FIELD STUDIES OF SUSPENDED SEDIMENT DYNAMICS IN GERMAN ESTUARIES

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Investigation Area: EMS - estuary

- Heavily impacted by human intervention (waterway engineering, coastal protection)
- Up to > 3 Mio. m$^3$ dredged material per year
- Increase of surface - SSC, **1970**: ~ 200 - 400 mg/l, **today**: easily 4000-5000 mg/l
- Deepened from ~ 4m up to > 6.2 m on request ‡ Meyer shipyard.
Investigation Area: Transfer of seagoing cruiseliners from inland to the Open Sea

- Northsea
- Ems barrier
- Emden
- Oldersum
- Ems
- Weser
- Elbe

Field studies of suspended sediment dynamics

Particles in Europe 2010

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Motivation

BAW-DH expertise under the framework of the “Ems action plan” to improve the ‘over-all-situation’ in the Ems estuary

Fieldwork program

Cross sections

in-situ – Data of suspended transport rates on two cross sections near the Ems barrier

† validation of a high resolution 3d hydro- / morphodynamic numerical model

characterization and better knowledge of suspended sediment dynamic in the Ems between km 50 and 20

† improve system understanding and process studies (e.g. position, extension and concentration of the ETM)
Equipment

Coastal Digger
ca. 23 x 6 x 0.9

2 ADCP (300 / 600 Khz)

SES transducer
6-15 Khz

CTD

LISST100X
(80% PRM)

Calibration unit

Lab analysis
mg/l

Good idea!
EMS 2009
ADCP SPM measurement (briefly)

primary:
velocity profile
bottom profile

Secondary (acoustic backscatter):
SPM measurement

- Transect measurement with continuous data recording
- Periodical interruption to perform calibration on stationery vertical profiles:
  - watersamples
  - CTD (salinity, temperature)
  - OBS (turbidity, optical backscatter)
  - LISST 100 (grainsize distribution, optical attenuation) if possible (visibility)
example: 10 SSC profiles „around highwater“ at the cross section POGUM

<table>
<thead>
<tr>
<th>Pegel [m/NN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>-1</td>
</tr>
<tr>
<td>-2</td>
</tr>
</tbody>
</table>

Integration of cross sections gives time series of transport rates (and others)

<table>
<thead>
<tr>
<th></th>
<th>Pogum</th>
<th>Gandersum</th>
</tr>
</thead>
<tbody>
<tr>
<td>duration (1 Tide)</td>
<td>08.07.2009 09:14 – 21:42</td>
<td>06.07.2009 07:18 – 20:35</td>
</tr>
<tr>
<td>transect length</td>
<td>570 m</td>
<td>470 m</td>
</tr>
<tr>
<td># crossings</td>
<td>142</td>
<td>173</td>
</tr>
<tr>
<td># calibrations</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td># watersamples</td>
<td>91</td>
<td>98</td>
</tr>
</tbody>
</table>
result: clear signal of upstream transport in the magnitude of „some thousand tons / tide“

*: referring to the measured profile

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EMS 2009 – cross section Gandersum
Grainsize distribution from LISST 100X – measurements

- Sampling depth 6 - 10 m
- Range LISST100X: 2,73 – 462 μm
- LISST operable as long SSC < ca. 500 mg/l
EMS 2009 – cross section Pogum
Grainsize distribution from LISST 100X – measurements

- Sampling depth 6 - 10 m
- Range LISST100X: 2,73 – 462 μm
- LISST operable as long SSC < ca. 500 mg/l

D50_{mittel} = 50 \, \mu m
D50_{min} = 44 \, \mu m
D50_{max} = 62 \, \mu m

\[ \begin{align*}
\text{Strömung [m/s]} & : v_m = 0.7 \\
\text{Pegel [m/NN]} & : v_m = 0.68
\end{align*} \]
SSC – Longitudinal between km51 (Knock) and km15 (Leer)
“around flood“ at 07. Juli 2009

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07. Juli 2009
Particles in Europe 2010
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SSC – Longitudinal between km47 (Geisespitze) and km19 (Jemgum)
“around Ebbe at 09. Juli 2009

09. Juli 2009

0 25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 500 600 800 mg/l

No measurement

Knock
Emden
Pogum
Sperrwerk
Oldersum
Terborg
Jemgum
Leer

50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15
Comparison of SSC – longitudinals
07. Juli / 09. Juli

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SSC longitudinal combined with SES Profil
Terborg / 07. Juli 2009

SSC profile from ADCP - Backscatter
ca. 1300 m

ADCP – Bottomprofile

Emden  Sperrwerk  Pogum  Terborg  Leer

Particles in Europe 2010
Field studies of suspended sediment dynamics
SSC longitudinal combined with SES Profil
Terborg / 07. Juli 2009

SSC profile from ADCP - Backscatter

ADCP – bottom profile

Echo print SES ‡ 4 layers

2 fluid mud layer
2 consolidated layer

c. 1300 m

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Schwebstoff-Probe unterhalb des ADCP-Bodenprofils

SSC profile from ADCP - Backscatter

ADCP – bottom profile

Echo print SES ‡ 4 layers
Properties of high concentrated suspensions (keywords)

- elastic fluid ≠ viscous fluid
- cohesiv (adhesiv)
- thixotropic
- Very little specific gravity
- minor trend to consolidate
  (24 hours of settling time, 'mixed up' to 'consolidated')
• Clear signal of upstream transport in the magnitude of 5000-7000 tons / tide on two cross section in the area of the Ems barrier (Gandersum / Pogum)
  – cause: concentrations transported with flood (upstream) are higher than concentrations transported with ebb (downstream)
  – The detected transport rates are in the same scale then the dredging volume

• Longitudinals are showing a very different view of SSC distribution during flood and ebb
  – Due to high turbidity during ebb current there was no more measurement possible upstream Terborg.

• There is a demand for operational methods to describe the complex conditions in the bottom boundary layer.

Note: all statements are based on 4 (!) days measurements