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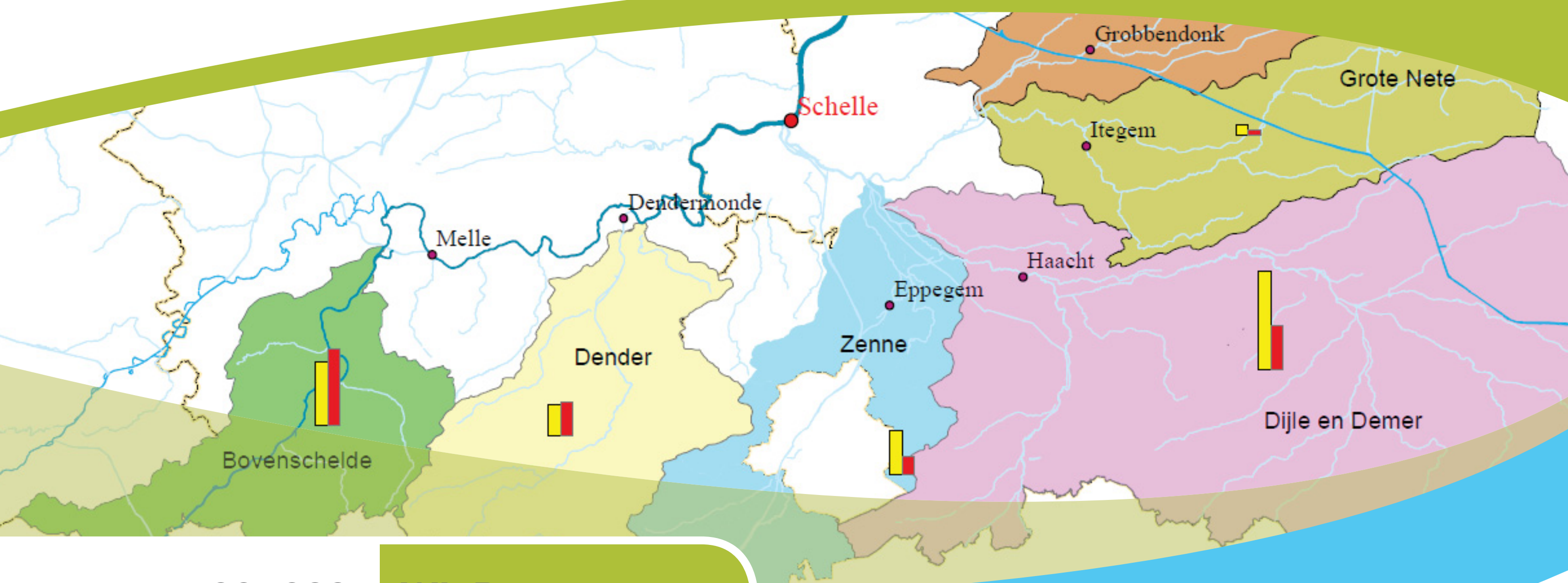
Slibbalans Zeeschelde

DEELRAPPORT 2: SEDIMENT LOAD FOR THE RIVER SCHELDT AND ITS MAIN TRIBUTARIES (1972 – 2009)



00_029 WL Rapporten

waterbouwkundig LABORATORIUM

Vlaamse overheid

Slibbalans Zeeschelde

Deelrapport 2 – Sediment load for the river Scheldt and its main tributaries (1972 – 2009)

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Juli 2014

WL2014R00_029_2

Deze publicatie dient als volgt geciteerd te worden:

Van Hoestenberghe, T.; Ferket, B.; De Boeck, K.; Vanlierde, E.; Vanlede, J.; Verwaest, T.; Mostaert, F. (2014). Slibbalans Zeeschelde: Deelrapport 2 – Sediment load for the river Scheldt and its main tributaries (1972 – 2009). Versie 5.0. WL Rapporten, 00_029. Waterbouwkundig Laboratorium & Antea Group. Antwerpen, België.

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Documentidentificatie

Titel:	Slibbalans Zeeschelde: Deelrapport 2 – Sediment load for the river Scheldt and its main tributaries (1972 – 2009)		
Opdrachtgever:	Maritieme Toegang	Ref.:	WL2014R00_029_2
Keywords (3-5):	Sea Scheldt, Sediment flux, Discharge		
Tekst (p.):	71	Bijlagen (p.):	8

Vertrouwelijk:	☐ Ja	Uitzondering:	☐ Opdrachtgever
			☐ Intern
			☐ Vlaamse overheid
		Vrijgegeven vanaf:	
	☒ Nee	☒ Online beschikbaar	

Goedkeuring

Auteur	Revisor	Projectleider	S&A Directeur	Afdelingshoofd
Van Hoestenberghe, T.	Vanlierde, E.	Vanlede, J.	Verwaest, T.	Mostaert, F.

Revisies

Nr.	Datum	Omschrijving	Auteur(s)
1.0	25/04/2013	Conceptversie	Van Hoestenberghe, T.
2.0	25/04/2013	Inhoudelijke revisie	Vanlierde, E.; Vanlede, J.
3.0	27/02/2014	Revisie opdrachtgever	Roose, F.
4.0	13/04/2014	Inhoudelijke revisie	Van Hoestenberghe, T.; Vanlede, J.
5.0	29/07/2014	Definitieve versie	Ferket, B.

Abstract

From 1972 onwards, sediment samples have been collected at locations at the borders of the tidal reaches of the river Scheldt and on the Upper Scheldt. These reaches are located at different tributaries, such as the Zenne, Kleine Nete, Grote Nete, Dijle and Dender. By combining these sediment data with the discharge data at the same locations, sediment fluxes entering the Sea Scheldt and passing the measurements location 'Schelle' can be calculated.

Three different calculation methods to obtain these sediment fluxes are compared and a preliminary estimation of the associated uncertainties is presented.

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1. Methodology

The goal of this study is to give the best estimate of the sediment load for the river Scheldt and five of its tributaries: Kleine Nete, Grote Nete, Dijle, Zenne and Dender during the period 1972-2009. No daily suspended sediment concentration (SSC) measurements are available, while there are daily discharge (Q) measurement data. Therefore, to obtain estimated daily sediment concentrations, we need to analyze the relationship between measured sediment concentrations and discharges at measuring locations. Besides the calculation of the sediment load, the related uncertainty is estimated. The results of the different calculation methods will be compared to quantify the impact on the calculated sediment load.

The methodology to calculate the sediment load for each tributary of the Scheldt consists of the following steps:

a) Data exploration

b) Building linear regression models (using daily averaged discharge as explanatory variable for daily averaged SSC)

c) Calculation of sediment load using three different methods.
   1. Method "Taverniers 1": calculation of monthly mean sediment load by multiplying monthly averaged (measured) discharge values with SSC-values derived from linear regression models (using monthly averaged (measured) discharge). Separate regression models are created for every individual calendar year.
   2. Method "Taverniers 2": calculation of monthly averaged sediment load by multiplying the monthly averaged (measured) SSC-values with monthly averaged (measured) discharge values.
   3. Interpolation method: sediment load is calculated by multiplying daily averaged (measured) SSC-values with daily averaged (measured) discharge values. Missing values of SSC are calculated from daily averaged (measured) discharge by the annual linear regression models.

REMARK: At some measuring locations (e.g. Melle), negative discharges are measured sporadically. These data indicate that the net water (and therefore also sediment) transport was negative (or moving upstream), due to the fact that the tides do not have a duration of exactly 12h. When using monthly averages of Q (Methods Taverniers 1 and 2), these negative transports are incorporated in the averages, which always have a (positive) net discharge. The interpolation method, however, uses the correlation between Q and SSC to fill in missing average daily SSC-values. If negative daily average discharges occur, its absolute value was used to find a corresponding daily average SSC-value. Afterwards, this value is multiplied with the (negative) discharge value and will hence reduce the total sediment load observed at this location.

The first two methods (Taverniers1 and Taverniers2) are based on the approach used for the earlier sediment load calculations reported for the years 1992-1999 (Claessens,1993, 1994; Taverniers, 1995, 1996, 1997, 1998, 1999 and 2000). These methods as well as the third method (the interpolation method) are explained in detail in De Boeck et al. (2013).

2. Data description

2.1. Measurement locations

Table 1 describes the sediment sampling locations used in this research.

Table 1: Sediment sampling locations used in this study

River	Station	Location
Kleine Nete	Grobbendonk	This measurement location is situated downstream the Albertkanaal, and is referred to as 'Grobbendonk-3e sas'. This station is newly created in WISKI.
Grote Nete	Itegem	This station is newly created in WISKI
Dijle	Haacht	This station is newly created in WISKI
Zenne	Eppegem	This measurement location is the same as the HIC station 1711-1066
Dender	Dendermonde	This measurement location is the same as the HIC station ADM/2618-1066.
Dender	Denderbelle*	For the period 1971-1992, there is no clear information available about the exact location of this station, it is assumed that the measurements are taken at the HIC station downstream of the weir 2627-1066. From 1993 onwards, the location changed to Dendermonde (Appels).
Schelde	Merelbeke	This measurement location is the same as the HIC station 3121-1066 Ringvaart Opwaarts. Sediment samples are taken at this location.
Schelde	Melle	The discharge measurements of Melle are used for the calculation of the sediment loads using the samples from Merelbeke. The measured discharges at Melle, correspond to station 3208-1066 which is in WISKI.

2.2. Discharge data

Table 2 shows the discharge measurement locations used in this research.

Table 2: Discharge measurement locations used in this study

River	Station	Measured parameter	Backwater?	Remark
Kleine Nete	Grobbendonk Derde sas	H	Backwater	Daily average discharge determined using Q/H_{LW} relationship
Grote Nete	Itegem	H	Backwater	Daily average discharge determined using Q/H_{LW} relationship
Dijle	Haacht	H	Backwater	Daily average discharge determined using Q/H_{LW} relationship
Zenne	Eppegem	H	No backwater	Instantaneous discharge determined using Q/H relationship
Dender	Dendermonde (Appels)	Q	Backwater	Discharge measured using ADM, Q/Q relationship is applied
Boven Zeeschelde	Melle	Q	Tidal flow	Discharge measured using ADM, Q/Q relationship is applied

Discharge can be determined directly (measuring the streamflow using ADCP or ADM equipment) or by measuring the gauge height and applying a Q/H relationship.

At locations where there are tidal flows, the latter method cannot be used, and it is necessary to have actual discharge or velocity measurements. This is the case for the measurement locations of Melle and Appels (Dendermonde).

However, when the streamflow is hindered by the tides, part of the river becomes temporarily a backwater (the water level rises, but not due to an increase in discharge, but rather because of the water backing up under the influence of the incoming tide).

Therefore at these locations a Q/H relationship can be used, but only during low water levels. Therefore, daily average LW-levels are determined and a consequent Q/H_{LW} is applied to determine the daily average discharge.

2.3. Sediment concentration data

2.3.1. Baalhoek commissie

From 1972 till 1986, sediment concentrations were measured during sampling campaigns executed within the framework of the “Baalhoek commission”. During these campaigns, multiple samples were taken at one location, during multiple hours. The measurement locations for this campaign are Grobbendonk, Itegem, Haacht, Eppegem, Merelbeke and Denderbelle. For most locations (e.g. Eppegem, Melle, Itegem), there is (in general) one measurement each 2 weeks. The multiple samples are combined to one daily average SSC-concentration (De Boeck et al., 2013).

The samples were taken by means of a bucket. The measured sediment concentrations from these campaigns, were digitized manually and converted to zrx-format. These zrx files are then imported in WISKI. Within the framework of this research, average daily values are calculated using all samples available on a single day. The suspended sediment concentrations were determined by the provincial center of environmental hygiene in Antwerp (PIH).

For some stations, there are some SSC-concentrations available of 1971 as well. The stations Eppegem, Haacht and Dendermonde have (at most) 4 measurements in 1971. Due to the small amount of measurements for only 3 stations in 1971, data for 1971 is omitted in this report.

2.3.2. Dataset hydrometrie

From 1992 till present, weekly samples have been collected at the measurement locations Grobbendonk, Itegem, Haacht, Eppegem and Merelbeke. In 1992 the measurement location on the Dender was Denderbelle, but from 1993 onwards the location changed to Dendermonde (Appels). From 1992 up until 2009 (and later), the sampling was executed using a bucket, and a 1L bottle was subsampled from that bucket.

From 1992 up until 2009, 100ml was once more sub-sampled from the 1L bottle and consequently filtered to determine the concentration.

From 2009 onwards, half a litre was sampled and the entire bottle was filtered.

From 2011 onwards, samples are taken using a weighted bottle sampler (using 0.5L bottles). The entire content of the bottle was filtered to determine the sediment concentration.

From 1992-2011, the sediment load per year was already calculated in the past in Excel templates. These files are used to extract the time series with the sediment concentrations at the measurement locations. Some of these data needed to be provided with a proper measurement date. The lacking dates were thus completed using analogue forms containing dates of measurement campaigns, and matching the dates which correspond to the measured discharges. The resulting time series are converted to zrx-formats, which are then imported in WISKI.

2.3.3. Missing Data

No SSC data is available from 1987 up until (and including) 1991.

3. Grobbendonk

3.1. Exploring the data

3.1.1. Description of dataset

The dataset consists of measurements of water discharge (Q) and suspended sediment concentration (SSC) on the river ‘Kleine Nete’ (near the Albert Canal) in the Flemish Region, throughout a period of 37,9 years (1972-2009). The water discharge Q is expressed in m³/s (1 cubic meter or thousand liters per second), the sediment concentration SSC is expressed in mg/l (milligrams per liter). Every combination of Q and SSC has a “measurement date”, which is set on a daily value, and can be classified as an ordinal categorical variable.

During these 37.9 years there have been 1149 simultaneous measurements of water discharge and sediment concentration, which means on average one measurement every 1.71 weeks. However, the dataset can be split into two parts: measurements before and after 1992. Before 1992, the frequency of measurements is lower than afterwards. There is little information available about the method of measuring before 1992, but there are reasons to suppose that it differs from the one after 1992.

The original dataset consists of 1149 data rows. All datapoints with the exception of five outliers (concentrations above 1500 mg/l) are shown in Figure 1. Some additional outliers were removed, because very high sediment concentrations (for the river ‘Kleine Nete’) coincided with low discharges (which is improbable). Some of the omitted data points are shown in Figure 2. In total, 12 combinations of Q and SSC were omitted, reducing the dataset to 1137 time steps with simultaneous Q and SSC measurements.

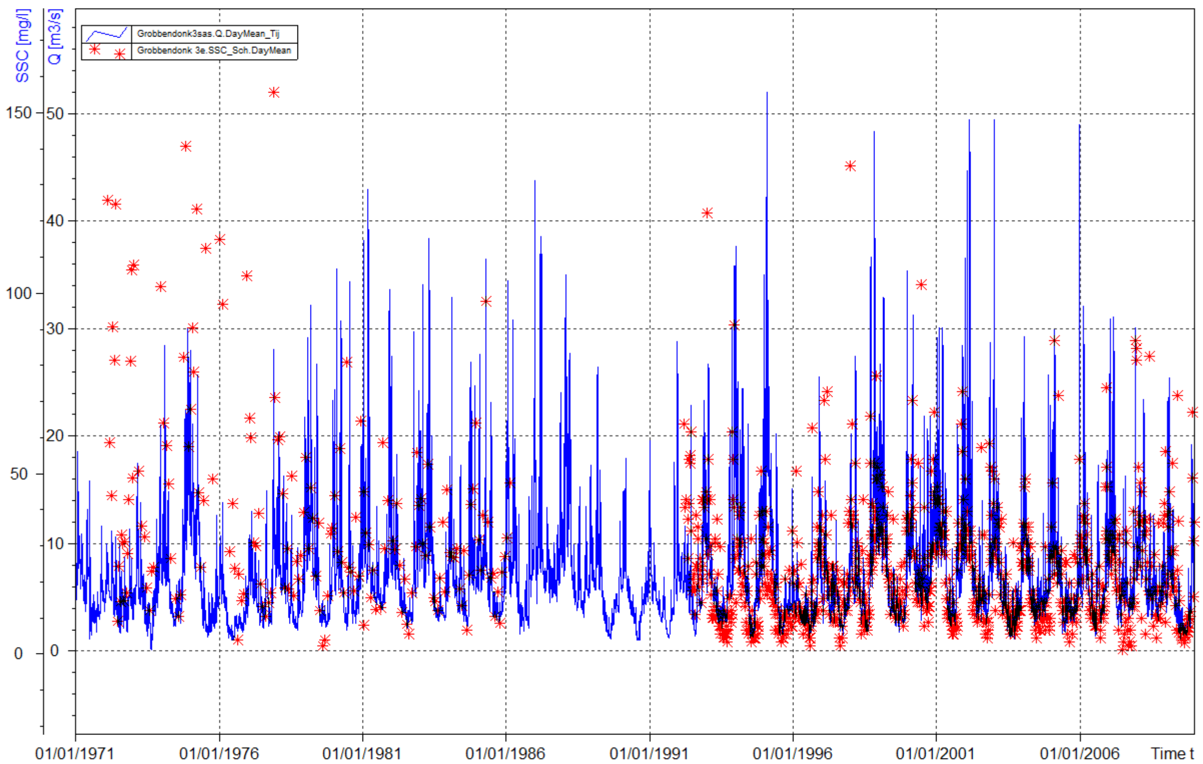


Figure 1: Dataset for Grobbendonk (Kleine Nete) containing simultaneous discharge (Q) and suspended sediment concentration (SSC) measurements between 1972 and 2009, without five SSC measurements higher than 1500 mg/l

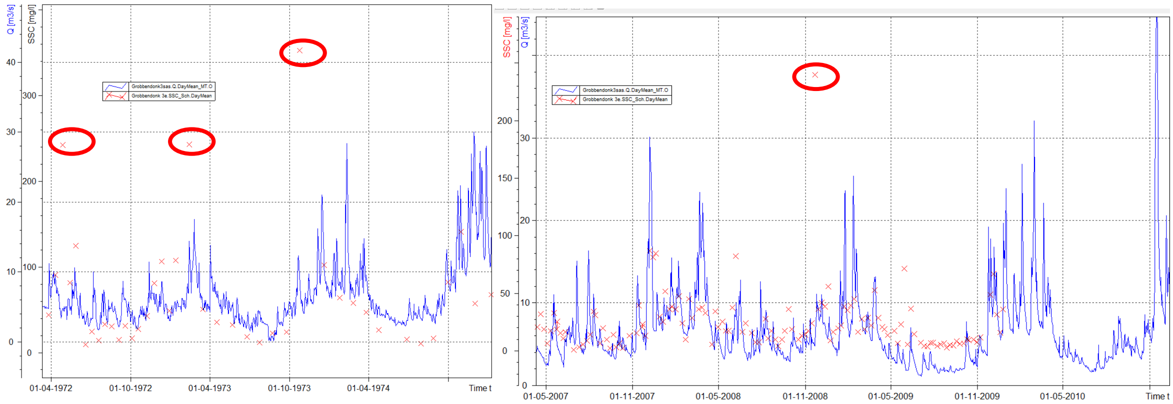


Figure 2: Outliers removed from the dataset of Grobbendonk (Kleine Nete), i.e. very high SSC coinciding with low Q measurements

Besides the distinction between measurements before and after 1992, experience teaches that summer and winter conditions often create different relationships between both variables, due to different types of weather conditions and land use. Therefore, we want to investigate whether we can find significant differences between four groups of measurements: before 1992, after 1992, summer and winter. The next step is to investigate whether this results in significant better relationships between sediment concentration and water discharge compared to the application of the total dataset.

The “measurement date” is used to create two dummy variables: “Before/after 1992” and “Summer/winter”. If we create with this dummy variable different groups for the dependent variable “SSC”, four subgroups for SSC are made: SSC Winter, SSC Summer, SSC before 1992 and SSC after 1992. The descriptive statistics of these variables are shown in Table 3.

Table 3: Descriptive statistics for Q, SSC and the SSC subgroups based on the categorical variables “Before/After 1992” and “Summer/Winter”

One Variable Summary	Q (m³/s) Grobbendonk	SSC (mg/l) Grobbendonk	SSC Winter (mg/l) Grobbendonk	SSC summer (mg/l) Grobbendonk	SSC before 1992 (mg/l) Grobbendonk	SSC after 1992 (mg/l) Grobbendonk
Mean	7,3	25,0	32,0	17,9	39,7	22,5
Variance	31,0	368,4	417,1	220,6	904,5	236,5
Std. Dev.	5,6	19,2	20,4	14,9	30,1	15,4
Skewness	2,7	2,3	2,2	3,0	1,6	1,8
Kurtosis	13,7	11,4	10,7	16,2	5,3	9,4
Median	5,8	20,9	28,6	14,3	29,0	18,7
Mean Abs. Dev.	3,8	13,5	13,8	9,6	22,4	11,7
Mode	4,0	9,9	9,9	11,0	16,0	9,9
Minimum	0,8	1,0	2,0	1,0	3,0	1,0
Maximum	47,2	155,0	155,0	124,6	155,0	135,0
Range	46,4	154,0	153,0	123,6	152,0	134,0
Count	1.072,0	1.072,0	535,0	537,0	154,0	918,0
Sum	7.863,1	26.751,9	17.138,5	9.613,4	6.117,1	20.634,9
1st Quartile	3,9	11,6	19,8	9,4	18,0	11,0
3rd Quartile	9,0	33,0	38,5	21,0	48,0	30,8
Interquartile Range	5,1	21,5	18,7	11,7	30,0	19,8

In Figure 3 the boxplots for Q, SSC and the different subgroups of SSC are shown. There are quite some mild & extreme outliers, which is typical for “natural” river data.

Boxplots of Q and SSC

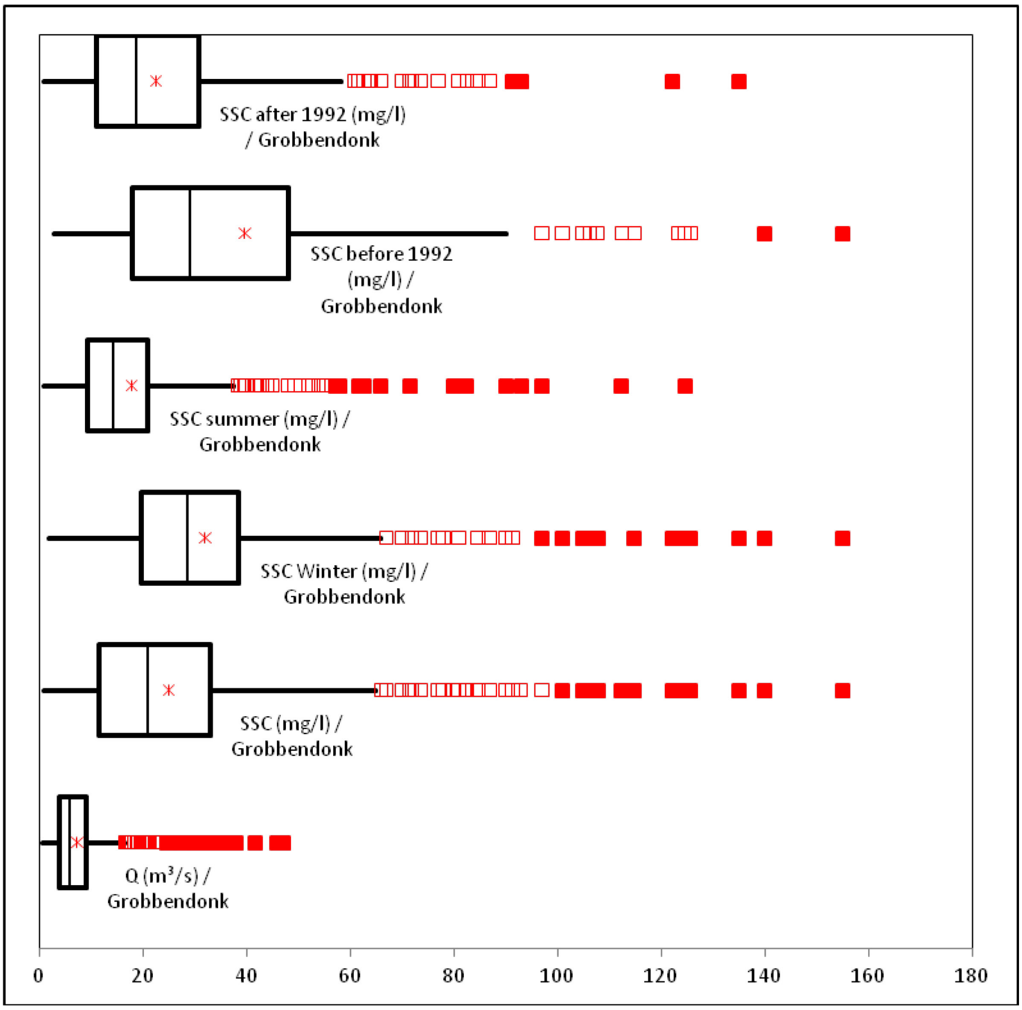


Figure 3: Box plots for Q, SSC and SSC-subgroups based on the categorical variables "Before/After 1992" and "Summer/Winter"

In Figure 4 and Figure 5 scatterplots for SSC are shown, with distinction of SSC measured before and after 1992 (Figure 4) and with distinction between SSC measured in summer and winter (Figure 5).

Visually, one can see the difference in spreading between both groups. Also the descriptive statistics (Table 3) can be related to these scatterplots: because of the larger spreading of SSC-values for winter compared to summer SSC-values, one can deduct a larger standard deviation for SSC-values measured during winter. The same can be stated for the SSC-values before and after 1992: SSC-values before 1992 have a larger spread (and consequently larger Standard Deviation) than the SSC-values after 1992.

The correlation of the total group is 0.41, which means that (the variance in) Q is explaining 41% of the variance in SSC. Since in natural phenomena good correlation values are typically R>0.7, no good correlation was found here.

Scatterplot

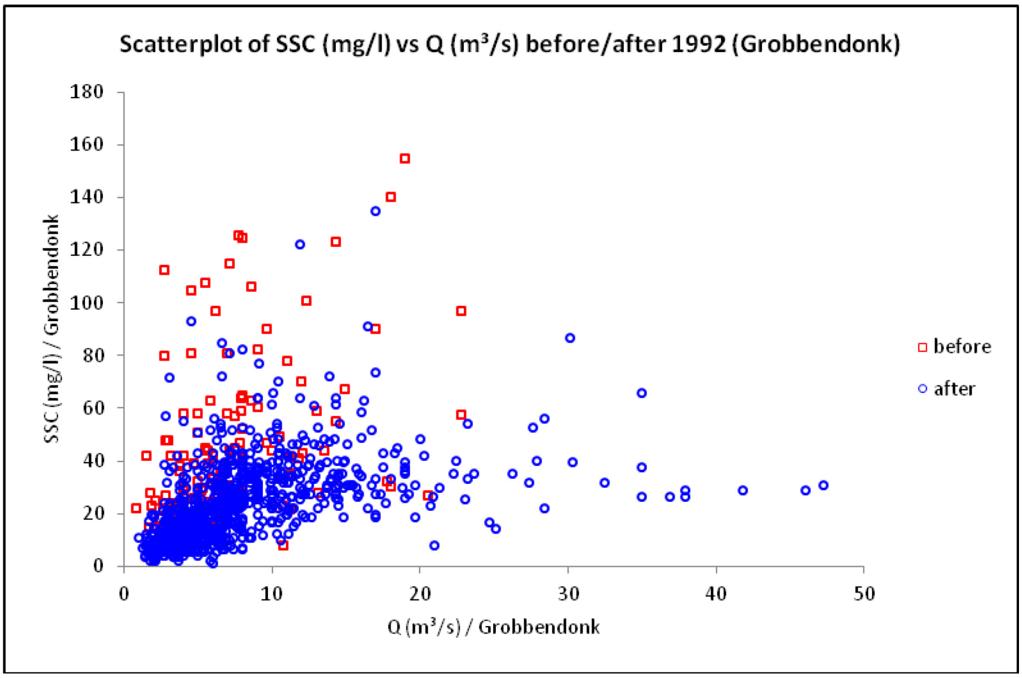


Figure 4: Scatterplot of SSC versus Q, classified by the categorical variable 'Before/After 1992'

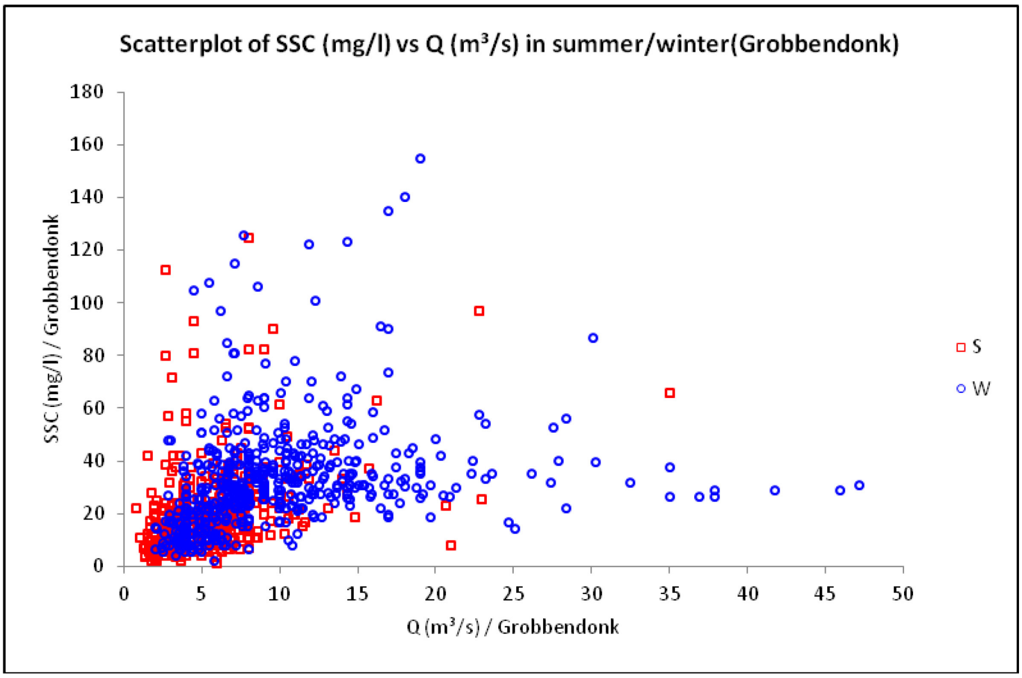


Figure 5: Scatterplot of SSC versus Q, classified by the categorical variable 'Summer/Winter'

3.1.2. Hypothesis testing

Hypothesis & calculation

Hypothesis: There are different groups in the SSC-data (significant different mean).

This is to be checked by 'Hypothesis test for means/two sample Analysis (not on paired-samples)':

- Null hypothesis: Difference of mean = 0

- Alternative hypothesis: Difference of mean # 0

Table 4 shows the results of the two by two comparison of "SSC Winter-Summer" (left columns) and "SSC before - after 1992" (right columns).

Table 4: Two sample Analysis- hypothesis test for difference in means. Left: SSC Winter vs. SSC Summer. Right: SSC before 1992 vs. SSC after 1992

Sample Summaries	SSC Winter (mg/l) Grobbendonk	SSC summer (mg/l) Grobbendonk	SSC before 1992 (mg Grobbendonk	SC after 1992 (mg/l Grobbendonk
Sample Size	535	537	154	918
Sample Mean	32,03	17,90	39,72	22,48
Sample Std Dev	20,42	14,85	30,08	15,38
Hypothesis Test (Difference of Means)	Equal Variances	Unequal Variances	Equal Variances	Unequal Variances
Hypothesized Mean Difference	0	0	0	0
Alternative Hypothesis	> 0	> 0	> 0	> 0
Sample Mean Difference	14,13	14,13	17,24	17,24
Standard Error of Difference	1,090454998	1,091082881	1,586796235	2,476139272
Degrees of Freedom	1070	975	1070	166
t-Test Statistic	12,9602	12,9528	10,8666	6,9637
p-Value	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Null Hypoth. at 10% Significance	Reject	Reject	Reject	Reject
Null Hypoth. at 5% Significance	Reject	Reject	Reject	Reject
Null Hypoth. at 1% Significance	Reject	Reject	Reject	Reject
Equality of Variances Test				
Ratio of Sample Variances	1,8912		3,8240	
p-Value	< 0.0001		< 0.0001	

Interpretation

The null hypothesis is rejected at 1% significance, which means that the means are (with 99% confidence) different for these groups.

This is also confirmed by the ANOVA-test in Table 5 (H0: population averages are the same). The F-value of "65" means that the "between variance" is 65 times the "within variance". This means that the population means are surely not all similar.

Table 5: One Way ANOVA table to test whether the mean of different population is the same (equal variances are assumed)

OneWay ANOVA Table	Sum of Squares	Degrees of Freedom	Mean Squares	F-Ratio	p-Value
Between Variation	91493,38	4	22873,34	64,95	< 0.0001
Within Variation	941742,69	2674	352,19		
Total Variation	1033236,07	2678			

To quantify the difference in regression, we performed the "Chow" test based on the comparison of squared residuals for the different regression results. The results are given in . The result of the Chow-test (506.8) can be compared to the F-value with k and N_i-2k degrees of freedom. Following this test, the regressions are significantly different on the 0.01 level (** in). So a division in subgroups seems to be appropriate.

Table 6: Chow-test to verify whether the means of different populations are the same (equal variances are assumed), with N_i = degrees of freedom for partial regressions and k = number of parameters.

Sum of squares total regression	66903,5			
N (degrees of freedom total regression)	1071 (1072-1)			
Subgroups	Winter before 1992	Winter after 1992	Summer before 1992	Summer after 1992
Sum of squares partial regression	9204,6	14997,8	8828,1	12369,3
N_i (degrees of freedom of partial regression i)	77	458	77	460
Chow-test	506,8**	$F/k/(N_1+N_2+N_3+N_4-2k)$		

Regression analysis

In Figure 6 the regressions for the different subgroups of SSC-Q are shown. Based on visual observation, one can state that these regression lines are different for the subgroups.

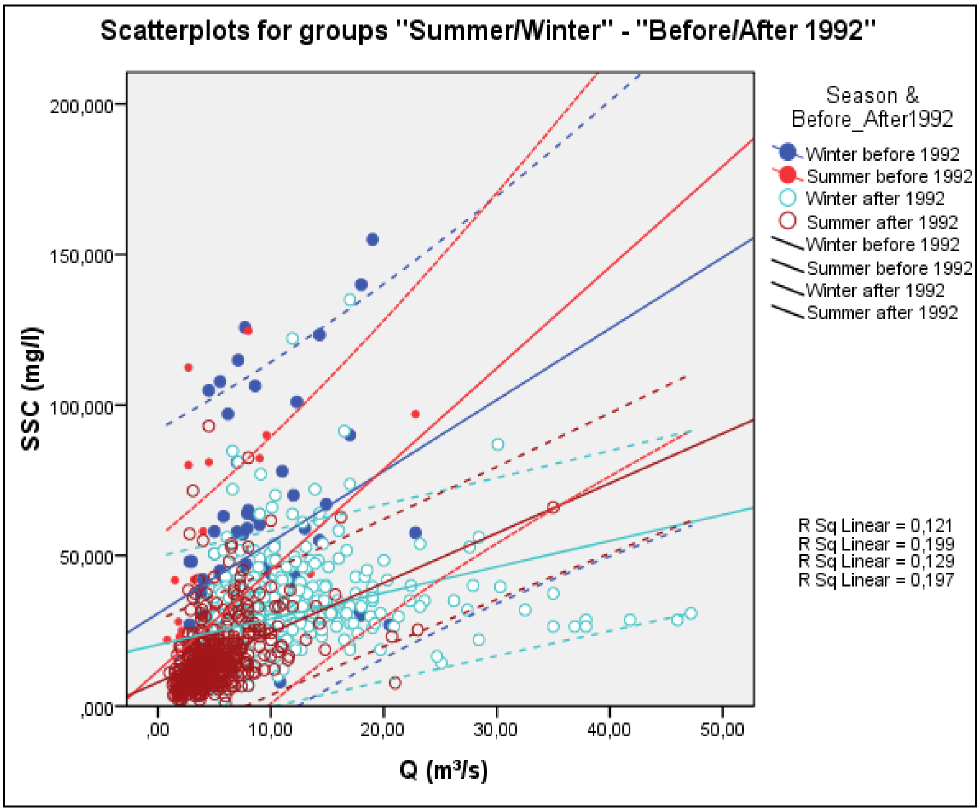


Figure 6: Linear regression result (full line) and confidence intervals (broken lines) for the subgroups of SSC

In table 5, the regression equations for the different subgroups and the total dataset are given for linear and power regression functions. In Figure 7 and Figure 8, regression evaluation results are shown. The power regression explains more variation, but still has a poor quality. Other types of regressions (logarithmic, polynomial, exponential, …) give worse results than power regression functions. The division in subgroups appears of little value: the quality of regression of subgroups is as bad as the quality of the regression of the total dataset. Therefore, the idea to divide the dataset into subgroups was abandoned, given that it did not result in an improvement of the regression model.

Table 7: One Way ANOVA to test whether the means of different populations are the same (equal variances are assumed), with k = number of parameters

	Subgroup 1 (Winter before 1992)	**Subgroup 2** (Winter after 1992)	**Subgroup 3** (Summer before 1992)	**Subgroup 4** (Summer after 1992)	Total dataset
Linear Regression equation (Y=)	2,36 * x + 30,77	0,86 * x + 20,38	3,35 * x + 11,64	1,65* x + 7,84	1.42 * x + 14.54
R^2	0,11	0,13	0,19	0,19	0,17
RMSE (mg/l)	29,82	14,88	21,79	10,51	17,50
Power regression equation (Y=)	$17,19 * x^{0,45}$	$6,94 * x^{0,60}$	$10,39 * x^{0,52}$	$5,04 * x^{0,65}$	$5.61 * x^{0.67}$
R^2	0,15	0,35	0,16	0,25	0,36
RMSE (mg/l)	0,57	0,47	0,63	0,57	0,58

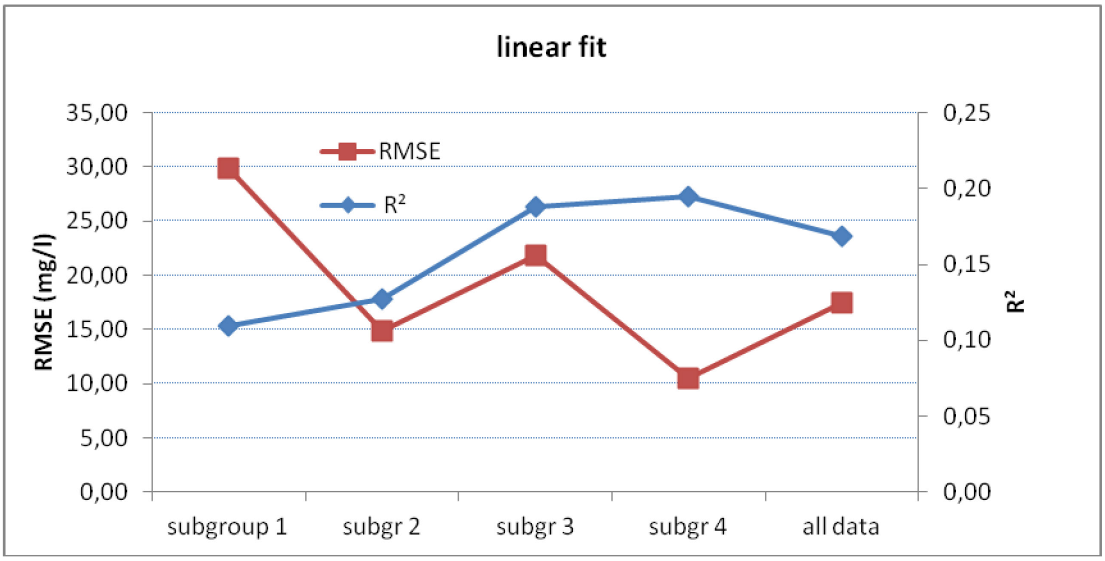


Figure 7: Linear regression result for the different subgroups and the total dataset

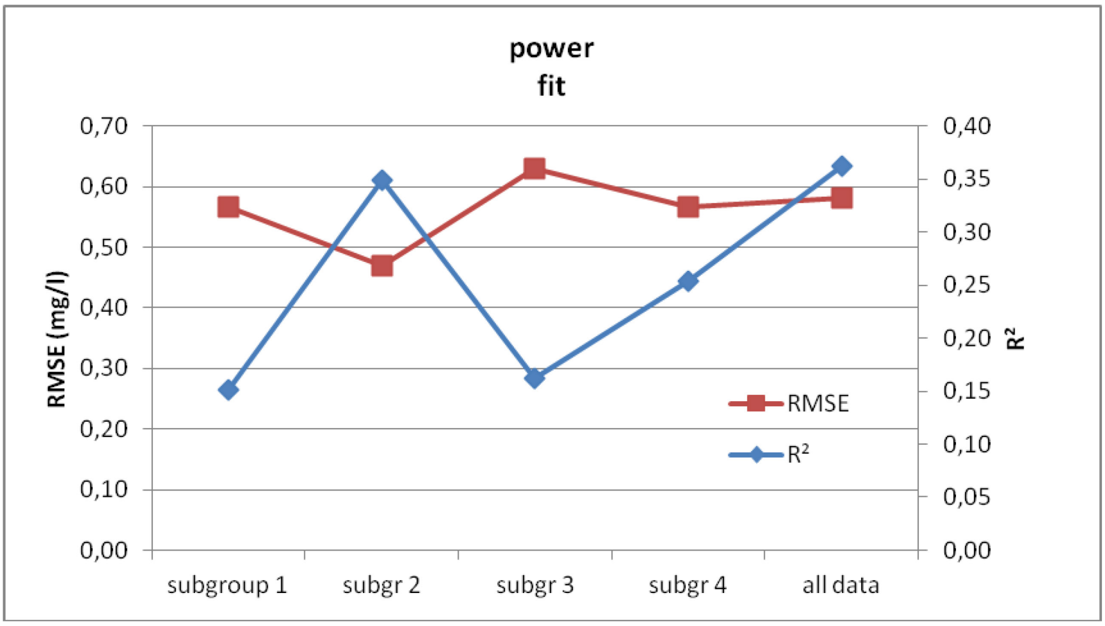


Figure 8: Power regression result for the subgroups and the total dataset

In Annex A the plots of another regression analysis are given. Linear, logarithmic, power and exponential regression models were applied on a yearly base. Some plots show a relatively good data fit (e.g. 1977, 1982 and 2006), while others are poor (e.g. 1980, 1981 and 2002). The R^2 value is very similar for all four models and on average slightly higher for the power regression (0.485) than for the logarithmic (0.460), linear (0.437) and exponential (0.412) models. Given that the type of regression has no major impact on the model quality, it was chosen to use a simple linear regression performed on yearly base in this study.

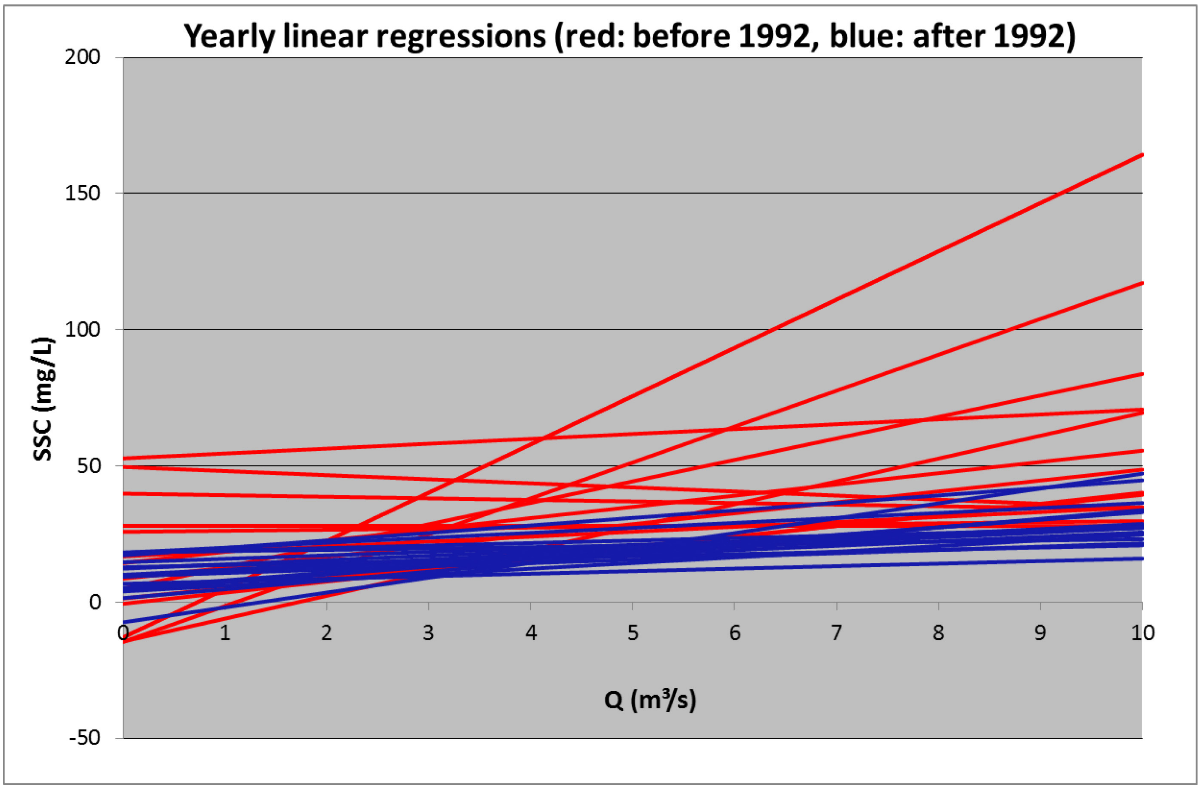
3.2. Calculation of sediment loads

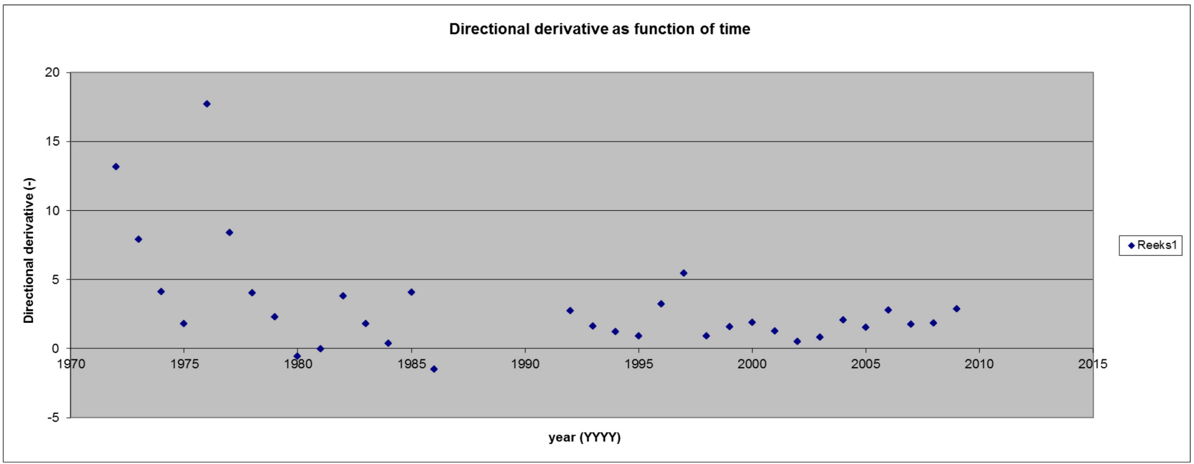
3.2.1. Regression between Q and SSC (daily values)

The directional derivative varies more before 1992 than it does afterwards. Possibly this is caused by different measuring/sampling methods used after 1992. Before 1992 the directional derivative was negative for some years. This means that the regression predicts a drop of sediment flux with increasing flow rates, which seems improbable. After 1992 no negative directional derivatives are found.

The same applies for the offset (Q = 0 m^3/s). Before 1992, there is a lot of variation in the offsets that were derived. After 1992 they remain more constant and are smaller in magnitude.

Remark: The directional derivative of the 1976 regression was very high (17,7). This lead to very high SSF values for the discharge peak of January 1976. To avoid this (unrealistic) overestimation, it was chosen to apply the average regression for the entire measuring period for this year.





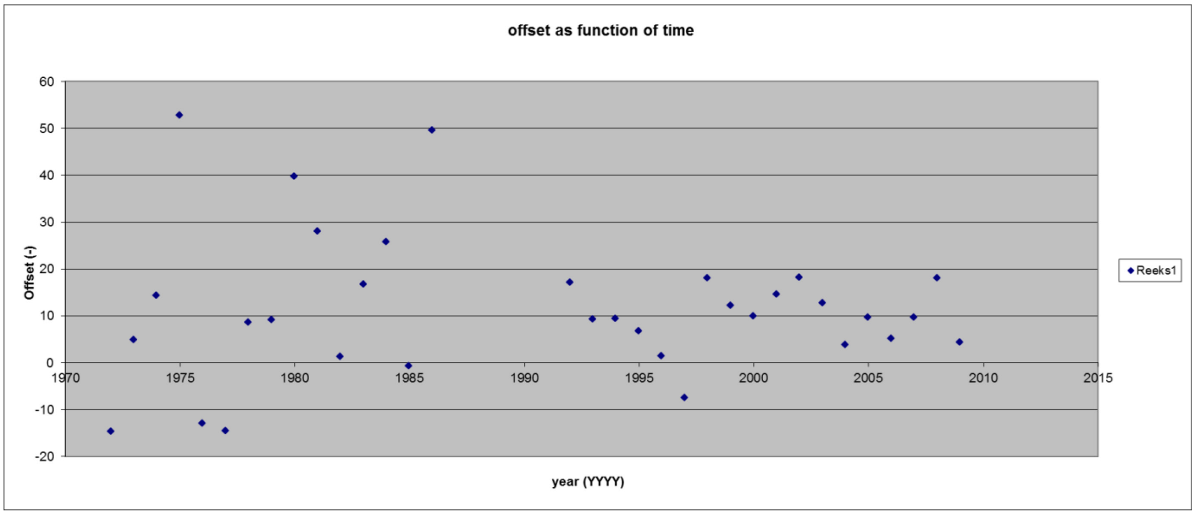


Figure 9: Overview of the yearly linear Q-SSC regressions for Grobbendonk (Kleine Nete)

3.2.2. Sediment fluxes/loads

Figure 11 depicts the sediment fluxes (SSF in kg/s) and cumulative sediment load (SSL in kg) determined for Grobbendonk. The (course of the) sediment fluxes (and consequently the sediment loads) calculated by the three methods is quite similar. First, the figure shows a clear winter/summer cycle: high winter loads and low summer loads. Next, the figure clearly shows a peak of the sediment flux around the year 1976. The cumulative sediment loads gradually diverge in time, being the largest for the interpolation method and the smallest for the Taverniers2 method. The cumulative sediment load appears to have a steeper slope before 1987 than afterwards for all three methods, probably due to differences in the measuring method before and after 1992 (no measurements of SSC between 1986 and 1992).

Figure 12 shows the situation after 1992. This detailed image confirms that the interpolation method calculates the highest sediment fluxes and loads and Taverniers2 the lowest. The figure however reveals that the difference between Taverniers1 and 2 is much smaller than suggested by Figure 11 and moreover that the latter methods have an almost equal final result in 2009.

The underestimation of sediment fluxes and loads by methods 1, as compared to method 3, is a direct consequence of the application of the correlation between Q and SSC. This is illustrated in Figure 10, where a linear regression was performed on all simultaneous Q and SSC measurements (daily averages) for Grobbendonk between 1971 and 2009 for the clarity of the illustration. The regressions applied in methods 1 and 3 are similar, but on an annual base. Typically, these plots (such as Figure 10) contain a data cloud in the range of low Q and low SSC values, which will mainly determine the linear regression. However, also some points can be selected which are not really fitting to the derived relation, but could not be identified as outliers either. These points occur in the low Q – high SSC range and vice versa. If the relation is then applied to determine the sediment flux it is clear that for high discharges, the resulting SSC can be an overestimation of the real SSC. Similarly, for low discharges, the resulting SSC can be an underestimation of the real one. But the sediment flux for method 'Taverniers' is calculated by multiplying the *monthly average* Q with corresponding SSC from the regression curve. So discharges for the Taverniers1-method will very rarely be in the 'high Q-low SSC' range, but will be biased towards the 'low Q-high SSC' range, where the SSC is *underestimated*.

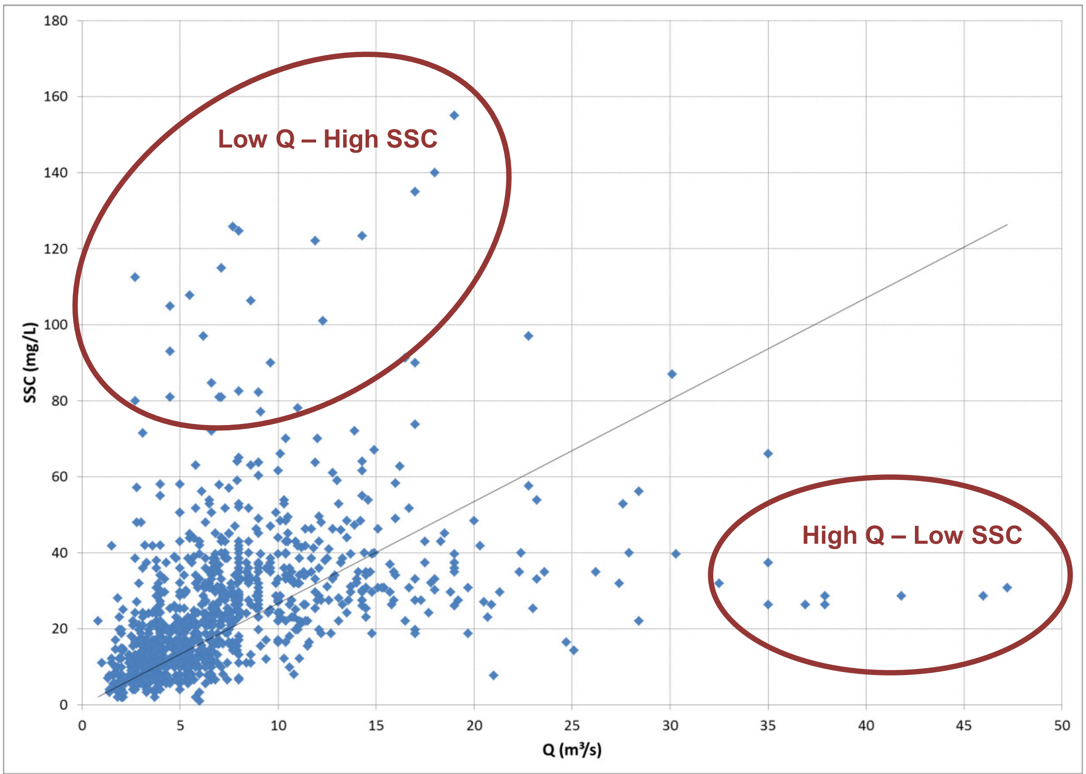


Figure 10: Scatterplot of discharge (Q) versus suspended sediment concentration (SSC) measured at Grobbendonk (Kleine Nete) between 1971 and 2009. For high discharges, SSC is mainly overestimated by the regression. For low discharges, SSC is mainly underestimated by the regression.

The calculated sediment flux will as a result be biased towards lower – underestimated – sediment fluxes for the Taverniers1 method compared to the interpolation method. Method 3 is based on daily averaged discharges, where the regression curve is being built upon, so the fluxes are not as much underestimated with this interpolation method as with the Taverniers1 method. The Interpolation method is believed to model closer the real fluxes than method 1.

Method Taverniers2 uses (monthly) averaged Q ánd SSC measurements and is therefore not subject to the problem described above. But monthly averaging the SSC measurements is probably also an underestimation of reality due to the sampling frequency (1 sampling event per 1.7 weeks on average). Because the highest fluxes appear when high discharges are combined with high SSC-values, the averaging will not take into account these high fluxes. On the other hand, lower fluxes will be overestimated as well. But in general, the yearly results by method Taverniers2 are for most cases (except Itegem) quite similar to the results by method Taverniers1. This confirms the hypothesis that the Taverniers2 method also underestimates the real fluxes more than method 3.

As a consequence from the above, the fluxes calculated with the interpolation method are believed to be the closest to the 'real' fluxes (as can be calculated with the available values). It is difficult to determine which of the Taverniers methods is the best and underestimates the least the fluxes calculated with method 3. For most cases, the fluxes calculated with both methods are quite similar. In general, which of the two methods is the closest to method 3 for a specific event or period depends on the range of discharges for that period. To illustrate this, two typical sequence and order of fluxes calculated with the different methods are shown in Figure 13 and Figure 14. When these events are occurring is shown in Figure 12 (black circles). In Figure 13, the Taverniers2 method is closer to the fluxes calculated with the interpolation method than the Taverniers1 method, and the discharges are at the low side. In Figure 14, the Taverniers1 method is closer to the fluxes calculated with the interpolation method than the Taverniers2 method, and the discharges are at the high side. As explained in some § here above, with higher discharges SSC tend to be less underestimated (and even overestimated) by the Taverniers1 method. This better performance of the Taverniers1 method with higher discharges is a 'general' rule, with exceptions on this rule because for several events/periods the measured SSC lead to higher (averaged monthly) SSC for the Taverniers2 method than for the Taverniers1 method.

Remark1: the legends in Figure 11 and Figure 12 use the following identifiers: _Corr (blue) for the Taverniers1 method, _Interpol (green) for the interpolation method and _Sch (red) for the Taverniers2 method. This methodology is used throughout the figures illustrating sediment fluxes and loads in this report (also for Figure 18, Figure 19, …).

Remark2: In Figure 13 and Figure 14, you can easily compare the Taverniers1 and Taverniers2 method by comparing the blue triangles (Taverniers 1 method) with the red crosses (Taverniers 2 method). The monthly discharges used in both methods are shown by cyan circles.

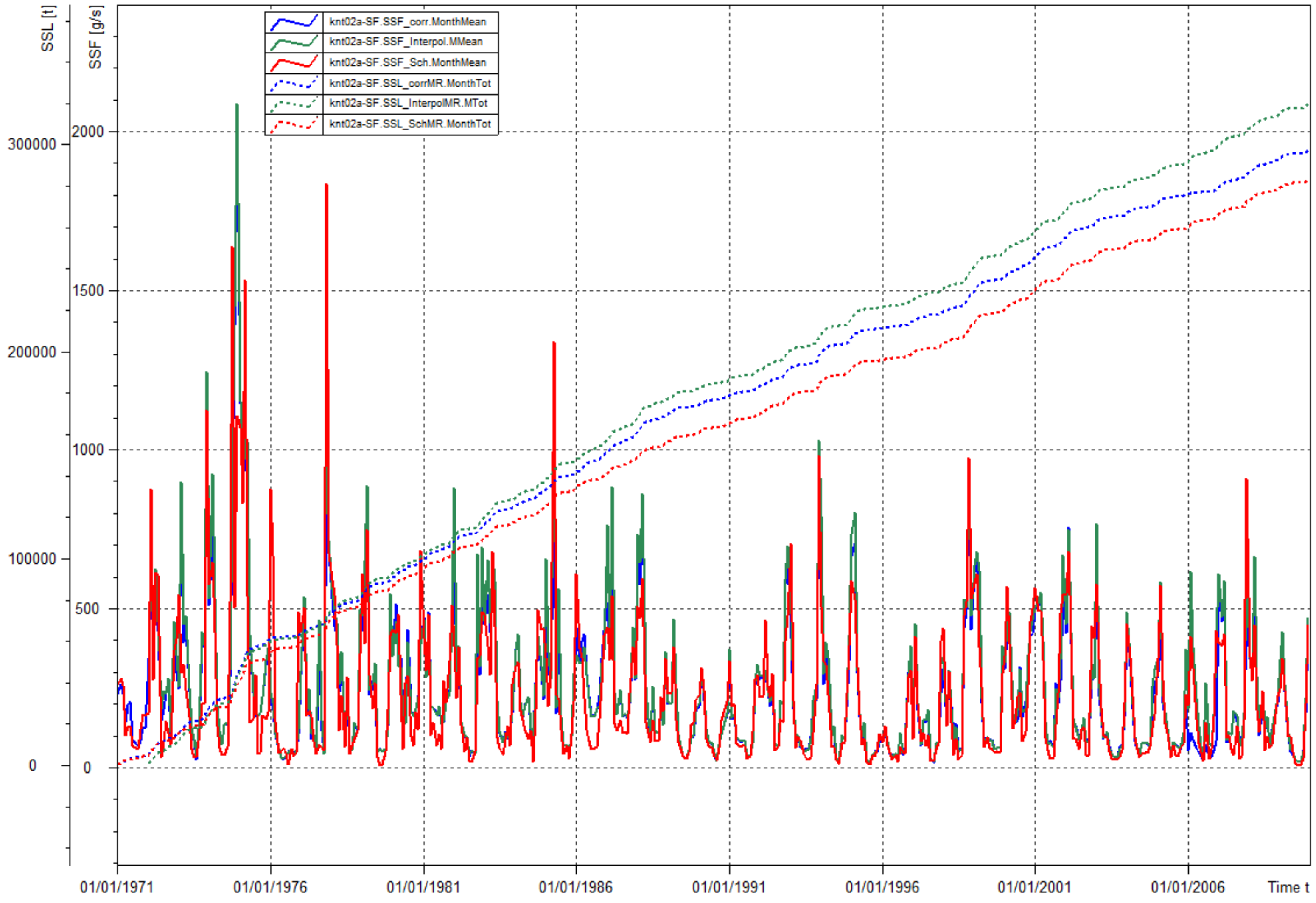


Figure 11: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Grobbendonk). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

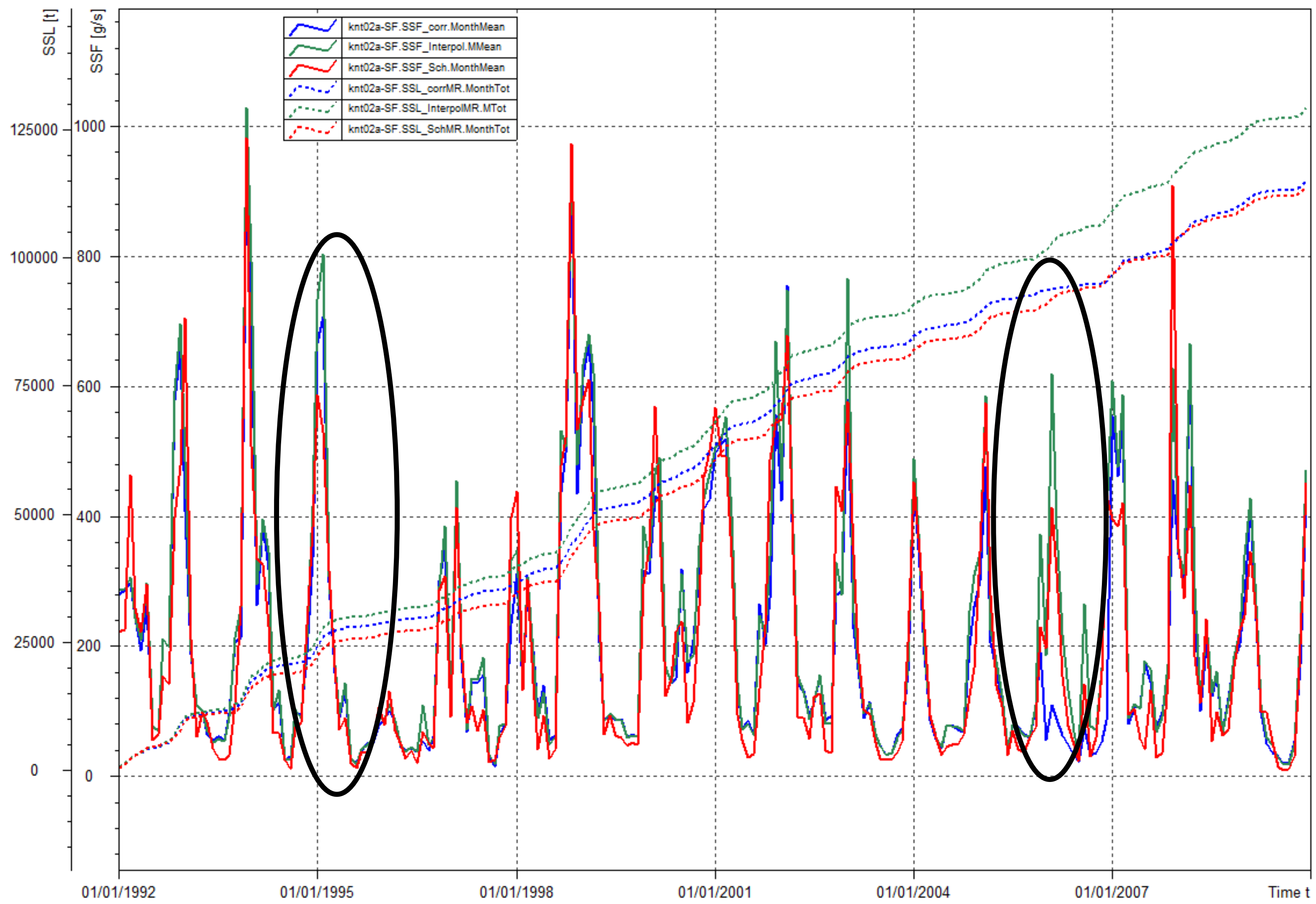


Figure 12: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Grobbendonk). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method. The two events in the black circles are used for illustrating the typical differences between the curves

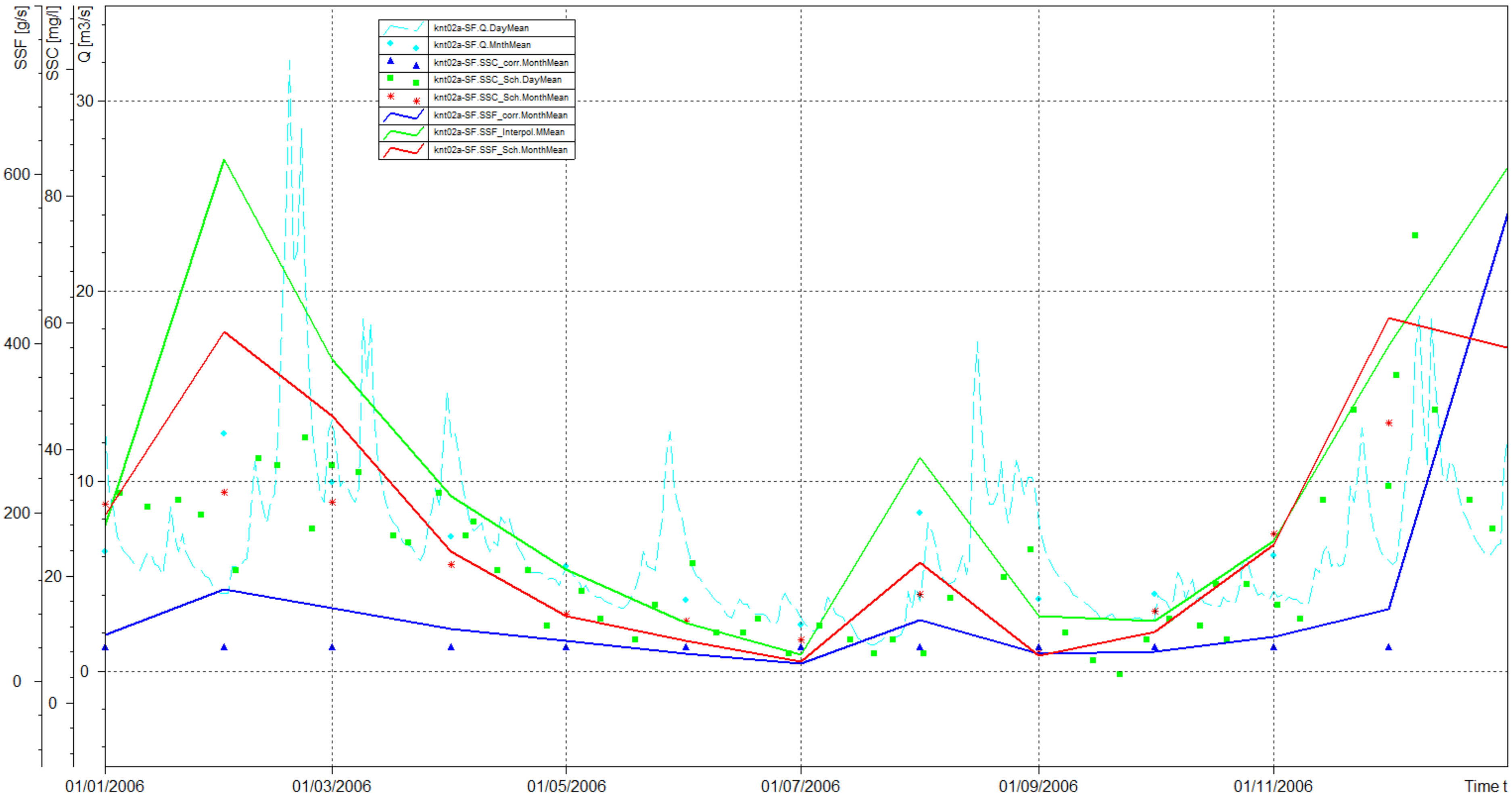


Figure 13: Sediment flux as full lines as function of time for Grobbendonk station. Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method. The blue curve is calculated by multiplying the cyan circles (monthly mean discharges) with the blue triangles (corresponding SSC derived from regression curve). The red curve is calculated by multiplying the cyan circles (monthly mean discharges) with the red stars (monthly SSC). The green curve is calculated by multiplying (on daily basis) the green squares with the daily discharges (dashed cyan line), complemented with daily SSC values derived from the regression line multiplied with daily discharges.

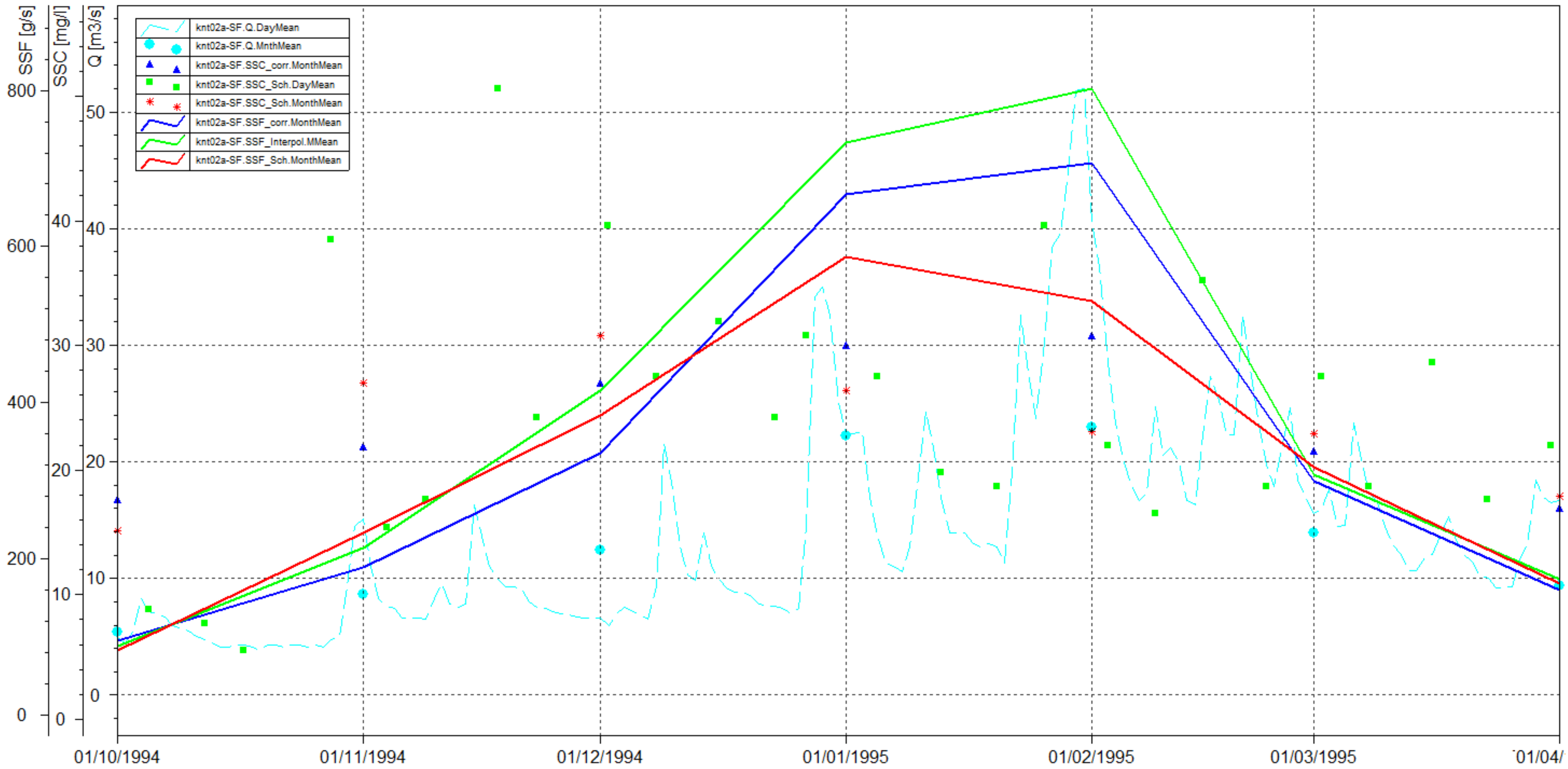


Figure 14: Sediment flux (full lines) calculated with different methods and basis time series to calculate these fluxes as function of time for Grobbendonk. Legend is the same as for Figure 13

4. Eppegem

4.1. Exploring the data

The dataset consists of measurements of water discharge (Q) and suspended sediment concentration (SSC) on the river 'Zenne' in the Flemish Region, throughout a period of 38.5 years (1971-2009).

During these 38.5 years there have been 1197 simultaneous measurements of water discharge and sediment concentration, which means on average one measurement every 1.67 weeks. However, as for the other locations, the dataset can be split into 2 parts: measurements before and after 1992. Before 1992, the frequency of measurements is lower than afterwards. There is little information available on the method of measuring before 1992, but there are reasons to suppose that it differs from the one after 1992.

The original dataset is shown in Figure 15. Eleven outliers were removed, because very high sediment concentrations coincided with low discharges (which is improbable). The omitted data points are shown in Figure 16. This reduced the dataset to 1186 time steps with simultaneous Q and SSC measurements.

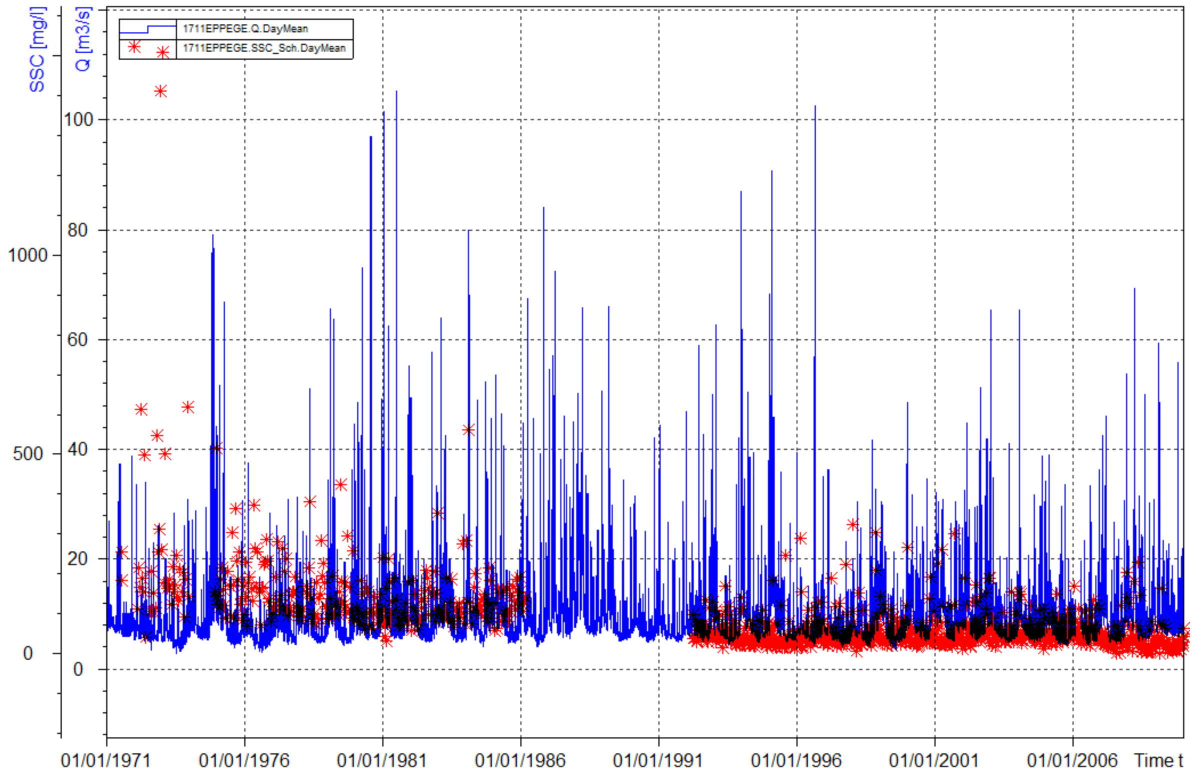


Figure 15: Dataset for Eppegem (Zenne) containing simultaneous Discharge (Q) and Suspended Sediment Concentration (SSC) measurements between 1971 and 2009

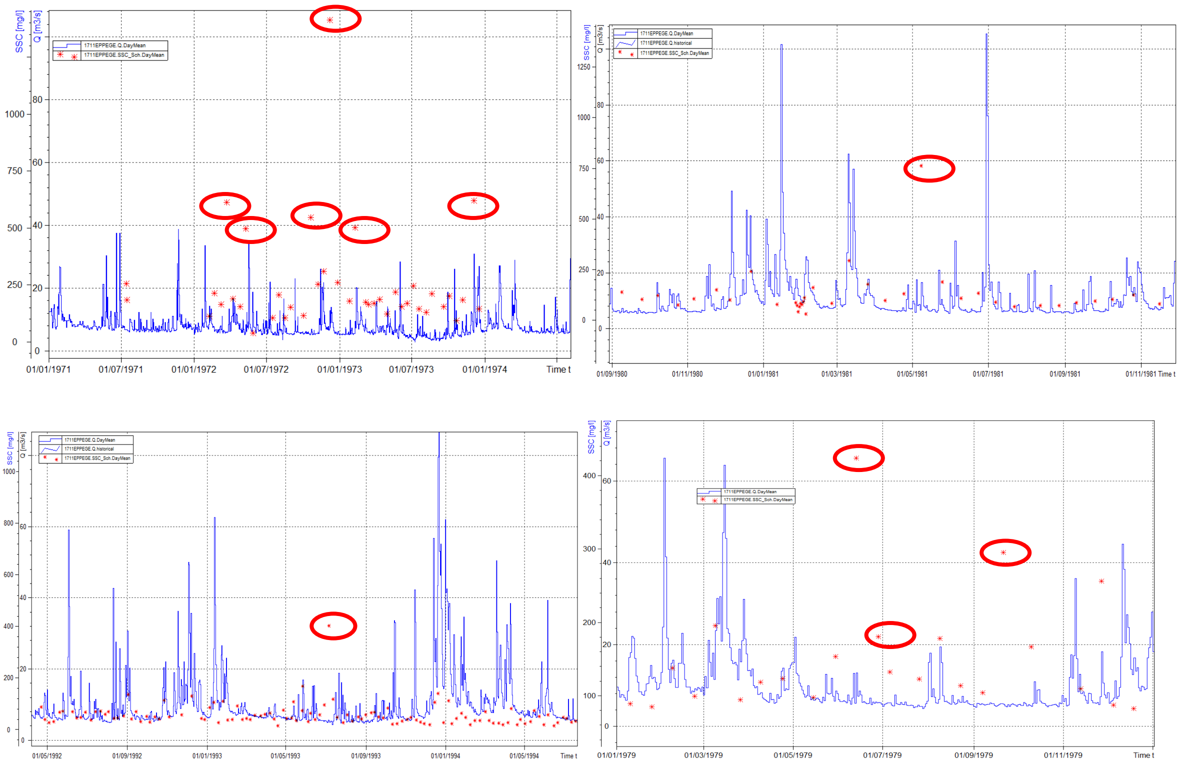


Figure 16: Outliers removed from the dataset of Eppegem (Zenne), i.e. very high SSC coinciding with low Q measurements

4.2. Calculation of sediment fluxes and loads

Regression between Q and SSC (daily values)

The magnitude of the directive derivative varies more before 1992 than it does afterwards. Also, there are four negative derivatives found before 1992 and only one after 1992.

The offsets are significantly larger for the regressions performed on the data before 1992. Additionally, there is more variation in the offset before 1992 than afterwards.

Remark: for 1971 only 2 coinciding Q and SSC measurements are available. Since the 2 Q values are equal, no regression could be determined. Therefore, it was chosen to apply the average regression for the entire measuring period for this year.

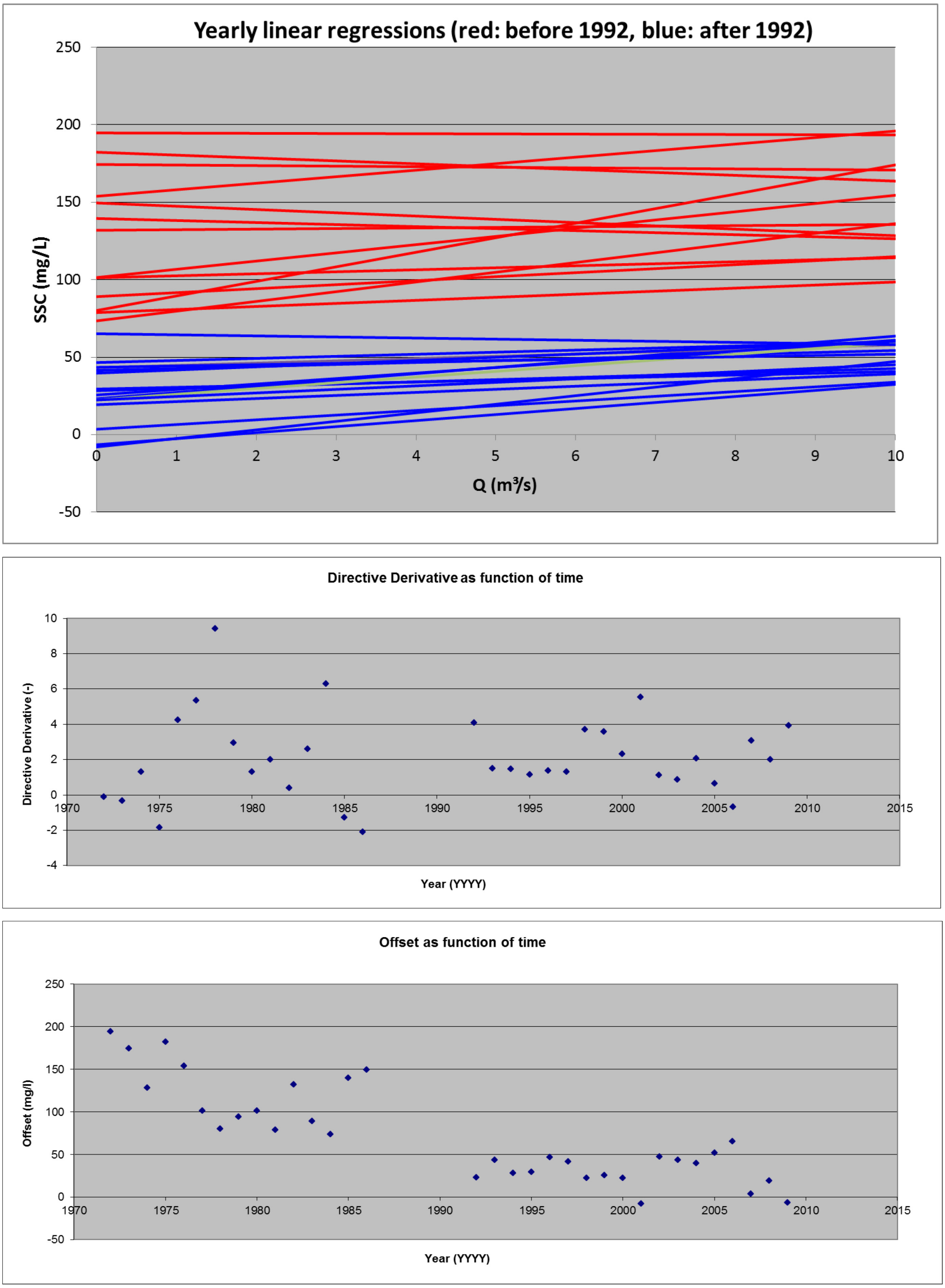


Figure 17: Overview of the yearly linear Q-SSC regressions for Eppegem (Zenne)

Sediment fluxes/loads

Figure 18 depicts the sediment fluxes and loads determined for Eppegem. The (course of the) sediment fluxes (and consequently the sediment loads) calculated by the three methods is generally quite similar. Again, the figure shows a clear winter/summer cycle: high winter loads and low summer loads. This is actually a cycle that can be seen in all observed stations. The cumulative sediment load appears to have a steeper slope before 1987 than afterwards for all three methods, probably due to differences in the measuring method before and after 1992 (no measurements of SSC between 1986 and 1992). From Figure 18 it is clear that method 3 calculates higher sediment fluxes compared to method 1 and 2, as was also observed for Grobbendonk. Consequently, sediment loads calculated by method 3 are higher than method 1 and 2, which is illustrated by the diverging course of the graphs.

Sediment fluxes and loads determined with method 2 are generally lower than their counterparts from method 1 and 3. This is partially because of the overestimation of the latter methods (especially method 3) by applying the relation between Q and SSC and partially because of the underestimation of the monthly average measured SSC for method 2 (as explained in Section 3.3.2).

Figure 19 shows the situation after 1992. This detailed image confirms that the interpolation method calculates the highest sediment fluxes and loads. The figure however reveals that the difference between Taverniers1 and 2 is smaller than suggested by Figure 18 and that the total load for method 2 is even a bit higher than for method 1.

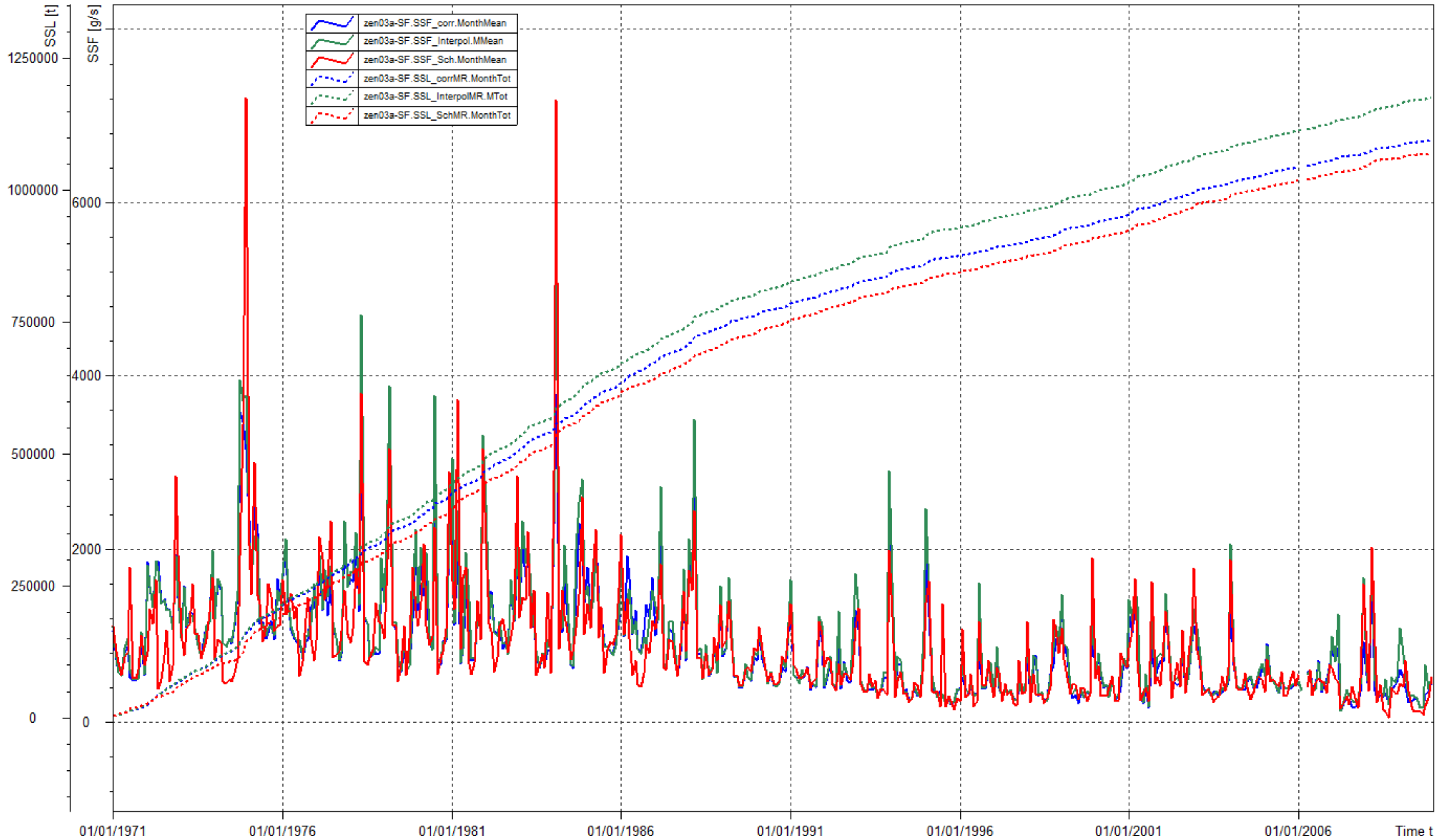


Figure 18: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Eppegem). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

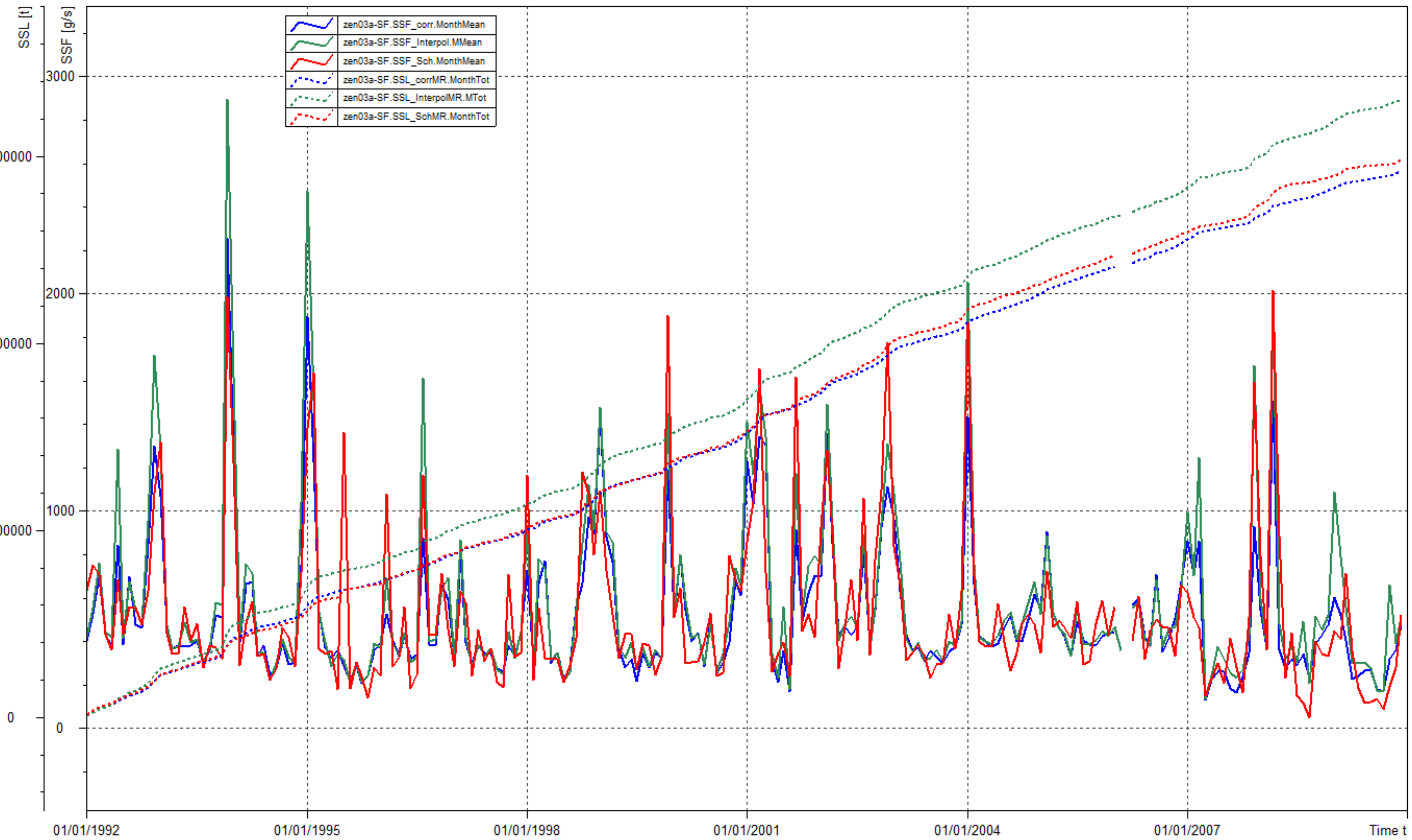


Figure 19: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Eppegem). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

5. Haacht

5.1. Exploring the data

The dataset consists of measurements of water discharge (Q) and suspended sediment concentration (SSC) on the river 'Dijle' in the Flemish Region, throughout a period of 38.5 years (1971-2009).

During these 38.5 years there have been 1161 simultaneous measurements of water discharge and sediment concentration, which means on average one measurement every 1.72 weeks. However, as for the other locations, the dataset can be split into 2 parts: measurements before and after 1992. Before 1992, the frequency of measurements is lower than afterwards. There is little information available on the method of measuring before 1992, but there are reasons to suppose that it differs from the one after 1992.

The original dataset is shown in Figure 20. Six outliers were removed, because very high sediment concentrations coincided with low discharges (which is improbable). The omitted data points are shown in Figure 21. This reduced the dataset to 1155 time steps with simultaneous Q and SSC measurements.

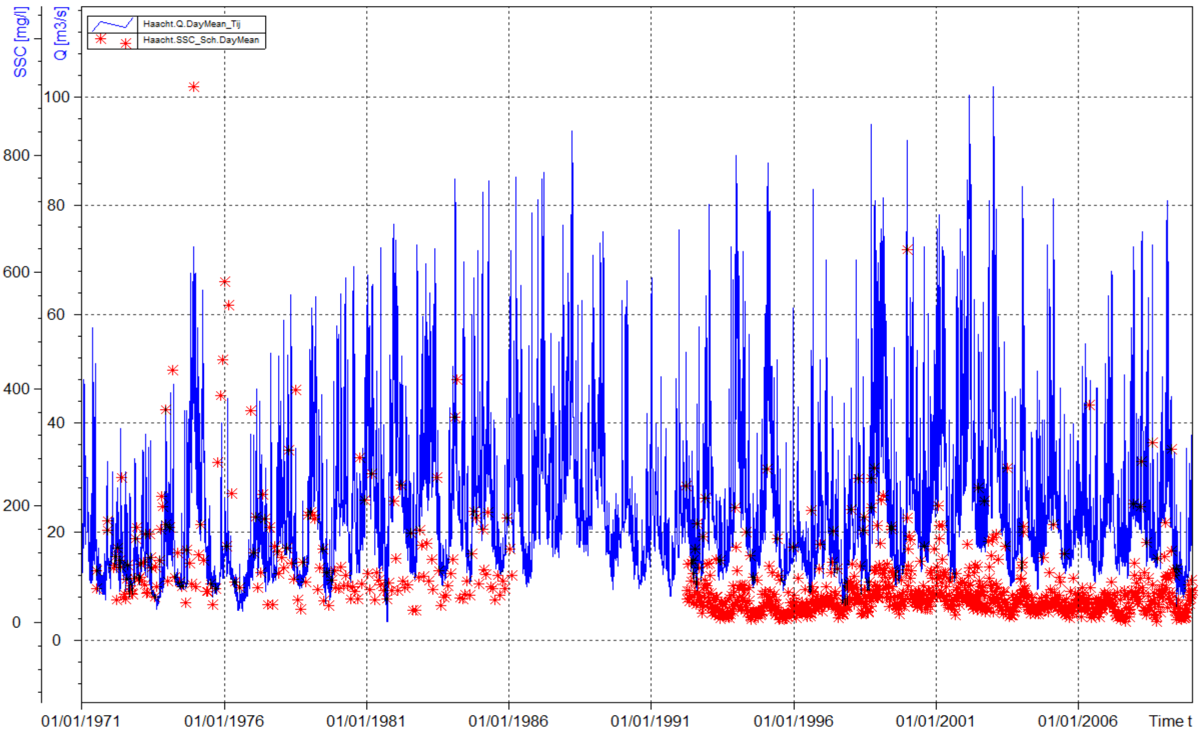


Figure 20: Dataset for Haacht (Dijle) containing simultaneous Discharge (Q) and Suspended Sediment Concentration (SSC) measurements between 1971 and 2009

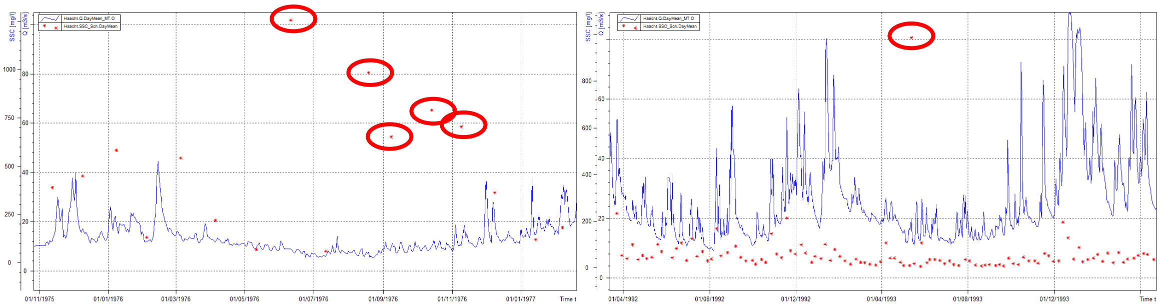
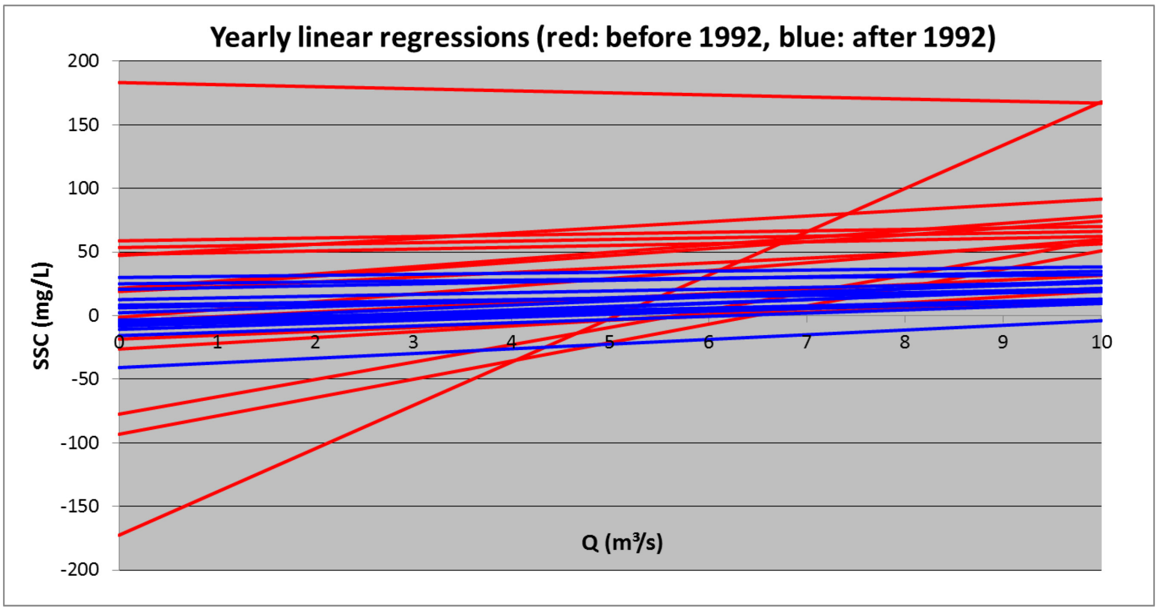


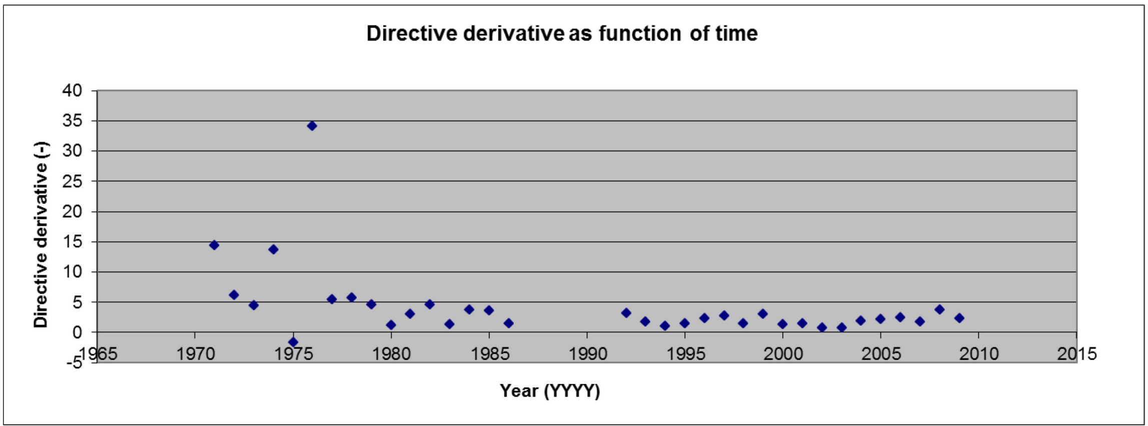
Figure 21: Outliers removed from the dataset of Haacht (Dijle), i.e. very high SSC coinciding with low Q measurements

5.2. Calculation of sediment loads

Regression between Q and SSC (daily values)

As was also observed for the other measuring locations, there is a significant difference between the regressions before and after 1992. Both the directive derivative and the offset vary more before 1992 and are larger in magnitude than afterwards. Negative derivatives and offsets occur more before 1992 than afterwards.





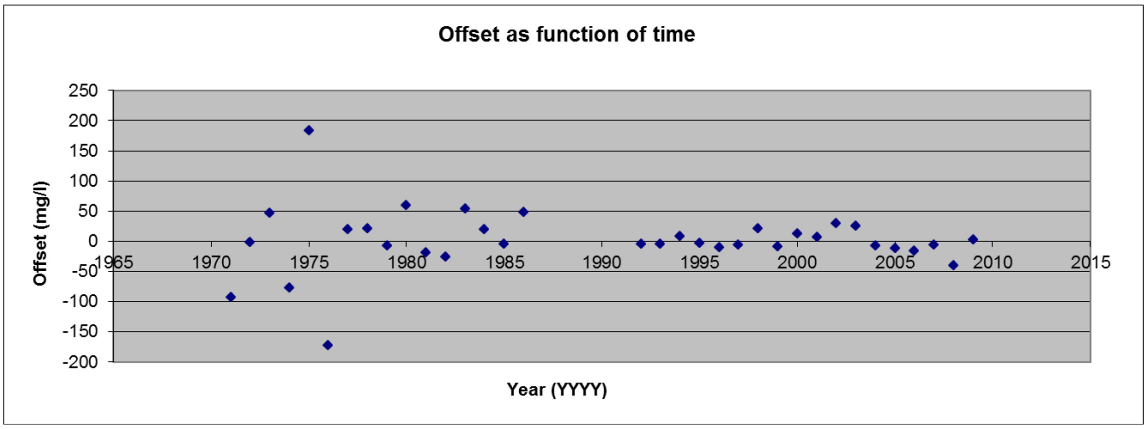


Figure 22: Overview of the yearly linear Q-SSC regressions for Haacht (Dijle)

Sediment fluxes/loads

Figure 23 depicts the sediment fluxes and loads determined for Haacht. The (course of the) sediment fluxes (and consequently the sediment loads) calculated by the three methods is generally quite similar. The cumulative sediment load appears to have a steeper slope before 1987 than afterwards for all three methods, probably due to differences in the measuring method before and after 1992 (no measurements of SSC between 1986 and 1992). From Figure 23 it is clear that method 3 calculates higher sediment fluxes compared to method 1 and 2, as was also observed for Grobbendonk and Eppegem. Consequently, sediment loads calculated by method 3 are higher than method 1 and 2, which is illustrated by the diverging course of the graphs.

Sediment fluxes and loads determined with method 2 are generally lower than their counterparts from method 1 and 3. This is partially because of the overestimation of the latter methods (especially method 3) by applying the relation between Q and SSC and partially because of the underestimation of the monthly average measured SSC for method 2 (as explained in Section 3.3.2).

Figure 24 shows the situation after 1992. This detailed image confirms that the interpolation method calculates the highest sediment fluxes and loads and Taverniers1 and 2 the lowest. The cumulative sediment loads calculated by Taverniers1 and Taverniers2 are very similar, as was also observed at Grobbendonk and Eppegem.

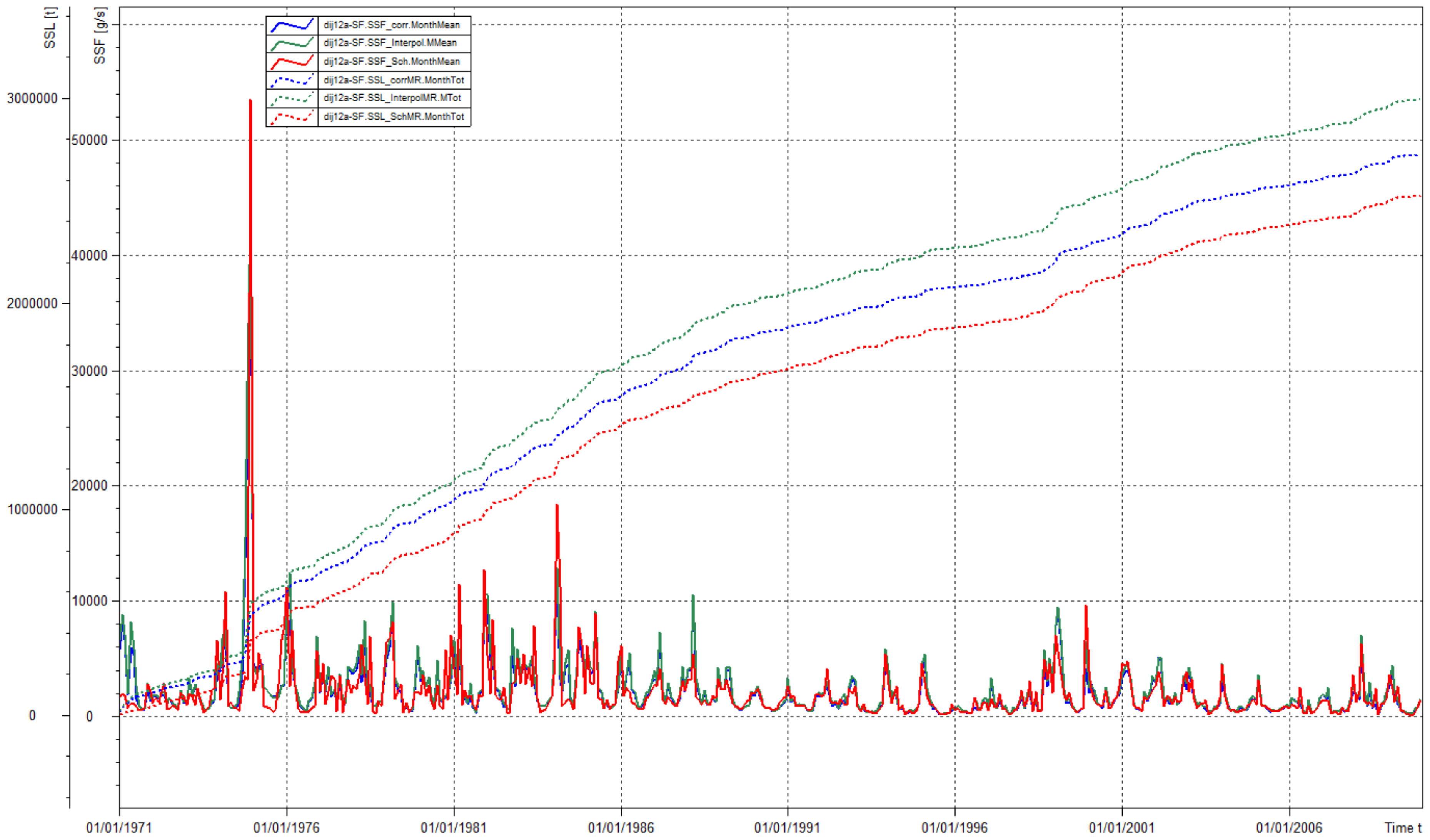


Figure 23: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Haacht). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

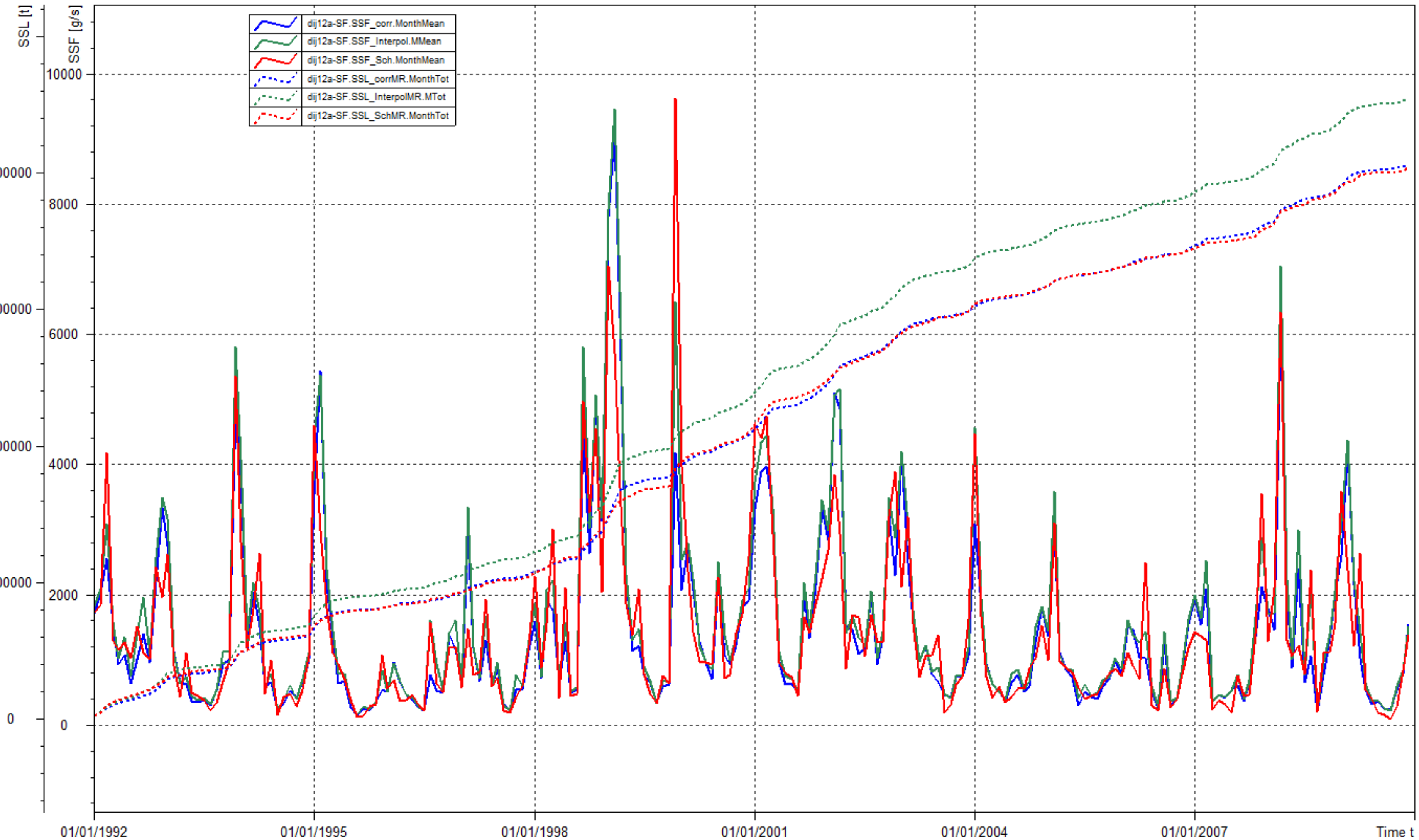


Figure 24: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Haacht). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

6. Dendermonde (Appels)

6.1. Exploring the data

The dataset consists of measurements of water discharge (Q) and suspended sediment concentration (SSC) on the river 'Dender' in the Flemish Region, throughout a period of 38.5 years (1971-2009).

During these 38.5 years there have been 1234 simultaneous measurements of water discharge and sediment concentration, which means on average one measurement every 1.62 weeks. However, as for the other locations, the dataset can be split into 2 parts: measurements before and after 1992. Before 1992, the frequency of measurements is lower than afterwards. There is little information available on the method of measuring before 1992, but there are reasons to suppose that it differs from the one after 1992.

The original dataset is shown in Figure 25. No outliers had to be omitted.

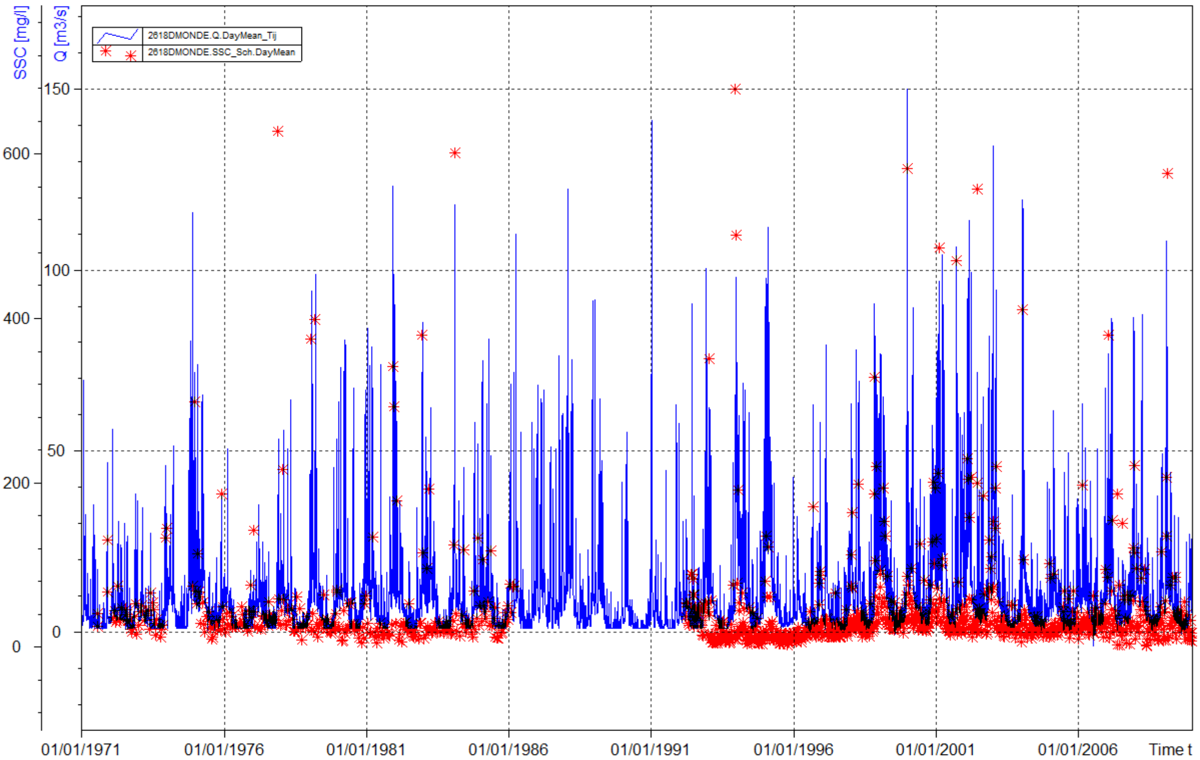
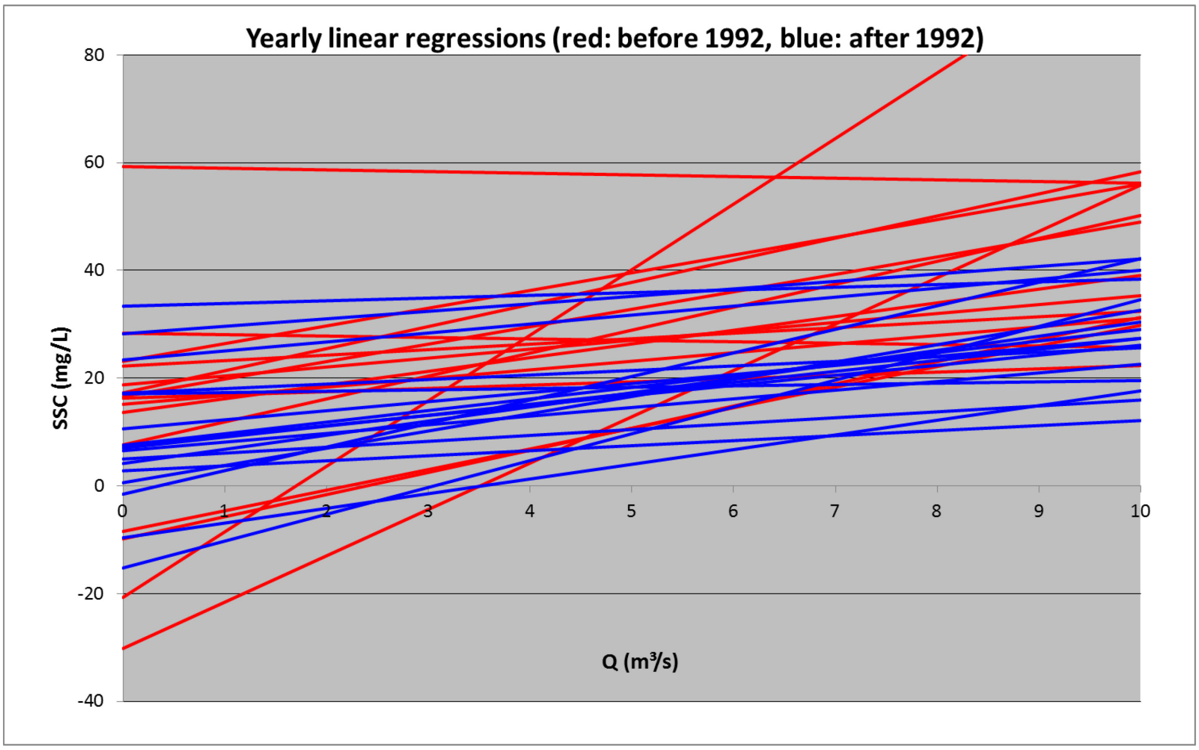


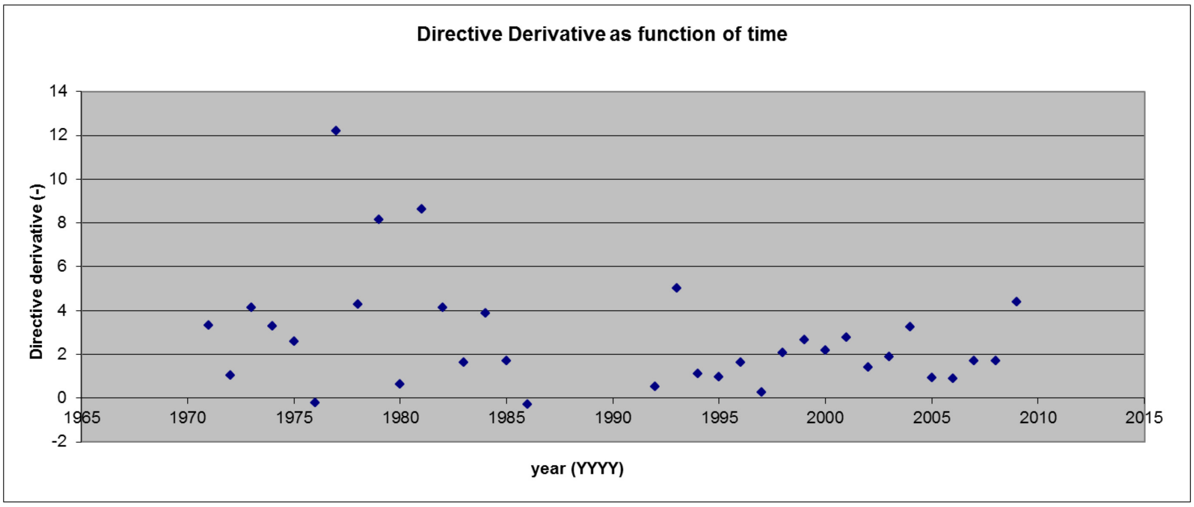
Figure 25: Dataset for Dendermonde (Dender) containing simultaneous Discharge (Q) and Suspended Sediment Concentration (SSC) measurements between 1971 and 2009

6.2. Calculation of sediment loads

Regression between Q and SSC (daily values)

In general, similar observations can be made as for the other locations (both the directive derivative and the offset vary more before 1992 and are larger in magnitude than afterwards), but less significant. Negative derivatives and offsets occur more before 1992 than afterwards.





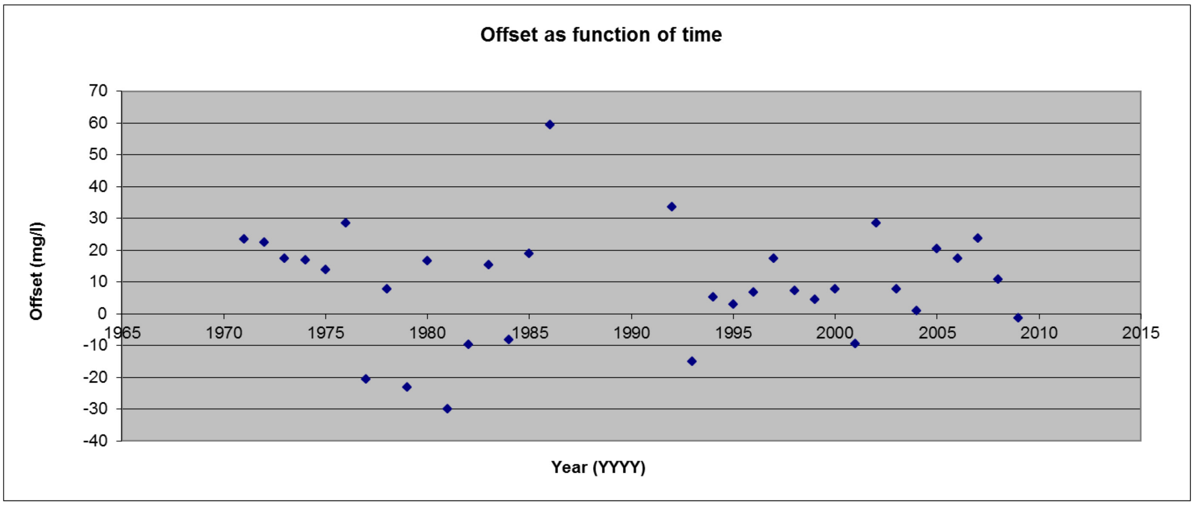


Figure 26: Overview of the yearly linear Q-SSC regressions for Dendermonde (Dender)

Sediment fluxes/loads

Figure 27 depicts the sediment fluxes and loads determined for Dendermonde. The (course of the) sediment fluxes (and consequently the sediment loads) calculated by the three methods is generally quite similar. From Figure 27 it is clear that method 3 calculates higher sediment fluxes compared to method 1 and 2, as was also observed for Grobbendonk, Eppegem and Haacht. Consequently, sediment loads calculated by method 3 are highest, which is illustrated by the diverging course of the graphs.

Sediment fluxes and loads determined with method 2 are generally lower than their counterparts from method 1 and 3. This is partially because of the overestimation of the latter methods (especially method 3) by applying the relation between Q and SSC and partially because of the underestimation of the monthly average measured SSC for method 2 (as explained in Section 3.3.2).

Figure 28 shows the situation after 1992. This detailed image confirms that the interpolation method calculates the highest sediment fluxes and loads. The cumulative sediment loads calculated by Taverniers1 and Taverniers2 are very similar, as was also observed for Grobbendonk, Eppegem and Haacht.

A significant increase in the sediment load occurred between 1998 and 2004.

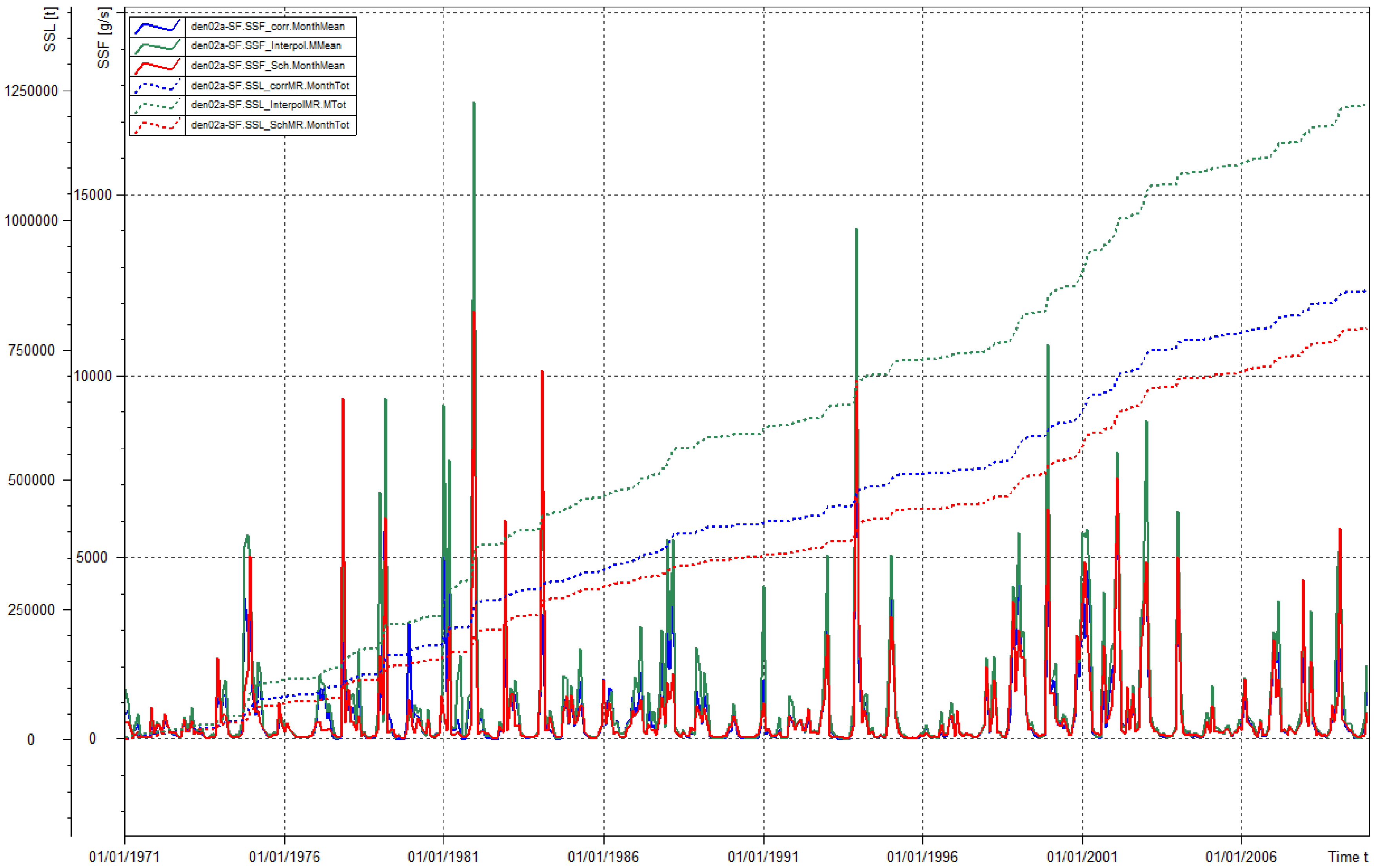


Figure 27: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Dendermonde). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

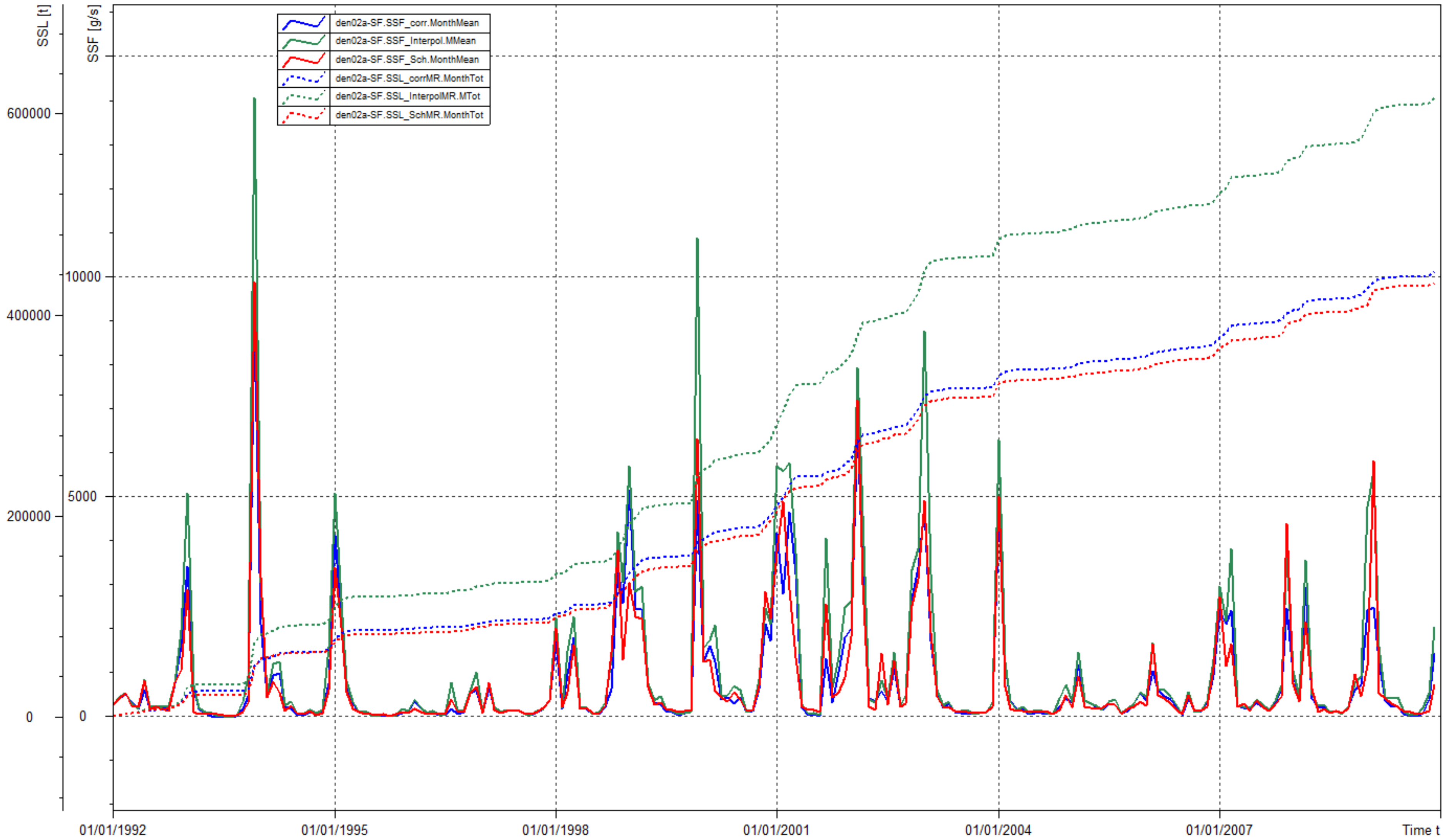


Figure 28: Sediment flux (fixed lines) and cumulative sediment load (dashed lines) as function of time (Dendermonde). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

7. Itegem

7.1. Exploring the data

The dataset consists of measurements of water discharge (Q) and suspended sediment concentration (SSC) on the river 'Grote Nete' in the Flemish Region, throughout a period of 37.9 years (1972-2009).

During these 37.9 years there have been 1185 simultaneous measurements of water discharge and sediment concentration, which means on average one measurement every 1.66 weeks. However, as for the other locations, the dataset can be split into 2 parts: measurements before and after 1992. Before 1992, the frequency of measurements is lower than afterwards. There is little information available on the method of measuring before 1992, but there are reasons to suppose that it differs from the one after 1992.

The original dataset is shown in Figure 29. Three outliers were removed, because very high sediment concentrations coincided with low discharges (which is improbable). The omitted data points are shown in Figure 30. This reduced the dataset to 1182 time steps with simultaneous Q and SSC measurements.

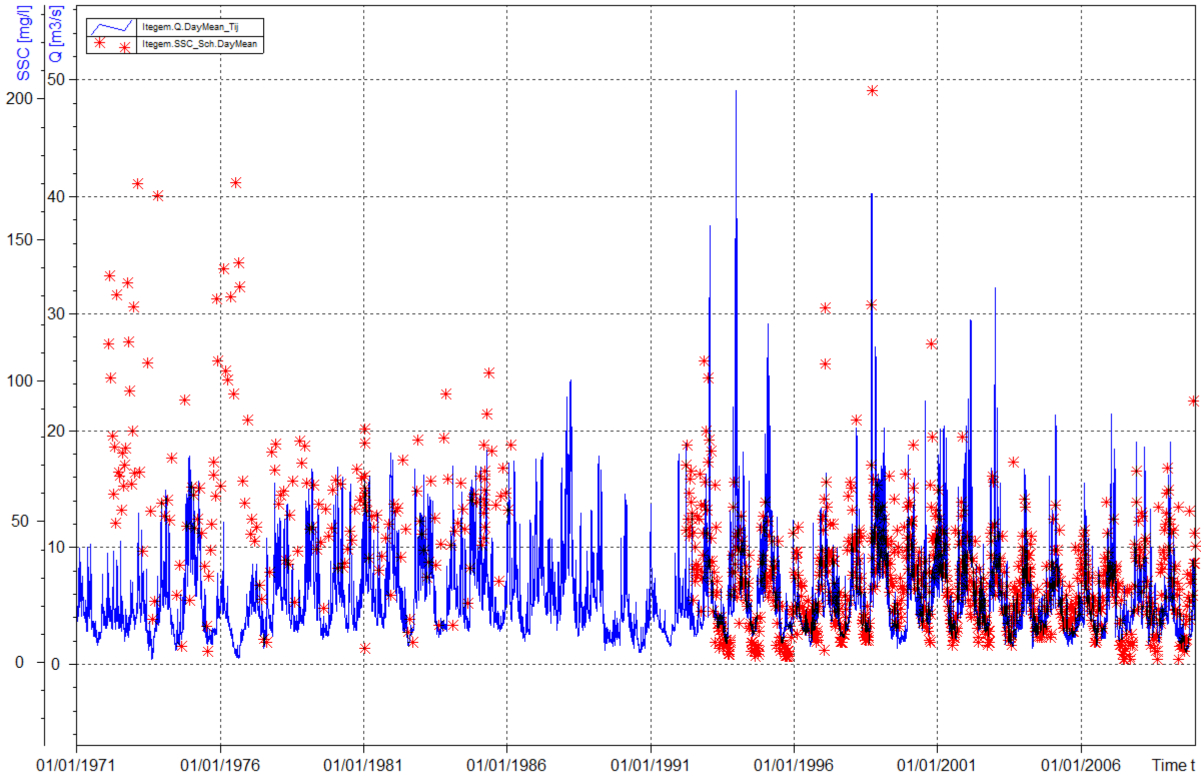


Figure 29: Dataset for Itegem (Grote Nete) containing simultaneous Discharge (Q) and Suspended Sediment Concentration (SSC) measurements between 1972 and 2009

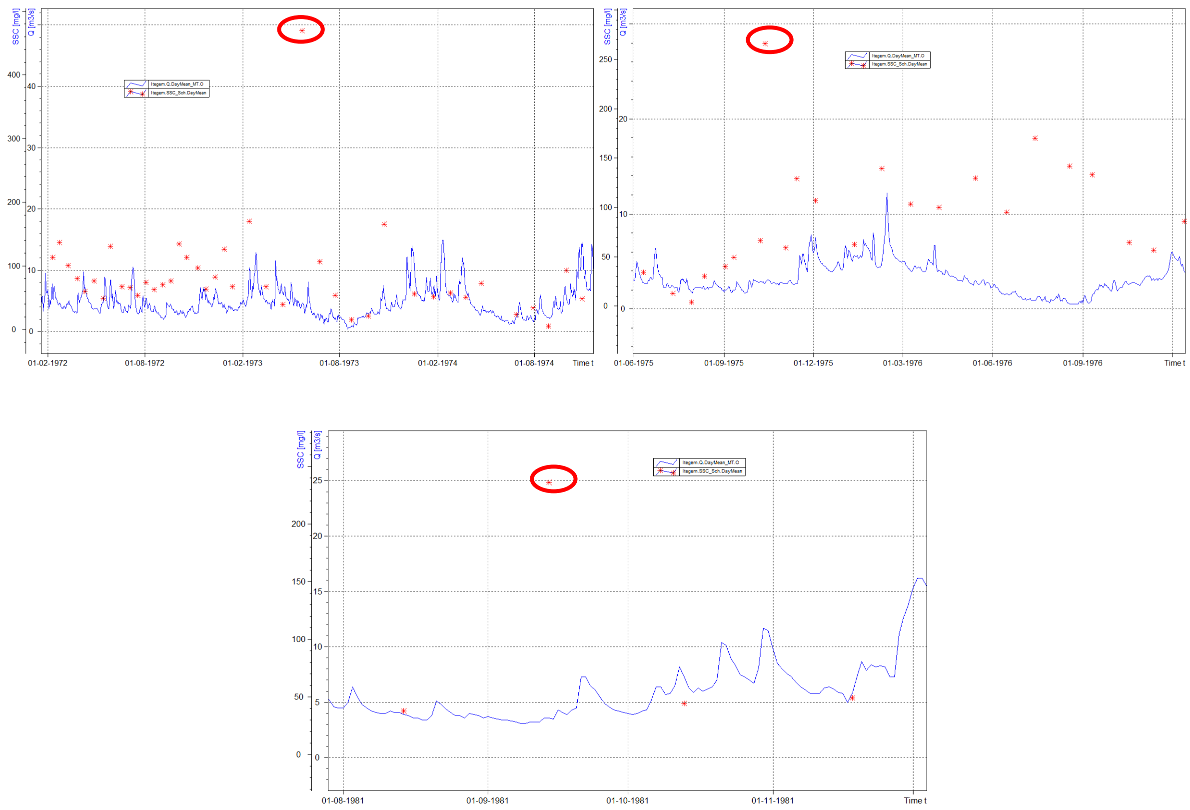
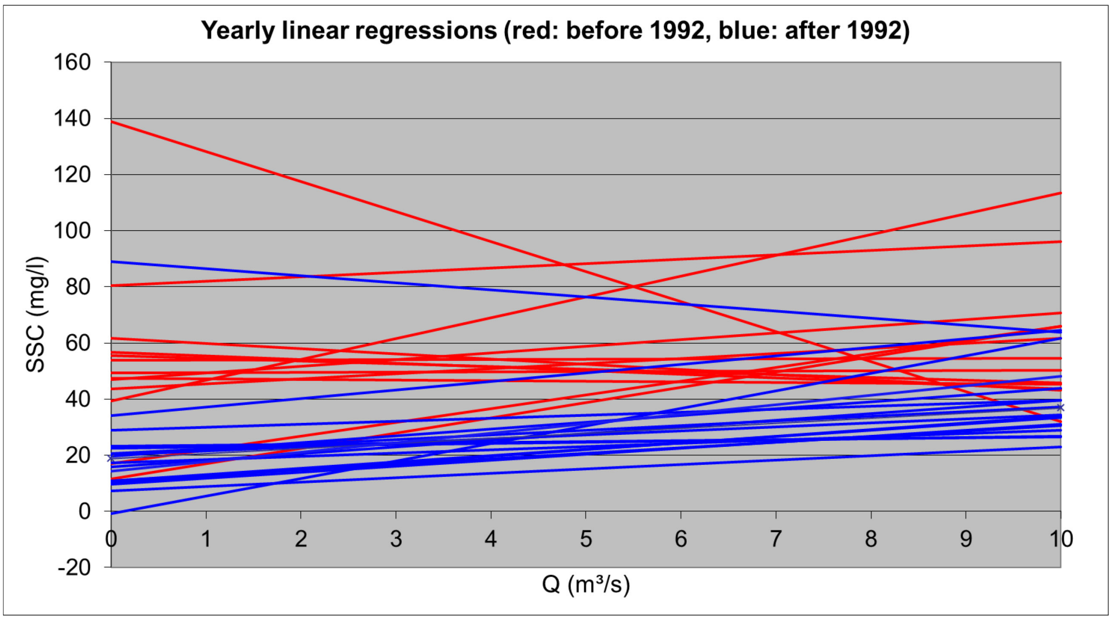


Figure 30: Outliers removed from the dataset of Itegem (Grote Nete), i.e. very high SSC coinciding with low Q measurements

7.2. Calculation of sediment loads

Regression between Q and SSC (daily values)

In general, similar observations can be made as for the other locations (both the directive derivative and the offset vary more before 1992 and are larger in magnitude than afterwards). Negative derivatives and offsets occur more before 1992 than afterwards.



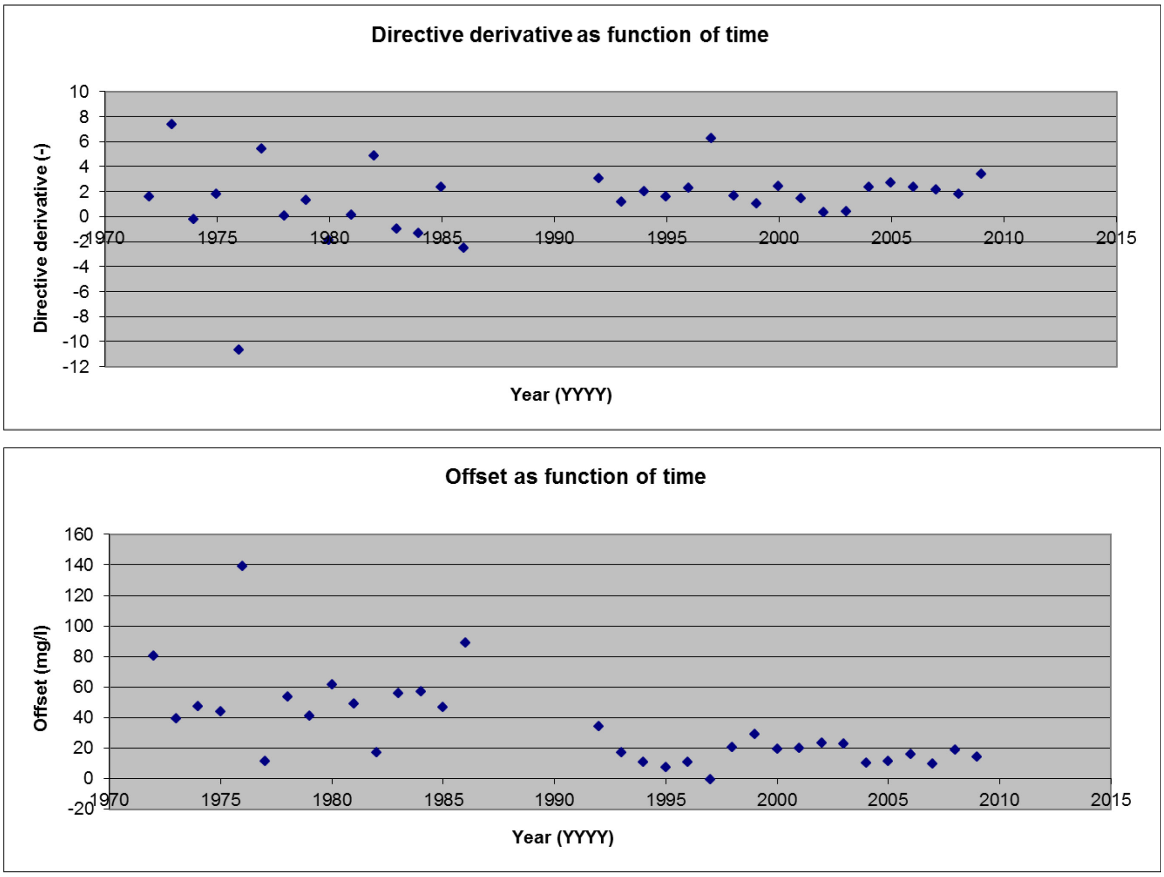


Figure 31: Overview of the yearly linear Q-SSC regressions for Itegem (Grote Nete)

Sediment fluxes/loads

Figure 32 depicts the sediment fluxes and loads determined for Itegem. The (course of the) sediment fluxes (and consequently the sediment loads) calculated by the three methods is generally very similar. The cumulative sediment load appears to have a steeper slope before 1987 than afterwards for all three methods, probably due to differences in the measuring method before and after 1992 (no measurements of SSC between 1986 and 1992). From Figure 32 it is clear that for Itegem, all three calculation methods have a very similar result. The cumulative sediment load curves follow the same course and only diverge limitedly from 1987 onwards (with method 3 calculating slightly higher values).

Figure 33 shows the situation after 1992. Again, fluxes and cumulative loads appear to be similar. However, the cumulative load calculated by Tavernier1 is lower than for the other two methods.

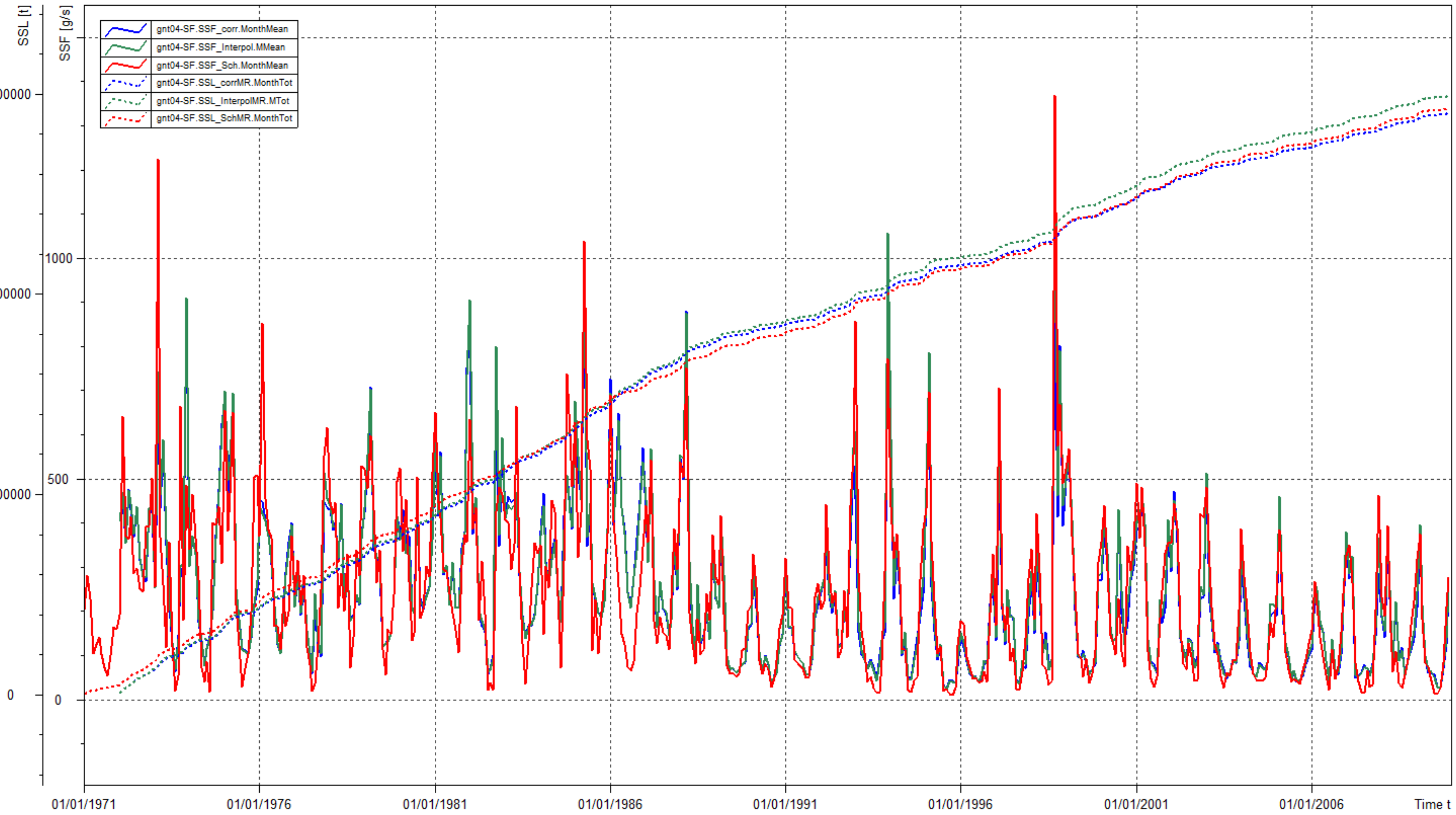


Figure 32: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Itegem). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

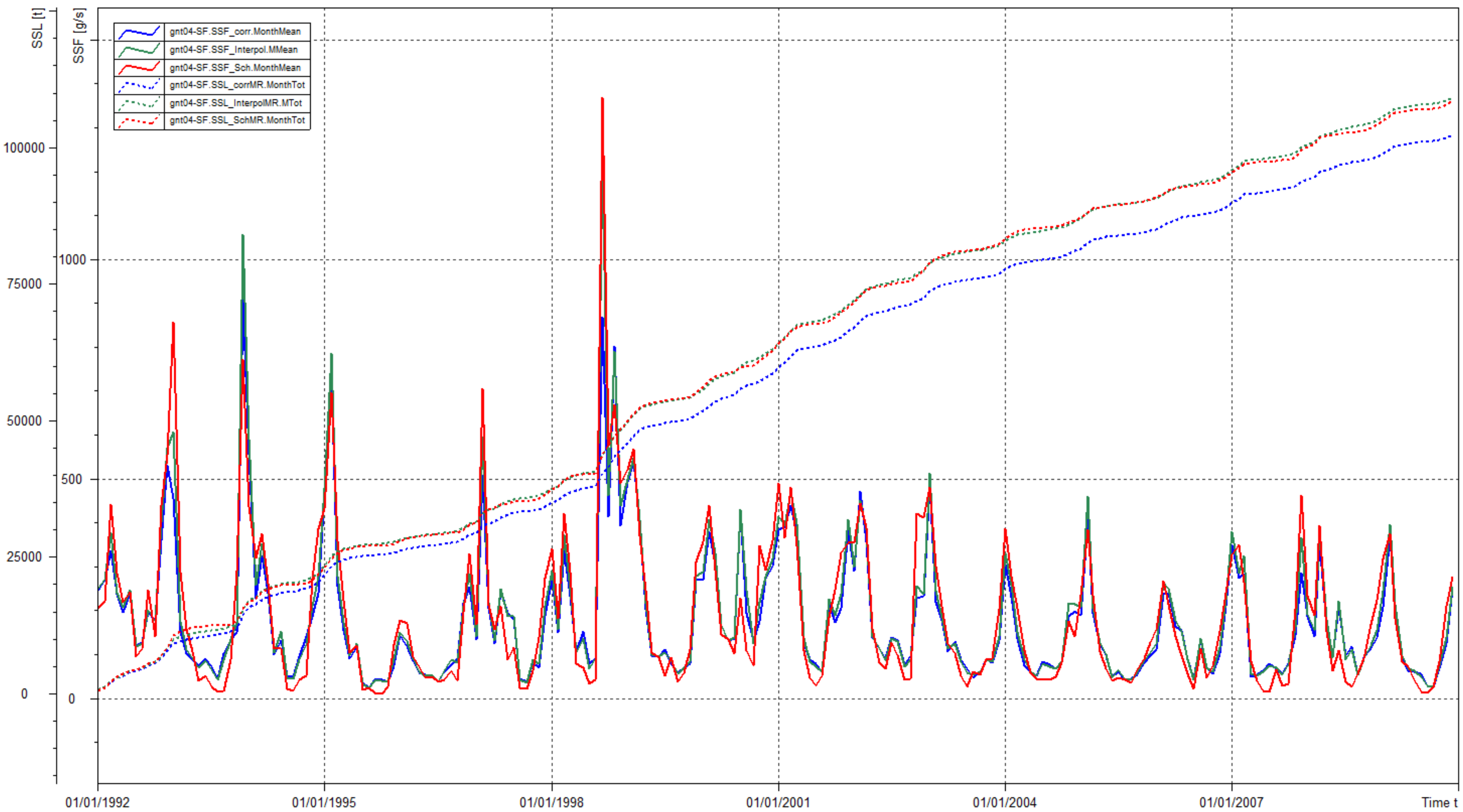


Figure 33: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Itegem). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

8. Melle (Q)/ Merelbeke (SSC)

8.1. Exploring the data

The dataset consists of measurements of water discharge (Q) and suspended sediment concentration (SSC) on the river Scheldt in the Flemish Region, throughout a period of 37.9 years (1971-2009). Melle is located in the tidal influence zone of the river 'the Schelde' which renders this location improper for the analysis of the sediment balance. Therefore, SSC was measured at Merelbeke, while Q was measured at Melle.

During this period there have been 1130 simultaneous measurements of water discharge and sediment concentration, which means on average one measurement every 1.74 weeks. However, as for the other locations, the dataset can be split into 2 parts: measurements before and after 1992. Before 1992, the frequency of measurements is lower than afterwards. There is little information available on the method of measuring before 1992, but there are reasons to suppose that it differs from the one after 1992.

The original dataset is shown in Figure 34. One outlier was removed, because a very high sediment concentration coincided with a low discharge (which is improbable). The omitted data point is shown in Figure 35. This reduced the dataset to 1129 time steps with simultaneous Q and SSC measurements.

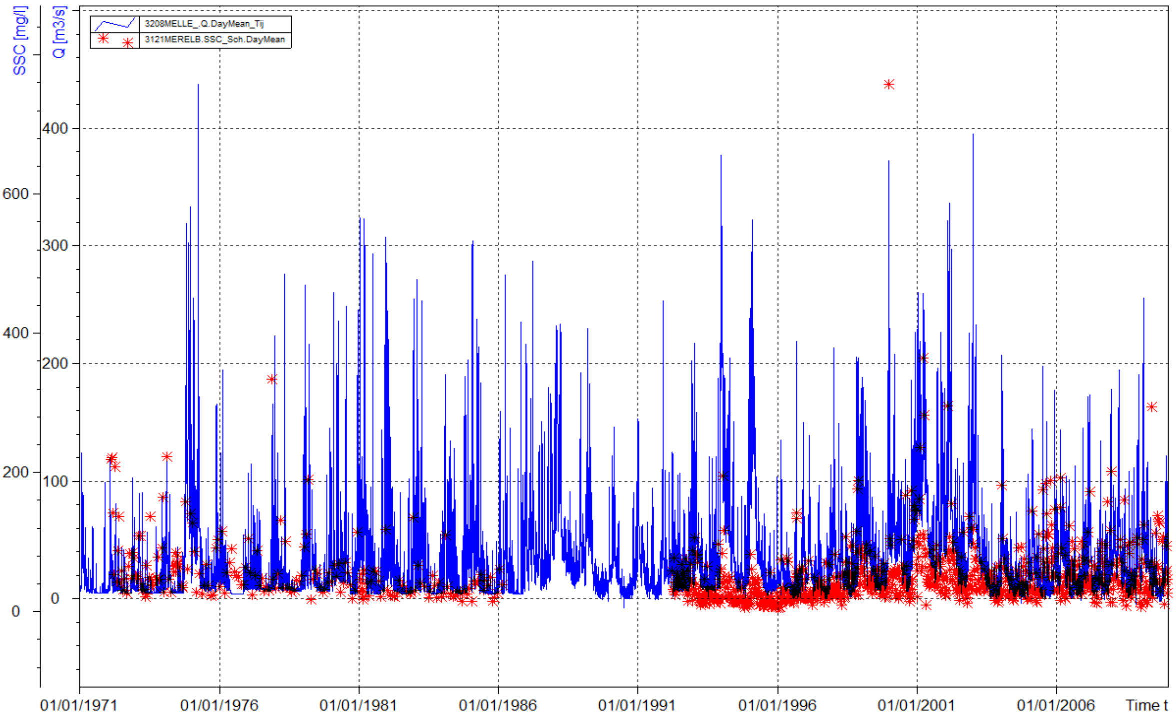


Figure 34: Dataset for Melle/Merelbeke (Scheldt) containing simultaneous Discharge (Q) and Suspended Sediment Concentration (SSC) measurements between 1972 and 2009

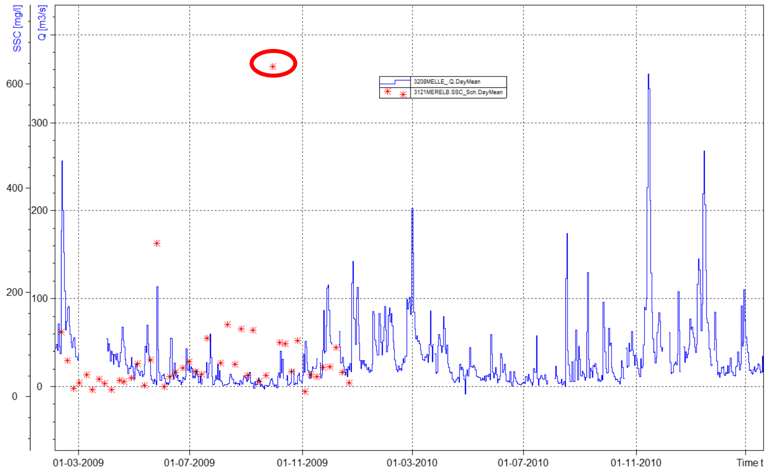
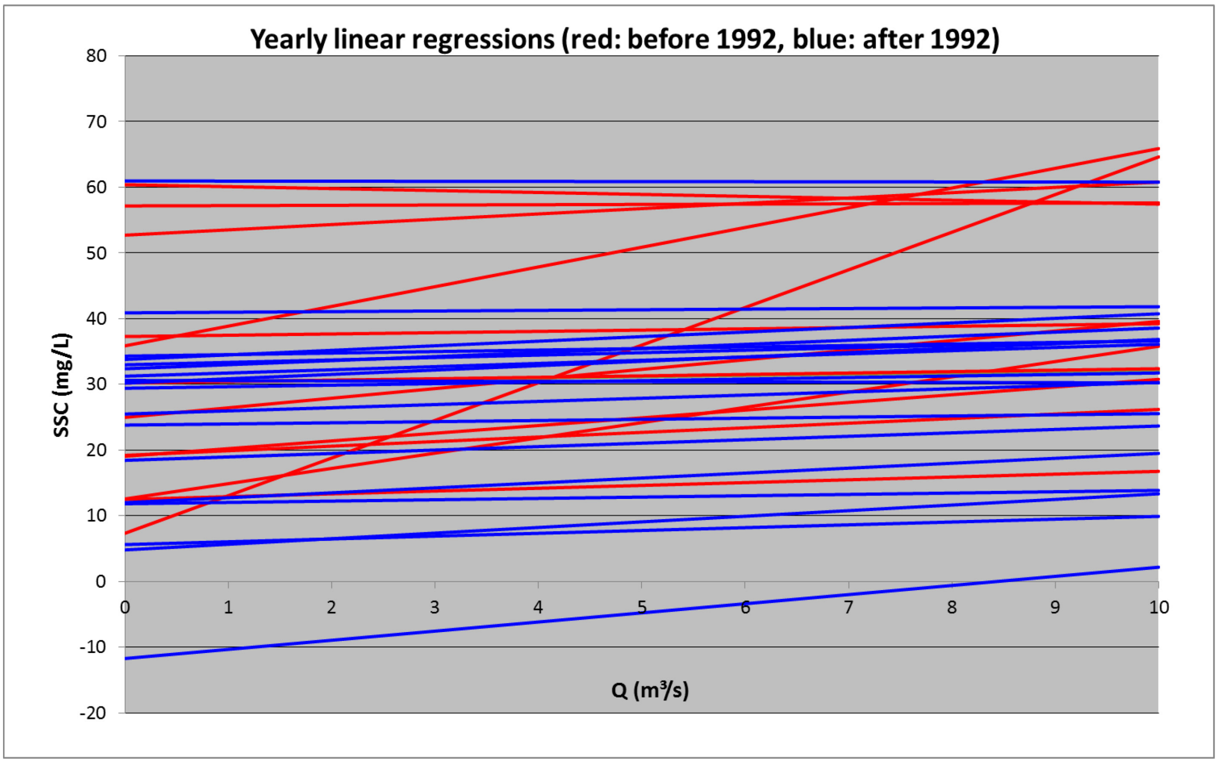


Figure 35: Outlier removed from the dataset of Melle/Merelbeke (Scheldt), i.e. very high SSC coinciding with low Q measurement

8.2. Calculation of sediment loads

Regression between Q and SSC (daily values)

In general, similar observations can be made as for the other locations concerning the directive derivative (more variation before 1992 and a larger magnitude than afterwards). However, no clear differences or patterns can be observed in the offsets before and after 1992, as opposed to the other measuring locations.



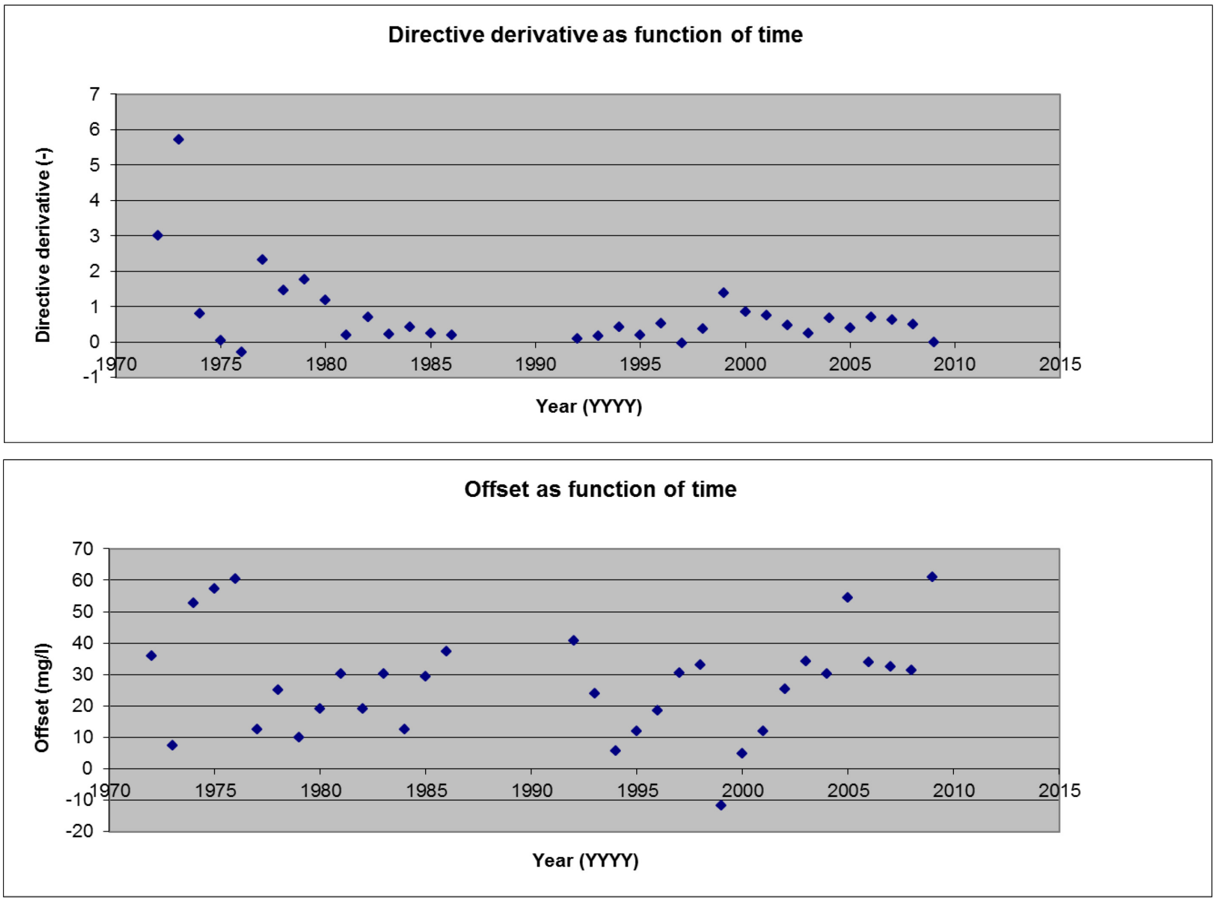


Figure 36: Overview of the yearly linear Q-SSC regressions for Melle/Merelbeke (Scheldt)

Sediment fluxes/loads

Figure 37 depicts the sediment fluxes and loads determined for Melle/Merelbeke. The (course of the) sediment fluxes (and consequently the sediment loads) calculated by the three methods is generally quite similar. From Figure 37 it is clear that method 3 calculates higher sediment fluxes compared to method 1 and 2, as was also observed for Grobbendonk, Eppegem, Haacht and Dendermonde. Consequently, sediment loads calculated by method 3 are highest, which is illustrated by the diverging course of the graphs.

Sediment fluxes and loads determined with method 2 are generally lower than their counterparts from method 1 and 3. This is partially because of the overestimation of the latter methods (especially method 3) by applying the relation between Q and SSC and partially because of the underestimation of the monthly average measured SSC for method 2 (as explained in Section 3.3.2).

Figure 38 shows the situation after 1992. This detailed image confirms that the interpolation method calculates the highest sediment fluxes and loads. The cumulative sediment loads calculated by Taverniers1 and Taverniers2 are very similar, as was also observed for Grobbendonk, Eppegem, Haacht. and Dendermonde.

A significant increase in the sediment load occurred between 1998 and 2004.

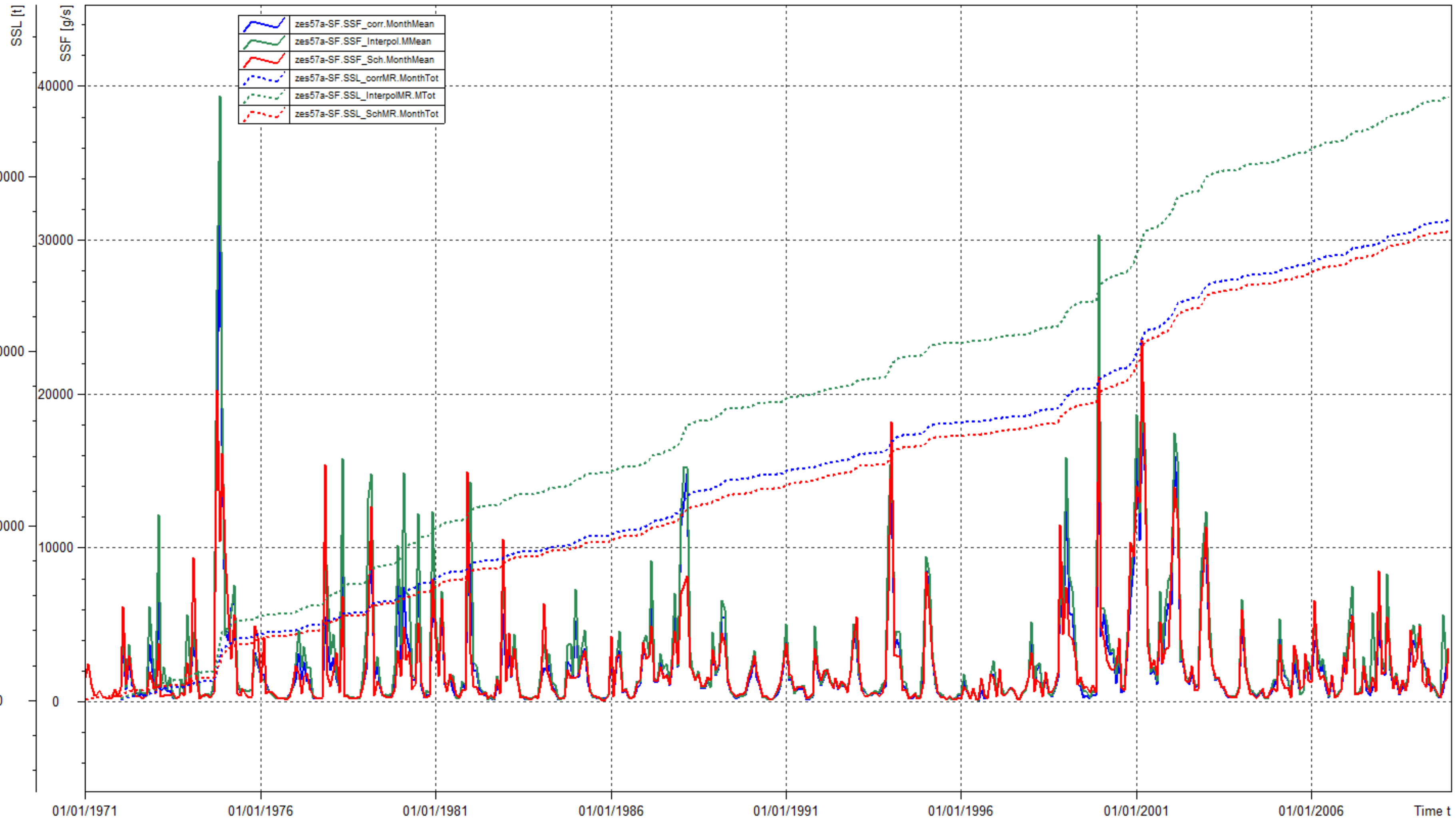


Figure 37: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Melle/Merelbeke). Blue curves are used for the Taverniers1 method , green curves are used for the interpolation method and red curves are used for the Taverniers2 method

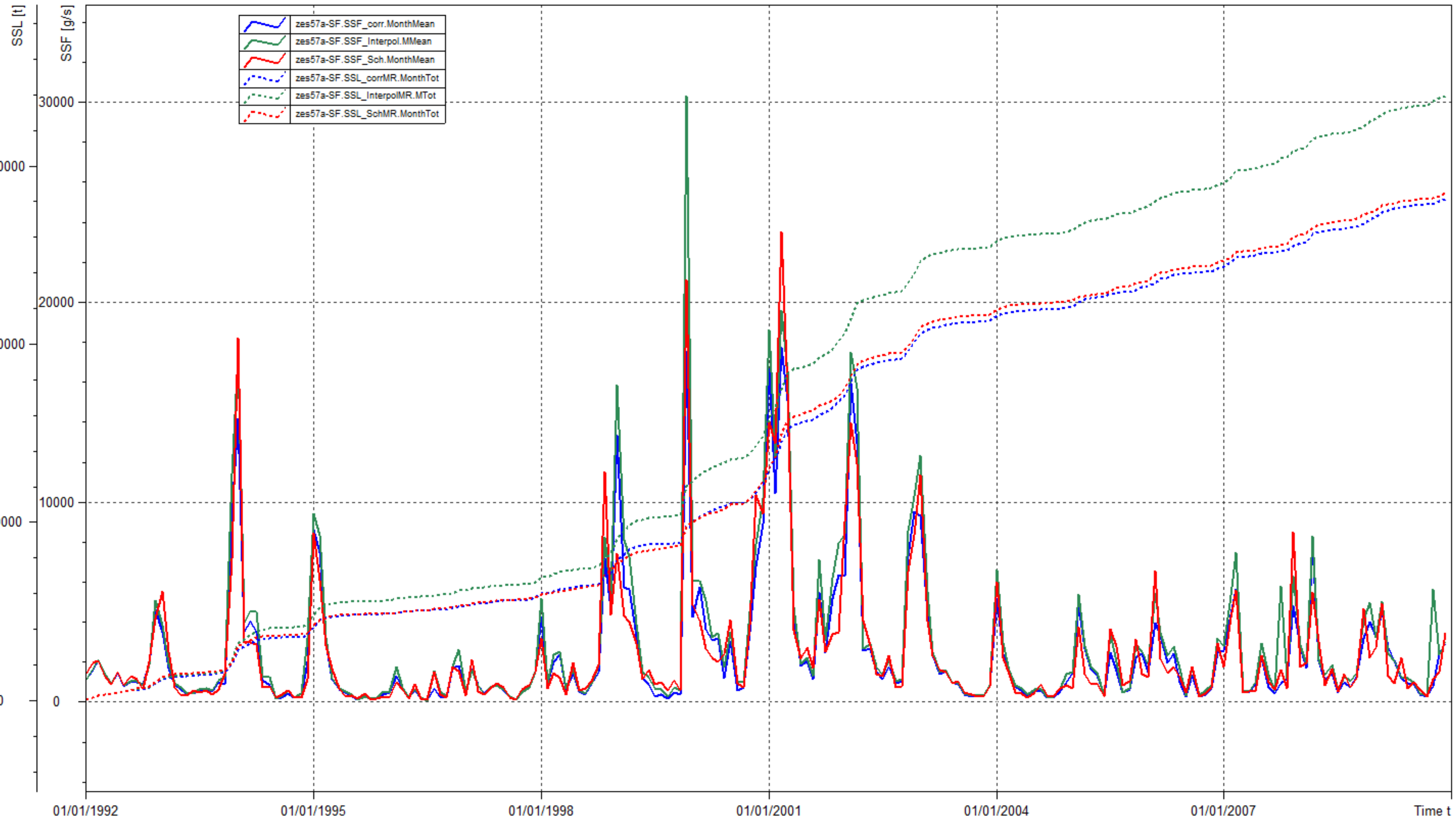


Figure 38: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Melle/Merelbeke). Blue curves are used for the Taverniers1 method , green curves are used for the interpolation method and red curves are used for the Taverniers2 method

9. Total sediment load entering the Sea Scheldt and at Schelle

9.1. Overview of yearly sediment loads

In Annex B the total yearly sediment loads at the six measuring locations calculated by the three methods are given. The total sediment loads per year at all measuring locations together, entering the Sea Scheldt and for the Scheldt at Schelle are presented in Table 8 and Table 9. These values are calculated by means of the three methods as described in De Boeck et at. (2013). The sediment loads for the basins of the Rupel, Nete, Schelde en Durme downstream the measuring stations are calculated by the specific sediment load (ton/km²). In

Table 10 the percentage of the total load that is estimated by this extrapolation is given. The total load at Schelle is illustrated in Figure 39 (on a monthly base) and Figure 40 (on a yearly base).

As explained in § 3.2.2, the interpolation method is believed to be most accurate, because (daily) measurements are used whenever available, and the regression curve is used on a daily basis. With the regression curve SSC-Q, which is built with daily values, daily SSC-values are derived from daily Q-values for the interpolation method. This is believed to be more accurate than the Taverniers1-method, because this method derives monthly values from a curve that is built with daily values. The Taverniers2-method (with monthly average Q and SSC-values) is also believed to be less accurate than the interpolation method, because averaging the daily values to monthly values omits the differences in SSC-values which can be attributed to differences in Q-values. These variation in SSC attributable to variation in Q are typically small (R^2 for most SSC-Q linear regression lines is lower than 0.25), but there is nevertheless some variation that is taken into account in the interpolation method and not in the Taverniers2-method.

Table 8 and Table 9 and Figure 39 and Figure 40 show that the sediment loads resulting from the measurements before 1987 are in general larger than after 1992 for all three methods. In the period 1987-1991 no SSC-measurements are available, and the regression Q-SSC for the whole period 1972-2009 is used for this period for the interpolation method. Differences in both periods can be explained by differences in rainfall and rain erosivity, but also to differences in measuring method before and after 1992. During the whole period measurements are done with a bucket. But there is at least one important difference in measurement method: after 1992 only a subsample of 100 ml is analysed of the whole bucket (§ 2). Chances are that, due to not perfectly mixing, the sediment concentration in the 100 ml bottle was not representative for the sediment concentration in the bucket. Another difference between the two periods is the amount of samples: less frequent sample days until 1986 compared with sample days after 1986, but more frequent samples during the day (which were averaged to daily SSC-concentrations, cfr. § 2).

Figure 39 and Figure 40 show that the interpolation method calculates the highest sediment loads and Taverniers2 the lowest. This ranking is especially clear during the period 1971-1986, while from 1992 until 2009 Taverniers1 and 2 are nearly equal (with Taverniers2 calculating even slightly higher values).

Most of the total sediment load calculation is covered by the measuring locations. Maximally 21.7% of the total load at Schelle had to be estimated by means of extrapolation (

Table 10). Moreover, these fractions are very similar for the three methods.

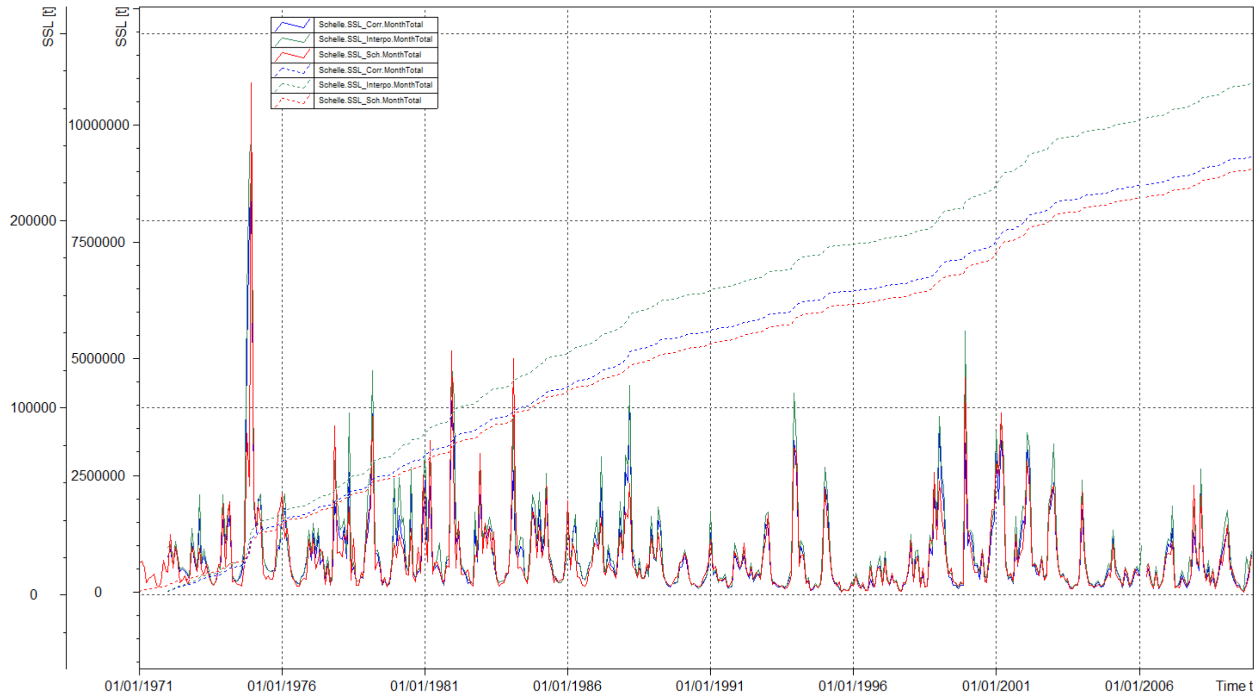


Figure 39: Total monthly sediment load (full line) and cumulative sediment load (dashed line) as function of time (Schelle). Blue curves are used for the Taverniers1 method, green curves are used for the interpolation method and red curves are used for the Taverniers2 method

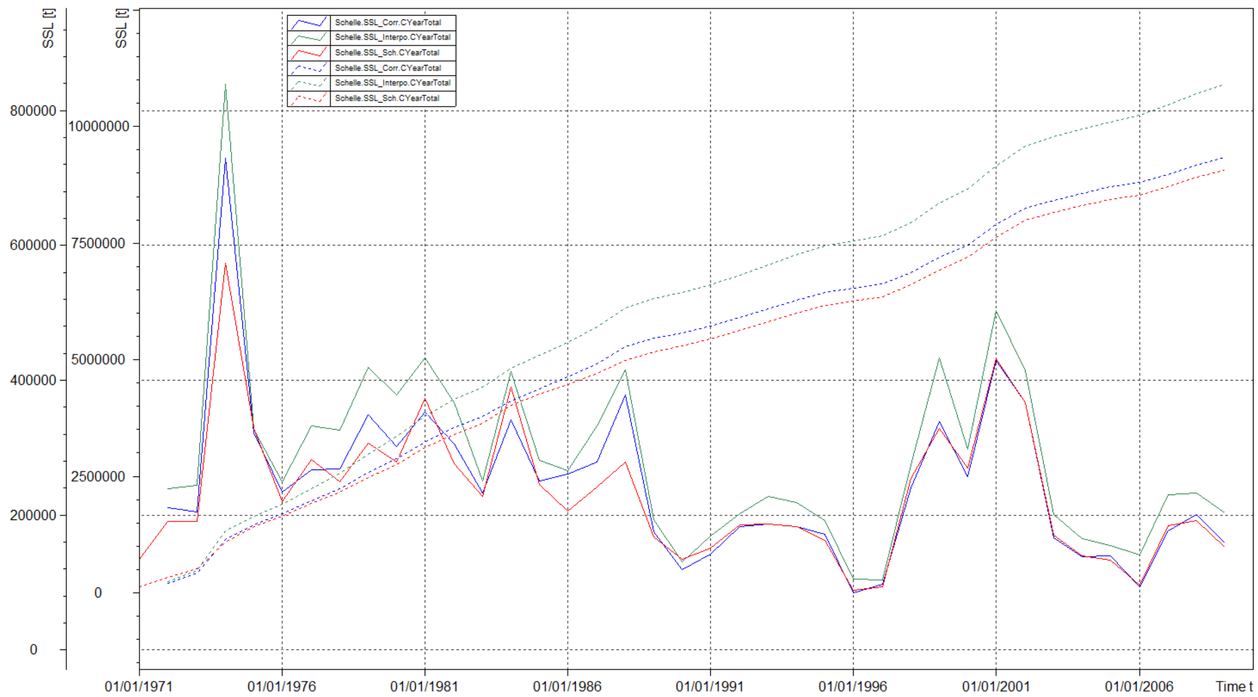


Figure 40: Total yearly sediment load (full lines) and cumulative sediment load (dashed lines) as function of time (Schelle). Blue curves are used for the Taverniers1 method , green curves are used for the interpolation method and red curves are used for the Taverniers2 method. In the period 1987-1991 no SSC-measurements are available, and the regression Q-SSC for the whole period 1972-2009 is used for this period for the interpolation method.

Table 8: Calculated total yearly sediment load (tons) at all measuring locations and the total load entering the Sea Scheldt for the three calculation methods

		Total SSL at measuring locations			**Total SSL entering Sea Scheldt**		
	Year	Interpol	Taverniers1	Taverniers2	Interpol	Taverniers1	Taverniers2
	1972	195,511	169,248	153,960	228,914	201,238	182,167
	1973	199,805	162,212	150,566	233,268	194,010	180,923
	1974	710,744	611,873	478,806	804,322	697,853	548,341
	1975	269,950	263,668	270,987	312,961	307,202	313,521
	1976	195,221	183,691	171,761	234,526	220,188	206,995
	1977	281,768	220,171	235,718	319,667	254,851	270,322
	1978	269,002	216,289	200,337	311,210	254,591	236,917
	1979	360,263	294,706	255,972	403,519	334,767	293,450
	1980	328,427	252,612	230,258	365,543	288,817	266,395
	1981	374,141	299,378	315,016	417,461	339,440	358,265
	1982	304,407	248,898	226,795	350,429	290,598	262,837
	1983	200,485	185,473	181,767	237,292	220,821	216,134
	1984	337,260	273,641	316,222	392,378	323,487	370,414
	1985	227,628	200,724	194,186	267,532	237,718	231,939
	1986	216,779	210,904	169,515	253,944	248,678	196,433
	1987	282,821	233,781	203,139	319,251	266,929	231,792
	1988	361,322	327,293	237,619	401,108	365,158	268,171
	1989	163,731	147,105	139,745	185,857	168,184	160,202
	1990	108,022	97,819	111,215	124,558	113,537	128,723
	1991	143,800	118,858	126,337	162,064	135,745	144,644
	1992	166,389	151,072	153,257	193,321	175,397	177,718
	1993	199,514	160,837	161,130	221,044	179,959	180,815
	1994	192,635	159,600	160,554	212,376	177,631	177,747
	1995	165,372	146,629	138,806	185,643	164,903	156,464
	1996	87,935	69,753	72,943	100,798	80,851	84,420
	1997	83,739	78,824	76,460	98,855	92,558	89,760
	1998	234,318	202,787	214,696	265,331	230,796	244,894
	1999	387,990	296,707	287,122	421,485	327,336	317,258
	2000	265,328	226,540	238,579	290,313	249,716	262,257
	2001	462,045	391,787	393,126	493,336	420,406	422,159
	2002	374,615	329,278	329,050	403,835	356,913	357,155
	2003	176,836	144,739	148,674	194,319	160,946	164,693
	2004	140,863	117,124	118,492	159,046	133,064	134,444
	2005	134,338	120,379	114,387	149,761	134,336	128,502
	2006	138,256	112,371	116,460	154,398	124,411	130,014
	2007	203,805	154,093	162,651	223,448	171,016	179,193
	2008	199,734	172,477	164,113	223,827	193,621	184,845
	2009	180,077	138,911	132,452	197,215	154,033	147,050
min	**1971-1991**	108,022	97,819	111,215	124,558	113,537	128,723
max		710,744	611,873	478,806	804,322	697,853	548,341
average		276,554	235,917	218,496	316,290	273,190	253,429
median		269,476	218,230	201,738	312,086	254,721	234,428
stdev		127,058	106,381	83,263	141,203	119,330	94,155

min	**1992-2009**	83,739	69,753	72,943	98,855	80,851	84,420
max		462,045	391,787	393,126	493,336	420,406	422,159
average		210,766	176,328	176,831	232,686	195,994	196,633
median		186,356	152,582	156,905	204,796	173,206	177,732
stdev		102,580	85,429	85,687	107,976	90,765	91,161
min	**1971-2009**	83,739	69,753	72,943	98,855	80,851	84,420
max		710,744	611,873	478,806	804,322	697,853	548,341
average		245,391	207,691	198,760	276,688	236,624	226,526
median		202,145	184,582	170,638	235,909	220,504	201,714
stdev		119,574	100,785	86,211	132,374	113,030	96,404

Table 9: Calculated total yearly sediment load (tons) at Schelle for the three calculation methods

		Total SSL at Schelle (Scheldt)		
	Year	Interpolation	Taverniers1	Taverniers2
	1972	239,661	211,573	191,099
	1973	243,932	204,189	190,970
	1974	838,846	729,448	573,679
	1975	327,153	321,687	327,889
	1976	249,201	233,724	219,384
	1977	332,729	266,912	282,087
	1978	326,185	268,073	249,759
	1979	418,724	348,816	306,508
	1980	378,502	301,304	278,838
	1981	432,709	353,342	373,751
	1982	366,640	305,348	275,615
	1983	249,950	232,983	228,041
	1984	412,604	341,549	390,259
	1985	280,987	250,310	244,847
	1986	266,499	261,312	205,573
	1987	331,673	278,216	241,519
	1988	414,836	378,218	278,598
	1989	193,713	175,657	167,388
	1990	130,319	118,989	134,812
	1991	168,404	141,576	150,975
	1992	202,140	183,240	185,711
	1993	228,069	186,161	187,114
	1994	218,651	183,347	183,235
	1995	192,394	170,950	162,344
	1996	105,185	84,572	88,305
	1997	103,753	97,015	93,997
	1998	275,383	239,840	254,588
	1999	433,322	338,085	327,919
	2000	298,280	257,081	269,835
	2001	503,842	429,955	431,874
	2002	413,985	366,459	366,777
	2003	200,270	166,479	170,098

	2004	165,222	138,428	139,875
	2005	154,807	138,953	133,129
	2006	159,552	128,629	134,354
	2007	229,699	176,325	184,397
	2008	232,083	200,756	191,968
	2009	202,998	159,101	151,878
min	**1971-1991**	130,319	118,989	134,812
max		838,846	729,448	573,679
average		330,163	286,161	265,579
median		326,669	267,493	247,303
stdev		146,638	124,259	98,323
min	**1992-2009**	103,753	84,572	88,305
max		503,842	429,955	431,874
average		239,980	202,521	203,189
median		210,824	179,782	183,816
stdev		109,914	92,634	93,088
min	**1971-2009**	103,753	84,572	88,305
max		838,846	729,448	573,679
average		287,445	246,542	236,026
median		249,575	233,353	212,478
stdev		137,253	117,644	100,274

Table 10: Percentage of the total sediment load that is not measured at monitoring stations, but estimated by extrapolation based on specific sediment loads

		Total SSL entering Sea Scheldt			**Total SSL at Schelle (Scheldt)**		
	Year	Interpol	Taverniers1	Taverniers2	Interpol	Taverniers1	Taverniers2
	1972	14.6%	15.9%	15.5%	18.4%	20.0%	19.4%
	1973	14.3%	16.4%	16.8%	18.1%	20.6%	21.2%
	1974	11.6%	12.3%	12.7%	15.3%	16.1%	16.5%
	1975	13.7%	14.2%	13.6%	17.5%	18.0%	17.4%
	1976	16.8%	16.6%	17.0%	21.7%	21.4%	21.7%
	1977	11.9%	13.6%	12.8%	15.3%	17.5%	16.4%
	1978	13.6%	15.0%	15.4%	17.5%	19.3%	19.8%
	1979	10.7%	12.0%	12.8%	14.0%	15.5%	16.5%
	1980	10.2%	12.5%	13.6%	13.2%	16.2%	17.4%
	1981	10.4%	11.8%	12.1%	13.5%	15.3%	15.7%
	1982	13.1%	14.3%	13.7%	17.0%	18.5%	17.7%
	1983	15.5%	16.0%	15.9%	19.8%	20.4%	20.3%
	1984	14.0%	15.4%	14.6%	18.3%	19.9%	19.0%
	1985	14.9%	15.6%	16.3%	19.0%	19.8%	20.7%
	1986	14.6%	15.2%	13.7%	18.7%	19.3%	17.5%
	1987	11.4%	12.4%	12.4%	14.7%	16.0%	15.9%
	1988	9.9%	10.4%	11.4%	12.9%	13.5%	14.7%
	1989	11.9%	12.5%	12.8%	15.5%	16.3%	16.5%
	1990	13.3%	13.8%	13.6%	17.1%	17.8%	17.5%
	1991	11.3%	12.4%	12.7%	14.6%	16.0%	16.3%

	1992	13.9%	13.9%	13.8%	17.7%	17.6%	17.5%
	1993	9.7%	10.6%	10.9%	12.5%	13.6%	13.9%
	1994	9.3%	10.2%	9.7%	11.9%	13.0%	12.4%
	1995	10.9%	11.1%	11.3%	14.0%	14.2%	14.5%
	1996	12.8%	13.7%	13.6%	16.4%	17.5%	17.4%
	1997	15.3%	14.8%	14.8%	19.3%	18.8%	18.7%
	1998	11.7%	12.1%	12.3%	14.9%	15.4%	15.7%
	1999	7.9%	9.4%	9.5%	10.5%	12.2%	12.4%
	2000	8.6%	9.3%	9.0%	11.0%	11.9%	11.6%
	2001	6.3%	6.8%	6.9%	8.3%	8.9%	9.0%
	2002	7.2%	7.7%	7.9%	9.5%	10.1%	10.3%
	2003	9.0%	10.1%	9.7%	11.7%	13.1%	12.6%
	2004	11.4%	12.0%	11.9%	14.7%	15.4%	15.3%
	2005	10.3%	10.4%	11.0%	13.2%	13.4%	14.1%
	2006	10.5%	9.7%	10.4%	13.3%	12.6%	13.3%
	2007	8.8%	9.9%	9.2%	11.3%	12.6%	11.8%
	2008	10.8%	10.9%	11.2%	13.9%	14.1%	14.5%
	2009	8.7%	9.8%	9.9%	11.3%	12.7%	12.8%
min	**1971-1991**	9.9%	10.4%	11.4%	12.9%	13.5%	14.7%
max		16.8%	16.6%	17.0%	21.7%	21.4%	21.7%
average		12.9%	13.9%	14.0%	16.6%	17.9%	17.9%
median		13.2%	14.0%	13.6%	17.0%	17.9%	17.5%
stdev		2.0%	1.8%	1.7%	2.4%	2.2%	2.0%
min	**1992-2009**	6.3%	6.8%	6.9%	8.3%	8.9%	9.0%
max		15.3%	14.8%	14.8%	19.3%	18.8%	18.7%
average		10.2%	10.7%	10.7%	13.1%	13.7%	13.8%
median		10.0%	10.3%	10.7%	12.9%	13.2%	13.6%
stdev		2.3%	2.0%	2.0%	2.8%	2.5%	2.5%
min	**1971-2009**	6.3%	6.8%	6.9%	8.3%	8.9%	9.0%
max		16.8%	16.6%	17.0%	21.7%	21.4%	21.7%
average		11.6%	12.4%	12.4%	14.9%	15.9%	15.9%
median		11.4%	12.4%	12.7%	14.7%	16.0%	16.4%
stdev		2.5%	2.5%	2.5%	3.1%	3.1%	3.1%

Methods Taverniers1 and 2 result often in similar total yearly loads, especially after 1992. This can be derived from the figures and tables above and was also observed at Grobbendonk, Eppegem, Haacht, Dendermonde and Melle/Merelbeke. For example, the total sediment load at Schelle differs only 318 tonnes in 2002 between both methods.

The interpolation method results in higher loads compared to the Taverniers1 and 2 method due to the underestimation of the latter as explained in § 3.2.2.

9.2. Overview of monthly sediment loads

Despite this observation, it is important to note that on a short(er) term (e.g. monthly), these methods clearly have different results (as shown for 2002 in Figure 41, or also in Figure 13 and Figure 14). Both methods use monthly averages of discharge data, with the Taverniers2 method data also using monthly averages for SSC. Moreover, the Q-SSC regressions used in the Taverniers1 method are calculated on a yearly base, so the SSC-values each year can be seen as approximately averaged based on the regression. This can (at least partly) explain why the Taverniers1 and Taverniers2 method have similar results when the total sediment loads per year are calculated (as in Figure 40).

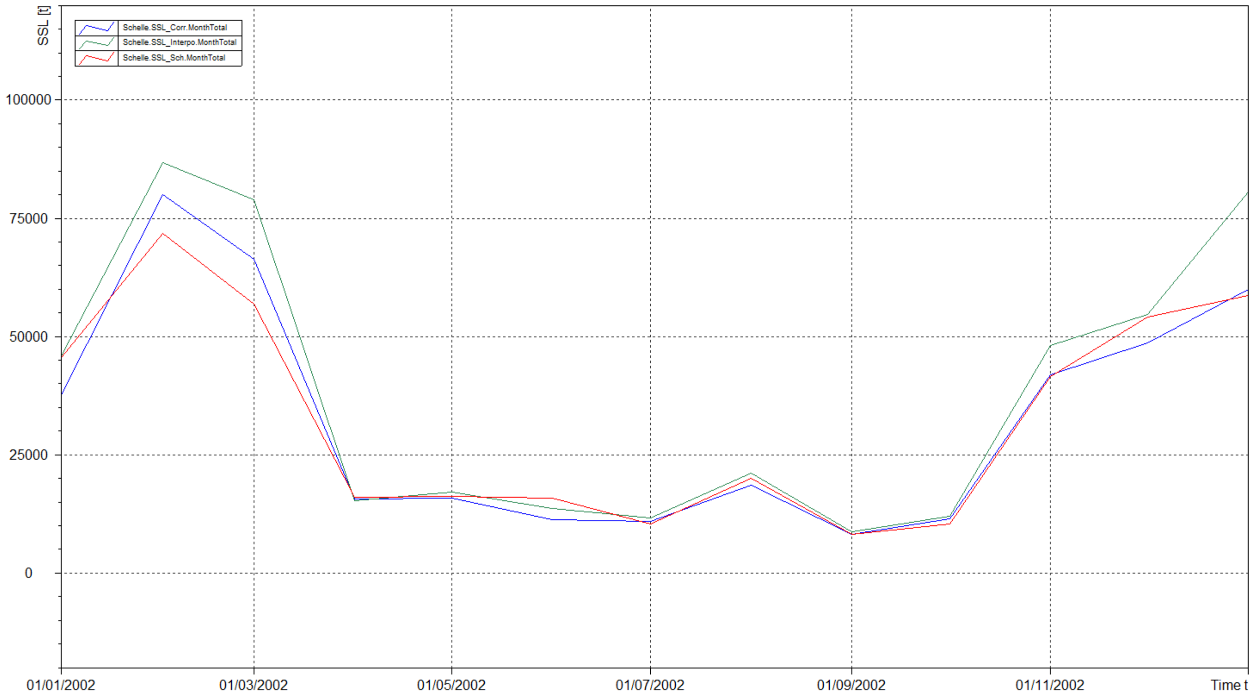


Figure 41: Average monthly sediment load in 2002 at Schelle. Blue curves are used for the Taverniers1 method , green curves are used for the interpolation method and red curves are used for the Taverniers2 method

Figure 42 shows the average total monthly sediment load at Schelle for the entire measuring period. It is clear that the Scheldt water contains the highest loads during winter (peak from December until March) and lowest during summer (July till September). In the latter period, the total sediment load is 3 to 5 times lower than during winter.

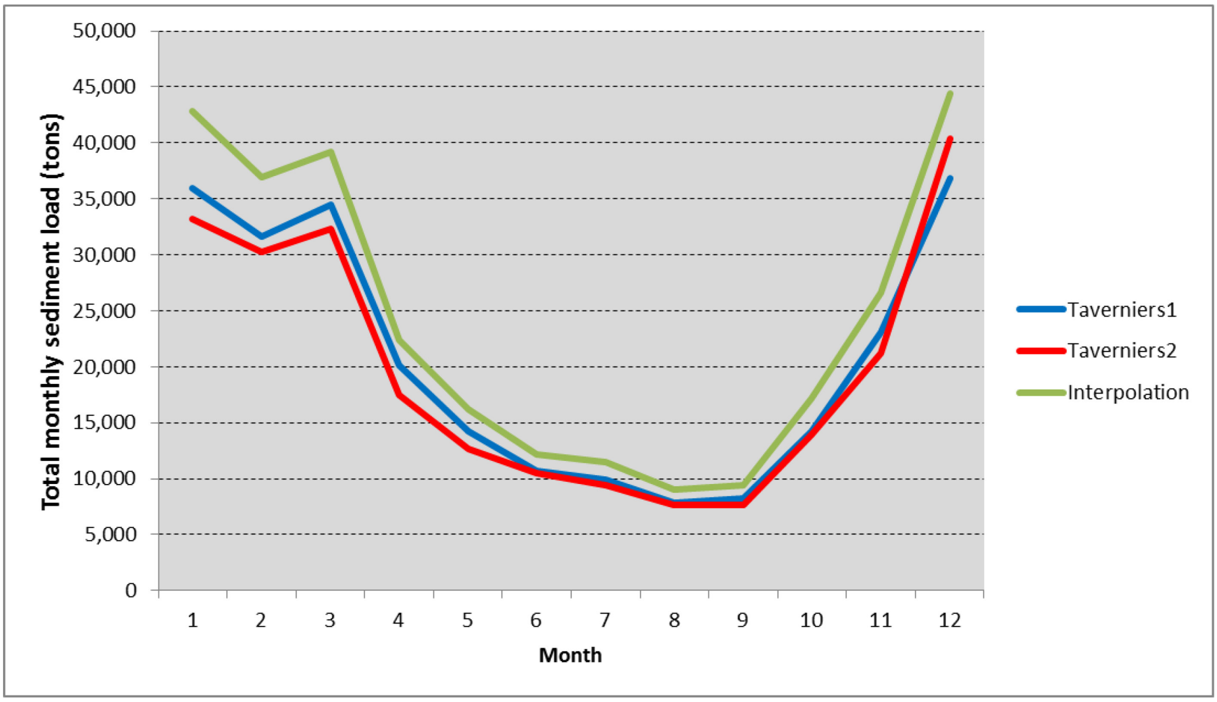


Figure 42: Average (1971-2009) total monthly sediment load at Schelle

9.3. Overview of sediment loads per subcatchment

Table 11 and Figure 43 give the average yearly sediment load for the different subcatchments of the Scheldt catchment for the three calculation methods. For the Rupel, Nete, Lower Scheldt and Durme, these loads were estimated by means of extrapolation. It is clear that the Dijle (Haacht) and the Upper Scheldt (Melle/Merelbeke) account for the major part of the total sediment load (both around 30%), followed by the Zenne and the Dender (both around 10%). Important is that the Dijle catchment includes the Demer catchment. The proportion represented by the subcatchments of both Netes is small: circa 5% each. The proportion represented by the estimated subcatchments (Rupel, Nete, Lower Scheldt and Durme) is rather low (around 10%), as was also derived from Tabel 10.

Table 11: Average yearly sediment load for the different subcatchments of the Scheldt catchment for the three calculation methods (for Rupel, Nete, Lower Scheldt and Durme these loads were estimated by means of extrapolation)

Subcatchment	Taverniers1	Taverniers2	Interpolation	Taverniers1	Taverniers2	Interpolation
Dender	22,576	20,642	31,949	9%	9%	11%
Zenne	30,538	29,692	32,802	12%	13%	11%
Kleine Nete	11,245	10,706	12,288	5%	5%	4%
Dijle (incl. Demer)	74,532	70,647	81,614	30%	30%	28%
Grote Nete	10,327	10,259	10,641	4%	4%	4%
Upper Scheldt	72,476	70,279	91,204	29%	30%	32%
Rupel	5,638	5,400	6,114	2%	2%	2%
Nete	2,506	2,400	2,717	1%	1%	1%
Lower Scheldt	9,918	9,500	10,757	4%	4%	4%
Durme	6,786	6,500	7,360	3%	3%	3%
Total (Schelle)	246,542	236,026	287,445	100%	100%	100%

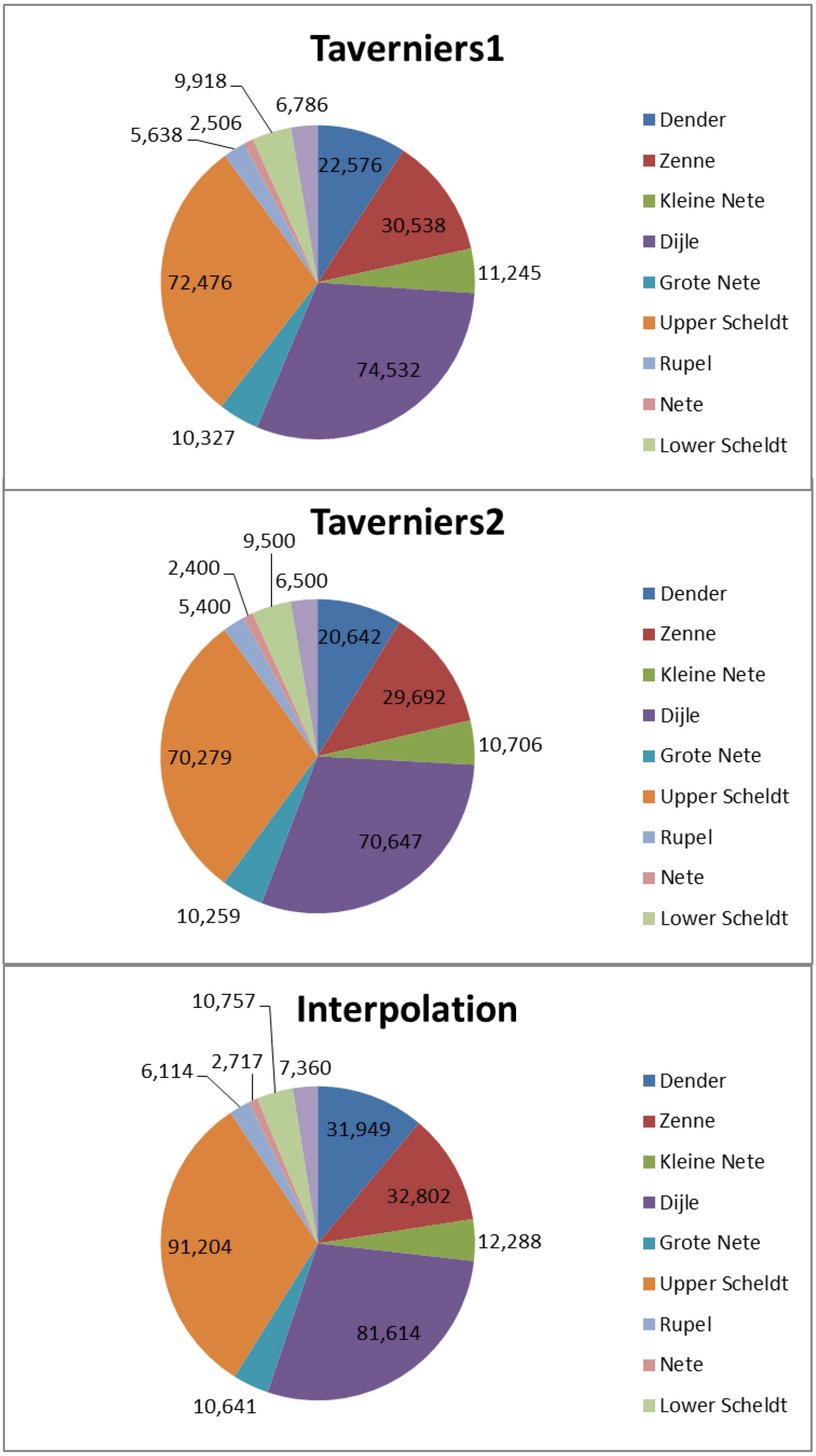


Figure 43: Average yearly sediment load (tons) for the different subcatchments of the Scheldt catchment for the three calculation methods (for Rupel, Nete, Lower Scheldt and Durme these loads were estimated by means of extrapolation). The Dijle catchment includes the Demer catchment

The differences between the loads calculated with the different methods as shown in Figure 43 can be explained by the underestimation issues as shown in § 3.2.2.

An overview of the total loads are given in Figure 45 on a yearly basis and in Figure 46 for the periods before and after 1991. The data for these figures can be found in Annex B (§ 13.2).

Some remarkable observations can be seen in
Table 11, Figure 43, Figure 45 and Figure 46:

- The general trend for all catchments is that the loads are higher before 1992 than after 1992. In the period after 1992, the highest loads can be found from 1998 till 2002 (wet years!). For the Bovenscheldt, these wet years around 2000 are causing a reverse trend: higher loads after 1992 than before 1992.
- The loads of the catchments of Bovenschelde and Dijle (incl. Demer) are very important in the total flux. On average, they both account for 30% of the total flux of all catchments together. Nevertheless, there are important differences between both catchments. From Figure 45 and Figure 46, it can be seen that the loads in the Demer catchment are significantly lower after 1991 compared with before 1992. After 2000, erosion control measures may play a role, but not in the ’90. So other reasons must be found.
- Also for specific years, there are remarkable differences. For the year 1974 for example, Bovenschelde and Demer both show very high loads. But in the Haacht station (Dijle), high discharges are combined with the highest SSC-values found in the whole measuring period (Figure 20). In the Melle station (Bovenschelde), there can also high discharges be found, but the SSC are low in comparison with later years. In the later decades, other similar discharges are found with higher SSC and higher loads as a consequence.
- The correlation of loads (calculated with the interpolation method) of Bovenschelde and Dijle (including Demer) with the total flux is shown in Figure 44. Both linear trends are remarkable similar. For both cases, the loads of the subcatchments are explaining circa 70% of variance in total loads. This doesn’t mean that Bovenschelde en Dijle/Demer- catchments respond the same way: the correlation between both subcatchments is only 0.13.

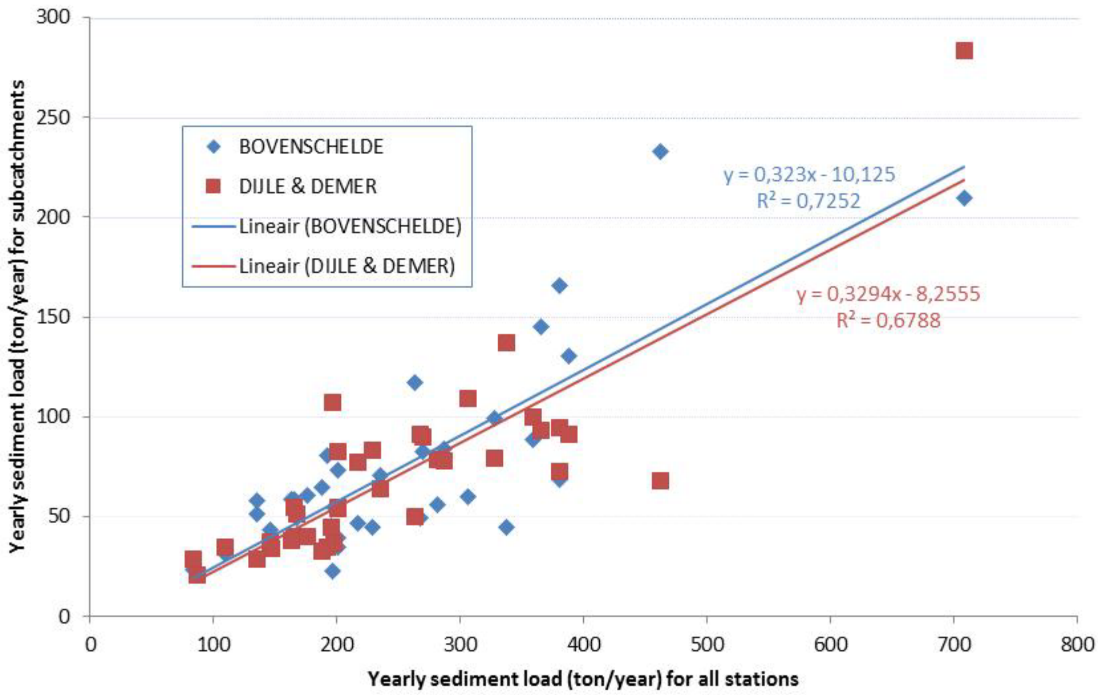


Figure 44: Correlation of loads of Bovenschelde and Dijle (including Demer) with the total flux. All sediment loads are calculated with the interpolation method

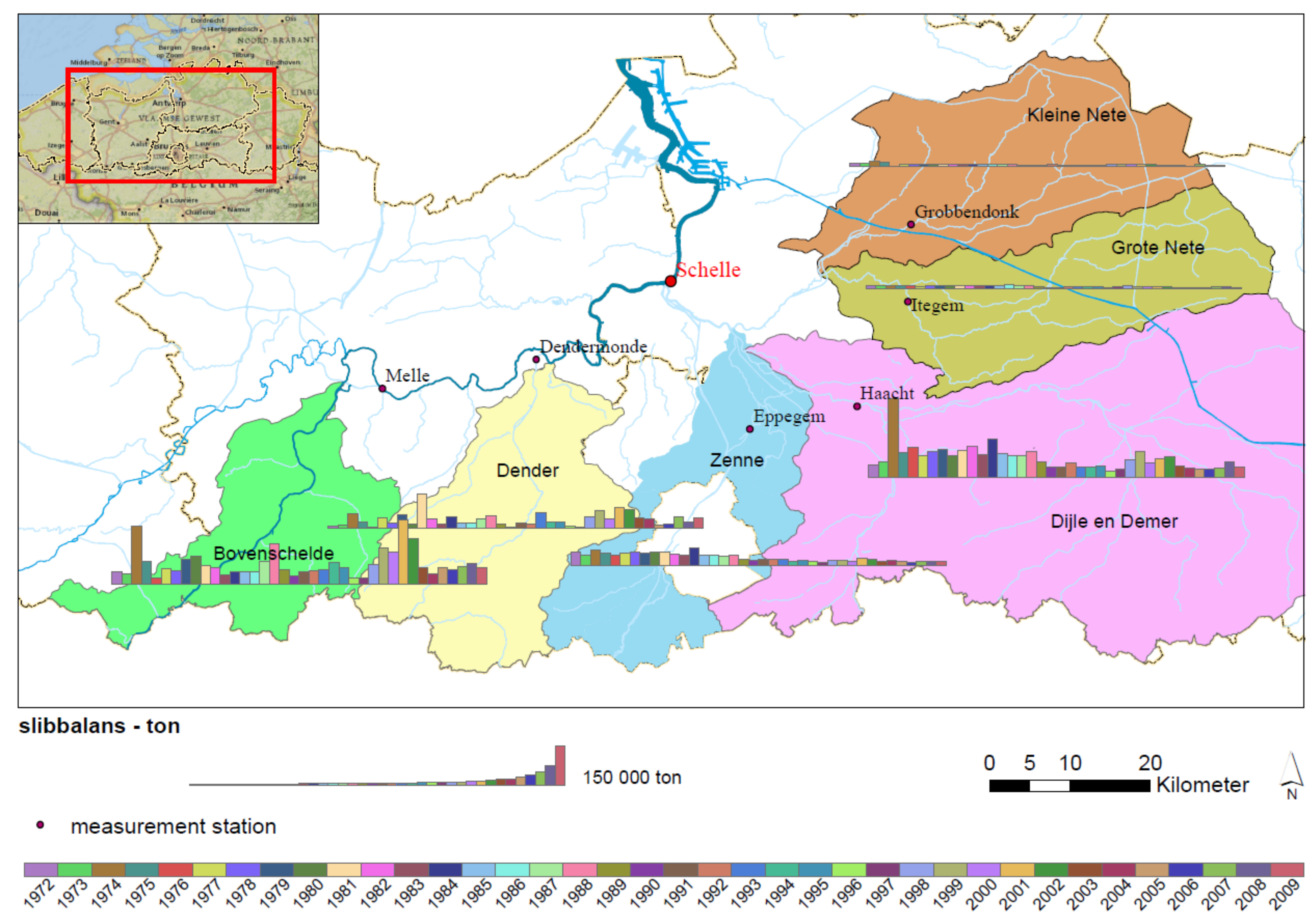


Figure 45: Yearly loads as calculated with the interpolation method (method 3) for the different subcatchments. The measurement stations for the different subcatchments are shown by a red circle. Schelle is also shown in the figure

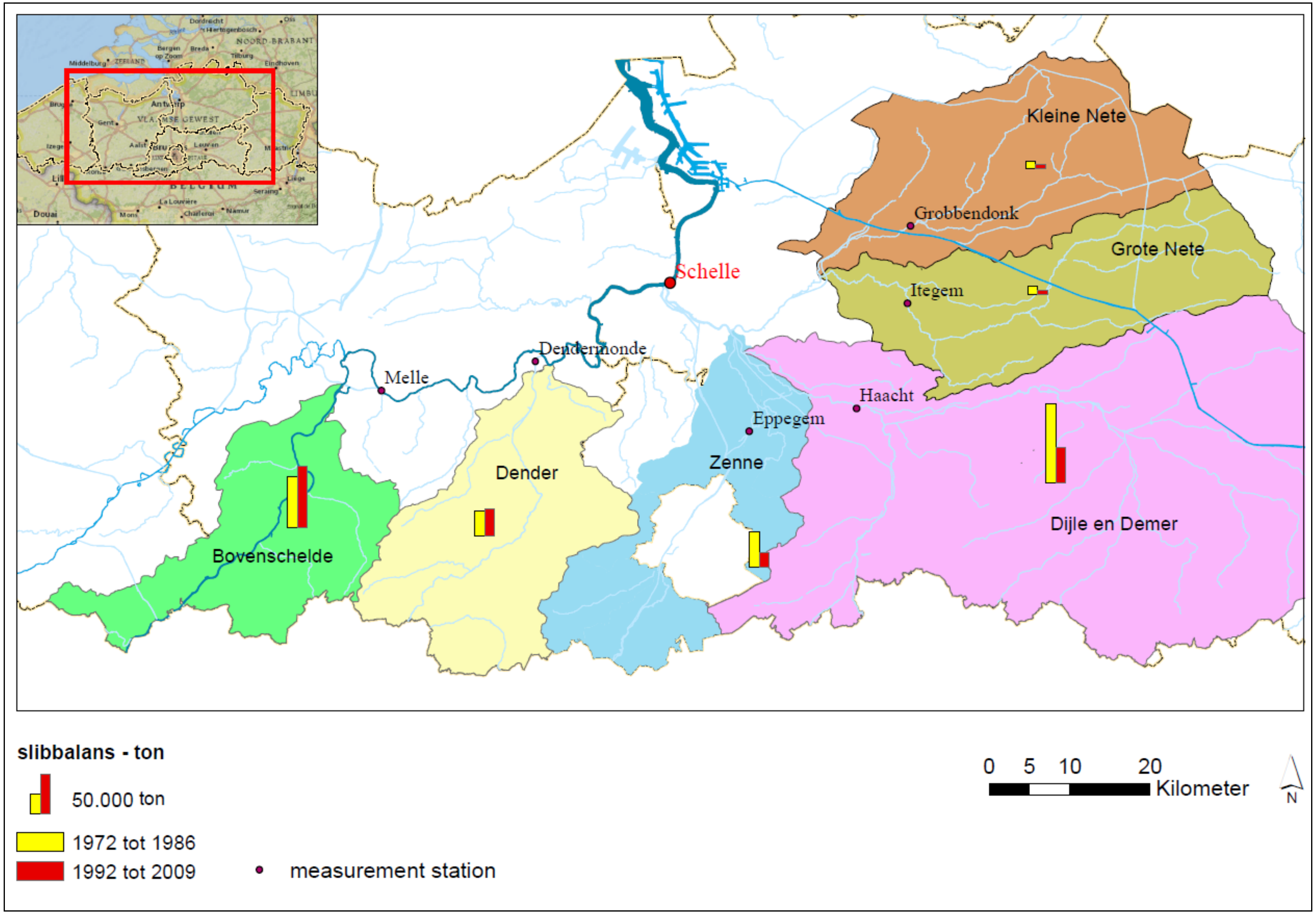


Figure 46: Yearly averaged loads for periods before and after 1992 as calculated with the interpolation method (method 3) for the different subcatchments. The scale is the same for both periods. The measurement stations for the different subcatchments are shown by a red circle. Schelle is also shown in the figure.

10. Uncertainty assessment

10.1. Factors of uncertainty

The uncertainty in sediment load can be attributed to following factors:

a) Uncertainty due to the regression techniques used in both the methods 'Taverniers 1' and 'Interpolation method'. The amount of uncertainty due to the regression techniques is assessed by applying confidence intervals to the regression lines, whose width is determined by the deviation from the regression line. Sediment loads are calculated with this confidence intervals, to assess the uncertainty introduced by the regression line on the calculated load. This is explained more in detail in § 10.2.

b) Uncertainty due to the sampling method. There are differences between point measurements (bucket sample, weighted bottle samples) and section averaged SSC-values. For some stations, corrections factors are estimated in the past based on detailed measurements for these sample locations. This is explained more in detail in § 10.3.

c) Correction factors for the up-scaling of the catchment upstream the monitoring locations to cover the entire subcatchment to the mouth of the tributary in the river Scheldt. This correction factors are explained in detail in De Boeck et al., 2013. They are already implemented in Wiski to calculate the total sediment load at Schelle (§ 9).

d) Some uncertainty can be attributed to different sampling frequencies during BHC-sampling campaigns, hydrometry-maintenance samplings, and automatic sampling. Part of this uncertainty will already be included in the uncertainty introduced by the confidence intervals. Also other factors responsible for high variation in the sediment concentrations (for example tide influences) cause more uncertainty, but these variations are considered as already (partially) taken into account by the confidence intervals.

10.2. Confidence intervals

The line of best fit (y = mx + b) is computed from a random sample of measurements of Q (x) and SSC (y). If we used a different data set we would most likely compute (slightly) different values for the m and b parameter. Thus the predicted values are always estimates and as such have a confidence interval associated with them. A confidence interval ('function' confidence interval) can be calculated in which it is 95% probable that the "true" regression line will be in this interval. The confidence interval where 95% of y-values (SSC) will be found given a certain x-value (Q) is somewhat broader (extra variance term) than the function interval and can be calculated as follows:

$$y_i \pm t(95\%, df) \cdot S_{yx} \cdot \sqrt{\frac{(x_i - \bar{x})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2} + 1 + \frac{1}{n}} \qquad \text{Equation 1}$$

Where y_i is the predicted value using the regression line, t is the critical t statistic, df the degrees of freedom (depending on n), S_{yx} the standard error of the estimate (=the standard error on every estimation of y for a given x), x_i the given value of x, ẋ is the average of the x values and n is the number of observations used in the regression analysis. The summation in the denominator equals the sum of quadratic deviations between the Q measurements and their average (SSX).

With [Equation 1], a non-simultaneous confidence interval is calculated meaning the confidence interval for a single predetermined x-value. This is in contrast with a simultaneous confidence interval, which is a measure for the confidence for all x-values (This should imply a f-statistic instead of a t-statistic).

The confidence intervals (according to Equation 1) are calculated from 1971 till 2009 for the Taverniers1 method at Eppegem. For 1971 and 1974 only 2 simultaneous Q and SSC measurements are available, so no confidence intervals could be determined. Neither could these calculations be performed for the period 1987-1991, since data is lacking. As an illustration, in Figure 47 and Figure 48 the confidence intervals are shown for 1972 and 1992.

When confidence intervals give negative concentrations, SSC-value are set to 0 mg/l. As a consequence, when having negative LCI-equations, the minimum sediment loads will be overestimated compared to the use of the LCI because a SSC of 0 mg/l is used instead of a negative SSC (for example for 1972). This correction is shown in Figure 47 and Figure 48 in red colour.

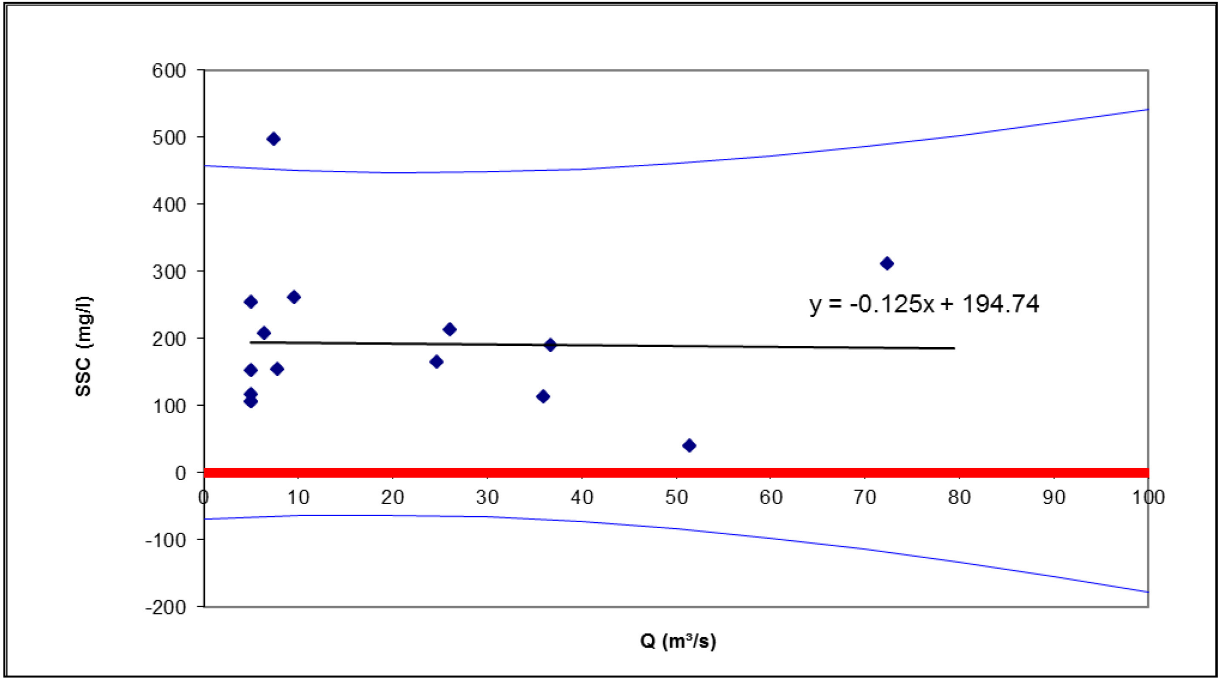


Figure 47: Regression line (black) and confidence intervals (blue), with correction for SSC<0 (red), for Q (m³/s) and SSC (mg/l) measurements in 1972 at station Eppegem

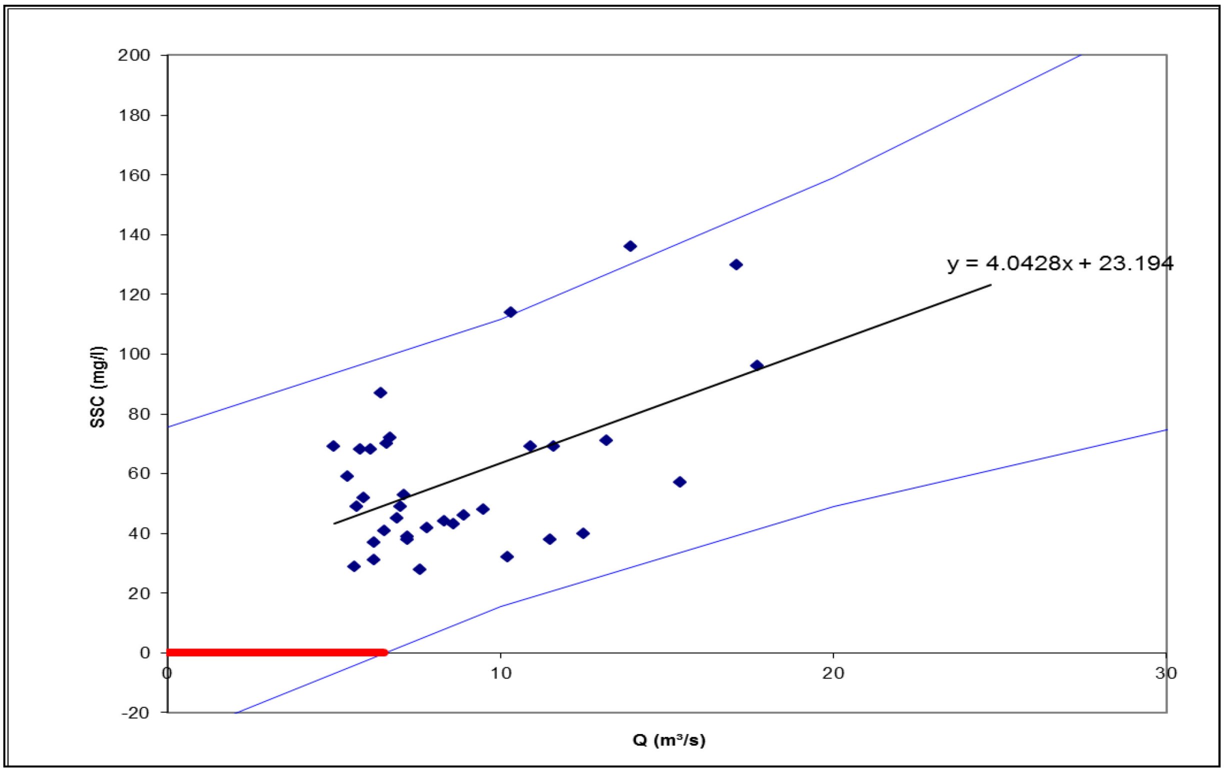
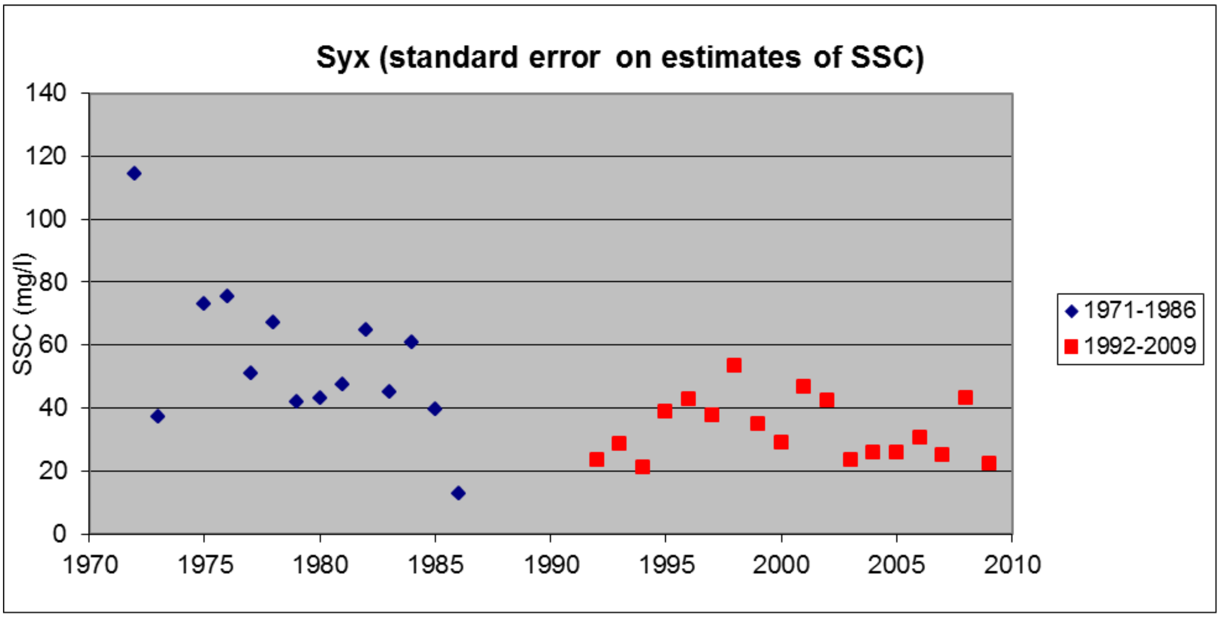


Figure 48: Regression line (black) and confidence intervals (blue), with correction for SSC<0 (red), for Q (m³/s) and SSC (mg/l) measurements in 1992 at station Eppegem

The differences in confidence intervals for 1972 and 1992 shown in Figure 47 and Figure 48 clearly indicate the influence of the standard error of the estimates and the spread of the data on the width of the confidence interval.

Figure 49 shows the yearly calculated "standard error" on SSC-predictions (S_{yx}) and "sum of quadratic deviations" between the Q-data and their average (SSX). In general, the S_{yx} values are lower after 1992 than before 1987. The SSX values generally appear to be larger after 1992 than before 1987. This explains why [Equation 1] calculates smaller confidence intervals after 1992 than before 1987 (see further).

The results of the calculation of the 95% confidence intervals are shown in Figure 50, Figure 51 and Table 12. On average, the confidence intervals are larger for the period 1971-1987 than for 1992-2009. However, in relative terms, the confidence intervals are larger for the period 1992-2009. Moreover, the difference between the sediment load and its LCI is, on average, lower than the difference with its UCI, which is a consequence of excluding negative SSC-values. For the total measuring period, the difference of the total cumulative sediment load with both its LCI and UCI equals respectively 86% and 98% of this sediment load. This results in a total uncertainty of 184%. The yearly uncertainty varies between 95% and 302%.



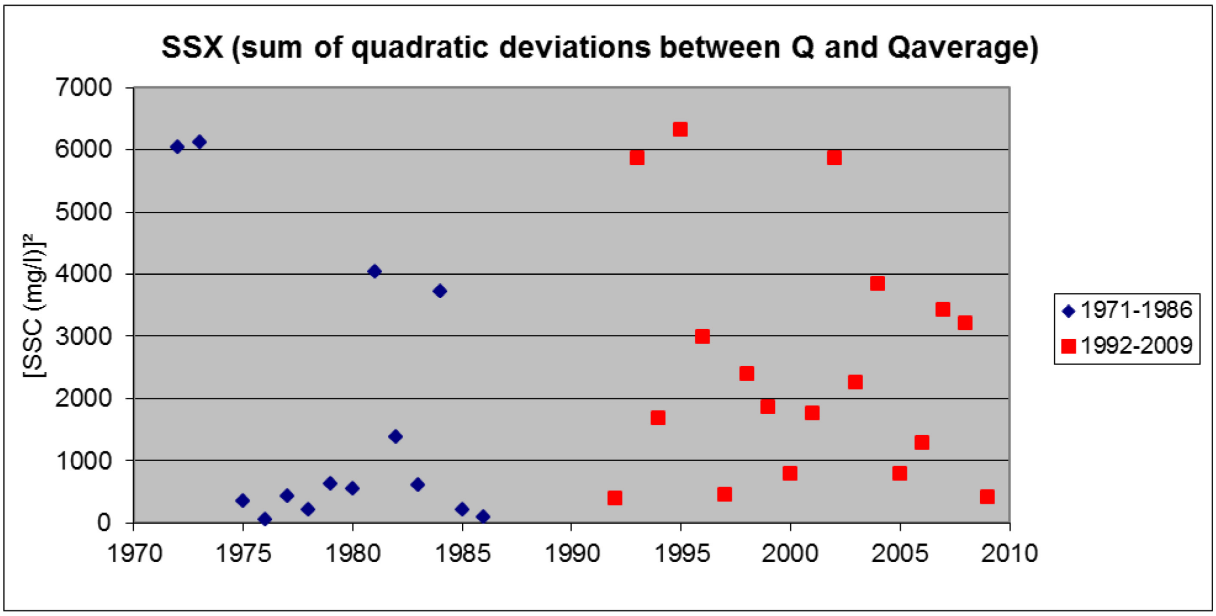


Figure 49: Standard error on SSC-predictions (S_{yx}) and Sum of quadratic deviations between the Q-data and their average (SSX)

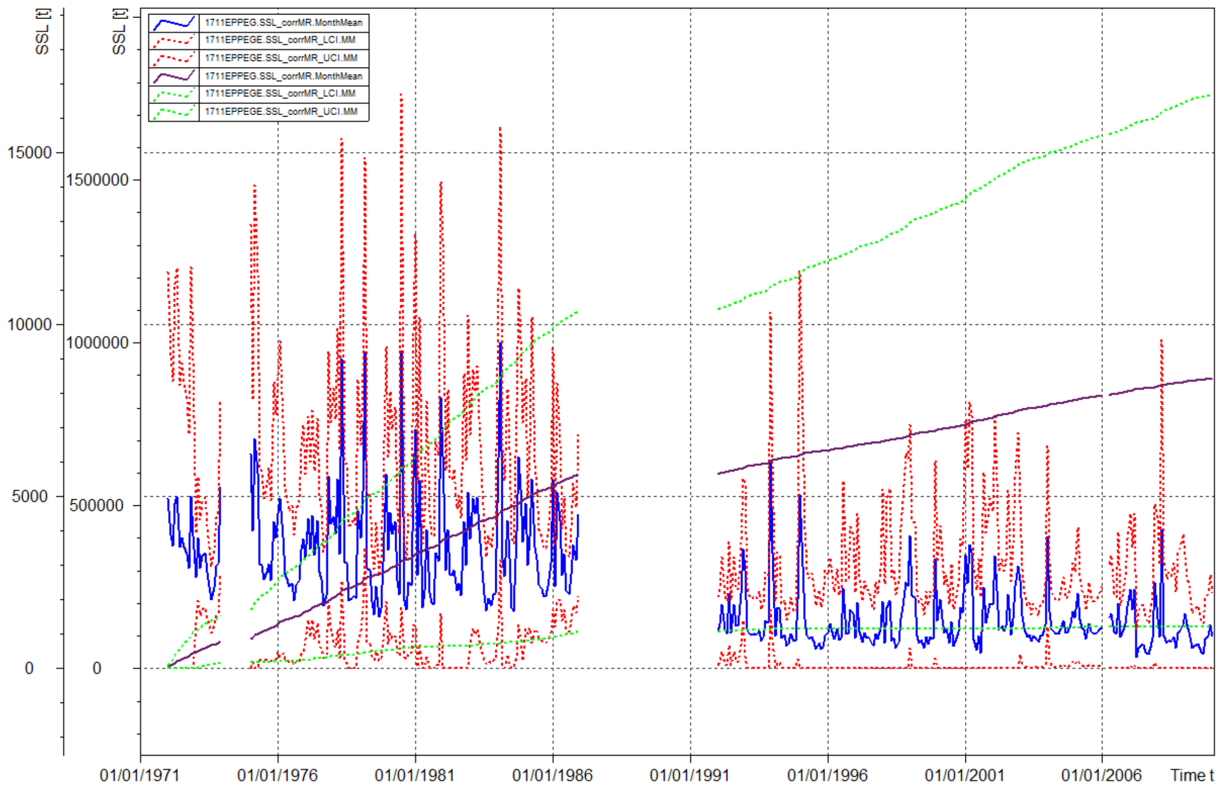


Figure 50: Total monthly sediment loads (Taverniers1 method, blue curve) with the 95% confidence intervals (red curves) for Eppegem (Zenne). The cumulative loads are shown in magenta, the cumulative 95% CI on the loads are shown in green

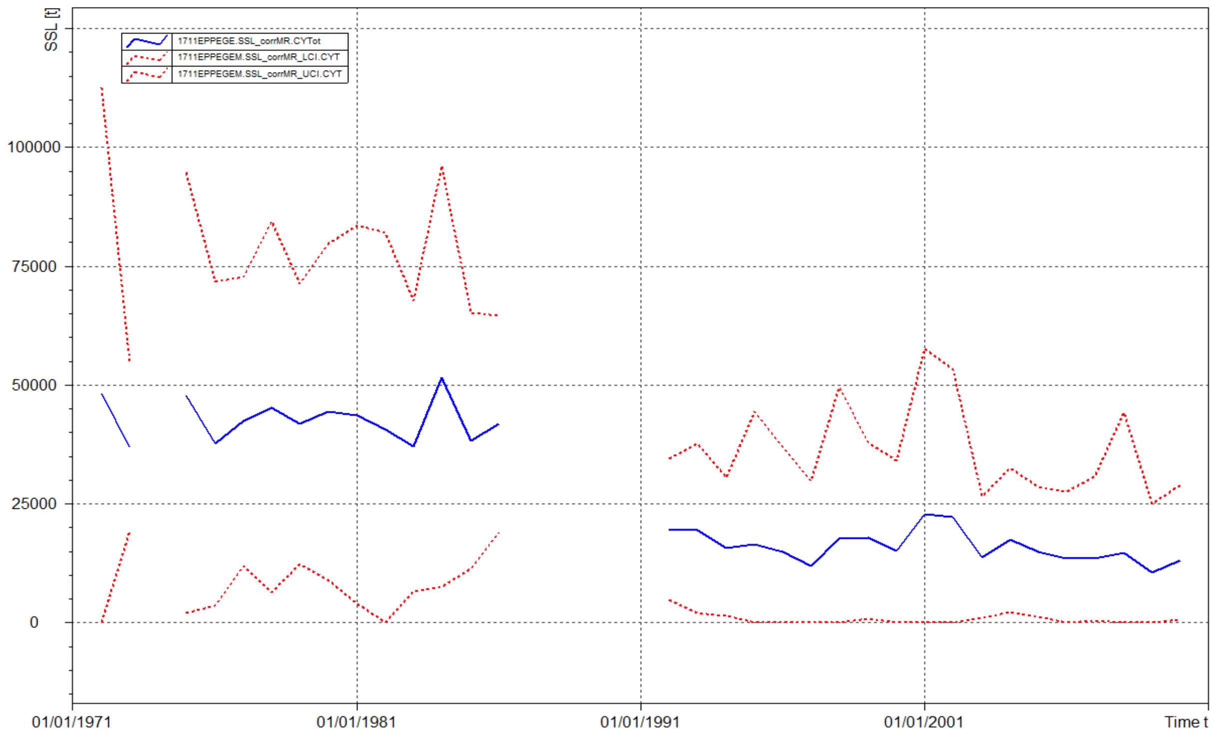


Figure 51: Total yearly sediment load (Taverniers1 method, blue curve) with the respective 95% confidence intervals (red curves) for Eppegem (Zenne). The loads in 1987-1991 could not be calculated since there are no measurements. For 1974, no confidence interval could be calculated with only 2 valid measurements for Eppegem

In Figure 51, the difference between the loads before and after 1992 can be clearly seen for the station 'Eppegem' for the Zenne. This was already visible in Figure 46 for most other subcatchments, but the peak loads of the period 1998-2002 masked the difference somewhat. The most obvious explanation for this difference is the difference in measurement techniques between the two periods. The subsampling of 100 ml out of bucket starting from 1992 might be an important factor, since a part of sediment might be left behind. Other factors related to the difference in real fluxes can hardly be found (the extra purification of the water due to the RWZI 'Brussel-North' cannot be an explanation since only working in 2007).

The loads before 1992 are falling (more or less) in the upper confidence band of the loads after 1992. The loads after 1992 are falling within the lower confidence band of the loads before 1992.

In Table 12, again the results of the calculation of the 95% confidence intervals (UCI and LCI) are given. The 'Diff'-columns represent the difference of the total sediment load with its respective confidence intervals, expressed as a percentage of the total sediment load. The Total_Diff is the sum of both latter columns. The total SSL for 1974 and 1987-1991 are given in Italic but are not used to calculate the total SSL for the entire period.

Table 12: Total yearly sediment load with the respective 95% confidence intervals (LCI and UCI) for Eppegem (Zenne).

Year	SSL [t]	LCI [t]	UCI [t]	Diff_LCI (%)	Diff_UCI (%)	Total_Diff (%)
1971						
1972	48,234	0	112,542	100%	133%	233%
1973	36,896	19,353	54,439	48%	48%	95%
1974	*54,667*					
1975	47,736	2,140	94,620	96%	98%	194%
1976	37,677	3,576	71,779	91%	91%	181%
1977	42,342	11,899	72,784	72%	72%	144%
1978	45,146	6,478	84,407	86%	87%	173%
1979	41,844	12,264	71,423	71%	71%	141%
1980	44,337	8,991	79,683	80%	80%	159%
1981	43,593	4,124	83,563	91%	92%	182%
1982	40,726	0	82,080	100%	102%	202%
1983	37,162	6,540	67,784	82%	82%	165%
1984	51,515	7,652	96,079	85%	87%	172%
1985	38,327	11,364	65,291	70%	70%	141%
1986	41,835	19,148	64,522	54%	54%	108%
1987-1991	*130,224*					
1992	19,671	4,856	34,486	75%	75%	151%
1993	19,544	2,100	37,680	89%	93%	182%
1994	15,761	1,443	30,558	91%	94%	185%
1995	16,529	0	44,329	100%	168%	268%
1996	14,860	0	36,884	100%	148%	248%
1997	11,972	0	29,674	100%	148%	248%
1998	17,721	0	49,524	100%	179%	279%
1999	17,800	901	37,956	95%	113%	208%
2000	15,072	0	34,070	100%	126%	226%
2001	22,775	0	57,653	100%	153%	253%
2002	22,159	0	53,298	100%	141%	241%
2003	13,783	1,019	26,547	93%	93%	185%
2004	17,398	2,302	32,495	87%	87%	174%
2005	14,947	1,218	28,675	92%	92%	184%

2006	13,432	0	27,576	100%	105%	205%
2007	13,594	378	30,670	97%	126%	223%
2008	14,656	0	44,260	100%	202%	302%
2009	10,561	0	24,973	100%	136%	236%
Total	889,608	127,747	1,762,303	86%	98%	184%
		Average per period	1971-1992	80%	83%	164%
			1992-2009	95%	127%	222%
			1971-2009	89%	108%	196%

10.3. Uncertainty due to sampling method

The SSC measurements used from 1972 till 2009 are not section averaged SSC-values, but are samples taken with a bucket on a location in the river. For some stations, corrections factors were estimated in the past based on section averaged SSC-measurements for these sample locations.

For Grobbendonk and Dendermonde correction factors of 1.1 and 1.2 have been determined respectively (reports Eric Taverniers). These correction factors are applied to the SSC-values obtained from the SSC-Q regression. It should be noted that the regression analyses are performed using uncorrected SSC measurements.

For the other stations, correction factors for deviation from sampling SSC-values (with bucket) to section averaged SSC-values are to be investigated.

To assess the uncertainty caused by the difference between point (bucket) SSC measurements and section averaged SSC-measurements, different types of measurements were performed at the station ‘Eppegem’ (Zenne). In Figure 52, the different measurements are shown on one plot. Measurements cover till 90% of the discharge percentiles. For the measurements with the bottle (‘verzwaarde fles’) and with the ISCO sampling device, linear regressions are made between these measurements and section averaged measurements (Equal Width Increment, “EWI”). Measurements from 4/10/2012 are suspicious and excluded from the analysis (‘outlier’). There are only 2 bucket measurements, so no linear regression was made.

From the regression coefficients, it is clear that the bottle measurements (‘verzwaarde fles’) are underestimating the section averaged measurements (EWI). Based on these measurements, one should use a correction factor of 7,2% and an offset of 11,4 mg/l to become section averaged SSC-values (EWI) from the bottle measurements. This correction factor is considered as (too) low to correct for bucket sampling. Bucket samples have often lower SSC-values than ISCO-samples and bottle samples, as is also the case for the measurements 7/3/2013 and 20/3/2013 (Figure 52 and Table 18). Based on experience, a correction factor of 20% is considered as more realistic. This correction factor is not implemented in the calculation, but gives the indication that more samples are necessary to become realistic section averaged SSC-values.

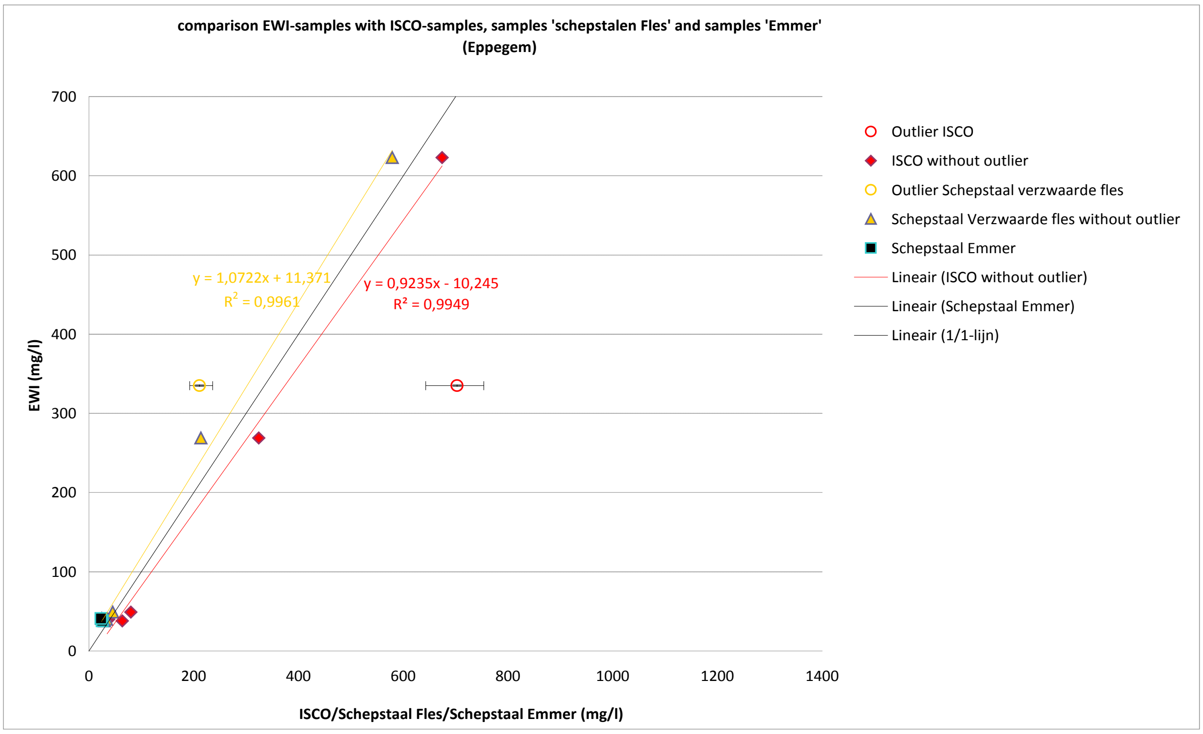


Figure 52: Comparison section averaged SSC-measurements (EWI) with non-section averaged SSC-measurements (ISCO, schepstalen Fles, schepstalen Emmer). The width of the bar connected to one measurements relates to differences in values during the measurements.

Figure 53 depicts the sediment flux and cumulative load for Eppegem, using a correction factor of 1.2. Obviously, the calculated values of all three methods are higher than the ones in Figure 18. Table 18 in Annex B shows the difference of 20% in total sediment load when using the correction of 20% for the SSC-concentrations. Therefore, not applying a (realistic) correction factor (of 20%) for the sampling method indeed results in an underestimation of the calculated total sediment load (with 20%).

When applying the uncertainty due to the confidence intervals together with the 20% correction due to the differences in sampling techniques, the loads (calculated with Taverniers1 method) and the confidence interval as shown in Figure 51 are shifting upwards with 20%. In Table 12 these total yearly sediment loads calculated with the respective 95% confidence intervals (LCI and UCI) for Eppegem (Zenne) and using a sampling correction factor of 1.2 are given.

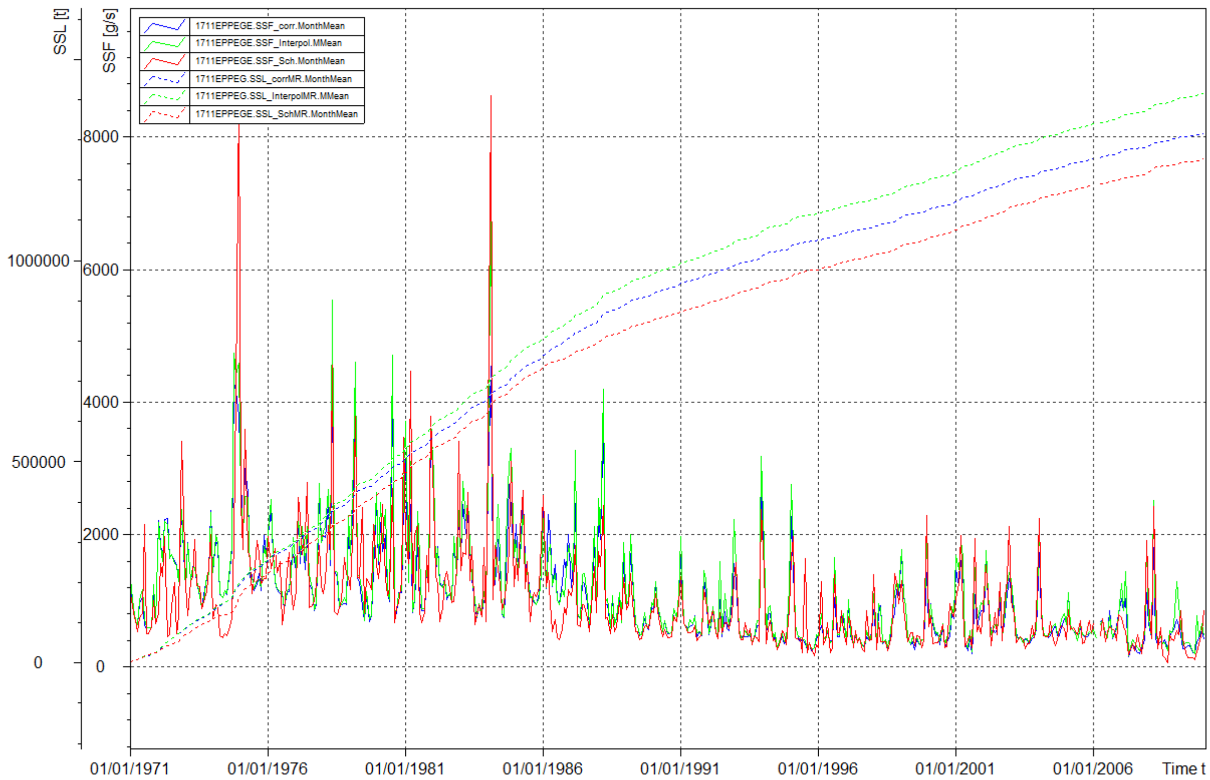


Figure 53: Sediment flux (full lines) and cumulative sediment load (dashed lines) as function of time (Eppegem), using a sampling correction factor of 1.2. Blue curves are used for the Taverniers1 method , green curves are used for the interpolation method and red curves are used for the Taverniers2 method

Table 13: Total yearly sediment load with the respective 95% confidence intervals (LCI and UCI) for Eppegem (Zenne), using a sampling correction factor of 1.2. The 'Diff'-columns represent the difference of the total sediment load with its respective confidence intervals, expressed as a percentage of the total sediment load. The Total_Diff is the sum of both latter columns. The total SSL for 1974 and 1987-1991 are given in Italic but are not used to calculate the total SSL for the entire period.

Year	SSL [t]	LCI [t]	UCI [t]	Diff_LCI (%)	Diff_UCI (%)	Total_Diff (%)
1971						
1972	48,234	0	112,542	100%	133%	233%
1973	36,896	19,353	54,439	48%	48%	95%
1974	*65,601*					
1975	47,736	2,140	94,620	96%	98%	194%
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1979	41,844	12,264	71,423	71%	71%	141%
1980	44,337	8,991	79,683	80%	80%	159%
1981	43,593	4,124	83,563	91%	92%	182%
1982	40,726	0	82,080	100%	102%	202%
1983	37,162	6,540	67,784	82%	82%	165%
1984	51,515	7,652	96,079	85%	87%	172%
1985	38,327	11,364	65,291	70%	70%	141%
1986	41,835	19,148	64,522	54%	54%	108%
1987-1991	*156,269*					

1992	19,671	4,856	34,486	75%	75%	151%
1993	19,544	2,100	37,680	89%	93%	182%
1994	15,761	1,443	30,558	91%	94%	185%
1995	16,529	0	44,329	100%	168%	268%
1996	14,860	0	36,884	100%	148%	248%
1997	11,972	0	29,674	100%	148%	248%
1998	17,721	0	49,524	100%	179%	279%
1999	17,800	901	37,956	95%	113%	208%
2000	15,072	0	34,070	100%	126%	226%
2001	22,775	0	57,653	100%	153%	253%
2002	22,159	0	53,298	100%	141%	241%
2003	13,783	1,019	26,547	93%	93%	185%
2004	17,398	2,302	32,495	87%	87%	174%
2005	14,947	1,218	28,675	92%	92%	184%
2006	13,432	0	27,576	100%	105%	205%
2007	13,594	378	30,670	97%	126%	223%
2008	14,656	0	44,260	100%	202%	302%
2009	10,561	0	24,973	100%	136%	236%
Total	889,608	127,747	1,762,303	86%	98%	184%
		Average per period	1971-1992	80%	83%	164%
			1992-2009	95%	127%	222%
			1971-2009	89%	108%	196%

Table 14: Different types of measurements were performed at the station 'Eppegem' (Zenne). Measurements cover till 90% of the discharge percentiles. Measurements from 4/10/2012 are suspicious and left out the analysis (red). "EWI" stands for Equal Width Increment.

Date	Time	EWI	Schepstaal Bottle ('verzwaarde fles')			Schepstaal Bucket			ISCO			Discharge	
			Start	Intermediate	Stop	Start	Intermediate	Stop	Start	Intermediate	Stop	Average	Percentile limits
		mg/l										m³/s	
23/06/2006	8:45:00	53	52									5,02	
15/09/2006	9:00:00	42	35									4,86	
26/01/2010	10:25:00	71										6,49	
26/01/2010	11:30:00	60										6,21	
26/01/2010	12:45:00	51										6,2	
16/12/2011	0:00:00	269	239	207	195				375	333	264	44,84	90e < x < 100e
6/01/2012	0:00:00	623	600	571	566				676	720	627	29,77	90e < x < 100e
27/01/2012	0:00:00	49	62	40	34				105	67	68	10,65	70e < x < 80e
22/03/2012	0:00:00	40	35	28	37				38	37	38	6,41	20e < x < 30e
4/10/2012	0:00:00	335	331	148	154				1313	264	532	76,73	90e < x < 100e
7/03/2013	0:00:00	38	28	31	29	30	28	19	74	65	52	6,87	30e < x < 40e
28/03/2013	0:00:00	41	23	25	25	23	22	25	37	38	29		

11. Conclusions

Concerning the selection of the regression model (Q-SSC), following conclusions can be made:

- Based on a “Chow” test, a division in subgroups (before and after 1992 and summer/winter) seemed to be appropriate. However, the quality of the regression models did not improve by this division. We could therefore conclude that it is not useful to divide the dataset into subgroups.
- Other types of regression functions (polynomial, power, …) did not significantly improve the data fit, nor for the subgroups, nor for the total dataset, nor on a yearly base.
- Generally, the quality of the regression models (data fit, R^2, …) is rather poor.
- The regression model used in this study is a simple linear regression on a yearly base.

Concerning the different regression models (Q-SSC) created, following conclusions can be made :

- There is a clear difference between the regressions before and after 1992 (probably due to a difference in measuring/sampling method). Both the directive derivative and the offset vary more before 1992 and are larger in magnitude than afterwards.
- Negative directive derivatives and offsets mostly occur for regressions carried out on measurements before 1992.

Concerning the three calculation methods, following conclusions can be made:

- The (course of the) sediment fluxes (and consequently the sediment loads) calculated by the three methods is in general quite similar.
- The interpolation method generally calculates the highest sediment fluxes and cumulative loads. This method is believed to be most accurate, because (daily) measurements are used whenever available, and the regression curve is used on a daily basis. The calculated sediment flux calculated with the Taverniers1-method will be biased towards lower – underestimated – sediment fluxes compared to the interpolation method. because this method derives monthly values from a curve that is built with daily values. The Taverniers2-method (with monthly average Q and SSC-values) is also believed to be less accurate than the interpolation method, because averaging the SSC-values will not take into account high fluxes.
- At five locations (Grobbendonk, Eppegem, Haacht, Dendermonde and Melle/Merelbeke) Taverniers1 and 2 calculate very similar values for the cumulative sediment load after 1992. On a yearly basis, one could question the relevance of regression techniques. On a monthly basis, there are largere differences between the results with the regression technique used by Taverniers1 and the results obtained with the monthly averages (Taverniers2).
- At Itegem, the cumulative loads are very similar for the three methods.

Concerning the evolution of the sediment load, following conclusions can be made:

- There is a clear winter/summer cycle for all stations: high winter loads and low summer loads. The total sediment load during winter months is up to 5 times higher than during summer months.
- For most catchments, the loads are higher before 1992 than after 1992. In the period after 1992, the highest loads can be found from 1998 till 2002. But in general, one can conclude that there is a clear difference between the loads before and after 1992. There might be different reasons for the difference, but one of them is probably the change in measurement techniques between the two periods. The subsampling of 100 ml out of bucket starting from 1992 might be an explanation of the lower fluxes, since a part of sediment might be left behind.

- The loads of the catchments of Bovenschelde and Dijle (incl. Demer) both account for 30% of the total flux of all catchments together. Both the loads of Bovenschelde and Dijle (including Demer) are good correlated with the total flux (both R^2 of +- 70%). Nevertheless, there are important differences between both catchments.
- All calculation methods show that the sediment load at Schelle was higher prior to 1992 than afterwards, probably due to differences in the measuring method. From 1992 onwards, there was a period (1999-2002), characterised by higher sediment loads, but from 2003 onwards, the loads decreased again.
- At Grobbendonk, Eppegem, Haacht and Itegem the cumulative sediment load appears to have a steeper slope before 1987 than afterwards for all three methods, probably due to differences in the measuring method before and after 1992 (no measurements of SSC between 1986 and 1992).
- At most stations, a significant increase in the sediment load occurred between 1998 and 2004.
- The interpolation method calculates the highest total sediment loads (for all measuring locations together, for the Sea Scheldt and at Schelle) and Taverniers2 the lowest. This ranking is especially clear during the period 1971-1991, while from 1992 until 2009 Taverniers1 and 2 are nearly equal (but only for a long term, e.g. when observing yearly total loads).
- Most of the total sediment load calculation is covered by the measuring locations. Maximally 21.7% of the total load at Schelle had to be estimated by extrapolation.

Concerning the uncertainty on the results, following conclusions can be made:

- Correction factors for the up-scaling of the catchment upstream the monitoring locations to cover the entire subcatchment to the mouth of the tributary in the river Scheldt are based on catchment surface. They are used to calculate the total sediment load at Schelle.
- For the total measuring period, the uncertainty caused by the scatter of the Q-SSC data (and the related use of linear regression) equals 184% of total sediment load. On a yearly basis, uncertainty can vary between 95% and 302%. This regards the uncertainty related to the Taverniers1-method, but gives an indication of the overall uncertainty on the measurement data.
- The loads before 1992 are falling (more or less) in the upper confidence band of the loads after 1992. The loads after 1992 are falling within the lower confidence band of the loads before 1992
- On average, the uncertainty (based on 95% confidence intervals) is larger for the period 1971-1987 than for 1992-2009, in absolute terms but vice versa in relative terms. The difference between the sediment load and its LCI is, on average, larger than the difference with its UCI, due to the exclusion of negative SSC values.
- The uncertainty related to the sampling method, is assessed by the measurements in Eppegem (Zenne). As a first indication, one should use a correction factor of 7,2% to become section averaged SSC-values (EWI) from the bottle measurements. But based on experience, this correction factor is considered as (too) low. As a consequence, this correction factor is not implemented in the calculation, but gives the indication that more samples are necessary to become realistic section averaged SSC-values.
- Correction factors for the up-scaling of the catchment upstream the monitoring locations to cover the entire subcatchment to the mouth of the tributary in the river Scheldt. This correction factors are explained in detail in De Boeck et al., 2013. They are already implemented in Wiski to calculate the total sediment load at Schelle (§ 9).
- Some uncertainty can be attributed to other factors, such as different sampling frequencies during BHC-sampling campaigns, hydrometry-maintenance samplings, and automatic sampling. Part of this uncertainty will already be included in the uncertainty introduced by the confidence intervals. Also other factors responsible for high variation in the sediment concentrations (for example tide influences) cause more uncertainty, but these variations are considered as already (partially) taken into account by the confidence intervals.

12. References

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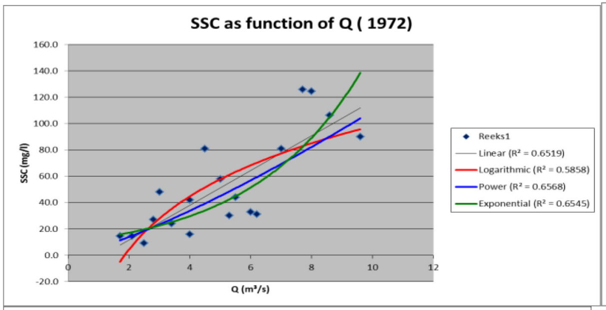
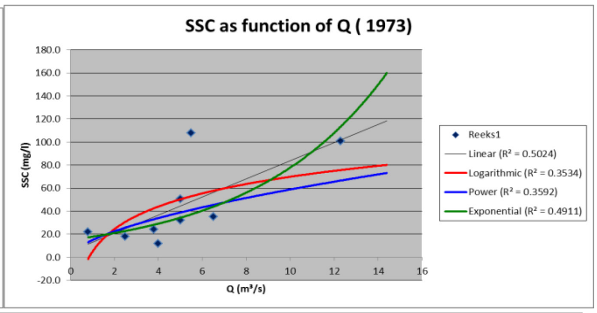
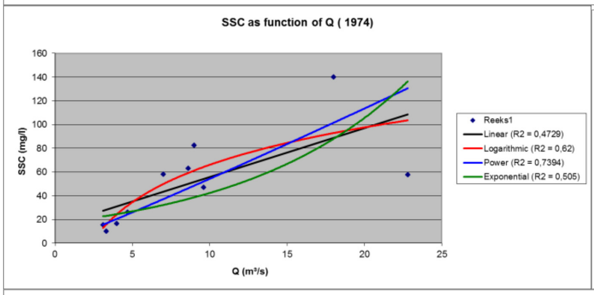
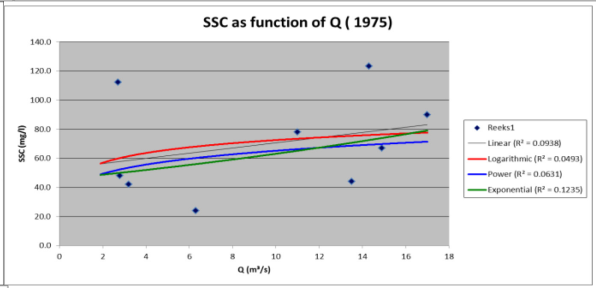
13. Annexes

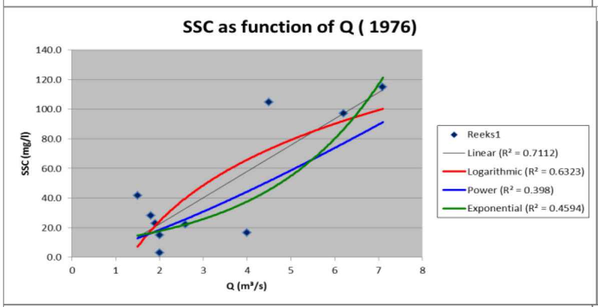
13.1. Annex A: Different regression models for Grobbendonk

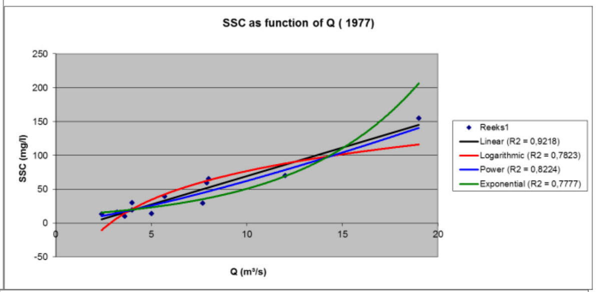


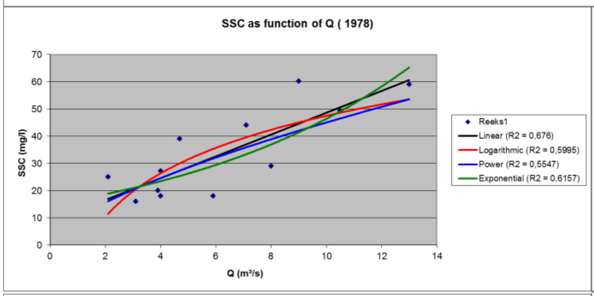


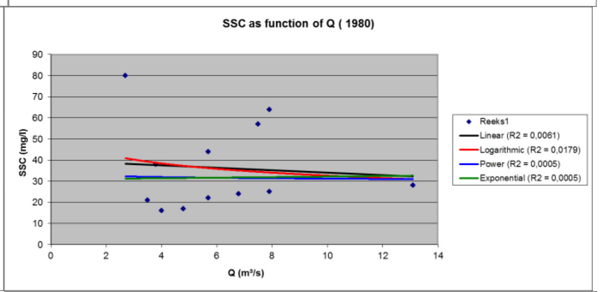


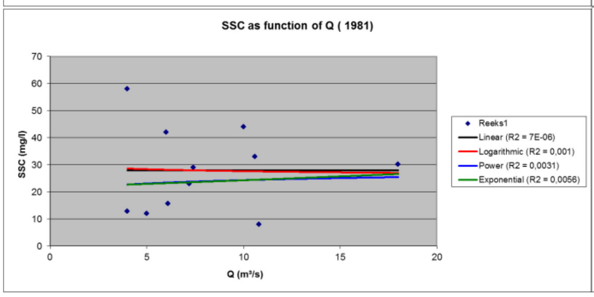


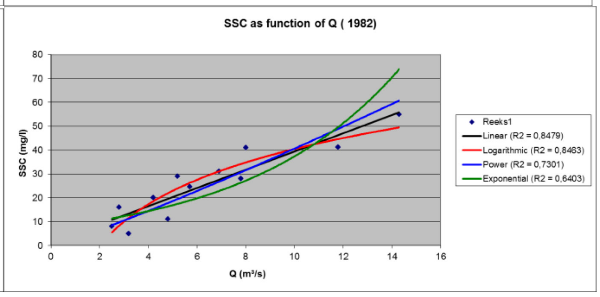


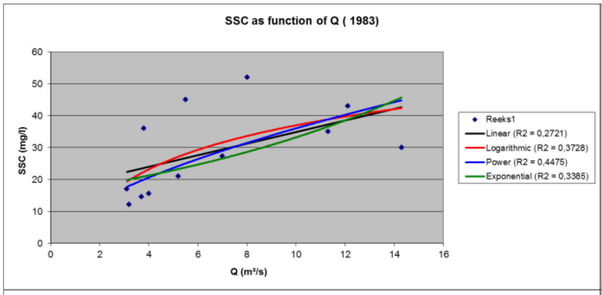


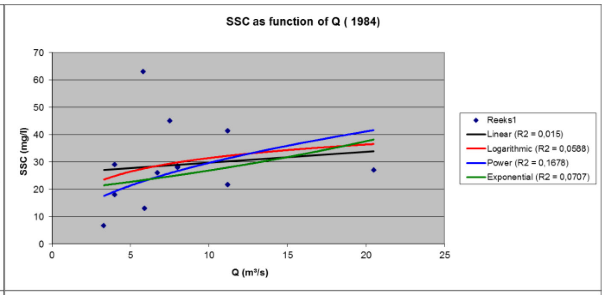


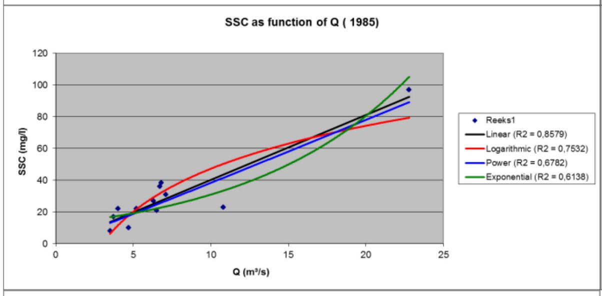


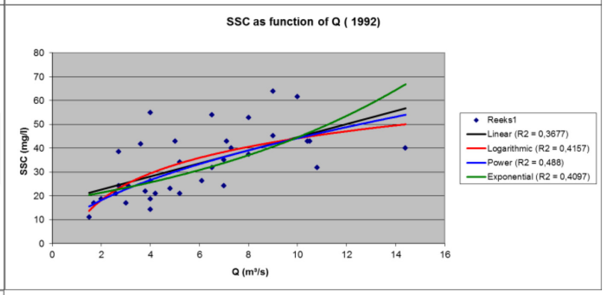


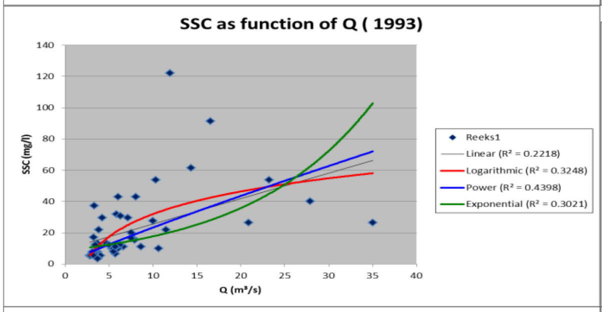



SSC as function of Q (1983)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,2721)
Logarithmic (R2 = 0,3728)
Power (R2 = 0,4475)
Exponential (R2 = 0,3385)


SSC as function of Q (1984)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,015)
Logarithmic (R2 = 0,0588)
Power (R2 = 0,1678)
Exponential (R2 = 0,0707)


SSC as function of Q (1985)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,8579)
Logarithmic (R2 = 0,7532)
Power (R2 = 0,6782)
Exponential (R2 = 0,6138)


SSC as function of Q (1992)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,3677)
Logarithmic (R2 = 0,4157)
Power (R2 = 0,488)
Exponential (R2 = 0,4097)


SSC as function of Q (1993)
SSC (mg/l)
Q (m³/s)
Reeks1
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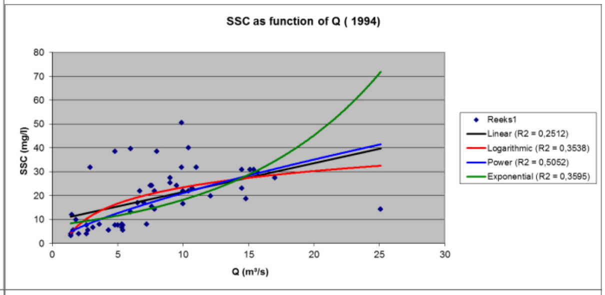
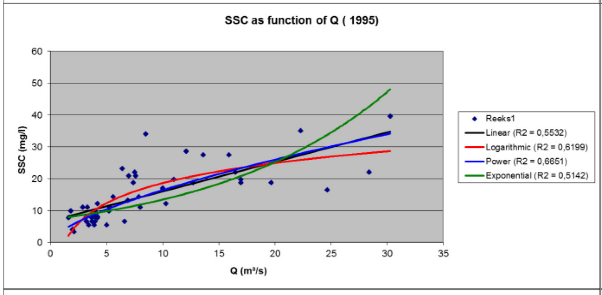
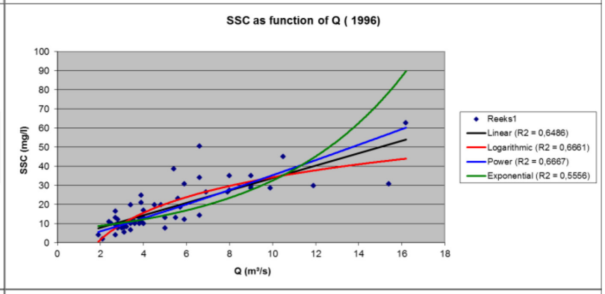
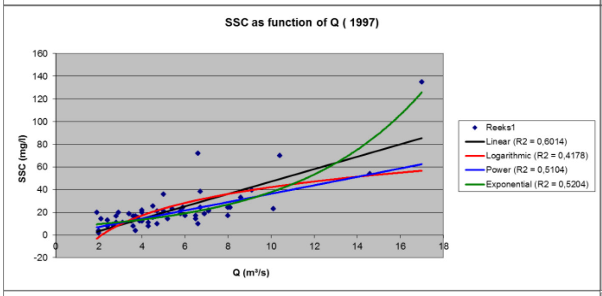
Power (R² = 0.4398)
Exponential (R² = 0.3021)


SSC as function of Q (1994)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,2512)
Logarithmic (R2 = 0,3538)
Power (R2 = 0,5052)
Exponential (R2 = 0,3595)


SSC as function of Q (1995)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,5532)
Logarithmic (R2 = 0,6199)
Power (R2 = 0,6651)
Exponential (R2 = 0,5142)


SSC as function of Q (1996)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,6486)
Logarithmic (R2 = 0,6661)
Power (R2 = 0,6667)
Exponential (R2 = 0,5556)


SSC as function of Q (1997)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,6014)
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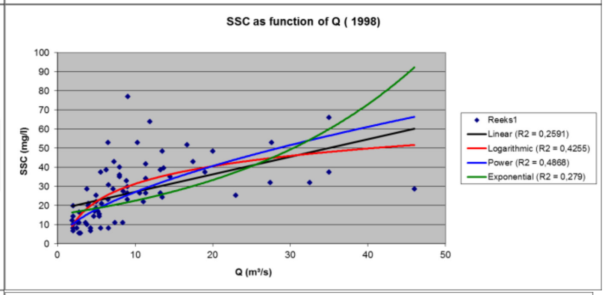
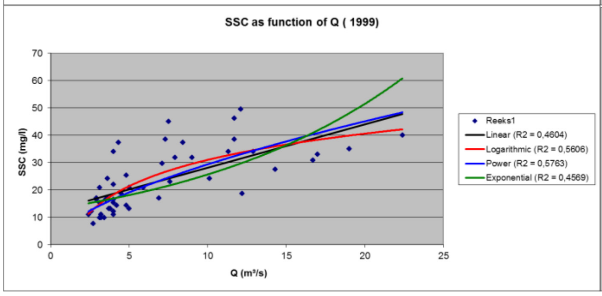
Power (R2 = 0,5104)
Exponential (R2 = 0,5204)


SSC as function of Q (1998)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,2591)
Logarithmic (R2 = 0,4255)
Power (R2 = 0,4868)
Exponential (R2 = 0,279)


SSC as function of Q (1999)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,4604)
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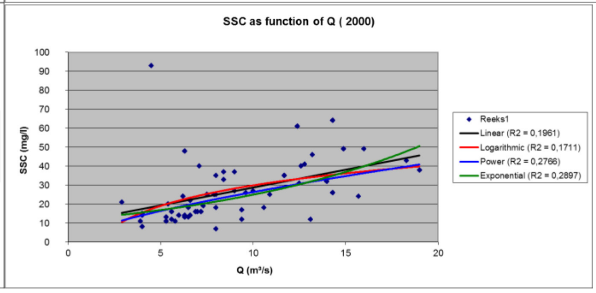
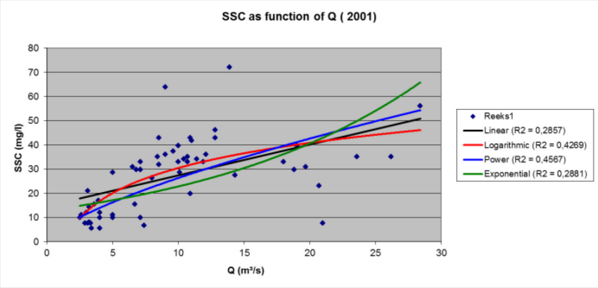
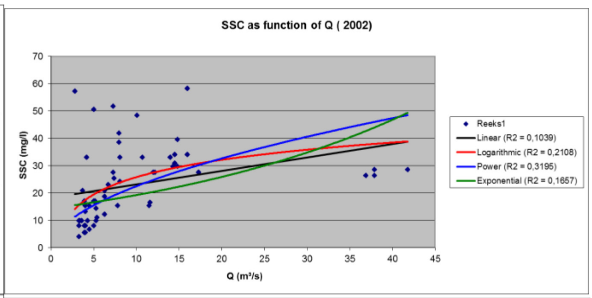
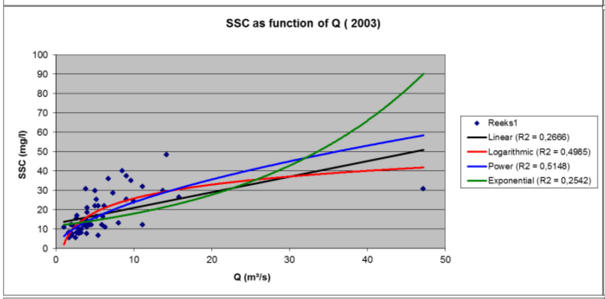
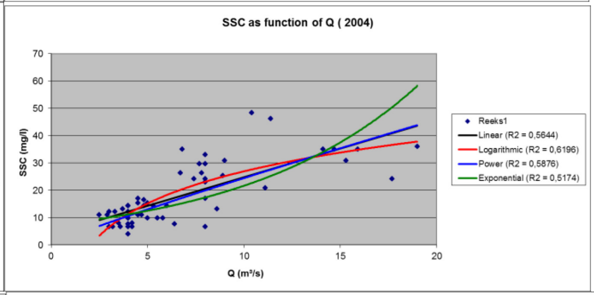
Power (R2 = 0,5763)
Exponential (R2 = 0,4569)

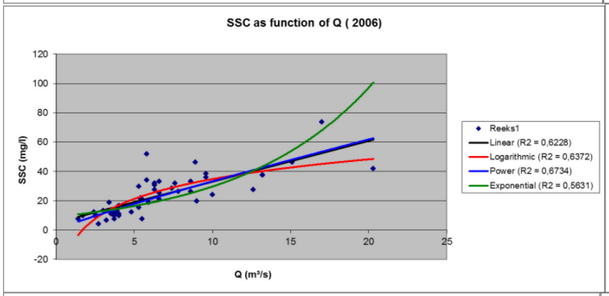

SSC as function of Q (2000)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,1961)
Logarithmic (R2 = 0,1711)
Power (R2 = 0,2766)
Exponential (R2 = 0,2897)

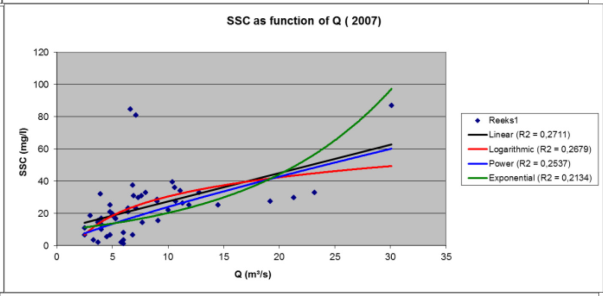

SSC as function of Q (2001)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,2857)
Logarithmic (R2 = 0,4269)
Power (R2 = 0,4567)
Exponential (R2 = 0,2881)

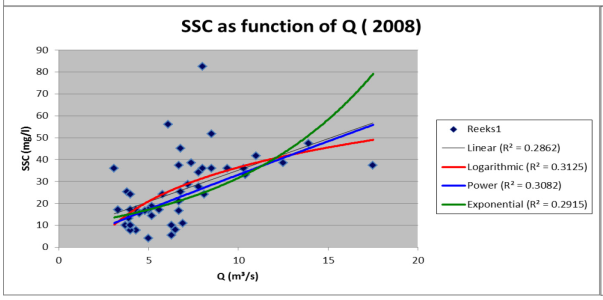

SSC as function of Q (2002)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,1039)
Logarithmic (R2 = 0,2108)
Power (R2 = 0,3195)
Exponential (R2 = 0,1657)


SSC as function of Q (2003)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,2666)
Logarithmic (R2 = 0,4985)
Power (R2 = 0,5148)
Exponential (R2 = 0,2542)


SSC as function of Q (2004)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,5644)
Logarithmic (R2 = 0,6196)
Power (R2 = 0,5876)
Exponential (R2 = 0,5174)


SSC as function of Q (2006)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,6228)
Logarithmic (R2 = 0,6372)
Power (R2 = 0,6734)
Exponential (R2 = 0,5631)


SSC as function of Q (2007)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,2711)
Logarithmic (R2 = 0,2679)
Power (R2 = 0,2537)
Exponential (R2 = 0,2134)


SSC as function of Q (2008)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R² = 0.2862)
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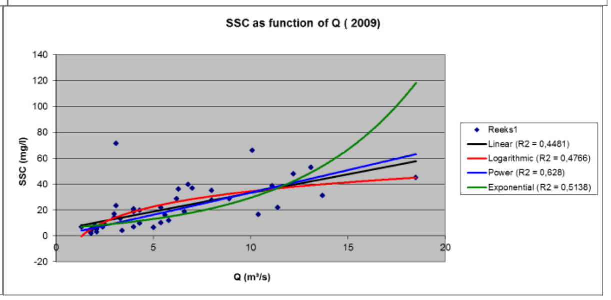
Power (R² = 0.3082)
Exponential (R² = 0.2915)


SSC as function of Q (2009)
SSC (mg/l)
Q (m³/s)
Reeks1
Linear (R2 = 0,4481)
Logarithmic (R2 = 0,4766)
Power (R2 = 0,628)
Exponential (R2 = 0,5138)

13.2. Annex B: Total yearly sediment loads at measuring locations

Table 15: Calculated total yearly sediment load (tons) at measuring locations Dendermonde and Eppegem

		Total SSL at Dendermonde			Total SSL at Eppegem		
	Year	Interpol	Taverniers1	Taverniers2	Interpol	Taverniers1	Taverniers2
	1972	9,944	8,366	8,661	47,842	48,234	35,455
	1973	11,837	9,213	10,278	36,570	36,896	34,563
	1974	54,299	37,306	27,964	58,391	54,667	48,492
	1975	24,448	17,987	15,075	45,774	47,736	46,560
	1976	4,473	4,546	4,608	38,735	37,677	36,320
	1977	38,435	26,659	31,335	44,537	42,342	42,572
	1978	19,491	13,143	10,273	50,704	45,146	41,341
	1979	49,248	45,509	29,962	45,577	41,844	39,673
	1980	14,392	11,720	10,644	47,464	44,337	41,997
	1981	117,816	72,277	45,213	49,656	43,593	48,528
	1982	31,487	20,147	27,200	41,710	40,726	38,911
	1983	15,509	12,835	10,087	39,221	37,162	35,420
	1984	42,365	21,206	39,055	61,857	51,515	58,305
	1985	18,700	13,263	12,576	36,947	38,327	38,101
	1986	20,114	22,011	14,601	37,457	41,835	29,231
	1987	35,983	21,874	15,502	35,945	31,974	31,103
	1988	46,774	33,785	17,576	38,578	35,919	33,492
	1989	15,487	9,346	8,260	23,208	22,002	23,082
	1990	6,187	4,206	5,563	20,573	19,600	21,375
	1991	20,434	9,256	8,521	22,570	20,729	22,083
	1992	16,225	14,300	13,092	22,868	19,671	19,269
	1993	57,195	36,882	36,309	22,530	19,544	19,117
	1994	22,800	15,742	16,442	17,958	15,761	14,903
	1995	24,273	19,915	17,007	18,814	16,529	17,644
	1996	9,376	6,017	6,162	17,472	14,860	16,059
	1997	6,003	5,622	5,721	12,317	11,972	12,214
	1998	41,119	31,142	30,623	19,238	17,721	18,172
	1999	64,550	43,584	41,425	19,457	17,800	18,577
	2000	34,849	26,967	28,388	15,878	15,072	14,778
	2001	77,262	51,100	46,300	26,357	22,775	22,299
	2002	68,209	55,270	55,288	23,823	22,159	26,200
	2003	36,776	21,572	22,086	14,661	13,783	13,739
	2004	26,085	19,723	19,041	20,141	17,398	17,954
	2005	11,913	10,585	8,306	15,105	14,947	14,661
	2006	16,715	12,774	13,676	14,189	13,432	12,627
	2007	40,005	30,436	31,610	18,156	13,594	14,346
	2008	21,784	18,430	15,913	17,350	14,656	16,192
	2009	41,493	23,151	24,038	14,498	10,561	9,381
min	**1971-1991**	4,473	4,206	4,608	20,573	19,600	21,375
max		117,816	72,277	45,213	61,857	54,667	58,305
average		29,871	20,733	17,648	41,166	39,113	37,330

median		20,274	15,625	13,589	40,465	41,281	37,211
stdev		26,029	16,604	11,777	10,136	8,798	8,911
min	1992-2009	6,003	5,622	5,721	12,317	10,561	9,381
max		77,262	55,270	55,288	26,357	22,775	26,200
average		34,257	24,623	23,968	18,378	16,235	16,563
median		30,467	20,743	20,564	18,057	15,417	16,125
stdev		21,127	14,467	14,093	3,743	3,304	3,897
min	1971-2009	4,473	4,206	4,608	12,317	10,561	9,381
max		117,816	72,277	55,288	61,857	54,667	58,305
average		31,949	22,576	20,642	30,372	28,276	27,493
median		24,360	19,819	16,177	23,515	22,081	22,691
stdev		23,284	15,424	13,089	14,114	13,649	12,753

Table 16: Calculated total yearly sediment load (tons) at measuring locations Grobbendonk and Haacht

		Total SSL at Grobbendonk			**Total SSL at Haacht**		
	Year	Interpol	Taverniers1	Taverniers2	Interpol	Taverniers1	Taverniers2
	1972	11,275	10,222	9,841	48,506	44,839	42,564
	1973	12,466	11,451	8,752	57,966	53,875	59,130
	1974	19,293	18,066	15,179	312,852	283,524	220,113
	1975	16,281	15,916	13,503	87,524	89,847	92,241
	1976	2,726	2,548	6,674	119,187	106,801	88,519
	1977	11,641	9,756	11,103	85,217	78,654	72,206
	1978	8,807	8,102	7,587	102,409	91,275	88,076
	1979	9,818	8,882	8,404	108,239	99,759	90,785
	1980	8,576	9,019	8,793	82,466	78,978	80,482
	1981	8,397	8,517	7,902	104,310	94,278	111,310
	1982	9,800	8,268	6,707	122,495	109,294	91,277
	1983	9,733	8,937	7,938	85,472	82,591	82,660
	1984	7,936	7,813	7,565	152,798	137,343	151,648
	1985	10,521	8,538	8,394	91,799	83,376	87,367
	1986	8,674	9,537	7,308	82,539	77,367	59,207
	1987	10,677	9,445	7,795	85,343	77,905	63,005
	1988	10,383	9,763	7,836	97,272	93,196	68,003
	1989	4,738	4,517	4,564	57,267	54,380	49,521
	1990	4,158	4,039	4,357	37,175	34,739	39,459
	1991	4,712	4,419	4,624	40,685	37,031	40,708
	1992	9,147	8,821	7,840	58,540	51,134	54,089
	1993	7,172	6,683	6,991	41,870	36,878	36,964
	1994	7,715	7,043	6,138	37,554	34,582	33,773
	1995	6,555	6,004	5,277	45,050	40,138	37,793
	1996	3,557	3,282	3,081	25,312	20,587	21,362
	1997	4,847	4,276	4,293	32,017	28,418	25,053
	1998	9,927	9,339	9,799	71,792	63,786	68,222
	1999	8,025	7,539	6,631	101,343	90,950	90,138
	2000	9,748	9,145	9,110	54,979	50,094	52,990
	2001	9,990	9,379	9,173	74,230	67,865	70,194

	2002	7,898	7,653	7,941	77,691	72,636	68,187
	2003	4,969	4,375	4,538	43,242	40,171	38,145
	2004	5,518	5,016	4,486	39,899	34,114	34,885
	2005	5,850	4,858	5,160	31,646	28,405	28,267
	2006	6,804	1,827	5,352	31,979	28,686	26,277
	2007	8,619	7,774	7,251	37,645	32,805	31,200
	2008	7,496	7,076	6,042	64,039	54,307	54,112
	2009	5,362	4,821	4,713	41,238	37,826	35,803
min	**1971-1991**	2,726	2,548	4,357	37,175	34,739	39,459
max		19,293	18,066	15,179	312,852	283,524	220,113
average		9,531	8,888	8,241	98,076	90,453	83,914
median		9,766	8,910	7,869	86,498	82,984	81,571
stdev		3,823	3,562	2,606	58,078	51,957	41,464
min	**1992-2009**	3,557	1,827	3,081	25,312	20,587	21,362
max		9,990	9,379	9,799	101,343	90,950	90,138
average		7,178	6,384	6,323	50,559	45,188	44,859
median		7,334	6,863	6,090	42,556	38,982	37,378
stdev		1,901	2,207	1,903	20,250	18,555	19,147
min	**1971-2009**	2,726	1,827	3,081	25,312	20,587	21,362
max		19,293	18,066	15,179	312,852	283,524	220,113
average		8,416	7,702	7,333	75,568	69,011	65,414
median		8,486	7,957	7,436	67,915	59,083	59,168
stdev		3,294	3,253	2,507	50,012	45,577	38,059

Table 17: Calculated total yearly sediment load (tons) at measuring locations Itegem and Melle/Merelbeke

		Total SSL at Itegem			**Total SSL at Melle Merelbeke**		
	Year	Interpol	Taverniers1	Taverniers2	Interpol	Taverniers1	Taverniers2
	1972	12,374	12,241	11,415	65,570	45,346	46,025
	1973	11,752	11,276	10,607	69,215	39,501	27,237
	1974	8,674	8,734	8,352	257,236	209,576	158,706
	1975	9,985	9,720	10,256	85,938	82,461	93,351
	1976	9,509	9,687	10,083	20,591	22,432	25,557
	1977	7,149	6,733	7,444	94,787	56,027	71,057
	1978	9,620	9,618	9,729	77,972	49,005	43,333
	1979	10,136	9,994	10,053	137,244	88,718	77,095
	1980	9,346	9,698	10,187	166,182	98,860	78,155
	1981	11,964	11,971	10,049	81,998	68,741	92,014
	1982	11,360	10,550	9,450	87,555	59,913	53,250
	1983	9,435	9,566	9,563	41,115	34,382	36,099
	1984	10,997	11,300	11,553	61,307	44,464	48,095
	1985	12,888	12,501	12,638	56,773	44,718	35,109
	1986	13,365	13,814	7,787	54,629	46,340	51,382
	1987	8,906	8,637	8,279	105,966	83,947	77,456
	1988	9,934	9,673	8,950	158,381	144,957	101,763
	1989	4,806	4,691	4,950	58,225	52,170	49,368
	1990	3,801	3,730	4,207	36,128	31,504	36,254

	1991	4,264	4,162	4,647	51,135	43,261	45,755
	1992	8,391	7,993	8,439	51,217	49,152	50,528
	1993	7,160	6,287	7,148	63,586	54,562	54,602
	1994	6,591	6,171	6,327	100,017	80,301	82,972
	1995	5,670	5,364	5,556	65,009	58,678	55,529
	1996	3,425	3,289	3,479	28,793	21,719	22,800
	1997	5,618	5,220	5,616	22,938	23,317	23,563
	1998	11,519	10,228	11,967	80,724	70,570	75,913
	1999	6,634	6,515	6,688	187,980	130,320	123,664
	2000	8,118	7,631	7,600	141,756	117,630	125,713
	2001	8,097	7,658	7,972	266,109	233,010	237,188
	2002	6,248	6,176	6,908	190,746	165,383	164,526
	2003	4,591	4,431	4,703	72,597	60,407	65,463
	2004	4,413	4,104	4,244	44,808	36,770	37,881
	2005	3,993	3,729	3,837	65,830	57,854	54,156
	2006	4,457	4,228	4,136	64,111	51,425	54,392
	2007	5,158	4,692	4,942	94,223	64,793	73,301
	2008	4,873	4,661	4,591	84,193	73,347	67,264
	2009	4,308	4,012	4,421	73,178	58,541	54,096
min	**1971-1991**	3,801	3,730	4,207	20,591	22,432	25,557
max		13,365	13,814	12,638	257,236	209,576	158,706
average		9,513	9,415	9,010	88,397	67,316	62,353
median		9,777	9,692	9,646	73,594	50,587	50,375
stdev		2,493	2,515	2,091	56,032	44,755	32,776
min	**1992-2009**	3,425	3,289	3,479	22,938	21,719	22,800
max		11,519	10,228	11,967	266,109	233,010	237,188
average		6,070	5,688	6,032	94,323	78,210	79,086
median		5,644	5,292	5,586	72,888	59,542	60,496
stdev		2,026	1,816	2,113	63,383	52,938	53,477
min	**1971-2009**	3,425	3,289	3,479	20,591	21,719	22,800
max		13,365	13,814	12,638	266,109	233,010	237,188
average		7,882	7,650	7,599	91,204	72,476	70,279
median		8,107	7,645	7,693	72,888	58,198	54,497
stdev		2,954	2,989	2,644	58,495	48,051	43,773

Table 18: Calculated total yearly sediment load (tons) at Eppegem, using a sampling correction factor of 1.2

		Total SSL at Eppegem			**Difference with Table 15**		
	Year	Interpol	Taverniers1	Taverniers2	Interpol	Taverniers1	Taverniers2
	1972	57,529	57,881	42,546	20%	20%	20%
	1973	44,006	44,275	41,475	20%	20%	20%
	1974	70,118	65,601	58,190	20%	20%	20%
	1975	55,031	57,283	55,872	20%	20%	20%
	1976	46,472	45,213	43,584	20%	20%	20%
	1977	53,333	50,810	51,087	20%	20%	20%
	1978	60,812	54,175	49,609	20%	20%	20%
	1979	54,596	50,212	53,975	20%	20%	20%

	1980	57,792	53,204	50,397	20%	20%	20%
	1981	59,338	52,311	58,234	20%	20%	20%
	1982	49,610	48,872	46,693	20%	20%	20%
	1983	47,148	44,595	42,504	20%	20%	20%
	1984	75,294	61,818	69,966	20%	20%	20%
	1985	44,454	45,993	45,722	20%	20%	20%
	1986	44,992	50,202	35,077	20%	20%	20%
	1987	43,134	38,369	37,324	20%	20%	20%
	1988	46,293	43,103	40,190	20%	20%	20%
	1989	27,850	26,402	27,699	20%	20%	20%
	1990	24,688	23,520	25,650	20%	20%	20%
	1991	27,084	24,875	26,500	20%	20%	20%
	1992	29,294	23,606	23,123	20%	20%	20%
	1993	26,190	23,453	22,940	20%	20%	20%
	1994	21,793	18,914	17,884	20%	20%	20%
	1995	22,467	19,835	21,173	20%	20%	20%
	1996	20,022	17,831	19,271	20%	20%	20%
	1997	14,787	14,367	14,657	20%	20%	20%
	1998	23,930	21,266	21,806	20%	20%	20%
	1999	23,583	21,360	22,292	20%	20%	20%
	2000	19,286	18,087	17,734	20%	20%	20%
	2001	31,900	27,330	26,759	20%	20%	20%
	2002	29,085	26,591	31,440	20%	20%	20%
	2003	17,570	16,539	16,487	20%	20%	20%
	2004	23,374	20,878	21,545	20%	20%	20%
	2005	18,285	17,936	17,593	20%	20%	20%
	2006	16,787	16,119	15,153	20%	20%	20%
	2007	21,112	16,312	17,216	20%	20%	20%
	2008	20,593	17,588	19,622	20%	20%	20%
	2009	17,481	12,673	11,000	20%	20%	20%
min	**1971-1991**	24,688	23,520	25,650	20%	20%	20%
max		75,294	65,601	69,966	20%	20%	20%
average		49,479	46,936	45,115	20%	20%	20%
median		48,379	49,537	44,653	20%	20%	20%
stdev		12,293	10,557	10,853	20%	20%	20%
min	**1992-2009**	14,787	12,673	11,000	20%	20%	20%
max		31,900	27,330	31,440	20%	20%	20%
average		22,086	19,482	19,872	20%	20%	20%
median		21,453	18,500	19,446	20%	20%	20%
stdev		4,692	3,965	4,704	20%	20%	20%
min	**1971-2009**	14,787	12,673	11,000	20%	20%	20%
max		75,294	65,601	69,966	20%	20%	20%
average		36,503	33,932	33,157	20%	20%	20%
median		29,190	26,497	27,229	20%	20%	20%
stdev		17,030	16,379	15,507	20%	20%	20%

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