 2004 was een voortzetting van het onderzoek van de voorbije jaren. Omwille van zijn cruciale positie, het is de schakel tussen primaire productie en de hogere trofische niveaus, is dit zooplankton een essentiële component voor het functioneren van een estuarium. Over het algemeen is de zooplanktongemeenschap in de schelde de laatste jaren toegenomen in abundantie, vergeleken met vroegere monitoring uit de jaren '60 en begin jaren '90. Deze verbetering wordt toegeschreven aan de verbeterde waterkwaliteit, vooral in het zoete deel.

In 2004 telde de taxonomsiche lijst 99 taxa, waarvan 40 nooit eerder werden gerapporteerd in de Schelde. Rotiferen zijn dominant in het zoete deel, zowel qua abundantie als qua soortenrijkdom: 40 species. Sommige exoten, die vorig jaar ook werden gerapporteerd, komen terug voor. De seizoenale verdeling van zooplankton is vrij costant over de jaren, maar de abundanties en ruimtelijke verspreiding blijven variable. Uit CCA analyses blijkt dat om een verbanden te leggen tussen zooplankton en milieufactoren meer gedetailleerde taxonomische bepalingen nodig zullen zijn. Nu komen enkel verbanden saliniteit en zuurstofconcentraties aan het licht.

2.1.7. Deelstudie 7: zijdelingse belasting

Deze studie onderzocht de zijdelingse belasting in het estuarium: welke vrachten komen via zijdelingse punten (kleine riviertjes, grachten, lozingspunten, sluizen, ...) in het estuarium. Deze studie was eenmalig; de resultaten werden in een afzonderlijk rapport gepubliceerd in 2003.

2.1.8. Deelstudie 8: Effecten van waterkwaliteit en getij op overstromingsgebieden.

Perceel 8 (Universiteit Antwerpen) onderzoekt de effecten van gecontroleerde overstromingen met gereduceerd getij op rietgroei en zware metalen in overstromingsgebieden. In 2003 en 2004 werd daarom het Scheldewater onderzocht op zware metalen: het gehalte zware metalen in de zwevende stof werd bepaald. Er is geen seizoenale trend waarneembaar tussen 2003 en 2004. Als de concentraties zware metalen in de zwevende stof worden getoest aan de bodemsaneringsnorm, is er een overschrijding voor cadmium en zink vastgesteld.

In Kruibeke worden in proefopstellingen bodems blootgesteld aan een gereduceerd getij. Twee van de proefopstellingen bevatten een met zware metalen gecontamineerde bodem (1 begroeid met riet, 1 onbegroeid), twee opstellingen bevatten niet gecontamineerde bodems (1 begroeid met riet, 1 onbegroeid). Het Scheldewater, vervuild met zware metalen, overspoelt deze proefopstelling. In de verschillende proefopstellingen werd het poriewater geanalyseerd. Voor de verschillende onderzochte parameters werd geen seizoenale trend vastgesteld. Ook kon er geen verschil opgetekend worden tussen de plots met en zonder riet. Het poriewater van de gecontamineerde plots bevatte bovendien geen afwijkende concentraties aan nutriënten of metalen ten opzichte van de referentiebodems. Slechts voor 4 parameters was er een verschil. NO_3-N was hoger in de vervuilde plot, SO_4 in de niet vervuilde plot, maar aangezien deze verschillen van meet af voorkwamen, kunnen ze niet gelinkt worden aan de proefopzet (overstromingsregimes, rietgroei, contaminatie). IJzer en mangaanconcentraties nemen toe met de diepte in het poriewater van de gecontamineerde plots. Dit is een gevolg van de anoxische toestand van de bodem vanaf een diepte van 40 cm: Fe en Mn, gebonden aan de bodem als Fe- en Mn-oxides, wordt gereduceerd in de anoxische zone.

In de bodems zelf werd ook geen seizoenale trend waargenomen in de metaalconcentraties. De sedimentatie in de proefopstellingen werd ook opgevolgd, maar tegen de verwachting in kon geen verschil waargenomen worden tussen begroeide en niet begroeide plots. De biomassa riet zelf, verschilde in 2004 ook niet tussen de niet vervuilde en de vervuilde plots, dit in tegenstelling tot 2003. Ook in het riet zelf werd geen verhoogde metaalconcentratie gedetecteerd op de vervuilde plots.

In een proefopstelling te Wilrijk wordt het effect van verschillende overstromingsregimes op rietgroei nagegaan. De twee ingestelde regimes hadden geen invloed op de rietgroei. De verschillende hoogteniveaus in de rietbakken daarentegen wel.

Hoofdstuk 3. Basiswaterkwaliteit

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Eindverslag voor deelstudie 1 (perceel 1), periode januari 2004-december 2004

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3.1. Inleiding

De Omes monitoringscampagnes van de voorbije jaren, tussen 1995 en 2003, illustreerden de trieste toestand van het Scheldewater. Het estuarium wordt gekendmerkt door zeer hoge organische belasting en hoge nutriëntvrachten (Van Damme et al, 2005). Het zuurstofpeil wordt door sterke bacteriële respiratie naar beneden gedrukt. In de zomers van de jaren '90 leidt dit dat quasi anoxische toestanden in gans het zoete deel van de Zeeschelde. Maar tussen 1998 en 2003 is er wel een duidelijke wijziging merkbaar: de zuurstofgehaltes stijgen, de nutriëntconcentraties dalen (op nitraat na). Tussen 1998 en 2002 werd een zeer sterke stijging van het afvoerdebiet van de Zeeschelde waargenomen (Maris et al., 2003). Deze stijging was significant gerelateerd aan de toename in neerslag in de beschouwde periode (Struyf et al, 2004). In dezelfde periode zien we de concentraties aan nutriënten evenredig afnemen; de hoge debieten veroorzaken duidelijk een verdunnend effect. De totale nutriëntvracht was immers niet afgenomen, maar net toegenomen (Struyf et al, 2004). Als voornaamste oorzaak van de toegenomen nutriëntenvracht wordt een toename van diffusie input, ten gevolge van verhoogde afvoer, naar voor geschoven.

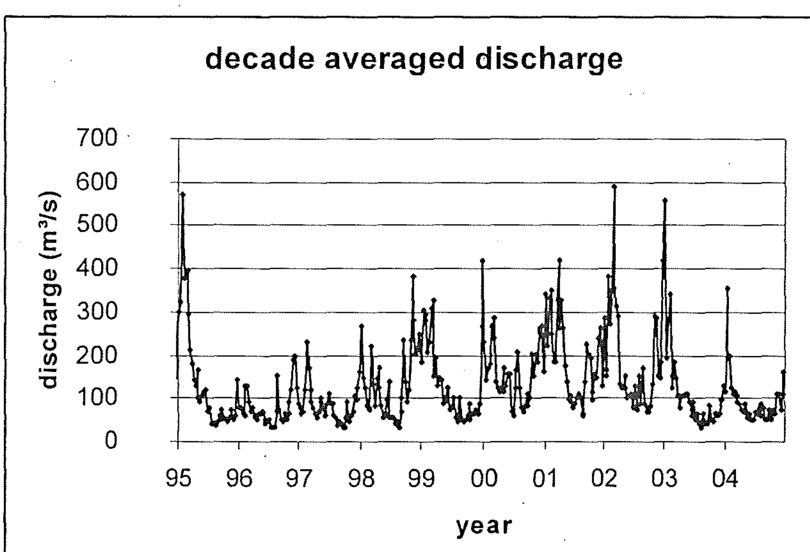
2003 was een keerpunt voor de afvoerdebieten: voor het eerst sinds 1998 daalde het afvoerdebiet terug aanzienlijk. Een verminderde verdunning leidde echter niet tot een toename van de nutriëntconcentraties (Maris et al, 2004). Hierdoor kon voor 2003 een sterke afname van de vrachten genoteerd worden, vooral de stikstofvracht daalde sterk.

2004 is weerom een jaar met lagere afvoerdebieten. In de volgende hoofdstukken wordt nagegaan in hoeverre de trendbreuk van 2003 zich ook in 2004 verder zet.

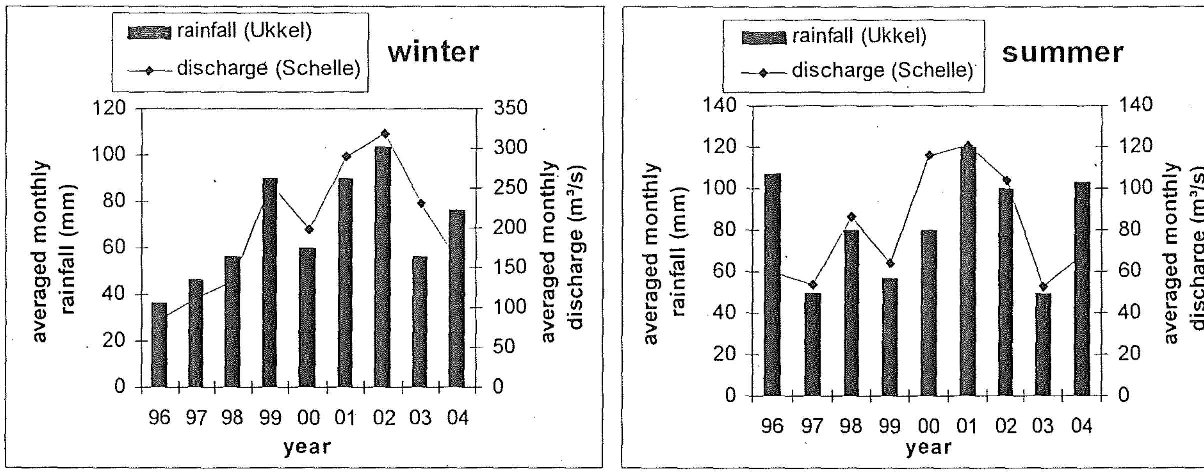
3.2. Hydrologie

2004 kenmerkt zich door lage afvoerdebieten te Schelle (fig 3.1). Met een gemiddeld jaarlijks debiet van 125 m^3/s in de periode 1980 – 2004, kan 2004, met een gemiddeld debiet van 95 m^3/s, als een "droog" jaar bestempeld worden. Nochtans blijkt dit niet uit de statistieken van het KMI (www.meteo.be). Te Ukkel was de enige bijzonderheid voor 2004 de hoge gemiddelde temperatuur, met een jaarwaarde die als zeer abnormaal kan worden gekarakteriseerd. De jaarwaarde voor neerslag was, in tegenstelling tot de debieten, ook abnormaal hoog (913.7 mm in 2004, normaal 780.1 mm). Deze abnormaal hoge waarde is vooral te wijten aan de zeer natte januarimaand: het tweede decade van januari was het natste sinds 1901. Qua debiet is dit decade "nat" (356 m^3/s), maar gedurende de natte winters tussen 1999 en 2002 kwam dit decadegemiddelde meermaals voor, uitschieters in 2002 (3[de] decade februari '02: 591 m^3/s) en 2003 (1[ste] decade januari '03: 557 m^3/s) kenden veel hogere debieten. Verder meldt Ukkel dat de lente droger was dan normaal, de zomer iets natter. Blijkbaar zijn de debieten niet meer eenvoudigweg gerelateerd aan de hoeveelheid neerslag (fig 3.2). Tussen 1996 en 2002 bestond er 's winters een duidelijke relatie tussen neerslag en debiet, zoals eerder beschreven door Struyf et al (2004). Sinds 2003 is deze relatie niet meer duidelijk (fig 3.3). Is er mogelijk een wijziging in het hydrologisch beheer in het bovenbekken van het estuarium? Ook het zomerdebiet in 2004 wijkt sterk af van het neerslagpatroon. Zulke afwijkingen zijn reeds vaker voorgekomen. Een mogelijke oorzaak kan het sluisbeheer zijn te Gent, dat tijdens de zomermaanden zoet water van de Bovenschelde afleidt naar het kanaal Gent-Terneuzen. Een meer gedetailleerd onderzoek naar de neerslag in het Scheldebekken, een studie van de afvoerdebieten op verschillende lokaties in het estuarium en inzicht in het sluisbeheer dringen zich op.

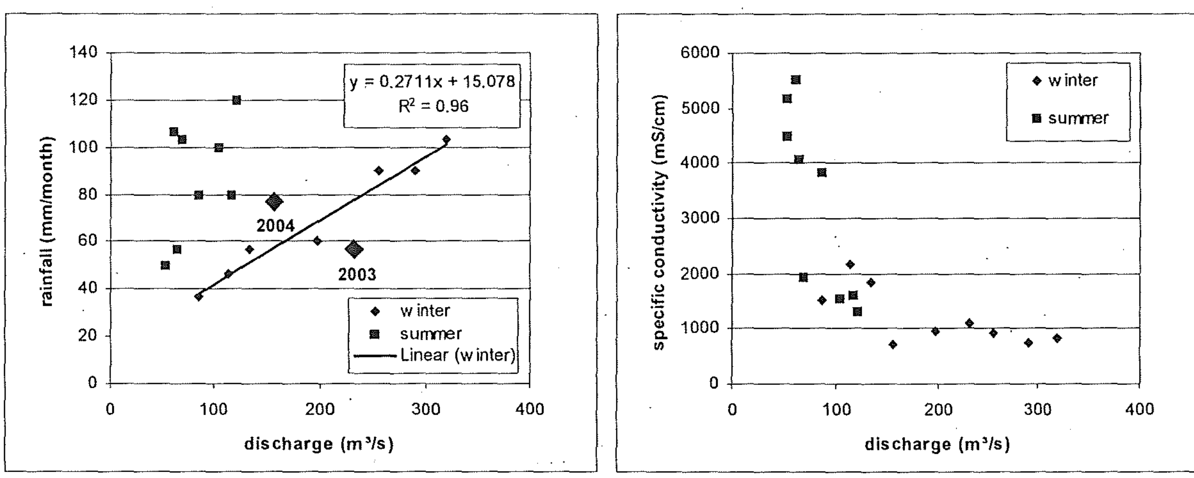
De relatie tussen afvoerdebiet en specifieke conductiviteit blijft in 2004 ongewijzigd (fig 3.3). Hoge debieten dringen het zoutgehalte terug, bij lage debieten stijgt de geleidbaarheid. 2004 kenmerkt zich door een hogere gemiddelde geleidbaarheid van het Scheldewater, zowel in de winter als in de zomer, ten gevolge van de lagere afvoer. De hoge neerslagpieken in 2004 te Ukkel hebben hierop geen invloed.



figuur 3.1: decade gemiddelde afvoerdebieten te Schelle (data AWZ)



figuur 3.2: winter- en zomergemiddelden voor neerslag en debiet. (winter: jan-feb-mrt; zomer: juli-aug-sept)



figuur 3.3: relatie tussen debiet (Schelle) en neerslag (Ukkel) en debiet (Schelle) en specifieke conductiviteit (Kruibeke). (periode 1996-2004; winter: jan-feb-mrt; zomer: juli-aug-sept)

3.3. Algemene waterkwaliteit

De waterkwaliteit voor 2004 wordt per parameter besproken en vergeleken met de voorbije jaren aan de hand "surface plots" (Surfers 3.1 tot 3.8). Deze werden gemaakt met de SURFER sotfware, versie 5.01, met een lineare ordinary kriging interpolatie, anisotropie radius 1/100. Deze plots geven op een compacte wijze de temporele en spaciale variaties weer. De x-as geeft het jaartal weer, de y-as de afstand tot de monding (Vlissingen). De plots geven de ruimtelijke patronen weer vanaf de Belgisch-Nederlandse grens (meetstation Boei 87, ca km 67) tot aan Gent (meetstation Melle, ca km 163). De kleurschaal geeft de concentratie weer. Om belangrijke verschillen bij lage concentraties duidelijk te kunnen weergeven, is de kleurschaal niet steeds lineair.

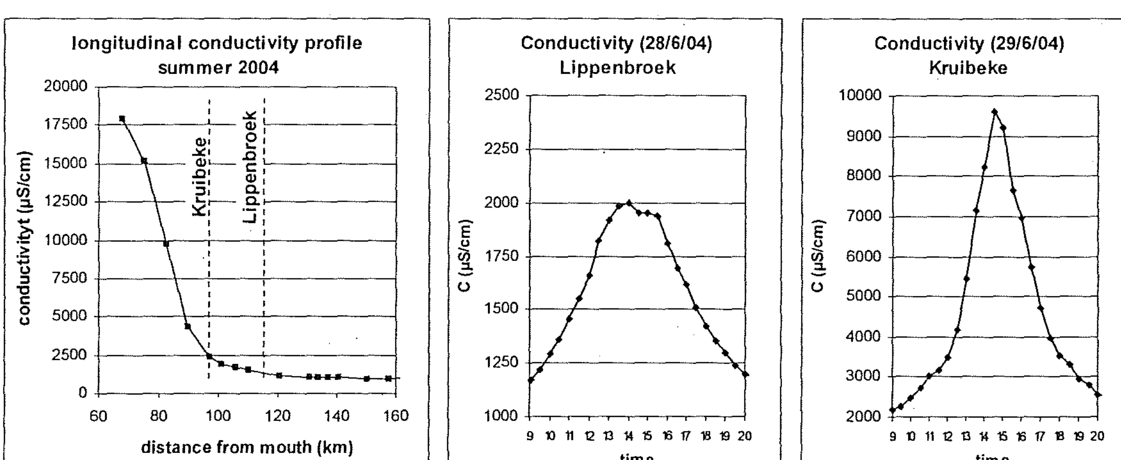
Basis voor de surface plots zijn de maandelijkse staalnames in het kader van de verschillende Omes-programma's sinds 1996. Deze maandelijkse staalnames werden ongeacht het getij genomen. Aangezien er voor verschillende parameters een sterke tidale variatie bestaat, geeft deze staalname geen correct beeld van de tijgemiddelde waterkwaliteit. Daarom werden de verschillende parameters ook uitvoerig bestudeerd tijdens enkele volledige tijcycli, en dit voor verschillende lokaties in het estuarium.

De surface plots zijn opgebouwd uit interpolaties met tweemaandelijkse gemiddelden, waardoor de tijvariatie gedeeltelijk wordt uitgemiddeld. De plots (Surfers 3.1 tot 3.8, in kleur) staan achteraan dit deelrapport gebundeld.

3.4. Conductiviteit

De specifieke conductiviteit kent duidelijke seizoenale trends, een gevolg van de sterkere winterdebieten en zwakkere zomerdebieten (surfer 3.1). Gemiddeld dringt de saliniteit zo'n 20 km verder het estuarium in tijdens de zomermaanden. Kruibeke (ca km 97), dat zich 's winters volledig in het zoete gedeelte van het estuarium bevindt, kent tijdens de zomer een sterke conductiviteitsgradient. Zo'n sterke gradient leidt ook tot grote tidale schommelingen in geleidbaarheid in de zomer (fig 3.4). Tussen de grens en Kruibeke is de gradiënt in de zomer het sterkst, tussen Kruibeke en Dendermonde daalt de conductiviteit slechts langzaam om vanaf Dendermonde quasi constant te blijven. Dit longitudinale conductiviteitsverloop vertaalt zich mooi in de tidale patronen. Lippenbroek, dat zich in de zone met zwakke conductiviteitsgradiënt bevindt, kent een langzame stijging van de geleidbaarheid bij vloed, gevolgd door een geleidelijke daling bij eb. In Kruibeke, dat zich op de overgang tussen de sterke en de zwakke gradiënt bevindt, stijgt de conductiviteit eerst langzaam, om dan zeer stijl omhoog te klimmen. In de winter verdwijnen deze schommelingen quasi volledig te Kruibeke: de hoge winterafvoer dringt de saliniteit sterk terug.

Tijdens de 13uursmeting in juni bereikte de conductiviteit te Lippenbroek bij vloed een maximum van ca 2000 µS/cm; in Kruibeke werd deze waarde benaderd bij eb. Op basis van deze data kan men ruwweg stellen dat de watermassa die bij vloed het Lippenbroek bereikt, bij eb aan Kruibeke passeert, zo'n 18 km meer stroomafwaarts.



Figuur 3.4: Longitudinale en tidale conductiviteitsprofielen

De reeds eerder gerapporteerde stijging van het afvoerdebiet tussen 1996 en 2002 zorgde voor een sterke terugdringing van de zoutintrusie. In de zeer natte winter 2000-2001 zien we dat bijna de volledige Zeeschelde zoet wordt. De lage afvoerdebieten in de zomer van 2003 en 2004 daarentegen maken dat een tidale conductivititeitsvariatie duidelijk voelbaar wordt tot voorbij Temse. De sterke conductiviteitsgradiënt kan in droge zomers zo'n 10 km verder landinwaarts schuiven ten opzichte van natte zomers. De zeer lage debieten in het najaar van 2004 maken zelfs dat de conductiviteit te Kruibeke even hoog wordt als de conductiviteit aan de Belgisch-Nederlandse grens tijdens het natte najaar van 2000, een verschuiving van de conductiviteitsgradiënt met meer dan 20 km. Nochtans staat 2004 niet gekend als een droog jaar wat betreft hoeveelheden neerslag.

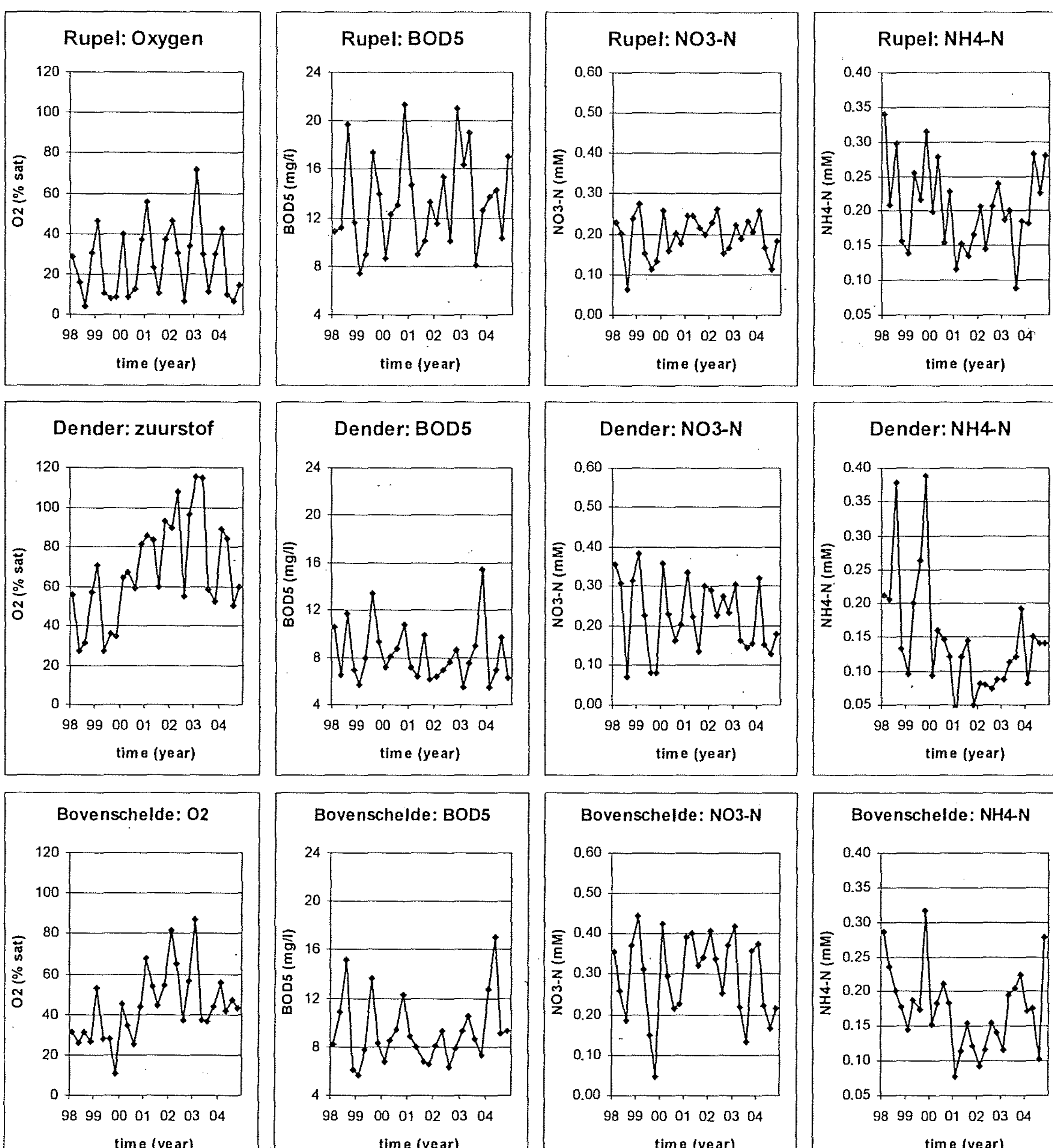
3.5. Zuurstof

Ter hoogte van de Nederlandse grens, waar de Zeeschelde plots sterk verbreedt en overgaat in Westerschelde, kent het estuarium steeds een goede zuurstofverzadiging (surfer 3.2). Tijdens alle Omescampagnes tussen 1996 en 2004 daalde het zuurstofpeil nooit onder de 50%, zowel tijdens de zomer als winter. 's Winters wordt meestal 70% of meer gehaald. Enkel tijdens de jaren met zeer hoge afvoerdebieten (1999-2000-2001-2002) merken we een lichte daling van de zuurstofwaarden aan de grens. Vermoedelijk wordt de bijna anoxische watermassa rond de Rupelmonding door de hoge debieten verder uitgesmeerd naar de monding toe. Want hoewel de Rupel een veel grotere zone met een groter zuurstofdeficit kent tussen 1996 en 1999 dan in 2000, worden in het zeer natte 2000 lagere zuurstofwaarden genoteerd aan de grens dan in de voorbijgaande periode. In 2003 en vooral 2004 kent de zone aan de grens quasi continu hoge zuurstofwaarden (60-80%), wellicht te danken aan de lage debieten en de sterk verbeterde zuurstofhuishouding in de Boven-Zeeschelde.

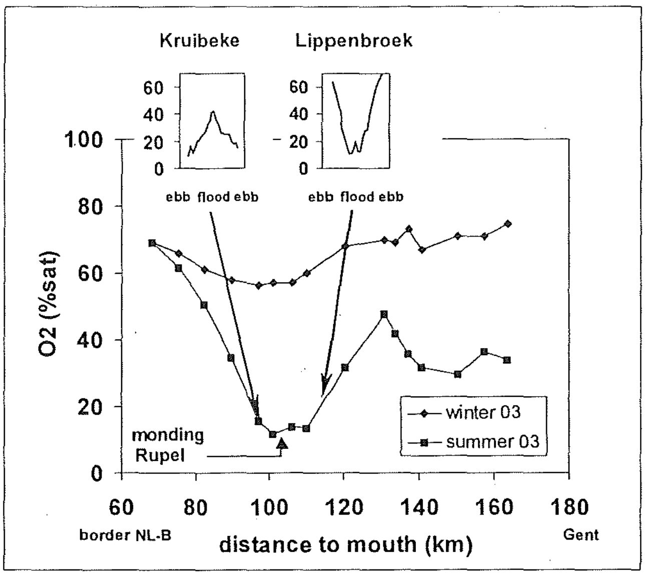
Wat het sterkst in het oog springt is de sterke verbetering van de zuurstofverzadiging stroomopwaarts de Rupel. Daar waar de vervuilde zone zich in 1996 en '97 nog uitstrekt van Antwerpen tot bijna in Gent, beperkt de anoxische zone zich vanaf 2003 tot de meetstations rond de Rupel, tussen Kruibeke (ca km 97) en Steendorp (ca km 106) (surfer 3.2). Nochtans is de kwaliteit van het Rupelwater zelf niet zo sterk verbeterd de laatste jaren (fig. 3.5). De zuurstofverzadiging kende tijdens de wintermaanden wel een stijgende trend, maar vanaf medio 2003 daalt het zuurstofgehalte terug. 2004 was het jaar met het gemiddeld laagste zuurstofgehalte in de Rupel sinds de start van de monitoring in 1998. Hiermee gepaard zien we ook het ammoniumgehalte terug toenemen sinds midden 2003, het nitraatgehalte terug afnemen in de Rupel. Ondanks de toegenomen inspanning op gebied van waterzuivering, blijft de Rupel nog steeds een zeer vervuilde rivier, gedomineerd door respiratie (lage zuurstof, lagere pH (surfer 3.9)). Brussel loost immers nog steeds ongezuiverd afvalwater via de Zenne in het Rupelbekken. Veel verbetering wordt verwacht als het nieuwe zuiveringsstation op de Zenne in werking treedt.

De verbetering van de zuurstofverzadiging rond de Rupelmonding zal dus veeleer een gevolg zijn van een betere zuurstofhuishouding meer stroomopwaarts de Schelde, dan van een verbetering van het Rupelwater. Meer stroomopwaarts komen immers de laatste jaren, ten gevolge van sterke primaire productie, hogere zuurstofwaarden voor die hun invloed zullen hebben op de lage waarden rond de Rupel. De nutriëntvracht die stroomopwaarts in de Zeeschelde stroomt is echter niet sterk gewijzigd (zie verder).

Tijdens de 13-uursmetingen werd de invloed van de vuilvracht van de Rupel op de zuurstofverzadiging in het estuarium mooi geïllustreerd (fig. 3.6). In juni en september werden 13-uursmetingen verricht stroomopwaarts (Lippenbroek) en stroomafwaarts (Kruibeke) de Rupelmonding. Bijgevolg zien we bij vloed de zuurstofarme watermassa vanuit Rupelmonde naar Lippenbroek migreren, bij eb zien we de zuurstofarme zone naar Kruibeke schuiven (fig 3.6). Als gevolg hiervan kennen Kruibeke en Lippenbroek een invers tidaal patroon: te Kruibeke is er een zuurstofminimum bij eb, in Lippenbroek vinden we dezelfde minimumwaarde terug bij vloed. Dit zuurstofminimum doet zich voor bij een conductiviteit van ca 2000 µS/cm, de conductiviteit die gemiddeld teruggevonden wordt tussen Kruibeke en Bazel. Het zuurstofminimum in het estuarium bevindt dus een 5-tal km stroomafwaarts van de Rupelmonding (ca km 103). Figuur 3.7 toont het zuurstofverloop in functie van de conductiviteit voor de twee 13-uurscampagnes. Bij een zelfde oefening voor de maandelijkse longitudinale campagnes, bekomt men een zelfde patroon, zodat de waterkwaliteit tijonafhankelijk kan worden weergegeven. De juli campagne had hoogwater rond de middag, de staalname in augustus kende laagwater op de middag. Beide maanden hadden vergelijkbare afvoerdebieten. De lagere afvoerdebieten van juni zijn een mogelijke verklaring voor de afwijkende relatie tijdens deze longitudinale campagne. In de zone met weinig tot geen conductiviteitsgradiënt (< 1500 µS/cm) is geen duidelijke relatie meer op te stellen.

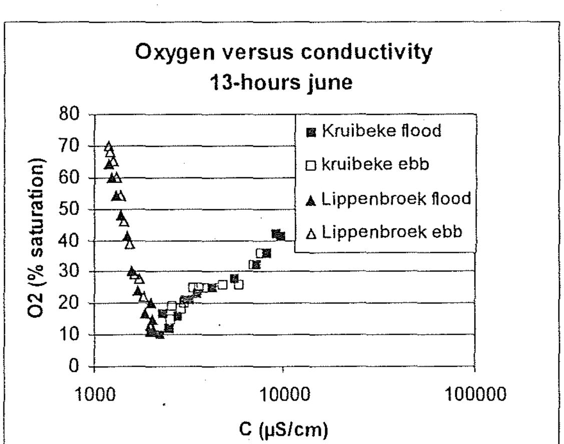


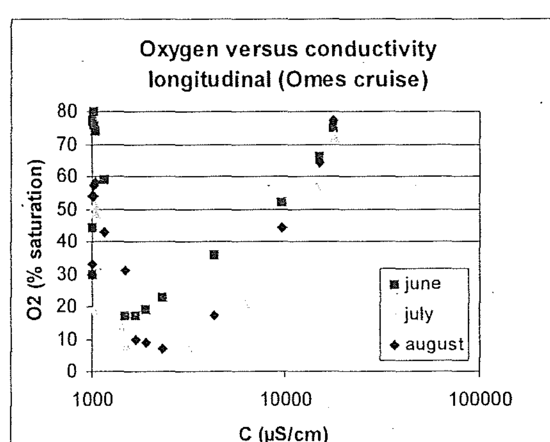
figuur 3.5: Zuurstofverzadiging, Biologische Zuurstofvraag (BOD5), Nitraat (NO3-N) en Ammonium (NH4-N) in de Rupel, Bovenschelde en Dender.



Figuur 3.6: Tidale zuurstofpatronen te Kruibeke (29/06/04) en Lippenbroek (28/06/04), gesitueerd langsheen het longitudinale profiel op de Zeeschelde

De tidale patronen, zowel te Kruibeke als te Lippenbroek, zijn opvallend symmetrisch (zowel in juni als september). Wordt zuurstof uitgezet ten opzichte van conductiviteit, dan kennen de eb en de vloedstalen eenzelfde relatie (fig. 3.7). Blijkbaar wordt het zuurstofarme water niet sterk geaereerd in 1 tijbeweging. Enkel te Lippenbroek is er een zeer lichte toename van zuurstof in het ebwater ten opzichte van het vloedwater, maar niet significant. Te Kruibeke verwacht men een aanrijking tijdens vloed, maar dit werd niet waargenomen.





Figuur 3.7: zuurstof in functie van saliniteit (log-schaal) tijdens de 13uurscampagnes te Kruibeke (29/06/05) en Lippenbroek (28/06/05) en tijdens 3 maandelijkse boottochten in 2004.

Stroomopwaarts de Rupel, tussen kilometer 120 en 140, is de waterkwaliteit sinds 1996 duidelijk in stijgende lijn. In 1996 daalt het zuurstofgehalte nog onder de 5% tijdens de zomer, vermoedelijk ten gevolge van sterke bacteriële productie en zeer beperkte primaire prodcutie. In de winter steeg het zuurstofgehalte tot 30 à 40%: grotere afvoerdebieten verdunnen de vuilvracht en de lagere temperaturen belemmeren sterke bacteriële zuurstofconsumptie. De laatste jaren is die slechte situatie rond Dendermonde drastisch gewijzigd: in 2004 werden in de zomerse zuurstofwaarden boven de 80% verzadiging genoteerd, de beste waarden sinds de start van de Omes campagnes. Een sterke verbetering van de waterkwaliteit van de Dender ligt wellicht mee aan de basis, samen met een sterke primaire productie. De chlorofylconcentraties zijn immers spectaculair toegenomen op de Zeeschelde. Parallel met de pieken in chl a neemt pH toe, wat ook op primaire productie wijst (surfer 3.9). Ook de Dender kent een stijging van primaire productie, vooral in 2003: dan wordt een oversaturatie tot 115% waargenomen.

Kort bij Gent zet de verbetering van de zuurstofhuishouding zich niet meer voort. Daar waar in de zomer van de jaren '90 tussen de Rupelmonding en Gent 1 aaneengesloten hypoxische zone heerst, tekent zich in de zone rond Wetteren in 2001, 2003 en vooral 2004 een tweede zuurstofarme zone af. Nochtans heeft deze zone de hoogste chlorofyl a concentraties en verwacht men dus, dankzij sterke primaire productie, hogere O_2-waarden. Echter, deze zone krijgt de zeer grote vuilvracht vanuit de Bovenschelde te verwerken. Hoewel de zuurstofconcentraties in de Bovenschelde niet dramatische laag zijn, integendeel, liggen de concentraties aan nutriënten en BOD_5 hier gemiddeld hoger dan in de Rupel. De verwerking van deze vuilvracht ligt wellicht aan de basis van de daling van het zuurstofpeil: parallel aan een daling van BOD_5 en NH_4^+, zien we een daling van het zuurstofgehalte. Bacteriële respiratie overstijgt hier wellicht de primaire productie. Ter hoogte van km 120 bereiken de BOD_5- en NH_4^+-vrachten een minimum, nitraat een maximum. Meer stroomafwaarts keren de trends terug om: we komen in de invloedsfeer van de Rupel. Het zuurstofmaximum wordt echter niet waargenomen ter hoogte van km 120, de zone met minimale belasting, maar 20 à 30 km meer stroomopwaarts, waar de belasting veel hoger is. Een zeer sterke primaire productie verkomt hier wellicht de uitgestrekte hypoxische zone uit de jaren '90, en geeft aanleiding tot een zuurstofmaximum tussen Dendermonde (ca 130 km) en Appels (ca 140 km) in 2001, 2003 en vooral 2004. Het belang van primaire productie wordt mooi geillustreerd in 2002. 2002 kent veel lagere chlorofylgehaltes (en lagere pH) dan 2001 en 2003-2004, en bijgevolg ook een lagere primaire productie. In dat jaar zien we dan ook een sterke daling van de zuurstofverzadiging, tot onder de 10% , in de zone tussen Dendermonde en Appels, hoewel de belasting dat jaar niet hoger ligt. De ammoniumconcentraties zijn dat jaar zelfs de laagste sinds de start van de omes campagnes. Ook in 1997 worden hogere chl a en pH waarden geregistreerd, wat wijst op sterkere primaire productie. Echter de zuurstofgehaltes zijn dramatisch laag. De zuurstofproductie weegt dat jaar niet op tegen de vermoedelijk extreme consumptie: de ammonium- en BOD_5-concentraties bereiken in 1997 recordhoogten.

3.6. Stikstof

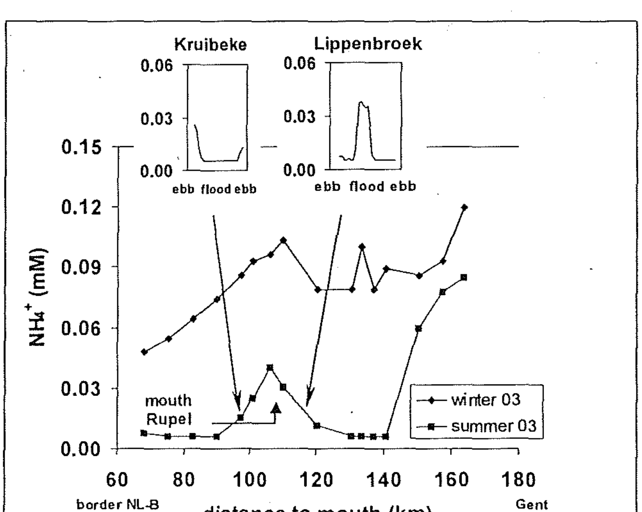
De ammoniumconcentratie (surfer 3.3) kenmerkt zich door een sterke seizoenale schommeling. In de zomer zorgt microbiële omzetting van ammonium tot nitraat voor een sterke daling van de NH_4^+-concentratie. Toegenomen zuurstofconcentraties hebben dit aerobe proces versterkt, zodat in de zomers van 2003 en vooral 2004 de ammoniumconcentraties in het ganse estuarium onder de 0.05 mM bleven. Zelfs ter hoogte van de Rupelmonding en in de meest stroomopwaartse delen van het estuarium waren de concentraties zeer laag, hoewel zowel Rupel als Bovenschelde nog concentraties tussen 10 en 30 mM vertonen (fig. 3.5). De verbetering die genoteerd werd tussen 1996 en 2002 kan grotendeels toegeschreven worden aan de toegenomen debieten: een sterke verdunning doet de concentraties dalen. De ammoniumvrachten dalen immers amper (fig. 3.8). Vanaf 2003 daalt echter ook de vracht aan ammonium. De zeer lage concentraties en de lage afvoerdebieten in zomer en najaar 2004 zorgen dan voor een historische lage ammniumvracht. De lage debieten van de voorbije 2 winters doen de concentratie wel terug toenemen ten opzichte van de natte winters, de vrachten stijgen niet.

Tegengesteld aan de ammoniumtrend, vertoont de nitraatconcentratie een duidelijke stijging, vooral in de zomermaanden (surfer 3.4). De stijging van het zuurstofgehalte heeft immers de omzetting van ammonium naar nitraat bevordert. De totale stikstofconcentratie daarentegen is weinig veranderd. Wel zijn de sterke seizoenale schommelingen vervaagd.

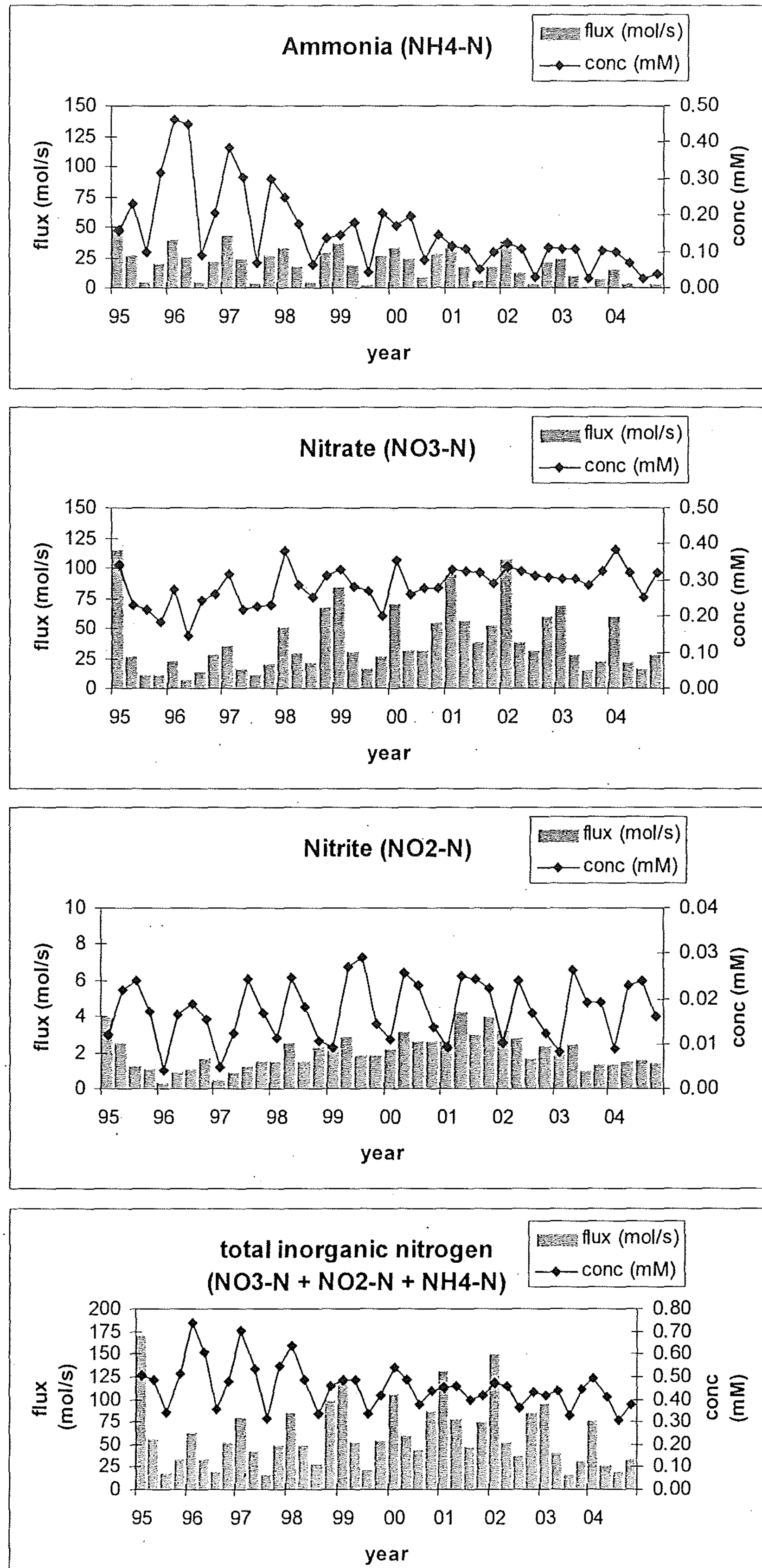
De toegenome zuurstofwaarden hebben waarschijnlijk ook de denitrificatie, een anaeroob proces, doen afnemen. Deze afname, en de potentiële stijging van de nitraatconcentraties, wordt misschien gemaskeerd door de toegenomen debieten in de periode 1997-2002. Want hoewel de verdunning sterk toenam, dalen de concentraties niet. Als gevolg daarvan zien we een sterke stijging van de nitraatvracht met een maximum in de winter van 2002 (fig. 3.8). Ook de totale stikstofvracht kent dan een maximum. Wat stikstof betreft is de waterkwaliteit in het estuarium er dus niet op vooruit gegaan tussen 1995 en 2002, in tegendeel.

In 2003 en 2004 wordt ondanks de gedaalde verdunning (lagere debieten), geen stijging van nitraat waargenomen. De vrachten voor het eerst terug tot het niveau van de jaren 96'-97'. Hoewel de totale stikstofconcentratie niet echt daalt, worden in 2003 en 2004 de laagste vrachten waargenomen sinds het begin van de Omes metingen (fig. 3.8).

In het longitudinale ammoniumprofiel worden 2 maxima waargenomen: 1 ter hoogte van de Rupel en 1 nabij de Bovenschelde (surfer 3.3; fig. 3.9). De ammoniumpluim van de Bovenschelde neemt langzaam af tot km 120. De vracht van de Rupel wordt door de tijbeweging uitgesmeerd tussen km 120 en 80. Deze tidale beweging wordt mooi geïllustreerd met de 13-uursdata: Kruibeke en Lippenbroek kennen een duidelijk tegengesteld tidaal patroon.



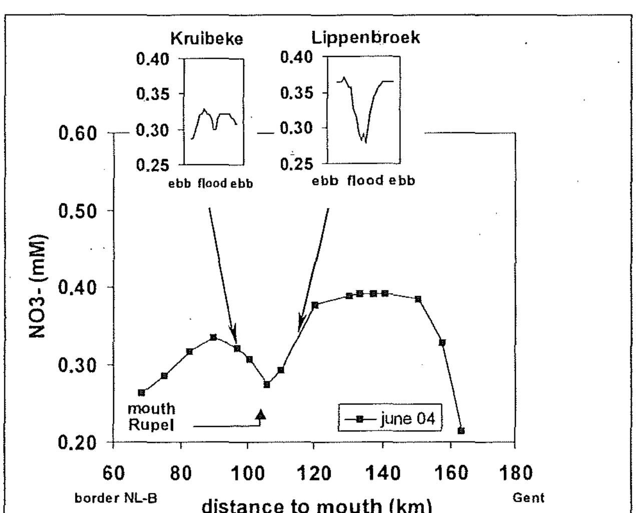
Figuur 3.9: Tidale ammoniumpatronen te Kruibeke (29/06/04) en Lippenbroek (28/06/04), gesitueerd langsheen het longitudinale profiel op de Zeeschelde



Figuur 3.8: Seizoensgemiddelde Ammonium-, Nitraat-, Nitriet- en totale stikstoffluxen te Schelle. (dispersie werd niet in rekening gebracht in de flux berekening).

Ook nitraat kent 2 maxima in het estuarium: tussen km 90 en 70 en tussen km 120 – 130 (surfer 3.4; fig. 3.10). Het eerste maximum (km 120 – 130; ca 0.40 mM in de zomers van 2003 - 2004) verschijnt wanneer ammonium door nitrificatie een minimum bereikt. Meer stroomafwaarts neemt de concentratie nitraat terug af door verdunning met nitraatarmer Rupelwater (ca 0.20 mM in de zomers van 2003 – 2004). Ook de pelagiale denitrificatie is aan de zuurstofarme Rupelmonding wellicht veel groter. Naar de grens toe stijgt de nitraatconcentratie opnieuw: ten gevolge van een stijgende zuurstofverzadiging stijgt nitrificatie en neemt denitrificatie wellicht af, zodat rond km 80 een maximum wordt bereikt. Verder stroomafwaarts zorgen verdunning, dispersie en denitrificatie voor een langame afname.

Deze patronen vertalen zich ook in de tidale schommeling van nitraat in Kruibeke en Lippenbroek (fig. 3.10). Lippenbroek, dat zich temidden een steile nitraatgradiënt bevindt, ziet de concentratie bij vloed sterk dalen, bij vloed sterk stijgen. Tijdens de 13-uurs van juni 2004, bevindt het nitraatmaximum zich nabij Antwerpen. Bij vloed ziet men het nitraatgehalte te Kruibeke eerst toenemen. Naar hoogwater toe is dit nitraatmaximum gepasseerd en daalt de concentratie terug tot het moment van kentering. Daarna ziet men het nitraatgehalte terug stijgen tot het maximum om vervolgens een minimum te bereiken bij eb, als de nitraatarmere watermassa van de Rupelmonding nadert.



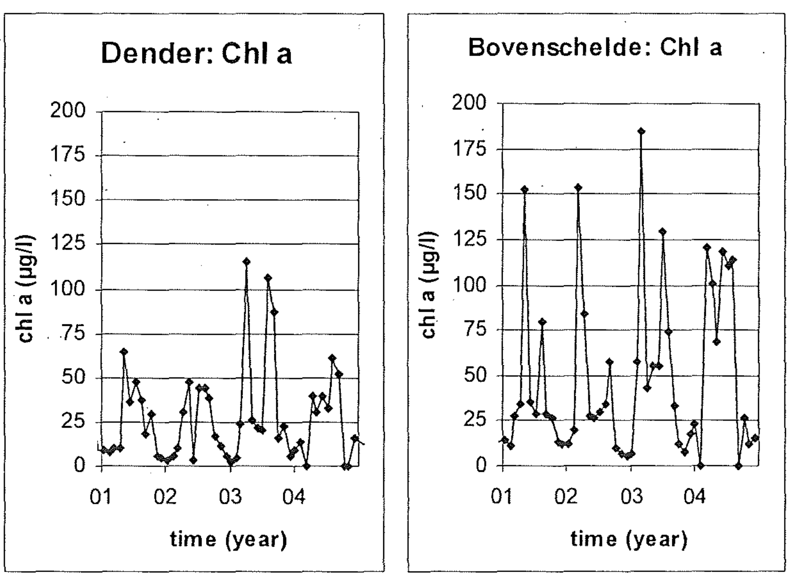
Figuur 3.10: Tidale nitraatpatronen te Kruibeke (29/06/04) en Lippenbroek (28/06/04), gesitueerd langsheen het longitudinale profiel op de Zeeschelde

3.7. Chlorofyl a

De chlorofyl a concentratie is sinds 1996 duidelijk in stijgende lijn, vooral in de zone tussen km 140 en 160 (surfer 3.5). Enkel in 2002 was er een lichte terugval. De stijging van het chlorofylgehalte schijnt niet beïnvloed te worden door de schommelingen in debiet: tussen 1997 en 2002 stegen zowel chla a als de debieten fors, in 2003 en 2004 daalden de debieten sterk, de chlorofyl a concentraties stegen sterk verder. Een oorzaak voor de stijging ligt niet meteen voor de hand: nutriënten zijn altijd in overvloed voorhanden, uitspoeling schijnt geen probleem te vormen. De belangrijkste limiterende factor voor fytoplanktongroei in de Zeeschelde is de lichtlimitatie. Er zijn geen echter aanwijzigingen dat het lichtklimaat sterk gewijzigd zou zijn. De concentraties aan zwevende stoffen zijn niet afgenomen de voorbije jaren, in tegendeel.

De toegenomen chl a gehaltes wijzen op een sterke toename van de primaire productie, wat zich vertaalt in hogere zuurstofgehaltes. Wellicht dankzij de hogere primaire productie kent de zone tussen Dendermonde en Appels geen anoxie meer, maar net een zuurstofmaximum.

De chl a concentratie kent een duidelijk longitudinale trend: naarmate de conductiviteit toeneemt zien we de concentratie sterk afnemen. In het brakke deel van de Zeeschelde komt geen fytoplanktonbloei meer voor. De zomerse planktonbloei van de voorbije jaren in het zoete deel van de Zeeschelde is wel een duidelijke estuariene bloei: de concentraties in het estuarium liggen hoger dan in de Dender of Bovenschelde. De stijgende trend van het estuarium wordt niet even duidelijk teruggevonden in deze rivieren (fig. 3.11). Wel kennen de rivieren ook duidelijke periodes van streke fytoplanktonbloei: in de zomers van 2002 en 2003 kent de Dender zelfs oversaturatie van zuurstof (tot 115%). De fytoplanktonbloei in de rivieren valt meestal voor de bloeipiek in het estuarium.



Figuur 3.11: chlorofyl a concentraties (µg/l) in Dender en Bovenschelde

3.8. Biologische zuurstofvraag (BOD_5)

De BOD_5-concentraties vertonen een grillig patroon (surfer 3.6). De hoogste concentraties worden doorgaans waargenomen nabij Gent, tussen Gent en de Rupel is er een lichte daling. Vanaf Kruibeke nemen de concentraties sterk af. Tussen Kruibeke en de grens is er een duidelijk seizoenaal patroon met hogere concentraties in de winter. De lagere temperaturen inhiberen wellicht een snelle afbraak van de organische belasting. Meer stroomopwaarts vervaagt dit patroon volledig. Daar komen de hoogste concentraties meestal voor tussen zomer en herfst. Afstervende estuarien fytoplanktonbloei kan hiervan de oorzaak zijn. De BOD_5-concentraties in het zoete deel van de Zeeschelde zijn ook doorgaans hoger dan die van Dender of Bovenschelde (fig. 3.5). De Dender kent een zeer duidelijk seizoenaal patroon, met maxima op het einde van het groeiseizoen. De Bovenschelde kende in '98 en '99 en '00 ook maxima op het einde van de fytoplanktonpiek, minima in de winter. Maar sinds 2002 vallen de minima van BOD_5 in het najaar, de maxima in het voorjaar. In die periode werd wel reeds in maart een sterke fytoplanktonpiek waargenomen.

Een duidelijke relatie tussen chl a en BOD_5 werd niet waargenomen in het estuarium. Ook het verband tussen debiet en BOD_5 is niet eenduidig.

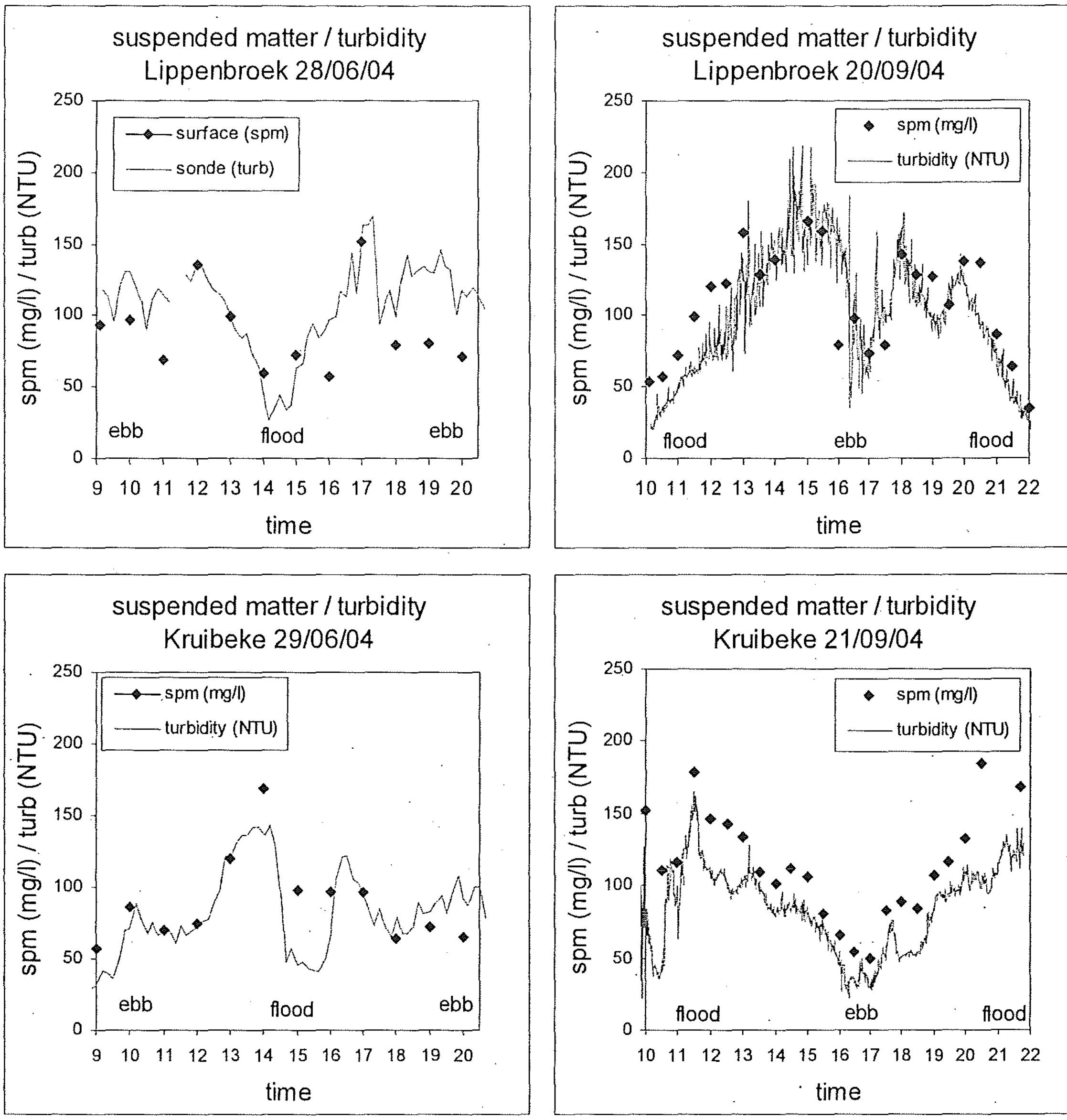
3.9. Zwevende stof (SPM)

De zwevende stofgehaltes in het oppervlaktewater van de Zeeschelde vertonen een zeer grillig patroon, waarin geen duidelijke trends te onderscheiden vallen (fig. 3.7). Er is geen duidelijke seizoenale trend. Wel zien we een algemene afname van SPM tussen 1996 en 2000, de laatste jaren neemt de concentratie terug toe. Vooral in het brakke deel van de Zeeschelde is er een toename.

Sommige van de zomerpieken in het zoete deel vallen samen met pieken van fytoplanktonbloei. Echter niet alle SPM-pieken vallen samen met hoge chl a-waarden.

Over de ganse monitoringsperiode beschouwd, doet er zich een turbiditeitsmaximum voor in de zone tussen km 110 en 120. In deze zone is de getijdewerking zeer sterk: men vindt hier bij vloed de hoogste waterstanden in het estuarium. Twee 13-uurs in deze zone, te Lippenbroek, tonen een spm-gehalte dat langzaam daalt naar kentering hoogwater toe, om dan een minimum te bereiken en vervolgens weer te stijgen (fig. 3.12). Rond kentering laagwater is er kortere fase waarin de zwevende stof plots daalt, en nadien weer snel terug stijgt.

In Kruibeke is dit patroon anders: daar daalde de spm-concentratie langzaam tijdens beide 13-uurs naar kentering laagwater toe, en was er een plotse daling en nadien stijging rond kentering hoogwater.



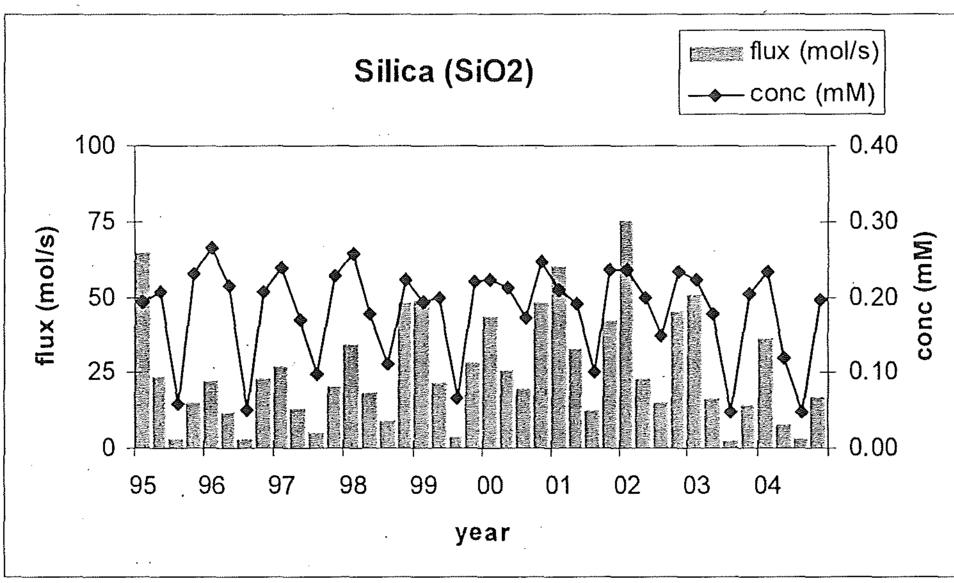
Figuur 3.12: zwevende stof (spm) en turbiditeit tijdens verschillende 13-uurscampagnes te Kruibeke en Lippenbroek.

3.10. Silicium

Silicium vertoont duidelijke seizoenale en longitudinale trends (fig. 3.8). Jaarlijks worden de maxima in de winter waargenomen, de minima naar het einde van de zomer. Dan is immers de siliciumpoel langzaam uitgeput door diatomeeën, een algengroep die silicium gebruikt als essentiële bouwsteen voor zijn skelet. Uitputting van de siliciumpoel gaat dan ook mooi gepaard met maxima in chlorofyl a. De zeer hoge chl a maxima in 2003 en 2004 geven dan ook aanleiding tot zeer lage siliciumconcentraties. De siliciumwaarden in de zomer van 2004 zijn de laagste sinds de start van de omes metingen. In 2001, een jaar met toch ook hoge chl a-waarden, wordt geen Si-uitputting vastgesteld. Waarschijnlijk liggen de hoge debieten aan de basis van dit fenomeen: diatomeeën zijn vrij gevoelig voor uitspoeling. Jammer genoeg zijn er onvoldoende data voorhanden om de siliciumdip in 1999 te verklaren. Ook de lage waarden in 1996 zijn vooralsnog onverklaard.

Longitudinaal vallen de siliciumdalingen samen met de zones waarin de fytoplanktonbloei maximaal is. Ter hoogte van de Rupel neemt de depletie in 2004 terug af: doordat er slechts zeer beperkte fytoplanktonbloei is in de Rupel, vormt deze rivier een belangrijke bron aan silicium voor de Schelde. Eenmaal voorbij de Rupel, neemt de concentratie verder af.

Silicium is essentieel voor het voedselweb in de kustwateren. De totale geëxporteerde Si-vracht naar de Noordzee is dus van belang. Door de toename van vooral de zomerdebieten, en de beperkte fytoplantonbloei in de zeeschelde, nam de export tussen 1996 en 2002 sterk toe (fig. 3.13). Door enerzijds een sterke stijging van de Si consumptie in het estuarium, en anderzijds een daling van de afvoerdebieten, daalde de export terug zeer sterk in de zomers van 2003 en 2004.



figuur 3.13: Seizoensgemiddelde siliciumfluxen en –concentraties te schelle

3.11. Conclusies

2004 was, ondanks de hoge regenval, een jaar met lage debieten. Ondanks een afname van de verdunning, zijn de concentraties aan nutriënten niet gestegen, wat dus een sterke daling van de vrachten met zich mee brengt. Na de steeds stijgende stikstofexport naar de Noordzee, zagen we in 2003 voor het eerst terug een daling van de N-vracht, die zich in 2004 duidelijk verder zet. De stijging tussen 1997 en 2002 kan verklaard worden door de toegenomen debieten, en de aldus toegenomen diffuse export uit het bekken. Gedaalde debieten in 2003 en 2004, brengen de totale stikstofvrachten terug tot het peil van 1996-1997, jaren met vergelijkbare afvoer. Van een echte verbetering van de waterkwaliteit wat betreft stikstofexport is dus nog niet echt sprake, ondanks de investeringen in tertiare zuivering.

Veel heil wordt verwacht van het toekomstige zuiveringsstation op de Zenne. Dit zou de stikstofvracht (en de totale organische belasting) vanuit de Rupel aanzienlijk kunnen verminderen. Een forse stijging van de zuurstofgehaltes rond de Rupelmonding kunnen dan verwacht worden. Echter, de Rupel is momenteel niet de belangrijkste stikstofbron voor het estuarium. Voor de nitraat is er rond de Rupelmonding een minimum, de ammoniumconcentratie naar Gent toe liggen ook veel hoger. Mogelijks zorgt het anaerobe klimaat in de Rupel voor een efficiënte verwijdering van de stikstofvracht.

De belangrijkste stikstof- en koolstofstroom komt vanuit de Boven-Zeeschelde. Naar Gent toe nemen de concentraties ammonium en BOD_5 toe. Op basis van deze belasting, zou men een zuurstofminimum kunnen verwachten in het zoete deel van het estuarium. Dankzij een zeer sterke primaire productie in 2001, 2003 en 2004 treffen we hier echter zuurstofmaxima aan. BOD_5 en ammonium worden efficiënt omgezet in deze zuurstofrijke zone. De export van nitraat daarentegen wordt erg hoog. Als de zuurstofverzadiging rond de Rupel sterk verbetert, en peliagiale denitrificatie afneemt, zal een toenemende nitraatvracht naar de Noordzee stromen.

Als gevolg van de toegenomen primaire productie in het zoete deel van de Zeeschelde, is de concentratie aan opgelost silicium sterk afgenomen. 2004 kent de laagste concentraties sinds de start van de Omes monitoring. De dalende export van silicium en de hoge stikstofvracht zullen zeer nefast zijn voor de kustwateren. Maatregelen om de estuariene siliciumcyclering te stimuleren, en de stikstofvrachten te beperken dringen zich op.

3.12. Referenties

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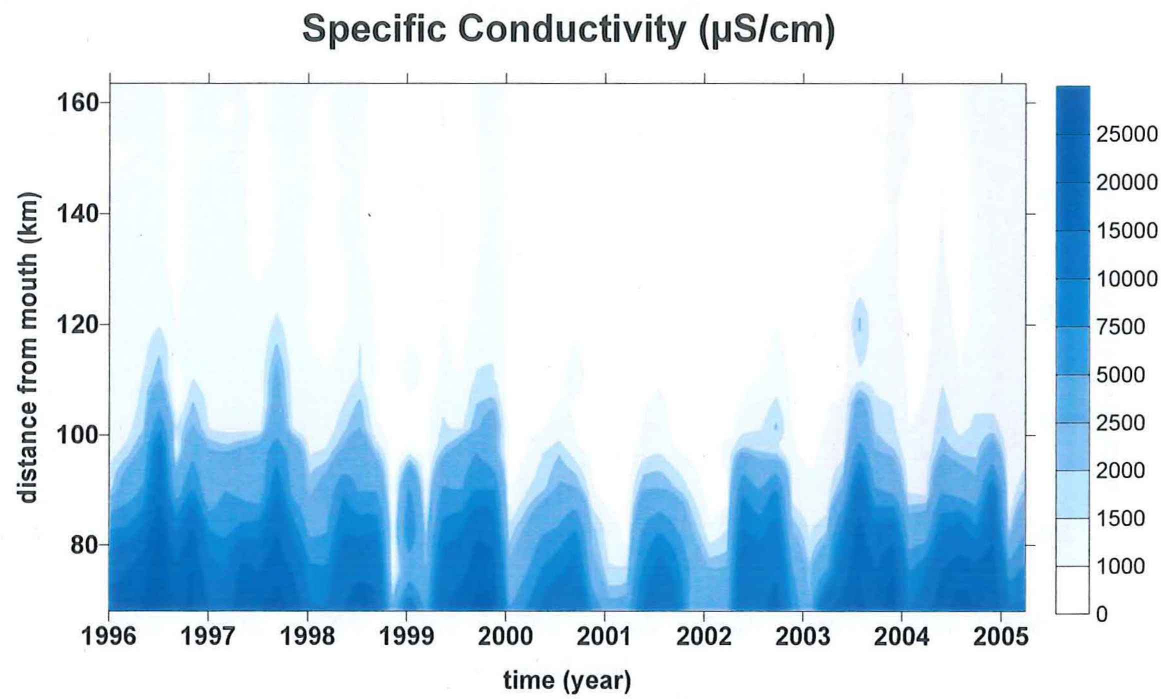
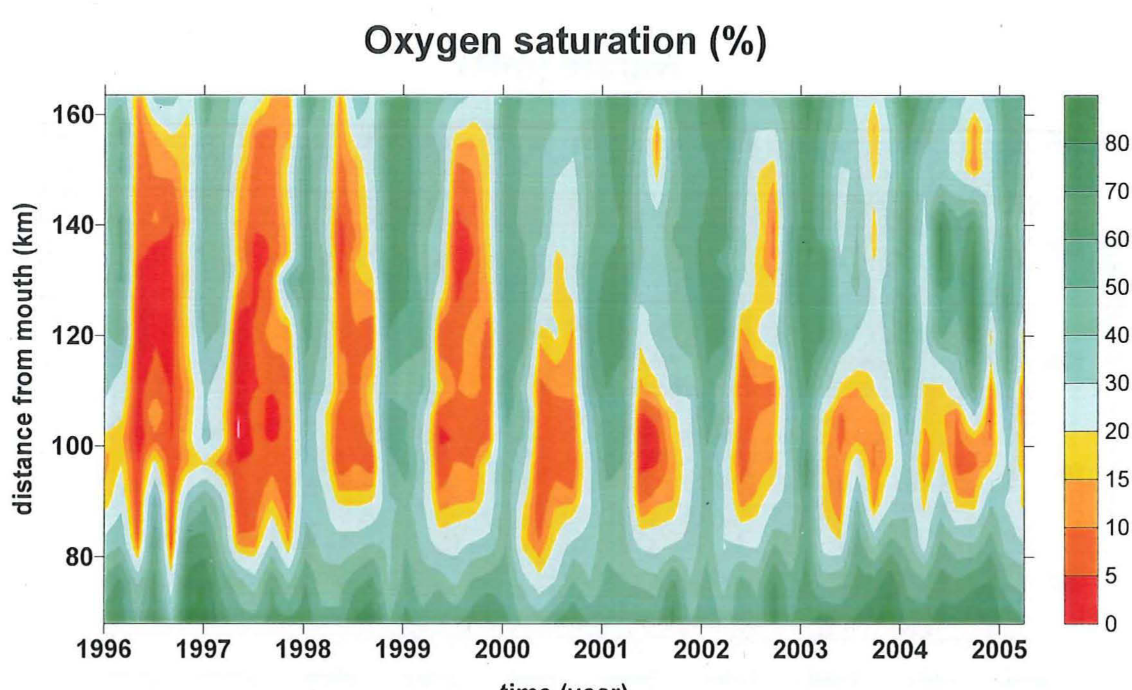
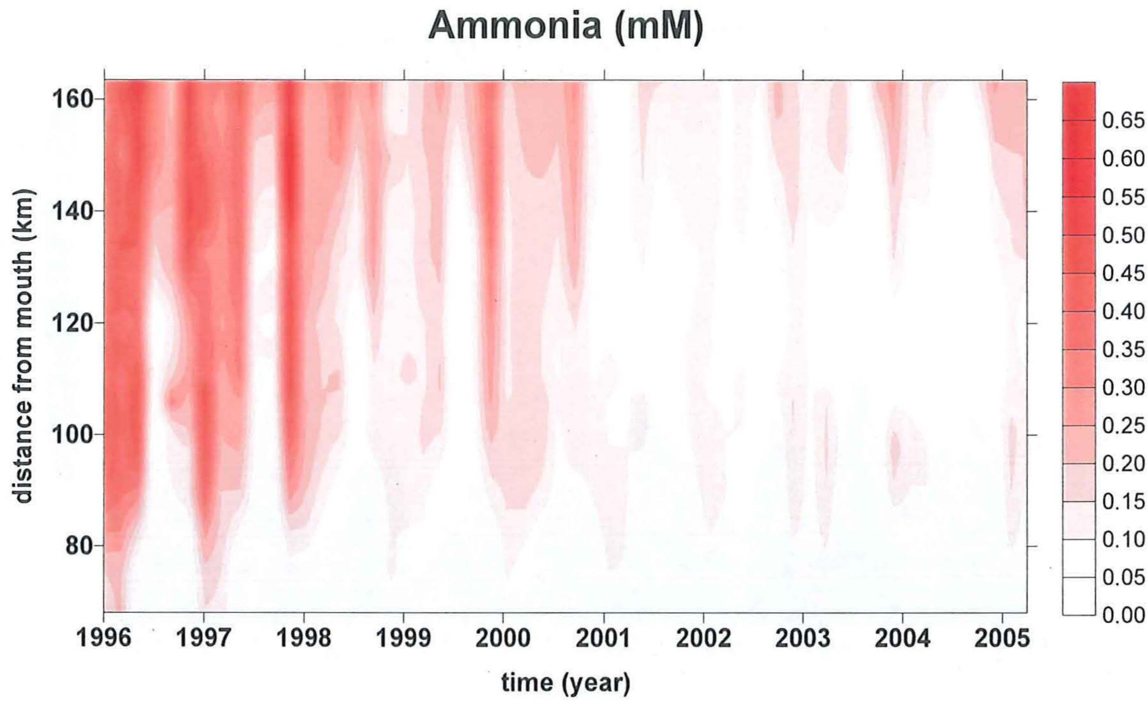


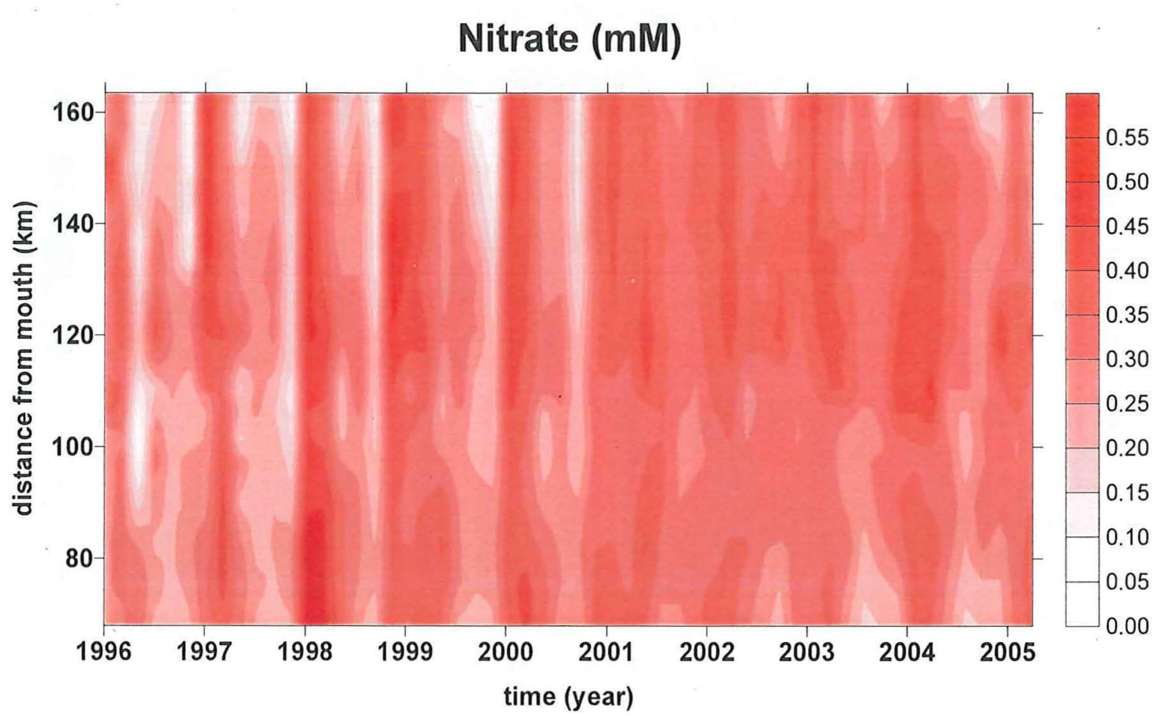
Surfer 3.1: specifieke conductiviteit (µS/cm)



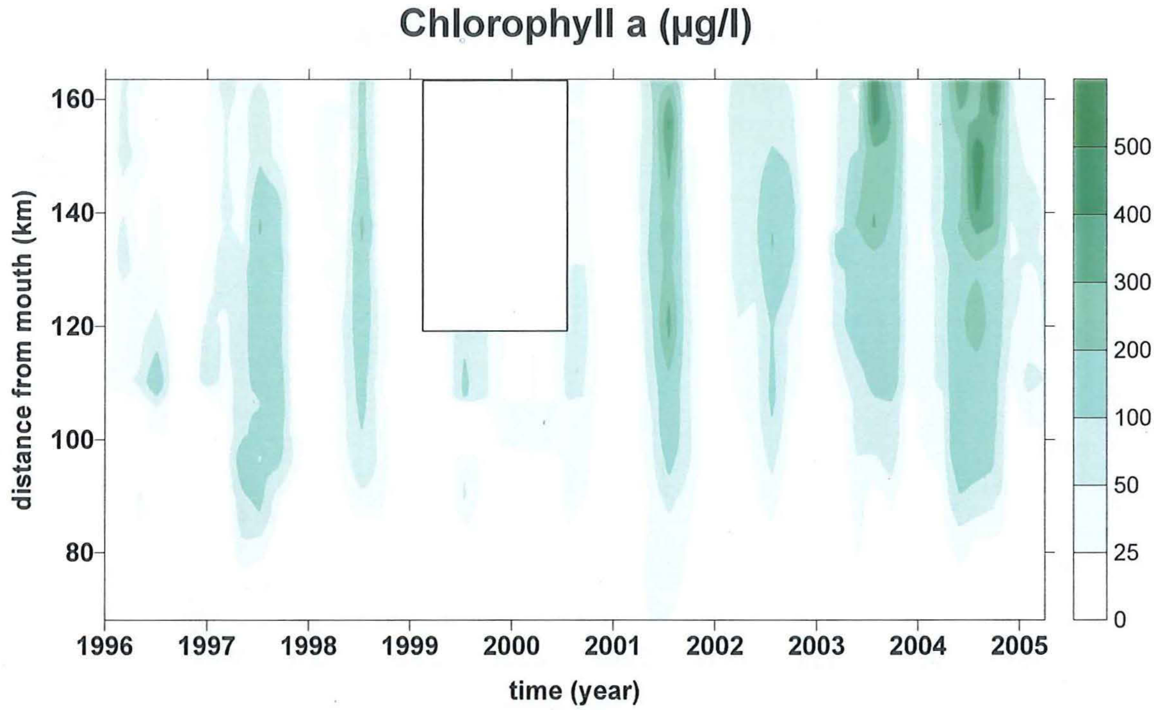
Surfer 3.2: zuurstofverzadiging (%)



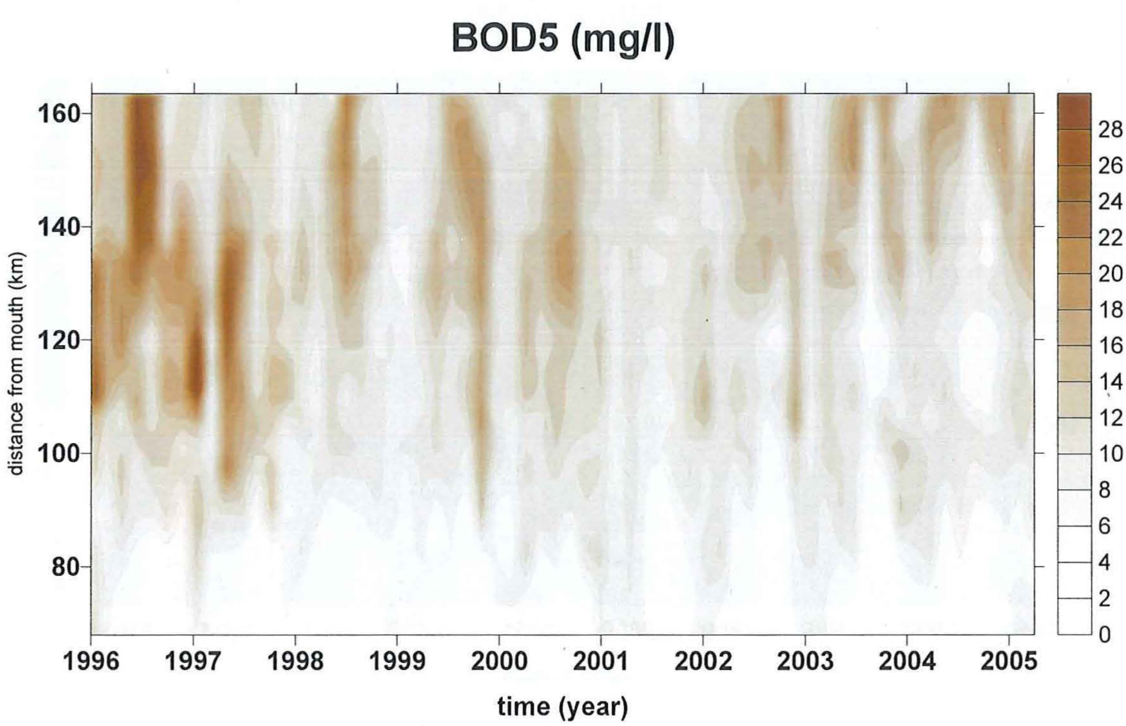
Surfer 3.3: Ammoniumconcentratie (mM)



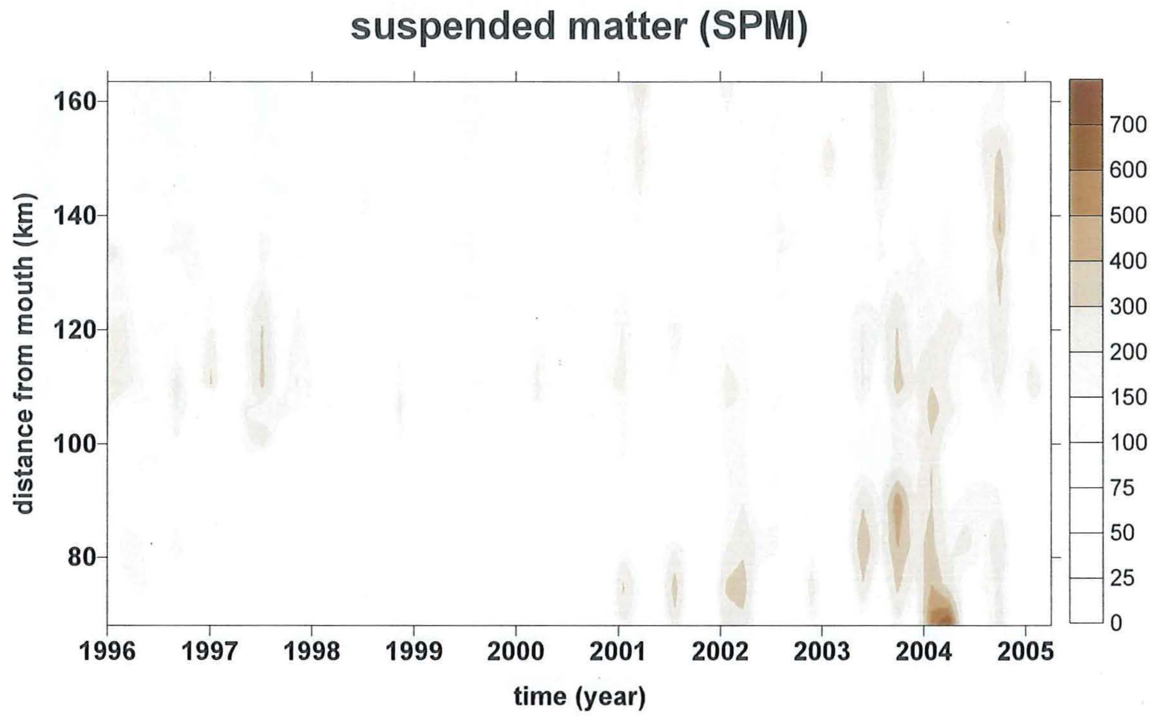
Surfer 3.4: Nitraatconcentratie (mM)



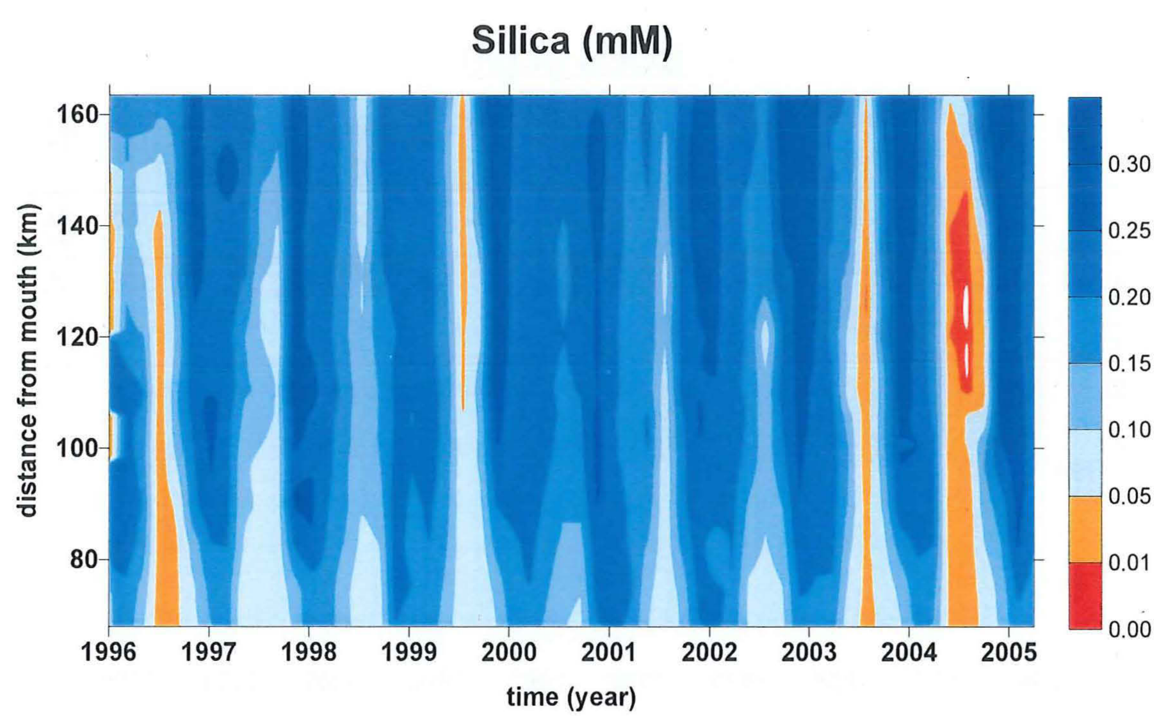
Surfer 3.5: Chlorofyl a concentratie (µg/l)



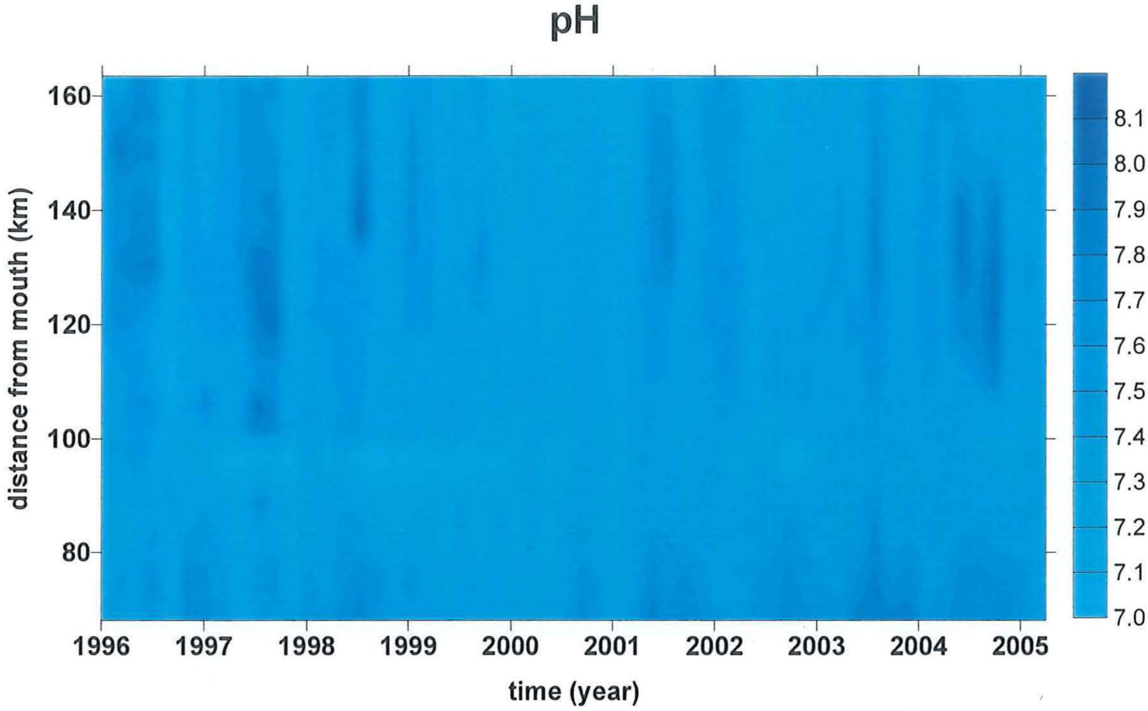
Surfer 3.6: Biologische zuurstofvraag (BOD5) (mg/l)



Surfer 3.7: Zwevende stofconcentratie (SPM) (mg/l)



Surfer 3.8: Siliciumconcentratie (DSI, opgelost silicium) (mM)


pH
distance from mouth (km)
160
140
120
100
80
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
time (year)
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0

Surfer 3.9: pH

Hoofdstuk 4. Studie Koolstofcyclus in het Vlaams gedeelte van het Schelde-estuarium

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Eindverslag voor deelstudie 2 (perceel 2), periode januari 2003-december 2003

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4.1. Introduction

We report here on the seasonal evolution of a number of parameters sampled monthly along the Zeeschelde between the Dutch – Belgian border and Gent, from January till December 2004. These parameters include: total suspended matter, particulate organic carbon and nitrogen, total alkalinity, pH and $^{13}C/^{12}C$ isotopic signature of dissolved inorganic carbon.

4.2. Methods

Sampling

Sampling occurred monthly at 16 stations in de Zeeschelde, as well as 7 stations in the mouth of the major tributaries being Rupel, Durme, Dender, Bovenschelde, Zandvliet, Baalhoek and Hansweert. Nine stations, located between km 57.5 and 111 (i.e. distance from Vlissingen, = km 0), and the seven tributaries were sampled day 1. Seven stations, located between km 118 and 155, were sampled day 2.

Surface water was sampled with a clean bucket. Subsamples for total suspended matter and particulate organic carbon and nitrogen were taken in clean polyethylene containers, rinsed three times with the sampled surface waters. Well homogenised fractions (2/station) of 150 to 200 ml were subsequently filtered on board using pre-ashed (450°C) and pre-weighed Whatman GF/F filters (47 mm diameter). Filters were packed in Millipore Petri-dishes and stored at -20°C till later on-shore analysis. Subsamples for total alkalinity were stored in 100ml PE vials and 20 µl of a saturated $HgCl_2$ solution was added to inhibit all further biological activity. Subsamples (2/station) for $\delta^{13}C$ of dissolved inorganic carbon were treated the same way but stored in 25ml serum vials, avoiding headspace formation. The serum vials were sealed with a gas-tight rubber stopper and an aluminium seal tightened with a crimp.

Analysis
The following is a brief description of the methods described in detail in Hellings (2000) and Hellings et al. (1999, 2000 and 2001). In the shore-based laboratory filters are thawed and dried at 50°C till constant weight (about 8 hours drying). They are then weighed to assess the load of total suspended matter. For the assessment of organic C and N, filter discs of 10 mm diameter were cut-out from these weighed filters and left for 24 hours in contact with HCl vapour, inside an evacuated container, to remove carbonates. These filter discs were subsequently packed in tin cups, ready for analysis per elemental analyzer (Carlo Erba NA 1500). For calibration weighed amounts of acetanilide were used. Blank filters were subjected to the same treatment.

Total Alkalinity (TAlk) was determined on 25ml sample by automatic titration (Mettler-Toledo) using standardised 0.01N HCl solutions (Merck). The titration was conducted till the bicarbonate end-point. The dissolved inorganic carbon content (DIC = Σ of bicarbonate, carbonate and dissolved CO_2) and the partial pressure of CO_2 were calculated from these TAlk values and the pH data obtained on board, following Cai and Wang (1998).

For the $^{13}C/^{12}C$ isotopic ratio of dissolved inorganic carbon see Bouillon et al. (2003). Briefly, a 5 ml headspace volume was created in the serum vials by replacing water by He injected through the vial septum. Then 0.5 ml of *ortho*-phosphoric acid (99% crystal) was injected and the sample left overnight for CO_2 extraction in the headspace to proceed. Between 150 and 300 μl of He-CO_2 mixture were injected through a GC sample port mounted between the reduction oven and the water trap of a CN - ConFlo- IRMS system. (single inlet Finnigan Mat Delta+XL). Measurement was against CO_2 from a tank previous calibrated against Carrara marble work-standard and NBS 19 carbonate. Efficiency of the extraction was assessed via repeated analysis of aliquots of reference water (North Sea water and/or groundwater) with well known composition.

4.3. Results

Table 1 gives the full data set for January till December 2004. For several parameters general trends can be deduced from their correlative behaviour, based on their average values for the whole Zeeschelde transect (Figure 1). Relationships are apparent between POC and TSM; $\delta^{13}C_{DIC}$ and SST (Surface Temperature); $\delta^{13}C_{DIC}$ and C/N ratio of suspended matter in 2004, as it was observed in 2003.
The positive relationship between $\delta^{13}C_{DIC}$ and SST, and C/N ratio of suspended matter reflects the phytoplankton photosynthesis and respiration during the growth season. The preferential uptake of ^{12}C over ^{13}C during the photosynthetic carbon fixation in spring and summer results in the DIC pool becoming relatively enriched in ^{13}C. The latter effect is paralleled by the enrichment of ^{12}C in the POM pool during periods of significant phytoplankton activity (Hellings *et al.*, 1999). Bacterial respiration results in the opposite effect on $\delta^{13}C_{DIC}$. Respiration prevails over primary production throughout the year, but its relative importance is particularly strong in autumn and winter when phytoplankton activity is low to absent.

To study the spatial and temporal evolutions of the different parameters, it is more appropriate to consider that the sampled Zeeschelde section consists of different subsystems. Based on the physico-chemical characteristics the analysed transect along the Zeeschelde the transect was split up in the following zones: Zone 1 from Boei-87 (km 57.5) to Kruibeke (km 85); Zone 2 from Bazel (km 88) to St-Amands (km 111) (this section receives the Rupel tributary); Zone 3 from Vlassenbroek (km 118) to Melle (km 155); Zone 4 represents the tributaries Bovenschelde, Durme and Dender. Furthermore, the Rupel mouth is considered as a separate subsystem, what is justified by the specific physico-chemical characteristics of this tributary.

In Figures 2a to 2e the temporal evolutions of TSM, POC, C/N, TAlk, $\delta^{13}C_{DIC}$ are shown for the different zones identified above. As observed in 2003, each zone, especially Zone 3, shows higher TSM and POC concentrations during late summer-autumn, probably reflecting enhanced phytoplankton biomass. For TSM, the highest values are observed in July and October in Zones 1 and 2, in June in the tributaries, and in October in Zone 1 and Rupel. For POC, the same trend is observed, except for Zone 1, where POC concentrations are not higher in Summer. There is trend of decreasing POC contents over 2002, 2003 and 2004 for Zone 1. This trend is not clear for Zones 2, 3 and 4. Lowest C/N atom ratios are observed from May to September. The general profile of TAlk shows minima in August. Talk values in Zone 1 are lower than the values observed in the other zones.

The $\delta^{13}C_{DIC}$ signal in river water is set by the groundwater isotopic composition, but local riverine processes will impact on this. The Schelde water has an average isotopic signature (about -13‰) that approaches the one for groundwater that has its DIC system controlled in equal parts by carbonate dissolution (isotopic signature close to 0‰) and heterotrophic respiration on soil C-3 organic matter (isotopic signature close to -27‰). Respiration processes in the river proper will drive this signature towards more negative numbers while photosynthesis will drive it towards less negative numbers. This explains the observed seasonal trend, with $\delta^{13}C_{DIC}$ values around -13.5‰ in Zones 2, 3, 4 and -12.5‰ in Zone 1 in Jan, Dec. 2004, and increasing to -11‰ (Zones 2, 3, 4) and even -10‰ (Zone 1) during spring and summer 2004. This increase is observed for Rupel, where the lowest values of $\delta^{13}C_{DIC}$ are –14,5‰ in Jan, Dec., and the highest are observed in May (-13‰). However, the $\delta^{13}C_{DIC}$ values in Rupel over the year are always lower compared to Zones 1, 2, 3 and 4. Figure 2f shows the spatial distribution of $\delta^{13}C_{DIC}$ over the Zeeschelde for two seasons (summer and winter). For both seasons, Zone 1 (km 57.5 – 85) shows clearly less negative DIC signals, compared to the other zones (especially in summer) and reflect mixing between the riverine and marine end-members (typically -11 to -15‰ and -1 to 0‰, respectively). The impact of the Rupel, decreasing $\delta^{13}C_{DIC}$ in the Zeeschelde, is clearly visible (km 85-95). In Zones 2 and 3, less negative values of $\delta^{13}C_{DIC}$ are observed in summer compared to winter. This is also the case for the tributaries Dender, Durme and Bovenschelde. The $\delta^{13}C_{DIC}$ values in Rupel are not significantly different in summer and in winter.

Long term trends

For a $\delta^{13}C_{DIC}$ and Talk, we have compared the 2004 results with data obtained for 2002 and 2003 (annual reports 2002 and 2003) and also earlier during the OMES I program (Hellings, 2000; Hellings et al., 1999, 2001). Figure 3a shows the trends of $\delta^{13}C_{DIC}$ for the period from January 2002 till December 2004 for the same zones we identified here. This comparison shows a trend of increasing $\delta^{13}C_{DIC}$ values from

2003 to 2004, especially in winter for Zone 1. Figure 3b shows the trends of $\delta^{13}C_{DIC}$ since December 1995 (with a break in the monitoring between April 1999 and December 2001) for all sites. This figure shows clearly the seasonal cycling of the DIC pool and suggests the trend of increasing $\delta^{13}C_{DIC}$ is a recent development.
Figure 4 shows the trends of Talk from December 1995 till April 1999 and from January 2002 to December 2004. All zones (except Rupel) show quite a clear trend of decreasing Talk over the successive years. While it is possible that some of this decrease in Talk results from enhanced nitrification activity in the Schelde, probably due to improved oxygenation of the river and estuary, the increase of river discharge is probably another important cause of this change in TAlk over the years.

4.4. References

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Table 1: Zeeschelde 2004. Data for total alkalinity (TAlk), total suspended matter (TSM), particulate organic carbon (POC), particulate nitrogen (PN), C/N atom ratio, $^{13}C/^{12}C$ isotopic ratio of dissolved inorganic carbon, ($\delta^{13}C_{DIC}$, in per mil)

Station	Code	Km	SPM, mg l^{-1}	TAlk, meq l^{-1}	POC, µM	PN, µM	C/N	$\delta^{13}C_{DIC}$
Jan. 2004								
Boei 87	9,1	57,5	104,4	3,70	267	26	10,2	-10,81
Boei 92	10,1	63	115,0	3,97	285	26	11,1	-11,63
Boei 105	11,1	71,5	100,8	4,35	220	22	9,9	-12,57
A'pen	12,1	78,5	79,3	4,51	227	23	9,8	-13,95
Kruibeke	13,1	85	68,0	4,63	238	25	9,6	-13,16
Bazel	13,2	88	78,0	4,71	259	29	8,9	-13,54
Steendorp	14,1	94	76,8	4,87	312	32	9,8	-13,79
Temse	14,2	97,5	171,3	4,95	458	48	9,5	-13,44
St Amands	15,1	111	87,0	5,05	290	29	10,1	-13,37
Vlassenbroek	16,1	118	51,5	5,14	238	39	6,1	-13,62
Dendermonde	16,2	121,5	51,0	5,22	205	21	9,7	-13,84
St Onolfs	17,1	127	56,3	5,27	232	24	9,7	-13,79
Appels	17,2	133	25,0	5,31	149	17	8,8	-13,89
Uitbergen	18,1	140	43,5	5,19	212	23	9,2	-13,63
Wetteren	19,1	147	49,8	5,01	195	21	9,1	-13,59
Melle	20,1	155	52,8	5,08	262	28	9,3	-13,58
Bovenschelde			84,5	5,50	326	35	9,2	-12,74
Durme			133,8	5,77	423	42	10,0	-13,86
Dender			33,5	5,73	145	15	9,5	-13,16
Rupel			39,3	5,64	232	23	9,9	-14,25
Feb. 2004								
Boei 87	9,1	57,5	159,0	3,36	352	37	9,4	-10,07
Boei 92	10,1	63	202,0	3,38	496	49	10,0	-10,70
Boei 105	11,1	71,5	179,0	3,62	428	45	9,6	-12,13
A'pen	12,1	78,5	101,3	3,84	319	34	9,4	-13,18
Kruibeke	13,1	85	96,8	4,02	322	36	9,0	-13,14
Bazel	13,2	88	101,8	4,19	325	36	9,0	-13,46
Steendorp	14,1	94	111,8	4,68	384	41	9,3	-13,11
Temse	14,2	97,5	135,0	4,98	471	50	9,4	-12,93
St Amands	15,1	111	64,0	5,28	250	32	7,9	-13,09
Vlassenbroek	16,1	118	44,0	5,17	197	23	8,6	-12,92
Dendermonde	16,2	121,5	36,3	-	161	20	8,0	-13,29
St Onolfs	17,1	127	33,3	5,38	159	19	8,2	-13,29
Appels	17,2	133	59,5	5,42	271	31	8,8	-13,24
Uitbergen	18,1	140	33,5	5,54	201	24	8,3	-13,24
Wetteren	19,1	147	49,5	-	250	32	7,8	-12,98
Melle	20,1	155	35,3	5,60	252	31	8,1	-12,85
Bovenschelde			73,5	5,75	276	35	7,9	-13,11
Durme			68,8	4,94	348	37	9,4	-13,71
Dender			33,7	5,78	154	21	7,4	-12,97
Rupel			65,3	3,87	400	44	9,2	-13,97

Table 1: Continued

Station	Code	Km	SPM, mg l^{-1}	TAlk, meq l^{-1}	POC, µM	PN, µM	C/N	$\delta^{13}C_{DIC}$
Mar. 2004								
Boei 87	9,1	57,5	81,4	3,48	210	25	8,4	-10,22
Boei 92	10,1	63	84,8	3,80	237	27	8,8	-10,91
Boei 105	11,1	71,5	70,0	3,98	244	28	8,7	-12,31
A'pen	12,1	78,5	31,6	4,28	149	20	7,4	-12,81
Kruibeke	13,1	85	27,3	-	160	22	7,2	-13,01
Bazel	13,2	88	45,6	4,50	210	26	8,2	-12,75
Steendorp	14,1	94	55,6	5,07	230	27	8,6	-12,55
Temse	14,2	97,5	139,7	5,27	503	55	9,1	-12,42
St Amands	15,1	111	142,9	5,29	473	52	9,1	-12,15
Vlassenbroek	16,1	118	38,3	4,15	173	22	7,7	-12,74
Dendermonde	16,2	121,5	48,2	-	234	29	8,0	-12,84
St Onolfs	17,1	127	74,3	-	333	41	8,0	-12,88
Appels	17,2	133	59,3	-	268	36	7,5	-12,74
Uitbergen	18,1	140	59,2	-	329	42	7,8	-12,98
Wetteren	19,1	147	53,0	-	316	41	7,7	-12,98
Melle	20,1	155	48,7	-	325	43	7,5	-12,97
Bovenschelde			61,3	5,08	348	46	7,5	-12,69
Durme			91,3	5,03	339	39	8,6	-13,43
Dender			11,4	5,32	117	17	6,7	-11,68
Rupel			57,6	3,23	390	47	8,3	-13,77
Apr. 2004								
Boei 87	9,1	57,5	105,5	3,53	183	20	9,3	-9,90
Boei 92	10,1	63	65,3	2,60	125	15	8,6	-11,29
Boei 105	11,1	71,5	101,8	4,10	282	31	9,2	-12,03
A'pen	12,1	78,5	27,5	4,29	122	18	6,9	-12,72
Kruibeke	13,1	85	25,2	4,40	131	19	7,0	-12,64
Bazel	13,2	88	30,5	4,58	170	24	7,0	-12,58
Steendorp	14,1	94	37,5	4,86	161	20	8,0	-12,04
Temse	14,2	97,5	100,0	5,05	382	44	8,8	-11,71
St Amands	15,1	111	104,3	5,25	400	49	8,2	-11,81
Vlassenbroek	16,1	118	70,0	5,16	353	42	8,5	-11,82
Dendermonde	16,2	121,5	61,5	4,67	295	37	7,9	-12,16
St Onolfs	17,1	127	125,8	5,16	420	52	8,1	-12,07
Appels	17,2	133	78,0	5,22	358	45	8,0	-11,93
Uitbergen	18,1	140	51,0	5,40	291	40	7,3	-12,06
Wetteren	19,1	147	40,5	5,50	305	44	6,9	-11,93
Melle	20,1	155	35,5	-	293	42	7,0	-12,48
Bovenschelde			37,5	5,76	376	49	7,6	-11,81
Durme			54,8	5,37	327	47	7,0	-12,59
Dender			17,5	6,07	185	31	6,0	-11,30
Rupel			51,8	4,01	395	51	7,7	-13,38

Table 1: Continued

Station	Code	Km	SPM, mg l^{-1}	TAlk, meq l^{-1}	POC, µM	PN, µM	C/N	$\delta^{13}C_{DIC}$
May 2004								
Boei 87	9,1	57,5	43,7	3,43	103	14	7,1	-8,72
Boei 92	10,1	63	60,2	3,53	125	17	7,5	-9,17
Boei 105	11,1	71,5	94,4	3,69	213	25	8,5	-10,05
A'pen	12,1	78,5	67,4	3,97	213	28	7,6	-11,00
Kruibeke	13,1	85	53,3	-	227	30	7,5	-11,91
Bazel	13,2	88	76,4	4,39	307	38	8,0	-12,07
Steendorp	14,1	94	27,3	-	187	27	6,9	-12,28
Temse	14,2	97,5	71,1	4,58	328	42	7,8	-11,49
St Amands	15,1	111	93,8	5,26	407	51	8,0	-10,68
Vlassenbroek	16,1	118	32,9	5,50	250	36	7,0	-11,78
Dendermonde	16,2	121,5	44,4	5,47	287	41	7,1	-11,77
St Onolfs	17,1	127	39,5	5,46	306	43	7,2	-11,84
Appels	17,2	133	66,7	5,36	388	51	7,6	-11,86
Uitbergen	18,1	140	61,1	5,26	367	48	7,7	-12,20
Wetteren	19,1	147	126,3	5,07	563	71	8,0	-12,12
Melle	20,1	155	74,0	5,10	391	51	7,7	-12,36
Bovenschelde			35,3	4,87	325	44	7,4	-12,50
Durme			67,0	5,06	328	42	7,8	-11,74
Dender			13,8	5,50	146	22	6,8	-12,99
Rupel			33,1	4,09	227	31	7,3	-12,54
June 2004								
Boei 87	9,1	57,5	56,2	3,60	135	16	8,4	-8,81
Boei 92	10,1	63	50,2	3,57	128	16	8,0	-9,76
Boei 105	11,1	71,5	43,6	3,88	139	19	7,2	-10,41
A'pen	12,1	78,5	54,3	4,10	248	32	7,7	-10,68
Kruibeke	13,1	85	80,6	4,18	410	52	7,8	-11,00
Bazel	13,2	88	85,9	4,28	436	55	8,0	-11,49
Steendorp	14,1	94	80,0	4,37	459	58	7,9	-11,46
Temse	14,2	97,5	88,5	4,50	452	54	8,4	-11,33
St Amands	15,1	111	180,8	4,94	687	75	9,2	-10,38
Vlassenbroek	16,1	118	125,3	5,27	520	60	8,7	-10,49
Dendermonde	16,2	121,5	122,6	5,32	553	66	8,4	-10,45
St Onolfs	17,1	127	125,2	5,27	611	69	8,9	-10,30
Appels	17,2	133	48,6	5,26	392	49	8,1	-10,31
Uitbergen	18,1	140	46,3	5,17	414	50	8,3	-10,62
Wetteren	19,1	147	69,7	5,28	563	73	7,7	-11,06
Melle	20,1	155	96,7	5,50	677	89	7,6	-11,94
Bovenschelde			45,7	5,59	286	38	7,5	-13,57
Durme			348,7	4,35	1215	131	9,3	-12,32
Dender			15,9	6,00	198	30	6,6	-8,81
Rupel			35,0	4,52	400	65	6,1	-14,28

Table 1: Continued

Station	Code	Km	SPM, mg l^{-1}	TAlk, meq l^{-1}	POC, µM	PN, µM	C/N	$\delta^{13}C_{DIC}$
July 2004								
Boei 87	9,1	57,5	35,4	3,51	67	9	7,3	-8,75
Boei 92	10,1	63	34,0	3,71	84	12	7,1	-9,18
Boei 105	11,1	71,5	26,3	4,01	113	17	6,6	-10,68
A'pen	12,1	78,5	41,3	4,04	200	29	7,0	-11,18
Kruibeke	13,1	85	50,8	3,90	276	39	7,1	-11,71
Bazel	13,2	88	52,6	3,84	285	40	7,1	-12,21
Steendorp	14,1	94	103,0	3,86	436	54	8,1	-11,73
Temse	14,2	97,5	75,9	4,56	371	46	8,0	-11,16
St Amands	15,1	111	219,7	5,11	800	88	9,1	-10,61
Vlassenbroek	16,1	118	143,8	3,79	719	87	8,3	-10,62
Dendermonde	16,2	121,5	141,7	-	769	93	8,3	-10,87
St Onolfs	17,1	127	135,6	5,13	790	98	8,1	-10,84
Appels	17,2	133	128,2	-	738	93	7,9	-10,98
Uitbergen	18,1	140	109,3	5,07	612	79	7,7	-11,38
Wetteren	19,1	147	188,0	5,01	839	105	8,0	-11,38
Melle	20,1	155	98,3	-	553	58	9,5	-11,29
Bovenschelde			40,0	-	357	45	8,0	-11,63
Durme			123,3	4,88	614	70	8,8	-10,35
Dender			19,4	5,01	159	20	8,1	-11,73
Rupel			55,2	3,43	442	56	7,9	-13,94
Aug. 2004								
Boei 87	9,1	57,5	63,8	3,27	103	12	8,3	-7,31
Boei 92	10,1	63	58,8	3,40	105	13	8,2	-9,02
Boei 105	11,1	71,5	72,4	3,51	160	18	8,8	-9,72
A'pen	12,1	78,5	64,6	3,60	226	27	8,2	-10,94
Kruibeke	13,1	85	104,4	3,50	419	55	7,6	-11,51
Bazel	13,2	88	91,8	3,49	404	50	8,0	-11,79
Steendorp	14,1	94	72,2	3,65	378	41	9,2	-11,67
Temse	14,2	97,5	62,3	4,44	323	45	7,1	-10,78
St Amands	15,1	111	97,8	4,43	553	53	10,5	-10,71
Vlassenbroek	16,1	118	32,2	4,39	321	40	7,9	-10,84
Dendermonde	16,2	121,5	60,4	4,26	495	61	8,1	-10,83
St Onolfs	17,1	127	78,0	5,38	570	73	7,9	-10,85
Appels	17,2	133	101,0	4,06	729	90	8,1	-10,70
Uitbergen	18,1	140	144,0	4,71	901	112	8,0	-10,63
Wetteren	19,1	147	73,0		541	71	7,6	-10,68
Melle	20,1	155	84,6	4,91	517	67	7,7	-10,86
Bovenschelde		180	43,2	5,13	381	45	8,4	-11,63
Durme		185	58,6	4,39	417	41	10,1	-10,54
Dender		190	26,6	4,01	335	51	6,6	-12,06
Rupel		195	59,8	2,94	406	47	8,7	-13,27

Table 1: Continued

Station	Code	Km	SPM, mg l^{-1}	TAlk, meq l^{-1}	POC, µM	PN, µM	C/N	$\delta^{13}C_{DIC}$
Sept. 2004								
Boei 87	9,1	57,5	105,7	3,21	177	20	8,9	-8,09
Boei 92	10,1	63	79,9	3,29	130	15	8,5	-9,21
Boei 105	11,1	71,5	71,5	3,48	174	21	8,3	-10,27
A'pen	12,1	78,5	86,1	3,63	320	39	8,3	-11,19
Kruibeke	13,1	85	92,4	3,80	414	53	7,9	-11,72
Bazel	13,2	88	94,0	3,88	508	62	8,2	-12,06
Steendorp	14,1	94	171,8	3,93	671	79	8,5	-11,90
Temse	14,2	97,5	143,3	4,02	604	70	8,6	-10,73
St Amands	15,1	111	59,6	4,25	412	53	7,8	-10,46
Vlassenbroek	16,1	118	87,7	4,21	436	56	7,8	-10,47
Dendermonde	16,2	121,5	124,5	4,24	559	66	8,4	-10,53
St Onolfs	17,1	127	255,2	4,23	1027	133	7,7	-10,36
Appels	17,2	133	166,9	4,29	800	78	10,3	-10,67
Uitbergen	18,1	140	67,6	4,54	598	103	5,8	-10,39
Wetteren	19,1	147	122,7	4,69	847	107	7,9	-10,48
Melle	20,1	155	182,5	4,60	1142	146	7,8	-10,95
Bovenschelde			49,3	4,92	373	46	8,2	-11,52
Durme			97,3	4,16	591	63	9,4	-12,87
Dender			21,6	4,33	216	30	7,2	-9,93
Rupel			86,5	3,58	613	77	7,9	-13,94
Oct. 2004								
Boei 87	9,1	57,5	106,3	3,32	171	17	9,8	-8,41
Boei 92	10,1	63	108,0	3,34	183	18	10,0	-10,20
Boei 105	11,1	71,5	213,3	3,56	335	34	9,7	-10,97
A'pen	12,1	78,5	90,0	3,80	390	42	9,3	-12,25
Kruibeke	13,1	85	86,5	3,99	315	39	8,1	-12,84
Bazel	13,2	88	98,0	4,05	366	43	8,5	-12,57
Steendorp	14,1	94	68,8	4,25	328	38	8,6	-11,97
Temse	14,2	97,5	214,4	4,49	492	56	8,8	-11,20
St Amands	15,1	111	175,8	4,98	688	76	9,1	-11,24
Vlassenbroek	16,1	118	321,9	5,04	836	125	6,7	-11,05
Dendermonde	16,2	121,5	249,6	5,19	1052	111	9,5	-11,27
St Onolfs	17,1	127	295,7	5,15	1040	101	10,3	-11,12
Appels	17,2	133	186,7	5,13	1072	142	7,5	-11,15
Uitbergen	18,1	140	205,0	5,27	978	127	7,7	-11,63
Wetteren	19,1	147	143,8	5,42	853	107	8,0	-12,22
Melle	20,1	155	78,2	5,40	605	77	7,9	-12,62
Bovenschelde			40,8	5,43	432	55	7,8	-12,91
Durme			176,5	5,46	636	74	8,6	-10,21
Dender			18,4	5,88	517	60	8,6	-12,61
Rupel			123,7	4,67	637	74	8,6	-13,95

Table 1: Continued

Station	Code	Km	SPM, mg l^{-1}	TAlk, meq l^{-1}	POC, µM	PN, µM	C/N	$\delta^{13}C_{DIC}$
Nov. 2004								
Boei 87	9,1	57,5	139,8	3,13	341	30	11,5	-7,45
Boei 92	10,1	63	74,0	3,28	184	17	10,7	-8,68
Boei 105	11,1	71,5	135,1	3,47	348	31	11,3	-10,17
A'pen	12,1	78,5	49,0	3,78	187	19	9,7	-12,00
Kruibeke	13,1	85	47,1	3,99	214	23	9,1	-12,48
Bazel	13,2	88	101,6	4,13	402	43	9,4	-12,51
Steendorp	14,1	94	92,2	4,42	369	39	9,4	-12,23
Temse	14,2	97,5	137,2	4,64	541	57	9,4	-11,86
St Amands	15,1	111	93,7	5,17	400	45	8,9	-11,73
Vlassenbroek	16,1	118	99,6	5,18	441	49	9,0	-11,70
Dendermonde	16,2	121,5	85,5	5,30	400	45	8,9	-11,99
St Onolfs	17,1	127	114,2	5,30	528	61	8,7	-12,68
Appels	17,2	133	104,3	5,26	510	61	8,3	-12,37
Uitbergen	18,1	140	170,1	5,54	728	85	8,6	-12,82
Wetteren	19,1	147	91,4	5,81	468	55	8,6	-13,30
Melle	20,1	155	69,3	6,06	389	43	8,9	-13,53
Bovenschelde			45,1	6,22	329	35	9,4	-13,78
Durme			101,0	4,90	459	49	9,3	-11,83
Dender			13,9	6,42	107	14	7,7	-13,22
Rupel			83,2	4,05	506	59	8,6	-13,60
Dec. 2004								
Boei 87	9,1	57,5	64,6	3,24	79	7	11,0	-10,55
Boei 92	10,1	63	41,8	3,39	116	11	10,4	-9,31
Boei 105	11,1	71,5	20,4	3,32	72	7	9,8	-11,44
A'pen	12,1	78,5	23,2	3,61	96	10	9,5	-12,82
Kruibeke	13,1	85	16,9	3,48	91	10	9,4	-13,37
Bazel	13,2	88	35,6	3,66	153	16	9,8	-13,25
Steendorp	14,1	94	46,6	3,75	205	21	9,7	-13,53
Temse	14,2	97,5	70,4	4,16	309	30	10,2	-13,38
St Amands	15,1	111	76,8	4,59	306	29	10,4	-12,72
Vlassenbroek	16,1	118	63,3	5,29	311	32	9,8	-13,45
Dendermonde	16,2	121,5	40,3	5,31	227	24	9,6	-13,59
St Onolfs	17,1	127	46,9	5,18	245	24	10,0	-13,74
Appels	17,2	133	99,1	5,09	400	39	10,3	-13,73
Uitbergen	18,1	140	142,8	5,32	540	51	10,6	-13,69
Wetteren	19,1	147	109,5	5,67	445	42	10,6	-13,79
Melle	20,1	155	88,2	5,79	383	36	10,7	-13,59
Bovenschelde			31,6	6,05	192	19	10,1	-13,75
Durme			13,1	4,35	101	12	8,8	-12,78
Dender			11,2	6,10	106	11	9,2	-13,80
Rupel			22,9	3,92	221	27	8,1	-14,03

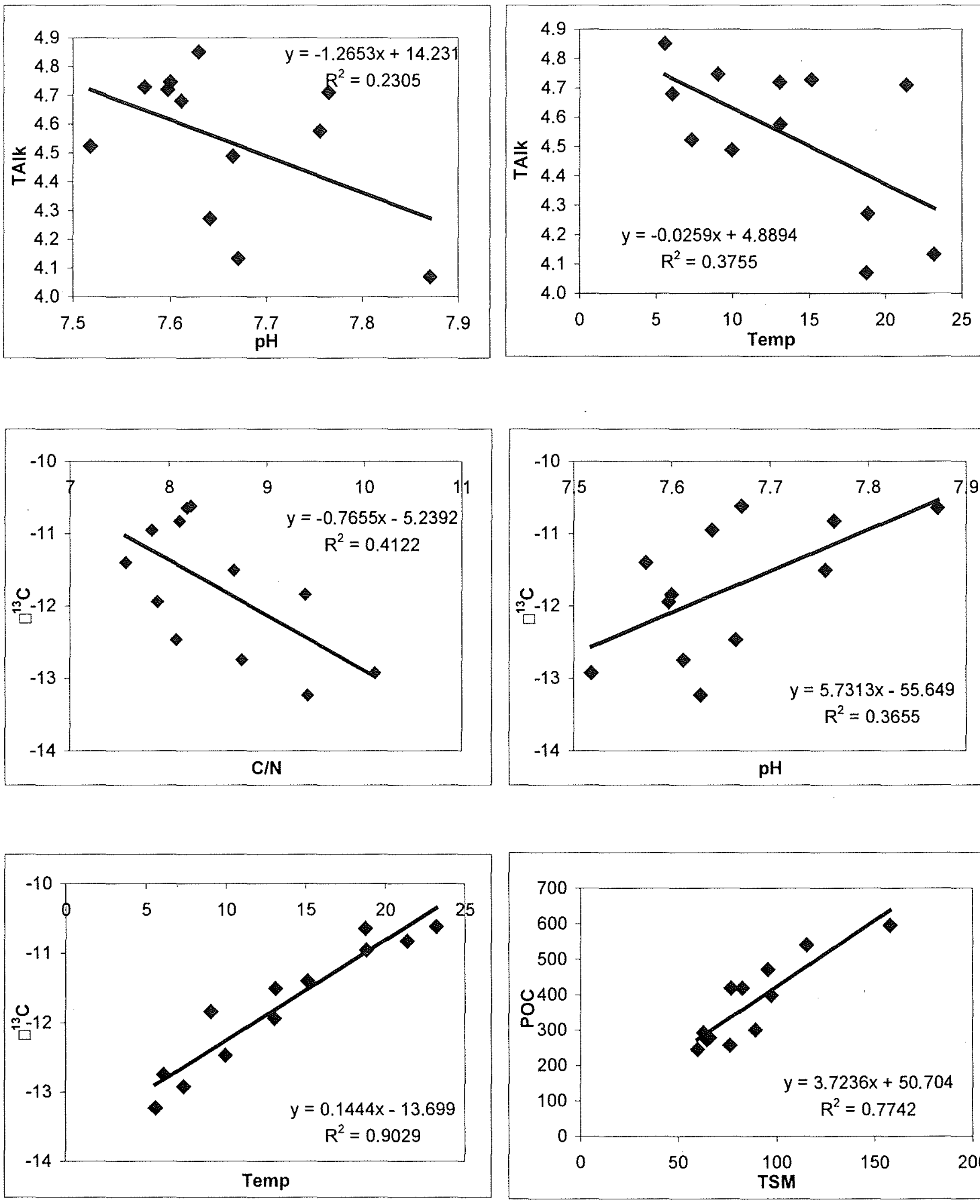


Figure 1: Zeeschelde in 2004. Correlations between monthly averaged values; Talk - pH; Talk - Temp; $\delta^{13}C_{DIC}$ - C/N; $\delta^{13}C_{DIC}$ - pH; $\delta^{13}C_{DIC}$ – Temp, POC – TSM.

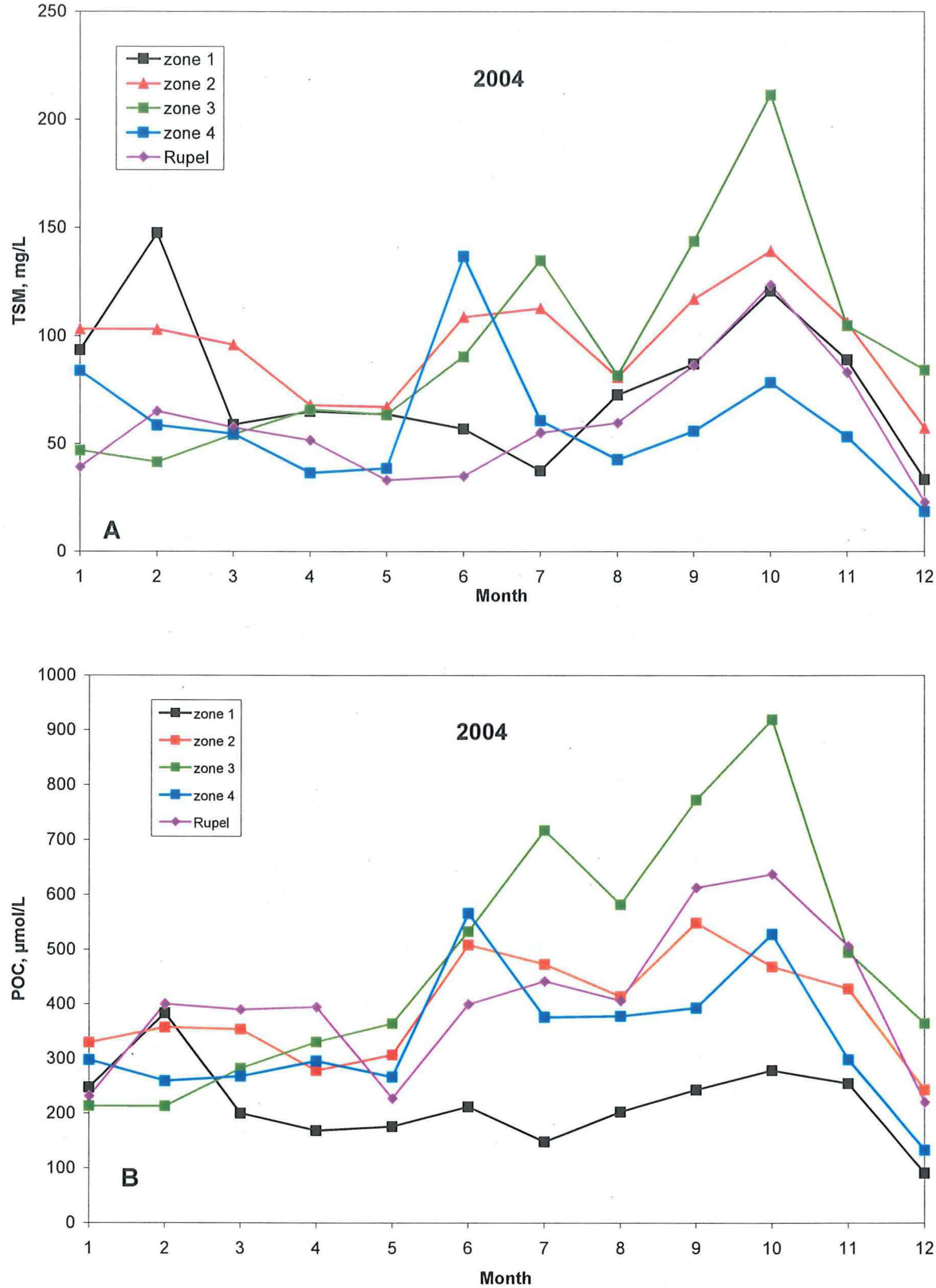
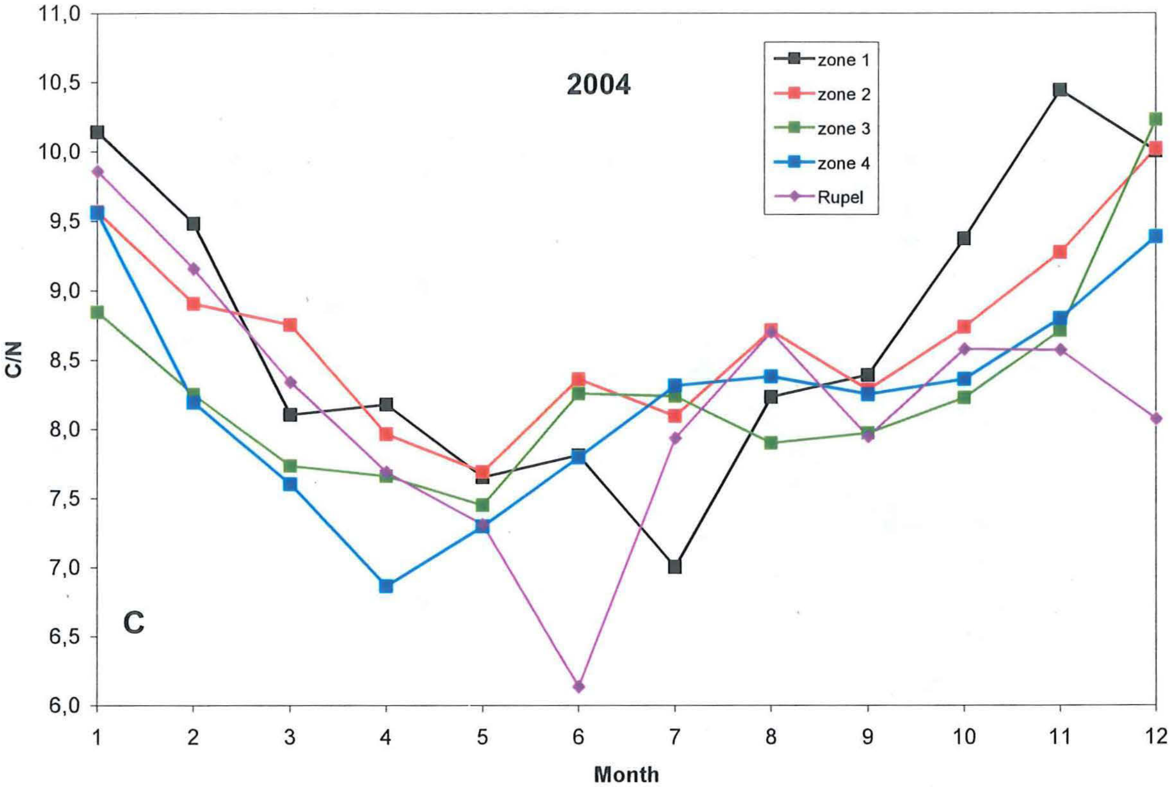


Figure 2a,b: Zeeschelde 2004. Monthly evolution of (A) zonally averaged TSM (mg/l); (B) zonally averaged POC (µmol/l). Zone 1: km 57.5 – 85 (Boei 87 – Kruibeke); Zone 2: km 88 – 111 (Bazel – St Amands); Zone 3: km 118 – 155 (Vlassenbroek – Melle); Zone 4: Tributaries (Bovenschelde, Durme, Dender); Rupel.



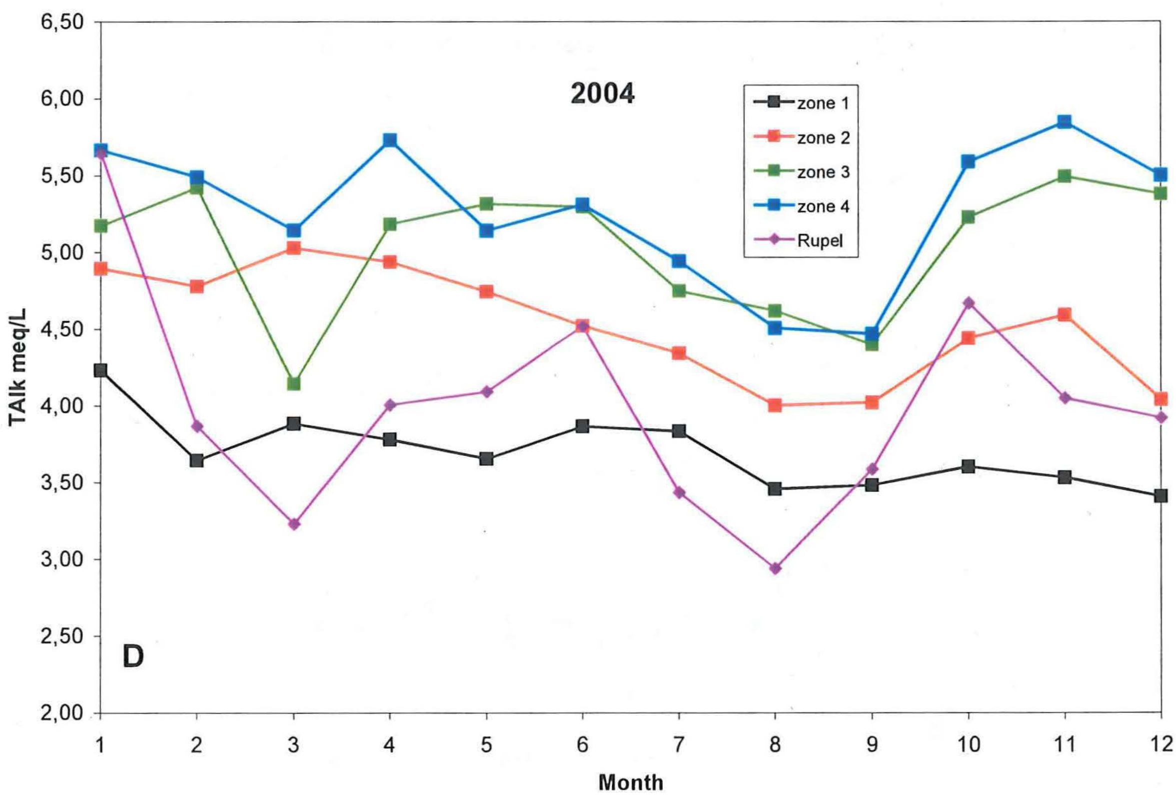
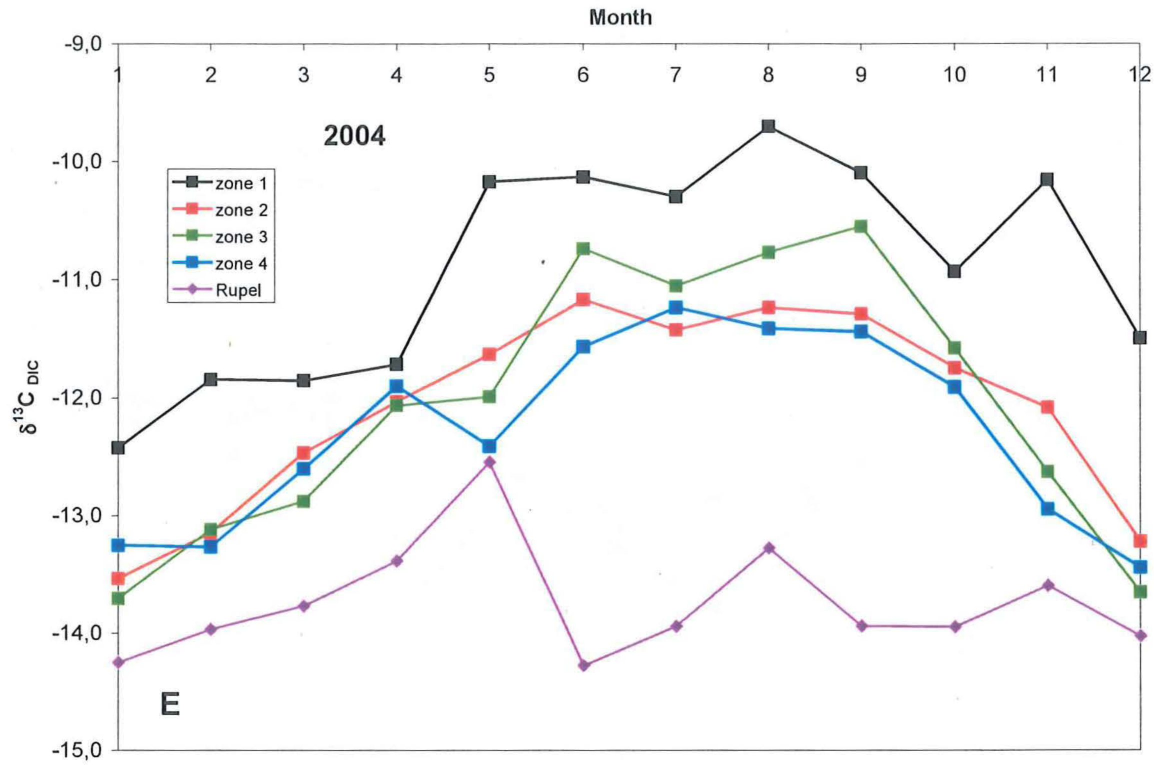


Figure 2 c,d: Zeeschelde 2004. Monthly evolution of (C) zonally averaged C/N atom ratio; (D) zonally averaged Talk (meq/L). Zone 1: km 57.5 – 85 (Boei 87 – Kruibeke); Zone 2: km 88 – 111 (Bazel – St Amands); Zone 3: km 118 – 155 (Vlassenbroek – Melle); Zone 4: Tribitutaries (Bovenschelde, Durme, Dender); Rupel.



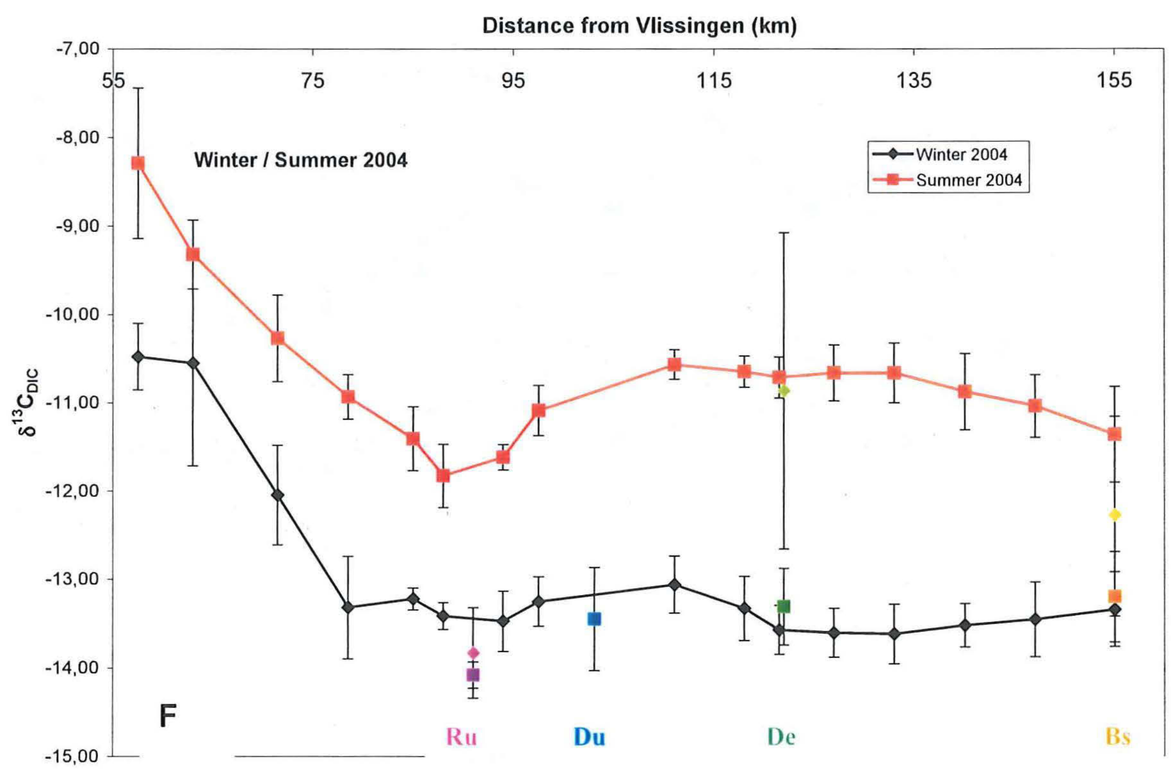


Figure 2e, f: Zeeschelde 2004. Monthly evolution of (E) zonally averaged $\delta^{13}C_{DIC}$ (‰). Zone 1: km 57.5 – 85 (Boei 87 – Kruibeke); Zone 2: km 88 – 111 (Bazel – St Amands); Zone 3: km 118 – 155 (Vlassenbroek – Melle); Zone 4: Tributaries (Bovenschelde, Durme, Dender); Rupel. (F) Spatial evolution of $\delta^{13}C_{DIC}$ (‰) in winter and summer 2004.

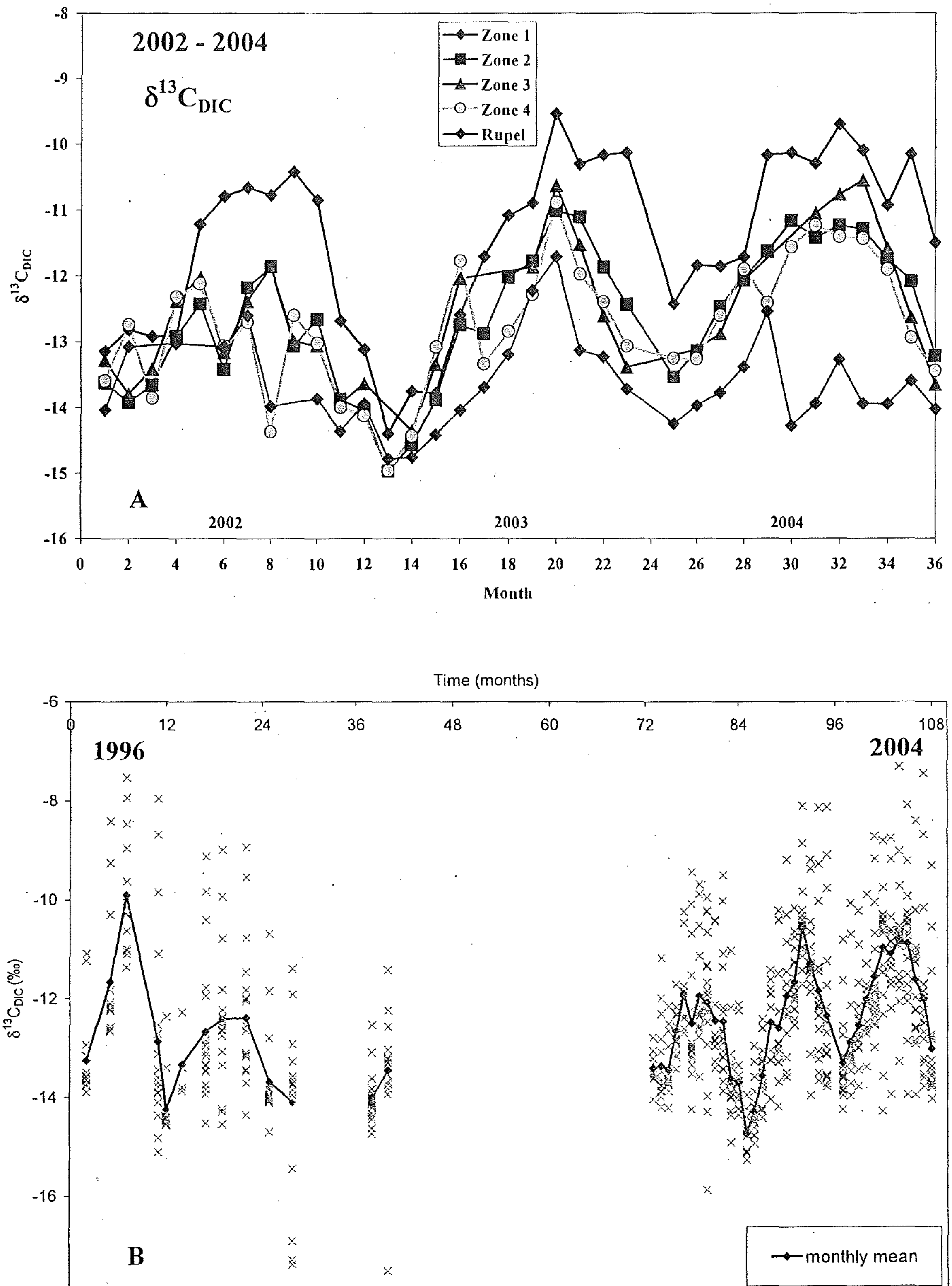


Figure 3a, b: Zeeschelde. Temporal evolution of $\delta^{13}C_{DIC}$ (‰) between (A) Jan. 2002 and Dec. 2004, and between(B) Dec. 1995 and Dec. 2004.

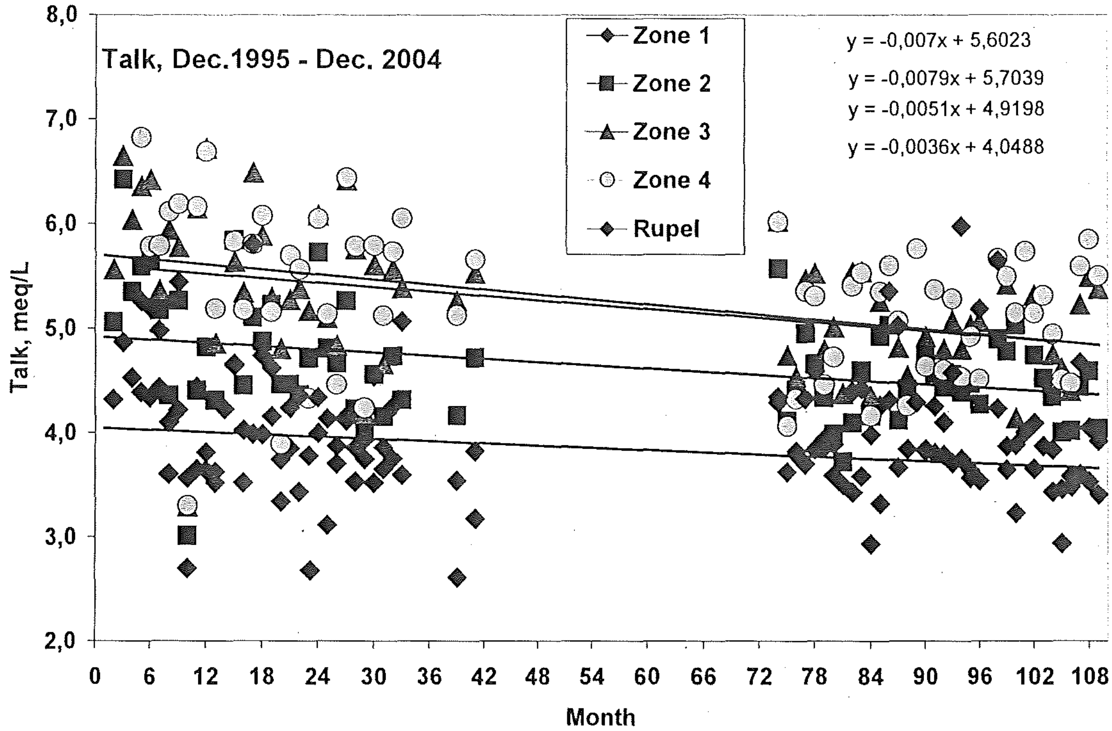


Figure 4: Zeeschelde Dec. 1995 – Dec. 2004. Temporal evolution of TAlk (meq/l), since December 1995 (= month 1).

Hoofdstuk 5. Zwevende stof in het Schelde estuarium (Gent – grens B-NL)

Suspended-matter in the Schelde estuary between Gent and the Belgian-Dutch border (january 2004 – december 2004)

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Eindverslag deelstudie 3 Sedimentologie (perceel 3). januari 2004– december 2004

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Vrije Universiteit Brussel

5.1. Introduction

This report describes the observations and measurements performed in fulfilment of the contract: *Onderzoek naar de gevolgen van het SIGMAPLAN, baggeractiviteiten en havenuitbreiding in de Zeeschelde op het milieu – Studie naar de sedimentologie.*

Monthly observations of suspended-matter (SPM) concentration, current velocity and salinity distribution over the water column were performed between the Belgian-Dutch border and Gent at 16 stations located in the main channel (table 1).

From March till December 2004 three additional stations in the Westerschelde, Waarde, Baalhoek and Bath, were sampled for suspended-matter concentration only. These samples were taken by the crew of the research vessel "Luctor" (Yerseke, The Netherlands).

Additionally, surface water was collected at 4 boundary stations located at the Schelde (Merelbeke), the Dender (Dendermonde), the Durme (Tielrode), and at the Rupel (Willebroek). From May 2004 surface water was also collected in the entrance channel to the Zandvliet sluice. The samples were taken near the sluice gate. At these boundary stations only the suspended-matter concentration was measured to evaluate the sediment supply from the river basin.

Table 1: measuring stations in the Zeeschelde.

NR.	Locatity	km from mouth	compartment
1	Buoy 87	58	1
2	Buoy 92	63	2
3	Buoy 105	72	3
4	Antwerpen (Steen)	79	4
5	Kruibeke (ponton)	85	5
6	Bazel (pontoon)	88	6a
7	Steendorp (kerk)	94	6b
8	Temse (brug)	98	7a
9	Mariekerke (veer)	111	7b
10	Vlassenbroek (kapel)	118	8
11	Dendermonde (ponton)	122	9a
12	St. Onolfs	127	9b
13	Appels (veer)	133	10
14	Uitbergen (brug)	140	11
15	Wetteren (baanbrug)	147	12
16	Melle (brug)	155	13

Next to the monthly observations complete-tide measurements were performed in late spring and early autumn near Lippenbroek, Kruibeke and Pas van Rilland. The measured parameters are suspended-matter concentration, current velocity and salinity.

In order to have a better understanding of the sediment dynamics at the complete-tide measurement stations 8 bottom samples were collected in the neighbourhood of the Lippenbroek station.

The third aspect of the study dealt with the evaluation of the accumulation rate of the sediments based on the vertical distribution of radioisotopes (^{210}Pb, ^{226}Ra, ^{241}Am) in tidal flat and marsh deposits. Sediment cores from 3 locations were analysed: Konkelschoor, Paal (The Netherlands) and Paulinapolder (The Netherlands).

5.2. Methodology

5.2.1. Field sampling of suspended sediment

Samples for the measurement of the suspended matter concentration were taken by pumping water from 5 predefined depths (10%, 25%, 50%, 75% and 90% of the actual water depth) and collecting between 150 and 200 ml water in PVC bottles of 250 ml. In order to minimise biochemical processes the bottles were immediately stored in a cooler box and, after transport to the laboratory, stored in a dark room at about 4°C till the filtering process. Total suspended sediment was collected on pre-weighed 0.45 µm sterile membrane filters (Whatman WCN type filters, Cat. No 7141-114) and dried at 105°C before weighing. Salts were removed by rinsing the filters for at least 3 times with at least 50 ml of demineralised water.

Samples for grain-size analyses were collected during maximum ebb and flood current using a centrifuge with a continues flow for at least 1 hour.

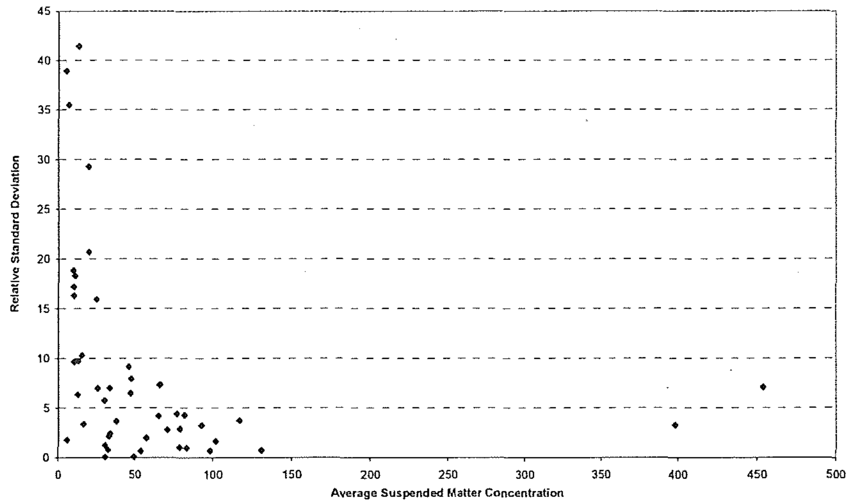


Figure 1: percent standard deviation observed in test samples as a function of concentration of suspended particulate matter in g m^{-3}.

The measured suspended matter concentrations in the Scheldt estuary are far from homogeneous. It varies with the tide along the estuary in depth as well as over the cross section. Therefore knowing the accuracy of the measuring technique is important. The accuracy of the sampling technique was tested on 52 samples taken in twofold on different occasions and at several sampling sites. The SPM concentration of these test samples varied from a few milligrams to 476 mg per litre covering the range of concentrations commonly observed in the river (figure 1). From these data it could be calculated that the average standard deviation is around 9%. The largest relative deviations (up to 40%) are observed in samples containing less than 25 g m^{-3}.

5.2.2. Field measurement of water velocity

Water velocities were measured at every sampling depth using either a calibrated OTT current meter or a VALEPORT model 802 two-axis electromagnetic current meter with underwater housing. The VALEPORT current meter measures the flow by an electromagnetic sensor that uses the Faraday principle to measure the flow past the sensor in two orthogonal axes. The magnetic field is generated within the sensor by a coil, and the electronics detect the signal generated across two pair of electrodes, one pair for each axis. The VALEPORT current meter was set at a data rate of 16 records per second. Each measurement was averaged over a time interval of 1 minute.

A series of measurements have been performed with the OTT current meter and the VALEPORT model 802 current-meter mounted next to each other on the same underwater frame, ballasted with a streamlined weight of 100 kg. The VALEPORT current meter was set at a data rate of 16 records per second. The recording time for both meters was set at 1 minute.

Figure 2 shows a comparison of the output of both meters. The data suggest that the VALEPORT gave a current velocity that was on the average 28% higher than the velocity recorded by the OTT current meter.

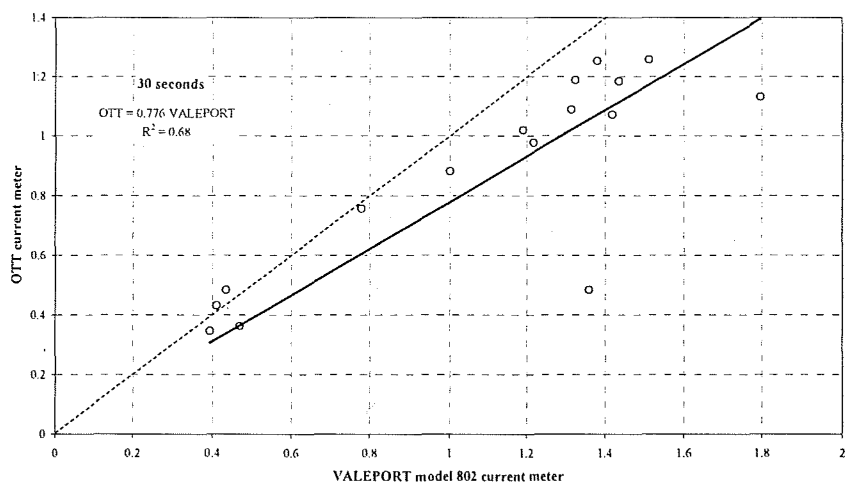


Figure 2: comparison of the current velocity simultaneously recorded by an electromagnetic VALEPORT- (x-axis) and a propeller type OTT (y-axis) current meter. The dashed line shows a 1:1 relationship. The full line is the linear regression of the data

A typical output of the VALEPORT current meter, recorded at station 11 (Dendermonde) at 95% of the water depth (7m), is shown in figure 3. The current velocity fluctuates mainly between 0.25 and 1 m s^{-1} with an average of 0.68 m s^{-1}. However short bursts exceeding 1 m s^{-1} and reaching up to 2.5 m s^{-1} also occur with an approximate frequency of 1.6 s^{-1}. The moving average per 5 seconds shows a fluctuation of the velocity between 0.55 and 1 m s^{-1}. It can be expected that the propeller type OTT current meter is less sensitive to these turbulent flow fluctuations and consequently will indicate a lower velocity.

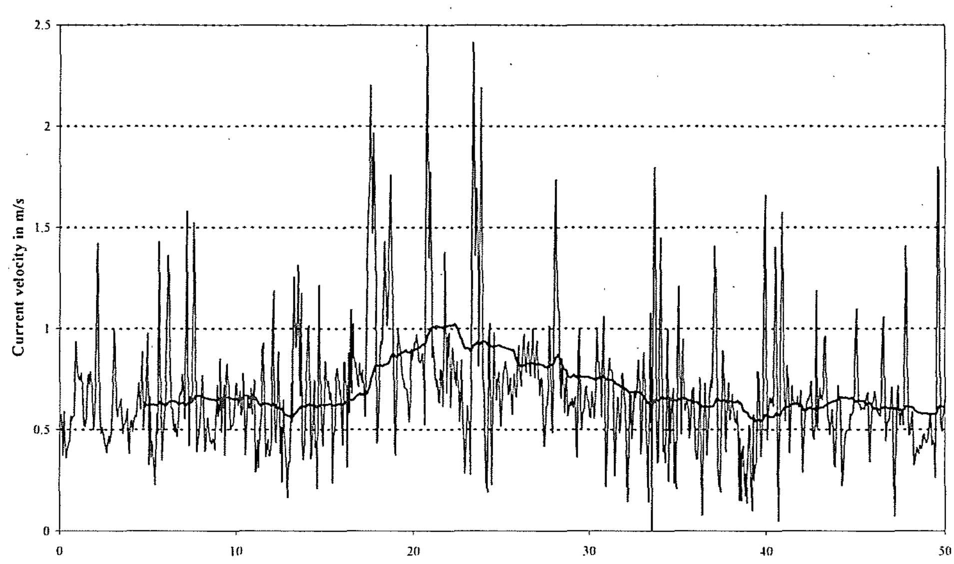


Figure 3: record of water velocity near the bottom using the VALEPORT model 802 current meter.

5.2.3. Measurement of salinity

Salinity was calculated using the electrical conductivity of the water measured at every sampling depth using a WTW LF325 conductivity meter. The salinity is expressed in Practical Salinity Units according to the UNESCO technical paper n°36 (Unesco, 1981).

5.2.4. Grain-size analyses

Samples were analysed using dry sieving for the fractions > 75 µm and the Sedigraph method for the fractions between 75 µm and 1.6 µm. A thorough description of the method is given in Wartel and Chen (2002).

5.2.5. Isotope analyses

Geochemistry of ^{210}Pb

Lead-210 ($t_{0.5}$=22.3 yr)[1] is a member of the ^{238}U decay series. A precursor of ^{210}Pb, ^{226}Ra, exists in most rocks, soils and sediments. Ra-226 ($t_{0.5}$=1622 yr) decays to ^{222}Rn, an inert gas that escapes from free surfaces into the atmosphere. Radon-222 ($t_{0.5}$=3.83 days) in turn decays through a series of short-lived isotopes to ^{210}Pb. Lead-210 itself decays to stable ^{206}Pb through a series of relatively short-lived daughter products.

The average atmospheric residence time for ^{222}Rn is about 4.2 days, during which the gas is distributed widely (Turekian et al., 1977). Lead-210 atoms adsorb onto atmospheric dust particles, which are deposited on land and water and can be supplied to a depositional area (in this case the Schelde estuary) following different pathways. Radium-226 is supplied to estuarine sediments as part of the particle erosive input. The ^{210}Pb formed by the in situ decay of this radium is denoted as the "supported" ^{210}Pb and is normally assumed to be in secular equilibrium with the ^{226}Ra present. "Unsupported" or "excess" ^{210}Pb is the one supplied from other sources as explained hereafter (Appleby and Oldfield, 1983; Oldfield and Appleby, 1984). Radium-226, however, may also be supplied to the estuary as a by-product from chemical industries such as phosphorous processing industries.

Direct atmospheric fallout.

Direct atmospheric fallout is generally taken to be the principal source of unsupported ^{210}Pb. A fraction of the radon atoms formed by ^{226}Ra decay in soils and rocks, escapes into the interstices and then diffuses through the soil into the atmosphere. The decay of ^{222}Rn in the atmosphere yields ^{210}Pb, which may be removed either by dry deposition or by wet fallout. When this ^{210}Pb falls directly into the estuarine waters, it is absorbed onto sediment particles and deposited on the bed of the estuary.

About 90% of all atmospheric ^{210}Pb fallout is delivered by wet deposition, so fallout rate is correlated with precipitation. The production of ^{210}Pb is dependent of geography, as the production of its antecedent, ^{222}Rn, is strictly continental. In regions that are dominated by continental air masses the ^{210}Pb fallout ranges from 0.0074 to 0.035 $Bq \cdot cm^{-2} yr^{-1}$. On a global scale this fallout averages below 0.0185 $Bq\ cm^{-2} yr^{-1}$ (Appleby and Oldfield, 1983; Benninger, 1978; Nozaki et al., 1978; Turekian et al., 1977).

1 $t_{0.5}$ is the half-life time of the isotope

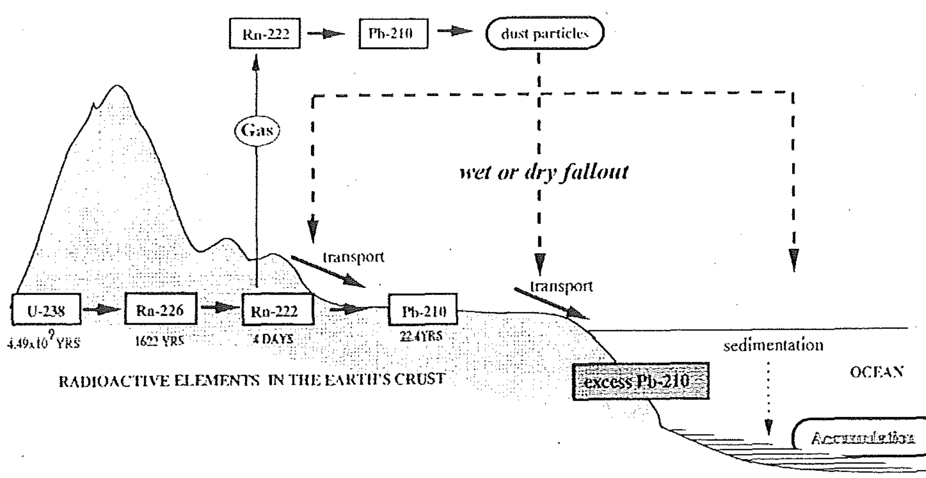


Figure 4: fate of ^{210}Pb in the environment. For explanation see text.

Indirect atmospheric fallout

Two components can be distinguished: C_1 for the atmospheric ^{210}Pb which is incorporated into the drainage net and flows quickly to the estuary waters without being detained on solid terrestrial particles and C_2 for the atmospheric ^{210}Pb becoming attached to fine particles with which it is delivered after a long residence time in the catchment area.

Radon decay in the water column

Radon is delivered to the water by diffusion from the underlying sediments, and by the decay of ^{226}Ra in the water column and in flowing streams. A part of the radon is lost by diffusion across the surface of the estuary, and the remainder decays in the water column to ^{210}Pb. A correction for this will be generally negligible.

The unsupported component of ^{210}Pb is the only one considered in dating, since once incorporated in the sediment, it decays exponentially with a characteristic half-life time of 22.3 years.

Regardless of the source of unsupported ^{210}Pb, the rate of which it is incorporated into the sediments nearly equals the local atmospheric fallout rate. Lead-210 falling into estuaries is rapidly and strongly absorbed onto sediment particles. Once incorporated into the sediment it moves with the particle fraction during any re-suspension and re-deposition processes. Some ^{210}Pb remobilize under reducing conditions, but is quickly reincorporated into sediments, especially by iron and manganese precipitates, when oxygen is reintroduced into the bottom water.

If no processes other than constant rates of sedimentation and burial affect ^{210}Pb, then the distribution of ^{210}Pb activity versus depth in a sediment core is described by an exponential declining curve due to normal decay. The curve of total activity does not converge to zero towards the bottom, but instead to a finite value which is equal to the supported ^{210}Pb. If other processes, such as re-dissolution or re-suspension of bulk sediments, or losses to ground water occur at a constant rate, the exponential curve persists but with another characteristic time (Binford et al., 1993).

Caesium-137

Caesium-137 is an artificial fission product ($t_{0.5}$ = 30 yr) that was released into the atmosphere from the testing of nuclear weapons since the early fifties. Significant fallout has been recorded since 1954 with peaks in 1954, 1958-1959 and especially in 1963 when a peak deposition was observed in the Northern hemisphere (Appleby et al., 1991).

The Chernobyl accident in May 1986 released a cloud of radioactive fission products into the atmosphere including ^{137}Cs. During the days following the catastrophe deposition of ^{137}Cs occurred in Western Europe (Oenema and DeLaune, 1988). The occurrence of high ^{137}Cs activities in sediment layers can be used to calculate the accumulation rate R_{Cs} as $R_{Cs} = z.t^{-1}$, (where z is the depth below the surface and t is the time).

The mobility of the ^{137}Cs isotope, however, causes a problem as Cs^+-ions may competitively be replaced by NH_4^+-ions and it may diffuse downward. Because of this mobility ^{137}Cs activities can be observed well below the 1954, 1963, or 1986 level of deposition dating.

Americium-241

Americium-241 is a decay product of ^{241}Pu ($t_{0.5}$ = 14.4 yr) that occurred in the fallout of weapons testing. It is much less mobile than ^{137}Cs and for that reason has widely been used for the relative dating of sedimentary deposits (Appleby et al., 1991).

Gamma-ray measurement

Lead-210, radium-226 and Americium-241 are determined without chemical separations by measuring the intensity of their respective characteristic gamma line using a low-energy germanium detector, capable of detecting low-energy radiations, connected to a CANBERRA-multichannel analyser. Caesium-137 is determined on the same sample but using a Hi-pure germanium detector.

Counting efficiencies were determined by preparing dry sediment samples labelled with known amounts of a standard solution of the radio-nuclides, ^{210}Pb and ^{226}Ra, and counting them in the proper geometric set up. Knowing the efficiency of the detector for these nuclides, the activity of samples measured under the same conditions can be calculated from the number of counts per second obtained. This method is less sensitive than beta-counting, but time-consuming sample preparations is not necessary (Gaggeler et al., 1976).

Random errors in determination of unsupported ^{210}Pb arise from the stochastic nature of the radioactive decay process, measurement errors of dry mass per unit wet volume, estimation of supported ^{210}Pb, counting time and mass of the sediment sample. A fair estimate of this error is obtained by running samples in six fold.

Instrumental set-up

The equipment for the analysis consists of a cylindrical lead shielding at the base of which a germanium-detector is placed. The sample is lowered into the shielding until it rests on the detector, then, each current pulse produced corresponds to energy deposited by an individual photon or particle emitted by the sample. The height of the pulse is a measure for the energy deposited. The following description of the counting process is taken from the Series 35 PLUS Operator's Manual.

The detector is connected to a multichannel analyser, the Canberra Series 35 PLUS which, through the pulse height analyser mode, quantifies the output signals from the detector. Since the nuclear or atomic decay that generates the incident radiation is a randomly occurring process, the pulse train from the detector to the Series 35 PLUS is a time-random mixture of pulses of all possible amplitudes. A pulse-height-analyser distribution histogram can provide both qualitative and quantitative results. As the channel number corresponds to input voltage, and input voltage corresponds to the energy of the radiation striking the detector, the energy of any peak in the spectrum can be easily determined.

The goal of the measurements is the determination of the radiation intensity for a given isotope, and, as the energy of the γ-line emitted by this nuclide is known, one needs only to divide the number of occurrences in that given energy interval by the total acquisition time, by the efficiency of the detector and by the abundance of the lines, in order to get a measure of the activity present. This is the principle of "counts divided by time", where the sum of all counts in a region of interest is given by the INTEGRAL, and the real number of events detected due to photons of the chosen energy is given by AREA (correction for Compton events of higher energy photons applied). Correction for background due to naturally occurring nuclides has still to be applied.

Preparation of samples
For the preparation of the samples, dried sediment from the analysed core level is mixed with microcrystalline cellulose powder in proportion 2:1. Sample and cement are then compressed at a pressure of 10 ton (using a SPECAC hydraulic press) in a hollow stainless steel cylinder, with inner diameter of 5.1 cm, to form a tablet (table 2).

Table 2: weight and thickness of tablets

weight	thickness
45 g	15 mm
30 g	10 mm
20 g	8 mm
15 g	5 mm

A code is assigned to the sample, and according to its mass, an optimum time for registering the decay of the radio-nuclides of interest is chosen.
To avoid systematic errors, the detector is properly calibrated, and its energy dependent efficiency is determined. In order to find a good technique to diminish both sources of errors preliminary tests were performed.

5.3. Monthly monitoring

5.3.1. Salinity

The salinity of the water was measured from January to December 2004. At every station measurements were made at 5 depths. The salinity of the water varies over the year. The measured salt content of the near-bottom water near the Belgian-Dutch border was lowest in January (salinity 5.9) and highest in September (salinity 15.9).

The most landward intrusion of salinity was measured in November and reached up to km 98 (Temse).

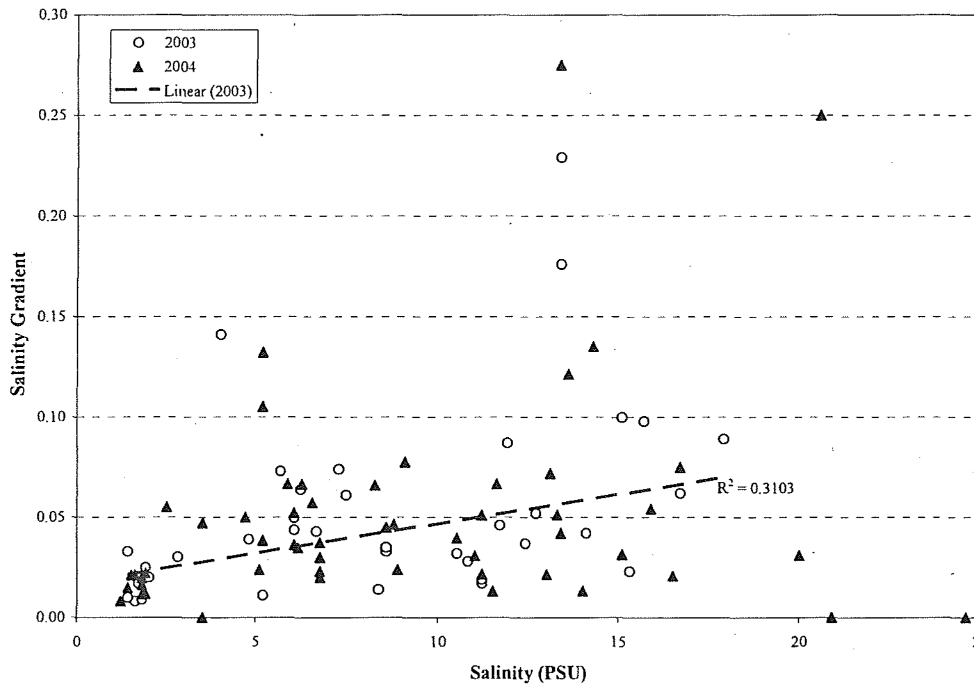


Figure 5: depth salinity gradient (m^{-1}) as a function of near-bottom salinity. The dashed line shows the linear regression

All measurements showed well mixed conditions. In most cases the salinity gradient is less than 0.1 m^{-1}. The largest depth salinity gradient was measured near the Belgian-Dutch border in June and was approximately 0.28 m^{-1} (figure 5). In general, there is only a moderate relationship between the depth salinity gradient and the near-bottom salinity. Figure 5 shows that the data of 2004 are in agreement with the data of 2003. Complete-tide measurements show that the salinity gradient increases shortly after slack of high water but is constant during the remaining of the tide.

5.3.2. Suspended matter

The results of the monthly measurement of suspended-matter concentration between January and December 2004 are given in the Annexe 3. The average suspended matter concentrations over the year 2004 for the near-bottom and the near-surface zones of the water column and for every sampling station are summarized in table 3.

The distance versus monthly SPM surface plots of the measured suspended-matter concentrations in the lowermost 10% of the water column for the period 2002 to 2004 are given in the Annexe 1. Attention should be drawn to the fact that this distance versus monthly SPM surface plot brings data together that were obtained at different moments of the tide. It does not give an image of the SPM concentration at a given time in the estuary but it gives the SPM concentration at the time of sampling which is different for each station. To overcome this problem, the distance versus monthly SPM data can be demonstrated showing the SPM load for a given water velocity (see below section 5 of this report).

Table 3: average SPM-concentrations in g m^{-3} at the near-surface and near-bottom for the period 2004.

Locality	Near-Surface SPM g m^{-3}	Near-Bottom SPM g m^{-3}
Buoy 87	82	406
Buoy 92	95	436
Buoy 105	126	479
Antwerpen	112	421
Kruibeke	91	204
Bazel	121	191
Steendorp	100	245
Temse	147	209
Mariekerke	153	214
Vlassenbroek	123	190
Dendermonde	127	184
St. Onolfs	128	184
Appels	119	211
Uitbergen	112	216
Wetteren	169	178
Melle	108	144

Suspended-matter concentrations exceeding 500 g m^{-3} extend from the Belgian-Dutch border to km 80. A sediment plume exceeding concentrations of 300 g m^{-3} extends to Mariekerke (km 110) from December 2003 till April 2004. Another zone with occasional high SPM concentrations occurs between km 130 and 140. In November – December 2004 this upstream zone fused with the downstream zone to form one long sediment plume covering the complete area between the Belgian-Dutch border and Wetteren. Between km 110 and 120 SPM concentrations are most of the time below 250 g m^{-3}. In the upper water layers sediment concentrations vary between 50 and 150 g m^{-3}.

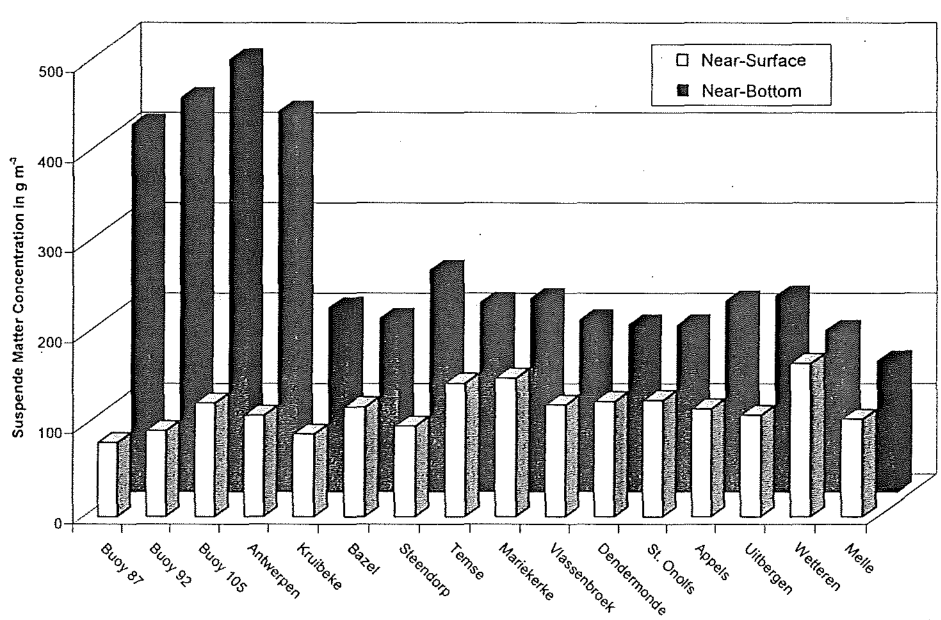


Figure 6: Average SPM concentration for the period 2002-2004 in the near-surface and near-bottom areas of the water column.

The average SPM concentration for the near-bottom and for the near-surface parts of the water column over the period 2002-2004 are given in figure 6. It can be observed that the near-surface SPM averages seem to reach a maximum in the area Temse - Mariekerke and in the neighbourhood of Wetteren. The near-bottom SPM averages are definitely at highest between the Belgian-Dutch border and Antwerpen. Secondary zones of less pronounced high concentrations occur between Temse and Vlassenbroek and in the neighbourhood of Uitbergen-Wetteren.

5.3.3. SPM and water velocities

The figures of SPM concentration against water velocity in the Annexe 1 (p.5.44-p.5.47) clearly show that periods of high SPM concentrations correspond to higher water velocities. In these figures (p.5.44-p.5.47) the SPM concentration is compared to the corresponding water velocities for near-surface (10% of the water depth) and for near-bottom (90% of the water depth) observations. The results demonstrate that:

- there is no systematic correlation between water velocity and SPM.
- the highest observed SPM concentration in the near-surface does not exceed 250 $g.m^{-3}$
- at low water velocities the SPM concentration may still be high due to a deposition lag at slack water after ebb (Chen, 2005)
- the near-bottom SPM concentrations are highest in the area between the Belgian-Dutch border and Antwerpen and may exceed 800 $mg.l^{-1}$.
- the highest observed near-bottom concentrations are lowest between Temse and St. Onolfs (<300 $g.m^{-3}$). Between Appels and Wetteren the highest observed concentrations exceed 300 $g.m^{-3}$.

5.3.4. Suspended-matter at the Westerschelde stations

From March till December 2004 water samples were taken at 5 depths of the water column at three stations in the Westerschelde: Waarde, Baalhoek and Bath. Table 4 shows the depth averaged salinity for these stations. The depth averaged suspended matter concentration is shown in table 5 and in figure 7.

Table 4: Depth averaged salinity for the Westerschelde stations in 2004.

Depth Averaged Salinity									
	March	April	June	July	August	September	October	November	December
Waarde	6.6	19.3	19.2	19.8	22.6	20.8	24.1	24.6	21.3
Baalhoek	6.6	15.3	15.1	16.1	19.9	17.2	23.3	20.9	18.5
Bath	6.6	10.5	12.7	14.0	14.4	13.7	20.4	16.4	15.7

The data show a strong increase in suspended matter concentration from Waarde to Bath with the exception of October 2004 when a exceptionally high value was observed in Waarde. It can also be observed that the concentrations were highest in March-April, decreased towards July-August and increased again toward November. This is in agreement with the evolution of the suspended matter concentration upstream of Bath in the Beneden-Zeeschelde (see Annexe 1).

Table 5: Depth averaged suspended matter concentration for the Westerschelde stations in 2004.

Depth Averaged SPM									
	March	April	June	July	August	September	October	November	December
Waarde	62	81	35	17	43	33	134	60	20
Baalhoek	108	110	35	15	45	30	48	48	15

Bath	308	215	53	42	91	61	40	139	29

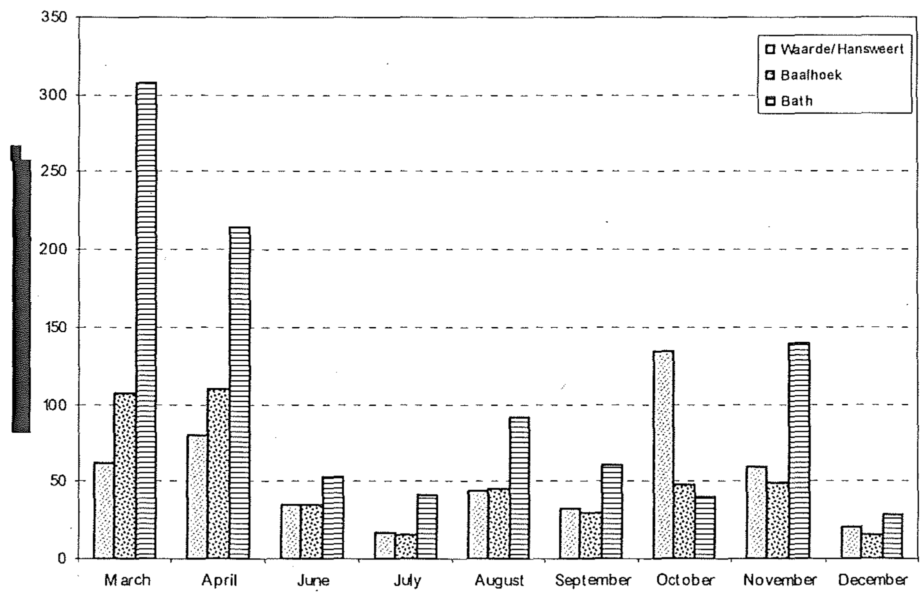


Figure 7: Depth averaged suspended matter concentrations for the westerschelde stations in 2004.

5.3.5. Suspended-matter at the boundary stations

The suspended-matter concentration at the boundary stations varies among rivers and varies also over the year. In general the suspended-matter concentration is highest in the Durme and lowest in the Dender (figures 6 to 9 and table 6).

Table 6: measured suspended matter

2004	Schelde	Durme	Dender	Rupel	Zandvliet
January 26	79	131	20	76	
February 24	54	98	31	71	
March 23	46	79	0	73	
April 01	26	83	5	65	
May 11	10	66	33	33	13
June 15	66	454	15	30	
July 13	38	117	20	47	13
August 17	42	57	31	102	10
September 14	55	83	16	47	6
October 12	33	398	11	92	6
November 16	49	82	0	77	13
December 7	25	34	4	10	10
average	43	140	15	60	10
standard deviation	19	136	12	27	4

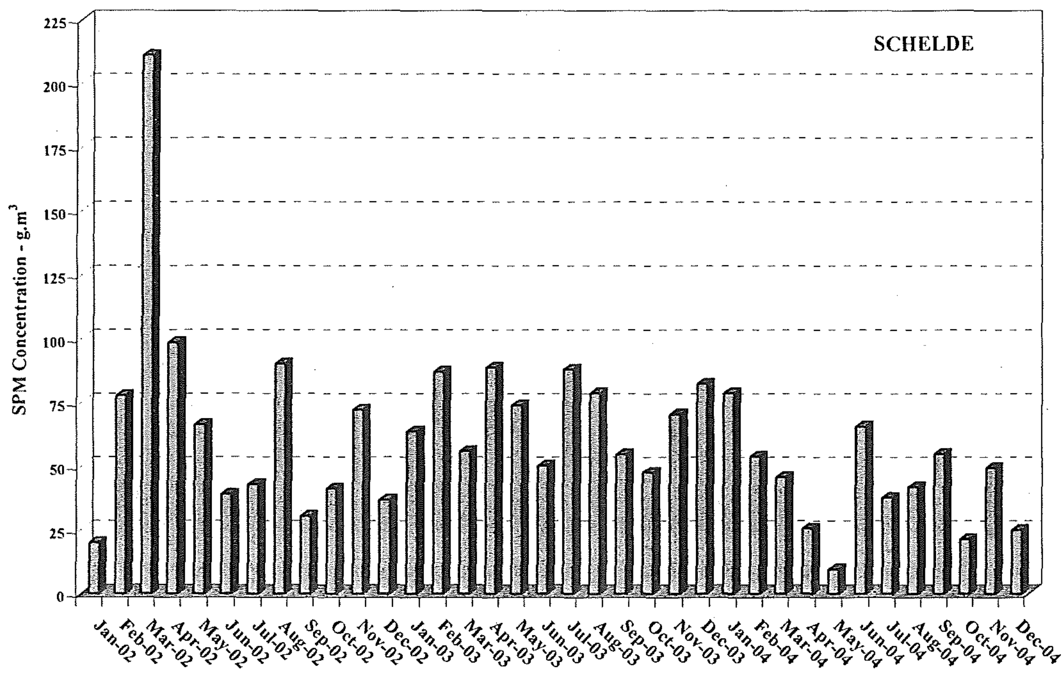


Figure 8: SPM concentrations in the Schelde (Merelbeke).concentrations at the boundary stations.

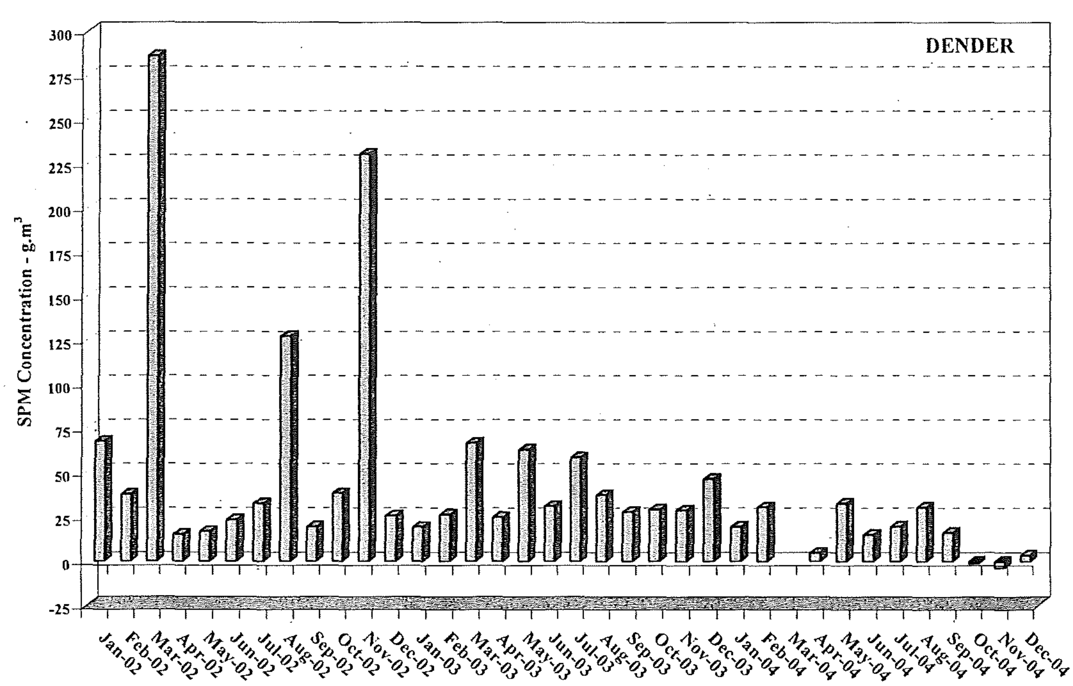


Figure 9: SPM concentrations in the Dender (Tijhut).

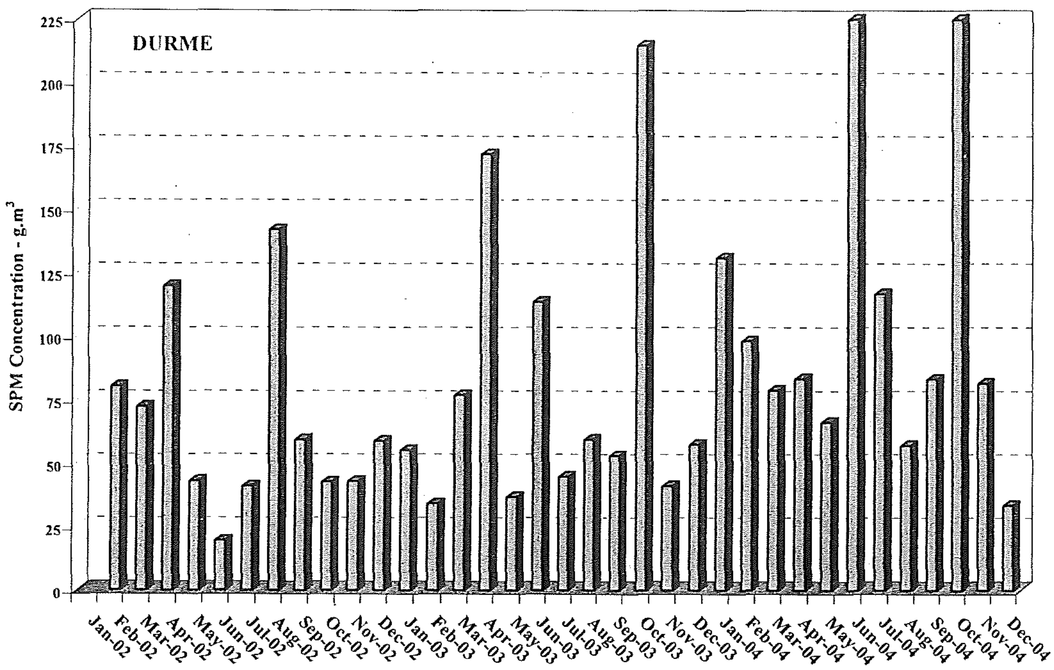


Figure 10: SPM concentrations in the Durme (Tielrode veer).

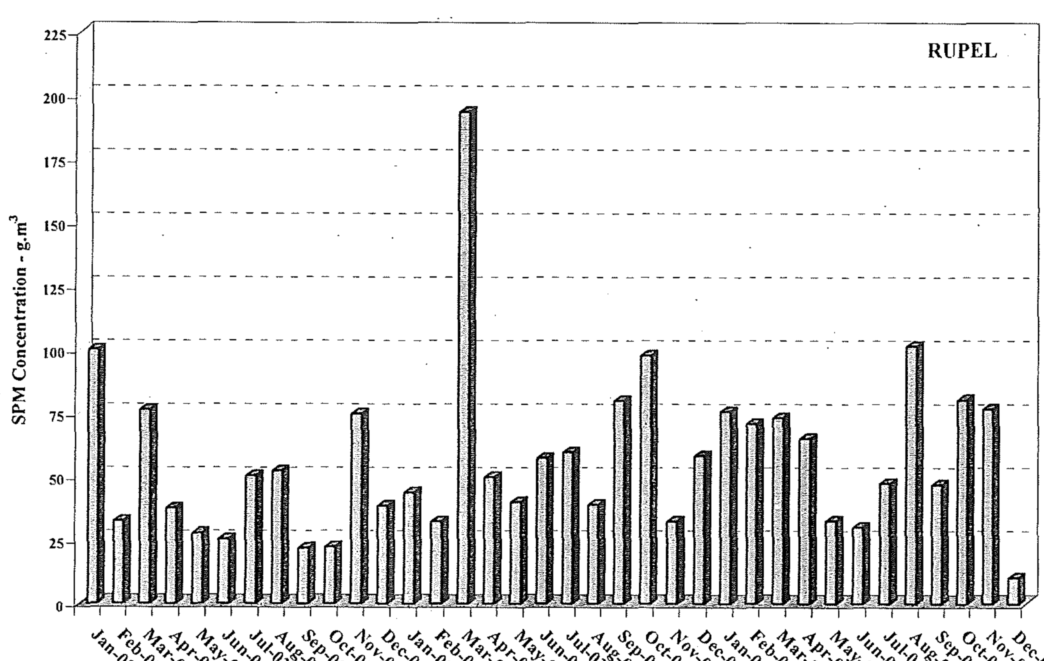


Figure 11: SPM concentrations in the Rupel (Willebroek veer).

There is not much difference in SPM between 2002 and 2003 (table 7). The high standard deviations result from peak values that may occur during the year. These peak values do not necessarily occur at the same time in the different rivers.

Table 7: average suspended particulate matter concentrations for 2002 and 2003.

	2002-2003	2002	2003	2004
Schelde	72 (±42)	73 (±52)	71 (±16)	42 (±20)
Durme	69 (±47)	65 (±42)	75 (±54)	139 (±132)
Dender	62 (±80)	78 (±98)	35 (±15)	16 (±13)
Rupel	51 (±40)	42 (±23)	66 (±536)	59 (±267)
Zandvliet				10 (±4)

When these peak values are omitted from the calculations (table 8) it can be observed that the average values of the suspended particulate matter concentrations were approximately 20% (in the Schelde and the Rupel) to 35% (in the Dender) higher in 2003 than in 2002.

Table 8: average suspended particulate matter concentrations for 2002 and 2003 after extreme high values have been excluded.

	2002-2003	2002	2003
Schelde	64 (±23)	60 (±25)	71 (±16)
Durme	53 (±22)	50 (±20)	56 (±24)
Dender	30 (±13)	26 (±9)	35 (±15)
Rupel	45 (±23)	42 (±23)	51 (±21)

5.4. Complete-tide measurements

Complete-tide measurements were performed at 3 sites: Lippenbroek, Kruibeke and Pas van Rilland. It should be noticed that the measuring station of Dendermonde – Baasrode of the previous years has been replaced by the station Lippenbroek. The purpose of these measurements was to collect suspended matter concentration and water velocity data over the whole water column as close to spring tide as possible and under different conditions of river discharge (table 7). From the table it can be seen that these conditions were only partly fulfilled.

Table 9: complete-tide measurements in 2004. The discharge value is the average for the third decade of the month.

	Tidal range Antwerpen m TAW	Discharge Schelle $m^3 s^{-1}$
June 28, 2004 - Lippenbroek	4.93	49
June 29, 2004 - Kruibeke	5.41	49
June 30, 2004 – Pas van Rilland	5.58	49
September 20, 2004 - Lippenbroek	5.60	73
September 21, 2004 – Kruibeke	5.11	73
September 22, 2004 – Pas van Rilland	4.90	73

Only the measurements at Kruibeke on June 29, at Pas van Rilland on June 30 and at Lippenbroek on September 20 can be considered as close to springtide. The other measurements were performed under "average" tidal conditions (average neap tide in Antwerpen is 4.69 meter TAW). The yearly average water discharge at Schelle in 2004 was 120 m^3. The discharge value during the September measurements (73 m^3 s^-

^{1}) can thus be considered as average for 2004. The discharge value during the June measurements (49 m^3 s^{-1}) was a rather low value for 2004.

5.4.1. Pas van Rilland - June 30, 2004

The figures 12-14 show the tidal curve, the salinity gradient, the suspended matter concentration and the water velocity for the near-bottom (at 90% of the water depth) and near-surface (at 10% of the water depth) parts of the water column. These measurements were performed under an average tidal range (4.90 m TAW at Antwerpen) and low river discharge conditions. (49 m^3 s^{-1} at Schelle).

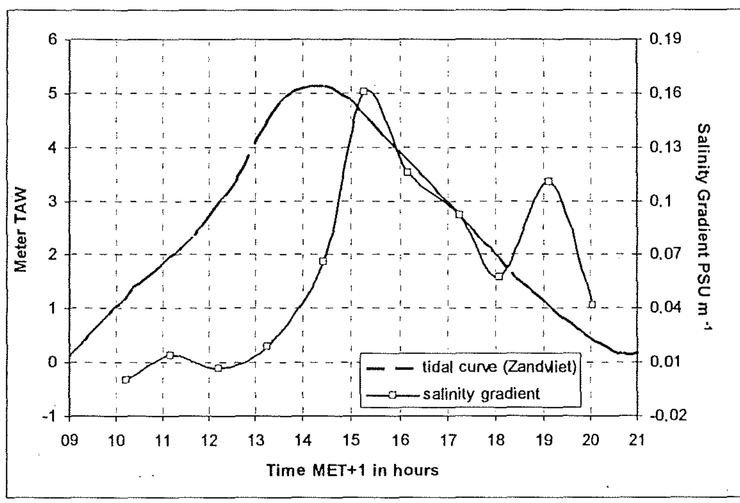


Figure 12: Tidal curve (Zandvliet) and the salinity gradient between near-bottom (90% of the water depth) and the near-surface (10% of water depth) for the complete tide measurements of 30 June 2004 at the Pas van Rilland.

It can be observed that the salinity gradient during first part of the flood stage is low but increases during the second part reaching a maximum (0.16 PSU m^{-1}) shortly after the slack of high water. The salinity gradient decreases during the ebb stage. The suspended matter concentration reaches a peak value of 350 g m^{-3} for a short time during the flood and drops rapidly staying low for the rest of the tide.

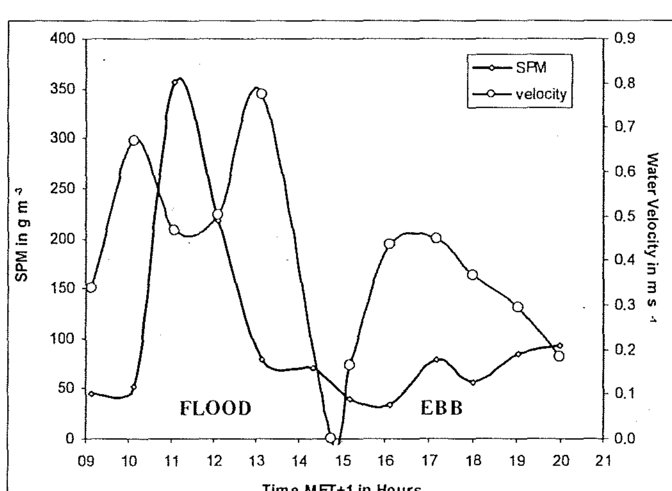


Figure 13: Suspended matter concentration and water velocity at the near-bottom (90% of water depth) for the complete tide measurements of 30 June 2004 at the Pas van Rilland.

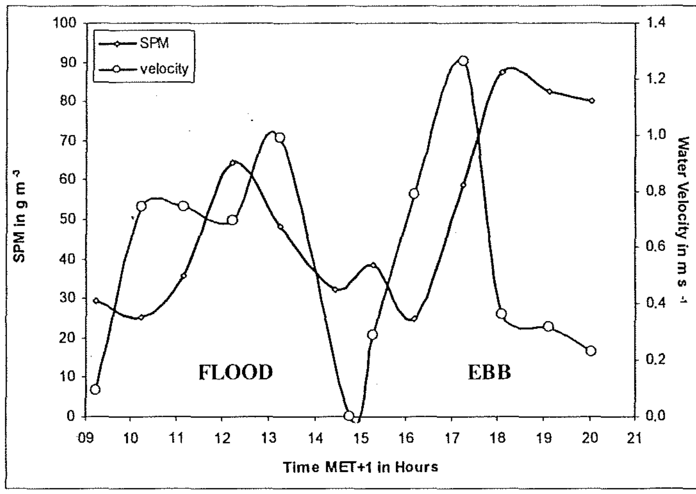


Figure 14: Suspended matter concentration and water velocity at the near-surface (10% of water depth) for the complete tide measurements of 30 June 2004 at the Pas van Rilland.

The suspended matter concentration at the near surface fluctuates between 30 and 90 g m^{-3}. This fluctuation seems to be independent of the water velocity. High SPM concentrations occur at mid-tide of flood and at mid-tide of ebb. The highest concentrations were recorded during ebb. The change in SPM concentration with time at the near surface follows a pattern that differs from the change in SPM concentration with time near the bottom.

5.4.2. Pas van Rilland - September 22, 2004

The following paragraphs describe the complete tide measurement of September 22, 2004 at Pas van Rilland. The tidal range (4.90 m TAW) was low and river discharge (73 m^3 s^{-1} was close to the average value for the year 2004.

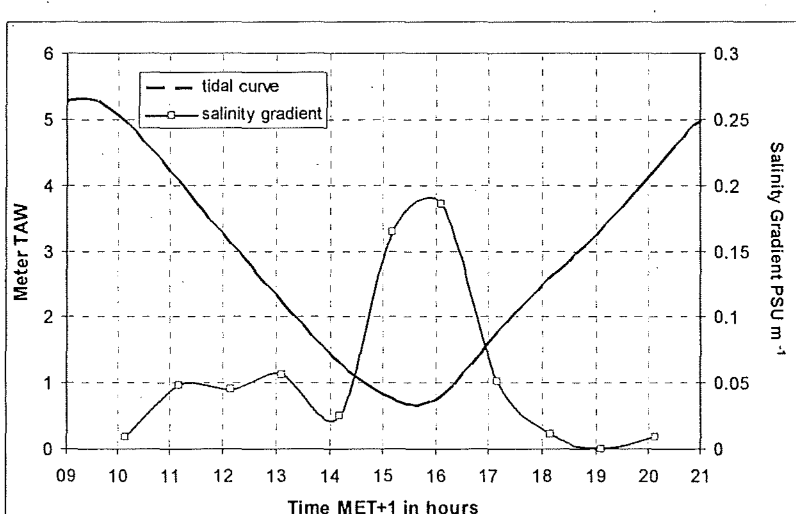


Figure 15: Tidal curve (Zandvliet) and the salinity gradient between the near-bottom (90% of the water depth) and the near-surface (10% of water depth) for the complete tide measurements of 22 September 2004 at the Pas van Rilland

The salinity gradient between near-bottom water (90% of the water depth) and near-surface water (10 % of the water depth) reaches a maximum of 0.19 PSU m^{-1} shortly after the slack of ebb and remains low (below 0.05 PSU m^{-1}) for the rest of the tide.

The maximum gradient is close to the maximum observed on June 30 (0.16 PSU m^{-1}). The evolution of the salinity gradient over the tide, however, is different.

The suspended matter concentration in the near-bottom water fluctuates between 20 and 140 g m^{-3}. No systematic change is observed. It can also be noticed that the SPM values are comparable to the previous measurements in June 2004 although the maximum observed value (146 g m^{-3}) is much lower.

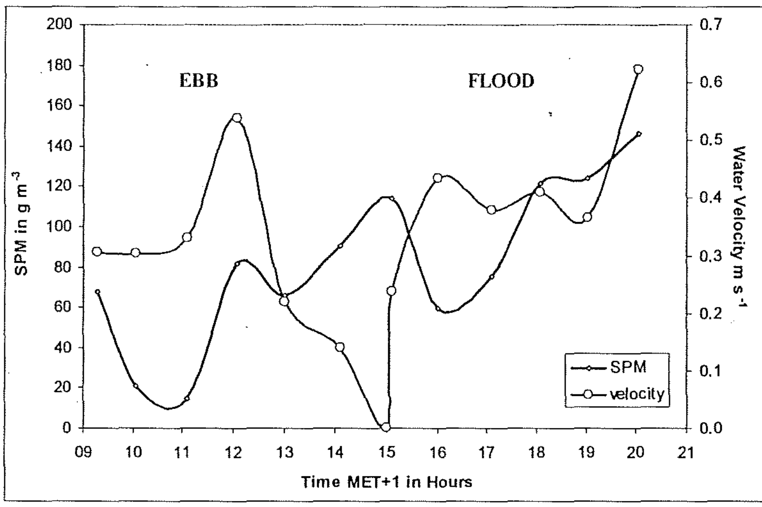


Figure 16: Suspended matter concentration and current velocity in the lowermost 10% of the water column) for the complete tide measurements of 22 September 2004 at the Pas van Rilland.

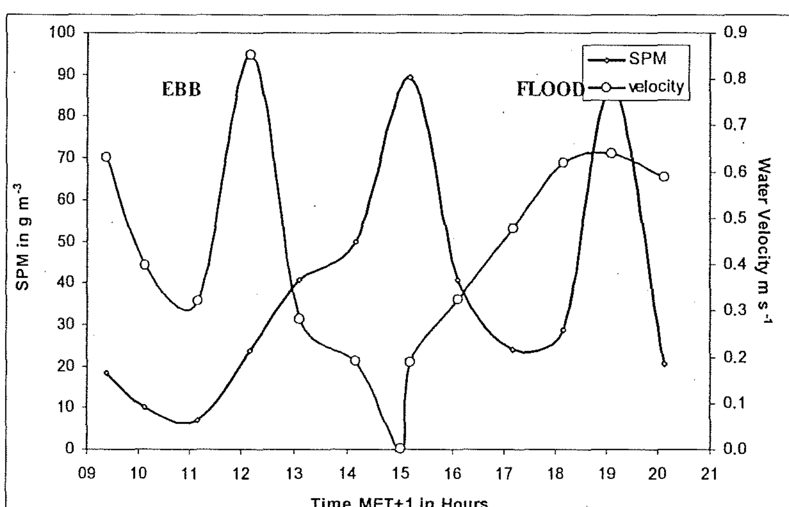


Figure 17: Suspended matter concentration and current velocity in the uppermost 10% of the water column for the complete tide measurements of 22 September 2004 at the Pas van Rilland.

In the upper part of the water column the suspended matter concentration increases to a maximum at the end of the ebb stage (89 g m^{-3}) and at the end of the flood stage (88 g m^{-3}). SPM values fluctuate between 10 and 90 g m^{-3}. The same pattern was observed during the measurements of June 2004 at the Pas van Rilland.

5.4.3. Kruibeke - June 29, 2004

The figures 18-20 show the tidal cure, the salinity gradient, the suspended matter concentration and the water velocity for the near-bottom and near-surface parts of the water column. The tidal range is close to spring tide (5.41 m TAW in Antwerpen) and the river discharge is low (49 m^{-3} s^{-1} at Schelle).

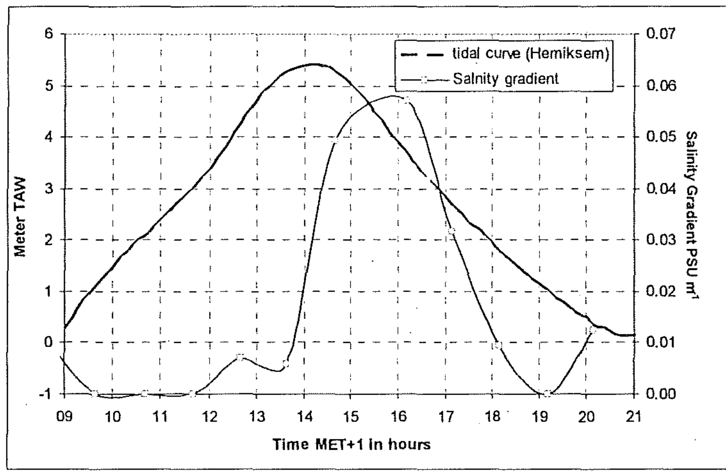


Figure 18: Tidal curve (Hemiksem) and the salinity gradient between near-bottom (90% of the water depth) and the near-surface (10% of water depth) for the complete tide measurements of 30 June 2004 at the Pas van Rilland.

The salinity gradient is close to zero except right after the slack of high water when a larger gradient (0.06 PSU m^{-1}) occurs. The suspended matter concentrations are represented in figures 19 and 20. It can be observed that as well near the surface as near the bottom the SPM concentrations are at highest just before and just after slack of high water. Near-bottom values reach up to 350 g m^{-3}. Near-surface values attain 150 g m^{-3}. The evolution of the SPM concentration in the near-surface water with time is more or less parallel to the changes in near-bottom SPM concentration.

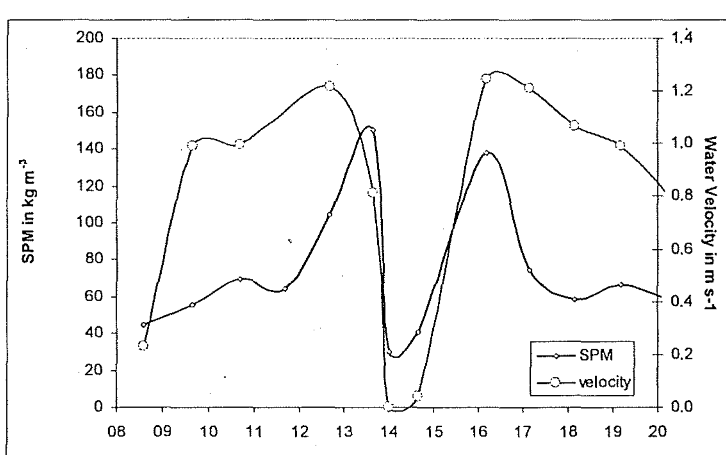


Figure 19: Suspended matter concentration and current velocity in the uppermost 10% of the water column for the complete tide measurements of 30 June 2004 at the Pas van Rilland.

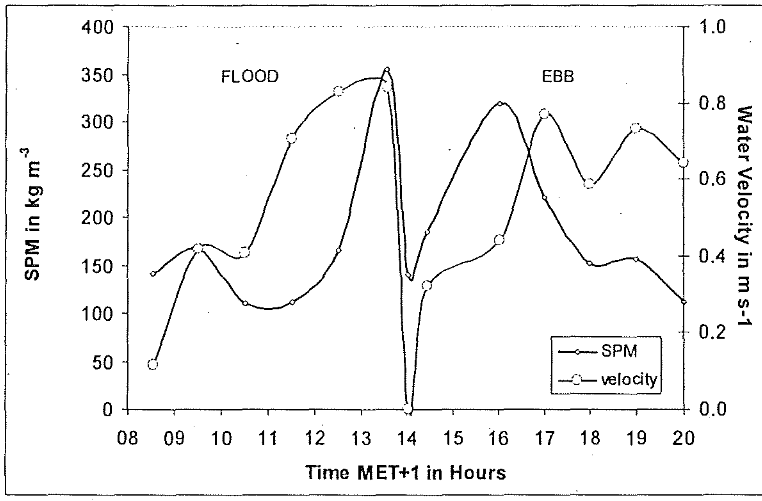


Figure 20: Suspended matter concentration and current velocity in the lowermost 10% of the water column for the complete tide measurements of 30 June 2004 at the Pas van Rilland.

5.4.4. Kruibeke - September 21, 2004

The figures 21-23 show the tidal cure, the salinity gradient, the suspended matter concentration and the water velocity for the near-bottom and near-surface parts of the water column. The tidal range is average (5.11 m TAW in Antwerpen) and the river discharge (73 m^{-3} s^{-1} at Schelle) is an average value for the year 2004.

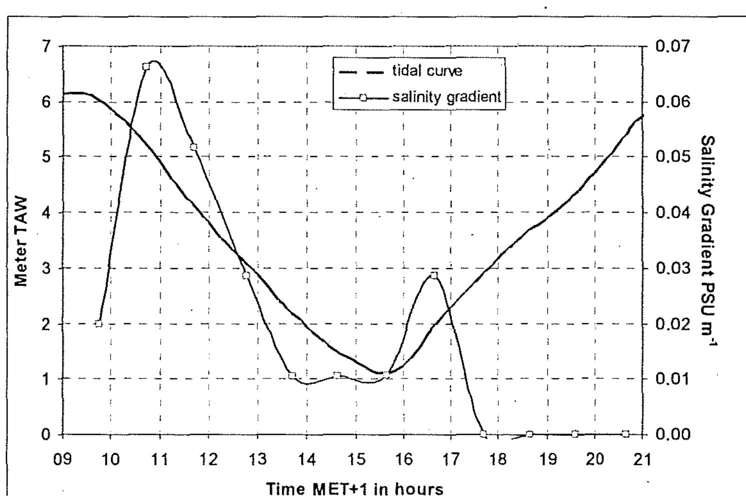


Figure 21: Tidal curve (Hemiksem) and the salinity gradient between near-bottom (90% of the water depth) and the near-surface (10% of water depth) for the complete tide measurements of 21 September 2004 at Kruibeke.

The salinity gradient is zero for most of the time. However, shortly after the slack of high water a larger gradient (0.07 PSU M^{-1}) is observed and shortly after low water a small gradient (0.03 PSU m^{-1}) occurs. This pattern is very similar to change in the salinity gradient with the tide observed on June 29.

The near-bottom suspended matter concentrations vary between 100 and 400 g m^{-3}. The highest values occur at the onset of the ebb tide and coincide with a peak in the salinity gradient. During the flood the SPM concentration remained below 200 g m^{-3}.

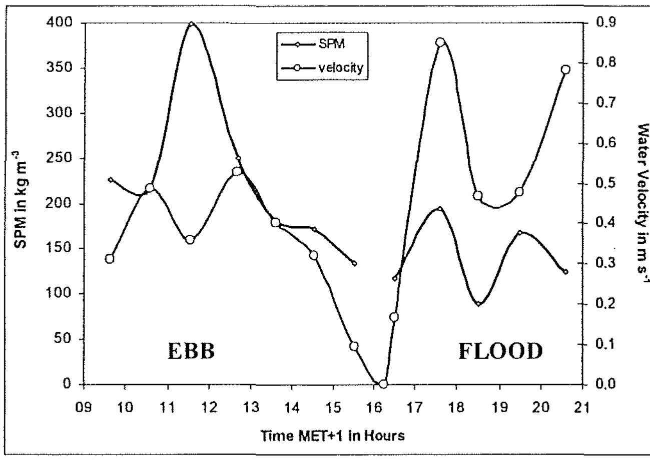


Figure 22: Suspended matter concentration and current velocity in the lowermost 10% of the water column for the complete tide measurements of 21 September 2004 at Kruibeke.

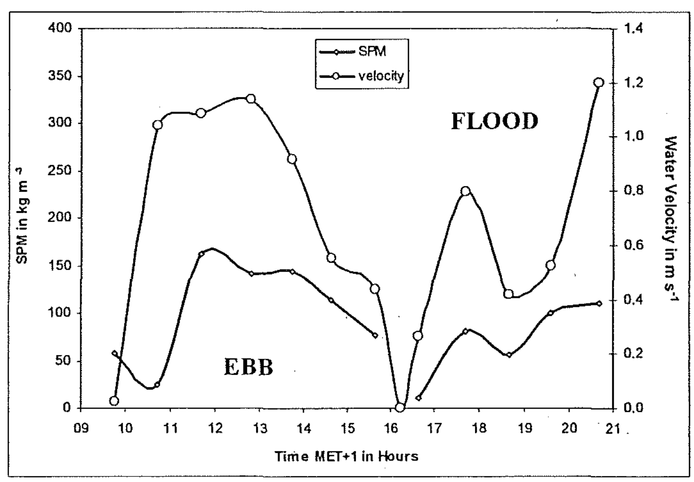


Figure 23: Suspended matter concentration and current velocity in the uppermost 10% of the water column for the complete tide measurements of 21 September 2004 at Kruibeke.

In the uppermost 10% of the water column (near-surface) the SPM concentrations vary between 10 and 150 g m^{-3}. Values are higher during ebb than during flood. The SPM concentrations observed during the September measurements agree well with the observation of SPM concentrations during the measurements of June 29.

5.4.5. Lippenbroek - June 28, 2004

The figures 24-26 show the tidal curve, the suspended matter concentration and the water velocity for the near-bottom (90% of the water depth) and near-surface (10% of the water depth) parts of the water column. The tidal range is low (4.93 m TAW in Antwerpen) and the water discharge is low (49 m^3 s^{-1}) for the year 2004. The suspended matter in the lowermost 10% of the water column varies between 79 and 284 g m^{-3}. The highest values are observed during the ebb. There seems to be a fair correlation between the SPM concentration and the water velocity: an increase in velocity corresponds to an increase in SPM concentration. In the uppermost 10% of the water column somewhat lower suspended matter concentrations occur varying between 20 and 177 g m^{-3}. The largest concentrations are observed during the ebb. The suspended matter concentration is fairly well correlated with the water velocity: an increase in velocity corresponds to in increase in SPM concentration. Furthermore, the difference in SPM concentration between surface and bottom is rather small.

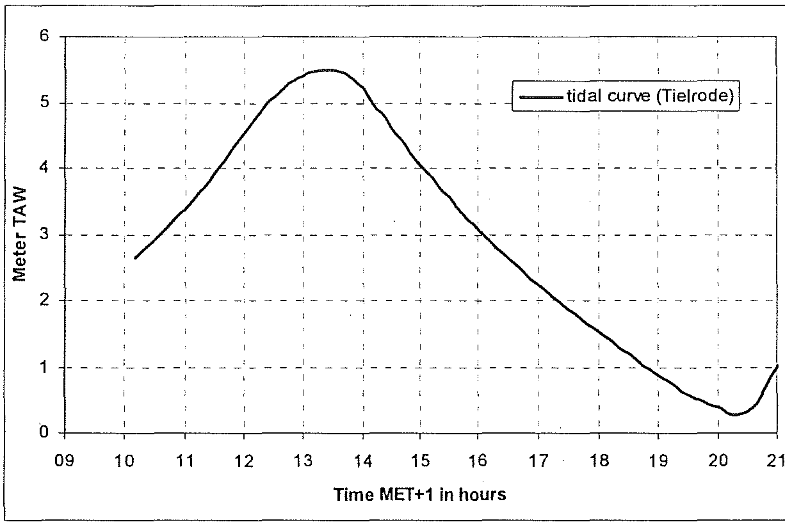


Figure 24: Tidal curve of June 28, 2004 at the tide gauge of Tielrode. Between 9 am and 10 am there was no tide recording.

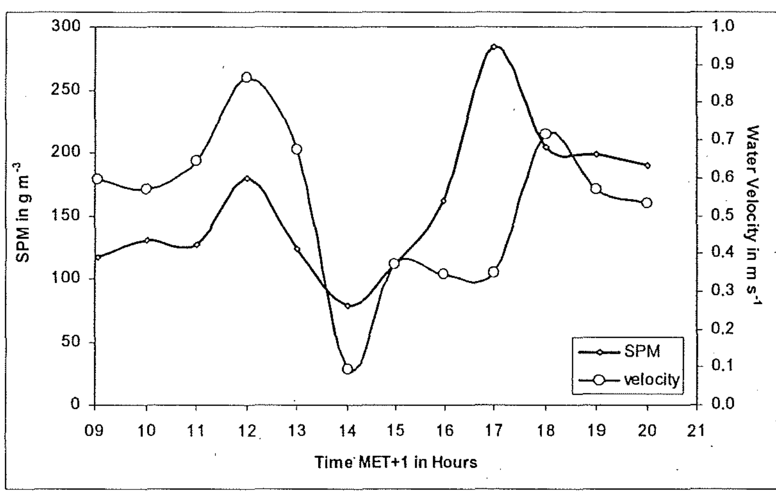


Figure 25: Suspended matter concentration and current velocity in the lowermost 10% of the water column for the complete tide measurements of 28 June 2004 at Lippenbroek.

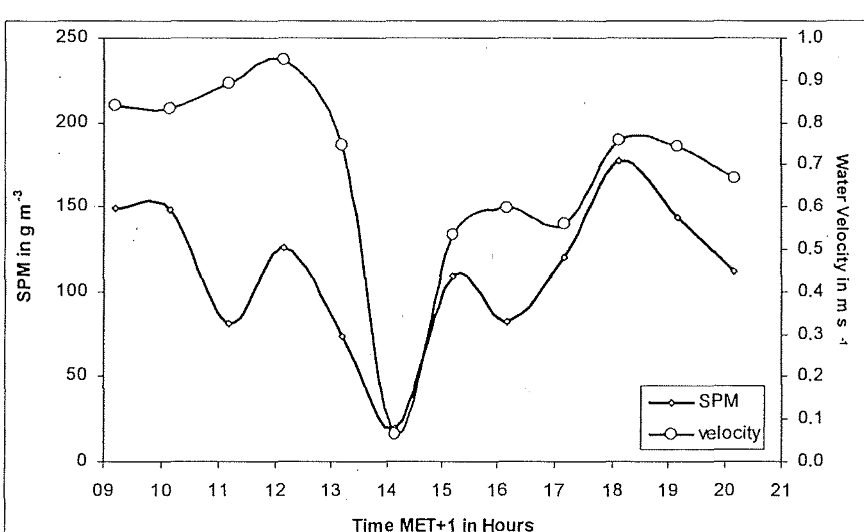


Figure 26: Suspended matter concentration and current velocity in the uppermost 10% of the water column for the complete tide measurements of 28 June 2004 at Lippenbroek.

5.4.6. Lippenbroek – September 20, 2004

The figures 27-29 show the tidal curve, the suspended matter concentration and the water velocity for the near-bottom (90% of the water depth) and near-surface parts (10% of the water depth) of the water column. The tidal range is close to spring tide (5.60 m TAW in Antwerpen) and the water discharge is average (73 m^3 s^{-1}) for the year 2004.

The suspended matter concentration in the lowermost 10% of the water column varies between 100 and 450 g m^{-3}. Values are higher during ebb than during flood. The highest values occur at the end of the ebb stage. In the uppermost 10% of the water column the suspended matter concentrations are lower (maximum below 250 g m^{-3}) a higher value is observed at the end of the ebb stage.

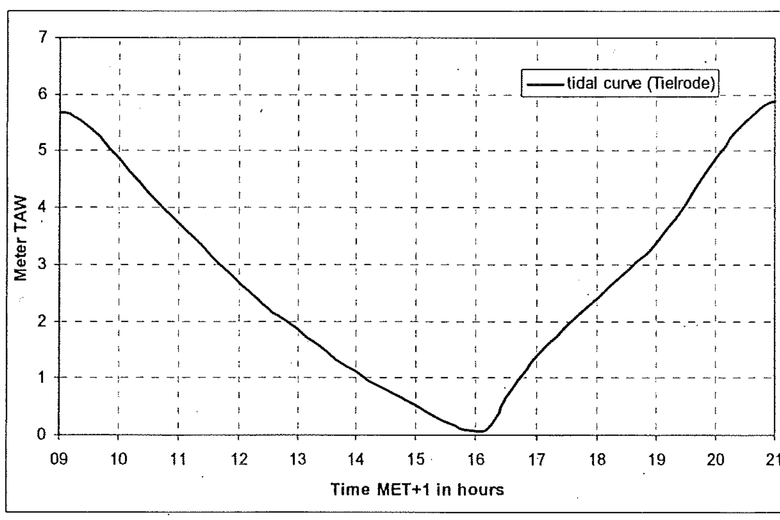


Figure 27: Tidal curve at the tide gauge of Tielrode on September 20, 2004.

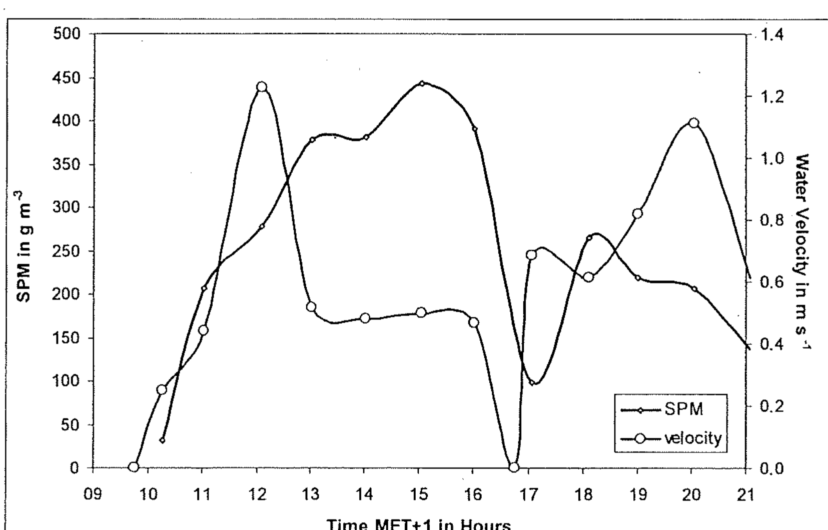


Figure 28: Suspended matter concentration and current velocity in the lowermost 10% of the water column for the complete tide measurements of 20 September 2004 at Lippenbroek

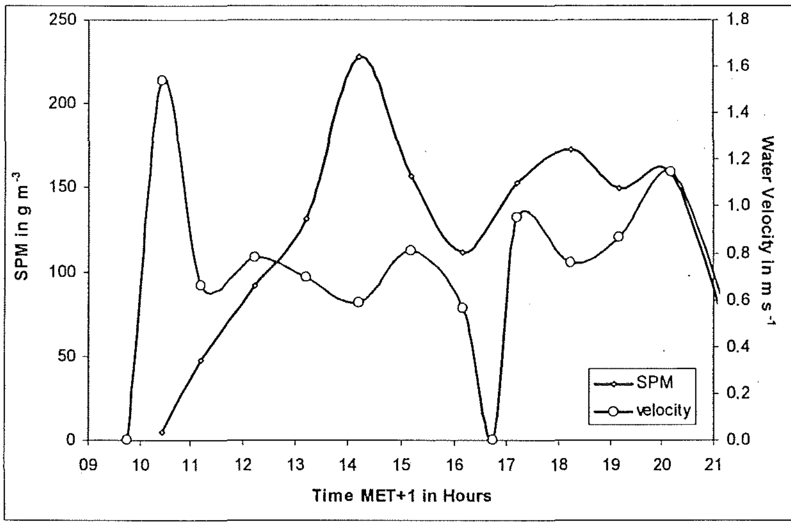


Figure 29: Suspended matter concentration and current velocity in the uppermost 10% of the water column for the complete tide measurements of 20 September 2004 at Lippenbroek

5.5. Estimation of the total suspended matter load in the estuary

5.5.1. Total load during complete tide measurements performed in 2002, 2003 and 2004

The total load at any given section of the estuary is a function of the sediment supply by advection and by the resuspension of sediments due to erosion. In the following paragraphs the total SPM load will be discussed in function of the depth averaged water velocity. This will be done for the complete tide measurements and for the data from the 16 monitoring stations.

Complete tide measurements performed near the Belgian-Dutch border

In 2002, 2003 and 2004 full tide measurements were performed in the lower part of the middle estuary near Zandvliet and in the Pas van Rilland. The tidal range extended from 4.9 m to 6.18 m and was close to spring tide conditions (5.7 m at Antwerpen), with the exception of the last measurements when the tidal range was close to neap tide (4.69 m at Antwerpen).

Table 10: Full tide measurements in the lower estuary (Zandvliet, Pas van Rilland).

Date	Locality	Tidal range (Antwerpen)
12 September 2002	Zandvliet	6.18 m
28 April 2003	Zandvliet	5.58 m
2 september 2003	Pas van Rilland	5.22 m (Bath)
30 June 2004	Pas van Rilland	5.58 m
22 September 2004	Pas van Rilland	4.9 m

The correlation between the total load expressed as kg m^{-1} s^{-1} and the depth averaged water velocity (DAV) expressed in m s^{-1} shows an exponential trend:

$Y = a\,e^{bx}$

At slack water, x = 0, then y = a, so the parameter a can be considered as the SPM load at slack water. The factor b is a measure for the SPM load with the DAV, the larger the b the faster the SPM will increase with increasing the DAV, and thus the b suggests, to certain extent, the resuspension capacity of a locality under given hydrodynamic conditions.

Near the Belgian-Dutch border the total load at slack water is approximately 0.05 kg m^{-1} s^{-1} and the exponential increase is 3.7 times the DAV.

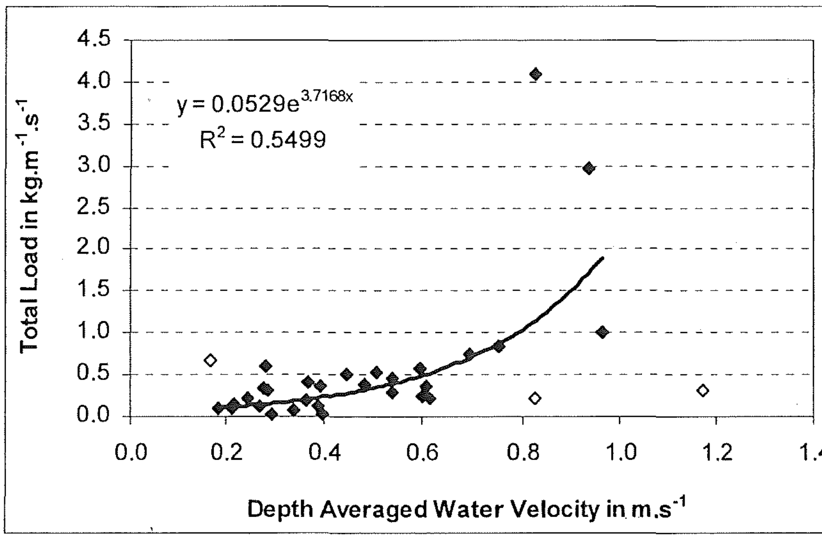


Figure 30: Total load versus depth averaged water velocity during ebb for the complete tide measurements at Zandvliet and Pas van Rilland. Open diamonds indicate points that were considered as outliers and were omitted from the regression calculation.

During the flood stage the total load increases exponentially with the DAV. At slack water the total load is approximately 0.07 $kg.m^{-1}.s^{-1}$. The exponential increase is 3.1 times the water velocity so the difference between ebb and flood is rather small.

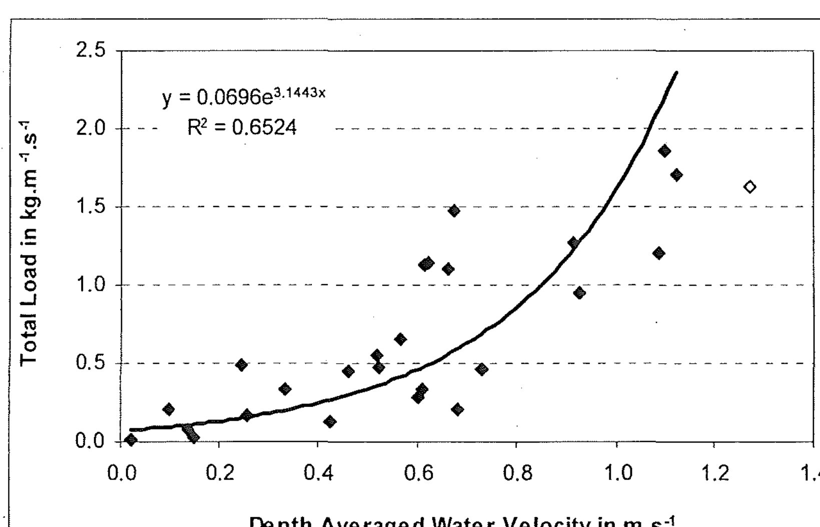


Figure 31: Total load versus depth averaged water velocity during flood for the complete tide measurements at Zandvliet and Pas van Rilland. Open diamonds indicate points that were considered as outliers and were omitted from the regression calculation.

Complete tide measurements between Antwerpen and the Rupel mouth.

Complete tide measurements were performed in the upper part of the middle estuary between Antwerpen and the Rupel mouth near Kruibeke. The tidal range extended from 5.11 m to 5.88 m and thus ranged from average (5.11 m) to spring tide conditions (5.88 m).

Table 11: complete tide measurements in the middle estuary (Kruibeke)

Date	Locality	Tidal range (Antwerpen)
16 April 2002	Kruibeke	5.88 m
07 May 2003	Kruibeke	5.22 m
29 June 2004	Kruibeke	5.41 m
21 September 2004	Kruibeke	5.11 m

During the ebb stage the total load increases exponentially with the DAV. At slack water the total load is approximately 0.13 $kg.m^{-1}.s^{-1}$ which is more than double of the value observed near the Belgian-Dutch border. The exponential increase is 2.67 times the water velocity and is lower than the value observed at the Belgian-Dutch border.

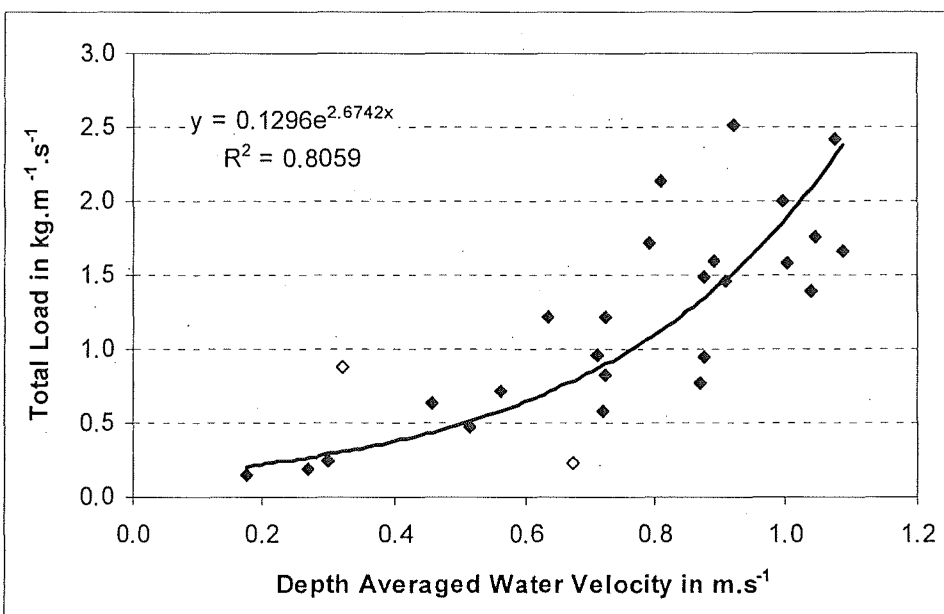


Figure 32: Total load versus depth averaged water velocity during ebb for the complete tide measurements at the upper part of the middle estuary (Kruibeke). Open diamonds indicate points that were considered as outliers and were omitted from the regression calculation.

During the flood stage the total load increases exponentially with the DAV. At slack water the total load is approximately 0.098 $kg.m^{-1}.s^{-1}$ and is higher than the value observed during the flood stage near the Belgian-Dutch border (0.07 $kg.m^{-1}.s^{-1}$). The exponential increase is 2.46 times the water velocity and is lower than the value observed during the flood stage near the Belgian-Dutch border

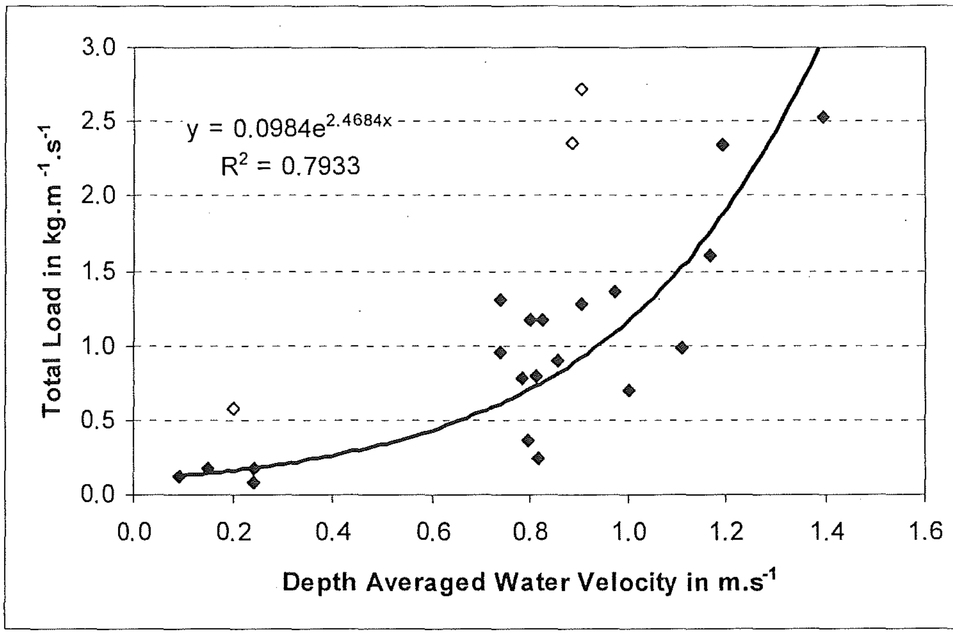


Figure 33: Total load versus depth averaged water velocity during flood for the complete tide measurements at the middle estuary (Kruibeke). Open diamonds indicate points that were considered as outliers and were omitted from the regression calculation.

Complete tide measurements in the upper estuary (Baasrode – Dendermonde – Lippenbroek).

Complete tide measurements were performed at Dendermonde, Baasrode and Lippenbroek. The tidal range extended from 4.93 m to 6.19 m, which, except for the measurement of 28 June 2004, were close to spring tide conditions.

Table 12: Complete tide measurements in the upper estuary

Date	Locality	Tidal range (Antwerpen)
30 April 2002	Dendermonde	6.19 m
22 August 2002	Baasrode	5.68 m
1 September 2003	Baasrode	6.07 m
28 June 2004	Lippenbroek	4.93 m
20 September 2004	Lippenbroek	5.60 m

During the ebb stage the total load increases exponentially with the DAV. At slack water the total load is approximately 0.06 $kg.m^{-1}.s^{-1}$. The exponential increase is 3.7 times the DAV. These values are almost the same as observed near the Belgian-Dutch border.

During the flood stage the total load increases exponentially with the DAV. The exponential increase is 4.24 times the DAV and is steeper than during ebb. At slack water the total load is approximately 0.03 $kg.m^{-1}.s^{-1}$ which is only half of the value during ebb.

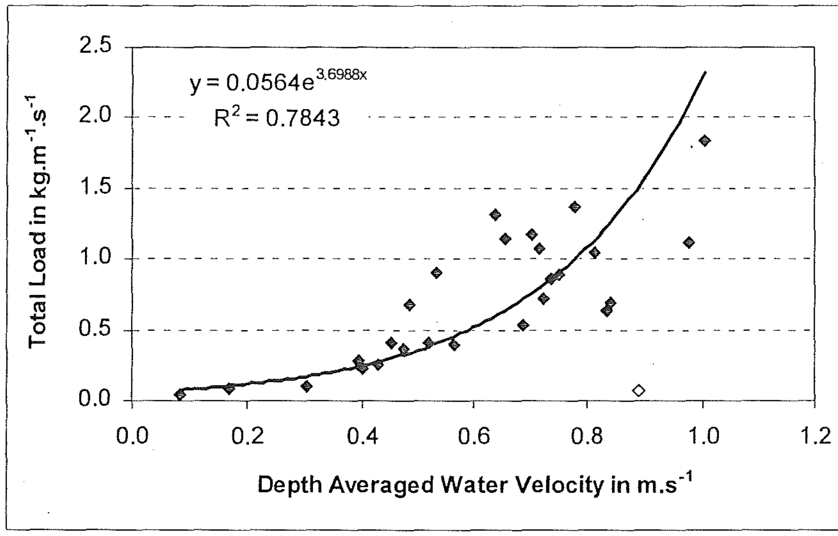


Figure 34: Total load versus depth averaged water velocity during ebb for the complete tide measurements at Dendermonde, Baasrode and Lippenbroek. Open diamonds indicate points that were considered as outliers and were omitted from the regression calculation.

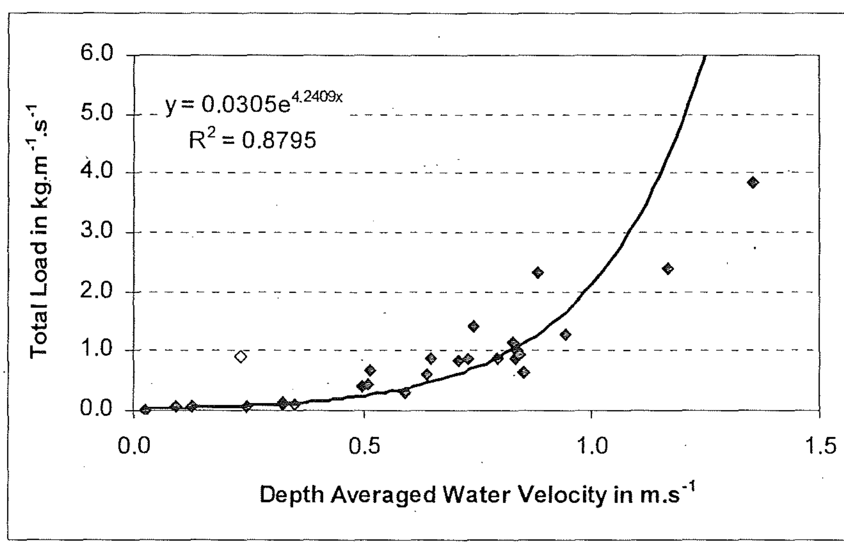


Figure 35: Total load versus depth averaged water velocity during flood for the complete tide measurements at Dendermonde, Baasrode and Lippenbroek. Open diamonds indicate points that were considered as outliers and were omitted from the regression calculation.

5.5.2. Analyses of the total load at the 16 stations.

In the following paragraphs the relationship between the total suspended matter load and the depth averaged water velocity will be discussed for the 16 monitoring stations. For every measurement at every station the total suspended matter load and the depth averaged water velocity were calculated using the observed suspended matter concentration and water velocity at 5 predefined water depths. Neighbouring stations showing some similarity in their results were grouped into the same graphs for the convenience of the comparison only. This grouping is thus more or less arbitrarily. The first part discusses the data obtained during ebb. In the second part the data obtained during flood will be analysed.

Measurements during the ebb stage

Group 1: Station 1 (buoy 87 - Zandvliet) and station 2 (buoy 92 - Liefkenshoek)

It can be observed that during ebb the total SPM load varies exponentially with the depth averaged water velocity (DAV). The total SPM load increases rapidly once the DAV rises above 0.4 m s^{-1}.

The regression line obtained from the grouped data shows an exponential increase of 3.92 times the DAV which is in agreement with the exponential increase (3.72 times the DAV) that was obtained from the full tide measurements near Zandvliet and in the Pas van Rilland. However, at slack water ($x = 0$ and $e^{ax} = 1$) the total load (0.08 kg m^{-1} s^{-1}) is higher than observed during the full tide measurements (0.05 kg m^{-1} s^{-1}).

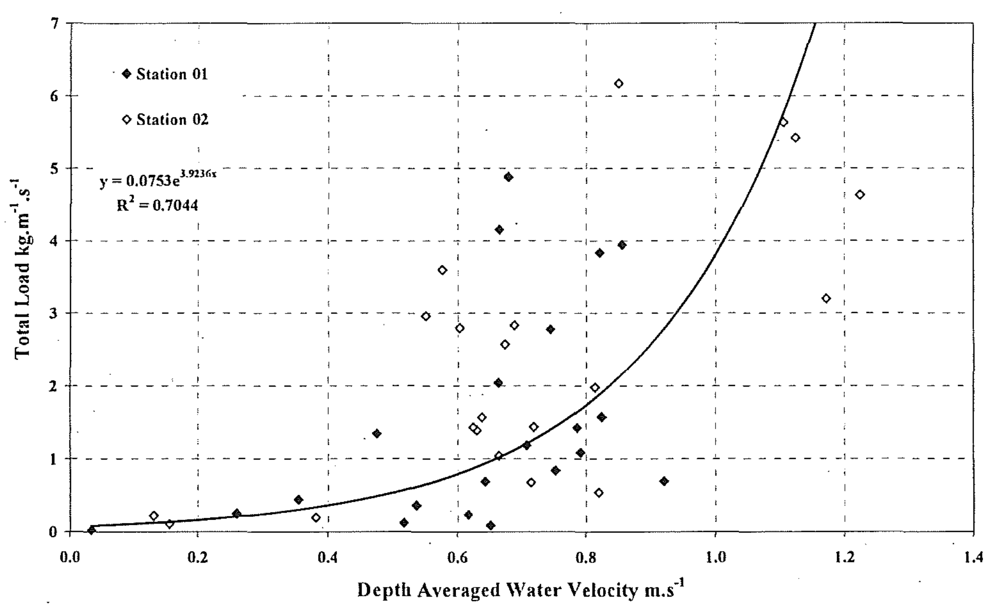


Figure 36: Total load versus depth averaged water velocity for all measurements made at stations 1 and 2 during the ebb stage.

Group 2: station 3 (buoy 105 – Melsele) and station 4 (Antwerpen – Steen)

The second group includes station 3 (buoy 105 – Melsele) and station 4 (Antwerpen – Steen). The highest values for the total load are about 5 kg m^{-1} s^{-1} and are obviously lower than the highest values around 6 kg m^{-1} s^{-1} observed at stations 1 and 2. The exponential increase is 2.16 times DAV and the total load at slack water is 0.23 kg m^{-1} s^{-1}. It can thus be observed that at the stations of group 2, between Zandvliet and Liefkenshoek, the total load at slack water is about 3 times higher than at the more downstream stations of group 1.

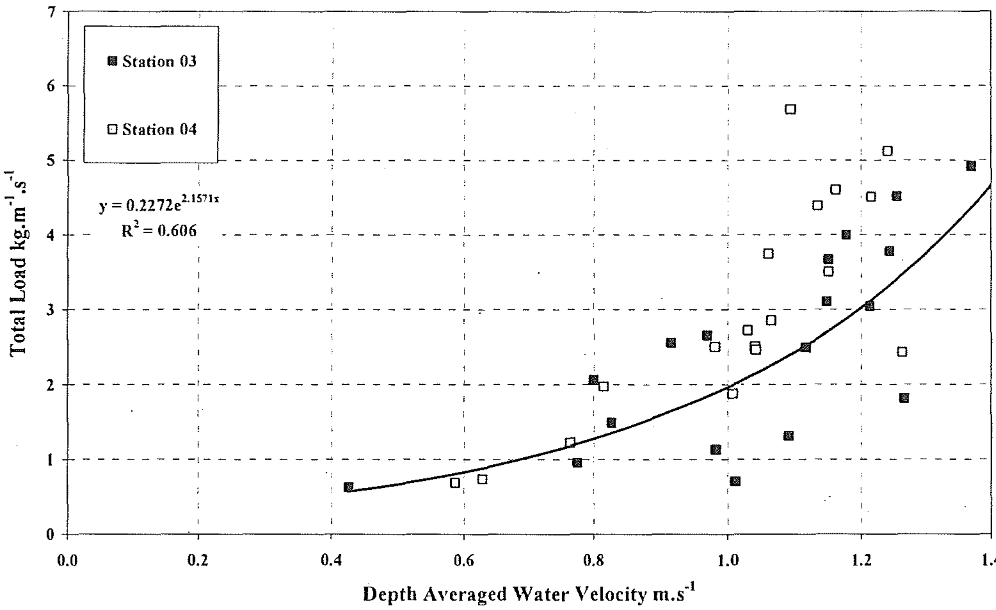


Figure 37: Total load versus depth averaged water velocity for all measurements made at station 3 and 4 during the ebb stage. In order to facilitate the comparison of the data of the four groups the co-ordinates have been kept constant for all groups.

Group 3: station 5 (Kruibeke – veer) to station 8 (Temse)

The third group includes the 4 stations between Kruibeke (station 5) and Temse (station 8). With the exception of two measurements showing values 3.31 and 4.85 kg m^{-1} s^{-1} the maximum load (3 kg m^{-1} s^{-1}) that is observed is lower than for the downstream stations of group 1 and 2. The SPM load at slack water is 0.13 kg m^{-1} s^{-1} and the exponential increase is 2.33 times DAV. Besides there is a very good agreement between these results and the results obtained from the complete tide measurements at Kruibeke showing a load at slack water of 0.13 kg m^{-1} s^{-1} and an exponential increase of 2.67 times DAV.

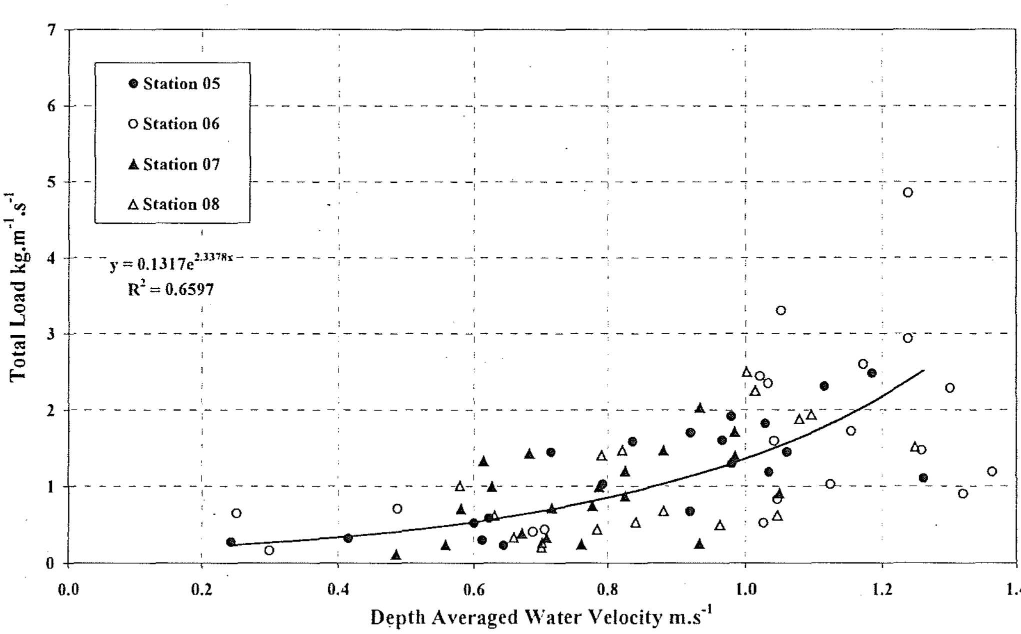


Figure 38: Total load versus depth averaged water velocity for all measurements made at stations 5 to 8 during the ebb stage. In order to facilitate the comparison of the data of the four groups the co-ordinates have been kept constant for all groups.

Group 4: station 9 (Mariekerke -veer) to station 16 (Melle - baanbrug)
The fourth group includes all the stations between Mariekerke (station 9) and Melle (station 16) and thus roughly covers the fresh water part of the estuary. From figure 39 it is obvious that the total load for the stations of this group is lower than for any of the stations of the previous groups. Because of this low value the deviation is rather large and consequently the determination coefficient is very low. Only at stations 10 to 13 the total load exceeds 1.5 kg m^{-1} s^{-1} and even this is still much lower than the high values observed in the downstream stations. The average load at slack water is 0.27 kg m^{-1} s^{-1} is higher than for the stations of group 3 (0.13 kg m^{-1} s^{-1}).

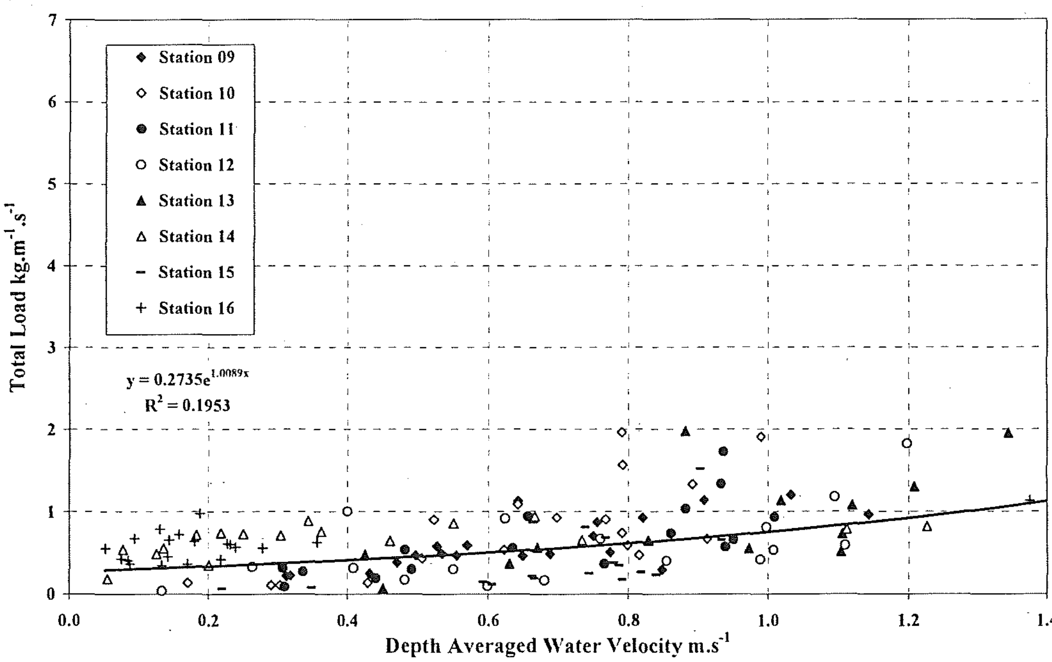


Figure 39: Total load versus depth averaged water velocity for all measurements made at stations 9 to 16 during the ebb stage. In order to facilitate the comparison of the data of the four groups the co-ordinates have been kept constant for all groups.

Measurements during the flood stage

Group 1: Station 1 (buoy 87 - Zandvliet) and station 2 (buoy 92 - Liefkenshoek)
The measurements during the flood stage at stations 1 and 2 are far incomplete in comparison with the data obtained during the ebb stage. There are no data available for depth averaged water velocities above 0.8 m s^{-1}. Nevertheless the exponential regression from the grouped data shows a good agreement with the data obtained during the ebb stage. The regression line obtained shows an exponential increase of 3.83 times DAV which is in good agreement with the exponential increase (3.9 times DAV) that was obtained from the grouped data for the ebb stage. However, the comparison with the flood stage of the full tide measurements near Zandvliet and in the Pas van Rilland (exponential increase is 3.14 times DAV) is less good.

At slack water ($x = 0$ and $e^{ax} = 1$) the total load (0.09 kg m^{-1} s^{-1}) is comparable to the total SPM load at slack water of ebb, but is higher than the value for the total SPM load observed at the flood stage of the complete tide measurements (0.07 kg $m^{-1}s^{-1}$) near the Belgian-Dutch border.

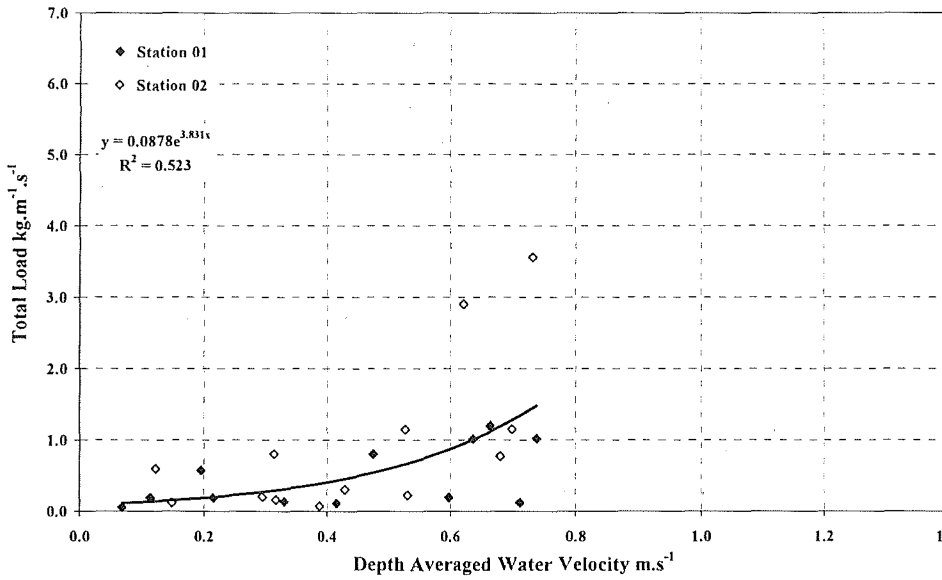


Figure 40: Total load versus depth averaged water velocity for all measurements made at stations 1 and 2 during the flood stage. In order to facilitate the comparison of the data of the four groups the co-ordinates have been kept constant for all groups.

Group 2: station 3 (buoy 105 – Melsele) and station 4 (Antwerpen – Steen)

The measurements during the flood stage at stations 3 and 4 are far incomplete in comparison with the data obtained during the ebb stage. There are no data available for depth averaged water velocities above 1 m s^{-1}. The exponential regression from the grouped data shows no agreement with the data obtained during the ebb stage. The regression line obtained shows an exponential increase of 3.62 times DAV which is different from the exponential increase (2.16 times DAV) that was obtained from the grouped data for the ebb stage. However, it is similar to the flood stage of the full tide measurements downstream near Zandvliet and in the Pas van Rilland (exponential increase is 3.5 times DAV).

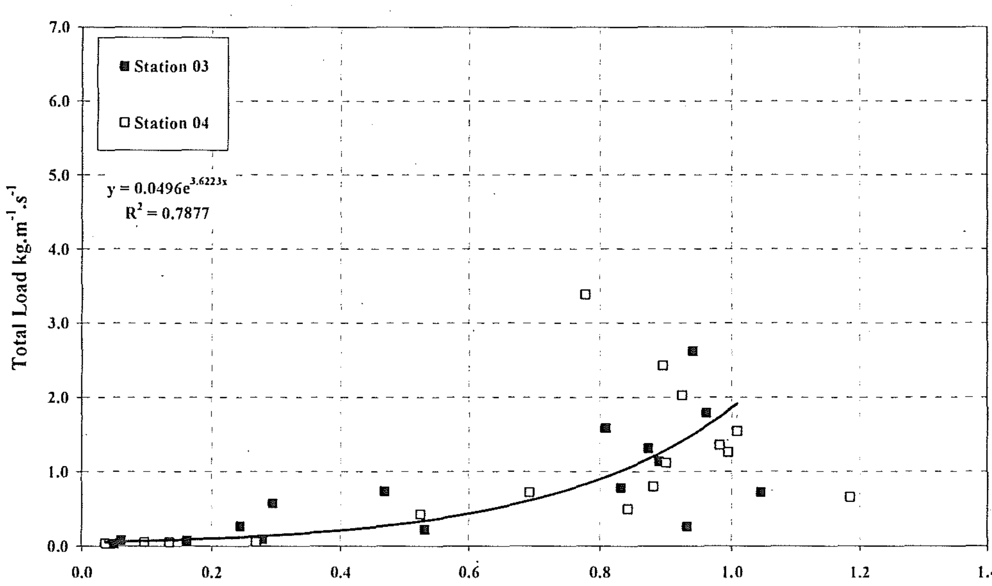


Figure 41: Total load versus depth averaged water velocity for all measurements made at stations 3 and 4 during the flood stage. In order to facilitate the comparison of the data of the four groups the co-ordinates have been kept constant for all groups.

The total load obtained for slack water (x = 0 and $e^{ax} = 1$) (0.05 kg m^{-1} s^{-1}) is much lower than to the total load obtained at slack water of ebb (0.23 kg m^{-1} s^{-1}).

Group 3: station 5 (Kruibeke – veer) to station 8 (Temse)
The third group includes 4 stations between Kruibeke (station 5) and Temse (station 8). Unlike the data of the previous stations the measurements during flood stage cover a wide range of depth averaged water velocities. The observed maximum SPM load (close to 3 kg m^{-1} s^{-1}) is comparable to the maximum load observed at the downstream stations. The exponential increase (1.97 times DAV) however is lower than the exponential increase observed at the downstream stations (3.8 times DAV).

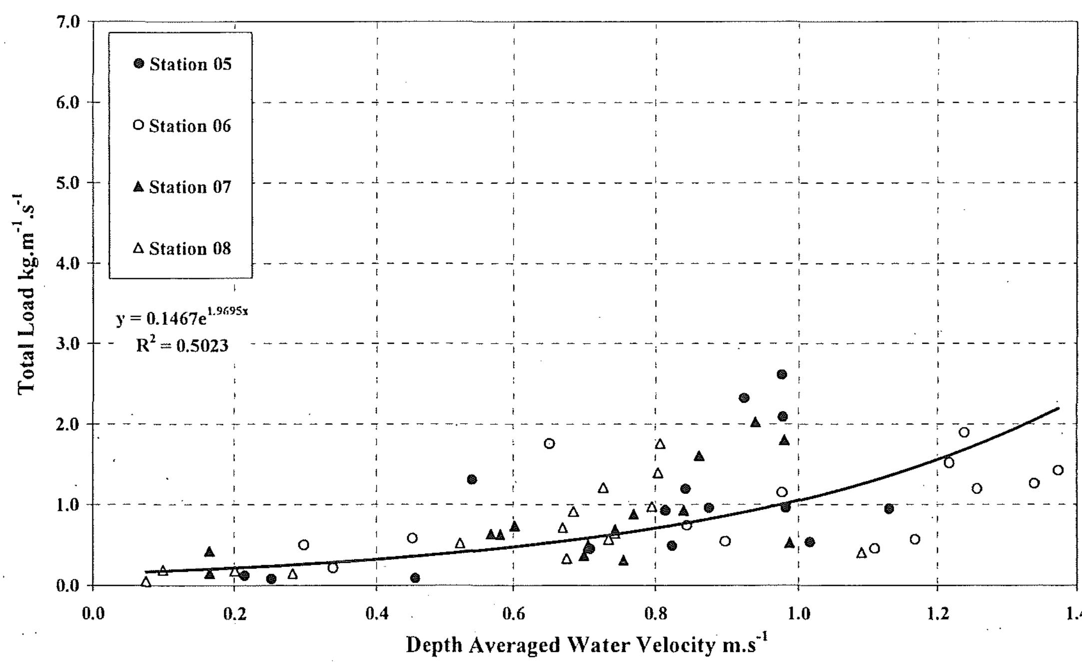


Figure 42: Total load versus depth averaged water velocity for all measurements made at stations 5 to 8 during the flood stage. In order to facilitate the comparison of the data of the four groups the co-ordinates have been kept constant for all groups.

Furthermore the results obtained here deviate from the results obtained during flood of the complete tide measurements at Kruibeke showing a SPM load at slack water of 0.098 kg m^{-1} s^{-1} and an exponential increase of 2.47 times DAV.

Group 4: station 9 (Mariekerke -veer) to station 16 (Melle - baanbrug)
The fourth group includes all stations between Mariekerke (station 9) and Melle (station 16). It is obvious that the total SPM load for the stations of this group is much lower than for any of the stations of the previous groups. Because of this low value the deviation is rather large and consequently the determination coefficient is very low. The total SPM load seldom exceeds 1.5 kg m^{-1} s^{-1} and is much lower than the high values observed in the downstream stations. The average SPM load at slack water is 0.29 kg m^{-1} s^{-1} which is higher than for the stations of group 3 (0.15 kg m^{-1} s^{-1}). The exponential increase is almost equal to the DAV (0.93 times DAV).

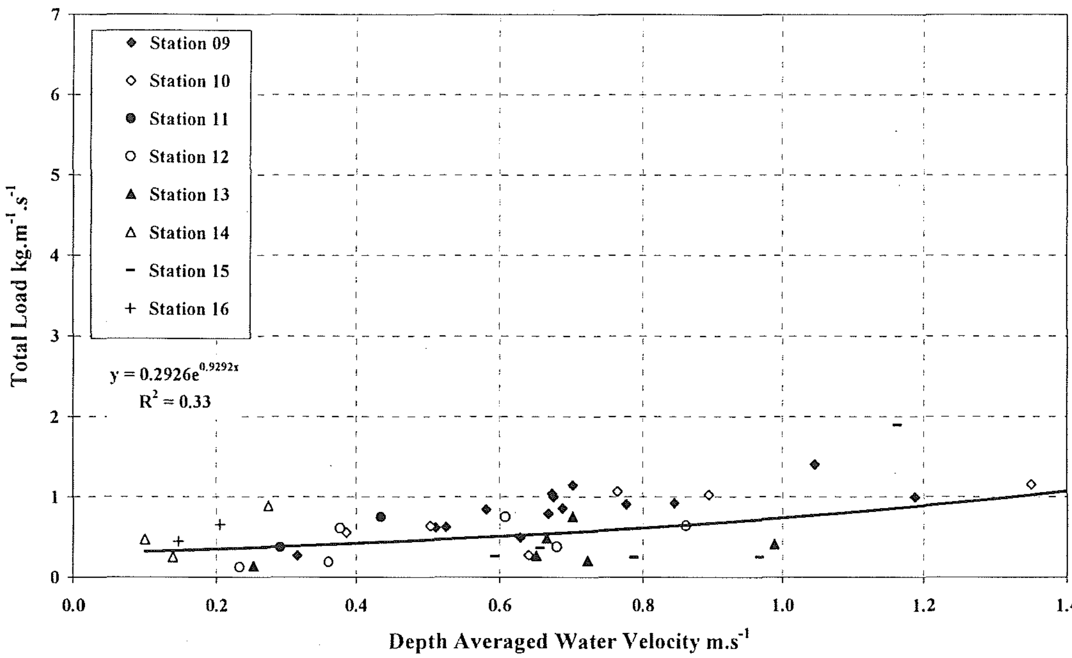


Figure 43: Total load versus depth averaged water velocity for all measurements made at stations 9 to 16 during the flood stage. In order to facilitate the comparison of the data of the four groups the co-ordinates have been kept constant for all groups.

5.6. Physical properties of suspended sediments

The sediment fraction of the suspended particulate matter has been analysed for all three sites where full tide measurements were performed: Lippenbroek, Kruibeke and Pas van Rilland.

Table 13: Suspended sediment samples. "Bottom" indicates samples taken in the near-bottom water at 90% of the total water depth. "Surface" stands for samples taken in the near-surface water at 10% of the total water depth.

Sample #	Locality	Tide	Depth	From hh:mm	To hh:mm	Loss %
04B01S	Lippenbroek	flood	bottom	09:40	12:30	28
04B02S	Lippenbroek	flood	surface	13:40	14:30	32
04B03S	Lippenbroek	ebb	surface	15:00	17:00	28
04B04S	Lippenbroek	ebb	bottom	18:00	19:00	26
04B05S	Kruibeke	flood	surface	10:00	11:00	29
04B06S	Kruibeke	flood	bottom	12:30	13:30	25
04B07S	Kruibeke	ebb	surface	15:20	16:30	27
04B08S	Kruibeke	ebb	bottom	17:10	18:30	25
04B09S	Pas van Rilland	flood	surface	09:13	11:04	30
04B10S	Pas van Rilland	flood	bottom	12:00	13:00	31
04B11S	Pas van Rilland	ebb	surface	15:24	17:00	-
04B12S	Pas van Rilland	ebb	bottom	17:26	19:00	31

Table 14: Grain-size properties of suspended sediment samples. The results obtained for sample 04B11S were not reliable because of the small sample size.

Sample #	Mean µm	C µm	Sand %	Silt %	Clay % <2	silt/clay
04B01S	1.11	104	3	51	46	1.1
04B02S	0.25	74	2	22	76	0.3
04B03S	0.53	77	2	37	61	0.6
04B04S	1.01	135	12	34	54	0.6
04B05S	0.89	116	6	40	54	0.7
04B06S	1.50	141	15	37	48	0.8
04B07S	0.74	103	3	41	55	0.8
04B08S	1.52	143	17	35	49	0.7
04B09S	0.51	80	2	36	62	0.6
04B10S	1.48	129	6	47	46	1.0
04B11S	-	-	-	-	-	-
04B12S	0.72	203	5	37	58	0.6

The total loss on pre-treatment (table 13), mainly organic matter, varies around 30%. The sand fraction (table 14) is highest in near-bottom suspended matter at Kruibeke and in one case also in Lippenbroek. The other samples show a sand content between 2 and 6%. The clay content varies between 46 and 76%. No systematic trend is observed in clay content along the estuary. The high clay content of 76% in one sample collected at Lippenbroek corresponds to a very low silt content (22%) leading to a low silt to clay ratio of 0.3. The other samples show a clay ration of 0.6 to 1.1.

5.7. Physical properties of bottom sediments

Since resuspension of bottom sediments is a well recognised process, it is important to know the composition of the bottom sediments. The grain-size spectrum of bottom sediments for the station Lippenbroek was analysed. In total 8 samples were taken at respectively at the right (samples 04B01 to 04B04) and left (samples 04B05 to 04B08) sides of the river main channel in front of the outflow of the Lippenbroek Polder.

Table 15: Sample description of Lippenbroek bottom samples

Sample #	Sediment description	Time hh:mm	Water depth m	Easting m	Northing m	Loss %
04B01	mud	13:16	5.25	582767.8	5660494.0	14
04B02	coarse sand	13:19	5.56	582750.7	5660460.8	13
04B03	coarse sand	13:21	5.52	582718.6	5660418.2	4
04B04	black mud	13:23	6.33	582665.9	5660367.6	17
04B05	mud, loose	13:27	6.44	582312.3	5660593.5	11
04B06	medium fine sand	13:31	7.22	582374.0	5660655.0	4
04B07	fine sand	13:33	4.70	582401.8	5660657.0	3
04B08	fine sand	13:37	3.59	582428.9	5660656.2	5

Table 16: Grain-size properties of lippenbroek bottom samples

Sample #	Mean µm	C µm	M µm	Gravel %	Sand %	Silt %	Clay %<2	Silt/clay
04B01	46	212	112	0.00	75	15	10	1.5
04B02	323	1168	375	0.00	97	1	2	0.5
04B03		900	200	0.09	87	12	1	12
04B04	3	206	6	0.00	21	40	39	1.02
04B05	56	316	126	0.00	80	11	9	1.2
04B06		340	220	0.00	94	2	4	0.5
04B07		275	170	0.00	94	3	3	1
04B08	103	364	166	0.00	91	3	6	0.5

Table 16 clearly illustrates the sandy nature of the bottom in front of Lippenbroek. Most samples show a sand content exceeding 75%. Only sample 04B04, right side of the river channel, has a very low sand content (21%) and about equally high silt and clay content. All other samples show clay content below 10%. The coarsest sand fraction is large and ranges between 206 and 1168 µm. These are the coarsest bottom sediments observed so far in the Schelde estuary. In the bottom the silt to clay ratio (mostly above 1) is higher than the silt to clay ratios (mostly below 1) of the suspended sediments. It follows that not only the bottom sediments are coarser but they also contain more silt than the sediments in the suspension.

5.8. Radio-nuclides in intertidal sediments

During the year 2004 three more cores from tidal marshes have been analysed: Konkelschoor, Paal and Paulinapolder. A complete discussion of all data and a final interpretation will be given in the next report.

5.8.1. Konkelschoor

A 0.9 m long core was collected on the tidal marsh Konkelschoor at the left bank of the river. The sediment is of a clayey-silt with very little sand. The clay fraction ranges from 13 to 28% and the sand fraction is mostly below 4% (S. Temmerman, 2003).

The ^{210}Pb distribution with depth does not follow the expected exponential decrease but instead shows the highest value (140 Bq kg-mud^{-1}) at approximately 0.9 m below the marsh surface. It decreases to 0.38 Bq kg-mud^{-1} in the uppermost layer of the core. The ^{226}Ra isotope shows one high values at 0.38 m below the surface. This peak coincides more or less with a ^{210}Pb peak.

Americium-241 shows a gradual increase from the surface to the bottom of the core.

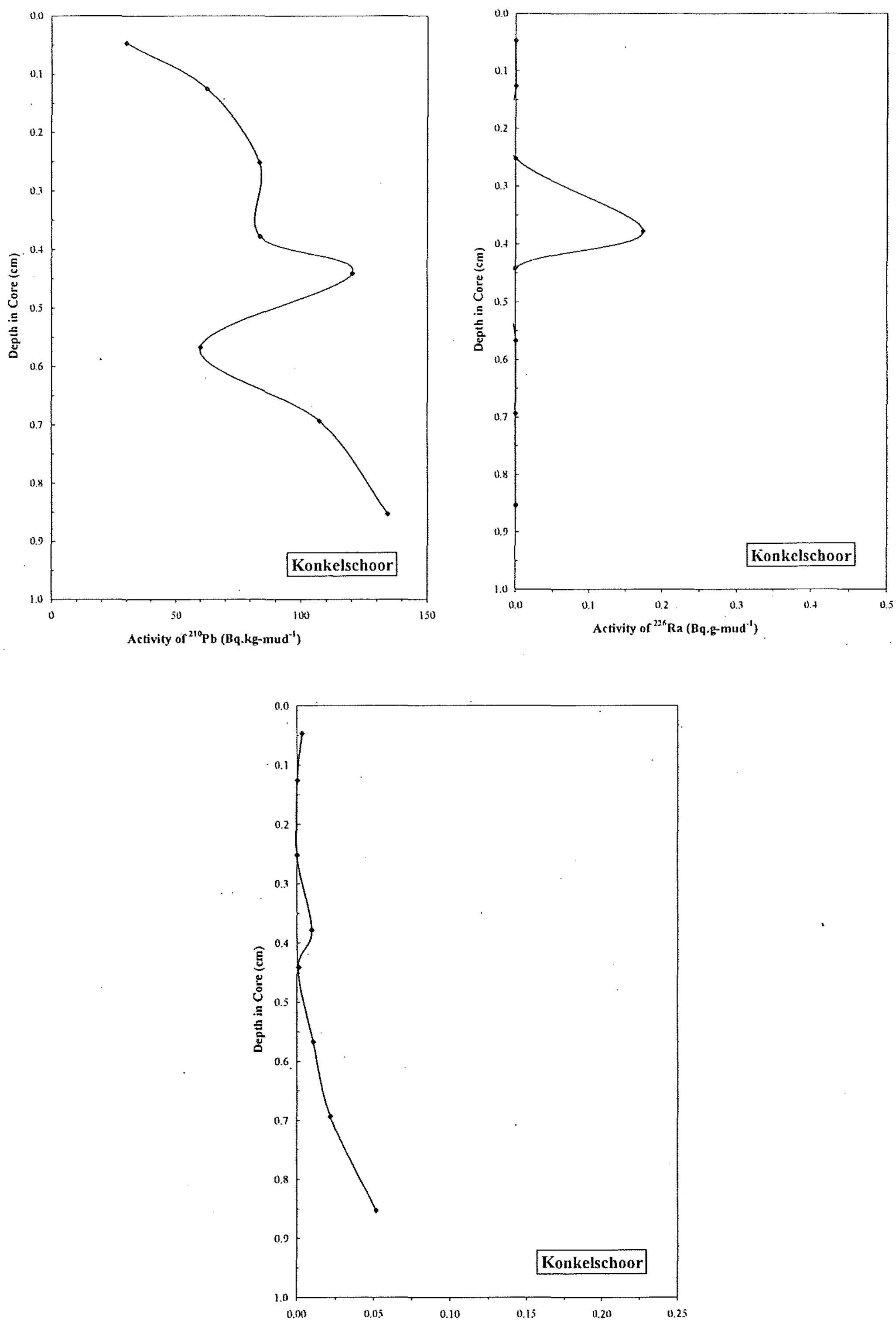
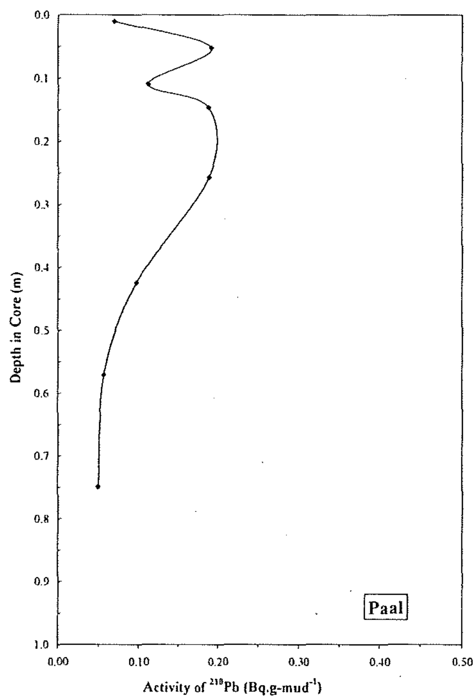
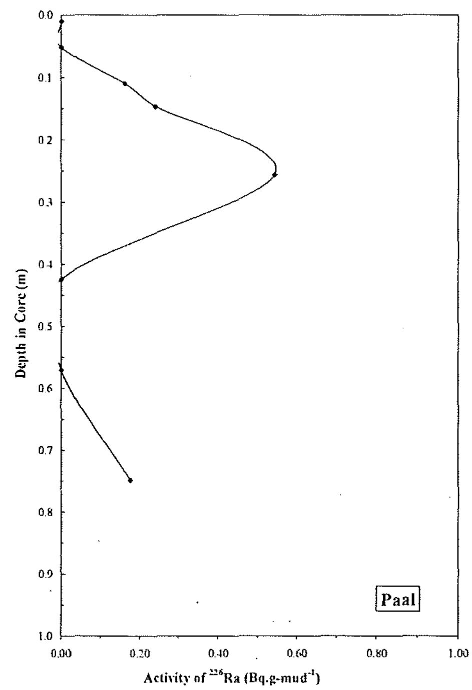


Figure 44: ^{210}Pb ^{226}Ra and ^{241}Am isotope analyses of marsh sediments – Konkelschoor

5.8.2. Paal

The core from Paal marsh was 0.8 m long. It consists of very fine sediment with mud content above 94 %. The sand content is below 2 % (S. Temmerman, 2003) and is lowest in the uppermost 15 cm. The ^{210}Pb profile shows an exponential decrease with depth from 0.2 m towards the base of the core. The upper part of the core shows a decrease of the ^{210}Pb activity toward the surface. Considering the lower part of the core an accumulation rate of 1.8 cm per year is found. The ^{226}Ra profile shows a high values at 0.6 m below the surface and at respectively 0.21 m and close to the surface. This profile is similar to the radium profile observed at the Schor van Branst (Wartel, S. and Chen, M.S. 2004). Americium-241 shows high values at in the uppermost 0.4 m of the core.





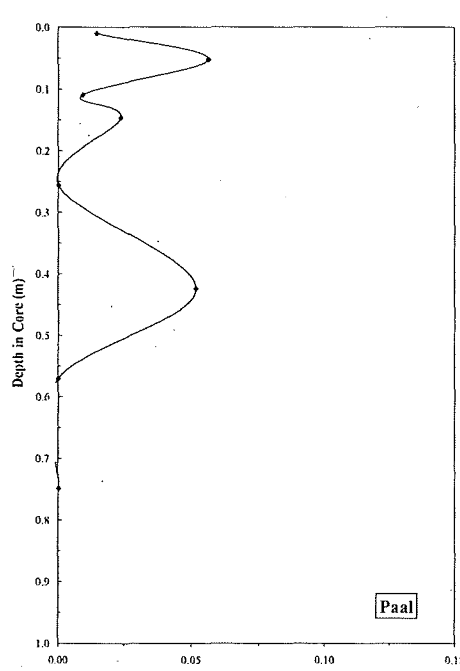


Figure 45: : ^{210}Pb ^{226}Ra and ^{241}Am isotope analyses of marsh sediments at Paal

5.8.3. Paulinapolder

The core from Paulinapolder marsh was approximately 0.6 m deep. It consists of very fine sediment with mud content above 95 %. Sand content is below 2 % being lowest (<1%) in the uppermost 10 cm of the core. In the lower 0.25 m of the core the sand contents exceeds 10 % (S. Temmerman, 2003).

The ^{210}Pb profile shows a similar shape as the core of Galgenschoor (Wartel, S. and Chen, M.S. 2004). Lead-210 decreases with depth from 0.25 m towards the base of the core. The upper part of the core shows a decrease of the ^{210}Pb activity toward the surface.

Considering the lower part of the core an accumulation rate of 1.06 cm per year is found. The ^{226}Ra profile shows a high values between 0.2 and 0.6 m below the surface.

Americium-241 shows high values at 0.6 m and in the uppermost 0.2 m of the core. The Americium profile is comparable to the Americium profile of the Schor van Branst (Wartel, S. and Chen, M.S. 2004).

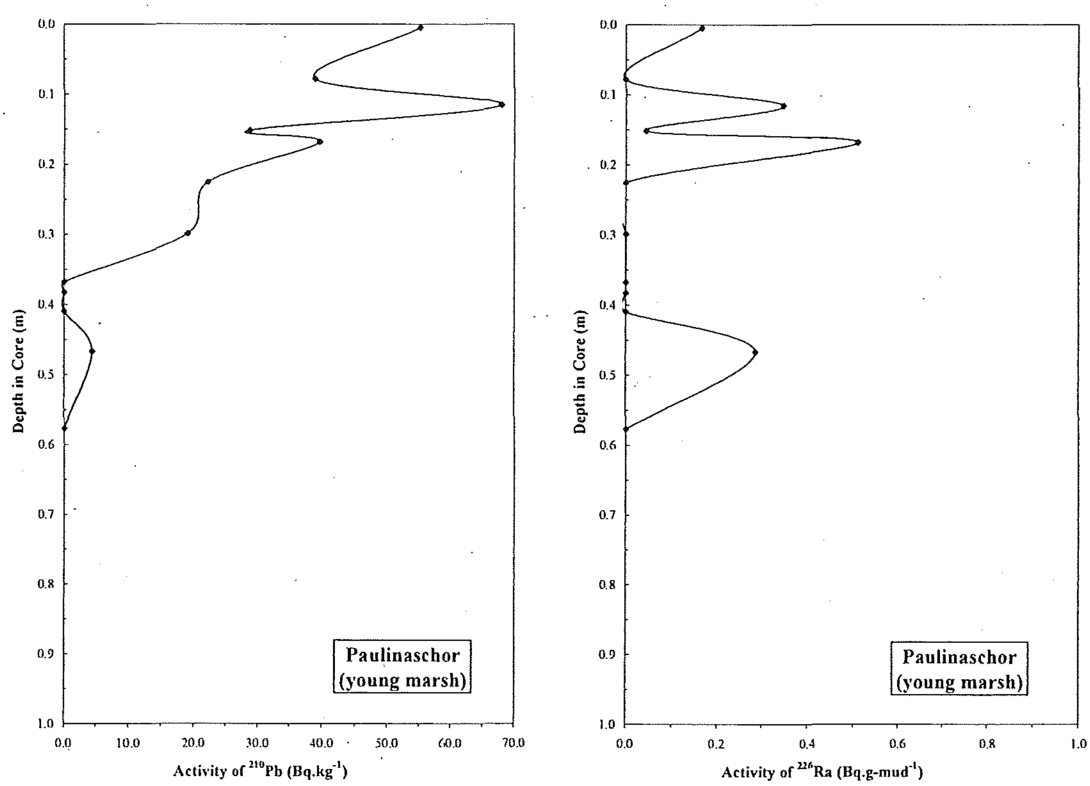


Figure 46: isotope analyses of marsh sediments – Kruispolderhaven

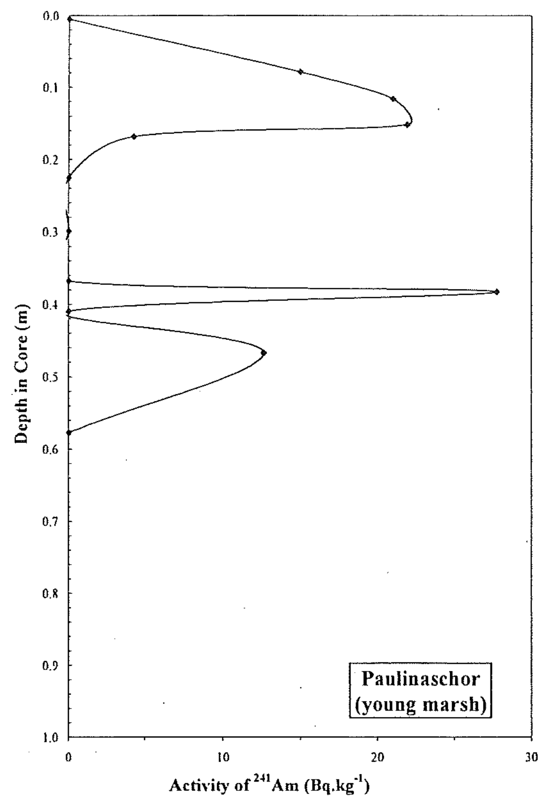


Figure 47 (cont.): isotope analyses of marsh sediments – Kruispolderhaven

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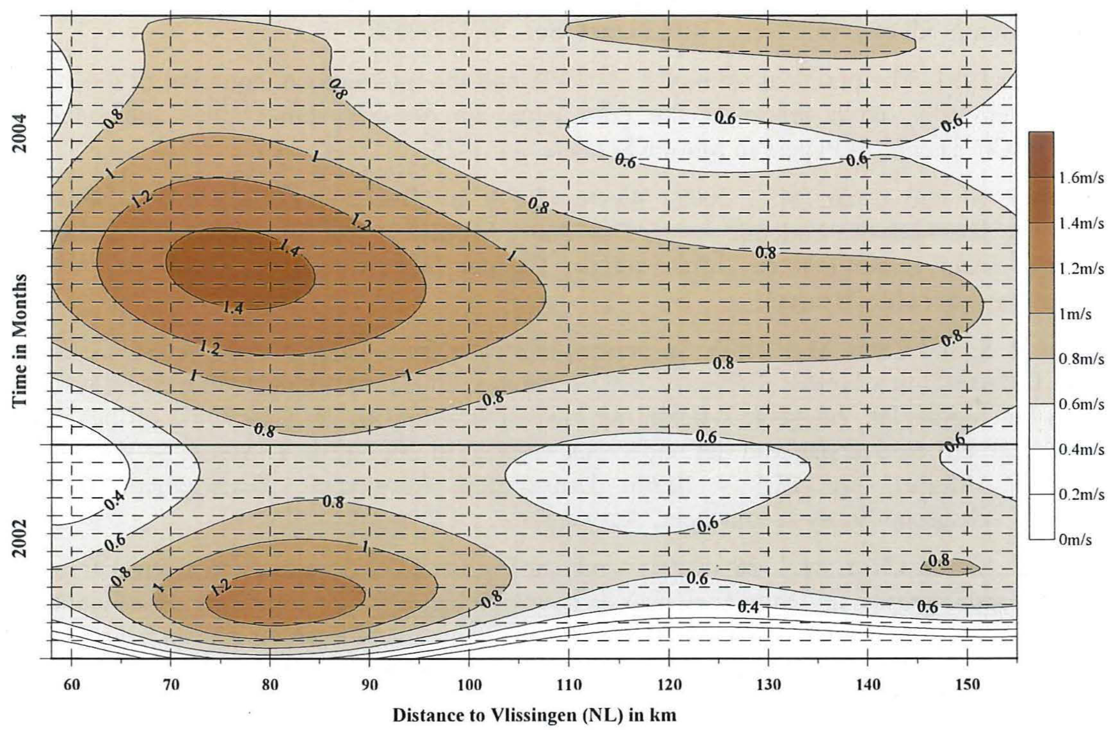
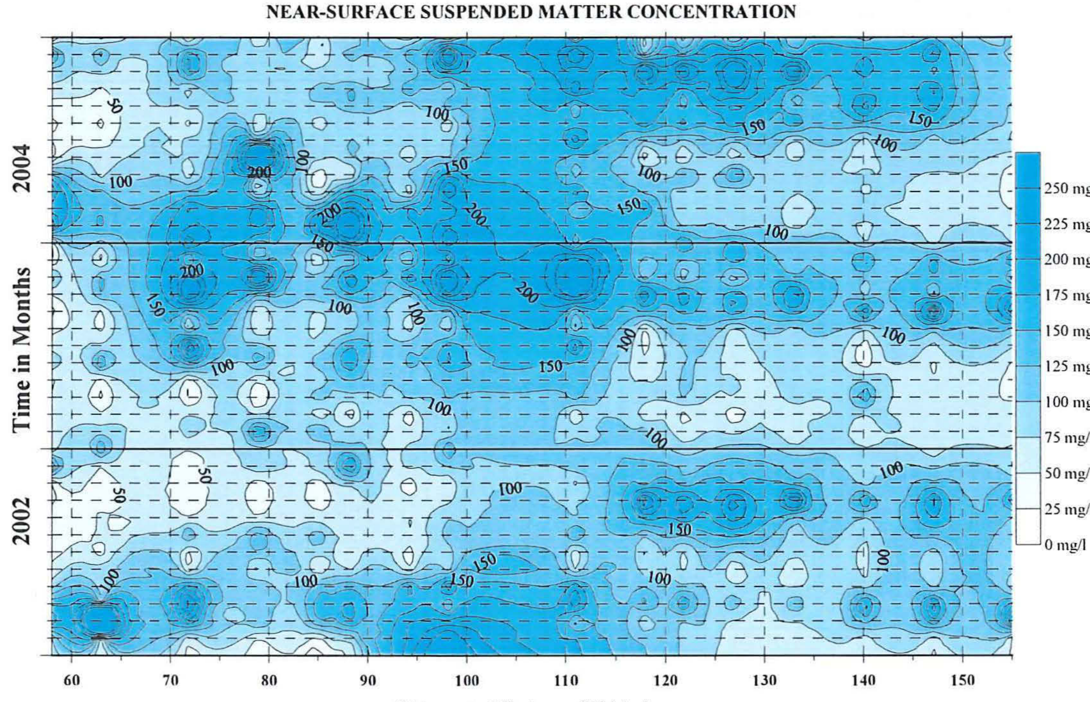
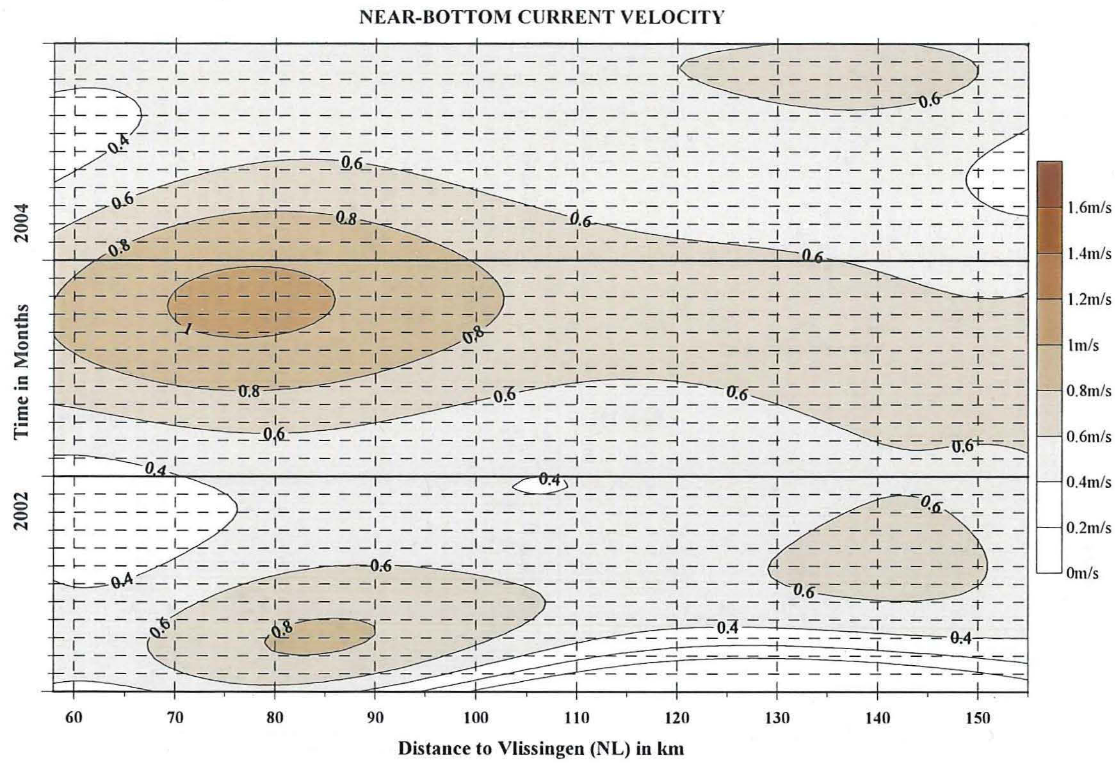
5.10. Annexe 1: Current velocity and suspended matter concentration

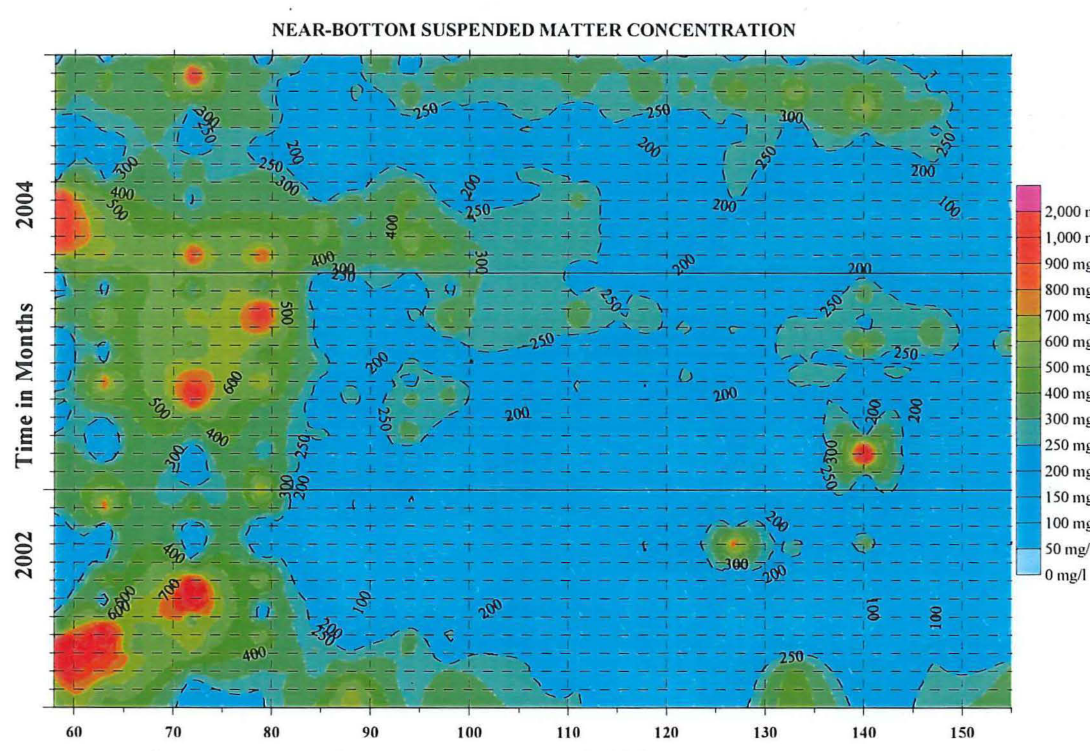
NEAR-SURFACE CURRENT VELOCITY

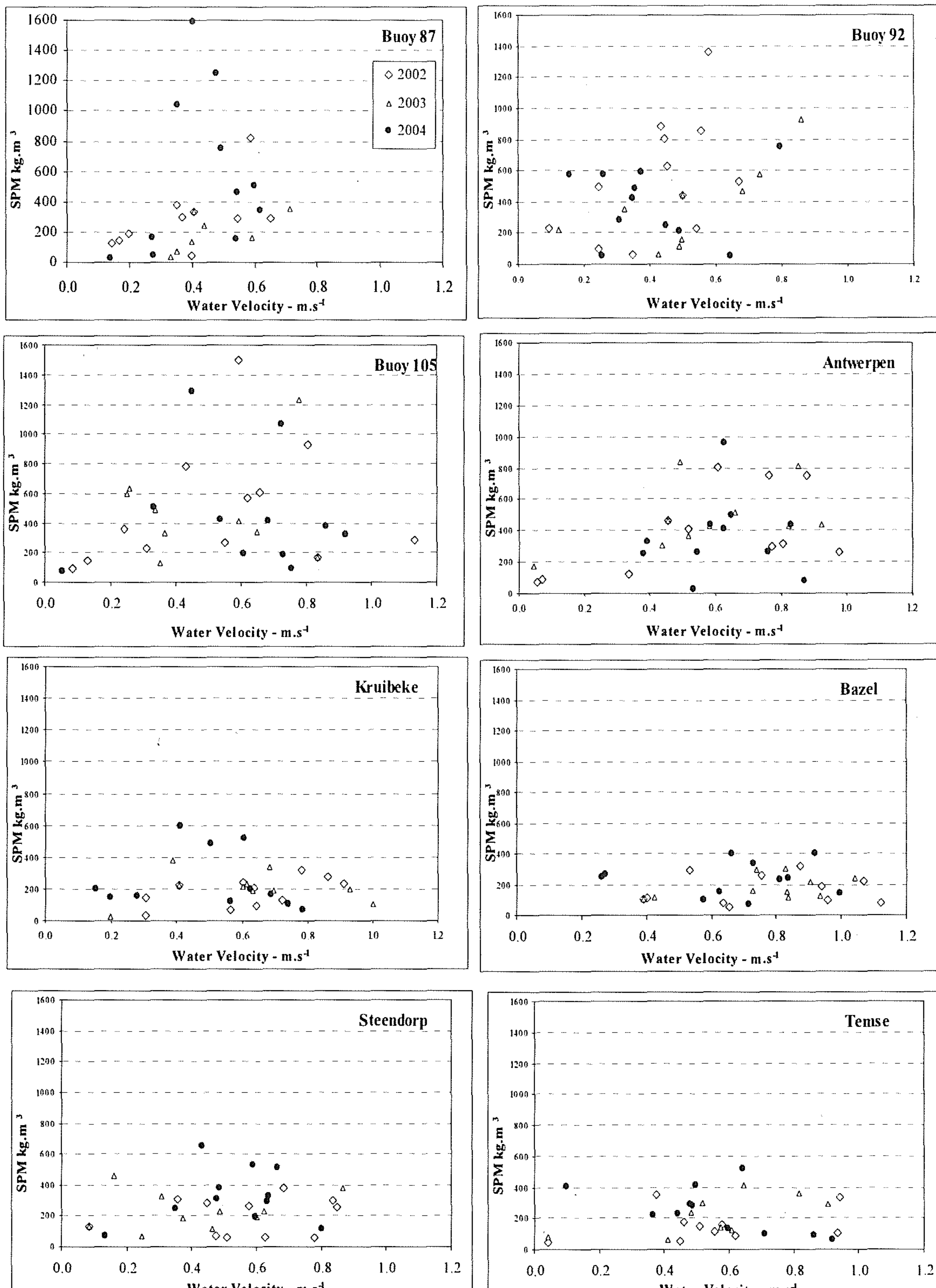


NEAR-SURFACE SUSPENDED MATTER CONCENTRATION

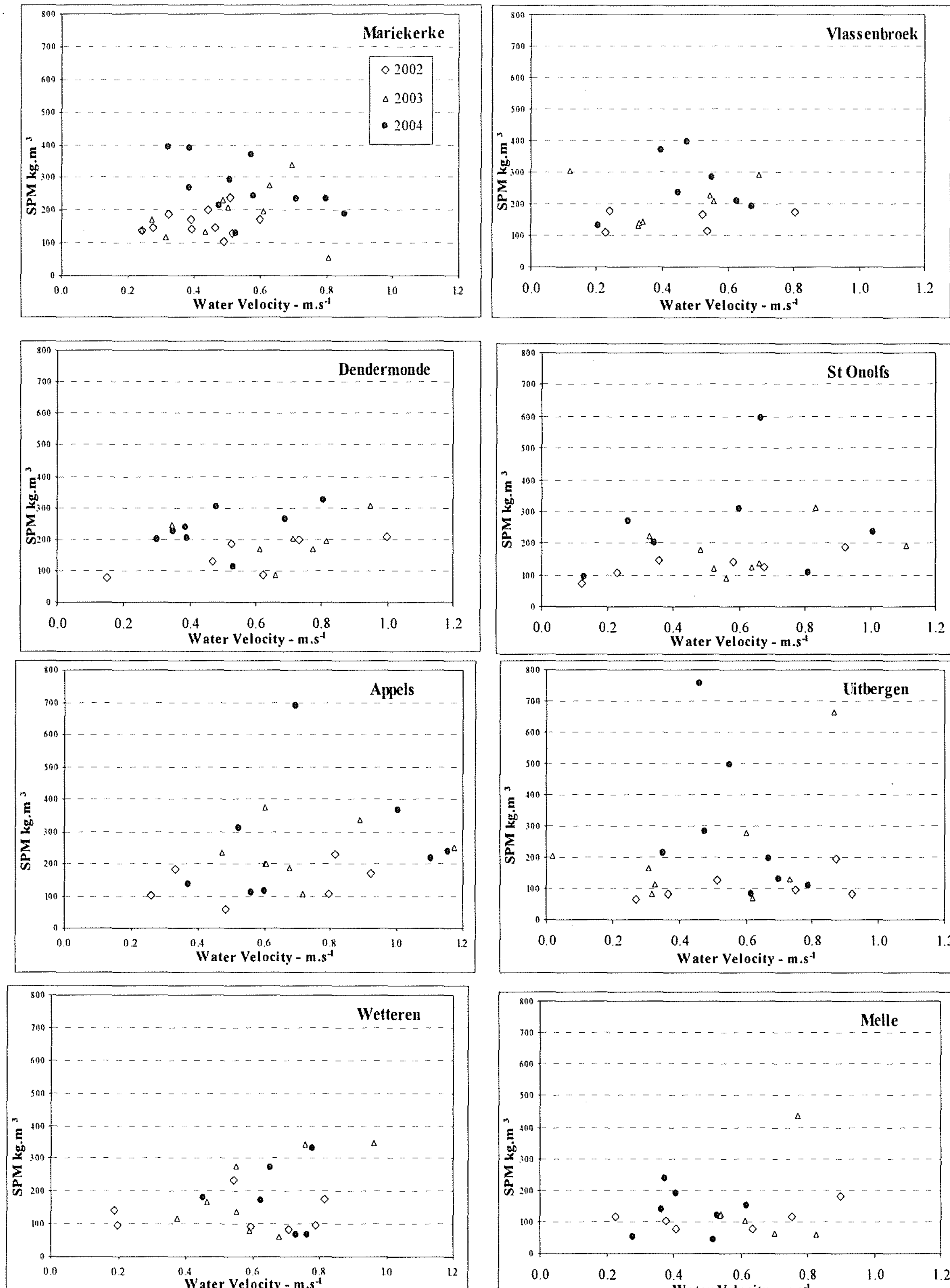



NEAR-BOTTOM CURRENT VELOCITY
Time in Months
2004
2002
Distance to Vlissingen (NL) in km
60
70
80
90
100
110
120
130
140
150
1.6m/s
1.4m/s
1.2m/s
1m/s
0.8m/s
0.6m/s
0.4m/s
0.2m/s
0m/s

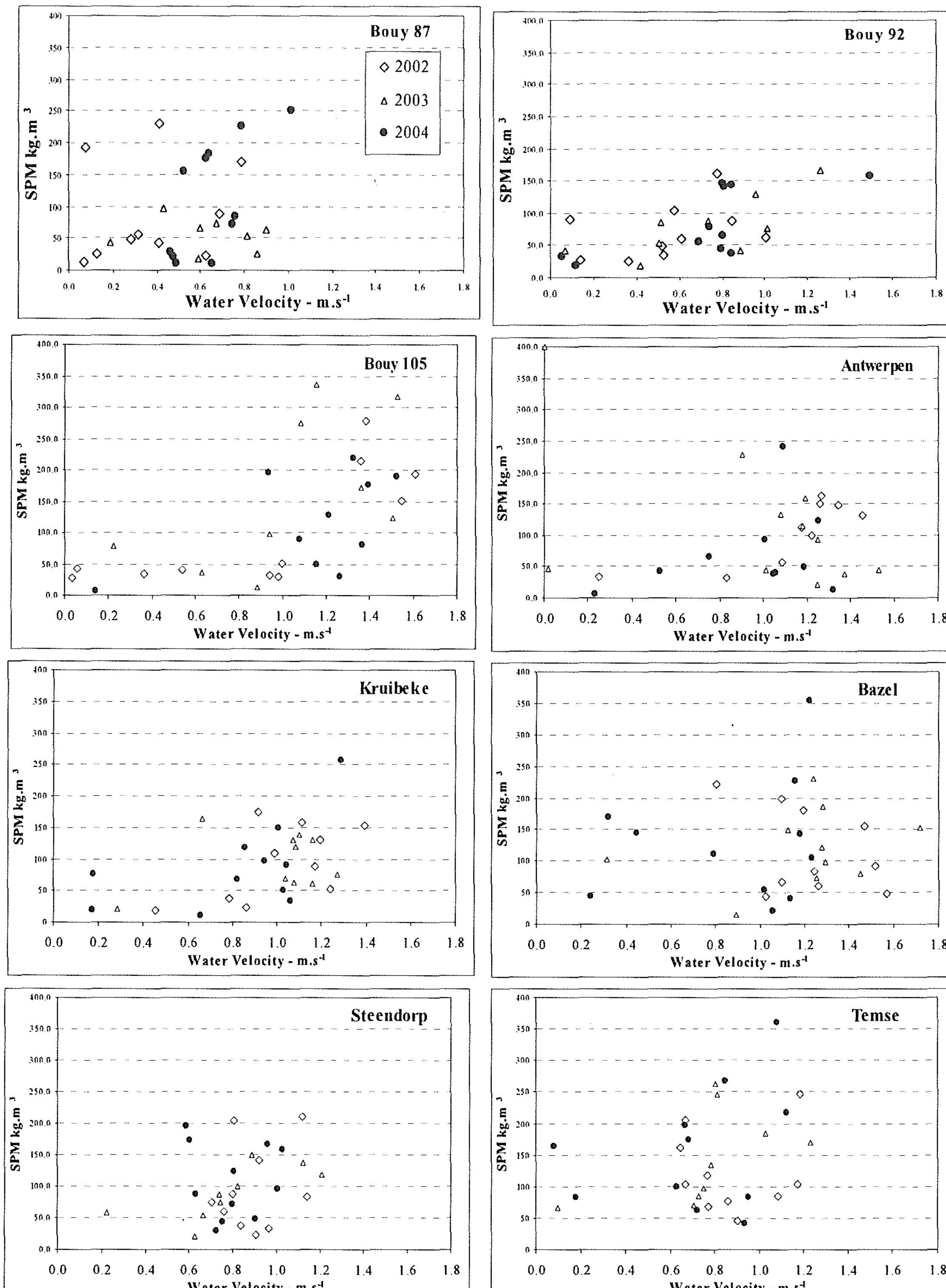

NEAR-BOTTOM SUSPENDED MATTER CONCENTRATION
Time in Months
2004
2002
Distance to Vlissingen (NL) in km
60
70
80
90
100
110
120
130
140
150
2,000 mg/l
1,000 mg/l
900 mg/l
800 mg/l
700 mg/l
600 mg/l
500 mg/l
400 mg/l
300 mg/l
250 mg/l
200 mg/l
150 mg/l
100 mg/l
50 mg/l
0 mg/l



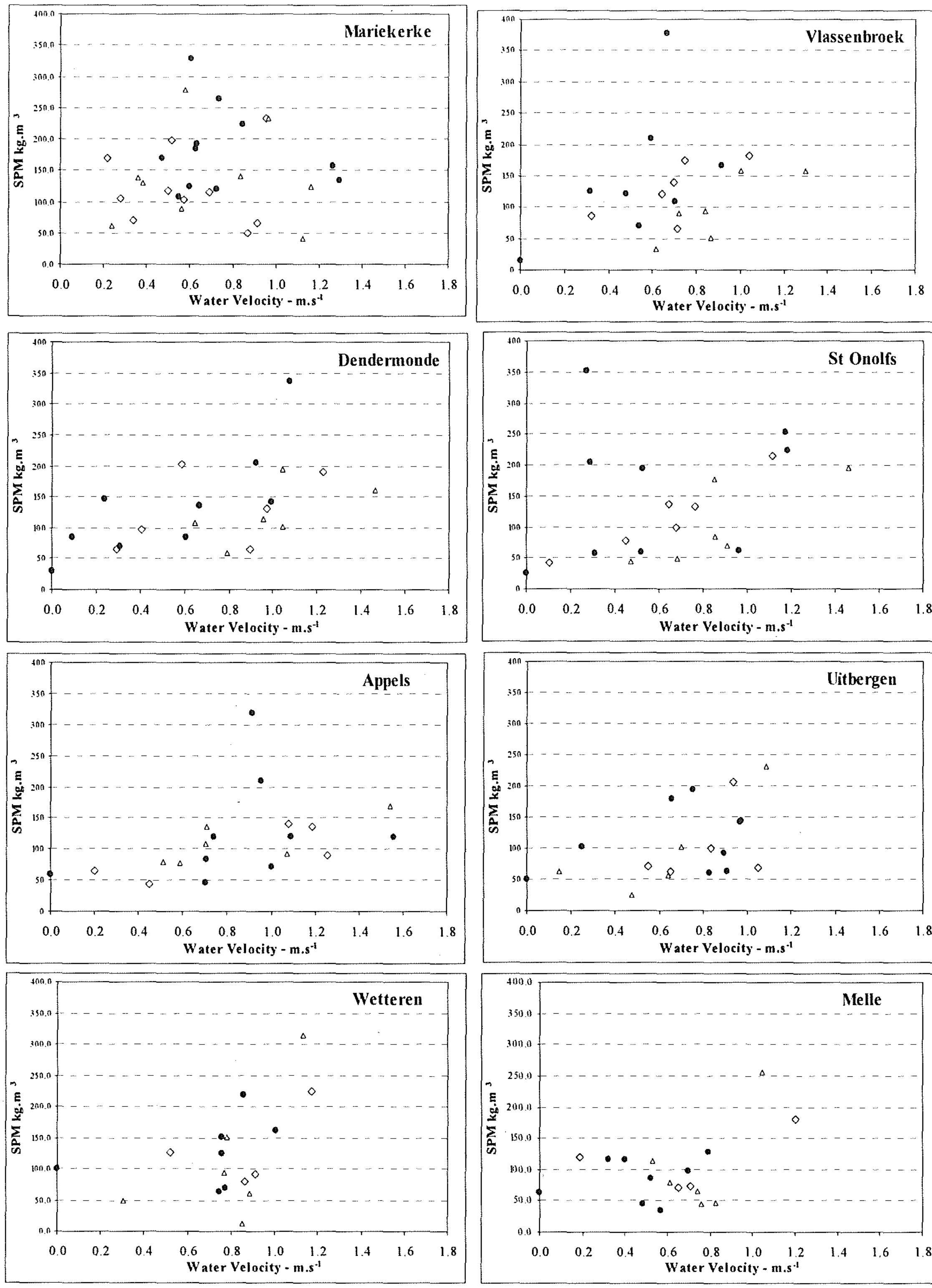
SPM (g m^{-3}) as a function of water velocity (m s^{-1}) for near-bottom sediments.



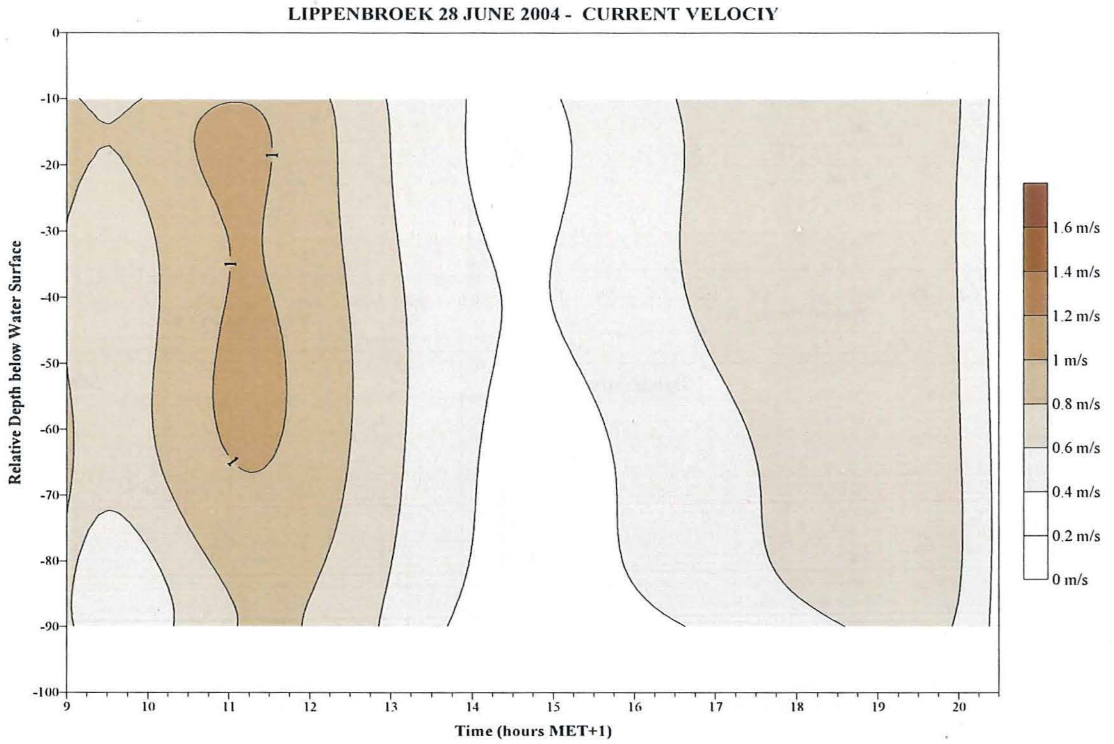
SPM (g m^{-3}) as a function of water velocity (m s^{-1}) for near-bottom sediments

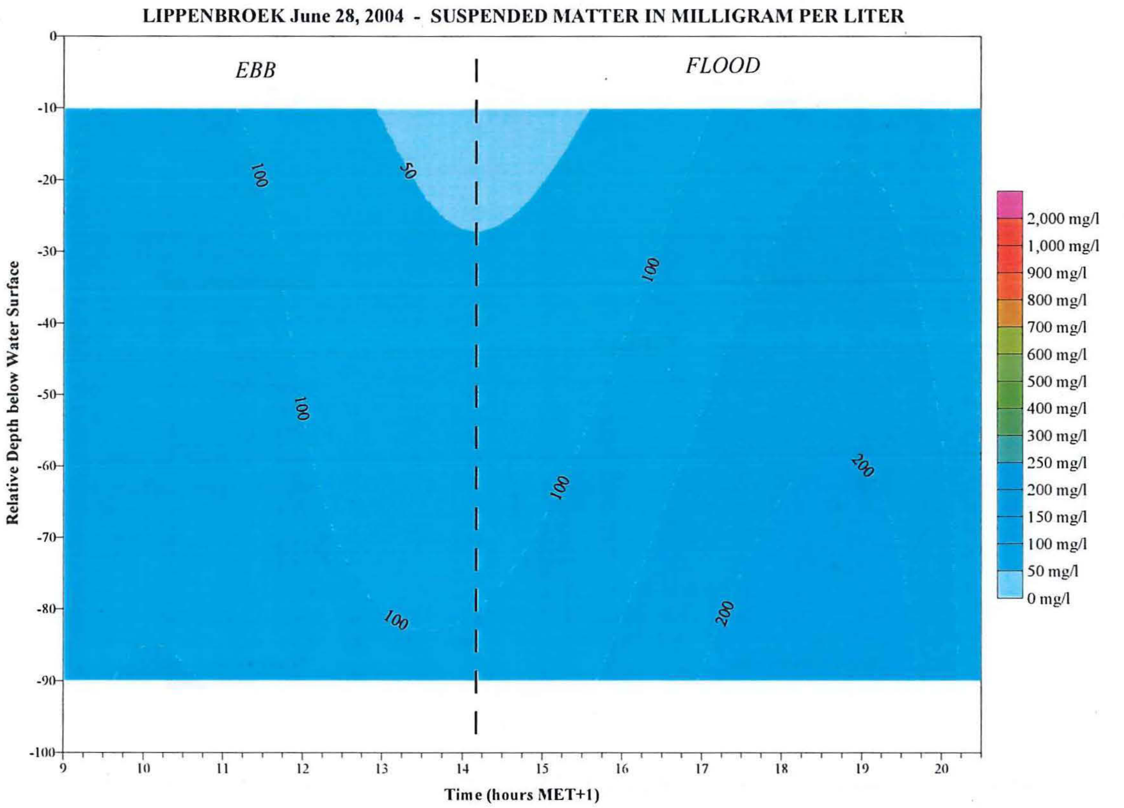


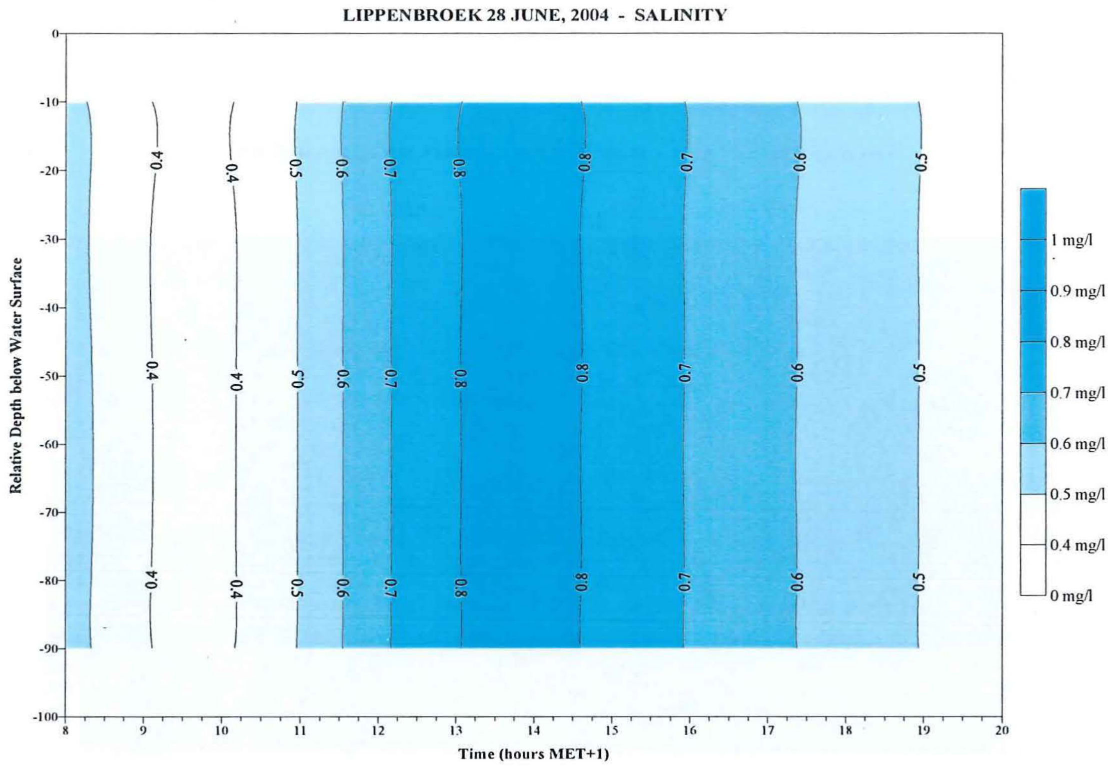
SPM (g m^{-3}) as a function of water velocity (m s^{-1}) for near-surface sediments

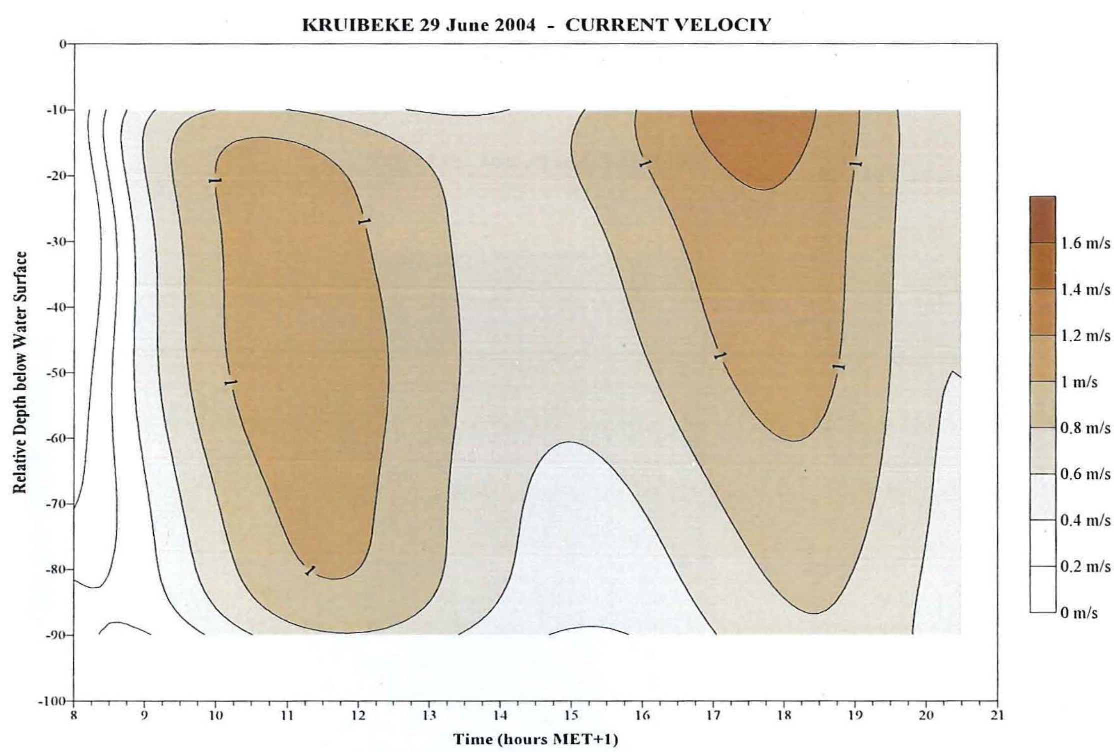


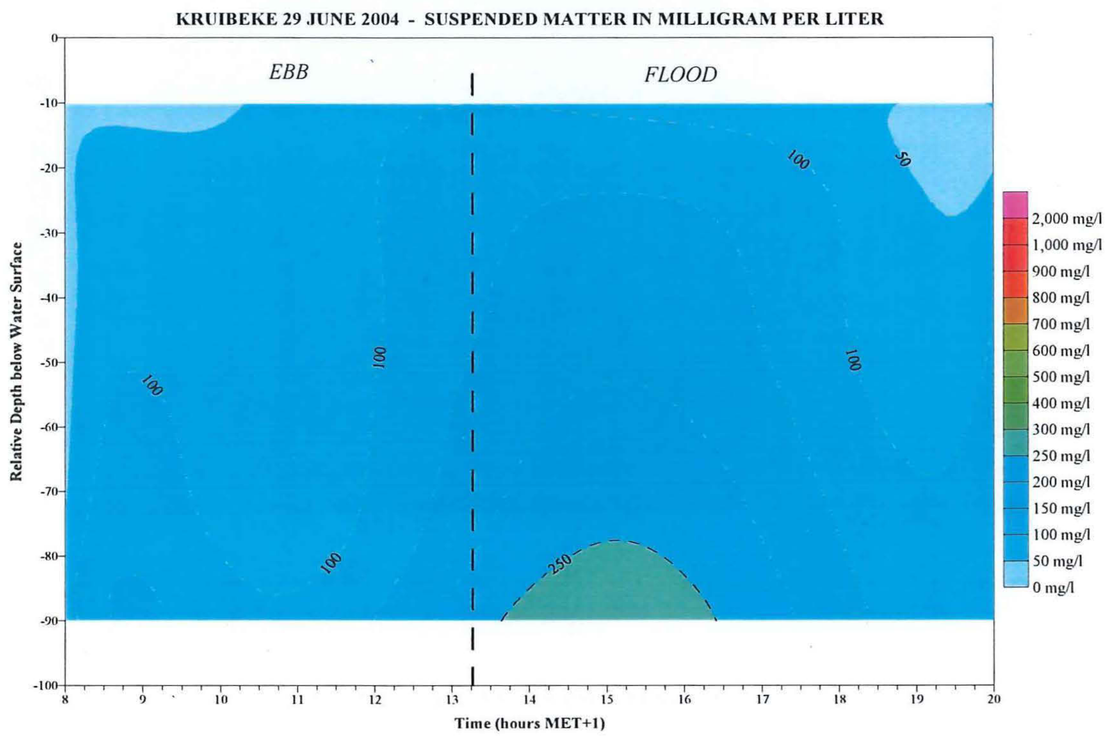
SPM (g m^{-3}) as a function of water velocity (m s^{-1}) for near-surface sediments

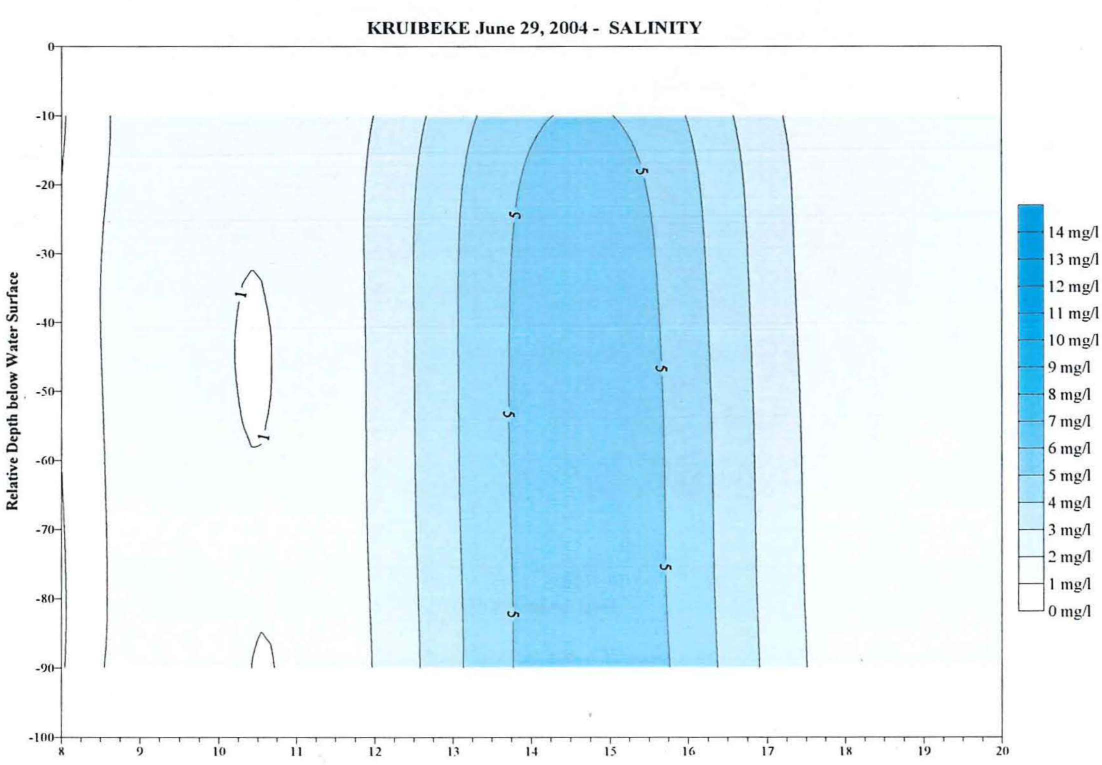

LIPPENBROEK 28 JUNE 2004 - CURRENT VELOCIY
Relative Depth below Water Surface
Time (hours MET+1)
1.6 m/s
1.4 m/s
1.2 m/s
1 m/s
0.8 m/s
0.6 m/s
0.4 m/s
0.2 m/s
0 m/s

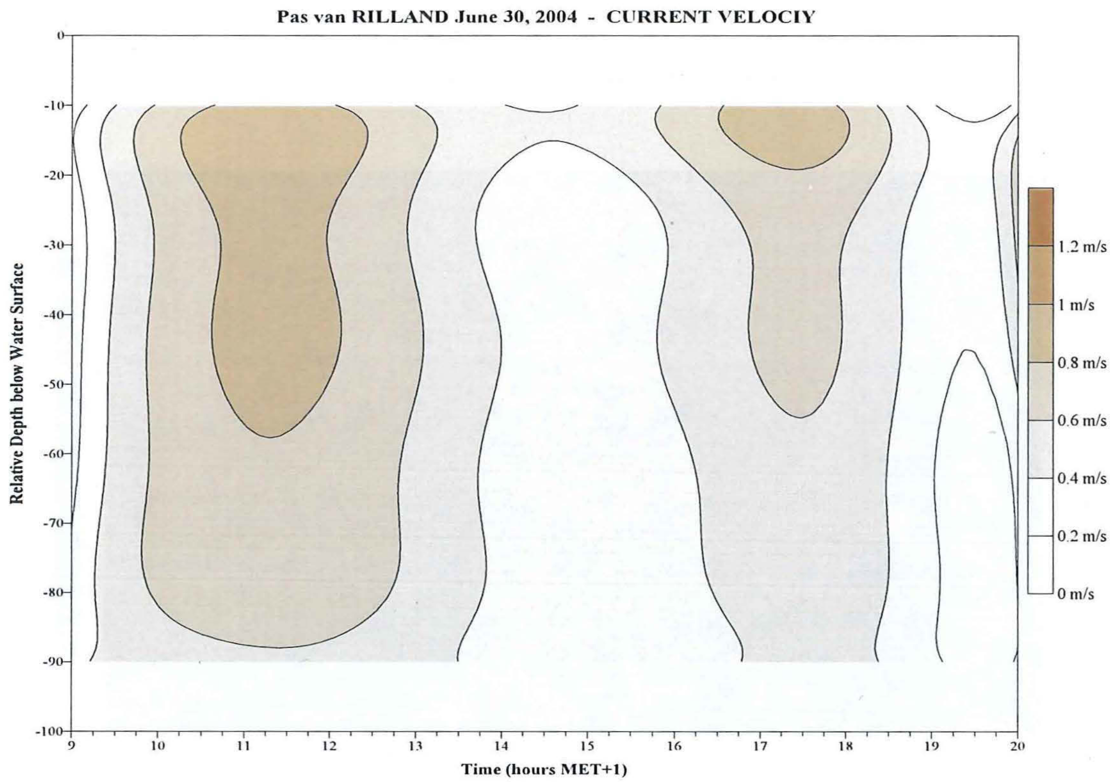

LIPPENBROEK June 28, 2004 - SUSPENDED MATTER IN MILLIGRAM PER LITER
EBB
FLOOD
Relative Depth below Water Surface
Time (hours MET+1)
2,000 mg/l
1,000 mg/l
900 mg/l
800 mg/l
700 mg/l
600 mg/l
500 mg/l
400 mg/l
300 mg/l
250 mg/l
200 mg/l
150 mg/l
100 mg/l
50 mg/l
0 mg/l

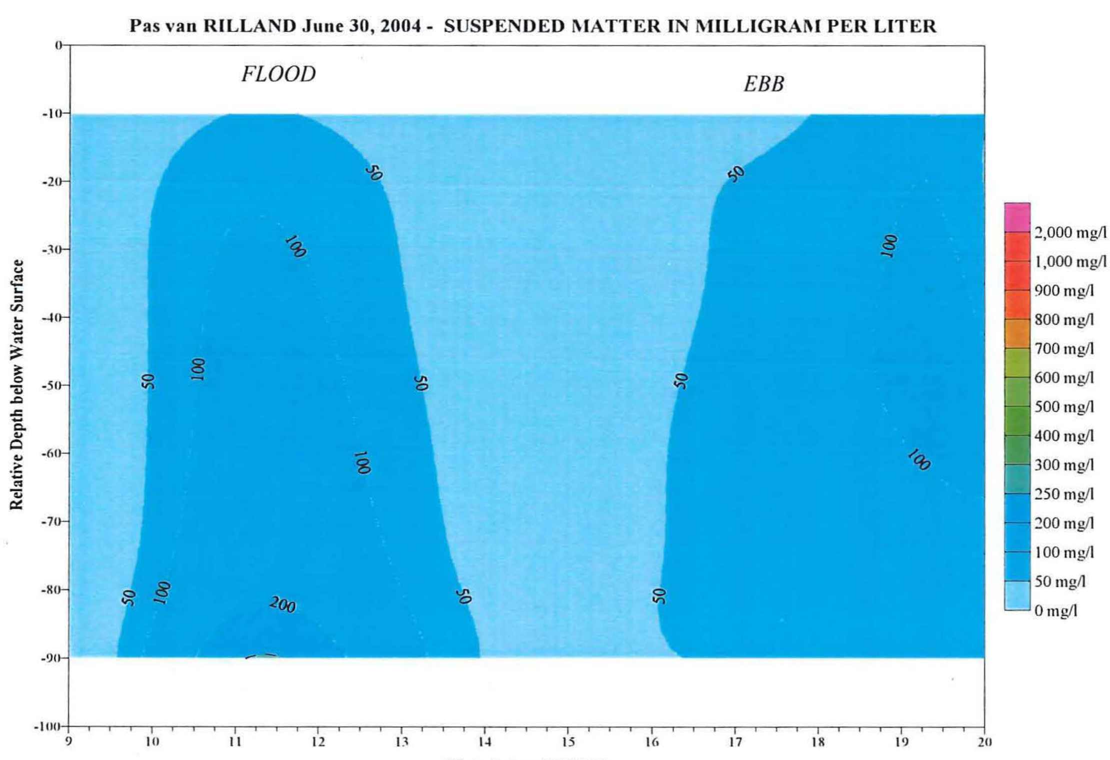

LIPPENBROEK 28 JUNE, 2004 - SALINITY
Relative Depth below Water Surface
Time (hours MET+1)
1 mg/l
0.9 mg/l
0.8 mg/l
0.7 mg/l
0.6 mg/l
0.5 mg/l
0.4 mg/l
0 mg/l

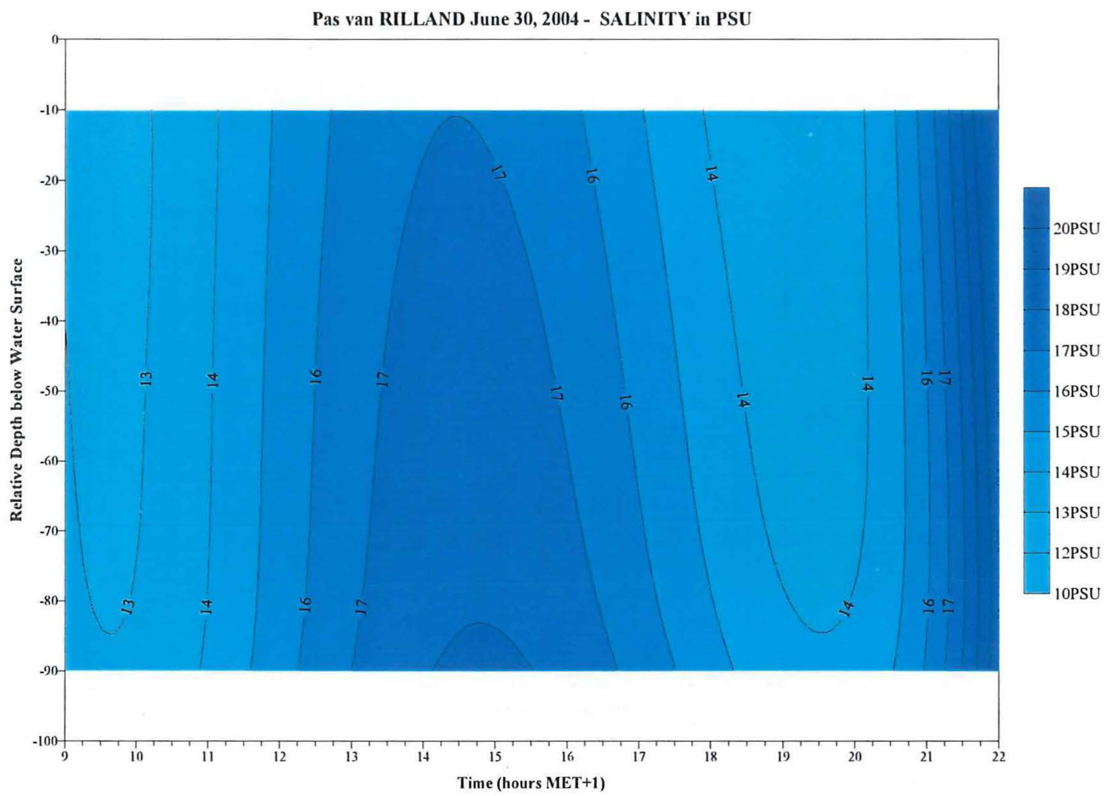

KRUIBEKE 29 June 2004 - CURRENT VELOCIY
Relative Depth below Water Surface
Time (hours MET+1)
1.6 m/s
1.4 m/s
1.2 m/s
1 m/s
0.8 m/s
0.6 m/s
0.4 m/s
0.2 m/s
0 m/s


KRUIBEKE 29 JUNE 2004 - SUSPENDED MATTER IN MILLIGRAM PER LITER
EBB
FLOOD
100
50
250
2,000 mg/l
1,000 mg/l
900 mg/l
800 mg/l
700 mg/l
600 mg/l
500 mg/l
400 mg/l
300 mg/l
250 mg/l
200 mg/l
150 mg/l
100 mg/l
50 mg/l
0 mg/l
Relative Depth below Water Surface
Time (hours MET+1)


KRUIBEKE June 29, 2004 - SALINITY
1
5
14 mg/l
13 mg/l
12 mg/l
11 mg/l
10 mg/l
9 mg/l
8 mg/l
7 mg/l
6 mg/l
5 mg/l
4 mg/l
3 mg/l
2 mg/l
1 mg/l
0 mg/l
Relative Depth below Water Surface
Time (hours MET+1)


Pas van RILLAND June 30, 2004 - CURRENT VELOCIY
Relative Depth below Water Surface
Time (hours MET+1)
1.2 m/s
1 m/s
0.8 m/s
0.6 m/s
0.4 m/s
0.2 m/s
0 m/s


Pas van RILLAND June 30, 2004 - SUSPENDED MATTER IN MILLIGRAM PER LITER
FLOOD
EBB
Relative Depth below Water Surface
Time (hours MET+1)
2,000 mg/l
1,000 mg/l
900 mg/l
800 mg/l
700 mg/l
600 mg/l
500 mg/l
400 mg/l
300 mg/l
250 mg/l
200 mg/l
100 mg/l
50 mg/l
0 mg/l


Pas van RILLAND June 30, 2004 - SALINITY in PSU
Relative Depth below Water Surface
Time (hours MET+1)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
9
10
11
12
13
14
15
16
17
18
19
20
21
22
20PSU
19PSU
18PSU
17PSU
16PSU
15PSU
14PSU
13PSU
12PSU
10PSU

5.11. Annexe 2: Physical properties of sediments

Physical properties of suspend sediments: Lippenbroek - Kruibeke – Pas van Rilland

		FLOOD				EBB			
		04B01-S		04B02-S		04B03-S		04B04-S	
		bottom		surface		bottom		surface	
µm	ϕ	%	%C	%	%C	%	%C	%	%C
250	2.00	0.06	0.06						
212	2.24							0.09	0.09
180	2.47							0.11	0.20
150	2.74							0.21	0.41
125	3.00	0.17	0.22					1.05	1.46
106	3.24							1.57	3.03
93	3.43							3.13	6.16
76	3.72	2.08	2.30	0.87	0.87	1.06	1.06	4.51	10.67
62.5	4.00	0.59	2.89	0.99	1.86	1.19	2.25	1.23	11.90
52.6	4.25	0.10	2.99	0.20	2.06	0.40	2.64	1.14	13.04
44.2	4.50	0.10	3.09	0.10	2.16	0.10	2.74	0.88	13.92
37.2	4.75	1.07	4.16	0.10	2.26	0.10	2.84	1.32	15.23
31.3	5.00	1.85	6.01	0.50	2.75	0.59	3.44	1.75	16.98
26.3	5.25	2.05	8.06	0.10	2.85	1.19	4.62	1.67	18.65
22.1	5.50	2.44	10.50	0.30	3.15	1.38	6.01	1.49	20.14
18.6	5.75	2.83	13.33	0.40	3.55	1.38	7.39	2.02	22.16
15.6	6.00	3.32	16.65	0.40	3.94	1.48	8.88	2.81	24.97
13.1	6.25	3.81	20.45	0.40	4.34	1.38	10.26	2.19	27.16
11	6.51	3.32	23.77	0.79	5.13	1.58	11.84	1.84	29.00
9.3	6.75	3.32	27.09	0.59	5.73	1.88	13.72	1.49	30.49
7.8	7.00	3.90	30.99	0.89	6.62	2.57	16.30	1.23	31.72
6.6	7.24	3.81	34.80	1.59	8.21	2.18	18.47	1.67	33.39
5.5	7.51	4.10	38.89	1.88	10.09	2.28	20.75	1.93	35.32
4.7	7.73	2.93	41.82	1.68	11.77	2.47	23.22	1.49	36.81
3.9	8.00	2.63	44.46	1.78	13.56	3.26	26.49	1.49	38.30
3.3	8.24	2.44	46.89	2.28	15.84	2.97	29.45	1.75	40.05
2.8	8.48	2.44	49.33	2.48	18.31	2.67	32.12	2.02	42.07
2.3	8.76	2.63	51.97	2.77	21.09	3.46	35.59	2.02	44.09
1.95	9.00	1.76	53.72	2.58	23.66	3.36	38.95	1.67	45.75
1.6	9.29	1.17	54.90	3.27	26.93	3.76	42.71	2.02	47.77

Grain-size sprectra of suspended matter samples from the Lippenbroek station at June 28, 2004

		FLOOD				EBB			
		surface		bottom		surface		bottom	
		04B05-S		04B06-S		04B07-S		04B08-S	
µm	ϕ	%	%C	%	%C	%	%C	%	%C
250	2.00	0.07	0.07	0.08	0.08	0.08	0.08	0.30	0.30
212	2.24			0.08	0.15			0.10	0.39
180	2.47			0.12	0.27			0.11	0.50
150	2.74			0.32	0.59			0.21	0.72
125	3.00	0.37	0.45	1.23	1.82	0.23	0.31	1.05	1.77
106	3.24			1.61	3.43			1.92	3.69
93	3.43			3.32	6.75			4.32	8.01
76	3.72	3.73	4.18	5.72	12.47	1.80	2.11	7.07	15.08
62.5	4.00	2.10	6.27	2.76	15.23	1.17	3.28	1.43	16.51
52.6	4.25	0.29	6.56	1.73	16.96	0.68	3.96	1.68	18.19
44.2	4.50	0.76	7.32	1.99	18.94	1.17	5.13	2.18	20.37
37.2	4.75	1.14	8.47	1.99	20.93	0.78	5.91	2.35	22.72
31.3	5.00	0.95	9.42	2.16	23.09	1.17	7.09	1.93	24.65
26.3	5.25	1.34	10.76	1.73	24.82	2.05	9.14	1.68	26.33
22.1	5.50	1.91	12.66	1.38	26.20	1.76	10.89	1.60	27.93
18.6	5.75	2.48	15.14	1.12	27.32	1.56	12.46	1.76	29.69
15.6	6.00	2.19	17.34	1.55	28.88	1.86	14.31	1.43	31.12
13.1	6.25	2.10	19.43	1.73	30.60	2.25	16.56	1.09	32.21
11	6.51	2.29	21.72	1.30	31.90	2.54	19.10	1.43	33.64
9.3	6.75	2.38	24.11	1.04	32.93	2.15	21.24	1.09	34.73
7.8	7.00	2.86	26.97	1.38	34.32	2.05	23.29	1.18	35.91
6.6	7.24	2.57	29.54	1.81	36.13	2.34	25.64	1.18	37.08
5.5	7.51	2.57	32.12	1.99	38.12	2.73	28.37	1.76	38.85
4.7	7.73	2.38	34.50	1.55	39.67	2.44	30.81	1.85	40.69
3.9	8.00	3.05	37.55	2.50	42.17	2.83	33.64	2.35	43.04
3.3	8.24	2.10	39.65	2.33	44.51	2.64	36.28	1.68	44.72
2.8	8.48	1.53	41.18	1.73	46.23	2.54	38.82	1.76	46.49
2.3	8.76	2.77	43.94	3.02	49.25	3.22	42.04	2.44	48.92
1.95	9.00	2.38	46.33	2.59	51.85	2.73	44.77	2.10	51.02
1.6	9.29	3.62	49.95	3.28	55.13	2.54	47.31	2.86	53.88

Grain-size sprectra of suspended matter samples from the Kruibeke station at June 29, 2004

		FLOOD				EBB			
		surface		bottom		surface		bottom	
		04B09-S		04B10-S		04B11-S		04B12-S	
µm	ϕ	%	%C	%	%C	%	%C	%	%C
250	2.00			0.04	0.04			0.15	0.15
212	2.24			0.04	0.08			2.85	3
180	2.47			0.04	0.11				
150	2.74			0.15	0.27				
125	3.00			0.88	1.15				
106	3.24			0.9	2.05				
93	3.43			1.17	3.22				
76	3.72	1.22	1.22	1.8	5.02	0.01	0.01	1.63	4.63
62.5	4.00	0.89	2.10	1.12	6.14	0.01	0.02	0.66	5.29
52.6	4.25	0.40	2.50	3.74	9.88	0.01	0.03	0.19	5.48
44.2	4.50	0.10	2.60	1.21	11.09	0.01	0.04	0.47	5.95
37.2	4.75	0.10	2.70	2.34	13.43	0.01	0.05	1.23	7.18
31.3	5.00	0.10	2.80	2.71	16.14	0.01	0.06	1.51	8.69
26.3	5.25	0.10	2.89	3.08	19.22	0.01	0.07	1.61	10.3
22.1	5.50	1.19	4.08	3.18	22.4	0.01	0.08	2.27	12.57
18.6	5.75	1.88	5.96	3.08	25.48	0.01	0.09	2.74	15.31
15.6	6.00	1.98	7.93	2.8	28.29	0.01	0.10	2.08	17.39
13.1	6.25	2.07	10.01	2.62	30.9	0.01	0.11	2.08	19.47
11	6.51	2.07	12.08	2.62	33.52	0.01	0.12	1.8	21.27
9.3	6.75	2.17	14.25	1.68	35.2	0.01	0.13	1.51	22.78
7.8	7.00	2.37	16.62	2.15	37.35	0.01	0.14	2.36	25.14
6.6	7.24	2.07	18.70	1.96	39.31	0.01	0.15	2.27	27.41
5.5	7.51	2.57	21.27	2.06	41.37	0.01	0.16	2.36	29.78
4.7	7.73	2.57	23.83	2.43	43.8	0.01	0.17	1.7	31.48
3.9	8.00	3.06	26.90	2.06	45.86	0.01	0.18	2.36	33.84
3.3	8.24	2.96	29.86	1.59	47.45	0.01	0.19	2.36	36.21
2.8	8.48	2.67	32.53	1.96	49.41	0.01	0.20	1.42	37.62
2.3	8.76	3.16	35.69	2.24	51.65	0.01	0.21	2.27	39.89
1.95	9.00	2.77	38.45	1.96	53.61	0.01	0.22	2.46	42.35
1.6	9.29	2.86	41.32	2.99	56.6	0.01	0.23	2.36	44.72

Grain-size spectra of suspended matter samples from the Pas van Rilland station at June 30, 2004

Physical properties of bottom sediments: Lippenbroek

		04B01		04B02		04B03		04B04	
µm	ϕ	%	%C	%	%C	%	%C	%	%C
2000	-1.00					0.09	0.09		
1600	-0.68			0.38	0.38	0.10	0.20		
1400	-0.49			0.21	0.59	0.13	0.32		
1250	-0.32			0.16	0.75	0.07	0.39		
1000	0.00			0.82	1.57	0.43	0.82		
850	0.23			1.16	2.72	0.89	1.71		
710	0.49			2.55	5.27	2.38	4.09		
600	0.74			4.11	9.38	3.40	7.49		
500	1.00			5.36	14.73	3.56	11.05		
425	1.23	0.05	0.05	19.30	34.03	6.54	17.59	0.14	0.14
355	1.49	0.08	0.13	23.16	57.19	8.95	26.53	0.15	0.29
300	1.74	0.11	0.24	18.12	75.32	9.86	36.39	0.14	0.43
250	2.00	0.23	0.47	10.36	85.68	9.71	46.10	0.19	0.61
212	2.24	0.53	1.00	4.57	90.25	26.18	72.29	0.24	0.85
180	2.47	2.78	3.78	4.41	94.65	11.90	84.18	0.80	1.65
150	2.74	11.81	15.59	1.50	96.15	1.88	86.06	1.22	2.87
125	3.00	20.77	36.37	0.89	97.05	0.62	86.68	4.55	7.42
106	3.24	20.28	56.64	0.36	97.41	0.36	87.04	4.20	11.62
93	3.43	14.14	70.78	0.34	97.74	0.21	87.25	5.80	17.42
76	3.72	2.67	73.45	0.29	98.04	0.15	87.40	1.39	18.81
62.5	4.00	1.65	75.10	0.02	98.06	0.07	87.47	2.02	20.83
52.6	4.25	1.16	76.26	0.02	98.08	0.07	87.54	0.49	21.32
44.2	4.50	1.39	77.65	0.02	98.10	0.07	87.62	0.49	21.80
37.2	4.75	1.44	79.09	0.02	98.12	0.07	87.69	1.46	23.26
31.3	5.00	1.49	80.58	0.02	98.14	0.07	87.76	2.43	25.69
26.3	5.25	1.26	81.84	0.02	98.17	0.07	87.84	3.24	28.92
22.1	5.50	0.98	82.81	0.02	98.19	0.07	87.91	3.40	32.32
18.6	5.75	0.93	83.74	0.02	98.21	0.07	87.98	3.40	35.72
15.6	6.00	0.98	84.72	0.02	98.23	0.07	88.05	2.99	38.71
13.1	6.25	0.59	85.31	0.02	98.25	0.07	88.13	2.51	41.22
11	6.51	0.51	85.82	0.02	98.27	0.07	88.20	2.35	43.56
9.3	6.75	0.54	86.36	0.02	98.29	0.07	88.27	1.94	45.50
7.8	7.00	0.51	86.88	0.02	98.31	0.07	88.35	1.78	47.28
6.6	7.24	0.39	87.26	0.02	98.34	0.07	88.42	1.54	48.82
5.5	7.51	0.44	87.70	0.02	98.36	0.07	88.49	1.78	50.60
4.7	7.73	0.49	88.19	0.02	98.38	0.07	88.57	1.29	51.89
3.9	8.00	0.51	88.70	0.02	98.40	0.07	88.64	1.62	53.51
3.3	8.24	0.33	89.04	0.02	98.42	0.07	88.71	1.78	55.29
2.8	8.48	0.21	89.24	0.02	98.44	0.07	88.78	1.62	56.91
2.3	8.76	0.33	89.58	0.02	98.46	0.07	88.86	2.10	59.01
1.95	9.00	0.39	89.96	0.02	98.48	0.07	88.93	1.86	60.87
1.6	9.29	0.80	90.76	0.02	98.51	0.07	89.00	1.94	62.81

Bottom samples from the right side of the river main channel

		04B05		04B06		04B07		04B08	
µm	φ	%	%C	%	%C	%	%C	%	%C
2000	-1.00								
1600	-0.68								
1400	-0.49								
1250	-0.32								
1000	0.00								
850	0.23								
710	0.49								
600	0.74								
500	1.00	0.08	0.08	0.09	0.09	0.08	0.08	0.10	0.10
425	1.23	0.15	0.23	0.13	0.21	0.08	0.17	0.27	0.36
355	1.49	0.41	0.64	0.48	0.70	0.15	0.31	0.75	1.11
300	1.74	0.52	1.17	6.13	6.82	0.29	0.61	2.48	3.59
250	2.00	0.69	1.85	15.12	21.94	1.44	2.05	6.31	9.89
212	2.24	1.22	3.07	31.05	52.99	9.68	11.73	12.94	22.83
180	2.47	4.80	7.87	25.14	78.13	31.63	43.36	16.88	39.71
150	2.74	10.59	18.46	11.04	89.17	34.00	77.35	24.07	63.77
125	3.00	33.00	51.46	2.92	92.09	12.60	89.95	19.17	82.95
106	3.24	17.38	68.84	0.98	93.08	2.86	92.81	7.28	90.23
93	3.43	8.58	77.42	0.66	93.73	1.11	93.92	0.16	90.38
76	3.72	1.29	78.71	0.13	93.87	0.17	94.09	0.48	90.86
62.5	4.00	1.44	80.15	0.10	93.97	0.12	94.21	0.15	91.01
52.6	4.25	1.16	81.31	0.10	94.07	0.12	94.33	0.15	91.16
44.2	4.50	1.30	82.62	0.10	94.17	0.12	94.45	0.15	91.31
37.2	4.75	1.14	83.76	0.10	94.26	0.12	94.57	0.15	91.46
31.3	5.00	0.90	84.66	0.10	94.36	0.12	94.70	0.15	91.61
26.3	5.25	0.72	85.38	0.10	94.46	0.12	94.82	0.15	91.76
22.1	5.50	0.62	86.00	0.10	94.56	0.12	94.94	0.15	91.91
18.6	5.75	0.56	86.56	0.10	94.66	0.12	95.06	0.15	92.06
15.6	6.00	0.50	87.06	0.10	94.76	0.12	95.18	0.15	92.21
13.1	6.25	0.40	87.46	0.10	94.86	0.12	95.30	0.15	92.35
11	6.51	0.40	87.86	0.10	94.96	0.12	95.42	0.15	92.50
9.3	6.75	0.30	88.16	0.10	95.05	0.12	95.54	0.15	92.65
7.8	7.00	0.24	88.40	0.10	95.15	0.12	95.66	0.15	92.80
6.6	7.24	0.26	88.66	0.10	95.25	0.12	95.78	0.15	92.95
5.5	7.51	0.42	89.08	0.10	95.35	0.12	95.91	0.15	93.10
4.7	7.73	0.30	89.38	0.10	95.45	0.12	96.03	0.15	93.25
3.9	8.00	0.14	89.52	0.10	95.55	0.12	96.15	0.15	93.40
3.3	8.24	0.16	89.68	0.10	95.65	0.12	96.27	0.15	93.55
2.8	8.48	0.26	89.95	0.10	95.74	0.12	96.39	0.15	93.70
2.3	8.76	0.42	90.37	0.10	95.84	0.12	96.51	0.15	93.85
1.95	9.00	0.26	90.63	0.10	95.94	0.12	96.63	0.15	94.00
1.6	9.29	0.54	91.17	0.10	96.04	0.12	96.75	0.15	94.15

Bottom samples from the left side of the river main channel

Depth below surface m	Organic Matter %	carbonate %	Sediment %	Sand %	Silt %	Clay %
Konkelschor						
0.047	5.1	16.1	79	1.1	71.7	27.2
0.126	4.8	16.0	79	1.7	70.2	28.1
0.252	5.5	20.1	74	1.0	73.7	25.3
0.378	4.9	19.6	75	1.5	77.7	20.8
0.441	5.3	22.5	72	1.2	81.3	17.5
0.568	5.1	19.1	76	3.3	79.3	17.4
0.694	4.4	19.3	76	3.9	83.6	12.5
0.853	5.2	25.1	70	3.6	81.6	14.8
Paulina Polder						
0.005	13.2	25.1	62	5.6	76.3	18.1
0.079	8.7	18.6	73	29.8	49.7	20.5
0.116	1.3	22.4	76	23.8	59.1	17.1
0.152	9.7	16.8	73	32.3	48.8	18.8
0.163	0.5	12.6	87	61.7	27.6	10.7
0.226	4.3	6.5	89	73.8	19.7	6.50
0.299	1.8	4.5	94	86.9	9.40	3.80
0.368	0.7	4.5	95	81.8	12.9	5.30
0.383	1.3	5.4	93	85.6	10.5	3.90
0.410	0.7	8.3	91	82.2	12.0	5.70
0.467	1.4	9.9	89	83.7	11.6	4.60
0.578	1.4	10.3	88	87.4	9.00	3.60
Paal						
0.010	9.0	28.2	63	1.00	80.9	18.1
0.052	9.8	25.2	65	4.80	75.0	20.2
0.073	9.0	23.8	67	0.50	80.7	18.8
0.110	6.8	25.6	68	0.20	85.1	14.7
0.147	4.2	24.1	72	0.30	80.0	19.6
0.199	15.1	21.5	63	2.30	80.0	17.7
0.257	13.3	21.0	66	0.80	72.9	26.4
0.424	4.9	24.4	71	0.60	84.5	14.8
0.571	6.0	21.4	73	1.00	95.3	3.70
0.749	3.7	26.5	70	0.90	84.7	14.4

Grain-size properties of tidal marsch sediments.
Sediment = mineral fraction of total sample
Sand = fraction > 63 μm of sediment
Silt = fraction between 63 and 2 μm of sediment
Clay = fraction > 2 μm of sediment

5.12. Annexe 3: Tables

January 26, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
buoy 87	10.08	10.5	-9.5	0.49	754	5.9
		10.5	-7.9	0.67	627	5.8
		10.5	-5.3	0.84	684	5.7
		10.5	-2.6	0.83	296	5.3
	10.15	10.5	-1.1	1.01	250	5.2
buoy 92	10.43	13.4	-12.1	0.79	752	3.5
		13.4	-10.1	0.92	461	3.5
		13.4	-6.7	1.27	256	3.5
		13.4	-3.4	1.00	236	3.5
		13.4	-1.3	1.50	158	3.5
buoy 105	11.27	12.3	-11.1	0.73	1069	1.8
		12.3	-9.2	1.33	694	1.7
		12.3	-6.2	1.32	361	1.7
		12.3	-3.1	1.66	266	1.6
	11.35	12.3	-1.2	1.39	177	1.6
Antwerpen	12.02	11.1	-10.0	0.63	961	<0.5
		11.1	-8.3	1.02	602	<0.5
		11.1	-5.6	1.14	431	<0.5
		11.1	-2.8	1.32	247	<0.5
	12.11	11.1	-1.1	1.32	12	<0.5
Kruibeke	12.38	10.2	-9.2	0.60	523	<0.5
		10.2	-7.7	0.93	424	<0.5
		10.2	-5.1	1.03	364	<0.5
		10.2	-2.6	1.03	307	<0.5
	12.45	10.2	-1.0	1.29	257	<0.5
Bazel	12.58	11.7	-10.5	0.92	404	<0.5
		11.7	-8.8	0.96	404	<0.5
		11.7	-5.9	1.20	379	<0.5
		11.7	-2.9	1.24	386	<0.5
	13.05	11.7	-1.2	1.22	354	<0.5
Steendorp	13.25	5.1	-4.6	0.67	511	<0.5
		5.1	-3.8	0.73	448	<0.5
		5.1	-2.6	0.95	299	<0.5
		5.1	-1.3	1.03	286	<0.5
	13.38	5.1	-0.5	1.03	158	<0.5
Temse	14.03	7.7	-6.9	0.50	410	<0.5
		7.7	-5.8	0.72	416	<0.5
		7.7	-3.9	1.11	435	<0.5
		7.7	-1.9	0.99	385	<0.5
	14.10	7.7	-0.8	1.12	219	<0.5
Mariekerke	14.54	5.5	-5.0	0.38	269	<0.5
		5.5	-4.1	0.48	234	<0.5
		5.5	-2.8	0.49	182	<0.5
		5.5	-1.4	0.41	168	<0.5
	15.02	5.5	-0.6	0.47	169	<0.5

January 27, 2004						
locality	**time** MET	**water depth** m	**sample depth** m	**water velocity** m/s	**SPM** mg/l	**salinity** PSU
Vlassenbroek	9.33			0.67	192	<0.5
				0.71	183	<0.5
				0.73	179	<0.5
				0.81	127	<0.5
	9.45			0.48	122	<0.5
Dendermonde	10.05			0.39	205	<0.5
				0.34	147	<0.5
				0.31	92	<0.5
				0.16	120	<0.5
	10.16			0.09	84	<0.5
St. Onolfs	10.42			0.13	93	<0.5
				0.17	98	<0.5
				0.25	96	<0.5
				0.17	84	<0.5
	10:53			0.31	57	<0.5
Appels	11.15			0.60	116	<0.5
				0.59	85	<0.5
				0.79	78	<0.5
				0.87	63	<0.5
	11.25			0.70	46	<0.5
Uitbergen	12.10			0.70	131	<0.5
				0.84	117	<0.5
				0.82	110	<0.5
				0.78	110	<0.5
	12.23			0.83	60	<0.5
Wetteren baanbrug	No measurements - crane failure					
Melle baanbrug	No measurements - crane failure					

February 24, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
boei 87	10:19	9	-8.1	0.47	1249	6.3
		9	-6.8	0.71	861	6.2
		9	-4.5	0.94	594	5.9
		9	-2.3	0.84	299	5.8
	10:26	9	-0.9	0.63	183	5.7
boei 92	10:53	14	-12.6	0.16	578	4.7
		14	-10.5	0.29	478	4.6
		14	-7.0	0.56	455	4.4
		14	-3.5	0.84	461	4.1
	11:02	14	-1.4	0.85	143	4.0
boei 105	11:31	8.4	-7.6	0.68	414	1.9
		8.4	-6.3	0.88	370	1.8
		8.4	-4.2	1.07	295	1.8
		8.4	-2.1	1.05	310	1.8
	11:39	8.4	-0.8	1.33	219	1.8
Antwerpen Steen	12:10	10.6	-9.5	0.63	414	0.5
		10.6	-8.0	0.97	348	0.5
		10.6	-5.3	1.00	287	0.5
		10.6	-2.7	1.07	235	0.5
		10.6	-1.1	1.09	242	0.5
Kruibeke Ponton	13:00	9.3	-8.4	0.51	487	<0.5
		9.3	-7.0	0.83	383	<0.5
		9.3	-4.7	0.82	341	<0.5
		9.3	-2.3	0.99	238	<0.5
	13:08	9.3	-0.9	1.00	149	<0.5
Bazel ponton	13:25	11.9	-10.7	0.73	338	<0.5
		11.9	-8.9	0.87	338	<0.5
		11.9	-6.0	0.98	325	<0.5
		11.9	-3.0	0.99	313	<0.5
	13:30	11.9	-1.2	1.15	227	<0.5
Steendorp kerk	13:55	6.9	-6.2	0.43	657	<0.5
		6.9	-5.2	0.51	572	<0.5
		6.9	-3.5	0.54	353	<0.5
		6.9	-1.7	0.69	236	<0.5
	14:00	6.9	-0.7	0.59	197	<0.5
Temse ponton	14:45	7	-6.3	0.10	404	<0.5
		7	-5.3	0.10	415	<0.5
		7	-3.5	0.06	331	<0.5
		7	-1.8	0.11	247	<0.5
		7	-0.7	0.08	164	<0.5
Mariekerke veerpont	15:11	4.2	-3.8	0.51	292	<0.5
		4.2	-3.2	0.59	206	<0.5
		4.2	-2.1	0.60	216	<0.5
		4.2	-1.1	0.61	171	<0.5
		4.2	-0.4	0.60	124	<0.5

February 25, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
Vlassenbroek kapel	9:16	7.7	-6.9		152	<0.5
		7.7	-5.8		146	<0.5
		7.7	-3.9		216	<0.5
		7.7	-1.9		200	<0.5
		7.7	-0.8		192	<0.5
Dendermonde ponton	9:36	8	-7.2		259	<0.5
		8	-6.0		180	<0.5
		8	-4.0		91	<0.5
		8	-2.0		73	<0.5
		8	-0.8		69	<0.5
St. Onolfs 'bocht van Damme'	9:56	8.7	-7.8		154	<0.5
		8.7	-6.5		93	<0.5
		8.7	-4.4		90	<0.5
		8.7	-2.2		98	<0.5
		8.7	-0.9		88	<0.5
Appels veerpont	10:14	6.6	-5.9		131	<0.5
		6.6	-5.0		150	<0.5
		6.6	-3.3		95	<0.5
		6.6	-1.7		71	<0.5
		6.6	-0.7		76	<0.5
Uitbergen baanbrug	11:07	7.2	-6.5		135	<0.5
		7.2	-3.6		142	<0.5
		7.2	-0.7		115	<0.5
Wetteren baanbrug	11:44	7	-6.3		97	<0.5
		7	-3.5		82	<0.5
		7	-0.7		76	<0.5
Melle baanbrug	12:15	6.4	-5.8		50	<0.5
		6.4	-3.2		59	<0.5
		6.4	-0.6		49	<0.5

March 23, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
boei 87	10:06	8	-7.2	0.35	1041	6.8
		8	-6.0	0.59	803	6.7
		8	-4.0	0.67	654	6.6
		8	-2.0	0.93	301	6.5
	10:12	8	-0.8	0.79	225	6.5
boei 92	10:39	13	-11.7	0.38	590	5.2
		13	-9.8	0.41	649	5.1
		13	-6.5	0.72	424	4.8
		13	-3.3	0.75	249	4.7
	10:45	13	-1.3	0.81	141	4.7
boei 105	11:14	6.7	-6.0	0.86	374	1.4
		6.7	-5.0	0.80	387	1.4
		6.7	-3.4	0.96	137	1.4
		6.7	-1.7	1.09	135	1.3
	11:22	6.7	-0.7	1.21	128	1.3
Antwerpen Steen	11:50	8.6	-7.7	0.65	499	0.5
		8.6	-6.5	0.91	359	0.5
		8.6	-4.3	0.95	282	0.5
		8.6	-2.2	0.95	176	0.5
	11:59	8.6	-0.9	1.05	38	0.5
Kruibeke Ponton	12:30	9.7	-8.7	0.41	597	<0.5
		9.7	-7.3	0.66	455	<0.5
		9.7	-4.9	0.83	251	<0.5
		9.7	-2.4	0.99	117	<0.5
	12:35	9.7	-1.0	1.06	34	<0.5
Bazel ponton	13:12	10.2	-9.2	0.26	250	<0.5
		10.2	-7.7	0.27	251	<0.5
		10.2	-5.1	0.17	211	<0.5
		10.2	-2.6	0.35	127	<0.5
	13:16	10.2	-1.0	0.32	170	<0.5
Steendorp kerk	13:45	5.6	-5.0	0.63	292	<0.5
		5.6	-4.2	0.68	111	<0.5
		5.6	-2.8	0.68	55	<0.5
		5.6	-1.4	0.67	26	<0.5
	13:52	5.6	-0.6	0.73	29	<0.5
Temse ponton	14:17	7	-6.3	0.48	294	<0.5
		7	-5.3	0.63	271	<0.5
		7	-3.5	0.79	296	<0.5
		7	-1.8	0.84	303	<0.5
	14:22	7	-0.7	0.85	268	<0.5
Mariekerke veerpont	14;58	6	-5.4	0.58	245	<0.5
		6	-4.5	0.62	242	<0.5
		6	-3.0	0.58	220	<0.5
		6	-1.5	0.59	263	<0.5
	15:05	6	-0.6	0.63	193	<0.5

March 23-24, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
Vlassenbroek kapel	9:18	9	-8.1	0.21	132	<0.5
	9:19	9	-0.9	0.70	108	<0.5
Dendermonde ponton	9:34	11.4	-10.3	0.53	111	<0.5
	9:36	11.4	-1.1	0.61	85	<0.5
St. Onolfs 'bocht van Damme'	9:56	6.6	-5.9	0.81	108	<0.5
	9:59	6.6	-0.7	0.96	60	<0.5
Appels veerpont	10:14	7	-6.3	0.56	111	<0.5
	10:18	7	-0.7	1.00	70	<0.5
Uitbergen baanbrug	11:05	7	-6.3	0.62	81	<0.5
	11:09	7	-0.7	0.91	62	<0.5
Wetteren baanbrug	11:43	5.4	-4.9	0.73	65	<0.5
	11:45	5.4	-0.5	0.74	63	<0.5
Melle baanbrug	12:12	5.4	-4.9	0.28	54	<0.5
	12:15	5.4	-0.5	0.48	44	<0.5

April 21, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
boei 87	10:40	8.9	-8.0	0.40	1589	8.6
		8.9	-6.7	0.52	1406	8.5
		8.9	-4.5	0.78	848	8.3
		8.9	-2.2	0.69	262	8.2
	10:49	8.9	-0.9	0.53	154	8.2
boei 92	11:28	12.2	-11.0	0.26	572	6.6
		12.2	-9.2	0.51	380	6.3
		12.2	-6.1	0.61	250	5.9
		12.2	-3.1	0.71	80	5.9
	11:32	12.2	-1.2	0.70	55	5.9
boei 105	11:59	8.7	-7.8	0.61	191	1.8
		8.7	-6.5	0.51	248	1.8
		8.7	-4.4	0.76	177	1.8
		8.7	-2.2	0.73	140	1.7
	12:05	8.7	-0.9	0.89		1.7
Antwerpen Steen	12:34	10.5	-9.5	0.54	266	0.6
		10.5	-7.9	0.44	250	0.6
		10.5	-5.3	0.47	151	0.6
		10.5	-2.6	0.68	25	0.6
	12:40	10.5	-1.1	0.52	43	0.6
Kruibeke Ponton	13:12	9.5	-8.6	0.19	147	<0.5
		9.5	-7.1	0.26	84	<0.5
		9.5	-4.8	0.10	58	<0.5
		9.5	-2.4	0.26	27	<0.5
	13:16	9.5	-1.0	0.17	20	<0.5
Bazel ponton	13:35	10.8	-9.7	0.66	397	<0.5
		10.8	-8.1	0.71	269	<0.5
		10.8	-5.4	1.00	95	<0.5
		10.8	-2.7	0.92	26	<0.5
	13:42	10.8	-1.1	1.06	21	<0.5
Steendorp kerk	14:04	7.6	-6.8	0.59	530	<0.5
		7.6	-5.7	0.73	413	<0.5
		7.6	-3.8	0.84	223	<0.5
		7.6	-1.9	0.88	234	<0.5
	14:09	7.6	-0.8	0.80	123	<0.5
Temse ponton	14:24	6.5	-5.9	0.44	227	<0.5
		6.5	-4.9	0.55	192	<0.5
		6.5	-3.3	0.70	166	<0.5
		6.5	-1.6	0.63	213	<0.5
	14:32	6.5	-0.7	0.67	197	<0.5
Mariekerke veerpont	15:10	5.5	-5.0	0.57	368	<0.5
		5.5	-4.1	0.67	321	<0.5
		5.5	-2.8	0.66	284	<0.5
		5.5	-1.4	0.61	215	<0.5
	15:18	5.5	-0.6	0.55	107	<0.5

April 22, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
Vlassenbroek kapel	9:38	12.45	-11.2	0.45	237	<0.5
		12.45	-9.3	0.75	222	<0.5
		12.45	-6.2	0.94	205	<0.5
		12.45	-3.1	0.97	140	<0.5
	9:45	12.45	-1.2	0.31	124	<0.5
Dendermonde ponton	10:05	6.55	-5.9	0.35	223	<0.5
		6.55	-4.9	0.31	210	<0.5
		6.55	-3.3	0.18	189	<0.5
		6.55	-1.6	0.32	162	<0.5
	10:12	6.55	-0.7	0.24	147	<0.5
St. Onolfs 'bocht van Damme'	10:29	6.4	-5.8	0.26	269	<0.5
		6.4	-4.8	0.25	230	<0.5
		6.4	-3.2	0.19	221	<0.5
		6.4	-1.6	0.20	230	<0.5
	10:37	6.4	-0.6	0.29	204	<0.5
Appels veerpont	10:56	7.4	-6.7	1.10	219	<0.5
		7.4	-5.6	0.90	207	<0.5
		7.4	-3.7	1.20	159	<0.5
		7.4	-1.9	1.12	172	<0.5
	11:03	7.4	-0.7	1.09	120	<0.5
Uitbergen baanbrug	11:46	8.6	-7.7	0.79	108	<0.5
		8.6	-6.5	0.79	100	<0.5
		8.6	-4.3	0.80	116	<0.5
		8.6	-2.2	0.94	100	<0.5
	11:54	8.6	-0.9	0.89	92	<0.5
Wetteren baanbrug	12:25	6.2	-5.6	0.76	67	<0.5
		6.2	-4.7	0.71	72	<0.5
		6.2	-3.1	0.74	73	<0.5
		6.2	-1.6	0.69	61	<0.5
	12:32	6.2	-0.6	0.77	70	<0.5
Melle baanbrug	13:00	5.8	-5.2	0.52	43	<0.5
		5.8	-4.4	0.61	39	<0.5
		5.8	-2.9	0.63	38	<0.5
		5.8	-1.5	0.68	39	<0.5
	13:05	5.8	-0.6	0.56	35	<0.5

May 11, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
boei 87	10:50	12.5	-11.3	0.54	150	13.1
		12.5	-9.4	0.42	91	12.9
		12.5	-6.3	0.44	69	12.9
		12.5	-3.1	0.54	41	12.5
	10:57	12.5	-1.3	0.49	11	12.2
boei 92	11:22	16.2	-14.6	0.45	248	11.0
		16.2	-12.2	0.63	51	10.9
		16.2	-8.1	0.62	43	10.9
		16.2	-4.1	0.71	52	10.7
	11:29	16.2	-1.6	0.80	66	10.5
boei 105	11:54	10.6	-9.5	0.92	325	8.3
		10.6	-8.0	1.02	242	8.1
		10.6	-5.3	1.15	135	7.9
		10.6	-2.7	1.24	102	7.7
	12:01	10.6	-1.1	1.37	80	7.6
Antwerpen Steen	12:29	12.6	-11.3	0.83	440	5.1
		12.6	-9.5	0.90	318	4.9
		12.6	-6.3	1.24	264	4.9
		12.6	-3.2	1.27	220	4.9
	12:36	12.6	-1.3	1.31	706	4.8
Kruibeke Ponton	13:09	12.2	-11.0	0.69	164	1.2
		12.2	-9.2	0.73	148	1.2
		12.2	-6.1	0.87	128	1.2
		12.2	-3.1	1.08	97	1.1
	13:18	12.2	-1.2	1.04	90	1.1
Bazel ponton	13:34	11.9	-10.7	0.99	140	0.7
		11.9	-8.9	1.03	122	0.7
		11.9	-6.0	1.20	121	0.7
		11.9	-3.0	1.19	120	0.7
	13:40	11.9	-1.2	1.23	106	0.7
Steendorp kerk	14:06	9.3	-8.4	0.64	331	0.5
		9.3	-7.0	0.57	261	0.5
		9.3	-4.7	0.75	222	0.5
		9.3	-2.3	0.86	127	0.5
	14:13	9.3	-0.9	0.90	47	0.5
Temse ponton	14:44	6.8	-6.1	0.71	92	<0.5
		6.8	-5.1	0.88	87	<0.5
		6.8	-3.4	0.84	109	<0.5
		6.8	-1.7	0.95	104	<0.5
	14:53	6.8	-0.7	0.95	83	<0.5
Mariekerke veerpont	15:32	5.5	-5.0	0.71	235	<0.5
		5.5	-4.1	0.84	228	<0.5
		5.5	-2.8	1.10	174	<0.5
		5.5	-1.4	1.18	177	<0.5
	15:37	5.5	-0.6	1.30	134	<0.5

June 15, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
boei 87	10:37	8	-7.2	0.27	165	13.4
		8	-6.0	0.32	36	13.1
		8	-4.0	0.35	40	11.7
		8	-2.0	0.46	28	11.5
	10:41	8	-0.8	0.47	29	11.2
boei 92	11:08	13.9	-12.5	0.49	216	11.2
		13.9	-10.4	0.60	118	11.2
		13.9	-7.0	0.77	68	11.2
		13.9	-3.5	0.75	40	11.0
	11:14	13.9	-1.4	0.85	38	10.9
boei 105	11:38	8.9	-8.0	0.54	425	8.6
		8.9	-6.7	0.72	368	8.6
		8.9	-4.5	0.90	311	8.5
		8.9	-2.2	1.07	147	8.4
	11:46	8.9	-0.9	1.08	89	8.2
Antwerpen Steen	12:07	11.4	-10.3	0.76	261	6.1
		11.4	-8.6	0.78	209	6.1
		11.4	-5.7	0.94	219	6.1
		11.4	-2.9	0.99	103	5.8
	12:15	11.4	-1.1	1.05	39	5.5
Kruibeke Ponton	12:37	13.5	-12.2	0.57	123	1.9
		13.5	-10.1	0.60	123	1.8
		13.5	-6.8	0.76	113	1.7
		13.5	-3.4	0.93	130	1.6
	12:43	13.5	-1.4	0.94	98	1.6
Bazel ponton	13:06	11.15	-10.0	0.63	147	0.8
		11.15	-8.4	0.71	151	0.8
		11.15	-5.6	0.80		0.8
		11.15	-2.8	0.85	119	0.8
	13:12	11.15	-1.1	0.79	111	0.8
Steendorp kerk	13:34	8.4	-7.6	0.60	196	0.5
		8.4	-6.3	0.67	186	0.5
		8.4	-4.2	0.71	113	0.5
		8.4	-2.1	0.71	106	0.5
	13:42	8.4	-0.8	0.63	88	0.5
Temse ponton	14:08	8.4	-7.6	0.60	135	<0.5
		8.4	-6.3	0.67	127	<0.5
		8.4	-4.2	0.67	113	<0.5
		8.4	-2.1	0.72	101	<0.5
	14:13	8.4	-0.8	0.63	100	<0.5
Mariekerke veerpont	14:42	7.6	-6.8	0.80	233	<0.5
		7.6	-5.7	1.04	194	<0.5
		7.6	-3.8	1.03	194	<0.5
		7.6	-1.9	0.95	215	<0.5
		7.6	-0.8	0.84	223	<0.5

June 16, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
Vlassenbroek kapel	9:20		surface		101	<0.5
Dendermonde ponton	9:40		surface		89	<0.5
St. Onolfs 'bocht van Damme'	10:05		surface		99	<0.5
Appels veerpont	10:40		surface		44	<0.5
Uitbergen baanbrug	11:30		surface			<0.5
Wetteren baanbrug	12:15		surface		68	<0.5
Melle baanbrug	12:50		surface		103	<0.5

July 13, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
boei 87	8:33	9	-8.1	0.14	28	11.6
		9	-6.8	0.07	29	11.3
		9	-4.5	0.13	22	11.2
		9	-2.3	0.41	21	11.1
		9	-0.9	0.48	21	11.0
boei 92	9:08	9	-8.1	0.64	54	9.1
		9	-6.8	0.37	31	8.8
		9	-4.5	0.41	28	8.6
		9	-2.3	0.19	20	8.5
	9:14	9	-0.9	0.12	18	8.4
boei 105	9:43	9.5	-8.6	0.76	94	5.2
		9.5	-7.1	0.72	51	4.9
		9.5	-4.8	0.67	39	4.8
		9.5	-2.4	0.87	29	4.6
	9:48	9.5	-1.0	1.26	29	4.2
Antwerpen Steen	10:09	12.5	-11.3	0.87	76	1.6
		12.5	-9.4	0.92	65	1.6
		12.5	-6.3	1.19	69	1.6
		12.5	-3.1	1.13	50	1.6
	10:16	12.5	-1.3	1.18	49	1.6
Kruibeke Ponton	10:39	10.5	-9.5	0.79	67	0.8
		10.5	-7.9	0.84	63	0.8
		10.5	-5.3	0.93	54	0.9
		10.5	-2.6	0.98	49	0.9
	10:46	10.5	-1.1	1.02	51	0.9
Bazel ponton	10:59	9.8	-8.8	0.72	68	0.7
		9.8	-7.4	1.07	63	0.7
		9.8	-4.9	1.02	61	0.7
		9.8	-2.5	1.13	48	0.7
	11:08	9.8	-1.0	1.02	55	0.7
Steendorp kerk	11:32	6.5	-5.9	0.80	118	0.5
		6.5	-4.9	0.84	125	0.5
		6.5	-3.3	0.95	102	0.5
		6.5	-1.6	0.84	78	0.5
	11:37	6.5	-0.7	1.00	95	0.5
Temse ponton	11:54	6.5	-5.9	0.86	85	0.5
		6.5	-4.9	0.88	84	0.5
		6.5	-3.3	0.93	88	0.5
		6.5	-1.6	1.29	76	0.5
		6.5	-0.7	0.94	41	0.5
Mariekerke veerpont	12:44	5.6	-5.0	0.85	188	<0.5
		5.6	-4.2	1.05	189	<0.5
		5.6	-2.8	1.05	183	<0.5
		5.6	-1.4	1.13	177	<0.5
	12:50	5.6	-0.6	1.26	157	<0.5

July 14, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
Vlassenbroek kapel	9:20	9	-8.6	0.62	210	<0.5
		9	-7.1			<0.5
		9	-4.8			<0.5
		9	-2.4			<0.5
		9	-1.0	0.59	210	<0.5
Dendermonde ponton		6.1	-5.9	0.30	197	<0.5
		6.1	-5.0	0.36	195	<0.5
		6.1	-3.3	0.38	195	<0.5
		6.1	-1.7	0.38	191	<0.5
	9:49	6.1	-0.7	0.92	206	<0.5
St. Onolfs 'bocht van Damme'		2.2	-2.4	1.30	277	<0.5
		2.2	-2.0	1.27	243	<0.5
		2.2	-1.4	1.08	239	<0.5
		2.2	-0.7	1.42	219	<0.5
	10:18	2.2	-0.3	1.18	224	<0.5
Appels veerpont	10:40	5.5	-4.9	1.16	239	<0.5
		5.5	-4.0	1.00	239	<0.5
		5.5	-2.5	0.80	183	<0.5
		5.5	-1.0	1.13	175	<0.5
		5.5	-0.1	0.95	209	<0.5
Uitbergen baanbrug		4.5	-4.1	0.67	194	<0.5
		4.5	-3.4	0.81	193	<0.5
		4.5	-2.3	0.67	170	<0.5
		4.5	-1.1	0.76	163	<0.5
		4.5	-0.5	0.97	144	<0.5
Wetteren baanbrug		3.5	-3.2	0.78	331	<0.5
		3.5	-2.6	0.70	282	<0.5
		3.5	-1.8	0.83	276	<0.5
		3.5	-0.9	0.89	150	<0.5
		3.5	-0.4	1.01	162	<0.5
Melle baanbrug		4.1	-3.7	0.62	153	<0.5
		4.1	-3.1	0.49	137	<0.5
		4.1	-2.1	0.37	130	<0.5
		4.1	-1.0	0.45	116	<0.5
		4.1	-0.4	0.70	98	<0.5

August 17, 2004						
locality	time MET	water depth m	sample depth %	water velocity m/s	SPM mg/l	salinity PSU
1 - boei 87	8:25		-90.0		100	14.5
			-75.0		78	14.5
			-50.0		68	14.2
			-25.0		33	13.9
			-10.0		36	14.0
2 - boei 92	9:00		-90.0		310	11.5
			-75.0		243	11.5
			-50.0		175	11.1
			-25.0		109	10.8
			-10.0		43	10.8
3 - boei 105	9:35		-90.0		204	7.2
			-75.0		166	7.2
			-50.0		128	7.2
			-25.0		111	7.1
			-10.0		95	7.2
4 - Antwerpen Steen	10:10		-90.0		405	2.1
			-75.0		318	2.3
			-50.0		230	2.2
			-25.0		165	2.0
			-10.0		101	2.0
5 - Kruibeke Ponton	10:50		-90.0		146	0.8
			-75.0		135	0.8
			-50.0		125	0.8
			-25.0		112	0.7
			-10.0		99	0.7
6 - Bazel ponton	11:15		0.0		215	0.5
			0.0		167	0.5
			0.0		120	0.5
			0.0		123	0.5
			0.0		127	0.5
7 - Steendorp kerk	11:45		-90.0		157	<0.5
			-75.0		139	<0.5
			-50.0		121	<0.5
			-25.0		93	<0.5
			-10.0		65	<0.5
8 - Temse ponton	13:10		-90.0		248	<0.5
			-75.0		195	<0.5
			-50.0		142	<0.5
			-25.0		150	<0.5
			-10.0		157	<0.5
9 - Mariekerke veerpont	13:55		-90.0		218	<0.5
			-75.0		207	<0.5
			-50.0		197	<0.5
			-25.0		161	<0.5
			-10.0		124	<0.5

August 18, 2004						
locality	**time MET**	**water depth m**	**sample depth %**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
10 - Vlassenbroek kapel	9:20		-90.0		113	<0.5
			-50.0		188	<0.5
			-10.0		184	<0.5
11 - Dendermonde ponton	9:45		-90.0		91	<0.5
			-50.0		85	<0.5
			-10.0		132	<0.5
12 - St. Onolfs 'bocht van Damme'	10:05		-90.0		175	<0.5
			-50.0		214	<0.5
			-10.0		141	<0.5
13 - Appels veerpont	10:26		-90.0		97	<0.5
			-50.0		114	<0.5
			-10.0		99	<0.5
14 - Uitbergen baanbrug	11:25		-90.0		227	<0.5
			-50.0		256	<0.5
			-10.0		234	<0.5
15 - Wetteren baanbrug	12:00		-90.0		171	<0.5
			-50.0		213	<0.5
			-10.0		185	<0.5
16 - Melle baanbrug	12:32		-90.0		96	<0.5
			-50.0		98	<0.5
			-10.0		93	<0.5

September 14, 2004

locality	time MET	water depth m	sample depth %	water velocity m/s	SPM mg/l	salinity PSU
boei 87	8:54	9.5	-9.0	0.62	339	13.4
			-7.1	0.72	245	13.3
			-4.8	0.77	142	13.1
			-2.4	0.87	90	13.0
	9:00		-1.0	0.74	71	13.0
boei 92	9:22	13.7	-13.0	0.31	279	11.2
			-10.3	0.48	199	10.9
			-6.9	0.69	164	10.7
			-3.4	0.83	89	10.5
	9:30		-1.4	0.79	43	10.5
boei 105	9:59	8.2	-7.8	0.73	188	6.1
			-6.2	0.76	112	6.1
			-4.1	1.11	108	6.0
			-2.1	1.01	88	5.9
	10:06		-0.8	1.15	49	5.8
Antwerpen Steen	10:33	10.1	-9.6	0.39	335	1.8
			-7.6	0.66	232	1.7
			-5.1	0.70	232	1.7
			-2.5	0.84	114	1.6
	10:41		-1.0	1.00	93	1.6
Kruibeke Ponton	11:15	10.1	-9.6	0.63	195	0.8
			-7.6	0.79	146	0.8
			-5.1	0.75	135	0.8
			-2.5	0.72	101	0.8
	11:25		-1.0	0.85	117	0.8
Bazel ponton	11:44	11.8	-11.2	0.81	235	0.7
			-8.9	1.01	192	0.7
			-5.9	1.15	188	0.7
			-3.0	1.26	12	0.6
	11:50		-1.2	1.18	143	0.6
Steendorp kerk	12:10	7.3	-6.9	0.48	307	0.5
			-5.5	0.46	405	0.5
			-3.7	0.68	199	0.5
			-1.8	0.72	191	0.5
	12:17		-0.7	0.60	173	0.5
Temse ponton	12:44	6.1	-5.8	0.36	220	< 0.5
			-4.6	0.20	182	< 0.5
			-3.1	0.09	159	< 0.5
			-1.5	0.18	129	< 0.5
	12:52		-0.6	0.18	84	< 0.5
Mariekerke veerpont	13:33	5.5	-5.2	0.52	130	< 0.5
			-4.1	0.76	315	< 0.5
			-2.8	0.92	267	< 0.5
			-1.4	0.85	109	< 0.5
	13:40		-0.6	0.73	264	< 0.5

September 15, 2004						
locality	time MET	water depth m	sample depth %	water velocity m/s	SPM mg/l	salinity PSU
Vlassenbroek kapel	9:10	8.5	-8.1	0.55	284	< 0.5
			-6.4	0.85	231	< 0.5
			-4.3	1.04	301	< 0.5
			-2.1	1.24	257	< 0.5
	9:18		-0.9	0.91	166	< 0.5
Dendermonde ponton	9:30	7.4	-7.0	0.69	265	< 0.5
			-5.6	0.82	244	< 0.5
			-3.7	0.82	237	< 0.5
			-1.9	1.09	208	< 0.5
	9:36		-0.7	0.99	141	< 0.5
St. Onolfs 'bocht van Damme'	9:54	7	-6.7	1.01	234	< 0.5
			-5.3	1.06	242	< 0.5
			-3.5	1.15	233	< 0.5
			-1.8	1.28	245	< 0.5
	10:00		-0.7	1.17	252	< 0.5
Appels veerpont	10:16	6.1	-5.8	1.00	366	< 0.5
			-4.6	0.92	387	< 0.5
			-3.1	1.51	313	< 0.5
			-1.5	1.34	185	< 0.5
	10:22		-0.6	1.56	120	< 0.5
Uitbergen baanbrug	11:06	5.7	-5.4	0.46	758	< 0.5
			-4.3	0.97	547	< 0.5
			-2.9	1.12	399	< 0.5
			-1.4	1.18	286	< 0.5
	11:14		4.9	0.97	141	< 0.5
Wetteren baanbrug	11:47	5	-4.8		507	< 0.5
			-3.8		539	< 0.5
			-2.5		420	< 0.5
			-1.3		323	< 0.5
	11:55		-0.5		211	< 0.5
Melle baanbrug	12:20	4	-3.8	0.41	189	< 0.5
			-3.0	0.45	198	< 0.5
			-2.0	0.59	155	< 0.5
			-1.0	0.73	162	< 0.5
	12:29		-0.4	0.79	128	< 0.5

October 12, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
boei 87	8:35	7.8	-7.0	0.60	509	13.3
		7.8	-5.9	0.61	441	13.2
		7.8	-3.9	0.75	315	13.2
		7.8	-2.0	0.80	88	13.0
	8:40	7.8	-0.8	0.76	84	12.9
boei 92	9:11	12.6	-11.3	0.35	428	10.5
		12.6	-9.5	0.42	326	10.4
		12.6	-6.3	0.58	283	10.2
		12.6	-3.2	0.71	109	10.1
	9:18	12.6	-1.3	0.74	80	10.0
boei 105	9:45	6.8	-6.1	0.33	508	5.2
		6.8	-5.1	0.70	429	5.0
		6.8	-3.4	0.70	309	4.7
		6.8	-1.7	1.03	253	4.5
	9:50	6.8	-0.7	0.93	196	4.3
Antwerpen Steen	10:18	9.46	-8.5	0.38	252	1.5
		9.46	-7.1	0.45	221	1.5
		9.46	-4.7	0.59	183	1.4
		9.46	-2.4	0.65	97	1.3
	10:25	9.46	-0.9	0.75	66	1.3
Kruibeke Ponton	10:53	9.2	-8.3	0.15	202	0.8
		9.2	-6.9	0.28	162	0.8
		9.2	-4.6	0.24	132	0.8
		9.2	-2.3	0.22	112	0.8
	11:58	9.2	-0.9	0.18	75	0.8
Bazel ponton	11:13	5.2	-4.7	0.27	270	0.7
		5.2	-3.9	0.22	147	0.7
		5.2	-2.6	0.37	111	0.7
		5.2	-1.3	0.21	58	0.7
	11:23	5.2	-0.5	0.24	44	0.7
Steendorp kerk	10:04	6	-5.4	0.49	383	0.5
		6	-4.5	0.65	315	0.5
		6	-3.0	0.75	206	0.5
		6	-1.5	0.79	63	0.5
		6	-0.6	0.80	70	0.5
Temse ponton	12:09	6.9	-6.2	0.49	278	<0.5
		6.9	-5.2	0.64	263	<0.5
		6.9	-3.5	0.61	220	<0.5
		6.9	-1.7	0.66	214	<0.5
	12:17	6.9	-0.7	0.69	175	<0.5
Mariekerke veerpont	12:53	5.5	-5.0	0.32	392	<0.5
		5.5	-4.1	0.52	401	<0.5
		5.5	-2.8	0.58	322	<0.5
		5.5	-1.4	0.55	270	<0.5
		5.5	-0.6	0.63	184	<0.5

November 16, 2004						
locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
boei 87	9:25	9.2	-8.7	0.54	457	15.9
			-6.9	0.57	397	15.9
			-4.6	0.69	381	15.8
			-2.3	0.70	352	15.7
	9:33		-0.9	0.63	176	15.4
boei 92	10:00	13.9	-13.2	0.36	482	13.0
			-10.4	0.56	370	13.0
			-7.0	0.64	297	12.8
			-3.5	0.80	280	12.7
	10:05		-1.4	0.81	145	12.7
boei 105	10:39	8.6	-8.2	0.45	1288	8.8
			-6.5	0.95	457	8.7
			-4.3	1.10	244	8.6
			-2.2	1.33	222	8.5
	10:45		-0.9	1.52	188	8.4
Antwerpen Steen	11:14	10.6	-10.1	0.59	433	3.5
			-8.0	0.82	345	3.4
			-5.3	1.07	226	3.2
			-2.7	1.15	188	3.1
	11:20		-1.1	1.25	124	3.0
Kruibeke Ponton	11:48	9.4	-8.9	0.74	105	1.6
			-7.1	0.98	84	1.5
			-4.7	0.81	84	1.5
			-2.4	0.99	74	1.5
	11:54		-0.9	0.82	68	1.4
Bazel ponton	12:10	8.6	-8.2	0.84	238	1.1
			-6.5	0.30	195	1.1
			-4.3	0.44	151	1.1
			-2.2	0.41	148	1.1
	12:18		-0.9	0.45	144	1.1
Steendorp kerk	12:45	6.6	-6.3	0.35	246	0.7
			-5.0	0.64	233	0.7
			-3.3	0.85	201	0.7
			-1.7	0.86	191	0.7
	12:53		-0.7	0.96	167	0.7
Temse ponton	13:15	5.5	-5.2	0.64	521	0.6
			-4.1	0.93	439	0.6
			-2.8	1.03	450	0.6
			-1.4	1.05	396	0.6
	13:22		-0.6	1.08	360	0.6
Mariekerke veerpont	14:10	5.35	-5.1	0.38	391	<0.5
			-4.0	0.62	360	<0.5
			-2.7	0.64	392	<0.5
			-1.3	0.73	276	<0.5
	14:16		-0.5	0.60	329	<0.5

November 17, 2004

locality	time MET	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity PSU
Vlassenbroek kapel	9:26	10	-9.5	0.40	370	<0.5
			-7.5	0.48	246	<0.5
			-5.0	0.46	148	<0.5
			-2.5	0.60	148	<0.5
	9:31		-1.0	0.54	70	<0.5
Dendermonde ponton	9:45	7	-6.6	0.48	301	<0.5
			-5.5	0.57	244	<0.5
			-3.7	0.61	244	<0.5
			-1.8	0.72	195	<0.5
	9:51		-0.7	0.67	135	<0.5
St. Onolfs 'bocht van Damme'	10:06	6.6	-6.3	0.60	310	<0.5
			-5.2	0.63	257	<0.5
			-3.5	0.55	203	<0.5
			-1.7	0.66	232	<0.5
	10:14		-0.7	0.53	193	<0.5
Appels veerpont	10:35	7.7	-7.2	0.52	310	<0.5
			-6.0	0.52	271	<0.5
			-4.0	0.67	199	<0.5
			-2.0	0.64	124	<0.5
	10:41		-0.8	0.74	118	<0.5
Uitbergen baanbrug	11:22	5.8	-5.5	0.48	281	<0.5
			-4.6	0.64	280	<0.5
			-3.1	0.93	292	<0.5
			-1.5	0.88	232	<0.5
	11:29		-0.6	0.65	179	<0.5
Wetteren baanbrug	12:01	5.2	-5.0	0.65	274	<0.5
			-4.2	0.49	250	<0.5
			-2.8	0.82	223	<0.5
			-1.4	0.69	168	<0.5
	12:07		-0.6	0.86	219	<0.5
Melle baanbrug	12:33	4.2	-4.1	0.53	121	<0.5
			-3.4	0.48	115	<0.5
			-2.3	0.55	117	<0.5
			-1.1	0.61	97	<0.5
	12:40		-0.5	0.52	86	<0.5

December 7, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
boei 87	10:40	14.8	-13.3	0.28	43	14.3
			-11.1	0.46	41	14.3
			-7.4	0.72	32	13.5
			-3.7	0.52	15	12.8
	10:49		-1.5	0.65	9	12.3
boei 92	11:16	15.1	-13.6	0.26	51	11.5
			-11.3	0.32	42	11.5
			-7.6	0.46	37	11.5
			-3.8	0.25	34	11.4
	11:22		-1.5	0.05	32	11.3
boei 105	11:51	12.6	-11.3	0.05	72	8.9
			-9.5	0.14	73	8.9
			-6.3	0.21	43	8.8
			-3.2	0.15	24	8.8
	11:58		-1.3	0.14	7	8.6
Antwerpen Steen	12:24	14.3	-12.9	0.53	27	6.2
			-10.7	0.22	20	6.2
			-7.2	0.10	14	6.1
			-3.6	0.19	13	5.9
	12:30		-1.4	0.23	7	5.7
Kruibeke Ponton	12:54	14.5	-13.1	0.28	154	2.5
			-10.9	0.51	60	2.4
			-7.3	0.55	23	2.3
			-3.6	0.75	18	2.0
	13:01		-1.5	0.66	11	1.7
Bazel ponton	13:20	10	-9.0	0.58	93	0.8
		1	-7.5	0.76	73	0.8
			-5.0	1.01	59	0.8
			-2.5	1.10	47	0.8
	13:27		-1.0	1.13	40	0.8
Steendorp kerk	13:47	8.7	-7.8	0.13	69	< 0.5
			-6.5	0.21	65	< 0.5
			-4.4	0.64	60	< 0.5
			-2.2	0.72	57	< 0.5
	13:53		-0.9	0.76	44	< 0.5
Temse ponton	15:14	6.5	-5.9	0.92	64	< 0.5
			-4.9	0.79	70	< 0.5
			-3.3	0.29	70	< 0.5
			-1.6	0.57	65	< 0.5
	15:26		-0.7	0.72	63	< 0.5
Mariekerke veerpont	16:06	6.5	-5.9	0.47	214	< 0.5
			-4.9	0.53	188	< 0.5
			-3.3	0.80	183	< 0.5
			-1.6	0.79	127	< 0.5
	16:14		-0.7	0.72	119	< 0.5

December 8, 2004						
locality	**time MET**	**water depth m**	**sample depth m**	**water velocity m/s**	**SPM mg/l**	**salinity PSU**
Vlassenbroek kapel	9:30	7.3	-6.9		156	< 0.5
			-5.7		128	< 0.5
			-3.8		89	< 0.5
			-1.9		80	< 0.5
	9:34		-0.8		51	< 0.5
Dendermonde ponton	9:49	6.3	-6.0	0.39	240	< 0.5
			-5.0	0.25	163	< 0.5
			-3.3	0.38	120	< 0.5
			-1.7	0.28	116	< 0.5
	9:53		-0.7	0.31	71	< 0.5
St. Onolfs 'bocht van Damme'	10:12	7.8	-7.3	0.34	200	< 0.5
			-6.1	0.32	110	< 0.5
			-4.1	0.35	115	< 0.5
			-2.0	0.39	97	< 0.5
	10:20		-0.8	0.52	59	< 0.5
Appels veerpont	10:35	4.5	-4.4	0.37	137	< 0.5
			-3.6	0.50	107	< 0.5
			-2.4	0.78	106	< 0.5
			-1.2	0.64	68	< 0.5
	10:39		-0.5	0.71	84	< 0.5
Uitbergen baanbrug	11:17	3.8	-3.7	0.35	211	< 0.5
			-3.1	0.39	225	< 0.5
			-2.1	0.36	149	< 0.5
			-1.0	0.35	89	< 0.5
	5:31		-0.4	0.25	102	< 0.5
Wetteren baanbrug	11:57	3.4	-3.4	0.45	179	< 0.5
			-2.8	0.65	184	< 0.5
			-1.9	0.63	155	< 0.5
			-0.9	0.67	178	< 0.5
	12:01		-0.4	0.76	151	< 0.5
Melle baanbrug	12:29	3.1	-3.1	0.36	140	< 0.5
			-2.6	0.26	129	< 0.5
			-1.7	0.34	116	< 0.5
			-0.9	0.46	131	< 0.5
	12:33		-0.3	0.32	116	< 0.5

Suspended matter concentrations in the Westerschelde

		maart/23		april/01		juni/15	
locality	sample depth %	SPM mg/l	salinity PSU	SPM mg/l	salinity PSU	SPM mg/l	salinity PSU
Waarde	-90.0	83	6.8	86	19.5	49	20.6
	-75.0	77	6.7	93	19.3	39	20.3
	-50.0	74	6.6	89	19.3	38	19.5
	-25.0	39	6.5	69	19.3	28	18.0
	-10.0	34	6.5	63	19.3	20	17.6
Baalhoek	-90.0	50	6.8	50	15.7	36	15.1
	-75.0	70	6.7	50	15.7	43	15.4
	-50.0	98	6.6	93	15.3	38	15.2
	-25.0	177	6.5	190	14.8	27	14.8
	-10.0	144	6.5	172	14.8	31	14.8
Bath	-90.0	268	6.8	182	10.5	98	13.6
	-75.0	265	6.7	215	10.5	74	13.3
	-50.0	288	6.6	205	10.5	39	12.7
	-25.0	363	6.5	227	10.5	30	12.1
	-10.0	364	6.5	248	10.5	32	11.9

		juli/13		augustus/17		september/14	
locality	sample depth %	SPM mg/l	salinity PSU	SPM mg/l	salinity PSU	SPM mg/l	salinity PSU
Hansweert	-90.0	25	20.0	49	22.6	35	21.4
	-75.0	17	19.9	49	22.6	30	20.9
	-50.0	16	19.8	41	22.6	34	20.6
	-25.0	14	19.8	51	22.5	33	20.6
	-10.0	15	19.6	27	22.6	31	20.5
Baalhoek	-90.0	17	16.7	51	19.8	34	17.3
	-75.0	9	16.2	50	19.9	36	17.3
	-50.0	15	16.0	43	19.7	34	17.3
	-25.0	18	15.9	41	20.4	29	17.3
	-10.0	16	15.8	41	19.9	16	16.9
Bath	-90.0	72	14.0	117	14.4	69	14.0
	-75.0	50	14.0	102	14.5	68	13.8
	-50.0	33	14.0	88	14.4	66	13.8
	-25.0	32	14.0	70	14.3	52	13.6
	-10.0	25	13.8	83	14.5	46	13.5

		oktober/12		november/16		december/07	
locality	sample depth %	SPM mg/l	salinity PSU	SPM mg/l	salinity PSU	SPM mg/l	salinity PSU
Hansweert	-90.0	157	23.8	56	24.6	22	22.3
	-75.0	147	24.3	52	24.6	18	21.6
	-50.0	114	23.9	61	24.6	22	21.4
	-25.0	121	24.2	63	24.6	21	20.9
	-10.0	138	24.2	68	24.6	16	20.5
Baalhoek	-90.0	45	23.4	45	20.9	18	18.5
	-75.0	62	23.4	54	20.9	11	18.5
	-50.0	47	23.4	48	20.9	14	18.5
	-25.0	45	23.3	49	20.9	16	18.5
	-10.0	42	23.0	47	20.9	17	18.5
Bath	-90.0	58	21.0	146	16.5	28	16.2
	-75.0	37	20.3	182	16.5	25	15.9
	-50.0	37	20.2	149	16.5	35	15.6
	-25.0	37	20.2	116	16.2	30	15.5
	-10.0	33	20.2	98	16.2	23	15.2

Hour measurements of water velocity, suspended matter concentration and salinity

1. 13 hour measurements during summer season

   Kruibeke 29 June 2004
   Lippenbroek 28 June 2004
   Pas van Rilland (NL) 30 June 2004

2. 13 hour measurements during autumn season

   Lippenbroek 20 September 2004
   Kruibeke 21 September 2004
   Pas van Rilland (NL) 22 September 2004

KRUIBEKE - JUNE 29, 2004

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m^{-1}
1:00	8:33	9.3	-8.4	0.12	142	1.0	0.011
			-7.0	0.12	133	1.0	
			-4.7	0.20	97	1.0	
			-2.3	0.21	81	1.0	
			-0.9	0.23	44	0.9	
1:30	9:01	9.5	-8.6	0.25			
			-7.8	0.26			
			-7.1	0.30			
			-5.9	0.36			
			-4.8	0.47			
			-3.6	0.44			
			-2.4	0.41			
	9:11		-1.0	0.45			
2:00	9:30	11.4	-10.3	0.42	167	1.1	0.000
			-9.4	0.61			
			-8.6	0.73	111	1.1	
			-7.1	0.78			
			-5.7	0.82	93	1.1	
			-4.3	0.87			
			-2.9	0.93	59	1.1	
	9:39		-1.1	0.99	55	1.1	
3:00	10:30	12.7	-11.4	0.41	110	1.2	0.000
			-10.5	0.73			
			-9.5	0.86	90	1.2	
			-7.9	0.97			
			-6.4	0.97	82	1.2	
			-4.8	0.99			
			-3.2	0.98	82	1.2	
	10:41		-1.3	1.00	69	1.2	
4:00	11:30	13.7	-12.3	0.70	113	1.6	0.000
			-11.3	0.88			
			-10.3	0.86	97	1.6	
			-8.6	0.86			
			-6.9	0.95	86	1.6	
			-5.1	0.97			
			-3.4	1.02	90	1.6	
	11:40		-1.4	0.02	65	1.6	
5:00	12:30	14.1	-12.7	0.83	166	2.5	0.007
			-11.6	1.09			
			-10.6	1.20	123	2.6	
			-8.8	1.25			
			-7.1	1.28	117	2.6	
			-5.3	1.30			
			-3.5	1.24		2.6	
	12:40		-1.4	1.21	104	2.4	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m^{-1}
6:00	13:33	17.2	-15.5	0.84	355	4.5	0.006
			-14.2	0.92			
			-12.9	0.86	24	4.6	
			-10.8	0.83			
			-8.6	0.99	187	4.7	
			-6.5	0.99			
			-4.3	0.99	174	4.7	
			-1.7	0.81	150	4.4	
6:30	14:02	17	-15.3	0.43			
			-14.0	0.47			
			-12.8	0.62			
			-10.6	0.57			
			-8.5	0.61			
			-6.4	0.59			
			-4.3	0.49			
	14:11		-1.7	0.43			
7:00	14:27	16.2	-14.6	0.32	185	6.1	0.049
			-13.4	0.38			
			-12.2	0.34	180	6.1	
			-10.1	0.31			
			-8.1	0.55	175	6.2	
			-6.1	0.28			
			-4.1	0.26	138	6.1	
	14:39		-1.6	0.04	41	5.3	
7:30	15:03	15	-13.5	0.27			
			-12.4	0.38			
			-11.3	0.41			
			-9.4	0.42			
			-7.5	0.31			
			-5.6	0.44			
			-3.8	0.64			
	15:12		-1.5	0.78			
8:00	15:33	14.9	-13.4	0.38			
			-12.3	0.48			
			-11.2	0.57			
			-9.3	0.76			
			-7.5	0.89			
			-5.6	0.99			
			-3.7	1.06			
	15:42		-1.5	1.21			
8:30	16:03	14	-12.6	0.44	319	4.4	0.057
			-11.6	0.67			
			-10.5	0.73	262	4.2	
			-8.8	0.89			
			-7.0	0.99	192	4.0	
			-5.3	1.09			
			-3.5	1.16	168	3.8	
	16:10		-1.4	1.25	138	3.6	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m^{-1}
9:30	17:00	12.6	-11.3	0.77	222	2.7	0.032
			-10.4	0.67			
			-9.5	0.80	213	2.6	
			-7.9	0.95			
			-6.3	1.02	178	2.6	
			-4.7	1.10			
			-3.2	1.17	144	2.5	
	17:08		-1.3	1.21	75	2.3	
10:30	18:00	10.7	-9.6	0.59	152	1.8	0.009
			-8.8	0.79			
			-8.0	0.77	142	1.8	
			-6.7	0.89			
			-5.4	0.89	110	1.8	
			-4.0	1.02			
			-2.7	1.05	72	1.7	
	18:08		-1.1	1.07	59	1.7	
11:30	19:00	9.1	-8.2	0.73	157	1.4	0.000
			-7.5	0.76			
			-6.8	0.84	115	1.4	
			-5.7	0.85			
			-4.6	0.87	80	1.4	
			-3.4	0.91			
			-2.3	0.92	88	1.4	
	19:11		-0.9	0.99	66	1.4	
12:00	19:30	8.3	-7.5	0.68			
			-6.8	0.76			
			-6.2	0.70			
			-5.2	0.78			
			-4.2	0.82			
			-3.1	0.82			
			-2.1	0.87			
	19:40		-0.8	0.92			
12:30	20:00	8.1	-7.3	0.64	113	1.2	0.000
			-6.7	0.59			
			-6.1	0.59	151	1.2	
			-5.1	0.69			
			-4.1	0.74	120	1.2	
			-3.0	0.79			
			-2.0	0.81	63	1.2	
	20:09		-0.8	0.82	59	1.2	
13:00	20:30	8	-7.2	0.47			
			-6.6	0.51			
			-6.0	0.54			
			-5.0	0.57			
			-4.0	0.57			
			-3.0	0.63			
			-2.0	0.67			
			-0.8	0.67			

LIPPENBROEK - JUNE 28, 2004							
hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m⁻¹
1:00	9:04	8.5	-7.7	0.60	117	0.40	0.00
			-6.4	0.66	109	0.40	
			-4.3	0.73	94	0.40	
			-2.1	0.79	125	0.40	
	9:12		-0.9	0.84	149	0.40	
1:30	9:31	10.2	-9.2	0.54			
			-7.7	0.70			
			-5.1	0.80			
			-2.6	0.86			
	9:37		-1.0	0.86			
2:00	10:01	11.9	-10.7	0.57	130	0.40	0.00
			-9.8	0.73			
			-8.9	0.76	153	0.40	
			-7.4	0.84			
			-6.0	0.84	151	0.40	
			-4.5	0.78			
	10:08		-3.0	0.83	149	0.40	
			-1.2				
2:30	10:30	11.6	-10.4	0.60			
			-9.6	0.52			
			-8.7	0.70			
			-7.3	0.84			
			-5.8	0.91			
			-4.4	0.83			
			-2.9	0.83			
	10:38		-1.2	0.85			
3:00	11:00	11.6	-10.4	0.64	127	0.50	0.00
			-9.6	0.62			
			-8.7	0.75	125	0.50	
			-7.3	0.89			
			-5.8	0.87	116	0.50	
			-4.4	0.86			
			-2.9	0.87	107	0.50	
	11:10		-1.2	0.89	82	0.50	
3:30	11:30	10.9	-9.8	0.80			
			-9.0	0.88			
			-8.2	0.90			
			-6.8	0.90			
			-5.5	0.96			
			-4.1	1.02			
			-2.7	1.01			
			-1.1	0.92			

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
4:00	12:00	12.8	-11.5	0.86	180	0.70	0.00
			-10.6	0.89			
			-9.6	1.02	150	0.70	
			-8.0	1.09			
			-6.4	1.03	130	0.70	
			-4.8	1.07			
			-3.2	1.11	130	0.70	
	12:09		-1.3	0.95	126	0.70	
4:30	12:30	14.7	-13.2	0.76			
			-12.1	0.92			
			-11.0	0.92			
			-9.2	0.93			
			-7.4	0.94			
			-5.5	0.94			
			-3.7	0.91			
			-1.5	0.91			
5:00	13:00	13.7	-12.3	0.67	124	0.80	0.00
			-11.3	0.68			
			-10.3	0.76	96	0.80	
			-8.6	0.77			
			-6.9	0.78	106	0.80	
			-5.1	0.68			
			-3.4	0.78	29	0.80	
	13:11		-1.4	0.75	73	0.80	
5:30	13:32	15.1	-13.6	0.44			
			-12.5	0.37			
			-11.3	0.42			
			-9.4	0.44			
			-7.6	0.47			
			-5.7	0.43			
			-3.8	0.36			
	13:42		-1.5	0.27			
6:00	14:00	13.7	-12.3	0.09	79	0.80	0.00
			-11.3	0.13			
			-10.3	0.10	78	0.80	
			-8.6	0.08			
			-6.9	0.10	52	0.80	
			-5.1	0.09			
			-3.4	0.08	29	0.80	
	14:08		-1.4	0.06	20	0.80	
6:30	14:30	11.3	-10.2	0.29			
			-9.3	0.29			
			-8.5	0.28			
			-7.1	0.31			
			-5.7	0.32			
			-4.2	0.36			
			-2.8	0.06			
	14:40		-1.1	0.41			

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m^{-1}
7:00	14:59	9.6	-8.6	0.37	112	0.80	0.00
			-7.9	0.47			
			-7.2	0.45	77	0.80	
			-6.0	0.50			
			-4.8	0.54	78	0.80	
			-3.6	0.53			
			-2.4	0.54	53	0.80	
	15:12		-1.0	0.54	109	0.80	
7:30	15:30	8.8	-7.9	0.41			
			-7.3	0.48			
			-6.6	0.51			
			-5.5	0.55			
			-4.4	0.58			
			-3.3	0.64			
			-2.2	0.62			
			-0.9	0.57			
8:00	16:00	7.9	-7.1	0.35	161	0.70	0.00
			-6.5	0.44			
			-5.9	0.44	145	0.70	
			-4.9	0.47			
			-4.0	0.51	104	0.70	
			-3.0	0.60			
			-2.0	0.59	76	0.70	
	16:10		-0.8	0.60	82	0.70	
8:30	16:30	7.4	-6.7	0.32			
			-6.1	0.44			
			-5.6	0.49			
			-4.6	0.53			
			-3.7	0.53			
			-2.8	0.58			
			-1.9	0.60			
			-0.7	0.57			
9:00	17:00	7.2	-6.5	0.35	284	0.60	0.00
			-5.9	0.39			
			-5.4	0.42	237	0.60	
			-4.5	0.49			
			-3.6	0.56	183	0.60	
			-2.7	0.61			
			-1.8	0.63			
	17:11		-0.7	0.56	120	0.60	
9:30	17:30	6.5	-5.9	0.37			
			-5.4	0.53			
			-4.9	0.47			
			-4.1	0.41			
			-3.3	0.50			
			-2.4	0.60			
			-1.6	0.67			
	17:40		-0.7	0.63			

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m^{-1}
10:00	18:00	6.5	-5.9	0.72	204	0.60	0.09
			-5.4	0.73			
			-4.9	0.75	228	0.60	
			-4.1	0.69			
			-3.3	0.71	136	0.6	
			-2.4	0.78			
			-1.6	0.73	177	0.6	
			-0.7	0.76			
10:30	18:30	7.0	-6.3	0.70			
			-5.8	0.68			
			-5.3	0.75			
			-4.4	0.77			
			-3.5	0.73			
			-2.6	0.71			
			-1.8	0.79			
	18:40		-0.7	0.81			
11:00	19:00	6.7	-6.0	0.57	199	0.5	0.00
			-5.5	0.71			
			-5.0	0.72	210	0.5	
			-4.2	0.74			
			-3.4	0.73	181	0.5	
			-2.5	0.73			
			-1.7	0.73	169	0.5	
	19:09		-0.7	0.74	144	0.5	
11:30	19:30	7.0	-6.3	0.60			
			-5.8	0.65			
			-5.3	0.67			
			-4.4	0.71			
			-3.5	0.74			
			-2.6	0.70			
			-1.8	0.70			
	19:40		-0.7	0.70			
12:00	20:01	7.0	-6.3	0.53	190	0.4	0.00
			-5.8	0.62			
			-5.3	0.56	187	0.4	
			-4.4	0.61			
			-3.5	0.62	165	0.4	
			-2.6	0.67			
			-1.8	0.67	125	0.4	
			-0.7	0.67	112	0.4	
12:30	20:30	6.9	-6.2	0.35			
			-5.7	0.34			
			-5.2	0.34			
			-4.3	0.30			
			-3.5	0.27			
			-2.6	0.24			
			-1.7	0.20			
			-0.7	0.27			

Pas Van Rilland - JUNE 30, 2004

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m^{-1}
1:00	9:00	5.5	-5.0	0.34	44	13.10	0.16
			-4.5	0.23			
			-4.1	0.20	38	12.50	
			-3.4	0.12			
			-2.8	0.11	34	12.30	
			-2.1	0.08			
			-1.4	0.08	36	12.20	
	9:13		-0.6	0.09	29	12.20	
1:30	9:34	10.4	-9.4	0.37			
			-8.6	0.49			
			-7.8	0.56			
			-6.5	0.41			
			-5.2	0.39			
			-3.9	0.43			
			-2.6	0.38			
	9:45		-1.0	0.33			
2:00	10:00	12.0	-10.8	0.67	52	13.50	0.00
			-9.9	0.69			
			-9.0	0.67	67	13.50	
			-7.5	0.78			
			-6.0	0.77	49	13.50	
			-4.5	0.74			
			-3.0	0.75	66	13.50	
	10:13		-1.2	0.74	25	13.50	
3:00	11:04	14.8	-13.3	0.47	357	14.30	0.01
			-12.2	0.58			
			-11.1	0.63	176	14.30	
			-9.3	0.69			
			-7.4	0.72	151		
			-5.6	0.75		14.30	
			-3.7	0.76	98	14.30	
			-1.5	0.74	36	14.10	
4:00	12:00	15.5	-14.0	0.50	218	14.80	0.01
			-12.8	0.57			
			-11.6	0.63	155	14.80	
			-9.7	0.63			
			-7.8	0.68	98	14.80	
			-5.8	0.59			
			-3.9	0.59	89	14.80	
	12:12		-1.6	0.70	64	14.70	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m^{-1}
5:00	13:03	16.0	-14.4	0.77	78	16.20	0.02
			-13.2	0.79			
			-12.0	0.84	70	16.20	
			-10.0	0.88			
			-8.0	0.98	73	16.20	
			-6.0	1.01			
			-4.0	1.03	53	16.10	
	13:14		-1.6	0.99	48	15.90	
6:00	14:20	16.6	-14.9	0.02	70	19.10	1.15
			-13.7	0.02			
			-12.5	0.02	64	18.90	
			-10.4	0.02			
			-8.3	0.02	45	18.60	
			-6.2	0.02			
			-4.2	0.02	50	18.20	
			-1.7	0.02	32		
7:00	15:02	16.2	-14.6	0.17	39	19.10	0.16
			-13.4	0.22			
			-12.2	0.19	33	18.80	
			-10.1	0.24			
			-8.1	0.13	32	18.20	
			-6.1	0.27			
			-4.1	0.19	23	17.00	
	15:16		-1.6	0.29	39	16.50	
8:00	16:00	15.6	-14.0	0.44	34	17.40	0.12
			-12.9	0.47			
			-11.7	0.61	25	16.30	
			-9.8	0.58			
			-7.8	0.60	25	16.10	
			-5.9	0.57			
			-3.9	0.61	26	16.10	
	16:10		-1.6	0.79	25	15.60	
9:00	17:00	15.3	-13.8	0.45	79	16.00	0.09
			-12.6	0.59			
			-11.5	0.54	109	15.20	
			-9.6	0.48			
			-7.7	0.82	66	14.90	
			-5.7	0.77			
			-3.8	0.83	71	14.80	
	17:15		-1.5	1.26	59	14.60	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient $psu.m^{-1}$
10:00	18:00	13.9	-12.5	0.37	56	15.30	0.06
			-11.5	0.35			
			-10.4	0.44	62	14.90	
			-8.7	0.35			
			-7.0	0.39	97	14.70	
			-5.2	0.36			
			-3.5	0.33	101	14.60	
			-1.4	0.36	87	14.50	
11:00	19:00	12.7	-11.4	0.29	85	15.10	0.11
			-10.5	0.18			
			-9.5	0.16	82	14.30	
			-7.9	0.21			
			-6.4	0.28	128	14.10	
			-4.8	0.30			
			-3.2	0.38	90	13.80	
	19:07		-1.3	0.32	83	13.70	
11:30	19:40	12.9	-11.6	0.17			
			-10.6	0.18			
			-9.7	0.23			
			-8.1	0.26			
			-6.5	0.38			
			-4.8	0.45			
			-3.2	0.51			
	19:48		-1.3	0.12			
12:00	19:57	12.0	-10.8	0.18	93	13.90	0.04
			-9.9	0.15			
			-9.0	0.17	106	14.00	
			-7.5	0.17			
			-6.0	0.27	111	13.60	
			-4.5	0.47			
			-3.0	0.59	76	13.30	
			-1.2	0.23	80	13.40	

LIPPENBROEK - SEPTEMBER 20, 2004					
hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l
1:00	10:16	10.5	-10.0	0.25	32
			-9.5	1.45	
			-8.7	1.89	
			-7.9	0.49	7
			-6.6	2.60	
			-5.3	2.74	
			-4.2	2.50	0
			-2.6	0.92	
			-1.8	1.43	
	10:26		-1.1	1.54	5
2:00	11:02	9.6	-9.1	0.44	206
			-8.6	1.34	184
			-7.9	1.29	
			-7.2	0.88	182
			-6.0	1.01	
			-4.8	1.26	101
			-3.8	1.59	105
			-2.4	0.67	42
			-1.7	0.65	
	11:12		-1.0	0.66	47
3:00	12:05	8.5	-8.1	1.22	278
			-7.7	3.09	264
			-7.0	2.40	
			-6.4	2.37	262
			-5.3	2.65	
			-4.3	2.70	171
			-3.4	2.36	100
			-2.1	0.74	66
			-1.5	0.96	
	12:13		-0.9	0.78	91
4:00	13:01	7.8	-7.4	0.52	378
			-7.0	0.48	319
			-6.4	0.57	
			-5.9	2.64	355
			-4.9	0.77	
			-3.9	0.85	313
			-3.1	0.64	317
			-2.0	0.72	188
			-1.4	0.70	
	13:12		-0.8	0.70	132

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l
5:00	14:02	7	-6.7	0.48	382
			-6.3	0.49	369
			-5.8	0.58	
			-5.3	0.71	301
			-4.4	0.67	
			-3.5	0.73	220
			-2.8	0.74	214
			-1.8	0.70	170
			-1.2	0.63	
	14:11		-0.7	0.59	228
6:00	15:04	6.5	-6.2	0.50	443
			-5.9	0.64	391
			-5.4	0.62	
			-4.9	0.62	379
			-4.1	0.76	
			-3.3	0.75	218
			-2.6	0.74	229
			-1.6	0.75	186
			-1.1	0.78	
	15:11		-0.7	0.81	157
7:00	16:02	6	-5.7	0.47	390
			-5.4	0.49	328
			-5.0	0.50	
			-4.5	0.52	364
			-3.8	0.53	
			-3.0	0.54	362
			-2.4	0.58	272
			-1.5	0.55	225
			-1.1	0.58	
	16:10		-0.6	0.56	111
7:30	16:26	6.8	-6.5	0.13	
			-6.1	0.20	
			-5.6	0.24	
			-5.1	0.18	
			-4.3	0.25	
			-3.4	0.24	
			-2.7	0.22	
			-1.7	0.24	
			-1.2	0.25	
	16:32		-0.7	0.22	
8:00	17:03	8.2	-7.8	0.69	98
			-7.4	0.78	145
			-6.8	0.76	
			-6.2	0.84	134
			-5.1	0.82	
			-4.1	0.88	113
			-3.3	0.81	148
			-2.1	0.49	126
			-1.4	0.74	
	17:11		-0.8	0.95	153

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l
9:00	18:06	8.6	-8.2	0.61	265
			-7.7	0.67	268
			-7.1	0.72	
			-6.5	0.67	266
			-5.4	0.53	
			-4.3	0.72	242
			-3.4	0.92	189
			-2.2	0.82	185
			-1.5	0.74	
	18:14		-0.9	0.76	173
10:00	19:00	9.1	-8.6	0.82	219
			-8.2	0.89	172
			-7.5	0.91	
			-6.8	0.91	130
			-5.7	0.88	
			-4.6	0.92	144
			-3.6	1.08	155
			-2.3	1.08	141
			-1.6	0.95	
	19:09		-0.9	0.87	149
11:00	20:02	10.9	-10.4	1.11	207
			-9.8	0.95	215
			-9.0	1.26	
			-8.2	1.07	163
			-6.8	1.24	
			-5.5	1.23	189
			-4.4	1.26	216
			-2.7	1.33	208
			-1.9	1.28	
	20:10		-1.1	1.14	159
12:00	21:05	13	-12.4	0.61	136
			-11.7	0.55	139
			-10.7	0.67	
			-9.8	0.64	134
			-8.1	0.74	
			-6.5	0.68	102
			-5.2	0.73	104
			-3.3	0.71	80
			-2.3	0.64	
	21:12		-1.3	0.59	70
13:00	21:55	13.5	-12.8	0.23	
			-12.2	0.13	
			-11.1	0.16	
			-10.1	0.23	
			-8.4	0.24	
			-6.8	0.22	
			-5.4	0.28	
			-3.4	0.24	
			-2.4	0.20	
	22:02		-1.4	0.18	

KRUIBEKE - SEPTEMBER 21, 2004							
hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
1:00	9:38	15.1	-14.3	0.31	226	7.90	0.02
			-13.6	0.23	191	8.00	
			-12.5	0.24			
			-11.3	0.23	228	8.00	
			-9.4	0.25			
			-7.6	0.31		7.90	
			-6.0	0.26	160	7.80	
			-3.8	0.14	158	7.80	
			-2.6	0.11			
	9:46		-1.5	0.02	57	7.60	
2:00	10:36	13.6	-12.9	0.49	216	7.30	0.07
			-12.2	0.44	256	7.20	
			-11.2	0.52			
			-10.2	0.54		7.20	
			-8.5	0.60			
			-6.8	0.72	142	7.10	
			-5.4	0.80	131	7.00	
			-3.4	0.89	75	6.80	
			-2.4	0.96			
	10:44		-1.4	1.04	25	6.40	
3:00	11:34	11.6	-11.0	0.36	399	5.40	0.05
			-10.4	0.43	333	5.40	
			-9.6	0.22			
			-8.7	0.27		5.30	
			-7.3	0.85			
			-5.8	0.83	215	5.10	
			-4.6	1.02	237	5.20	
			-2.9	1.10	211	4.90	
			-2.0	1.07			
	11:42		-1.2	1.09	162	4.80	
4:00	12:40	10.5	-10.0	0.53	250	3.40	0.03
			-9.5	0.56	267	3.40	
			-8.7	0.64			
			-7.9	0.74		3.30	
			-6.6	0.76			
			-5.3	1.00	143	3.20	
			-4.2	0.97	170	3.20	
			-2.6	1.08	141	3.10	
			-1.8	1.07			
	12:47		-1.1	1.14	141	3.10	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
5:00	13:36	9.6	-9.1	0.40	181	2.60	0.01
			-8.6	0.33	175	2.60	
			-7.9	0.45			
			-7.2	0.57		2.60	
			-6.0	0.55			
			-4.8	0.77	129	2.50	
			-3.8	0.92	139	2.50	
			-2.4	0.92	107	2.40	
			-1.7	0.83			
	13:43		-1.0	0.92	143	2.50	
6:00	14:32	9.5	-9.0	0.32	171	2.10	0.01
			-8.6	0.32	173	2.10	
			-7.8	0.39			
			-7.1	0.34	153	2.10	
			-5.9	0.41			
			-4.8	0.49	152	2.10	
			-3.8	0.51	143	2.10	
			-2.4	0.48	110	2.00	
			-1.7	0.51			
	14:38		-1.0	0.55	113	2.00	
7:00	15:32	9.4	-8.9	0.09	133	1.70	0.01
			-8.5	0.06	135	1.70	
			-7.8	0.15			
			-7.1	0.12	116	1.70	
			-5.9	0.13			
			-4.7	0.39	85	1.70	
			-3.8	0.42	79	1.70	
			-2.4	0.28	59	1.60	
			-1.6	0.46			
	15:39		-0.9	0.44	77	1.60	
7:45	16:14	9.2	-8.7	0.11			0.00
			-8.3	0.08			
			-7.6	0.10			
			-6.9	0.13			
			-5.8	0.11			
			-4.6	0.09			
			-3.7	0.07			
			-2.3	0.04			
			-1.6	0.05			
	16:18		-0.9	0.07			

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
8:00	16:32	10.5	-10.0	0.17	117	1.60	0.03
			-9.5	0.20	64	1.60	
			-8.7	0.23			
			-7.9	0.29	31	1.50	
			-6.6	0.28			
			-5.3	0.22	25	1.50	
			-4.2	0.23	22	1.40	
			-2.6	0.23	17	1.40	
			-1.8	0.24			
	16:39		-1.1	0.26	10	1.30	
9:00	17:36	11.5	-10.9	0.85	193	1.80	0.00
			-10.4	0.86	169	1.80	
			-9.5	0.89			
			-8.6	1.03	160	1.80	
			-7.2	1.12			
			-5.8	1.00	96	1.80	
			-4.6	1.01	103	1.80	
			-2.9	1.03	75	1.80	
			-2.0	0.89			
	17:42		-1.2	0.80	80	1.80	
10:00	18:30	12.7	-12.1	0.47	89	2.30	0.00
			-11.4	0.71	85	2.40	
			-10.5	0.83			
			-9.5	0.95	71	2.40	
			-7.9	1.01			
			-6.4	0.95	82	2.40	
			-5.1	0.87	76	2.50	
			-3.2	0.54	65	2.30	
			-2.2	0.44			
	18:39		-1.3	0.42	56	2.30	
11:00	19:30	13.5	-12.8	0.48	168	3.10	0.00
			-12.2	0.62	177	3.10	
			-11.1	0.71			
			-10.1	0.94	136	3.20	
			-8.4	0.79			
			-6.8	0.87		3.10	
			-5.4	0.85	122	3.20	
			-3.4	0.53	132	3.10	
			-2.4	0.63			
	19:36		-1.4	0.52	101	3.10	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
12:00	20:34	14.3	-13.6	0.78	124	4.80	-0.01
			-12.9	0.79	206	4.90	
			-11.8	1.14			
			-10.7	1.22	163	5.00	
			-8.9	1.40			
			-7.2	1.37	127	5.00	
			-5.7	1.34		4.90	
			-3.6	1.20	133	5.00	
			-2.5	1.30			
	20:40		-1.4	1.20	109	5.00	
13:00	21:40	15.1	-14.3	0.60			
			-13.6	0.42			
			-12.5	0.48			
			-11.3	0.48			
			-9.4	0.50			
			-7.6	0.46			
			-6.0	0.56			
			-3.8	0.51			
			-2.6	0.50			
	21:44		-1.5	0.42			

PAS VAN RILLAND - SEPTEMBER 22, 2004							
hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
1:00	9:14	11.6	-11.0	0.31	68	18.70	0.01
			-10.4	0.29	61	18.70	
			-9.6	0.31			
			-8.7	0.38	58	18.70	
			-7.3	0.38			
			-5.8	0.29	69	18.70	
			-4.6	0.29	58	18.70	
			-2.9	0.12	39	18.70	
			-2.0	0.56			
	9:22		-1.2	0.63	18	18.60	
2:00	10:02	11	-10.5	0.30	21	18.90	0.01
			-9.9	0.41			
			-9.1	0.41			
			-8.3	0.29			
			-6.9	0.23			
			-5.5	0.10	6	18.80	
			-4.4	0.16			
			-2.8	0.29			
			-1.9	0.47			
	10:08		-1.1	0.40	10	18.80	
3:00	11:03	10.4	-9.9	0.33	15	18.30	0.05
			-9.4	0.33			
			-8.6	0.40			
			-7.8	0.40			
			-6.5	0.39			
			-5.2	0.41			
			-4.2	0.49	6	18.00	
			-2.6	0.47			
			-1.8	0.37			
	11:10		-1.0	0.32	7	17.80	
4:00	12:05	11	-10.5	0.54	82	15.60	-0.11
			-9.9	0.29			
			-9.1	0.39			
			-8.3	0.44			
			-6.9	0.48			
			-5.5	0.56			
			-4.4	0.72	19	15.70	
			-2.8	0.80			
			-1.9	0.82			
			-1.1	0.85	24	16.80	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
5:00	12:59	8.9	-8.5	0.22	66	16.10	0.06
			-8.0	0.21			
			-7.3	0.28			
			-6.7	0.32			
			-5.6	0.35			
			-4.5	0.23			
			-3.6	0.23	47	15.70	
			-2.2	0.23			
			-1.6	0.36			
	13:06		-0.9	0.28	41	15.60	
6:00	14:00	7.9	-7.5	0.14	90	15.40	0.03
			-7.1	0.20			
			-6.5	0.20			
			-5.9	0.14			
			-4.9	0.26			
			-4.0	0.20			
			-3.2	0.32	52	15.30	
			-2.0	0.23			
			-1.4	0.18			
	14:10		-0.8	0.19	50	15.20	
7:00	15:02	7.3	-6.9	0.24	114	15.80	0.16
			-6.6	0.23	66	15.50	
			-6.0	0.24			
			-5.5	0.19	102	15.00	
			-4.6	0.13			
			-3.7	0.24	88	14.70	
			-2.9	0.32	94	14.60	
			-1.8	0.23	93	14.60	
			-1.3	0.19			
	15:11		-0.7	0.19	89	14.60	
8:00	16:00	7	-6.7	0.43	60	15.30	0.19
			-6.3	0.24	52	14.80	
			-5.8	0.15			
			-5.3	0.43	51	14.90	
			-4.4	0.57			
			-3.5	0.35	50	14.60	
			-2.8	0.43	50	14.40	
			-1.8	0.43	39	14.20	
			-1.2	0.38			
	16:06		-0.7	0.32	41	14.00	

hour	time	water depth m	sample depth m	water velocity m/s	SPM mg/l	salinity	salinity gradient psu.m-1
9:00	17:02	7.8	-7.4	0.38	75	15.10	0.05
			-7.0	0.34	87	15.00	
			-6.4	0.45			
			-5.9	0.46	41	14.90	
			-4.9	0.42			
			-3.9	0.39	33	14.80	
			-3.1	0.43	28	14.60	
			-2.0	0.40	29	14.70	
			-1.4	0.42			
	17:10		-0.8	0.48	24	14.70	
10:00	18:05	8.7	-8.3	0.41	122	15.50	0.01
			-7.8	0.50	96	15.40	
			-7.2	0.51			
			-6.5	0.61	82	15.40	
			-5.4	0.62			
			-4.4	0.68	58	15.40	
			-3.5	0.63	71	15.40	
			-2.2	0.69	49	15.40	
			-1.5	0.67			
	18:10		-0.9	0.62	29	15.40	
11:00	19:02	9.3	-8.8	0.36	124	16.10	0.00
			-8.4	0.41	136	16.10	
			-7.7	0.32			
			-7.0	0.45	119	16.10	
			-5.8	0.54			
			-4.7	0.50	83	16.10	
			-3.7	0.58	91	16.10	
			-2.3	0.61	91	16.10	
			-1.6	0.58			
	19:07		-0.9	0.64	88	16.10	
12:00	20:02	10.5	-10.0	0.62	146	16.80	0.01
			-9.5	0.35	147	16.80	
			-8.7	0.51			
			-7.9	0.56	133	16.90	
			-6.6	0.58			
			-5.3	0.67	148	16.90	
			-4.2	0.56	164	16.90	
			-2.6	0.58	49	16.90	
			-1.8	0.49			
	20:07		-1.1	0.59	20	16.70	
13:00	9:02	11.04	-10.5	0.32			
			-9.9	0.47			
			-9.1	0.43			
			-8.3	0.36			
			-6.9	0.47			
			-5.5	0.49			
			-4.4	0.42			
			-2.8	0.53			
			-1.9	0.50			
	9:09		-1.1	0.59			

Hoofdstuk 6. Fytoplankton: resultaten van 2004 en vergelijking met vorige jaren

Monitoring phytoplankton: Results from 2004 and comparison with previous years.

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6.1. Monitoring of phytoplankton biomass and communities composition

6.1.1. Methodology microscopical analyses

Phytoplankton biomass and community composition were monitored in two ways. The first approach was by means of microscopical analysis of fixed plankton samples. A 50 ml water sample was fixed with acid Lugol's solution. To ensure long-term storage, samples were post-fixed with formalin (5% final concentration) in the lab within 3 months of sampling. The samples were analyzed using inverted microscopy. Therefore, a 5 to 10 ml subsample was transferred to a sedimentation chamber and phytoplankton cells were allowed to settle for one day. The sedimentation chamber was inspected by means of an inverted microscope (Zeiss Axiovert) at a magnification of 200 to 400 times. Identification was carried out to the species level or, where identification was impossible, by means of light microscopy up to the genus level. A fixed number of 100 phytoplankton 'units' were enumerated in each sample. A 'unit' corresponded to a phytoplankton cell, a coenobium or a colony. For each phytoplankton species or genus, 15 units were measured to estimate the biovolume. The total biovolume of each species or genus was then multiplied with its abundance to estimate the biovolume concentration in the sample. Using published conversion factors (Menden-Duer & Lessard, 2000), biovolume was converted to biomass (in µg C l^{-1}). These biomass data take into account a decrease in volume-specific biomass with an increase in cell size and differences in carbon content between different taxonomic groups.

6.1.2. Methodology HPLC analysis

The second approach for studying phytoplankton biomass and community composition was by means of HPLC pigment analysis. This approach is based on the fact that all phytoplankton cells contain pigments. These pigments are used either for photosynthesis or for protecting the photosynthetic apparatus against high light intensities. The pigment chlorophyll a is present in all phytoplankton groups and is therefore used as measure for total phytoplankton biomass. Other pigments are specific for one or only a few phytoplankton groups. For instance, diatoms contain the pigments chlorophyll c, fucoxanthin, diatoxanthin and diadinoxanthin in addition to chlorophyll a. Chlorophytes contain the pigments chlorophyll b, lutein, neoxanthin and violaxanthin in addition to chlorophyll a. Other algae, like euglenophytes, have pigments that are typical of diatoms (diadinoxanthin) or chlorophytes (chlorophyll b).

Phytoplankton and the pigments that are present in their cells are collected by filtering a known volume of water over a glass fiber filter (GF/F filter). This filter is immediately frozen and stored at a very low temperature (-80°C) to avoid degradation of the pigments. Phytoplankton pigments are lipophylic and therefore they were extracted in an organic solvent (acetone). Sonnication by means of a tip-sonnicator was used to destroy the phytoplankton cells and to make sure all pigments present on the filter were extracted in the solvent. The pigment extract was then injected into a Gilson HPLC or High Performance Liquid Chromatography system. This HPLC system is used in the first place to separate the different pigments present in the pigment extract. In the HPLC systems, the pigment extract has to travel through a 25 cm long chromatographical column packed with microspheres coated with an organic layer. A gradient of solvents is used to flush the pigments through the column. As some pigments move faster through the column than others, the column separates the pigments from one another. At the end of the column, absorbance and fluorescence detectors are placed which monitor the pigments leaving the column. The detectors yield a time-series graph with peaks in absorbance and fluorescence corresponding to different pigments leaving the column.

Each pigments travels at a fixed speed through the column. Therefore, the time at which a peak in absorbance or fluorescence is observed or the retention time can be used to identify the pigment associated with this peak. The surface of the peak can be used to quantify the amount of pigment that was present in the extract. By comparing retention times and peak surfaces with analysis of pure pigment extracts of known concentration, we can identify the pigment associated with the peak and calculate its concentration.

Moreover, we use a DAD or diode array detector to measure the absorption spectrum for each pigment. This absorption spectrum is unique for each pigment and is used in addition to retention time to identify the pigments. Our HPLC system was set up according to the method of Wright & Jeffrey (1997).

6.1.3. Methodology CHEMTAX analysis

Based on the different pigments, other than chlorophyll a, that are present in the samples, one can evaluate which phytoplankton groups are present. For instance, if high concentrations of fucoxanthin are found, this usually indicates a dominance of diatoms. If large concentrations of lutein are present, this indicates a dominance of chlorophytes. High concentrations of chlorophyll b and diadinoxanthin in the absence of lutein or fucoxanthin indicate the presence of euglenophytes. Using a software package especially developed for the analysis of phytoplankton pigment data (CHEMTAX, Mackey et al., 1996), the exact contribution of each phytoplankton groups to total chlorophyll a concentration or total phytoplankton biomass can be estimated.

CHEMTAX is a program that calculates phytoplankton class abundances from measurements of chlorophyll and carotenoid pigments determined by HPLC. To apply CHEMTAX, concentrations of all marker pigments, a theoretical matrix of marker pigment to chlorophyll a ratio's in each phytoplankton class and a limit matrix are necessary. The ratio matrix should be adapted to the environment studied. The ratio of a marker pigment to chlorophyll a for a given algal class can be found in the literature, it can be derived from a comparison of pigment data with microscopical analysis or it can be based on analysis of pure phytoplankton cultures. The limit matrix is used to fix boundaries during the calculation for the variations of the pigment ratios which have been entered. The program CHEMTAX divides the total concentration of chlorophyll a between phytoplankton class and we obtain a result in equivalent amounts of chlorophyll a for each phytoplankton class.

6.1.4. Phytoplankton community composition

As in 2003, phytoplankton biomass in the Schelde estuary in 2004 was dominated by diatoms (Figure 1). In winter, the dominant species along the estuary was *Stephanodiscus* sp. and a succession of minor species occurred from freshwater reaches to polyhaline zone. *Cyclotella scaldensis* in the freshwater reaches was replaced by *Nitzschia acicularis*, *Actinocyclus normannii* and *Aulacosira granulata* in the oligohaline zone, by *Chaetoceros subtilis* in the mesohaline zone. In summer, *Stephanodiscus* sp. was still present but winter-minor-species tended to be dominant. In contrast with 2003 (where green algae were important only in summer), in 2004, chlorophytes were present in a relatively large amount throughout the year and especially during spring time in the freshwater part with *Scenedesmus* spp., *Monoraphidium contortum*, *Tetrastrum komarekii* and *Crucigenia tetrapedia* as dominant species. Cyanobacteria, cryptophytes, euglenophytes and dinophytes were observed in the samples but never attained high biomass.

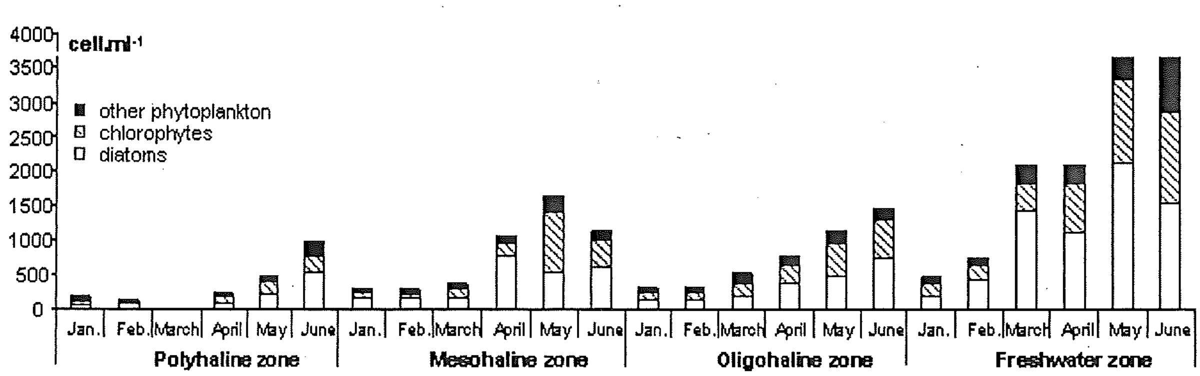


Figure 1: Phytoplankton density in cell.ml^{-1} divide in diatoms, chlorophytes and other phytoplankton groups (euglenophytes, cryptophytes, chrysophytes, cyanobacteria and dinophytes) in the polyhaline, mesohaline, oligohaline and freshwater zones of the Schelde estuary in 2004.

In the Schelde River (BS) (Figure 2) and in the most upstream part of the estuary, *Stephanodiscus* sp. was the dominant species in winter. From spring onwards, green algae gained importance and species like *Scenedesmus* sp. and *Tetrastrum komarekii* dominated the phytoplankton community in June. In the Dender River, *Stephanodiscus* sp. was dominant in winter with also a non negligible amount of cryptophytes (*Rhodomonas* sp. and *Cryptomonas* sp.). In spring, green algae dominated the phytoplankton community with *Scenedesmus* sp. and *Monoraphidium* *contortum* as the dominant species. In the Rupel tributary, diatoms were dominant in winter (*Stephanodiscus* sp.) and green algae like *Scenedesmus* sp. became more important towards summer.

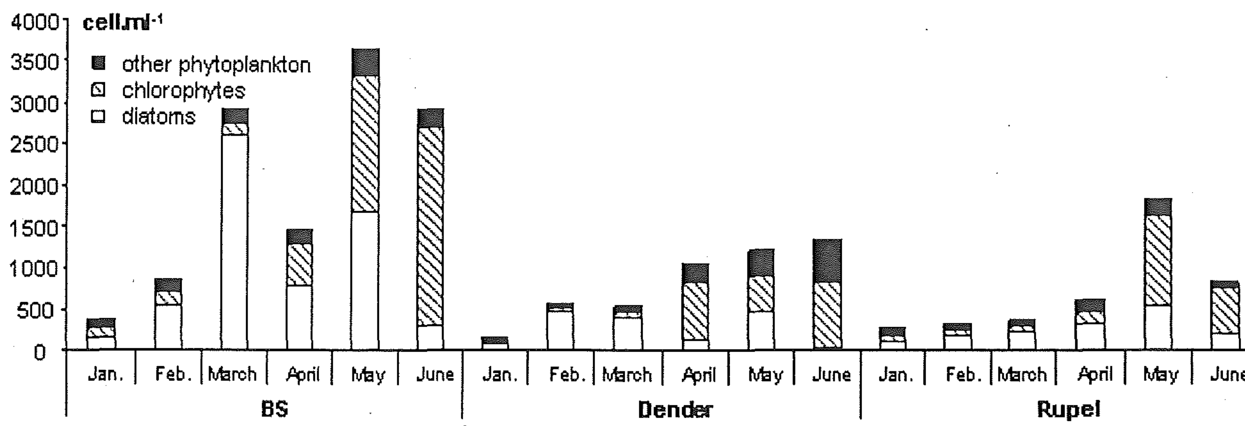


Figure 2: Phytoplankton density in cell.ml^{-1} divide in diatoms, chlorophytes and other phytoplankton groups (euglenophytes, cryptophytes, chrysophytes, cyanobacteria and dinophytes) in the Schelde River (BS), the Dender and the Rupel in 2004.

6.1.5. Comparison of microscopical and HPLC data (2003-2004)

Both the microscopical analysis and the HPLC/CHEMTAX analysis yield data on total phytoplankton biomass and biomass of the dominant phytoplankton groups present (e.g. chlorophytes, diatoms, cryptophytes, dinoflagellates, cyanobacteria). In addition, microscopical analysis yields information on the specific species of phytoplankton that are present. Although the microscopical analysis provides much taxonomical detail, the error on the counts is relatively large. If 100 phytoplankton 'units' are counted, the estimated error is about 20%. The biomass data that are derived from microscopical counts are likely to contain an additional error because biovolume measurements are only carried out on a relatively small number of individuals. The error decreases only slowly by counting more 'units' and/or measuring more individuals. Moreover, microscopical counts are time-consuming and require a high level of training to be able to identify the different species. HPLC/CHEMTAX analysis lacks the taxonomical detail of the microscopical analysis but is more accurate and reproducible than the microscopical analysis. It is less time-consuming and can to a large extent be carried out by laboratory technicians. Therefore, HPLC/CHEMTAX analysis is more suited for routine monitoring of large numbers of samples.

In 2002, a pigment ratio matrix to be used in CHEMTAX was developed for the upper Schelde estuary and its tributaries. This was mainly done by comparing pigment data with results from microscopical cell counts. Moreover, measurements were carried out on dominant phytoplankton species isolated from the Schelde estuary. Finally, 3 different CHEMTAX accessory pigments to chlorophyll a ratio matrices (Table 1) were established which varied depending on the season. In 2003 and 2004, microscopical analysis were reduced to 4 stations of the Schelde estuary (Boei 105, Bazel, Vlassenbroek, Wetteren) and 3 boundary stations (Boven Schelde, Dender and Rupel). Chlorophyll a is used as a measure of phytoplankton biomass in the HPLC approach. Biomass estimated from cell counts, biovolume measurements and published biomass biovolume regressions was used as a measure of phytoplankton biomass in the microscopical approach. In general, the results from both approaches agree very well. A strong correlation was found between log-transformed HPLC chlorophyll a and microscopy data in 2003 and 2004 (Figure 3).

Table 1: Matrices of pigment on chlorophyll a ratios established for the Schelde estuary in 2002. Perid: peridinin, Fuco: fucoxanthin, DDX: sum of diadinoxanthin and diatoxanthin, Allo: alloxanthine, Lut: lutein, Zea: zeaxanthin, Chl b: chlorophyll b, Chl a: chlorophyll a. Cyanobacteria I: coccales cyanobacteria, cyanobacteria II: filamentous cyanobacteria.

Winter ratio pigments matrix

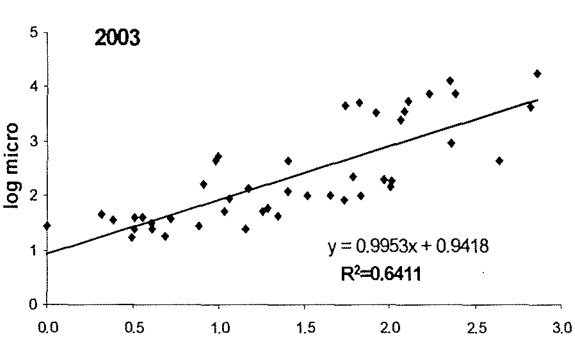
	Peri	Fuco	DDX	Allo	Lut	Zea	Echino	Chl b	Chl a
Chlorophytes	0.000	0.000	0.000	0.000	0.262	0.055	0.000	0.329	1.000
Cryptophytes	0.000	0.000	0.000	0.312	0.000	0.000	0.000	0.000	1.000
Cyanobacteria I	0.000	0.000	0.000	0.000	0.000	0.302	0.000	0.000	1.000
Cyanobacteria II	0.000	0.000	0.000	0.000	0.000	0.036	0.085	0.000	1.000
Diatoms	0.000	0.701	0.160	0.000	0.000	0.000	0.000	0.000	1.000
Dinophytes	0.760	0.000	0.402	0.000	0.000	0.000	0.000	0.000	1.000
Euglenophytes	0.000	0.000	0.333	0.000	0.000	0.000	0.000	0.472	1.000

Spring and Autumn ratio pigments matrix

	Peri	Fuco	DDX	Allo	Lut	Zea	Echino	Chl b	Chl a
Chlorophytes	0.000	0.000	0.000	0.000	0.232	0.025	0.000	0.096	1.000
Cryptophytes	0.000	0.000	0.000	0.275	0.000	0.000	0.000	0.000	1.000
Cyanobacteria I	0.000	0.000	0.000	0.000	0.000	0.202	0.000	0.000	1.000
Cyanobacteria II	0.000	0.000	0.000	0.000	0.000	0.047	0.111	0.000	1.000
Diatoms	0.000	0.663	0.075	0.000	0.000	0.000	0.000	0.000	1.000
Dinophytes	0.760	0.000	0.302	0.000	0.000	0.000	0.000	0.000	1.000
Euglenophytes	0.000	0.000	0.327	0.000	0.000	0.000	0.000	0.322	1.000

Summer ratio pigments matrix

	Peri	Fuco	DDX	Allo	Lut	Zea	Chl b	Chl a
Chlorophytes	0.000	0.000	0.000	0.000	0.162	0.025	0.229	1.000
Cryptophytes	0.000	0.000	0.000	0.212	0.000	0.000	0.000	1.000
Cyanobacteria I	0.000	0.000	0.000	0.000	0.000	0.202	0.000	1.000
Diatoms	0.000	0.701	0.160	0.000	0.000	0.000	0.000	1.000
Dinophytes	0.760	0.000	0.302	0.000	0.000	0.000	0.000	1.000
Euglenophytes	0.000	0.000	0.333	0.000	0.000	0.000	0.372	1.000



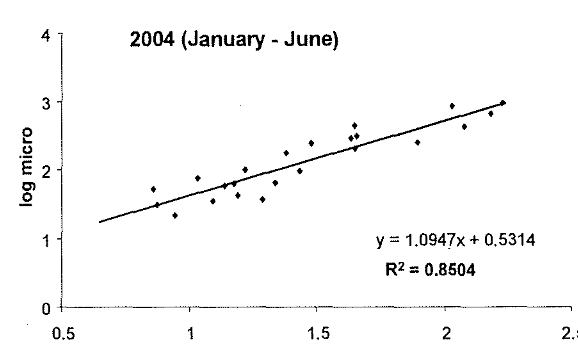


Figure 3: Correlation between log Chla (with Chla in µg Chl a. l^{-1}) found by HPLC analyses and log micro (with biomass in µg C. l^{-1}) found by microscopical counts.

Correlations found between the total biomass of phytoplankton communities estimated by HPLC/CHEMTAX analyses and microscopical counts are presented in Table 2. Graphics of the figure 4 permit to compare the spatio-temporal distribution of phytoplankton communities in the Schelde estuary found by these two methods. Phytoplankton was divided in three groups: diatoms, chlorophytes and "other phytoplankton", which comprise all the other phytoplankton groups that occur in the Schelde in low density. As diatoms and chlorophytes are dominants groups with clear marker pigments, the total biomass was not very difficult to estimate. But for the minor's phytoplankton groups, the matching was seldom good. This might be due to difficulties by counting rare phytoplankton groups using the microscope. The error of the count of rare cells is much higher than the error on the count of abundant cells. With HPLC even if the pigment concentration is low, it can be measured with relatively high precision. In conclusion, CHEMTAX is a good alternative method to microscopical counts and might be considered as better than microscopical counts for detecting rare phytoplankton groups. Microscopy can nevertheless be used to identify the dominant species. These two methods should therefore be considered as complementary.

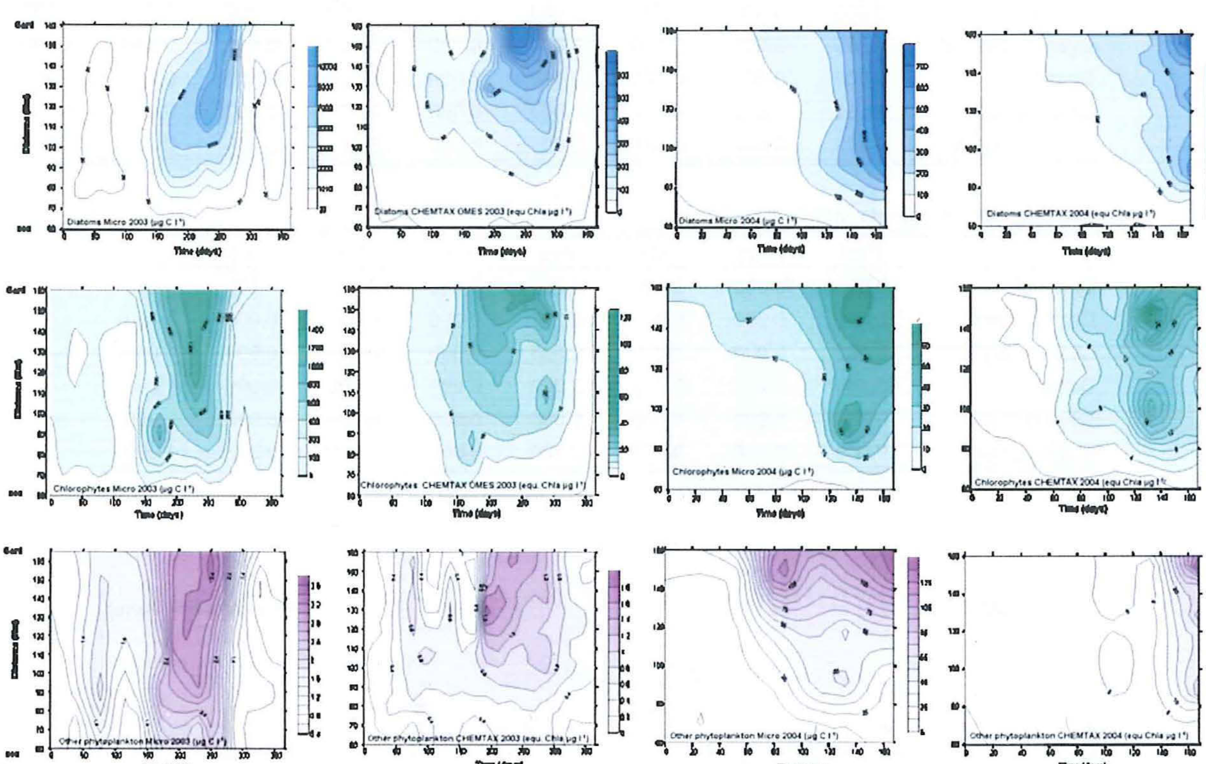


Figure 4: Graphics of the spatial repartition of diatoms, chlorophytes and other phytoplankton groups (euglenophytes, cryptophytes, chrysophytes, cyanobacteria and dinophytes) in the Schelde estuary in 2003 and 2004 by means of microscopical counts on one part and by HPLC/CHEMTAX analyses on the other part. For microscopical counts, the phytoplankton biomass is in µg $C.l^{-1}$ and in equivalent amount chlorophyll a µg. l^{-1} for HPLC/CHEMTAX analyses.

Table 2: Correlation between microscopical counts and HPLC/CHEMTAX analyses in 2002, 2003 and 2004 for diatoms, chlorophytes and other phytoplankton groups.

R^2	2002	2003	2004
Diatoms	0.67	0.66	0.71
Chlorophytes	0.22	0.69	0.70
Other phytoplankton	0.15	0.53	0.29

6.1.6. Chlorophyll a concentration in 2004

Like in previous year, a decrease in Chla concentration could be observed toward brackish sampling stations all around the year. This decrease could be explained firstly by an increase in salinity and secondly by a strong light limitation. The rapid increase in salinity in the brackish stations can lead to an osmotic choc in the phytoplankton cells. At the same time, a strong light limitation probably occurs in this zone due to a combination of a higher water column depth and a high turbidity.

In 2002 and 2003 two phytoplankton blooms were observed in the Schelde estuary (Figure 5). In 2002, the first bloom occurred in spring in the most upstream stations of the estuary and the second one occurred in late summer more downstream in the freshwater tidal estuary. In 2003, the summer bloom was situated in the most upstream part of the estuary. Another important factor was the increase in the Chla concentration. In 2002, the maximum was 200µg/l in summer, and in 2003, the maximum reached 662µg/l in August and 715µg/l in September. In the previous report, we assessed that this change could be linked with the extremely warm, sunny and dry summer in 2003. A reduced discharge was noted in 2003 compared with 2002. This leads to a higher retention time of the water in the Schelde estuary and allows for phytoplankton to attain a higher population density before being washed out to sea. Higher temperatures may also have stimulated the primary production.

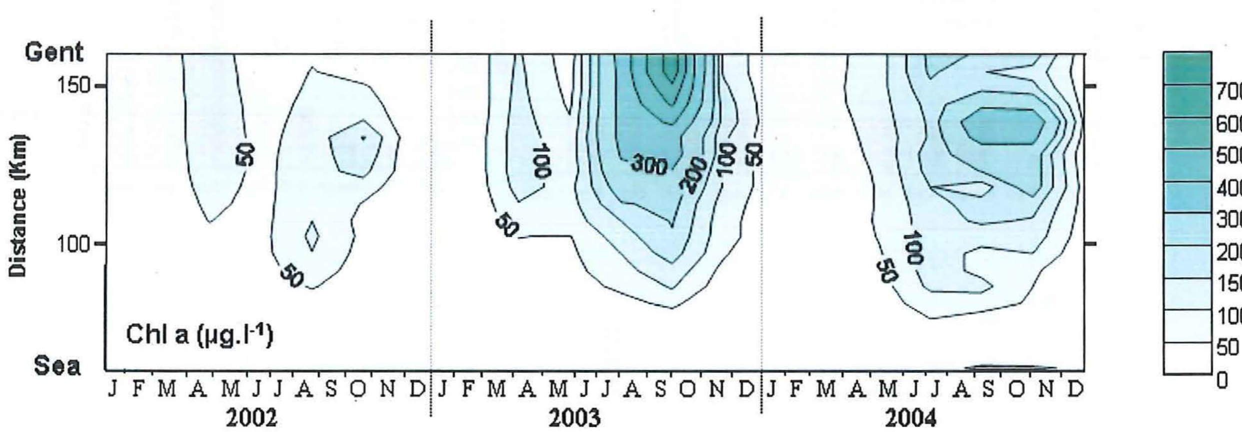


Figure 5: Chlorophyll a concentration (µg/l) in 2002, 2003 and 2004 along the Schelde estuary. The x axe represents the time and the y axe represents the distance in Km from the North Sea to Gent.

In 2002 and 2003 the spring bloom was clearly separated from the summer bloom by a period of low phytoplankton biomass. However, in 2004, a gradual transition has been observed from the spring to the summer bloom. Chlorophyll a concentrations in April-May in the freshwater tidal part of the estuary were comparable with those observed in 2002 and slightly lower than in 2003. In 2004 as in 2003, the chlorophyll a concentration during the summer bloom (400 µg/L in August) was much higher than in 2002 and this summer bloom was situated more upstream. Nevertheless, this bloom started earlier and lasted longer. An explanation could be the warm, sunny and dry summer in 2004 (as in 2003) inducing a lower water discharge and a higher phytoplankton retention time in the Schelde. These parameters all together could have induced an earlier and longer phytoplankton bloom in the Schelde estuary in 2003 and 2004 than in 2002 when the weather was not so good. The relation between chlorophyll a concentrations, SPM and discharge will be analyzed in the course of 2005.

6.1.7. Comparison between estuary and tributaries

The comparison between the estuary and its tributaries is important to gain a better understanding of the contribution of tributaries phytoplankton on the phytoplankton of the Schelde estuary. Figure 6 represents the amount of chlorophyll a in a tributary of the Schelde estuary and in the upstream and downstream stations in 2004.

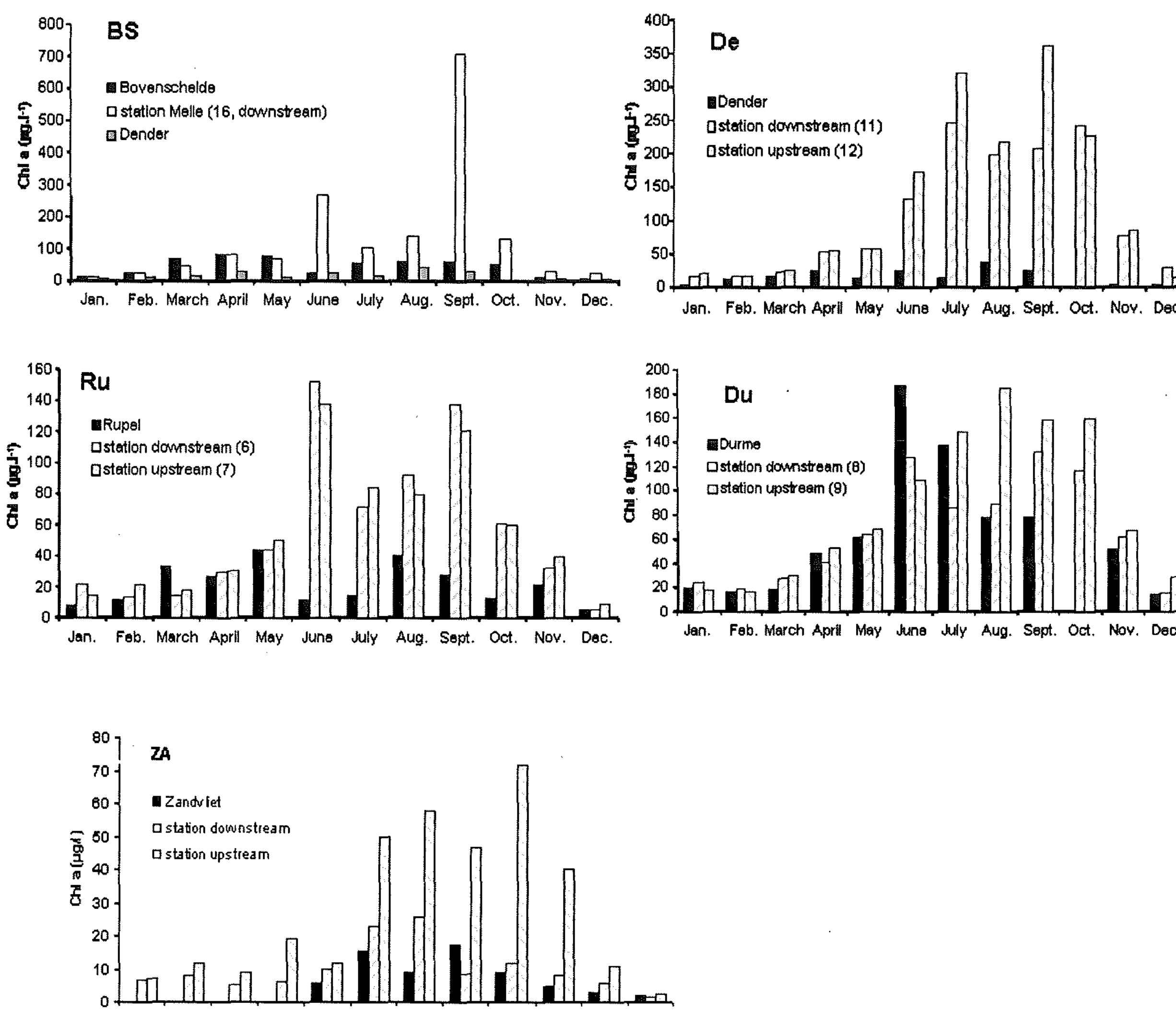


Figure 6: Monthly Chlorophyll a concentration in µg/l in the Tributaries Rivers of the Schelde estuary compared to adjacent monitoring stations in the estuary. BS: Boven Schelde, De: Dender, Ru: Rupel, Du: Durme, ZA: Zandvliet.

In the Schelde River (BS), the phytoplankton bloom occurred in March-April while the bloom was observed in June and September in the Schelde estuary. Thus, the Schelde River could have been a source of phytoplankton for the Schelde in spring but not in summer. At the same time, phytoplankton concentrations in the Dender River were much lower than in the Schelde estuary so the Dender could not have been an important phytoplankton source for the Schelde estuary. Moreover, the lower discharge of the Dender compared to the Schelde River also indicates that the Dender is a more important source of phytoplankton to the estuary than the Schelde.

Chlorophyll a concentrations are lower in the Rupel than in the estuary itself. This could be due to a higher discharge and higher turbidity preventing the development of the phytoplankton in this branch of the estuary. This pattern is similar to 2002 but differs from 2003 when phytoplankton concentrations were higher or comparable in the Rupel than in the estuary. A better monitoring of the Rupel could be interesting for a better understanding of the impact of the Rupel on the Schelde estuary. Extra sampling stations of the Rupel are already planed from June 2005.

Chlorophyll a concentrations in the Durme River were generally comparable with concentrations observed in the Schelde estuary. According to a paired t-test, this difference was not significant. At Zandvliet (monitored since May 2004), the chlorophyll a concentration is always lower than in the Schelde estuary (except in August where the bloom appeared one month later than in the Schelde estuary) which means that Zandvliet is not an important phytoplankton contribution for the Schelde estuary.

6.1.8. Chlorophyll a and SPM during the tidal cycle

On 18 and 19 June 2004, 13 hours measurements were carried out at two stations of the Schelde estuary to assess the impact of the tide on chlorophyll a and SPM concentrations. These measurements were carried out at Lippenbroek (in the freshwater part of the estuary) and at Kruibeke (in the brackish part of the estuary). Chlorophyll a was measured as in vivo fluorescence and water was filtered on pre-weighed GF/F filters in order to determine SPM concentration. Results are presented in figure 7.

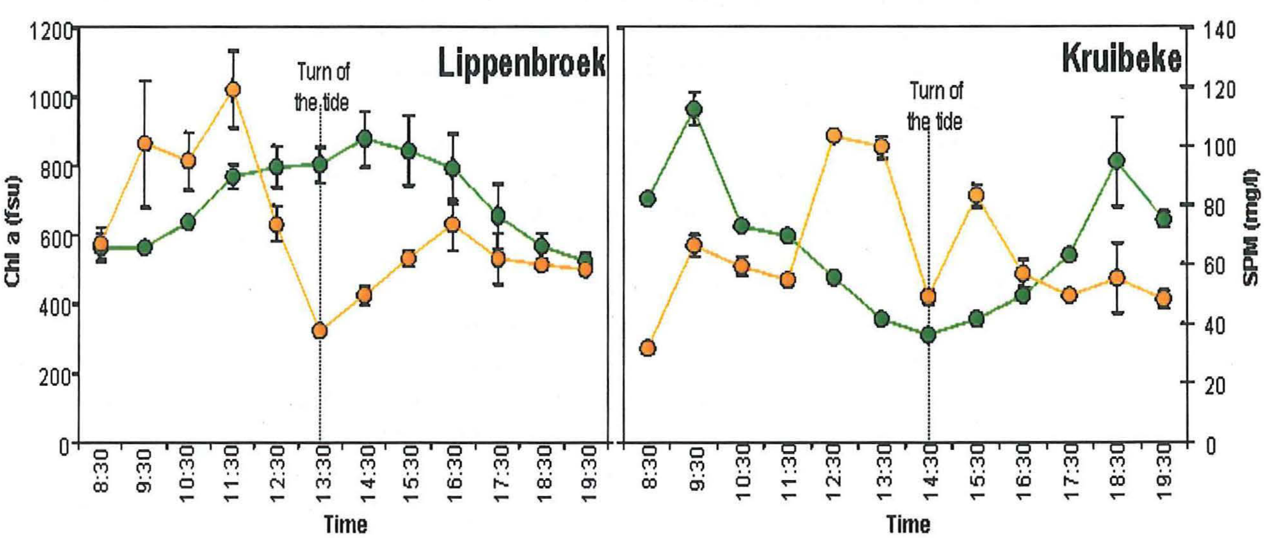


Figure 7: Chlorophyll a measured by fluorescence (fsu) in green and SPM (mg/l) in yellow at Lippenbroek and Kruibeke during the tidal cycle.

At Lippenbroek, we observed an increase in chlorophyll a during high tide while at Kruibeke a decrease was observed. This difference in the timing of the chlorophyll a maximum suggests that the maximum chlorophyll a concentration in the estuary was situated upstream Kruibeke but downstream Lippenbroek. The up- and downstream movement of the tide explains the observed fluctuations at Kruibeke and Lippenbroek during the tidal cycle.

Concerning SPM measurements, at high tide, they decreased at Lippenbroek and they increased at Kruibeke. At these two stations, the minimum value for SPM was observed at the turn of the tide. The low SPM concentrations at the turn of the tides can be explained by sedimentation of suspended matter when the current velocity is low or even zero. When current velocity is maximal, resuspended bottom sediments probably contribute to the high SPM concentrations. During 2005, data will be analysed further and will be compared with values of current velocity to validate this hypothesis.

6.2. Monitoring of microphytobenthos biomass at Ketenisse polder

The Ketenisse polder is an intertidal mudflat which was created during the course of 2002-2003 by depolderisation. Samples were collected monthly in 2003 along 6 transects of 3 to 6 stations going from the high to the low water line in order to assess the spatial variability in microphytobenthos biomass. The upper cm of sediment was sampled in situ using a perspex corer. The sediment samples were stored frozen until analysis. Before analysis, the samples were freeze-dried to remove water and pigments were subsequently extracted in 90% acetone using sonnication. The chlorophyll a concentration, as well as the concentration of chlorophyll degradation pigments (pheopigments) was measured by fluorescence according to Welschmeyer (1994). Chlorophyll a concentration varied between 0.3 and 118 µg/ g sediment dry weight and peaked in the spring period (March to June). The timing of the chlorophyll a maximum varied between the sites. Figure 8 show that chlorophyll a increased with increasing sediment median grain size (e.g. Lucas & Hilligan, 1999) as well as with increasing position above the low water level. This can be ascribe to the fact that sediments situated high above the low water level have a short submersion period and exposed to the light for longer periods. Chlorophyll a concentrations measured at Ketenisse polder are comparable to chlorophyll a concentration observed at Groot Buitenschoor, a mud flat situated nearby which indicates that the microphytobenthos can rapidly colonize newly constructed mudflats.

Microphytobenthos is known as important parameter in the stabilisation of the intertidal sediment. The effect is an increase of the sedimentation rate and a decrease of erosion. During this study, we found a good relation between sedimentation-erosion rate and chlorophyll a concentration (Figure 8). While sediments with low chlorophyll a concentration displayed net erosion, sediments with high chlorophyll a concentrations were characterized by a net sedimentation in 2003. Chlorophyll a concentration may therefore be considered as a potentially useful indicator of sedimentation and erosion in newly created marshes.

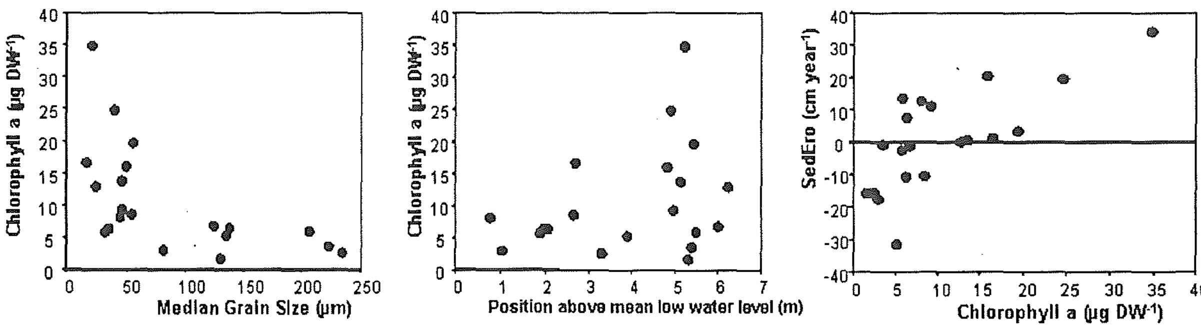


Figure 8: relation between annual average chlorophyll a concentration in 2003 and sediment median grain size, position above mean low water level and net sedimentation-erosion rates in 2003.

6.3. Future studies

- continued monitoring of phytoplankton pigments, including extra sampling stations in the Rupel.
- continued monitoring of species composition by microscopical counts at selected stations in the estuary and in the tributaries.
- continued monitoring of Schelde tributaries (Boven Schelde, Durme, Rupel, Dender and Zandvliet) with an extra station in the Rupel river.
- continued monitoring Chla and SPM during 13h measurements at Lippenbroek and Kruibeke and at a new station in the Rupel.
- continued monitoring of microphytobenthos at Ketenisse polder as well as at the Lippenbroek depolderisation site.

6.4. References

Lucas C.H., Holligan P.M. 1999. Nature and ecological implications of algal pigment diversity on the Molenplaat tidal flat (Westerschelde estuary, SW Netherlands). Marine Ecology Progress Series 180: 51-64.

Mackey M.D., D.J. Mackey, H.W. Higgins, S.W. Wright (1996) CHEMTAX- a program for estimating class abundances from chemical markers: application to HPLC measurements of phytoplankton. Mar. Ecol. Prog. Ser., 144, 265-283.

Menden-Deuer, S. and E.J. Lessard (2000) Carbon to volume relationships for dinoflagellates, diatoms, and other protist plankton. Limnology and Oceanography. 2000; 45:569-579.

Welschmeyer, N.A. 1994. Fluorometric analysis of chlorophyll a in the presence of chlorophyll b and pheopigments. Limnology and Oceanology 39: 1985-1992.

Wright, S.W. & Jeffrey, S.W. 1997 High-resolution HPLC system for chlorophylls and carotenoids of marine phytoplankton. In S.W. Jeffrey, R.F.C. Mantoura and S.W. Wright (ed.) Phytoplankton pigments in oceanography. UNESCO Publishing, Paris: 327-341.

Hoofdstuk 7. Studie naar de primaire productie

J.P. Vanderborght
Dir: Prof. Dr. Lei CHou

Eindverslag voor deelstudie 5 (perceel 5), periode januari – december 2004

Université Libre de Bruxelles, Laboratoire d'Océanographie Chimique et de Geochimie des Eaux

7.1. Introduction

Following the work initiated in 2002, our contribution to the OMES program has focused on two points: (1) monitoring the light climate within the water column and its relationship to suspended particulate matter concentration and turbidity, and (2) quantifying the photosynthetic parameters of the estuarine phytoplankton population and their variations in space and time. Accordingly, in situ light-field measurements, water sampling and laboratory determinations were performed between March and November 2004. No major changes were introduced in the methodology as compared with previous years. However, we have followed the recommendation issued in the previous (2003) annual report, i.e. direct k_d determination at a fixed depth by means of the "dual-sensor approach" has been applied as the standard technique during both monthly cruises and 13h measurements. The reader may consult the 2002 annual report for a detailed presentation of the methodology, together with a short introduction to basic concepts and measuring principles.

In addition, the complementary measurements that were added in 2003 have been routinely performed in 2004. For all monthly longitudinal profiles, dissolved silica concentration has been analysed. Continuous data acquisition using a multi-parameter monitoring system (temperature, conductivity, oxygen, pH, turbidity and chlorophyll a) has been performed during the six tidal cycles followed in 2004. A detailed list of available data is given in annex.

7.2. Synthesis of the results

1/ The light extinction coefficient for scalar irradiance k_d has been found to vary between 2.05 and 17,2 m^{-1}, a range of variation which is almost identical to the one observed in 2003 (1.71 to 17.5 m^{-1}). This corresponds to a euphotic depth (defined as the depth at which light is equal to 1% of the light at the water surface) varying between 2.3 and 0.27 m (respectively 2.7 and 0.25 m in 2003). The distribution of k_d values (based on measurements performed during monthly cruises) is given in Figure 1. Two third (67%) of the values are comprised between 4 and 9 m^{-1}; the median value is equal to 5.5 m^{-1}.

2/ The value of the extinction coefficient exhibits a distinctive longitudinal gradient along the estuary. This is especially apparent from the longitudinal profile of the euphotic depth (Figure 2), which is reported here using yearly average for each of the 16 sampling stations. It is important to note that the monthly OMES profiles are performed without consideration to synchronisation with the tidal cycle, neither in time, nor in space. For parameters that are linked to turbidity (in particular light penetration), this sampling strategy does not allow to draw direct conclusions from the comparison of monthly profiles, because of the strong tidal influence on SPM (suspended particulate matter) concentration. Averaging the data helps to overcome this difficulty by dampening the tidally induced turbidity fluctuations.

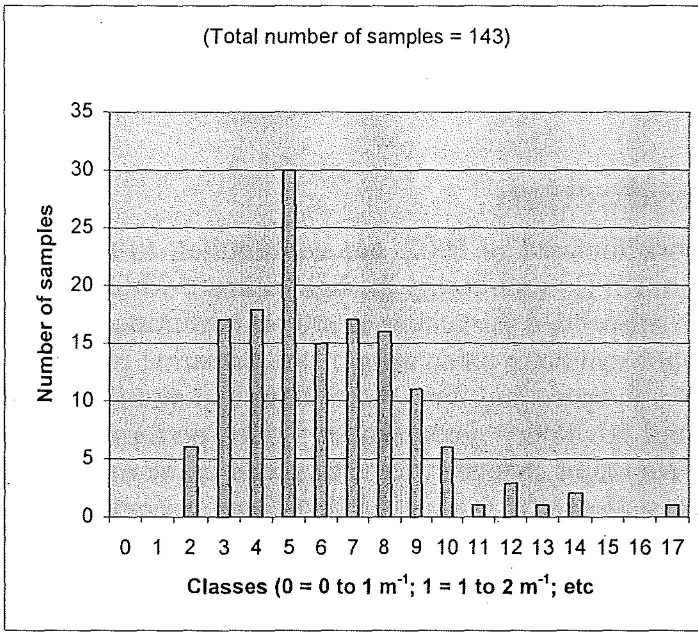


Figure 1: Distribution of k_d values

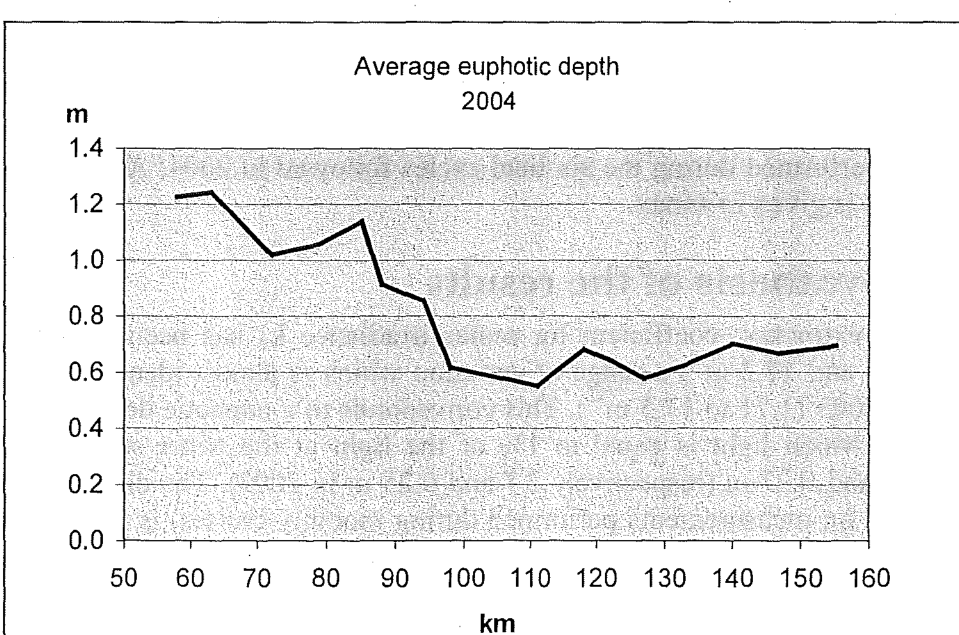


Figure 2: Average euphotic depth along the estuary

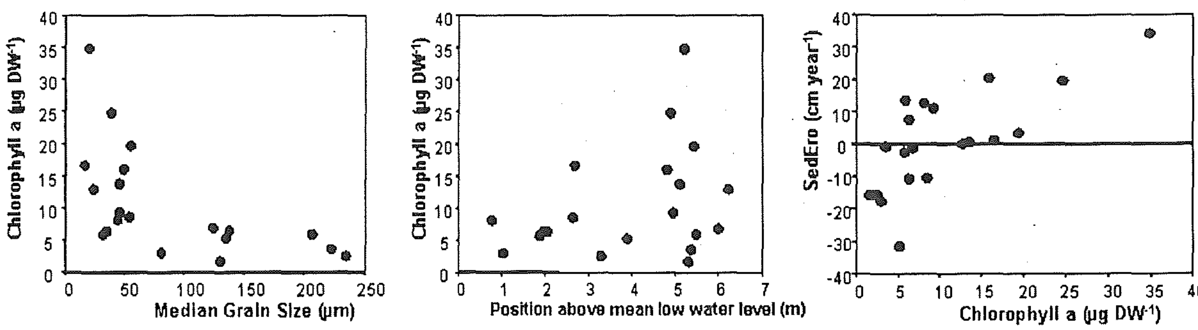


Figure 8: relation between annual average chlorophyll a concentration in 2003 and sediment median grain size, position above mean low water level and net sedimentation-erosion rates in 2003.

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Hoofdstuk 7. Studie naar de primaire productie

J.P. Vanderborght
Dir: Prof. Dr. Lei CHou

Eindverslag voor deelstudie 5 (perceel 5), periode januari – december 2004

Université Libre de Bruxelles, Laboratoire d'Océanographie Chimique et de Geochimie des Eaux

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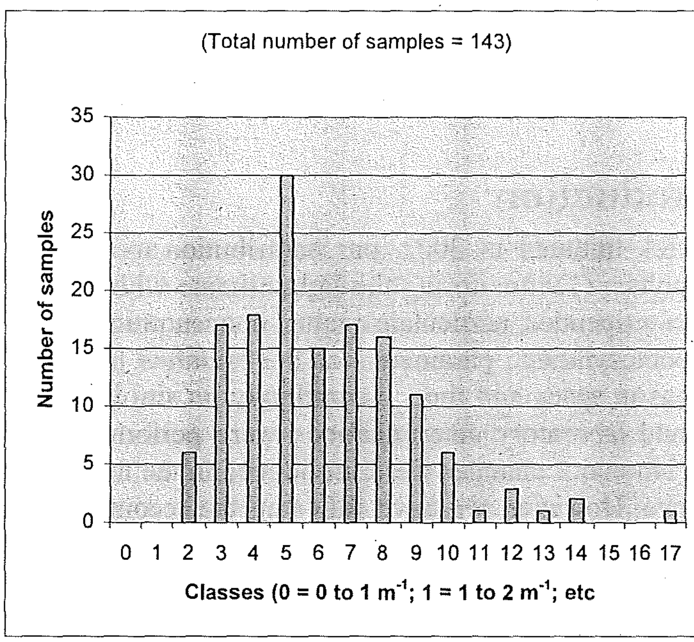


Figure 1: Distribution of k_d values

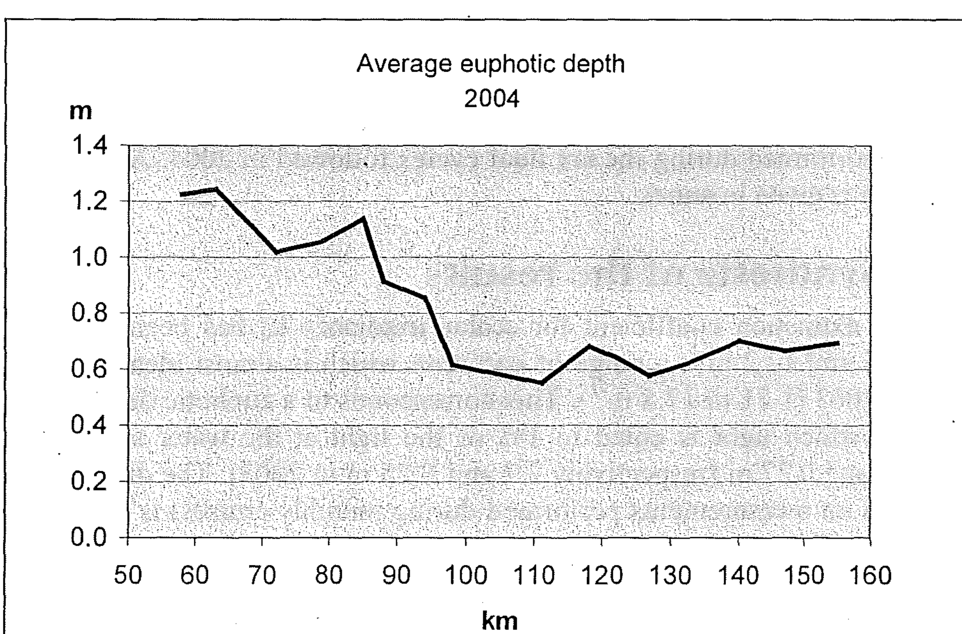


Figure 2: Average euphotic depth along the estuary

From the data of Figure 2, it can be seen that a mean euphotic depth equal to 0,65 m is observed in the tidal river (between Melle – km 155 and Temse – km 98). It then rapidly increases downstream (0,85 to 0,90 m between Steendorp – km 94 and Basel – km 88) to finally reach 1,0 m in Kruibeke (km 85) and 1,24 m at the Belgian-Dutch border (km 58).

3/ Our dataset confirms the relationship between the light absorption coefficient k_d and the SPM concentration (Figure 3). Taking into account the complete set of measurements (monthly profiles + 13h cycles, i.e. 199 couples of determinations), this relation may be linearized as follows:
$k_d = 0.055$ SPM $+ 2.14$ $(r^2 = 0.697)$

with k_d in m^{-1} and SPM in $mg.l^{-1}$. The coefficients are almost identical to the ones obtained in 2003 ($k_d = 0.055$ SPM $+ 2.06$) and differ only slightly from the 2002 results ($k_d = 0.048$ SPM $+ 2.21$).

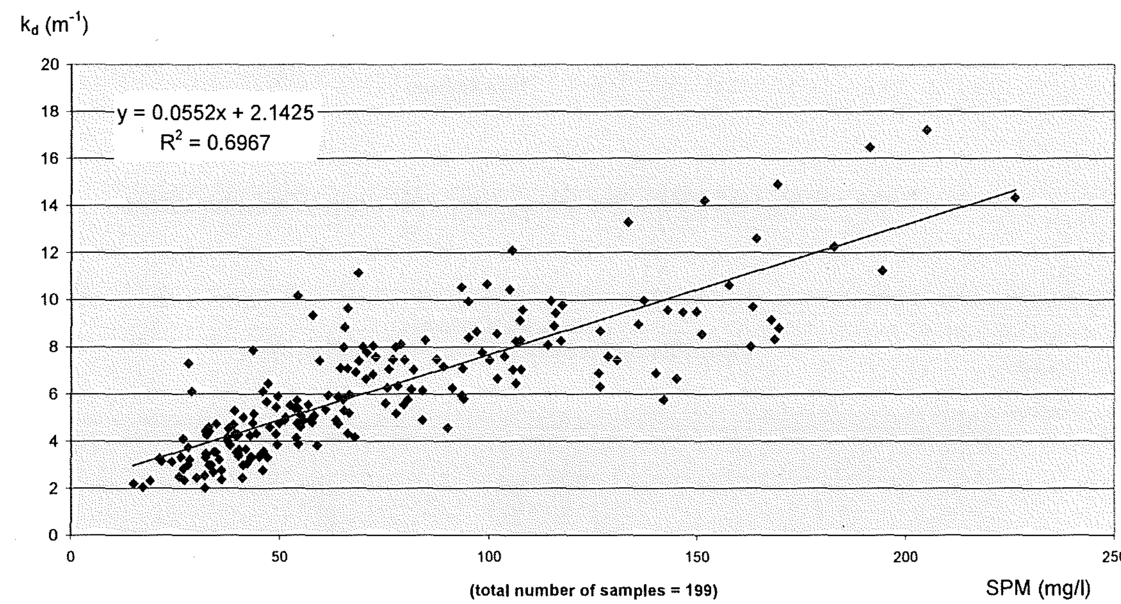


Figure 3: k_d – SPM correlation

4/ Results from the 13h experiments (Figures 4 to 9) confirm that the local light climate is strongly affected by the dynamics of suspended material during the tidal cycle. At all locations, a drop in SPM concentration systematically accompanies the decrease in current velocity, both at rising and falling tides. After slack, resuspension of the deposited material and mixing of the water column tend to restore the initial SPM values. k_d values follow the same pattern, starting to decrease one to two hours before slack water. This process is extremely fast at Kruibeke (Figures 5 and 8) where the steepest gradients are observed. It is less rapid at Lippenbroeck and Pass van Rilland. The shape of the resulting curve is clearly influenced by tidal asymmetry, and, most probably, by local hydrodynamic features responding to the effect of wind and local topography. Considering the importance of current velocity variations with respect to turbidity and hence, to light climate within the water column, we strongly recommend to consider the implementation of continuous velocity measurements as a priority for the future OMES campaigns.

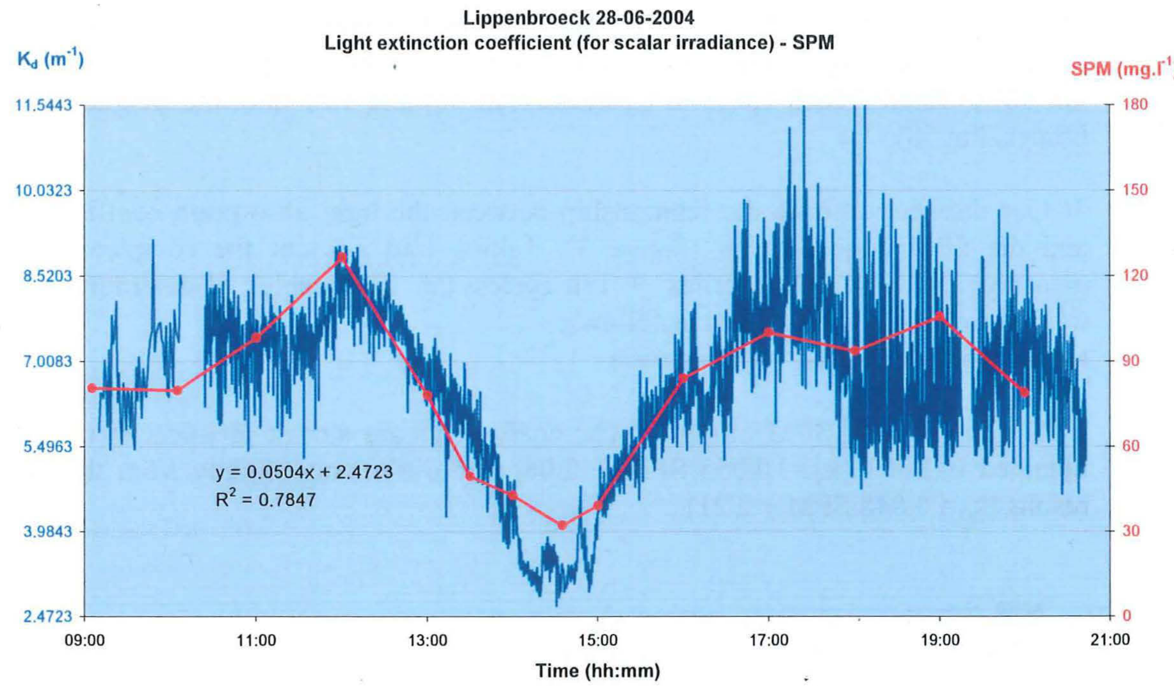


Figure 4: k_d and SPM profiles at Lippenbroeck (28 June 2004)

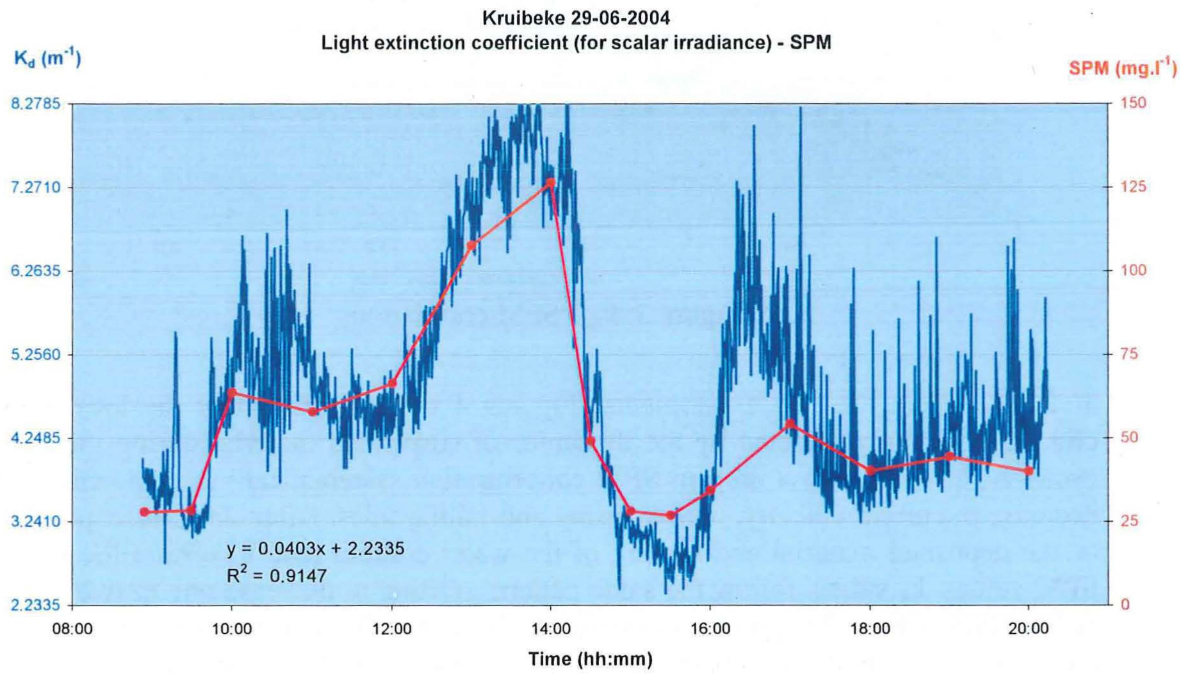


Figure 5: k_d and SPM profiles at Kruibeke (29 June 2004)

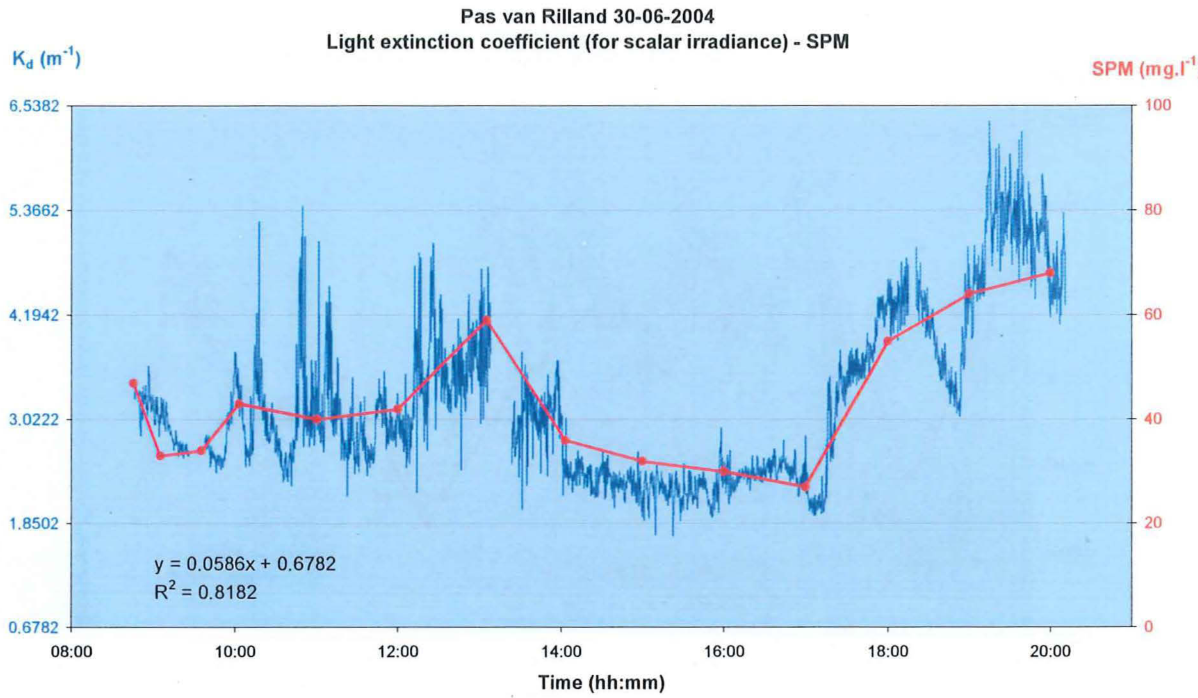


Figure 6: k_d and SPM profiles at Pas van Rilland (30 June 2004)

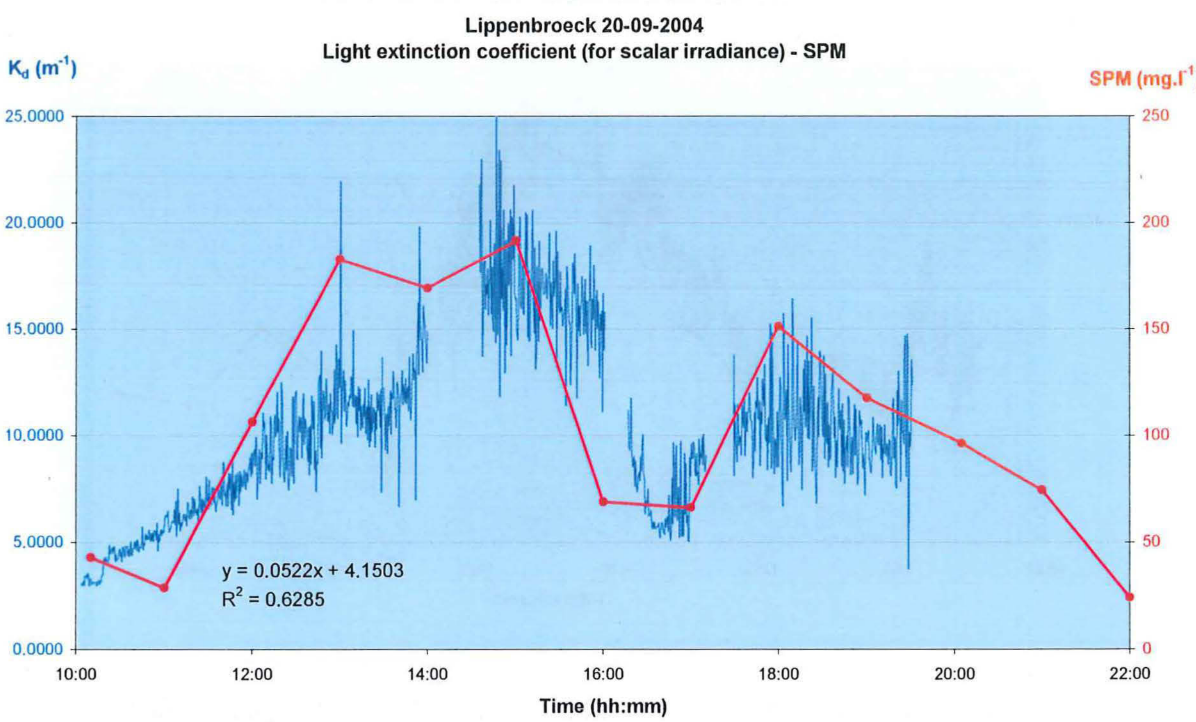


Figure 7: k_d and SPM profiles at Lippenbroeck (20 September 2004)

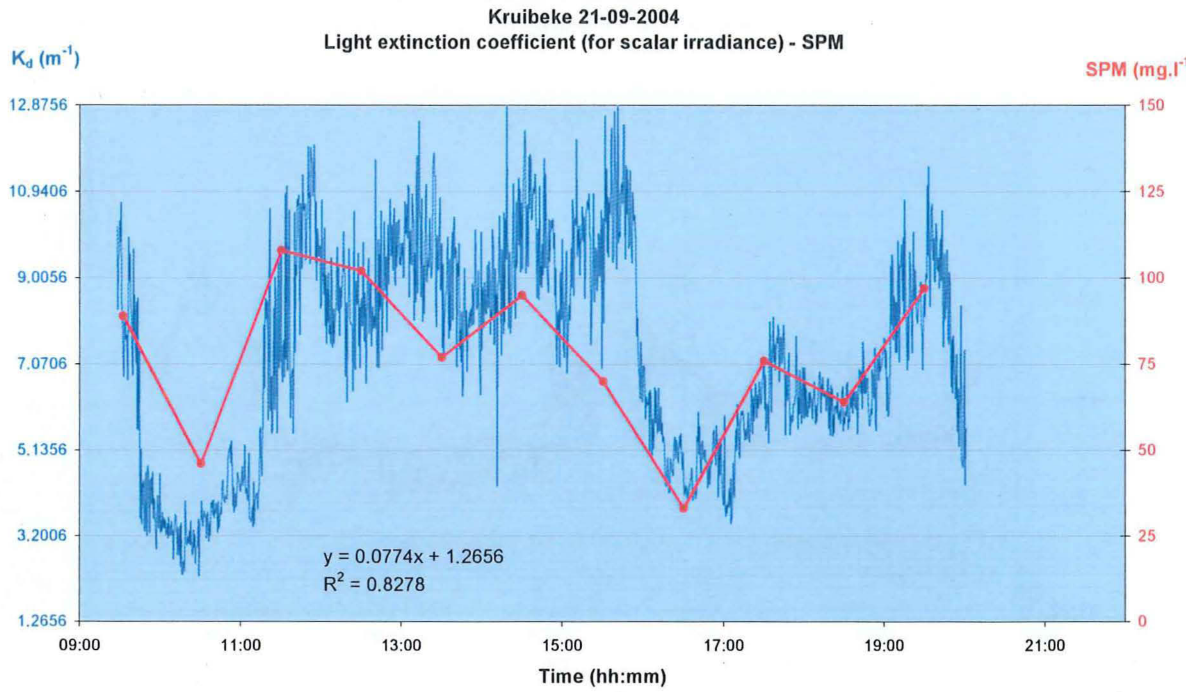


Figure 8: k_d and SPM profiles at Kruibeke (21 September 2004)

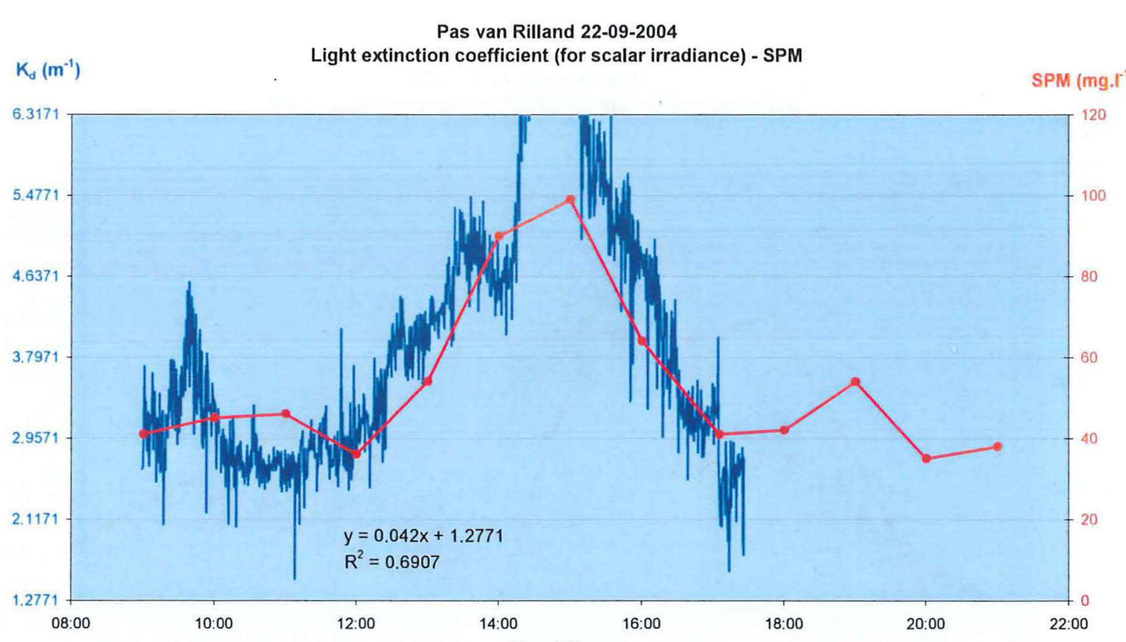


Figure 9: k_d and SPM profiles at Pas van Rilland (22 September 2004)

Note that, as demonstrated earlier, turbidity monitoring performed during 13h surveys is in close agreement with in situ, continuous measurement of the light absorption coefficient k_d using the "dual quantum sensor" technique. Figure 10 gives an example of the parallelism between both approaches.

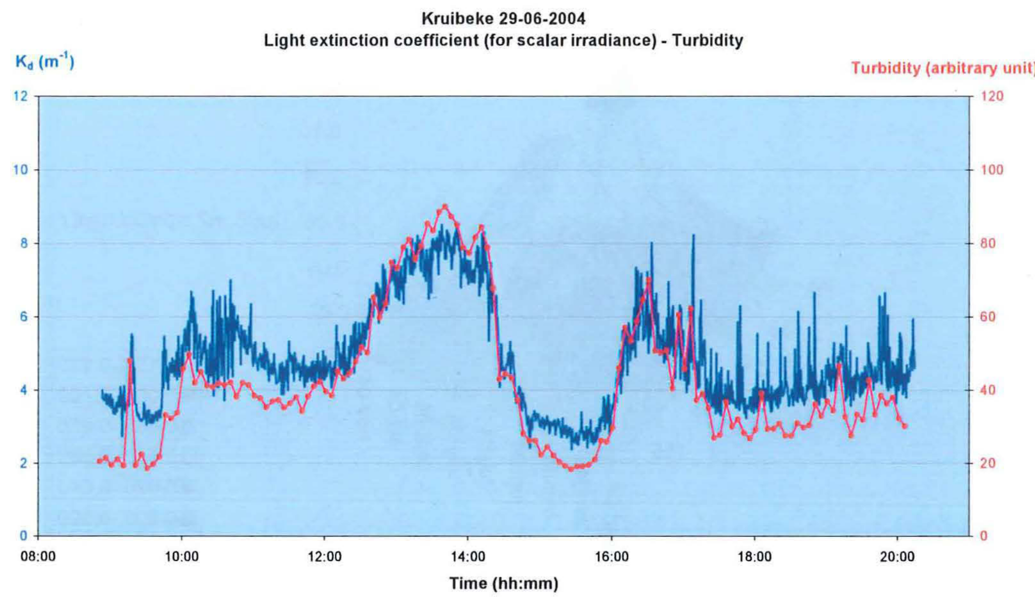


Figure 10: Comparison between k_d measurements and turbidity monitoring

6/ The photosynthetic parameters α and P^B_{max} have been estimated from ^{14}C-incorporation experiments between March and November 2004. The value of α varies between 0.008 and 0.071 (expressed in $\mu gC.m^2.s/\mu gChl.h.\mu E$), with a single value observed at 0.105. This range of variation is very close to the one observed in 2003 (0.007 to 0.052). The distribution of α is shown in Figure 11. The complete dataset for 2004 is presented in Figure 12. It shows that the higher values (0.030 to 0.060) are observed during the summer months (June to August). From March to May and after September, values are significantly lower (0.010 to 0.030). Although seasonal variations are more pronounced than spatial ones, a slight longitudinal gradient may be noticed: values measured at the downstream locations are generally higher than in the upstream zone.

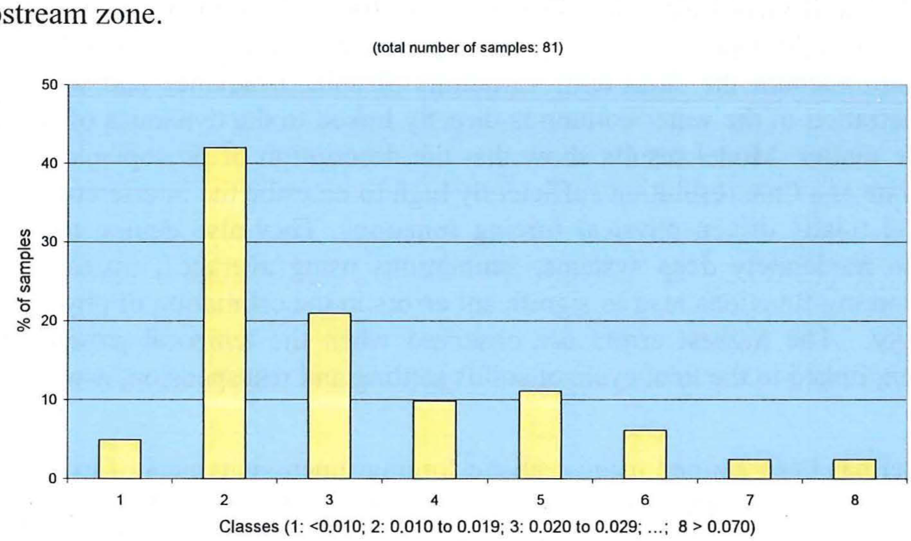


Figure 11: Distribution of α values (α expressed in $\mu gC.m^2.s/\mu gChl.h.\mu E$)

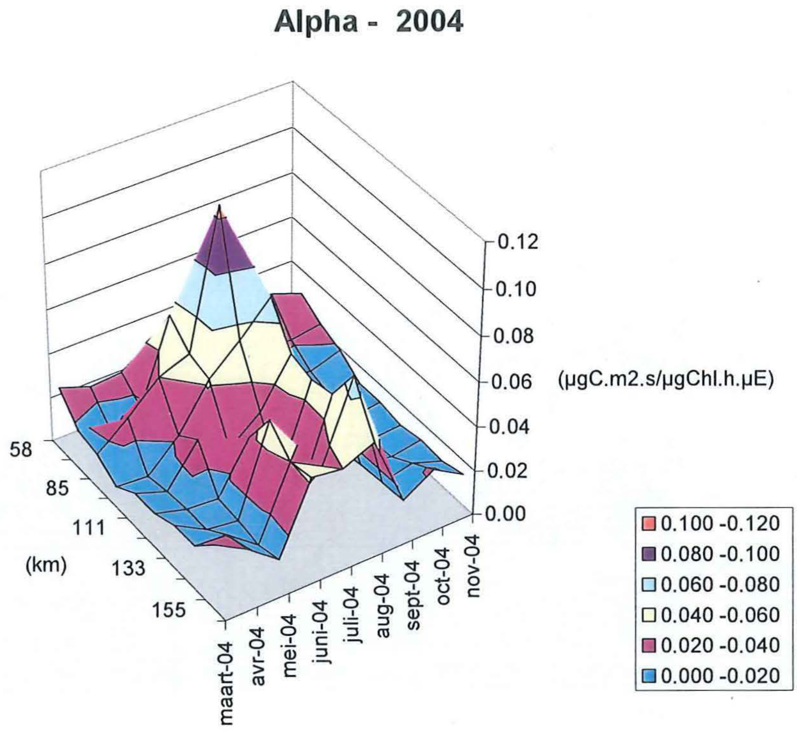


Figure 12: 3D-plot of α values

7/ $P^B{}_{max}$ values are mostly comprised between 2 and 20 µg C. (µg Chl)$^{-1}$.h^{-1}. The lower values (< 10) are observed in spring and autumn. Higher values (up to 50) are occasionally observed in summer. It should however be noted that, during this period, a large number of P-E curves display an almost linear behaviour over the whole range of irradiance used for laboratory incubation. As a consequence, a high level of precision cannot be achieved when determining the value of $P^B{}_{max}$.

8/ Repeated observations of the highly dynamic SPM behaviour in the Scheldt have led us to propose a zero-dimensional model for phytoplanktonic production in turbid, macro-tidal, well-mixed estuaries (Desmit et al 2005). This model is based on the description of light-dependent algal growth, phytoplankton respiration and mortality. It takes into account the short-term variations of solar irradiance and water depth. Light penetration in the water column is directly linked to the dynamics of suspended particulate matter. Model results show that the description of phytoplankton growth must operate at a time resolution sufficiently high to describe the interference between solarly and tidally driven physical forcing functions. They also demonstrate that in shallow to moderately deep systems, simulations using averaged, instead of time-varying, forcing functions lead to significant errors in the estimation of phytoplankton productivity. The highest errors are observed when the temporal pattern of light penetration, linked to the tidal cycle of solids settling and resuspension, is neglected.

This model has been applied using realistic forcing functions typical of two locations in the Scheldt estuary (Dendermonde and Antwerpen). It shows that a net positive phytoplanctonic production can be sustained at the upstream, shallower location (Dendermonde), despite the higher turbidity that is typically observed there. At the opposite, the greater water depth at the downstream location (Antwerpen) leads to a net negative production, although water turbidity is lower. Model results are thus consistent with the typical phytoplankton decay observed along the longitudinal, seaward axis in the tidal river and oligohaline part of the estuary.

7.3. References:

X. Desmit, J. P. Vanderborght, P. Regnier, and R.Wollast. Control of phytoplankton production by physical forcing in a strongly tidal, well-mixed estuary. Biogeosciences, 2, 205–218, 2005. (http://www.copernicus.org/EGU/bg/bg/2/205/bg-2-205.pdf)

7.4. Annex: Summary of the available results

The following set of results for 2004 have been made available under digital format for inclusion into the OMES database:

Licht klimaat

Transecten

kd – zphot – Transecten – 2004.xls

Numerical values and graphs of the light extinction coefficient and euphotic depth measured at the 16 stations during the 2-days monthly cruises, March to November 2004.

kd - SPM – Transecten - 2004.xls

Numerical values and graph of the correlation observed between the light extinction coefficient and the SPM concentration measured at the 16 stations during the two-days monthly cruises, March to November 2004.

13uur-metingen

Lippenbroeck 28 Juni 2004 kd.xls
Kruibeke 29 Juni 2004 kd.xls
Pas van Rilland 30 Juni 2004 kd.xls
Lippenbroeck 20 September 2004 kd.xls
Kruibeke 21 September 2004 kd.xls
Pas van Rilland 22 September 2004 kd.xls

Each of the above contains the following information:

Data Kd: numerical values of the following parameters: date, time, irradiance (E_0sup) measured by the upper sensor, irradiance (E_0inf) measured by the lower sensor, surface downward irradiance $E_d(0)$, light attenuation coefficient (k_d in m^{-1}). In addition, SPM concentrations (on-board filtration) and the corresponding values of k_d at the time of the sampling are reported.

Data Turbidity: numerical values of the following parameters: date, time, turbidity (YSI-6600 acquisition system).

$E_d(0)$: graph of the temporal evolution of the surface downward irradiance $E_d(0)$.

Kd-turb: graph of the temporal evolution of the light attenuation coefficient k_d (in m^{-1}) and of the turbidity (in arbitrary units).

Kd-SPM(1): graph of the temporal evolution of the light attenuation coefficient k_d (in m^{-1}) and of the SPM concentration (from on-board filtration, in $mg.l^{-1}$).

Kd-SPM(2): linear correlation between the light attenuation coefficient and the suspended particulate matter concentration.

Analyses en parameters

Transecten

Analyses - Transecten - 2004.xls

Results of analytical determinations performed on the samples taken at the 16 stations during the two-days monthly cruises, March to November 2004. The following parameters are reported (numerical values and graphs): temperature, pH, alcalinity, suspended particulate matter, dissolved silica, chlorophyll *a*, phaeopigments, DIC (Dissolved Inorganic Carbon).

Photosynthetic parameters - Transecten - 2004.xls

Results of ^{14}C incorporation experiments and evaluation of the photosynthetic parameters. Includes the following data:

Maart to November: numerical values of the following parameters, measured at nine stations during the two-days monthly cruises: chlorophyll a, dark ^{14}C uptake rate, photosynthetic efficiency α, maximum specific rate of photosynthesis P_B^{max}.

alpha: a surface plot of α values as a function of time and longitudinal position in the estuary.

PBmax: a surface plot of P_B^{max} values as a function of time and longitudinal position in the estuary.

13uur-metingen

Lippenbroeck Juni 2004
Kruibeke Juni 2004
Pas van Rilland Juni 2004
Lippenbroeck September 2004
Kruibeke September 2004
Pas van Rilland September 2004

Each of the above contains 3 files with the following information:

[Station name] [date] Parameters.xls

Numerical values and graphs of the temporal variation of temperature, conductivity, dissolved oxygen, pH and ORP (oxidoreduction potential) measured during one tidal cycle using an YSI-6600 multi-parameter probe.

[Station name] [date] chlorophyll.xls

Numerical values and graphs of the temporal variation of chlorophyll fluorescence measured during one tidal cycle using an YSI-6600 multi-parameter probe. Results of laboratory determinations of chlorophyll *a* and phaeopigments performed on the samples taken during one tidal cycle.

[Station name] [date] SPM.xls

Numerical values of the SPM concentration measured during one tidal cycle (on board filtration).

Hoofdstuk 8. Micro- en mesozoöplankton

M. Tackx
F. Azémar
B. Mialet
N. Paduraru

Eindverslag voor deelstudie 6 (perceel 6), periode januari – December 2004

Laboratoire d'Ecologie des Hydrosystèmes (LEH), Université Paul Sabatier, Toulouse, 29 rue Jeanne Marvig – BP 4349 - 31055 Toulouse cedex 4
Centre National de la Recherche Scientifidue (CNRS)

8.1. Summary

During 2004 - 2005, monthly sampling for micro – and mesozooplancton was continued from february 2004 till april 2005.

The taxonomic list at present counts 99 taxa of which 40 had - to our knowledge - not been previously reported from the Schelde. Rotifers are dominant in the freshwater reach, not only in numerical abundance but also in diversity: 40 species. Some exotic species continue to occur.

Seasonal distribution is quite constant from year to year but abundances and limits of spatial distribution remain variables.

CCA analysis performed on grouped taxa suggest the need to use more detailed taxonomic levels in order to reveal associations of zooplankton taxa with environmental factors other than salinity and associated higher oxygen concentrations in the brackish water zone as compared to the freshwater zone.

8.2. Introduction

The research carried out on micro- and mesozooplankton in the frame of the OMES project aims at following the evolution of the zooplankton composition and its spatio – temporal distribution in the Schelde estuary. Because of its central position, as a link between primary production and higher food levels, zooplankton is an essential component in the functioning of any aquatic ecosystem. Its drifting with the currents makes it also a good indicator of spatio – temporal variation in hydrological and concurrent water quality conditions.

In a general way, the zooplankton community in the Schelde (considering rotifera, cladocera and copepoda) has been increasing in abundance in recent years as compared to previous reports form the end of the 60ties and the early 90ties (De Pauw 1975, Soetaert *et al.* 1993, Tackx *et al.* 2005). This increase is interpreted as a response to the water quality improvement (Tackx *et al.* 2005). This improvement is mainly manifested in the freshwater reaches, and some species, such as the copepod *Eurytemora affinis* seem to profit from these new conditions to 'return' to their original habitat in the Schelde after a displacement to more brackish water observed during the early 90ties (Sautour *et al.* 1995, Appeltans *et al.* 2003).

In this report we analyse the spatio – temporal distribution of the total zooplankton community as revealed by using the 2003 dataset, and compare the results obtained in 2003 and 2004.

8.3. Material and methods

8.3.1. Sampling microzooplankton

Samples are taken by the ECOBE laboratory of the University of Antwerp (UIA). Transport to the 'Laboratoire d'Ecologie des Hydrosystèmes' (LEH) of University of Toulouse III is done by courrier or by LEH personnel.

10 OMES–monitoring stations, 6 in de Schelde (Boei 87, Antwerpen, Temse, Dendermonde, Uitbergen, Melle) and the 4 tributaries (Bovenschelde, Durme, Dender and Rupel) are sampled. For microzooplankton, a 2 litres sub-sample of the < 50 µm filtrate available from sampling for mesozooplankton (see further) is used. The 2 litres sample is filtered through 20 µm, and the retained microzooplankton anaesthetized with a carbonated solution and finally fixed in 4% formalin.

8.3.2. Analysis microzooplankton

Determination is carried out at species level as far as possible. Taxonomic verification is done by Dr. F. Fiers and Dr. H. Segers (Koninklijk Belgisch Instituut voor Natuurwetenschappen, KBIN). The analysis of the microzooplankton fraction is limited to Rotifera. The main references used are: Ruttner-Kolisko 1972, Pontin 1978, Pourriot *et al.* 1986, Segers 1995. Abundance is counted under binocular (90x), and converted to number of organisms m^{-3}. Details of the procedure are given in Tackx *et al.* 2004b.

8.3.3. Sampling mesozooplankton

Sampling stations for mesozooplankton are the same as those for microzooplankton. 50 litres water is taken with a bucket at surface and filtered through a 50 µm net. The collected mesozooplankton is processed in the same way as described above for the microzooplankton samples.

8.3.4. Analysis mesozooplankton

Determination is carried out at species level when possible. For copepods this is possible from Copepodits V onwards. Most important references used are: Dussart 1967, 1969 ; Kiefer 1978; Amoros 1984; Margaritora 1985, Einsle 1996, Karaytug 1999, Ueda 2003. Counting and calculation of numerical abundance (nr m^{-3}) is done as for microzooplankton.

8.4. Results and discussion

8.4.1. Taxonomic composition

The Tabels III-1 and III-2 give the taxonomic composition of the micro and mesozooplankton in the Schelde as known 07 2005. A total of 99 species (or genera) are observed, belonging to Rotifera, Crustacea (Copepoda and Branchiopoda). Occasional observations of Protozoa, Aschelminthes and Annelida were not further determined.

Within the microzooplankton we observe a total of 53 taxa of rotifers. *Brachionus bidentata, Notholca squamula, Synchaeta bicornis* are added to the list since Tackx *et al.* 2004a. *B. bidentata* and *S. bicornis* have not been reported from the Schelde before. *S. bicornis* is one of the rare typically marine rotifers moving upstream to the brackish estuary with the tidal flow. The importance of the population of this Synchaetidae in the marine estuary is unknown.

As to the mesozooplankton, one of the earlier reported copepoda species (Tackx *et al.* 2004a) has been revised. The work of Mirabdullayev *et al.* 2002, 2004 on the *A. robustus* – species complex has recently lead to the description of two new species and re-description of *A. robustus* itself. The ecology and distribution of the species newly or re-described is till now completely unknown. In the freshwater reach of the Shelde estuary, the copepod which is the most dominant during the entire year except during spring, was previously identified as *Acanthocyclops robustus* (G.O. Sars, 1863) but is in fact *A. trajani* Mirabdullayev, 2002. This study gives the first report for this species in Belgium and after verification of the OMES samples from 2002 to 2004, we can assume that *A. trajani* is the only species from the *robustus* - complex present in the Schelde estuary.

Two other cyclopoids, *Oithona brevicornis* and *Paracyclops imminutus* are also for the first time reported from the Schelde.

Some specimens of pelagic marine - brackish water harpacticoida were found in the brackish water zone: *Ectinosoma curticornis, Euterpina acutifrons* and *Halectinosoma barroisi*. The freshwater harpacticoids being mostly benthic, they were absent from our sub-surface samplings.

Branchiopoda are represented by 31 taxa of Cladocera. No new species have been observed as compared to Tackx *et al.* 2004a, except for some specimens of '*Dispalona leei*'. This North American species has not been reported before in the Schelde, and its determination is being verified prior to addition to the Schelde species list. Its only European occurrence is in central Spain (Boronat *et al.* 2001).

The continuous addition of species to the Schelde zooplankton species list reflects the usefulness of the maintained regular surveys and taxonomic effort. Mainly the freshwater stretch reveals a large number of species not reported earlier in the Schelde. This can be explained by the fact that the only consistent study in this area has been carried out end of the 1960ties by De Pauw, 1975. At that time, water quality conditions were very bad (Van Damme *et al.* 1995). The species composition reported by Tackx *et al.* 2004a on the 1996 OMES samples, taken under already improved conditions, did not include determination at species level of the rotifera, which contribute largely to the newly reported species.

The fact that zooplankton species richness is considerably higher in the Schelde than previously reported (Tackx *et al.* 2004a), opens perspectives for its use as a bio-indicator, through comparison with other European estuaries. The considerable complexity of the zooplankton community resulting from this diversity raises questions about the trophic functioning of the pelagic compartment in the Schelde estuary, which are presently studied in another framework (Azémar *et al.*, in prep; Lionard *et al.* 2005).

Tabel III-1. Taxonomic list of the Schelde zooplankton dd 07 2005.
* New taxa for the Schelde. In bold underlined, species added since Tackx *et al.* 2004a.

Protozoa

- Foraminifera

Aschelminthes

- Nematoda

Rotifera

Monogononta

- * *Anuraeopsis sp.*
- *Asplanchna brightwelli* (Gosse, 1850)
- *Asplanchna priodonta* Gosse 1850
- *Brachionus angularis Gosse, 1851*
- * ***Brachionus bidentatus Anderson, 1889***
- *Brachionus calyciflorus Pallas, 1766*
- * *Brachionus diversicornis* (Daday, 1883)
- * *Brachionus leydigi* (Rousselet, 1889)
- *Brachionus* quadridentatus Hermann 1783
- *Brachionus rubens Ehrb. 1838*
- *Brachionus* urceolaris O. F. Muller, 1773
- *Brachionus* variabilis Hempel, 1896
- *Cephalodella* sp.
- *Colurella sp.*
- *Epiphanes sp.*
- *Euchlanis dilatata* Ehrenberg, 1832
- *Filinia brachiata* (Rousselet, 1901)
- *Filinia longiseta* (Ehrb. 1834)
- * *Gastropus hyptopus* (Ehrb. 1838)
- * *Kellicottia longispina* (Kellocott, 1879)
- *Keratella cochlearis* (Gosse, 1851)
- * *Keratella cruciformis* (Thompson, 1892)
- *Keratella quadrata* (Müller, 1786)
- * *Keratella testudo (Ehrb. 1832)*
- *Keratella tropica* (Apstein, 1907)
- *Keratella valga* (Ehrenberg, 1834)
- * *Lecane closterocerca* (Schmarda, 1853)
- * *Lecane* decipiens (Murray, 1913)
- * *Lecane* bulla (Gosse, 1851)
- *Lecane flexilis* (Gosse, 1886)
- * *Lecane hamata* (Stokes, 1896)
- * *Lecane luna* (O.F. Müller, 1776)
- *Lecane sp.*
- *Lepadella ovalis* (O. F. Muller, 1786)
- *Notholca acuminata* (Ehrb. 1832)
- ***Notholca squamula (O. F. Muller, 1786)***
- * *Ploesoma sp.*
- * *Ploesoma hudsoni* (Imhof, 1891)
- * *Ploesoma truncatum* (Levander, 1894)
- * *Platyias quadricornis* (Ehrb. 1832)
- *Polyarthra sp.*
- * *Pompholyx sulcata* Hudson, 1855
- * *Rhinoglena frontalis* Ehrb. 1853
- *Synchaeta sp.*
- * ***Synchaeta bicornis Smith, 1904***
- * *Testudinella elliptica (Ehrenberg, 1834)*
- * *Testudinella patina (Hermann, 1783)*
- * *Trichocerca rattus (O. F. Muller, 1776)*
- *Trichocerca similis (Wiersejski, 1886)*
- * *Trichotria tetractis (Ehrenberg, 1830)*

Bdelloidea

- * *Dissotrocha sp.*
- *Rotaria neptunia* (Ehrenberg, 1832)

Annelida

- Oligochaeta

Moreover, the current climate change is supposed to have a strong influence on this functioning. All global change models predict an increase of run-off in North and Western Europe (Arnell 1999). Muylaert *et al.* 2001 showed changes in phytoplankton composition of the Schelde following freshets. During the period 1996-2000, the runoff of the Schelde has strongly and continuously increased and Struyf *et al.* 2004 have shown a possible effect on the modification on the Schelde estuarine nutrient fluxes. So, with the observed climate evolution, the monitoring of the major actors of the estuarine environment such as phytoplankton and zooplankton, which have influence on the entire food web, is particularly useful for estuarine modelling and related predictions.

Tabel III-2. Taxonomic list of the Schelde zooplankton dd 07 2005.
[(1)] Species previously identified as *A. robustus* (G.O. Sars, 1863).
* New taxa for the Schelde. In bold underlined, species added since Tackx *et al.* 2004a.

Crustacea

Calanoida

- *Acartia tonsa* Dana, 1848
- *Eurytemora affinis* (Poppe, 1880)
- *Eudiaptomus gracilis* (Sars, 1863)

Harpacticoida

- * *Bryocamptus (Br.) minutus* (Claus, 1863)
- * **<u>*Ectinosoma curticorne* Boeck, 1873</u>**
- **<u>*Euterpina acutifrons* (Dana, 1848)</u>**
- * **<u>*Halectinosoma barroisi* (Richard, 1893)</u>**

Branchiopoda

- * *Acroperus harpae* (Baird, 1835)
- * *Alona rectangula* Sars, 1862
- * *Biapertura affinis* (Leydig, 1860)
- *Bosmina coregoni* Baird, 1857
- *Bosmina longirostris* (O.F. Müller, 1785)
- *Ceriodaphnia quadrangula* (O.F. Müller, 1785)
- * *Ceriodaphnia laticaudata* P.E. Müller, 1867
- * *Ceriodaphnia pulchella* Sars, 1862
- * *Ceriodaphnia reticulata* (Jurine, 1820)
- *Chydorus sphaericus* (O.F. Müller, 1785)
- *Daphnia cucullata* Sars, 1862
- *Daphnia galeata* Sars, 1864
- *Daphnia hyalina* Leydig, 1860
- *Daphnia longispina* O.F. Müller, 1785
- *Daphnia magna* Straus, 1820
- *Daphnia obtusa* Kurz, 1874
- *Daphnia pulex* Leydig, 1860
- *Disparalona leei* (Chien, 1970)
- *Disparalona rostrata* (Koch, 1841)
- *Ilyocriptus agilis* Kurz, 1878
- *Ilyocryptus sordidus* (Liévin, 1848)
- *Leydigia acanthocercoides* (Fischer, 1854)
- *Leydigia leydigi* (Schoedler, 1858)
- *Macrothrix laticornis* (Jurine, 1820)
- *Moina brachiata* (Jurine, 1820)
- *Moina micrura* Kurz, 1874
- * *Pleuroxus aduncus* (Jurine 1820)
- * *Pleuroxus uncinatus* Baird, 1850
- * *Scapholeberis mucronata* (O.F. Müller 1785)
- * *Simocephalus exspinosus* (Koch, 1841)
- *Simocephalus vetulus* (O.F. Müller 1776)

Cyclopoida

- 1* **<u>*Acanthocyclops trajani* Mirabdullayev, 2002</u>**
- *Cyclops vicinus vicinus* Ulianine, 1875
- *Diacyclops bicuspidatus* (Claus, 1857)
- *Eucyclops serrulatus* (Fischer, 1851)
- *Eucyclops speratus* (Lilljeborg, 1901)
- * **<u>*Oithona brevicornis* Giesbrecht, 1891</u>**
- * **<u>*Paracyclops imminutus* (Kiefer, 1929)</u>**
- *Paracyclops fimbriatus* (Fischer, 1853)
- *Thermocyclops crassus* (Fisher, 1853)
- *Thermocyclops oithonoides* (G.O. Sars, 1863)
- *Tropocyclops prasinus* (Fisher, 1860)

The occurrence of exotic species in the Schelde is not surprising considering its intensive shipping activity brought about by the world harbour of Antwerp. In a biological – ecological context, the subject of potentially invasive species is very much in actuality. Up till present, the only exotic zooplanktonic species which seems to be 'installing' themselves in the Schelde are the calanoid *Acartia tonsa*, now dominant in the brackish estuary in summer, and the rotifer *Keratella tropica*, previously present in the cooling waters of factories (Leentvaar 1980) and now in the freshwater estuary in summer.

The specific case of the potentially invasive character of the calanoid copepod *E. affinis* will be discussed in the frame of its spatio –temporal distribution (see below).

8.4.2. Abundance and spatio – temporal distribution of mesozooplancton

The microzooplancton (essentially rotifers) being numerically always abundant especially in the freshwater reaches, this reports concentrates on the mesozooplancton.

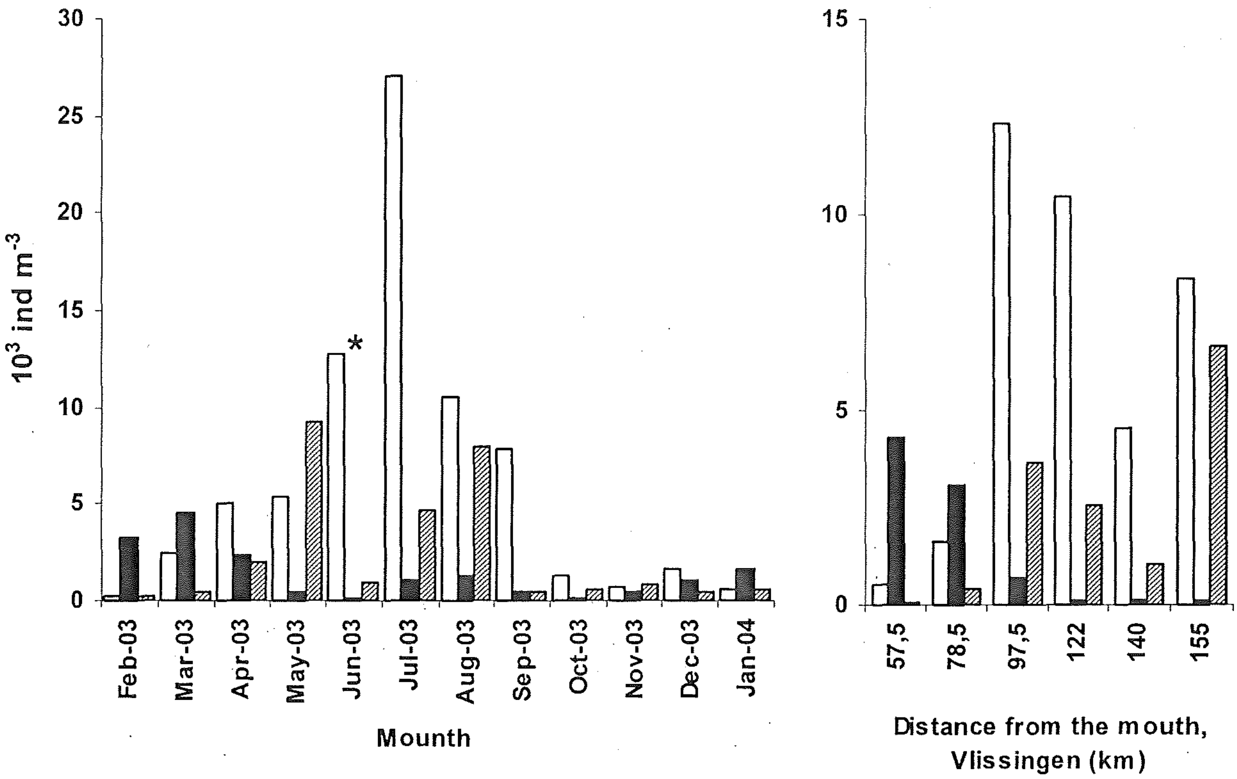


Fig. 1. Average numerical abundance of the main taxonomic mesozooplankton groups in the Schelde during 2003: cyclopids (white), calanoids (black) and cladocerans (striped).
a. Average over all 6 stations estuary per month. Asterisk indicates absence of data from the freshwater reach, in june 2003.
b. Average over all months for each station.

The average numerical abundance per month (Fig. 1a) shows that calanoides dominate during spring in the brackish water reaches. Cyclopoids abundance increase in the course of spring, to reach a maximum in june – july. Afterwards the population decreases gradually to low abundances in autumn - winter. The highest values were located in the freshwater area, just upstream the brackish reach. Cladocera have a more irregular occurrence with highest abundance around summer. Fig 1b show the typical spatial pattern of, on the one hand, Calanoida concentrated in the brackish water reaches (km 57.5 – 76.5) and, on the other hand, cyclopoida and cladocera in the freshwater reaches (km 97.5 – 155).

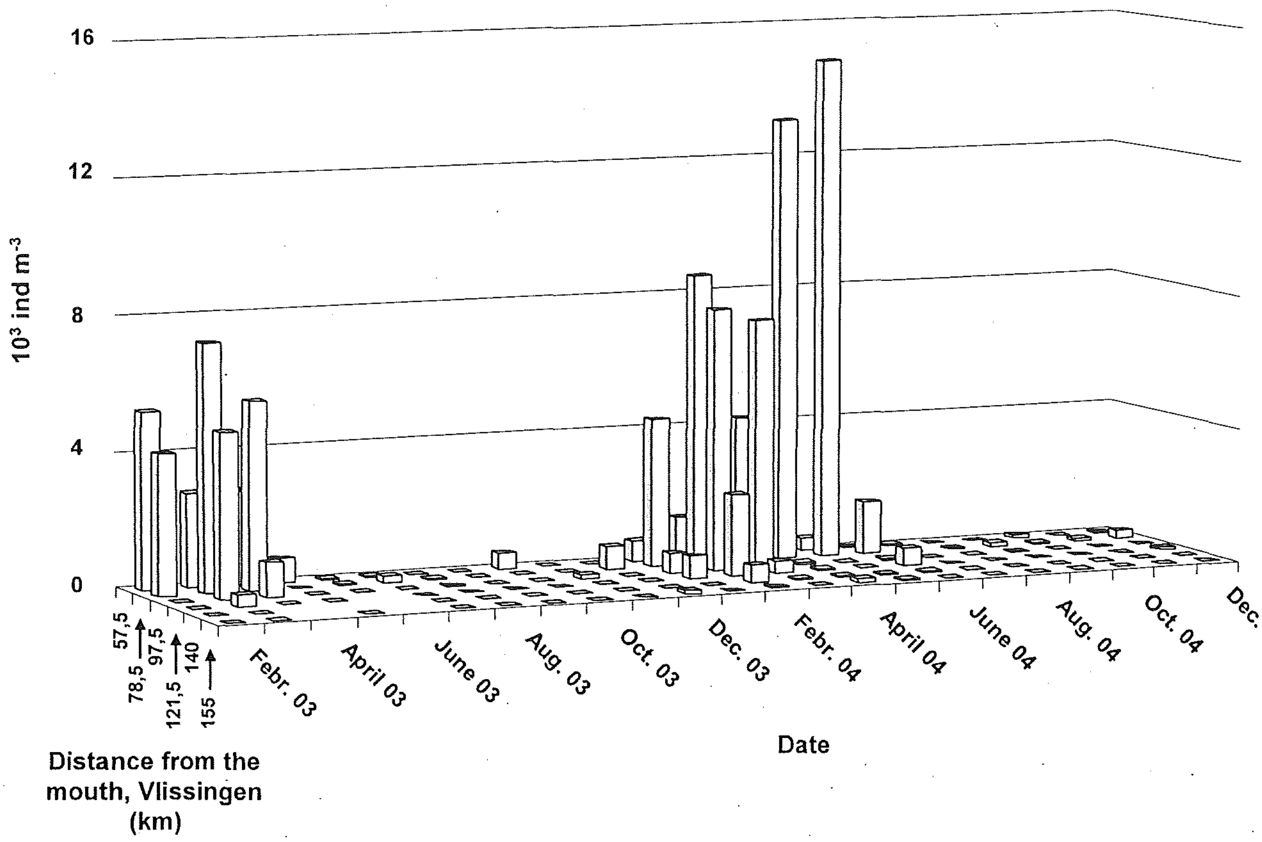
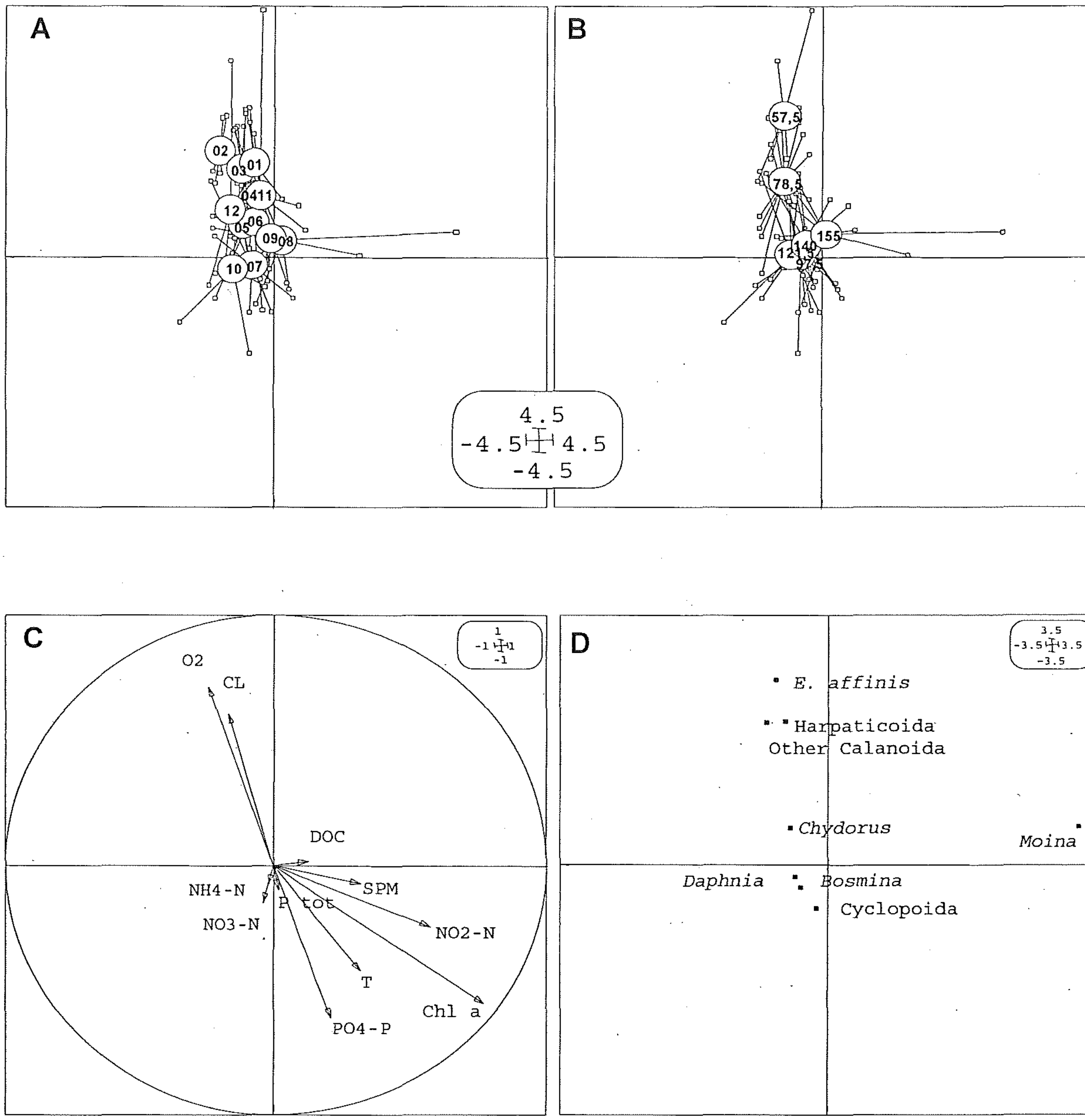


Fig. 2. Numerical abundance of *E. affinis* as observed in the Schelde during 2003-2004.

The calanoid copepod *Eurytemora affinis* is followed with special attention because of its migration to the freshwater area in recent years (Appeltans *et al.* 2003). Also during 2003 (Fig 2), the species was observed in both fresh – and brackish water. Its maximum abundance was observed in spring, around the Antwerp area (km 87,5). Contrary to the 2002 observations, (Tackx *et al.* 2004b) *E. affinis* did not occur during summer neither in 2003 nor 2004. The reason why this calanoid was found outside its usual distribution in 2002 remains unknown.



E

Axes	% Total Inertia
1	0,412
2	0,29
3	0,177

Fig 3. Results of the CCA analysis on mesozooplankton abundance data from February 2003 till January 2004.

Axes 1 et 2 of the ordination are shown.

A- Monthly average; B- Station average (station represented by distance from the mouth in km).

C- Environmental factors: Temperature (T), concentration of: Dissolved oxygen (O2), Dissolved Organic Carbon (DOC), Suspended Particulate Matter (SPM), N- Nitrate (NO2-N), N- Nitrite (NO3-N), Amonia (NH4), P- Phosphate (PO4-P), Total phosphorus (Ptot,), Chlorophyll a (CHLa). (from OMES database)

D- Zooplancton taxa : *Eurytemora affinis*, Calanoïda adults other than *E. affinis*, *Chydorus*, Cyclopoida adults, Harpaticoida adults, *Bosmina*, *Daphnia*, *Moina*.

E- Total inertia percentage.

CCA analysis applied to the 2003 samples shows that the zooplankton community is mainly structured (Fig 3 d) following the first axis, which explains 41 % of total inertia. This axis is associated with increasing chlorinity and oxygen concentration towards the upper left (Fig 3c). These circumstances correspond to the brackish water stations (km 57,5 and 78,5) (fig 3 b), where *E. affinis*, other calanoids (as *Acartia tonsa*) and, occasionally, marine harpacticoids are found (fig 4d). The lower right quadrat of the ordination is characterised by high temperature, and chlorophyll concentrations and high PO4-P and NO2-N concentrations.

The cladoceran *Moina*, present in the freshwater Schelde in summer is located on the extreme right, associated with high temperature, chlorophylle and NO_2.

The other taxa, located near the centre, do not show a clear relationship to the environmental factors considered. This is probably due to the grouping applied to 'other calanoida' and 'cyclopida', as these groups contain species occurring in various periods of the year. Other possibilities are that a majority of species occurring in the Shelde is quite unsensitive for the present environmental conditions, or, on the contrary that more detailed information on the feeding conditions (e.g. algal composition) should be included in the analysis. Indeed, Tackx *et al.* 1995, 2003, have shown the some dominant zooplankton species in the Schelde feed selectively on phytoplankton, even around the detritus dominated MTZ. A complete analysis using species abundance and a comparison of the ecological relevance of using different degrees of taxonomic resolution is in progress (Azémar *et al.*, in prep).

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Hoofdstuk 9. Effecten van waterkwaliteit en getij op overstromingsgebieden.

Study of the effects of water quality and tidal regime at controlled inundation areas

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9.1. Introduction

To protect inhabited areas from flooding, construction of controlled inundation areas can be considered as a possibility to store an amount of water during high water.

In the freshwater tidal zone of the Scheldt estuary, a controlled inundation area will be created in Kruibeke-Bazel-Rupelmonde, in which the hydrological characteristics will differ from those in the marshes, i.e. the duration of inundation will be much longer here than in the marshes.

On the marshes of the Scheldt-estuary, reed (*Phragmites australis*) is a dominant plant species (Criel et al., 1999) which influences the microbial processes in the soil and plays an important role in the nitrogen retention. It is able to withstand extreme environmental conditions, including the presence of toxic heavy metal contaminants such as Zn, Pb and Cd (Deleebeeck, 2001) and extreme water regimes.

It is expected that in the 'controlled inundation area', reed will be a dominant plant species. An increase in the reed-area could play an important role in the 'purification capacity' of the Scheldt-estuary and thus lead to a decrease in the nitrogen load to the North Sea. Therefore it is necessary to know how reed reacts at different situations.

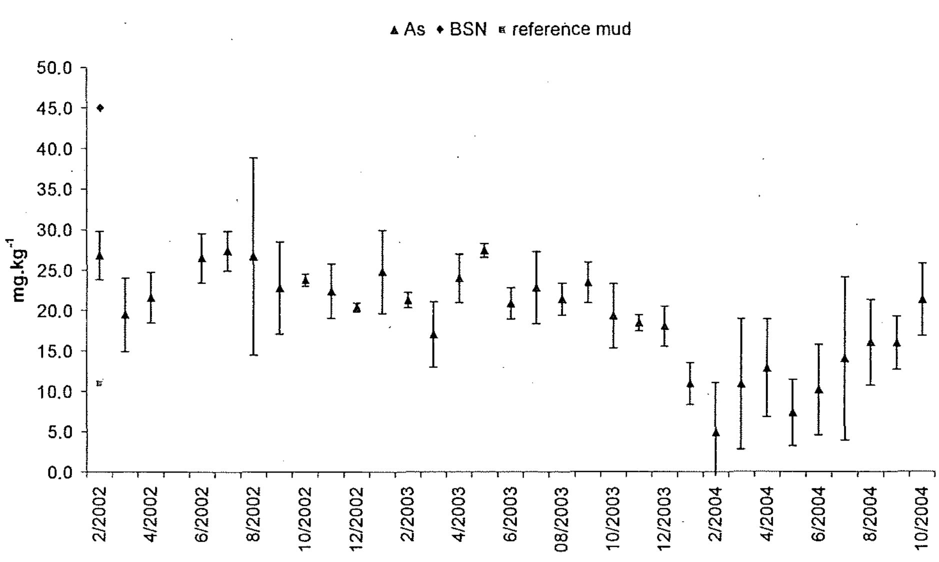
In order to achieve the above, 2 different experiments have been carried out: 1) a mesocosm experiment in which different tidal regimes are simulated. Reed is planted at different levels and subjected to different flooding regimes. The effect of different substrata (sandy loam and silt loam) on the growth of reed is also included in the experiment. The aim is to examine the influence of different tidal regimes on the growth and biomass production of reed. 2) A mesocosm experiment in Kruibeke in which the growth and metal uptake of *Phragmites australis,* grown on 'clean' and 'metal-contaminated' substrate under flooded (with contaminated water from the Scheldt) conditions will be investigated. The mobility of heavy metals in the flooded 'clean' and 'contaminated' soils will be measured. The aim is to examine the influence of contaminated soils on the growth and biomass production of reed, and the evolution of contamination and bioavailability in 'clean' and 'contaminated' soils when flooded with water from the Scheldt.

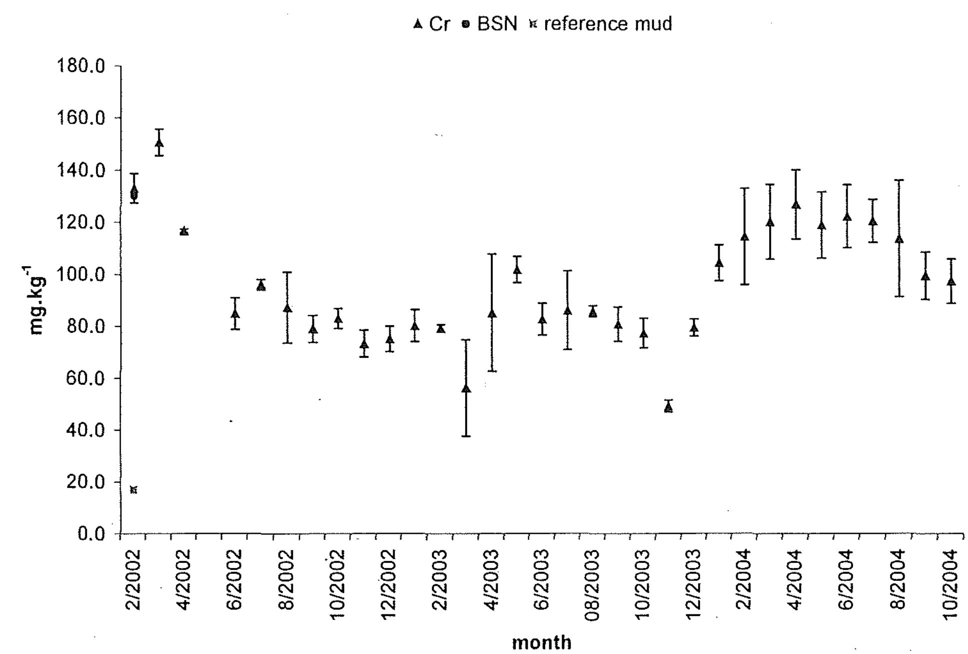
9.2. Monitoring river water at Kruibeke

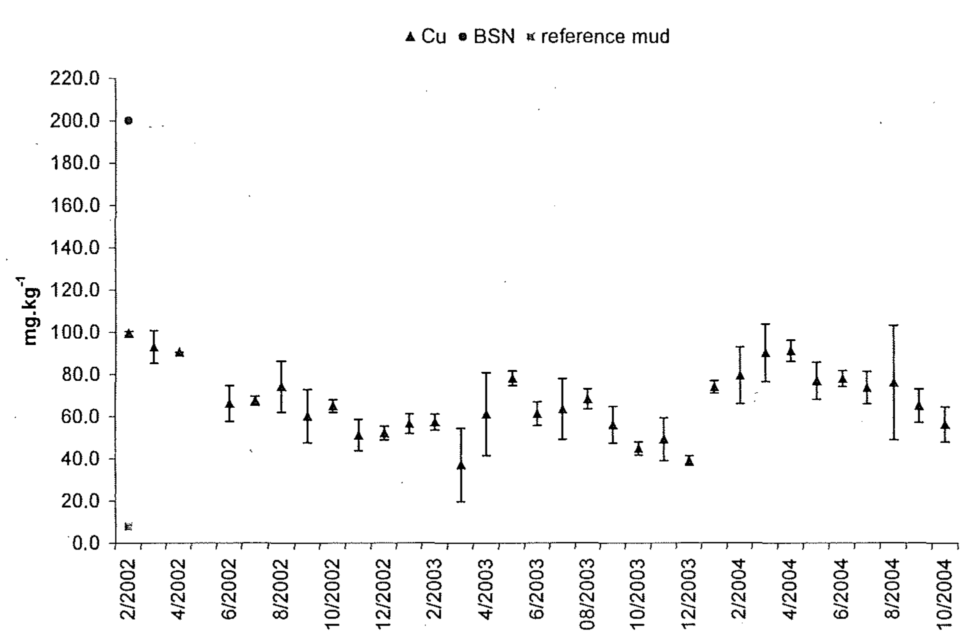
In 2003, a monthly monitoring of the water quality and the suspended sediments of the Scheldt was started. Water samples were taken at Kruibeke, near the mesocosm experiment, and heavy metals (As, Cd, Cr, Cu, Ni, Zn, and Pb) were measured on suspended sediments. 4 water samples were taken, 1 at 4m80, 1 at high water, 1 between 4m80 and high water, and 1 after high water. Water and suspended sediments are separated by a deposition method and dried at 70°C. Heavy metals were measured in the suspended solids. Destruction with aqua regia was done and the analyses were done using an ICP.

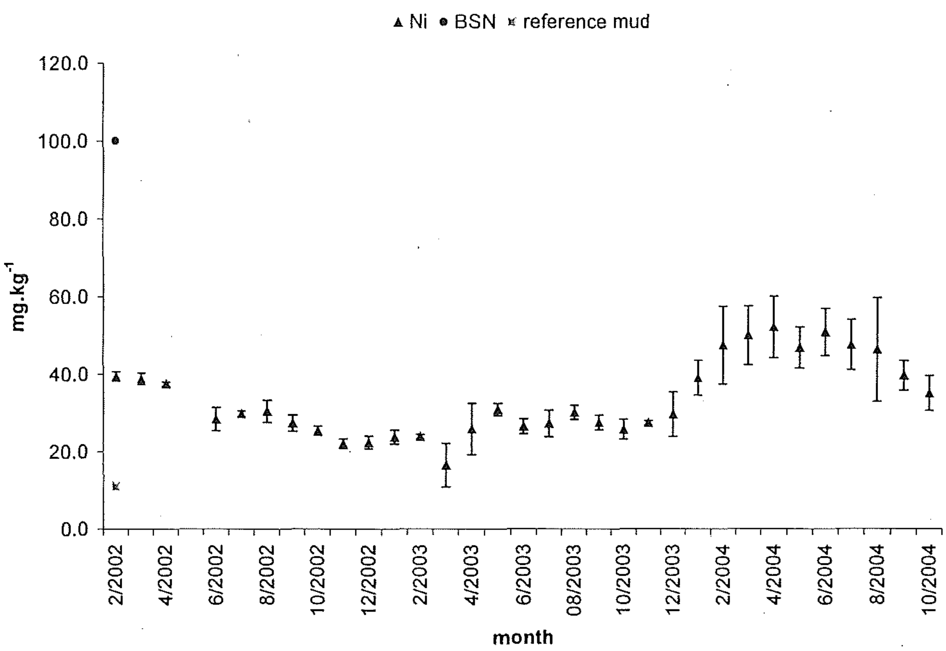
9.2.1. Results and discussion

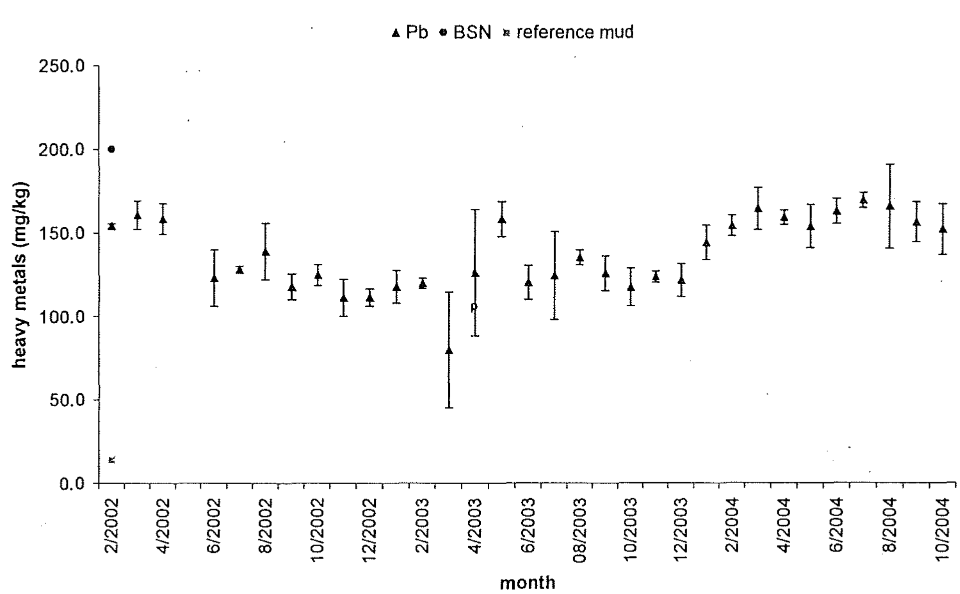
Samples are taken at the time when the water floods into the experiment. The suspended sediments are contaminated with heavy metals (see figure 1) By comparison of the soil remediation standard with the content of heavy metals in the suspended solids it is clear that the contamination exceeds the soil remediation standard for Cd and Zn. There isn't a trend in content of heavy metals during the year.




▲ Cr ● BSN ⌘ reference mud
mg.kg^{-1}
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
2/2002
4/2002
6/2002
8/2002
10/2002
12/2002
2/2003
4/2003
6/2003
08/2003
10/2003
12/2003
2/2004
4/2004
6/2004
8/2004
10/2004
month


▲ Cu ● BSN ⌘ reference mud
mg.kg^{-1}
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
2/2002
4/2002
6/2002
8/2002
10/2002
12/2002
2/2003
4/2003
6/2003
08/2003
10/2003
12/2003
2/2004
4/2004
6/2004
8/2004
10/2004
month


▲ Ni ● BSN ✕ reference mud
mg.kg-1
120.0
100.0
80.0
60.0
40.0
20.0
0.0
2/2002
4/2002
6/2002
8/2002
10/2002
12/2002
2/2003
4/2003
6/2003
08/2003
10/2003
12/2003
2/2004
4/2004
6/2004
8/2004
10/2004
month


▲ Pb ● BSN ✕ reference mud
heavy metals (mg/kg)
250.0
200.0
150.0
100.0
50.0
0.0
2/2002
4/2002
6/2002
8/2002
10/2002
12/2002
2/2003
4/2003
6/2003
08/2003
10/2003
12/2003
2/2004
4/2004
6/2004
8/2004
10/2004
month

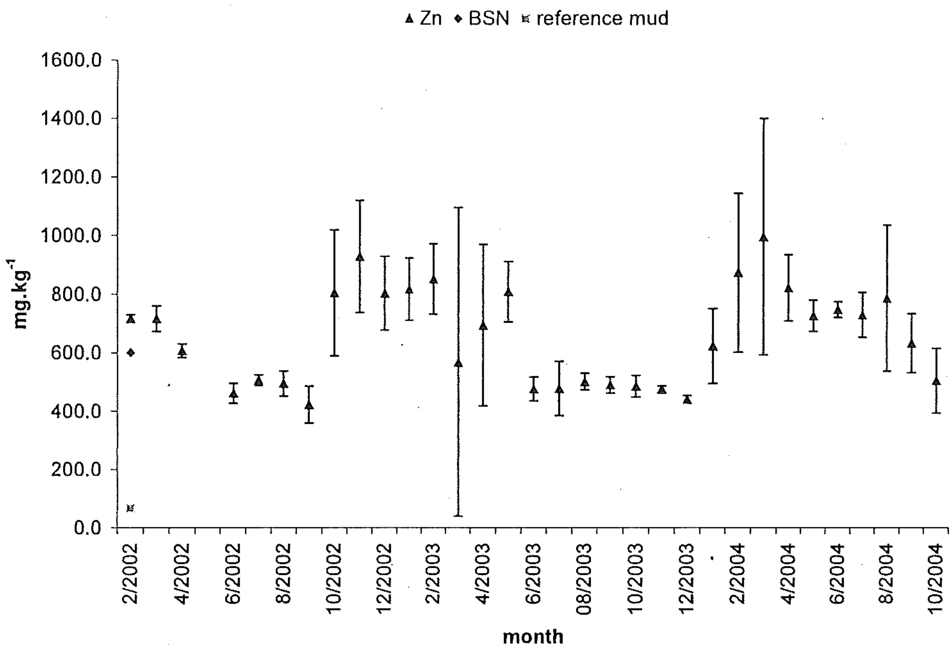


Figure 1: Heavy metals and standard error in suspended sediments of the river Scheldt. Samples were taken around 4.80m TAW near the mesocosm experiment Kruibeke, every month. BSN: soil remediation standard for a specific metal.

9.3. Monitoring of pore water and soil in the mesocosm experiment Kruibeke and the effect of contamination on phragmites and vice versa

9.3.1. Monitoring of pore water:

At Kruibeke, "peepers", in situ samples, were placed in April 2003, so pore water measurements could start. In June 2003, first measurements were started. Every two months, samples were taken.

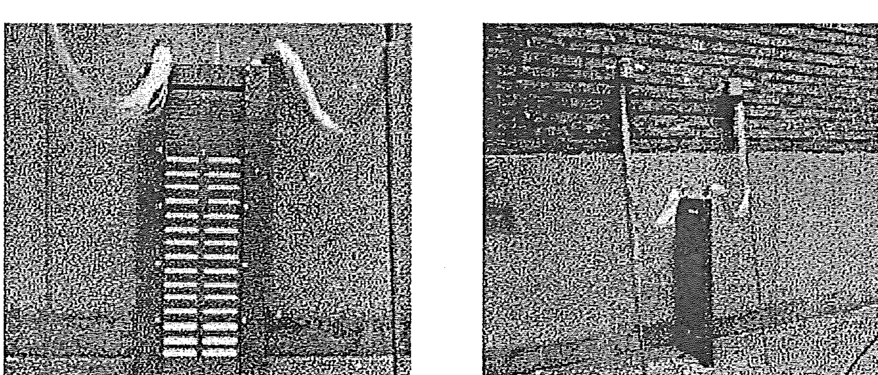


Figure 2 : picture of the in situ sampler (peeper).

The method for analyses of nutrients was the same as methods used in perceel 1. Measurements of heavy metals were done by an 'Inductively Coupled Plasma Emission Spectrophotometer' (ICP), coupled to a 'Charged Injection Device'-detector (CID-detector).

9.3.2. Results and discussion

For NO_2-N, concentrations were mostly lower than the detection limit. NO_3-N: the concentrations were lower than the detection limit in almost all samples of the clean treatment. In the contaminated treatment, concentrations were low in the upper soil level but increased with depth and reached highest concentrations (3-5 mgN/l) around 30cm of depth. Deeper than -30cm, concentrations start decreasing, until below the detection limit at -50cm. For the parameter NH_4-N, there was a lot of variation in the measurements, whereas we found a range of – detection limit until 1.50 mgN/l. No trend was found in depth. For all 3 parameters, no seasonal trends were present.

For PO_4, no trends were present. The concentration was between 0 and 2,5 mgP/l.

SO_4 concentration is much higher in the clean treatment than in the contaminated treatment. No seasonal trend is present.

Fe and Mn: no seasonal trend was present. In the contaminated treatment, the concentration of both Fe and Mn increased. This is due to the reduction of the Fe- and Mn-oxides in the anoxic soil.

Cd, Cr, Cu, Ni, Pb and Zn showed no differences in concentrations between the contaminated and the clean treatments and no seasonal trends were detected.

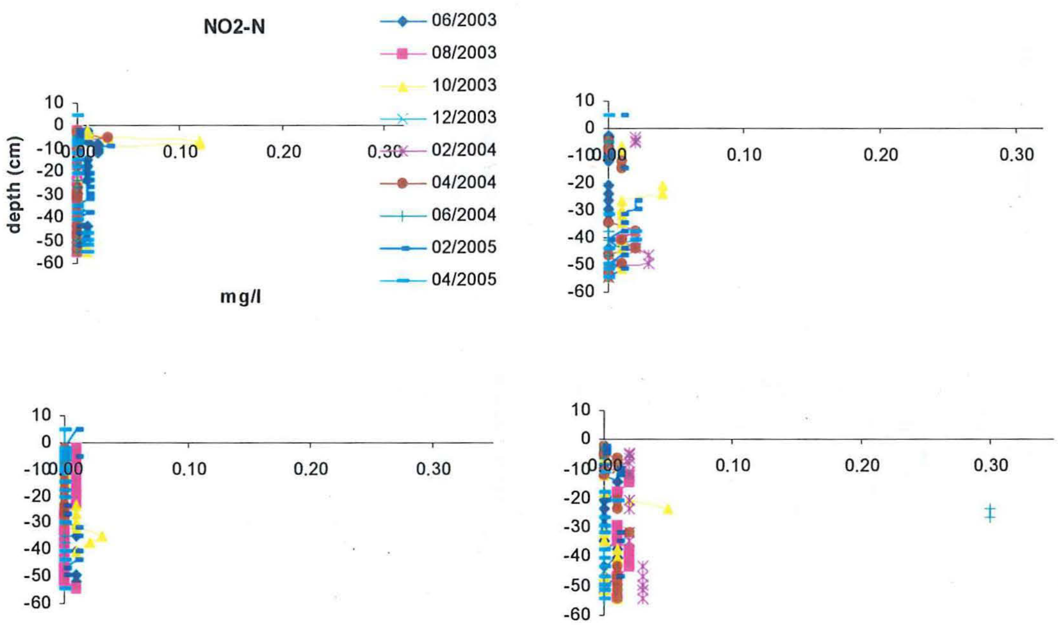
Conclusion pore water samples:

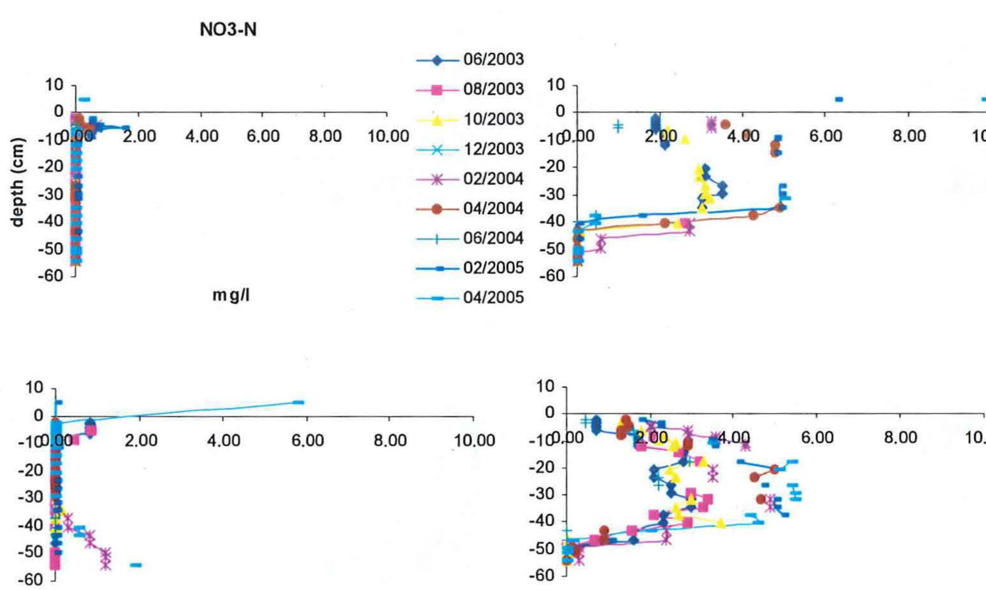
a. We did not found a seasonal trend in the different parameters

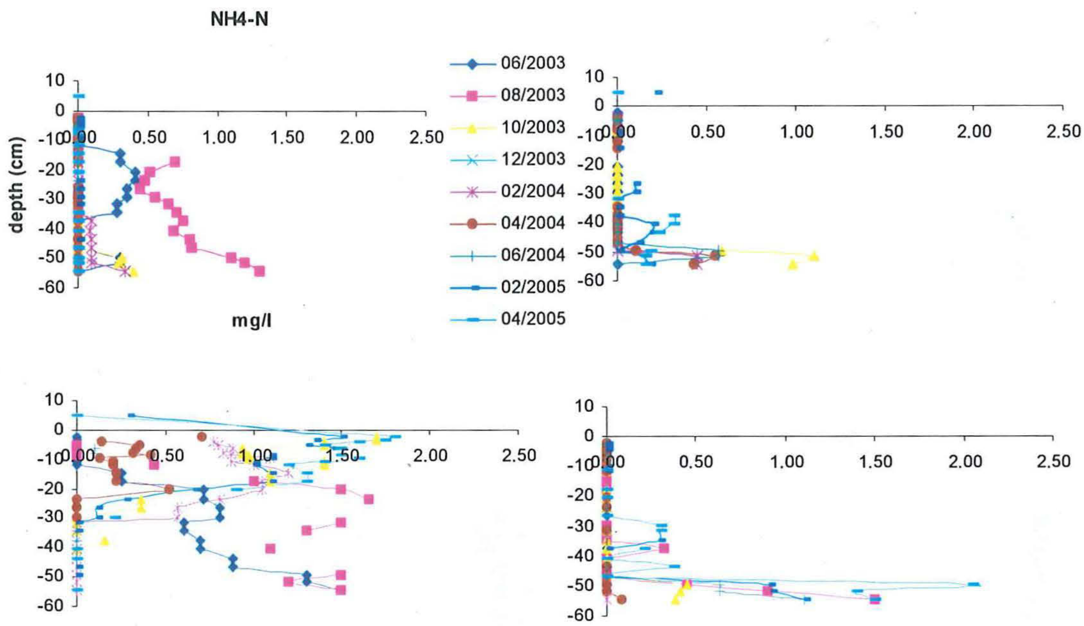
b. We did not found differences in concentrations of the parameters between the treatments planted with and without *Phragmites australis*.

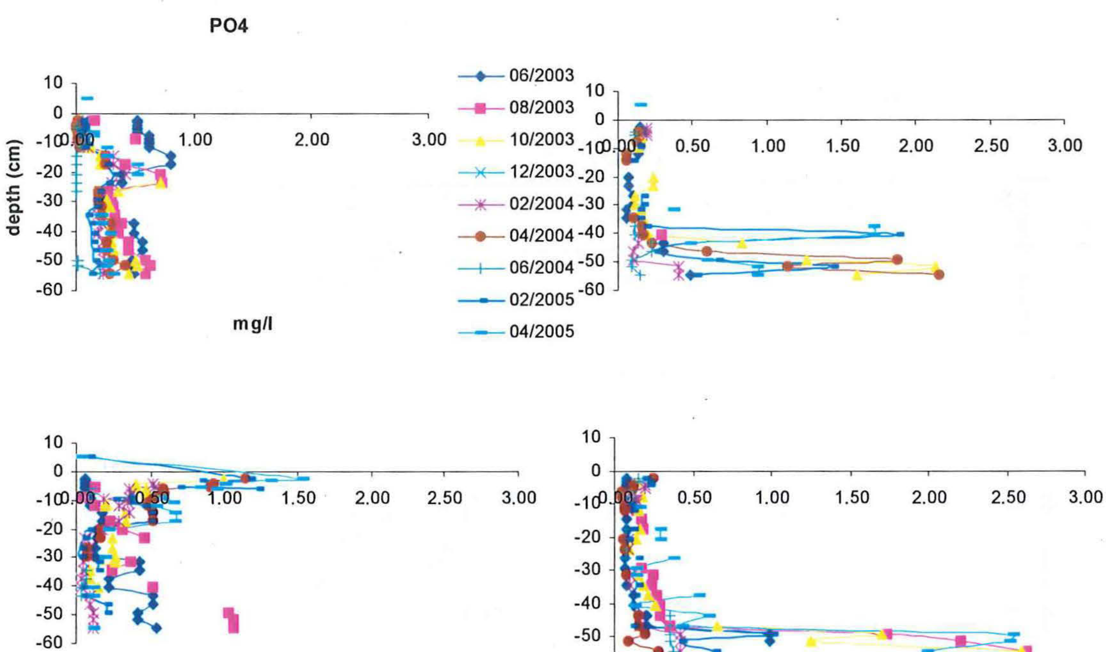
c. Most measured elements did not have a difference in concentration between the contaminated and the clean treatment. This difference was only true for 4 parameters: NO3-N, the concentrations were highest in the contaminated soil. SO4, where concentrations were higher in the not contaminated soil. These 2 differences are present since the start of the experiment and as such is not a consequence of the treatments (flooding, reed, contamination); Fe and Mn concentrations increased in the contaminated soil at the deepest levels. If we look to the NO_3-N concentration, we can see that when this concentration decreases, the concentration of Fe and Mn increases. This will be due to the anoxic state of the soil at the depth from –40cm on. Fe and Mn are bound as Fe- and Mn-oxides, but in an anoxic soil, reduction of the Fe and Mn oxides takes place.

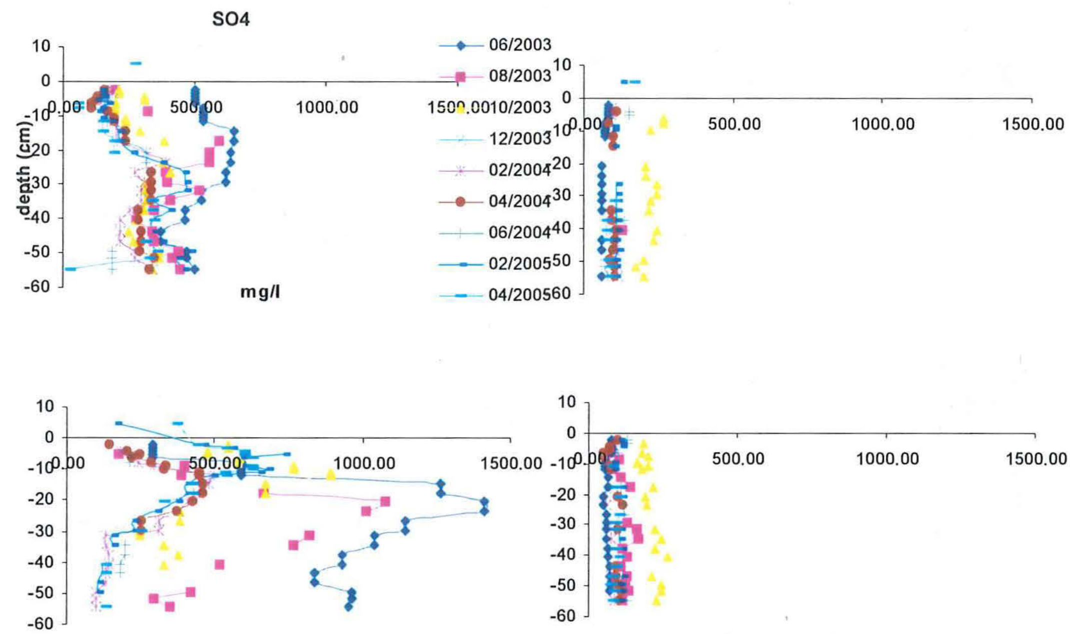
Clean soil + reed	Contaminated soil+ reed
Clean soil	Contaminated soil

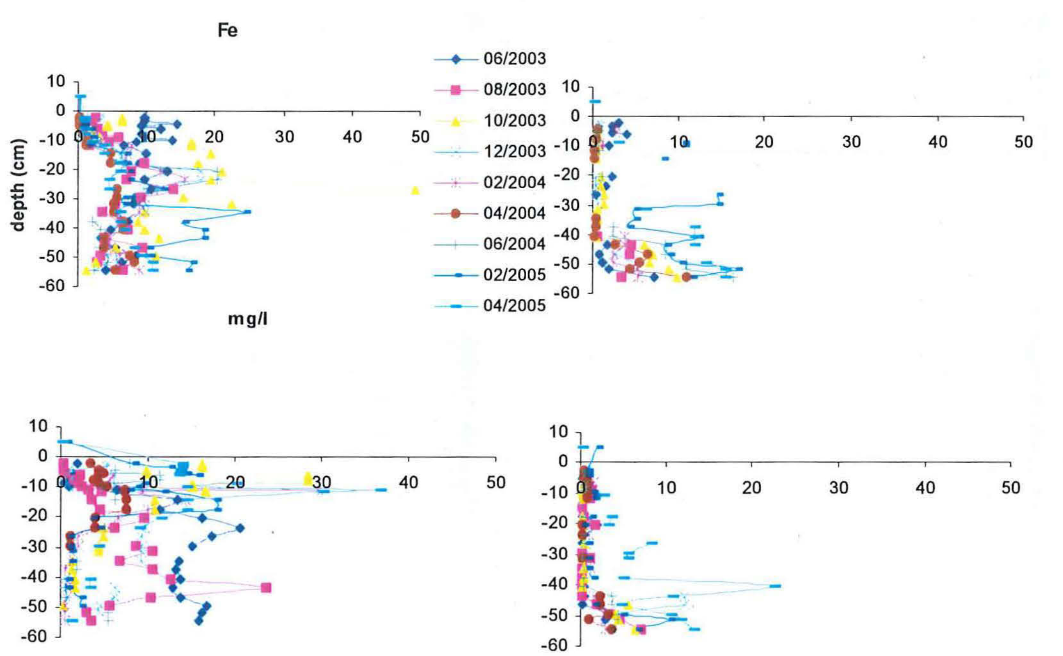


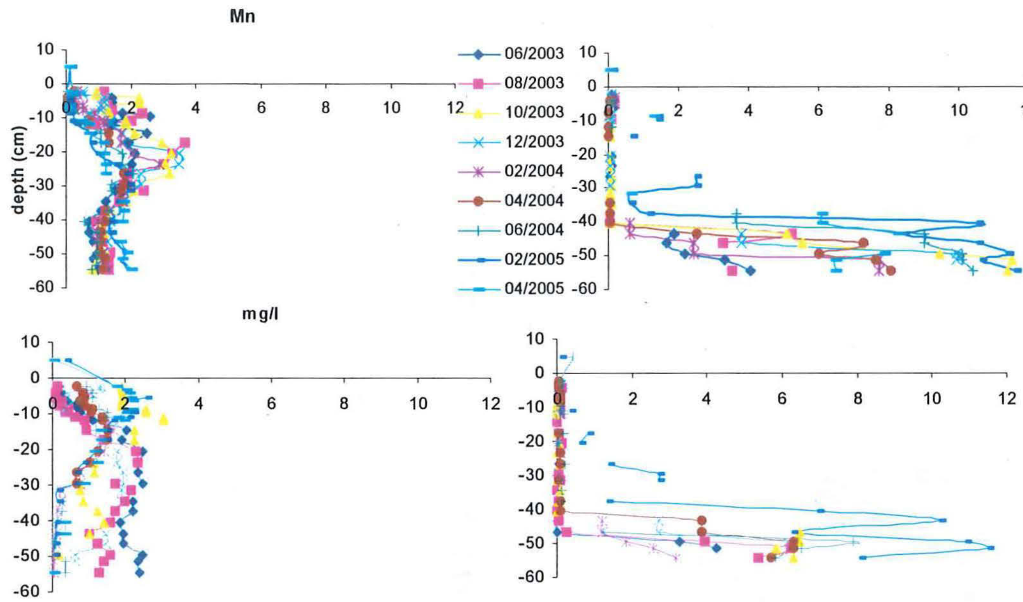


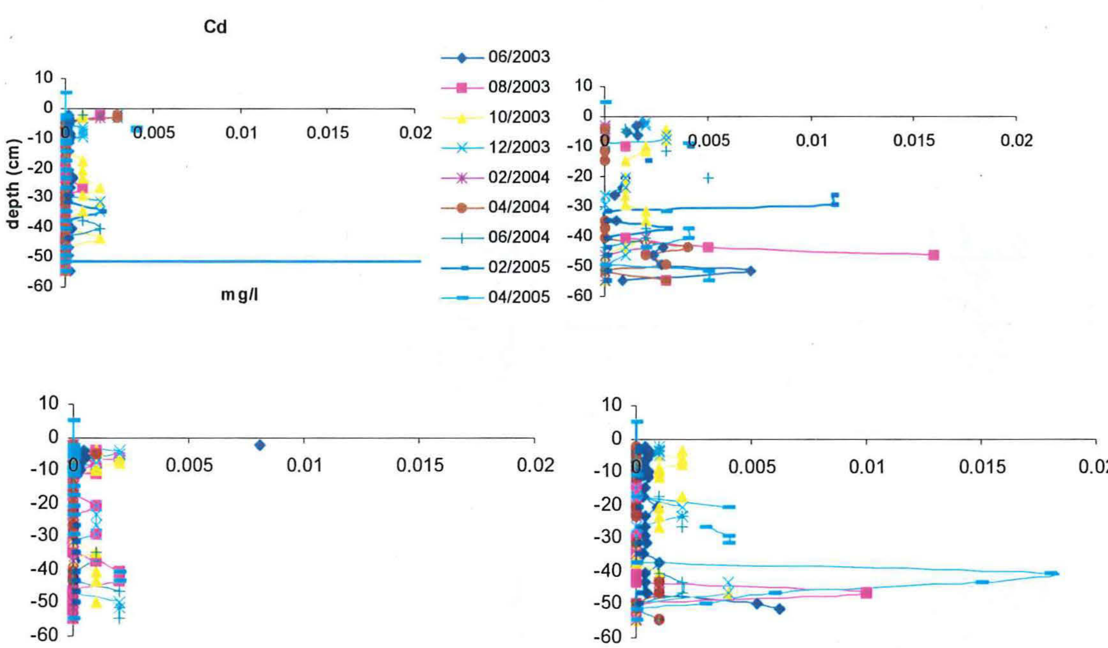

NH4-N
depth (cm)
mg/l
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005

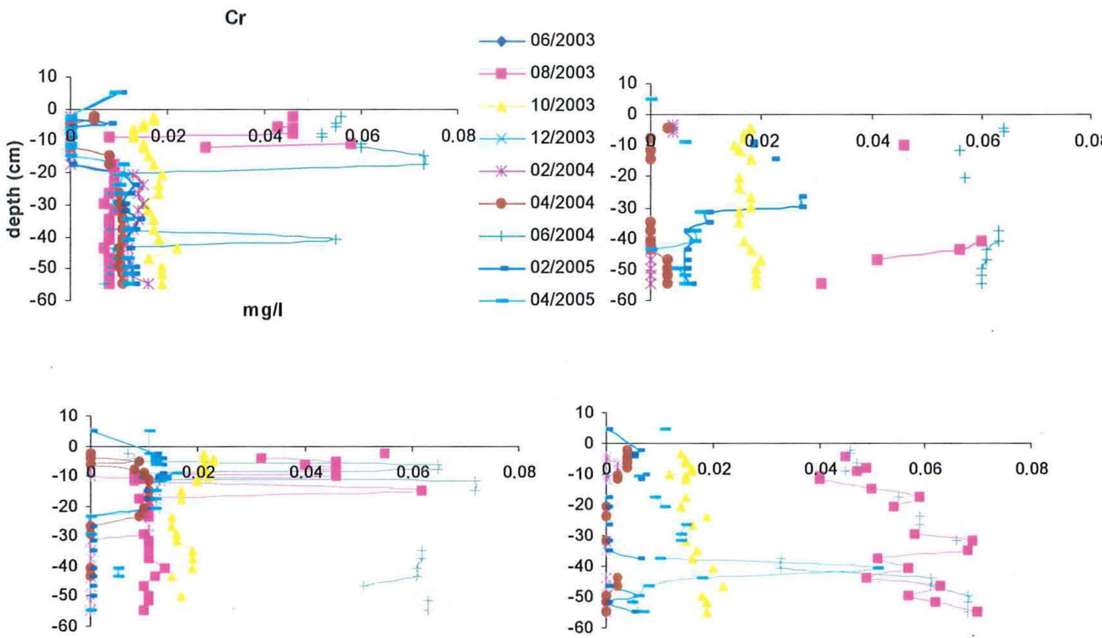

PO4
depth (cm)
mg/l
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005

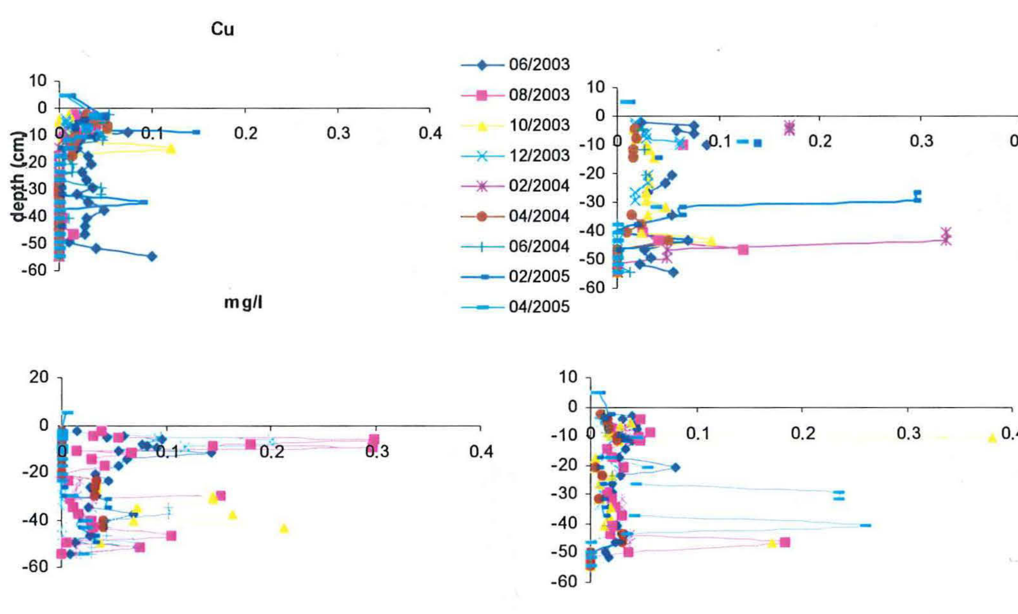

SO4
depth (cm)
mg/l
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005
0.00
500.00
1000.00
1500.00

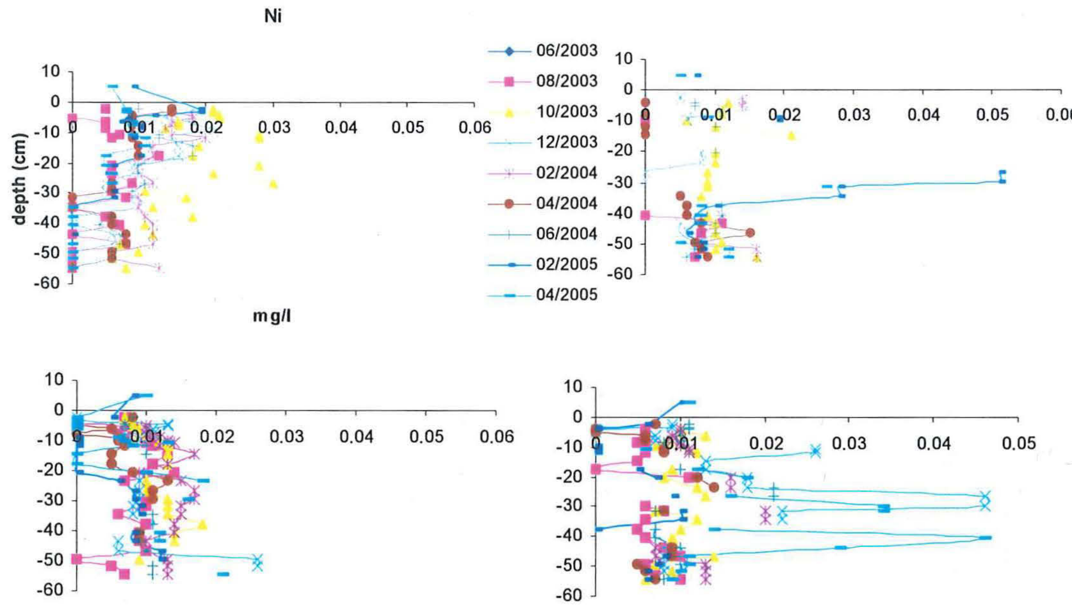

Fe
depth (cm)
mg/l
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005

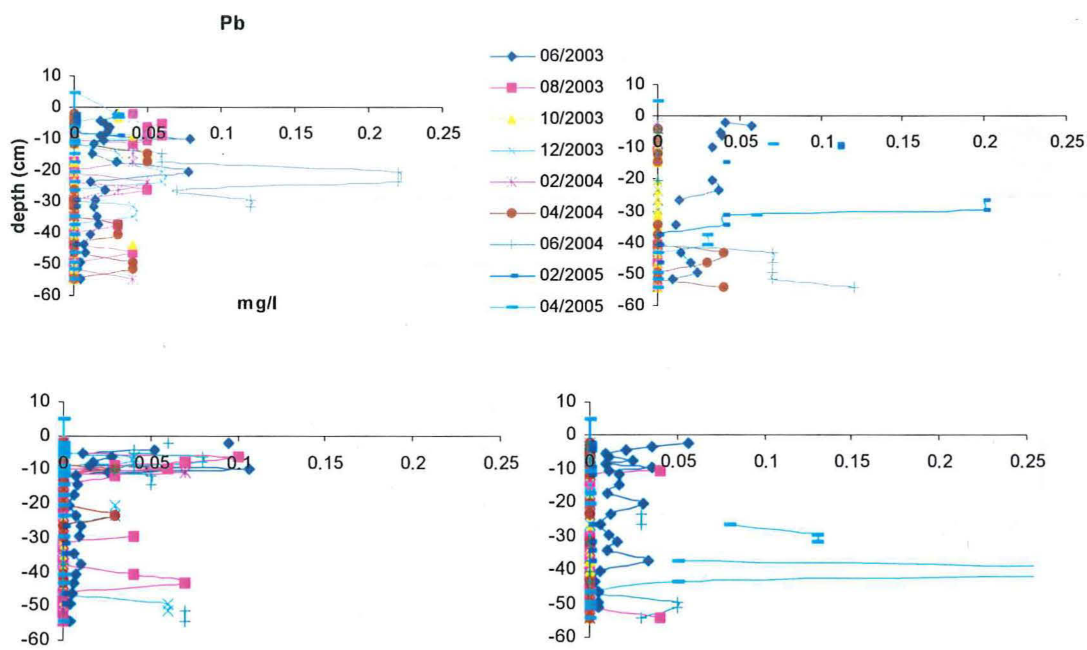

Mn
depth (cm)
mg/l
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005


Cd
depth (cm)
mg/l
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005


Cr
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005
depth (cm)
mg/l


Cu
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005
depth (cm)
mg/l


Ni
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005
depth (cm)
mg/l


Pb
06/2003
08/2003
10/2003
12/2003
02/2004
04/2004
06/2004
02/2005
04/2005
depth (cm)
mg/l

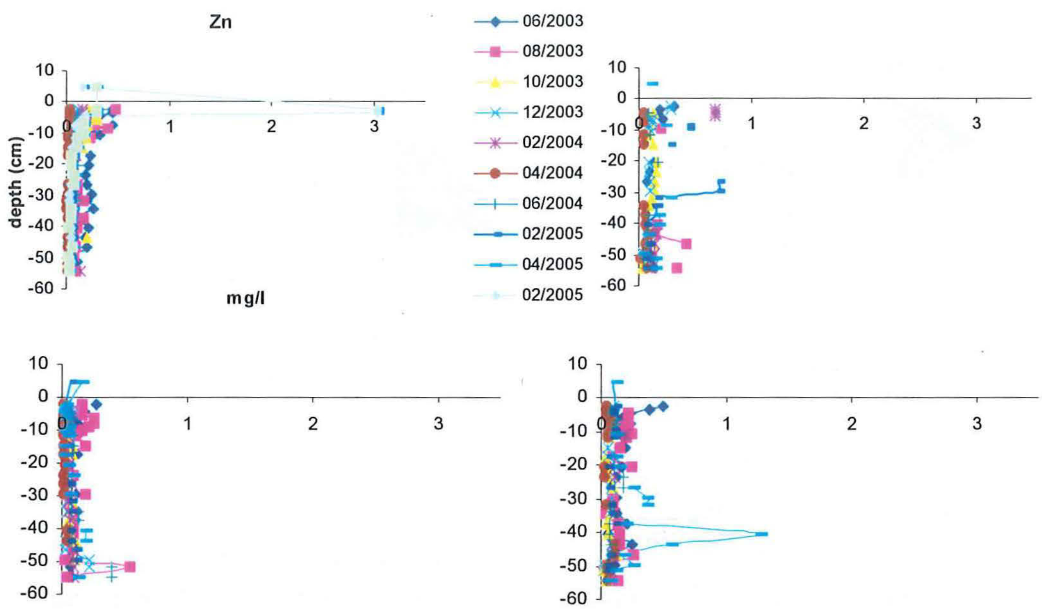


Figure 3: Results of pore water analyses in experimental setup Kruibeke

9.3.3. Monitoring of soil:

The mesocosm experiment at Kruibeke was placed during spring of 2002. The experiment was filled with soil in May 2002. Two treatments were filled with soil contaminated with heavy metals; two treatments were filled with a clean soil.

To find the needed soil, samples were taken at different places nearby Kruibeke. The suitable soil was found in Lippenbroek, in Hamme (contaminated soil) and in a brickyard in Niel (clean soil).

From august 2003 on, every two months, soil samples were taken and analysed.

Figure 4: Picture of filling of the mesocosm with both soils. First, water permeable plastic was placed to avoid that soil would leak out of the mesocosm.

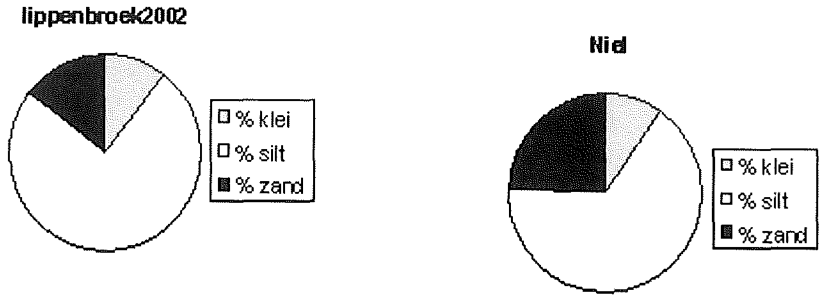


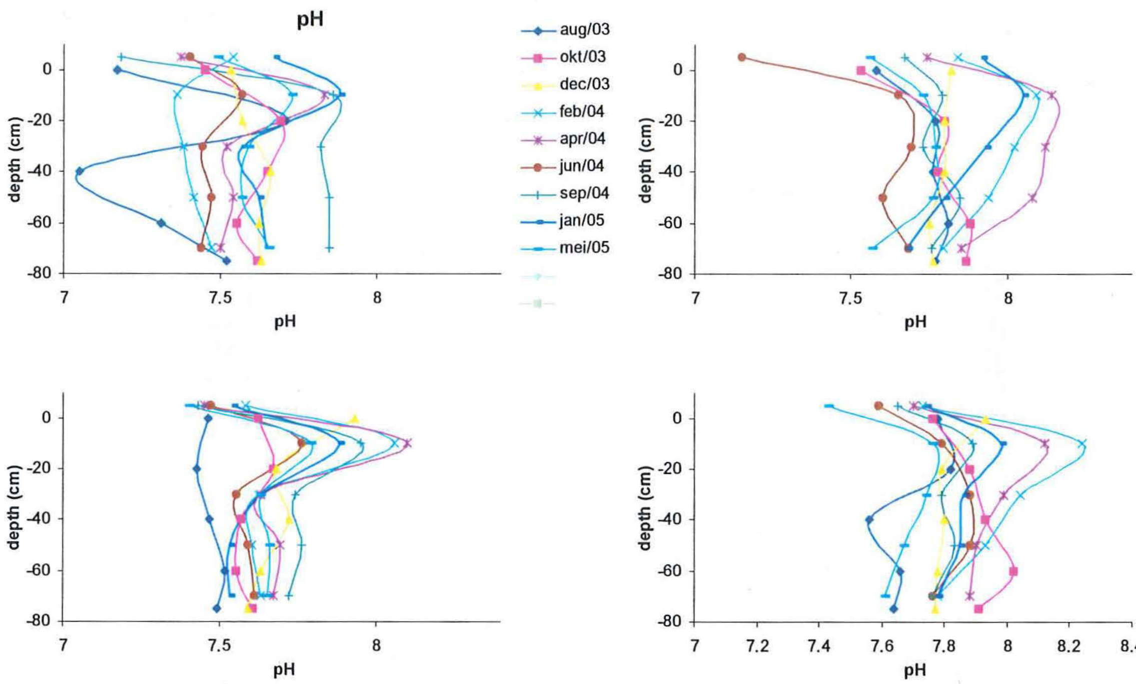
Figure 5: The soil texture of both
soils. Lippenbroek 2002 = contaminated soil, Niel= clean soil.

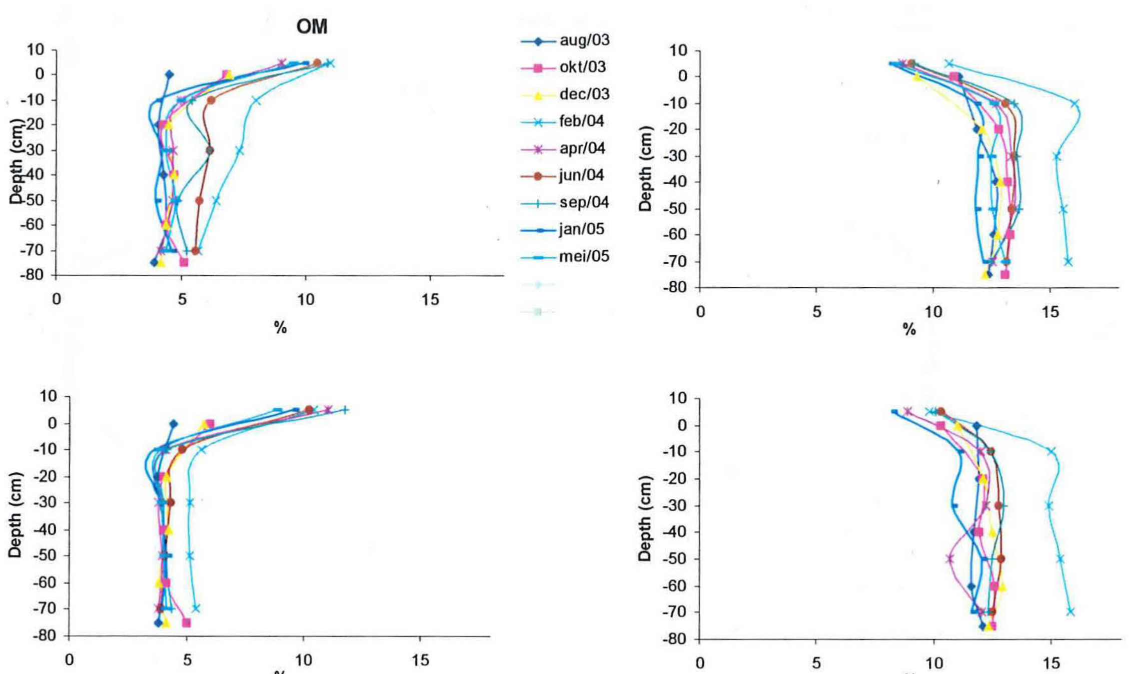
9.3.4. Results and discussion:

The main mechanism of heavy metal retention in soils is the adsoption on soil compounds, increasing with pH, content of organic matter, CaCO3 and cation exchange capacity and Fe-, Mn- and other oxides (Verloo 2000, Wenzel et al. 1992) The pH is around 7,5-8 in all four treatments. If we look to organic matter (OM) the highest concentrations are found in the contaminated soil. Also important factors concerning the bioavailability of metals are $CaCO_3$ and CEC (cation exchange capacity). These parameters are both highest in the contaminated soil.

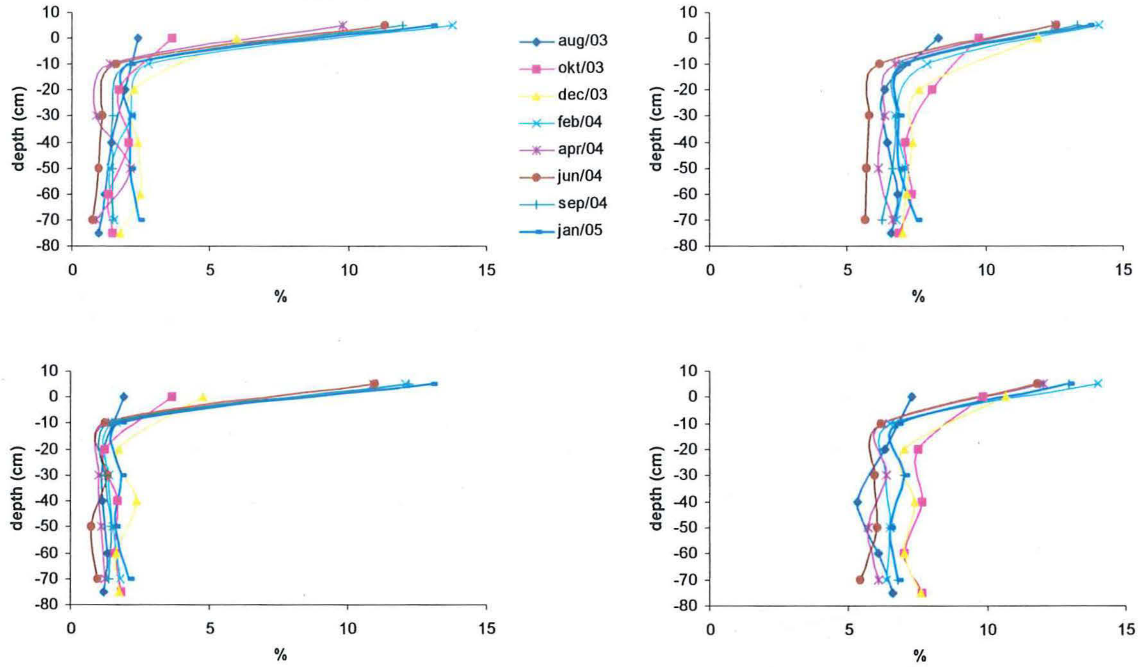
For all the metals, concentrations are higher in the contaminated soil. In the upper layer of the clean soil, metal content increased. In the upper layer of the contaminated soil, metal content decreased. This is due to the sedimentation in the experiment. We don't find a seasonal trend in metal content in both soil types.

Clean soil + reed	Contaminated soil+ reed
Clean soil	Contaminated soil

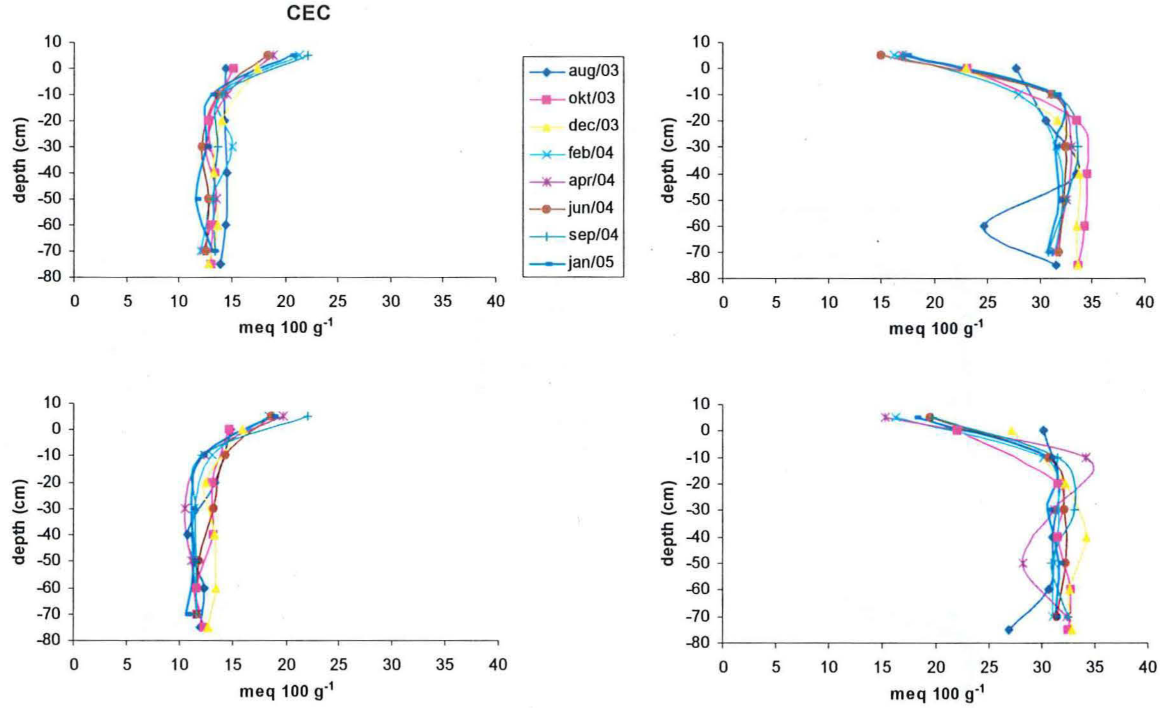


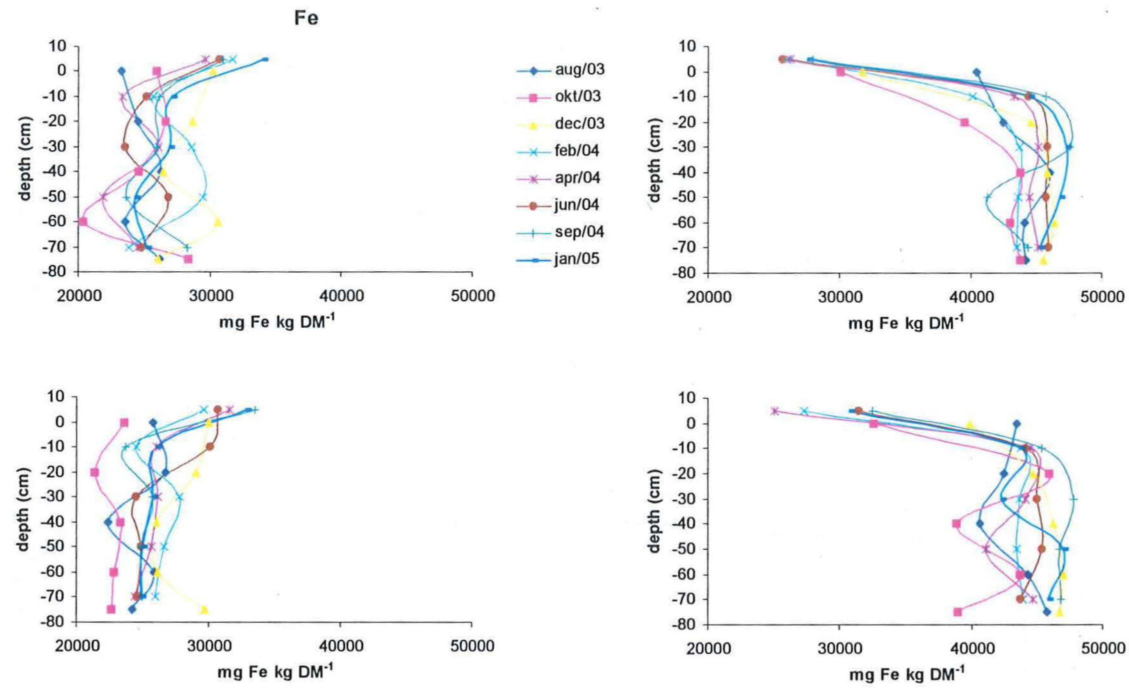


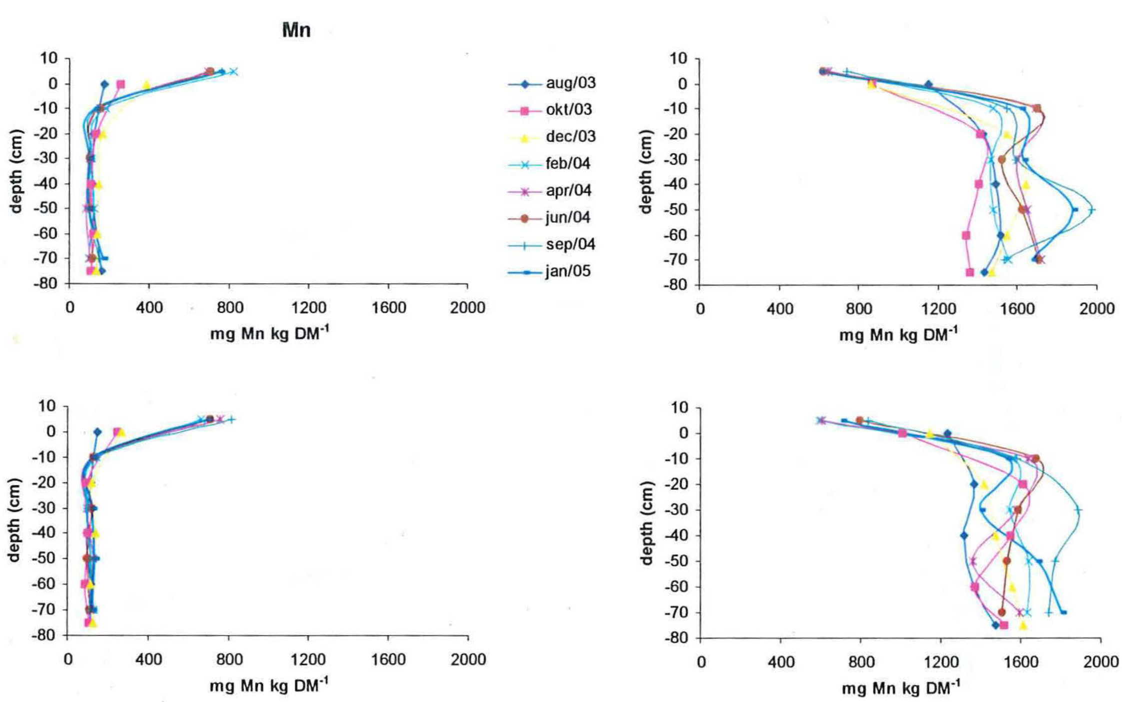
$CaCO_3$

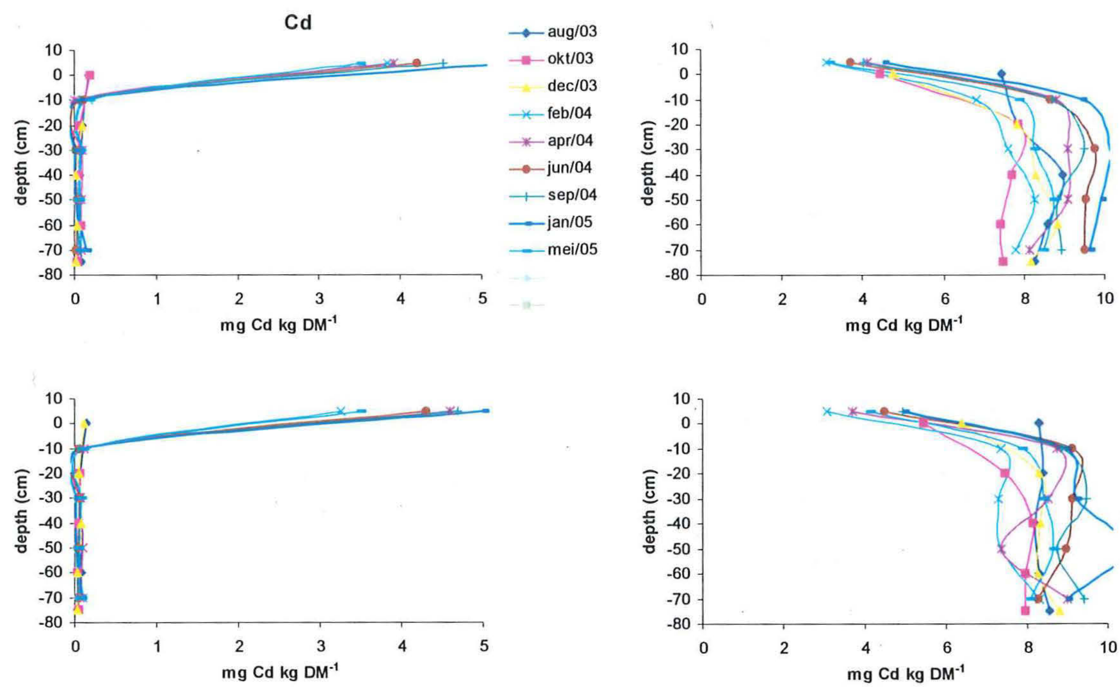

aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05
depth (cm)
%

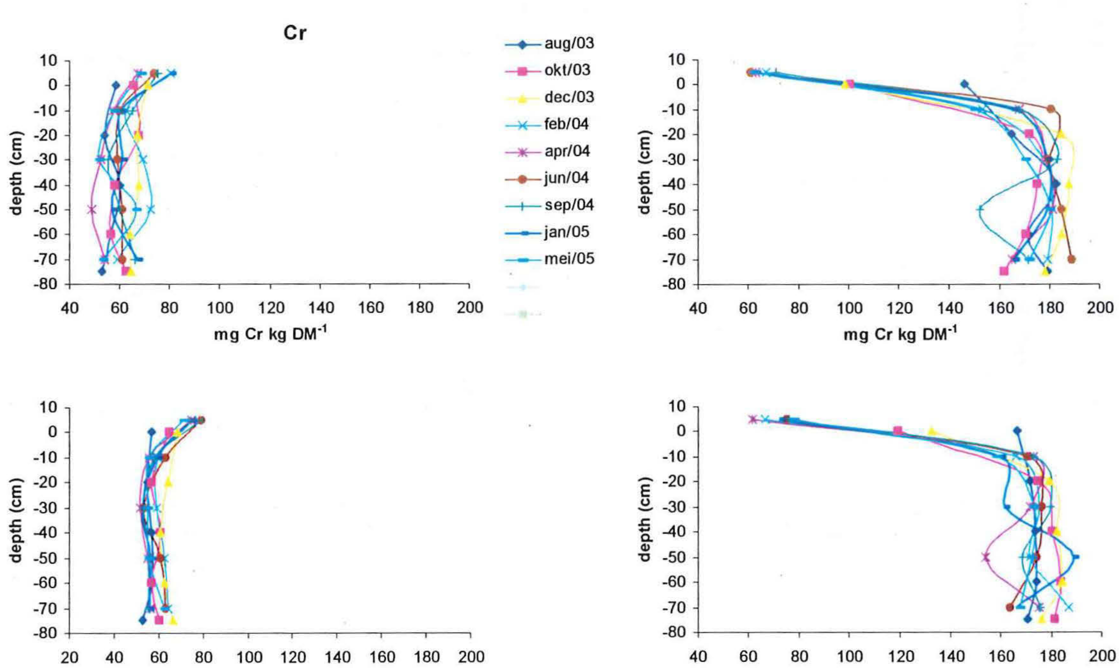
CEC

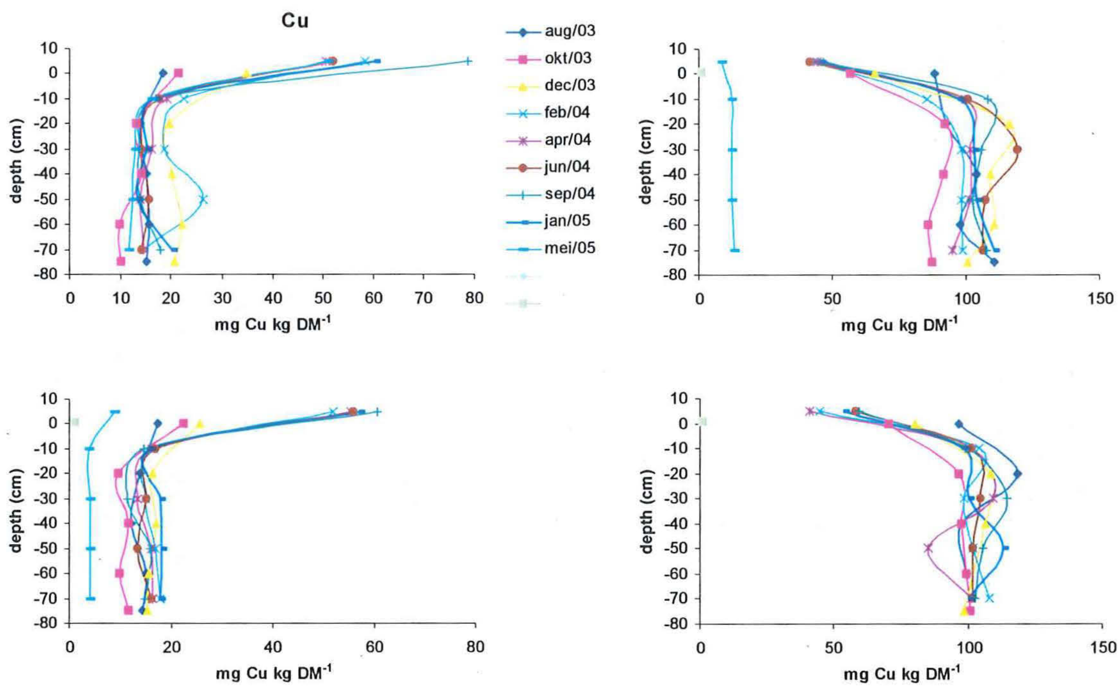

aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05
depth (cm)
meq 100 g-1

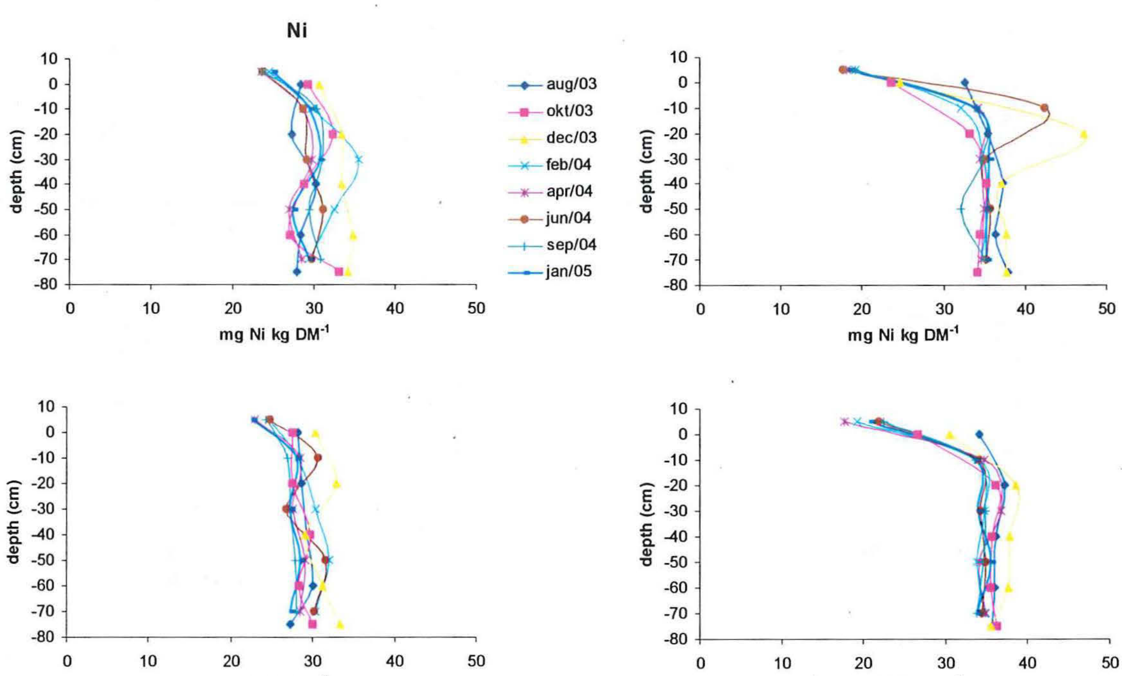

Fe
depth (cm)
mg Fe kg DM-1
aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05


Mn
depth (cm)
mg Mn kg DM-1
aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05


Cd
aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05
mei/05
depth (cm)
mg Cd kg DM-1


Cr
aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05
mei/05
depth (cm)
mg Cr kg DM-1


Cu
aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05
mei/05
depth (cm)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
10
20
30
40
50
60
70
80
mg Cu kg DM-1
0
50
100
150
mg Cu kg DM-1
0
20
40
60
80
mg Cu kg DM-1
0
50
100
150
mg Cu kg DM-1


Ni
aug/03
okt/03
dec/03
feb/04
apr/04
jun/04
sep/04
jan/05
depth (cm)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
10
20
30
40
50
mg Ni kg DM-1
mg Ni kg DM-1
mg Ni kg DM-1
mg Ni kg DM-1

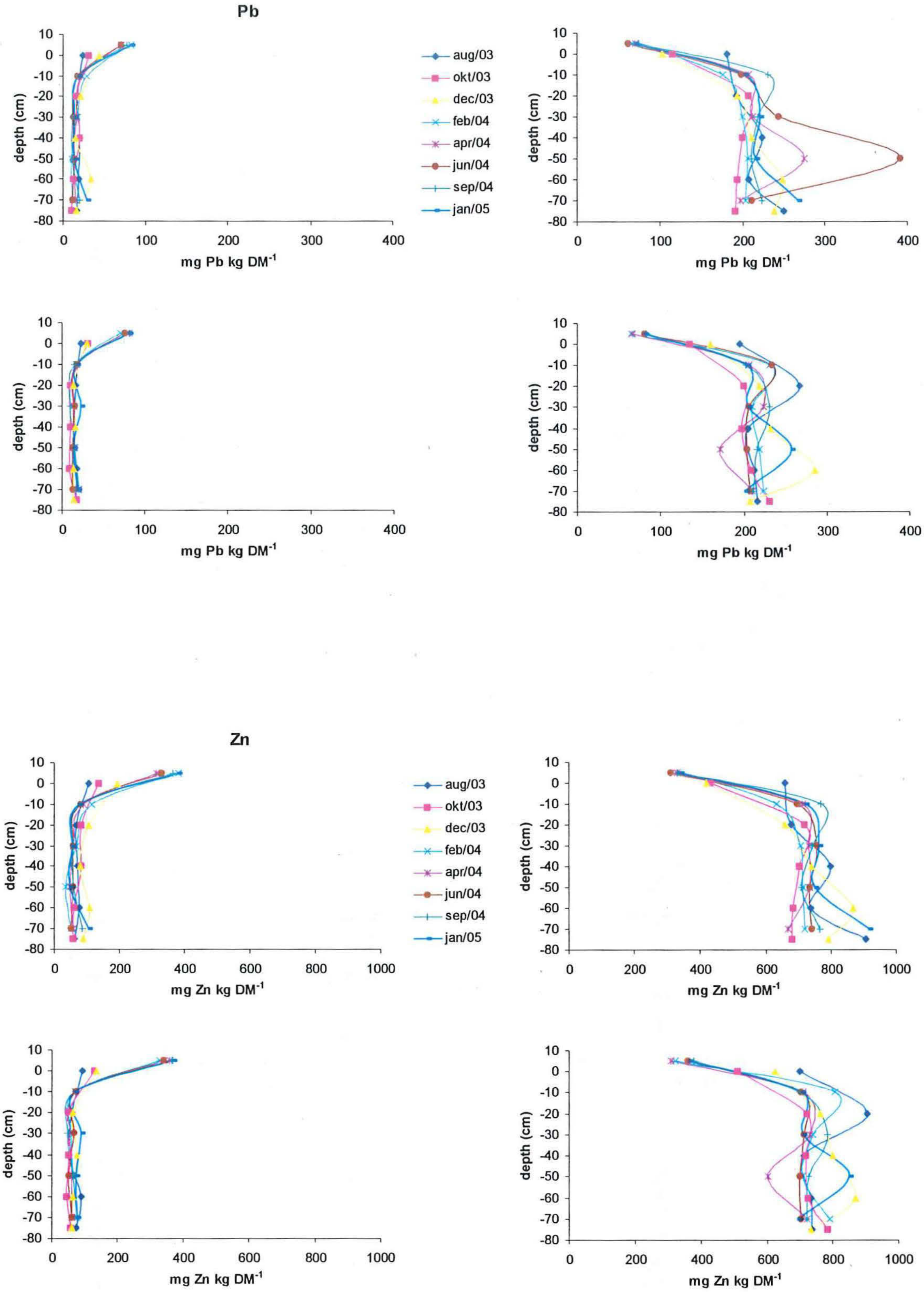


Figure 6. Heavy metal content and other fysico-chemical parameters in the two different soil types in the mesocosm experiment Kruibeke. Data from Dieter Vanthuyne, Ghent University, Laboratory of Analytical chemistry and applied ecochemistry

9.3.5. Monitoring of sedimentation:

In April 2003, one sedimentation plot was placed in every treatment. The sedimentation is measured in June 2003, October 2003, February 2004, June 2004, September 2004 and December 2004. Kaolien field plots are used for the sedimentation measurements. This is a mixture of white sand and kaolien clay and is water and vegetation permeable. It forms a white layer on the soil. Sedimentation can be measured by taking soil samples with a small soil core and by measuring the soil thickness above the white kaolien layer. In the figure below, the average sedimentation in the 4 treatments is given. Treatments A with reed and C without reed are the clean treatments. Treatments B with reed and D without reed are the contaminated treatments.

Results

A difference in sedimentation between the vegetated and not vegetated treatments was expected but not measured. 20 months after the start of the experiment, the sediment layer has a thickness of 110-130 cm.

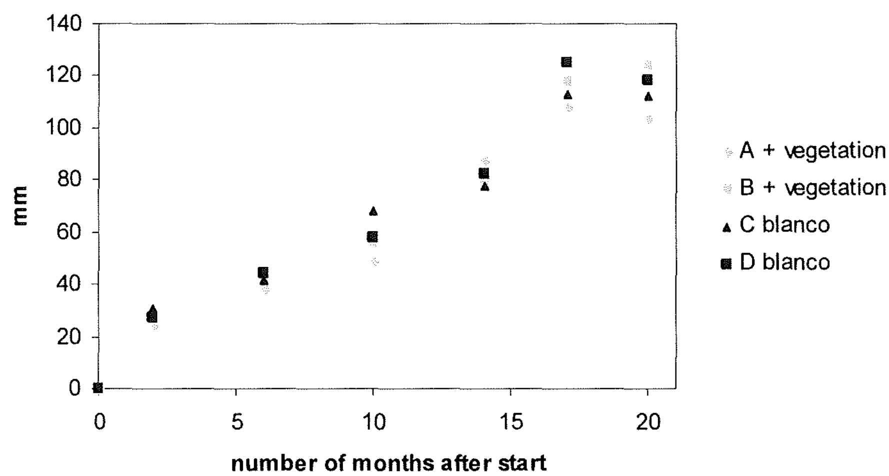


Figure 7. The height of sedimentation after filling the experiment with soil.

9.3.6. The water regime in the experiment

The flood dynamics: At 4.80m TAW water is coming in the experiment, and follows the tide. The groundwater was measured using data loggers.

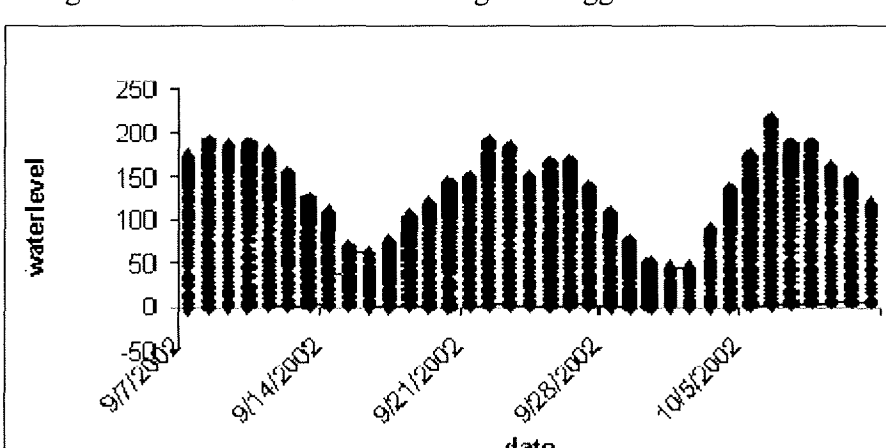


Figure 8. The tidal regime, measured inside the experiment

9.3.7. The effect of contamination on Phragmites australis and vice versa

In April 2003 reed rhizomes were harvested in Kijkverdriet, Steendorp. Reed was planted in one contaminated and one clean soil. In both treatments, the same amount of reed was planted, taking into account the number of living nodes at the rhizomes and the weight of the rhizomes (see table 1).

Table 1. Number of nodes at the rhizomes and weight of the rhizomes that were planted in the mesocosm experiment. Bak A is the clean soil; bak B is the contaminated soil

	Number of nodes	Weight (g)
Bak A	285	4259
Bak B	277	4445

Results:

In November 2004, the entire reed vegetation was harvested in the mesocosm experiment Kruibeke. Results are shown below. The results of the metal content in the different parts of the reed will be shown in the report of 2005 because the samples have to be analysed in December 2005. For the discussion, the results of metal content of the harvest of 2003 will be used. There was no significant difference in density, biomass production and growth parameters between the plants growing in the contaminated versus clean soil.

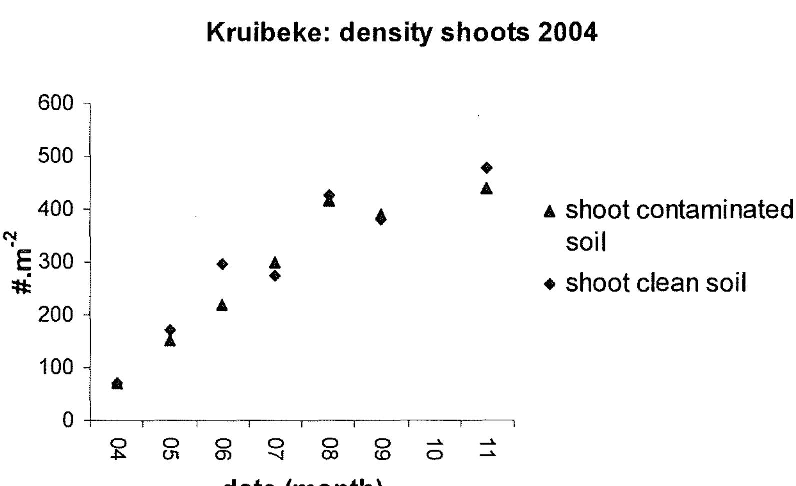


Figure 9. The density (shoots.m^{-2}) at the end of the growing season 2004.

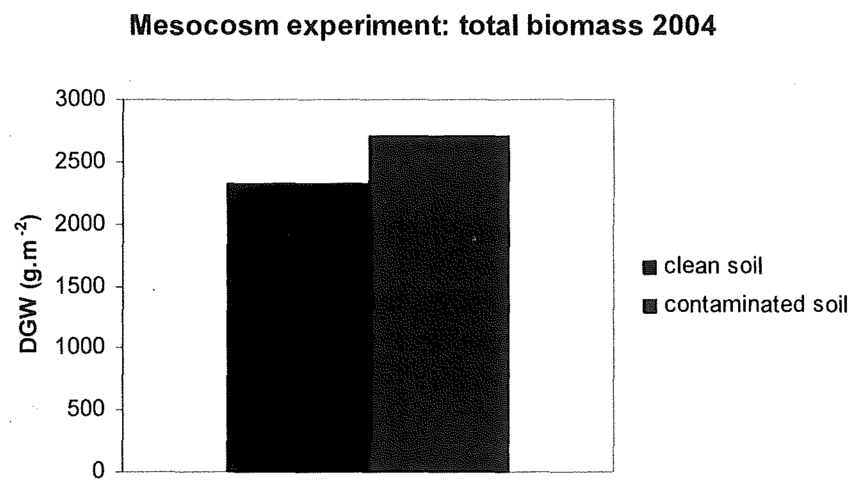


Figure 10. The dry weight (g.m^{-2}) of Phragmites australis at the end of the growing season 2004. Treatment A is the clean soil, treatment B is the contaminated soil.

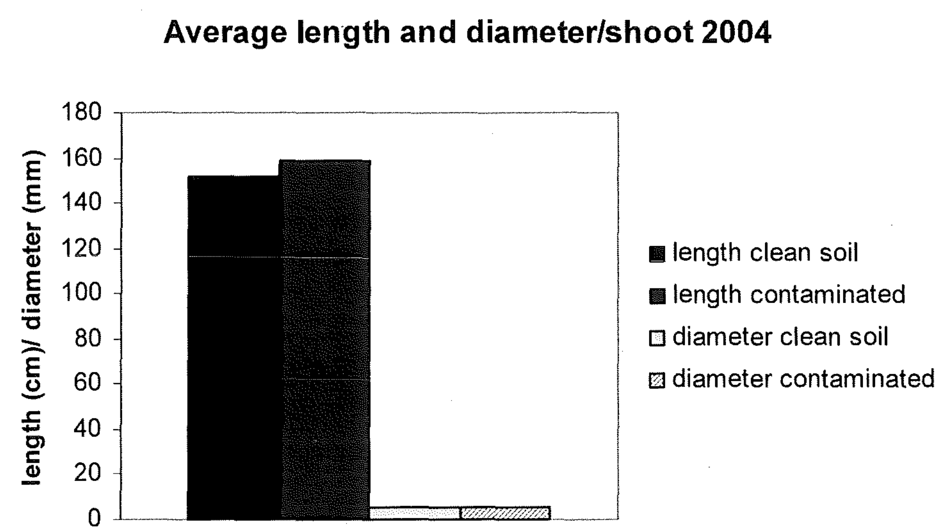


Figure 11. The average length (cm) and average diameter (mm) of phragmites australis at the end of the growing season. Treatment A is the clean soil, treatment B is the contaminated soil.

Conclusions mesocosm experiment Kruibeke:

To determine the bioavailability of heavy metals, it is important to know in which phase of the compartment the metals are available. The most bioavailable metal forms are found in the 'water-soluble fraction' (Du Laing et al. 2002). In the experiment, the contaminated soil, metal concentrations are much higher than in the clean soil. This is not true for the metal concentrations in the pore water. Here there is almost no difference in metal concentrations between the contaminated soil and the clean soil. We can conclude that in a soil with high metal concentrations the bioavailability is not necessarily higher than in a soil with low metal concentrations. It has been reported that metals in soil-sediments are more strongly immobilized under flooded than dry conditions (Gambrell et al. 1980; Gambrell, 1994). The bioavailability and the ecotoxicological behaviour of metals in sediments are determined by their specific physiochemical form, rather than by there total content (Tack and Verloo, 1995). Also other parameters are important to determine the bioavailability such as pH, organic matter (OM), $CaCO_3$ and cation exchange capacity (CEC). If OM, $CaCO_3$ or CEC is high, more metals can be bound and metals are less bio available. In the experiment, OM, CaCO3 and CEC are higher in the contaminated soil, which explains the lower concentrations of metals in the pore water.

Helophyte plants, including *Phragmites australis,* which are growing in wetlands in anoxic soils, release oxygen in the rhizosphere (Armstrong, J. 1978 & Armstrong, J & Armstrong, W. 1990). Because of the oxygen release, we expected a difference in the metal bioavailability between the treatments with and without reed. *Phragmites australis* was only growing in 2 of the 4 treatments, but this did not have any effect on the concentrations of heavy metals in the soil and the pore water.

The uptake of heavy metals in plants and the differentiation between the different organs is dependent on both the parameters of environment and the plant species itself (Deleebeeck 2001). The influence of the bioavailability of metals in the soil is very important. Plants who are growing in a contaminated soil can have a decrease in growth due to the interaction of heavy metals in cells or essential reactions (Van Brempt, 1994, Deleebeeck, 2001). In 2004, we did not found significant differences in reed growth and biomass production, which was also true for 2003.

Plants generally take up more metals when grown under dry than flooded conditions (Gambrell & Patrick, 1989). No significant differences in concentrations of heavy metals in reed between the 2 different treatments (contaminated and clean) were found (see report 2003). The concentration of metals was highest in plant leafs. Raven et al., 1992 determined healthy concentration ranges in plants for some essential heavy metals, for Fe, Cu, Zn and Mn it was respectively 25-300; 4-30; 15-100; 15-800 µg/g. If we compare these ranges with the concentrations in *Phragmites australis* in the experiment, only the Fe concentration in the experimental plants was much higher (leafs around 3500µg/g) than the above ranges. All other metal concentrations were around the concentrations given above.

9.4. Measurements of vegetation in different tidal regime in the mesocosm experiment at the University of Antwerp

9.4.1. The influence of tidal regime

In the mesocosm experiment at the University of Antwerp, two different tidal regimes were simulated during 2003 and 2004. Reed was growing on two different sediments (sandy loam and silt loam).

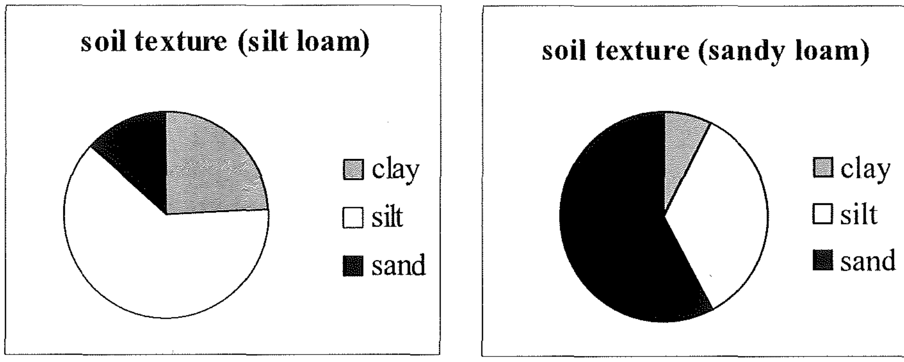


Figure 13. The distribution of clay, silt and sand in the two different soil textures.

One tidal regime was more or less the same as the tidal regime of the river Scheldt. A neap and spring tidal regime resulting in different frequencies of flooding, different duration of flooding and a different height of flooding between the different levels. The second tidal regime was a neap and spring tidal regime with a longer duration of inundation every high water.

The flooding frequency, flooding height an –duration were simulated by computer.

The groundwater was measured in an irrigation tube, with a closed PVC tube on top. The tube was placed circa 80cm into the soil. Data loggers, placed in the tube, measured the water level in the tube every 15 min; one barometer data logger was placed to compensate for barometric pressure.

In the winter of 2003, we measured differences in light intensity at different levels in the experiment. To exclude the influence of differences in light, in April 2004, a construction was build to create the same shadow/light conditions in all the different levels.

Every month, the weed growing between the reed was removed.

At the end of the growing season 2004(October), the reed was harvested and intensively measured.

9.4.2. Results and discussion:

Several controlled inundation areas are planned near the fresh water part of the Scheldt estuary (Belgium). In these inundation areas it will be possible to create controlled reduced tidal regimes. The present ecosystems however will change, because the terrestrial vegetation is not adapted to a flooding regime. This means that plants have to adapt to flooding in order to survive in the floodplains (Nabben et al. 1999), and/or more flood-tolerant plants such as *Phragmites australis* will replace the existing plants. The duration and frequency of flooding can be determining for the effect of inundation (Sival et al. 2001). Knowledge concerning the effect of tidal flooding is small.

In the experimental setup, two different tidal regimes were created. If we look the results, reed can grow in both simulated tidal regimes. There was a significant difference in biomass at the end of the growing season between the six different levels, but no significant difference was found between the two different tidal regimes. The same was true for the density in the different treatments, as well as the diameter of the basal node and the length of the shoots.

Because we excluded the difference in light penetration (2004) in the different levels of the experiment we can conclude that the difference in water regime cause the differences in growth and not a difference in light intensity or a combined effect.

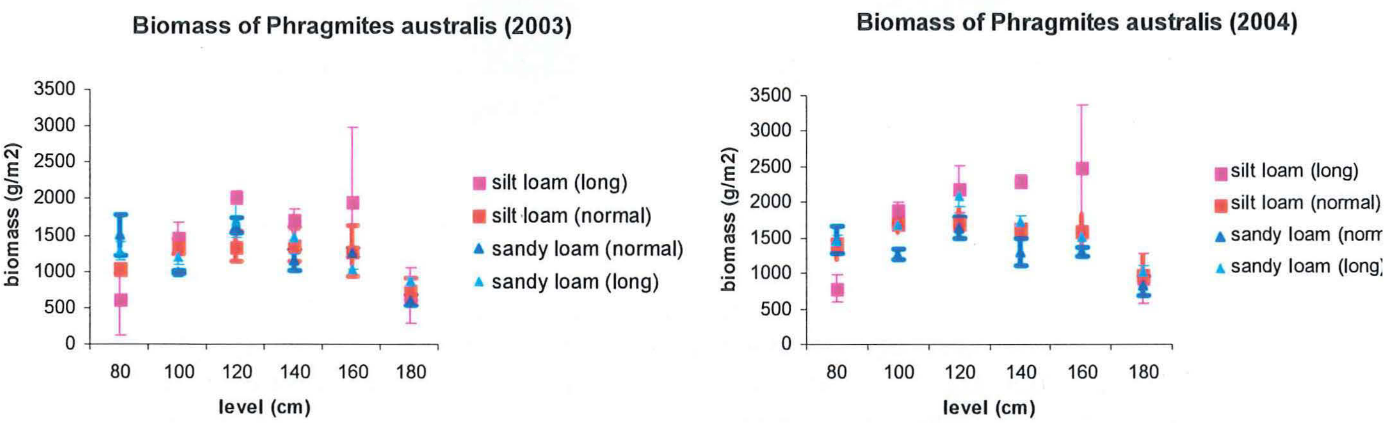


Figure 17. The biomass of *Phragmites australis* at the end of the growing season 2003.

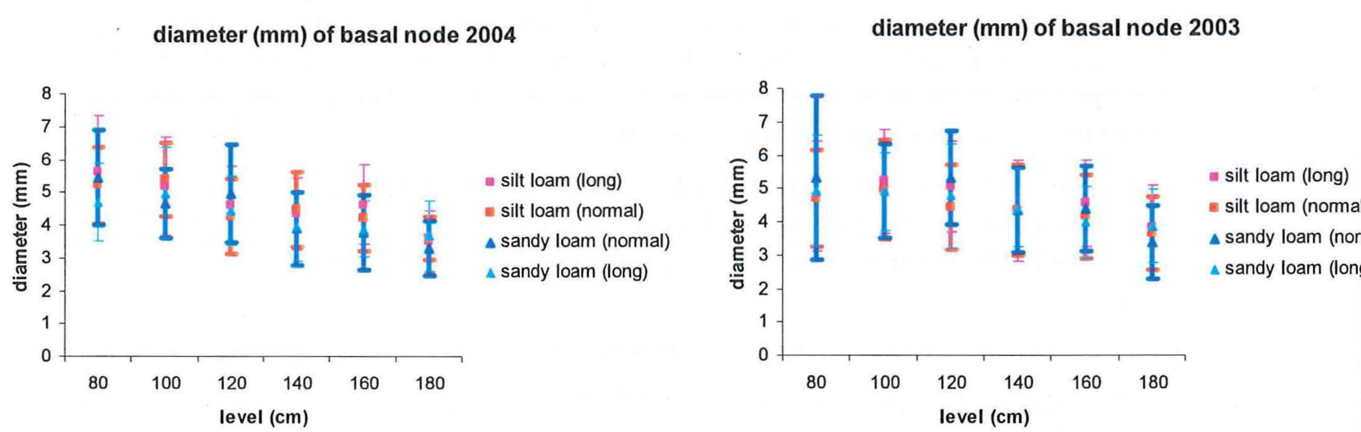


Figure 18. The average diameter of the basal node in the 6 different treatments at the end of the growing season.

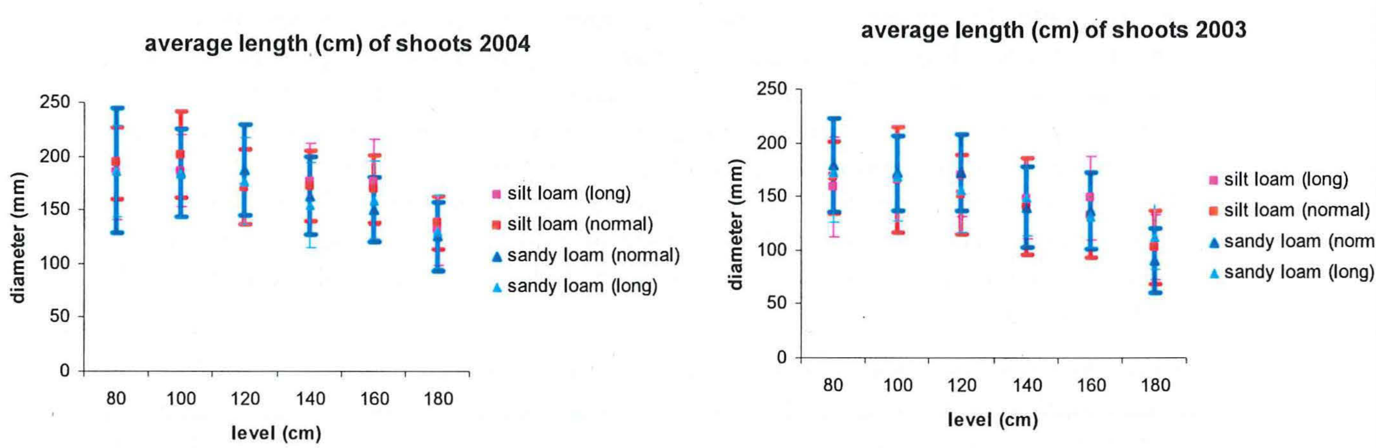
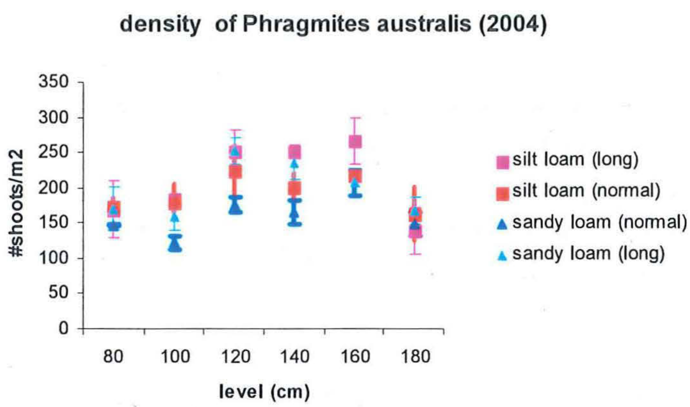


Figure 19. The average length (cm) per shoot in the 6 treatments at the end of the growing season.



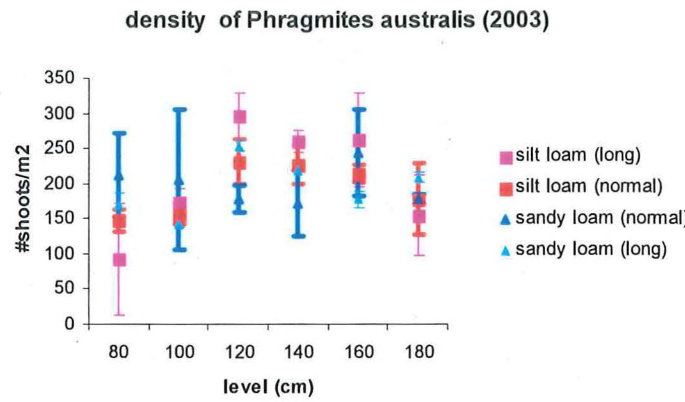


Figure 20. The density (number of shoots per m^2) in the 6 treatments at the end of the growing season.

9.5. References

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