

Prepared for:

RIKZ

**Data acquisition for LTV Research &
Monitoring 'Natural development'**

Report

December 2007

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Tineke Troost

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I Introduction

I.1 Objective

In the subproject 'HVI Validatietechnieken' it was noted that for validation of the 'Zoute Wateren Ecotopen Stelsel' (ZES.1) additional data is required (Van Wesenbeeck, 2007). This is especially true for the physical data used in the grid maps on which the ZES.1 was based. One problem is that the available data are difficult to locate. Also, it is not clear whether these data are publicly available. Another problem is that the data required for (validation of) the ZES.1 is not always sufficiently accurate. Some data are based on model results, while measured data may be more accurate than modeled data. Furthermore, as was also observed by Van Wesenbeeck (2007), a need exists for coupled ecological-physical data. Therefore, it would be very valuable to bring together all relevant monitoring data, as well as all area-specific data, and to make these data more broadly available. In this project, a first step in this direction is taken by drawing up an inventory of monitoring data of the Westerschelde, by collecting the relevant data sets and by incorporating these in a suitable data managing tool.

The objective of the current project is thus to carry out activities for the inventory and acquisition of additional data (possibly including the purchase of data) and for the collection and organization of data on the Westerschelde in a data managing tool. This will facilitate the validation of the ZES.1, as well as any future activities within the framework of 'LTV O&M Natural Development'.

I.2 Approach

First, an overview is given of the long-term monitoring programs in the Westerschelde. In the sections on 'Data availability', the location and specifics of the data are discussed, as well as their general relevance for the project 'HVI Validatietechnieken'. In addition to the long-term monitoring programs, many short-term projects were carried out in the Westerschelde. These programs were designed for specific purposes, and with a focus on specific areas, variables, species or periods, which make them generally less useful than the long-term monitoring programs. Therefore, only the short-term projects with direct relevance are discussed in detail.

In the sections on 'Data requirement', the specific data requirements and availability are discussed for each ZES-parameter, and it is discussed which data should be acquired (or, if necessary, purchased). To keep the report well-organized, data availability and requirements were discussed per parameter-type: bathymetric parameters (Chapter 2), physical parameters (Chapter 3), chemical parameters and sediment (Chapter 4), and biological parameters (Chapter 5). Finally, it is discussed in Chapter 6 in which format the data are stored, and in which data managing tool.

2 Bathymetric parameters

2.1 Data availability

2.1.1 MWTL Morphological monitoring network

Since 1971, a series of national monitoring programs are carried out by order of the Dutch Directorate for Public Works and Water Management (RWS). Together, these monitoring programs are named 'MWTL', which is the abbreviation of the Dutch 'Monitoring of the Waterstaatkundige Toestand des Lands'. The objective of the MWTL programs is to provide information for formulation and evaluation of the national water policy, and of (inter)national agreements and treaties.

The MWTL programs are carried out by the National Institute for Coastal and Marine Management (RIKZ) and Institute for Inland Water Management and Waste Water Treatment (RIZA). Hence, all data measured in this framework are incorporated in the national database DONAR ('Data Opslag Natte Rijkswaterstaat'), or are otherwise publicly available at RWS. They can be obtained via the 'basisinfodesk' of the RIKZ, or from various websites (www.actuelewaterdata.nl, www.waterstat.nl, www.waterbase.nl). Metadata on the datasets is available at www.scheldemonitor.nl and www.vliz.be. Detailed measurement plans of 2007 are given in RIKZ report RIKZ/2007.002.

Bathymetric data obtained in the MWTL morphological monitoring program are:

- Coastline photos
- Coastline maps
- 'Vaklodingen'
- 'Detaillodingen'

Details are given in Table 1. For a more detailed overview of available 'vaklodingen' and 'detaillodingen', see de Jong et al. (1997).

Table 1 Overview of data and measurements carried out in the Westerschelde for the MWTL morphological monitoring network

	period	frequency	Location(s)	resolu- tion	available at
Coastline photos	1993 1999 2005	1	coast		RIKZ www.kustfoto.nl www.watermarkt.nl/ kustENZEEBODEM

	period	frequency	Location(s)	resolution	available at
JARKUS Coastline maps & depth measurements (Overlodingen)	Since 1998	1	transects along the coast	400m	RIKZ www.kustlijnkaart.nl www.watermarkt.nl/ kustenzeebodem
Depth measurements (Vaklodingen)	since 1931 mouth: 1964	two-yearly, once a year	whole area	east: 100m, rest: 200m	RIKZ (DONAR)
High resolution depth measurements (Detaillodingen)		1,2,4	9 small plots	15-100m	RIKZ (DONAR)

2.1.2 Short term projects or datasets

- Elevation measurements on the salt-marshes and mudflats of the Westerschelde, by means of laser altimetry and carried out by the AGI in 2001 (5x5m grid), and in 2004 (2x2m grid). These measurements were used for the ecotope maps and are available at RWS/Directie Zeeland.
- MOVE bathymetric measurements
For the MOVE project, bathymetric measurements are carried out to complement the MWTL monitoring. MOVE data are saved at the MOVE-project disc at RIKZ and are also available on the MOVE-intranet site. MOVE measurements include:
 - Elevation measurements by means of ‘waterpassingen’
These are done once in the two years on the salt-marshes and mudflats of the Westerschelde; transects lie 200m apart.
 - Elevation measurements by means of the triangular plot method
These are carried out on the highest intertidal areas (3-5 plots on 23 transects).
 - Additional depth measurements (vaklodingen and detaillodingen)
Additional vaklodingen are carried out to complement the MWTL vaklodingen, so that yearly measurements (or more) are available for the whole Westerschelde area. Additional detaillodingen are carried out on two plots that are not monitored in the MWTL program. For a detailed overview of the available data, see de Jong et al. (1997).

2.2 Data requirements

2.2.1 Bathymetric map

The depth/elevation grid maps used for the ZES.1 in 1996, 2001 and 2004 are based on depth- and elevation measurements (lodingen and waterpassingen) from the MWTL morphological monitoring network (section 2.1.1) and MOVE project (section 2.1.2). In 2001 and 2004 these grid maps were complemented with elevation measurements from altimetry surveys especially carried out for this occasion (section 2.1.2). Note that the resolution of the altimetry map in 2001 is different from that in 2004. Both measurements from 2001 and 2004 are transformed into a raster with the Souding-grid utility and interpolated into a 20x20m grid by DIGIPOL (Van der Veen-van Snik, 2006). As mentioned above, all resulting bathymetric maps, as well as the underlying data, are publicly available at RWS. The maps are considered to be sufficiently accurate for (validation of) the ZES.1 (Wijnhoven et al, 2007), so obtaining more morphological data is not a priority at this moment.

3 Physical parameters

3.1 Data availability

3.1.1 MWTL Physical monitoring network

For general information on the MWTL monitoring, see section 2.1.1. Measurements in the MWTL Physical monitoring network include part of the measurements carried out by MSW (section 3.1.2) and ZEGE (section 3.1.3). Data are incorporated in DONAR and are publicly available at RWS. They can be obtained via the 'basisinfodesk' of the RIKZ, or from various websites (www.actuelewaterdata.nl, www.waterstat.nl, www.waterbase.nl). In addition, tidal predictions are available at www.getij.nl, actual water data are available at www.actuelewaterdata.nl, and data on wave climate are available at www.golfklimaat.nl. Metadata on the datasets is available at www.scheldemonitor.nl and www.vliz.be. A detailed overview of the MWTL measurement plans for 2007 are described in RIKZ report RIKZ/2007.002.

In the MWTL Physical monitoring network, the following parameters are monitored:

- Discharges
- Water levels
- Water temperatures and salinity
- Wave climate

For details on the measurement locations and frequency see Table 2.

Table 2 Overview of parameters for the Westerschelde measured in the MWTL Physical monitoring network

	since	locations	frequency	parameters
Discharge	1959	none in the Westerschelde	daily	discharges
Water levels	1970	4 (MSW), 11 (ZEGE)	1970-1985: hourly since 1985: every 10 min.	water levels
Water temperatures	1987	2 (MSW), 4 (ZEGE)	fort-nightly	water temperatures
Wave climate	1985	2 (ZEGE)	hourly	average wave period, wave direction, wave height

3.1.2 MSW

The monitoring network 'Monitoring System Water' (MSW) was initiated in 1987, and consists of more than 160 measuring stations, which are connected to approximately 25

junction stations and a central computer system in The Hague. Four of the stations are located in the Westerschelde: Bath, Hansweert, Terneuzen and Vlissingen. At the measuring stations, every 10 seconds an average is determined from the measurements. At the central computer system, these 10-second averages are transformed into 10-minute averages. The MSW data are freely available at RWS. Note that part of the data is incorporated in the MWTL physical monitoring network (section 3.1.1). Measured parameters are:

- Water levels
- Water temperatures
- Current velocities (only measured in rivers, none in the Westerschelde)
- Discharges (only measured in rivers and sluices, none in the Westerschelde)

3.1.3 ZEGE

The monitoring program 'Meetnet Zeeuwse Getijdenwateren' (ZEGE) includes the (continuous) measurements of 6 physical parameters at 72 fixed stations, of which 30 are located in or around the Westerschelde (Table 3). The measurements are carried out by the Meetinformatiedienst of RWS Zeeland. More information and the resulting time-series are available at the Hydro Meteo Centrum Zeeland (<http://www.HMCZ.nl>). Part of the ZEGE measurements is incorporated in the MWTL physical monitoring network.

ZEGE-monitoring includes measurements of the following parameters:

- Water levels
- Water temperature
- Salinity (Calculated from chloride-concentration)
- Wind velocity and direction
- Wave height
- Discharges

For details on which parameters are measured at which locations, see Table 3. Discharges are not measured in the Westerschelde.

3.1.4 Short term projects or datasets

- Calculation of maximum current velocities ('Maximale ebstromsnelheid bij gemiddeld tij in de situatie voor de laatste verdieping anno 97'/98')
Maximum current velocities at an average tide in the situation before the deepening of the Westerschelde in 1997/1998 were calculated with the Waqua-model Scalwest1996, and are available at the RIKZ (RIKZ/AB/2003.813x).
- Calculation of maximum current velocities in 1996, 2001 and 2004
The maximum linear current velocities in 1996, 2001 and 2004 are based on bathymetric maps of the corresponding year (section 2.2.1), and on the tidal cycle of 5-5-1996 (section 3.1.2). Calculations were carried out for the ecotope maps of the ZES.1 (Bouma et al) and are done in the ScalWest model, while IDW-interpolations are done in ArcGIS (Van der Veen-van Snik, 2006).

- Calculated salinity map

A salinity map was calculated with the Waqua-model SCALDIS400, for which the bathymetry was based on lodingen from 1989-1992, and which was calibrated on basis of monthly and continuously water level measurements of 1990 at fixed ZEGE stations. For the tidal boundary condition, data from 1990 was used and discharges were based on based on decade-averages of freshwater river-inputs and salty water sluice-inputs (Lievense, 1994).

Table 3 Overview of measurements for the Westerschelde measured in the ZEGE network

Location	RD X	RD Y	Level	Temp. & Sal.	Wind	Wave
Antwerps Kanaalpand	075083	379912	X	X	-	-
Antwerpen	086038	360259	X	-	-	-
Baalhoek	065526	375971	X	X	-	-
Bath	073080	379550	X	-	-	-
Bath (golfbaak)	073087	379609	-	-	-	X
Bath (golfbaak)	073080	379550	-	-	-	X
Borssele	041652	381517	X	-	-	-
Breskens handelshaven	028206	380396	X	-	-	-
Cadzand	015214	378681	X	-	-	-
Cadzand Wind	015214	378681	-	-	X	X
Cadzand (waverider)	014588	379998	-	-	-	X
Deurloo (waverider)	006071	392601	-	-	-	X
Hansweert	058394	384996	X	-	-	-
Hansweert Wind	058394	384996	-	-	X	X
Hansweert (golfbaak)	058120	385089	-	-	-	X
Hoofdplaat	035614	377930	-	X	X	X
Hoofdplaat (golfbaak)	035645	377539	-	-	-	X
Kallo	079027	364845	X	-	-	-
Sluiskil	046730	368402	X	X	-	-
Brug Sas van Gent	044662	361302	X	X	-	-
Kanaal Gent-Terneuzen	045847	371877	X	-	-	-
Liefkenshoek	078185	368039	X	-	-	-
Marollegat	071992	388510	X	X	X	X
Overloop v. Hansweert	056180	380852	X	X	-	-
Plaat van Oude-Tonge	068585	410121	-	X	-	-
Prosperpolder	074935	373871	X	-	X	-
Pas van Terneuzen (waverider)	045053	374771	-	-	-	X
Schaar van de Noord	069909	377234	X	-	-	-
Terneuzen	045786	373070	X	-	-	-
Terneuzen Westsluis	045509	372128	-	-	X	-
Terneuzen Westsluis kanaalzijde	046066	370949	X	X	-	-
Terneuzen Westsluis kanaalzijde	045284	373233	X	X	-	-
Vlissingen	030575	385290	X	-	-	-
Vlakte van de Raan	006075	392714	X	X	X	-
Walsoorden	060290	379692	X	-	-	-
Westerschelde Container Terminal (waverider)	038185	383481	-	-	-	X
Wielingen (waverider)	017641	383875	-	-	-	X
Westkapelle	019860	394300	X	-	-	-

3.2 Data requirements

3.2.1 Exposure time

Exposure times are based on water level measurements, bathymetry, and the period of the tidal cycle. For the water level measurements, the MSW time series of Vlissingen, Terneuzen, Hansweert, and Bath are used (section 3.1.2). For the bathymetry, the bathymetric maps described in section 2.2.1 are used. The period of the tidal cycle is again based on MSW water level measurements, converted in the 'Melissa' program into time series of high and low water levels. These data are available at RWS (DONAR). Though Wijnhoven et al (2007) consider these data to be sufficiently accurate for validation of the ZES.1, the calculation method itself is subject to discussion (de Groot & West 2007).

3.2.2 Hydrodynamics

Whether an area is low or high-dynamic, is determined on the basis of four parameters:

- **Fetch length**
The fetch length is based on a bathymetric map (section 3.1.1), and consists of a calculation of the uninterrupted distances. The ZES-boundaries of this parameter are such that the parameter is only important in the mouth of the Westerschelde, and not important for distinguishing ecotopes in the Westerschelde itself.
- **Maximum linear current velocities**
The maximum linear current velocities in 1996, 2001 and 2004 are based on bathymetric maps of the corresponding year (section 2.2.1), and on the tidal cycle of 5-5-1996 (section 3.1.2). Calculations are done in the ScalWest model, and IDW-interpolations are done in ArcGIS (Van der Veen-van Snik, 2006). The ScalWest model typically lacks accuracy on tidal flats and other shallow areas. Substitution of modelled data with measured data would require major measurement efforts. Rather, the focus should lie on improving the hydrodynamic models (Wijnhoven et al 2007), but this is beyond the scope of the subproject 'HVI Validatietechnieken'.
- **Maximum orbital velocity**
The maximum orbital velocity is based on maximum wave heights, measurements of which are only available for the ebb tidal delta and for two locations within the Westerschelde (sections 2.1.1 and 3.1.3). Modelled data on orbital velocity are, just like the maximum current velocities, not accurate for littoral areas.
- **Aerial pictures on mega-ripples**
In the littoral areas, where hydrodynamic models are not accurate, aerial photos from ripple patterns are used to optically determine the local dynamic conditions.

3.2.3 Salinity

The year-average of salinity at high tide (with average freshwater discharge) and its variation are based on the salinity map resulting from SCALDIS400 (section 3.1.4). For all the ecotope maps (1996, 2001, 2004) the same salinity map was used. Though the resolution of the salinity map is rather small (400x400m²), it is assumed to be sufficiently accurate for validating the ZES (Wijnhoven et al. 2007). The fact that the same map is used for all years is not considered to be problematic either, as the effect of salinity on the distribution of species is mainly important at a large scale. However, it would be preferred to use newer salinity maps when these become available.

4 Chemical parameters and sediment

4.1 Data availability

4.1.1 MWTL Chemical monitoring network

For general information on the MWTL monitoring, see section 2.1.1. Data are available at RWS, and can be obtained via the 'basisinfodesk' of the RIKZ; data from the MWTL Chemical monitoring network are specifically available from www.waterstat.nl and www.waterbase.nl. Metadata on the datasets is available at www.scheldemonitor.nl and www.vliz.be. Detailed measurement plans of 2007 are given in RIKZ report RIKZ/2007.002.

In the MWTL Chemical monitoring network, the following parameters are monitored:

- Nutrients
- Suspended matter
- Organic micro-pollutants
- Heavy metals
- Sediment particle size

For details on measurement locations and frequencies, see Table 4.

Table 4 Overview of parameters for the Westerschelde measured in the MWTL Chemical monitoring network

Matrix	Locations	Freq.	Parameters	Carried out by
Water (Surface sampling)	Hansweert, Vlissingen, Terneuzen, Hoedekens-kerke, Schaar v. – Oudendoel, Wielingen, Goeree	6-18	VZ, T, PH, O2, DOC, POC, suspended matter, salinity, turbidity, extinciton, airpressure, incoming radiation, wind, Si, P, N, Chlfa, Feo, Fyp, flowcytometer counts, (Chemical) PO4, NO3, NO2, NH4, CZV, Fluorid, Pesiticides, Organotin, HCHs, heavy metals, and a range of other (radio) chemicals.	Meet informatie dienst
Suspended matter	Vlissingen, Terneuzen, Hansweert	4	OC, LUTUM, ZS, Heavy metals, HCB, PCBs, PAKs, Organotin, radiochemicals	dirZL
Suspended matter	Wielingen	13-26	OC, LUTUM, ZS, Heavy metals, PCBs, PAKs, Organotin, radiochemicals, CHLfa	Meet-inf. dienst
Sediment	Wielingen, Vlissingen, Borssele, Terneuzen, Baarland, Hoedekenskerke, Hansweert, Kruiningen, Speelmansgat, Bath (2x), Schaar v. Oudendoel	1995, 1999, 2003	Heavy metals, HCB, PAKs, PCBs, Organotin, broomvertragers, LUTUM, OC, sediment particle size.	Meet informatie dienst

4.1.2 MONITB

MONITB is a monitoring project on the Belgian continental shelf and the Westerschelde. The project was initiated at the Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea and Scheldt Estuary Mathematical Models (MUMM) in 1977, with a since then almost unchanged pattern of about 25 sampling stations at sea and 7 in the estuary, each one being visited with a frequency of 6 to 10 times a year, and water being taken from a standard depth of - 3m (Mommaerts, 1991).

Measured parameters are:

- Hydrography (temperature, salinity, suspended matter, secchi depth and/or quantameter)
- Meteorology (air temperature, sea state, wind speed and direction, relative humidity)
- nutrients (nitrites, ammonium, phosphates, silicates)
- heavy metals (mercury, cadmium, copper, zinc, lead)
- organic contaminants (PCB's, HCH's, DDT, DDE, DDD, HCB, members of the 'drins and 'zins families)
- plantpigments (chlorophyll-a and phaeophytin-a)

The dataset is available at the 'Koninklijk Belgisch Instituut voor Natuurwetenschappen, Beheerseenheid Mathematisch Model Noordzee en Schelde-estuarium' (BMM).

4.1.3 Short term projects or datasets

- Semi-continuous monitoring of chloride, temperature and mud content at some 17 stations on the Zeeschelde and Westerschelde.
The stations are sampled every four weeks. Three of the stations are located in the Westerschelde: Boei 79 (Bath), Boei 74, and Opwaardse Zinker Saeftingen. Parameters that are monitored are chloride, temperature, mud content, conductivity, and turbidity. This program is an extension of a long-term monitoring program of similar measurements in the Zeeschelde. Data are available at the Flemish Government (Waterbouwkundig Laboratorium).
- WSCHELDT (1973-1983)
Monitoring of the suspended matter and chemical and physical status of the Westerschelde estuary. This monitoring was carried out in the period 1973 – 1983. Measured parameters were the chemical oxygen use (CZV), chloride, dissolved oxygen, nutrients, pH, suspended matter, and temperature. Data are available at the Koninklijk Belgisch Instituut voor Natuurwetenschappen, Beheerseenheid Mathematisch Model Noordzee en Schelde-estuarium (BMM).
- Geomorphological maps
Geomorphological maps of 1996, 2001, and 2004 were made by the 'Adviesdienst Geoinformatie en ICT' (AGI) (Van der Veen-van Snik, 2006). The map was based on false-colour aerial or satellite pictures taken during low water at spring tide. The map was validated by people who know the system well, complemented by some custom sediment measurements in the field. These maps are available at RWS.

- **MOVE McLaren sediment sampling**
For the MOVE-project, an extended McLaren sediment measuring campaign was carried out in 2000, in which the whole Westerschelde was sampled. Detailed information on the sampled locations is available in de Jong (1997).

4.2 Data requirements

4.2.1 Sediment composition

Data on sediment composition may be extracted from geomorphological maps, as was done for the making of the ecotope-maps. The geomorphological maps are made by the 'Adviesdienst Geo-informatie en ICT' (AGI) (section 4.1.3). However, due to small-scale variability in sediment composition, median grain size or mud content extracted from the geomorphological map are not accurate enough for validating the ZES.1. For the same reason, the sediment composition cannot be based on measurements carried out in the MWTL Chemical monitoring network (section 4.1.1), or in the MOVE project (section 4.1.3).

Instead, sediments measurements are needed that are sampled at the same locations as the benthos samples, as was already noted by Van Wesenbeeck (2007). Such coupled sampling of sediment and benthos has become common use in the BIOMON program since 1990 (section 5.1.2) and in several short-term benthos projects (section 5.1.3). In the validation studies carried out by the NIOO (Wijnhoven et al. 2006, 2007), these coupled sediment data are already used. Their data set would be relevant to include in the validation of the ZES.1, but this is discussed in more detail in section 5.2.1.

Probably, future ecotope-maps will still be based on geomorphological maps, so the mismatch between ecotope-maps and actual relations between benthos and sediment may remain. A solution for this may be found in the choice of the sediment boundary values in the ZES, which should be based on the results of the upcoming validation study.

5 Biological parameters

5.1 Data availability

5.1.1 MWTL Biological monitoring network

For general information on the MWTL monitoring, see section 2.1.1. Data are available at RWS, and can be obtained via the 'basisinfodesk' of the RIKZ; data from the MWTL Biological monitoring network are mostly available from www.waterstat.nl, but also from some other websites (see bulleted list below). Metadata on the datasets is available at www.scheldemonitor.nl and www.vliz.be. Detailed measurement plans of 2007 are given in RIKZ report RIKZ/2007.002.

In the MWTL Biological monitoring network, the following parameters are monitored:

- Macrobenthos (also see section 5.1.2 on BIOMON)
- Phytoplankton (www.fytoplankton.nl, www.waterbase.nl)
- Birds
- Seals
- Fish diseases
- Bacteriology (shellfish-water quality)
- Mussels
- Periwinkle – intersex
- Vegetation mapping (www.kwelders.nl, www.zeegras.nl)

For details see Table 5.

5.1.2 BIOMON

Since 1990, the macrobenthos of the Westerschelde, the Oosterschelde, the Veerse Meer en the Grevelingen have been sampled by the Netherlands Institute for Ecology – Centre of Estuarine and Marine Ecology (NIOO-CEME). This is done by order of the National Institute for Coastal and Marine Management (RIKZ). BIOMON is part of the MWTL biological monitoring network, and is thus freely available at RWS. Here, we discuss it separately because of its high relevance with regard to LTV O&M.

The BIOMON benthos monitoring takes place twice a year, in spring and autumn. In the Westerschelde, benthos is sampled in three subareas: west, central and east. Within each subarea, four depth-transects are distinguished: above –2m NAP, between –2 and –5m NAP, between –5 and –8m NAP and deeper than –8m NAP. In each transect, benthos are sampled at ten randomly generated locations ('stratified random sampling'), so that in total 120 stations are sampled. In the sublittoral, sediment is collected with a Reineck box-corer. From

the box-corer three subsamples are taken with cores of 8 cm Ø. In the littoral, also three cores of 8 cm Ø are sampled. The subsamples are put together and sieved on a 1 mm sieve. Per species, the species name, biomass and density are determined. Since 1999, also a sediment sample is taken to determine the local median grain size.

5.1.3 Cockle surveys

Since 1992, a yearly inventarisation of the cockle-densities in the Westerschelde, Oosterschelde and Waddensea is carried out by the 'Centrum voor Schelpdier Onderzoek' of the Netherlands Institute for Fisheries Research (IMARES Yerseke). This monitoring is part of a national monitoring campaign by order of the Ministerie van LNV. This monitoring campaign forms the basis for the fishing plans of the cockle-fisheries.

The cockle survey takes place in the spring (april-june) on approximately 250 locations, and since 1996 also in autumn on approximately 100 locations on all mud flats of the Westerschelde (in 2000 this were 200 locations). The sampling locations are based on a regular grid (sinds 1994), and lie roughly half a kilometer apart. Per location, in total 0.1 m² is sampled with a special shovel. The cockles in the samples are divided into year classes; per year class the total number and biomass are determined. Of all other bivalves, the species name, numbers and biomasses are recorded as well.

The cockle-data may be relevant for the ZES.1 validation, as the cockles are sensitive to (changes in) environmental conditions. Therefore, they may be suitable for validation of the ZES. The data can be freely obtained from IMARES Yerseke.

5.1.4 Demersal fish survey (DFS)

The Dutch Demersal Fish Survey (DFS) is part of an international inshore survey and is carried out by IMARES IJmuiden. Internationally, all coastal and estuarine areas of the southern North Sea are covered. Three Dutch research vessels survey these areas every year for 12 weeks in total. The DFS was initiated in 1969, and has since then been carried out annually. The data are available from the institute's database (FRISBE).

The DFS survey takes place once a year between September and October. Monitored are young plaice (*Pleuronectes platessa*) and sole (*Solea solea*, *Solea vulgaris*) (groups 0-1) in their nursery grounds in the North Sea coastal zone, to provide plaice and sole recruitment indices. Additionally, brown shrimps (*Crangon crangon*) and non-commercial fish are monitored. Since 2002 (in the estuarine waters) and since 2004 (in the coastal waters), hydrographical data (temperature, salinity and visibility profiles) are also collected with a data-logging CTD. In earlier years only basic hydrographical measurements (surface water temperature and visibility estimates using a secchi disc) were collected.

The DFS-data may be relevant for the validation of the ZES.1, as it deals with young demersal fish for which the Westerschelde functions as a nursery ground. Therefore, they may be included in the validation. The data can be freely obtained from IMARES Yerseke.

Table 5 Overview of parameters for the Westerschelde measured in the MWTL Biological monitoring network

	since	locations	frequency	parameters	done by
Macro-benthos	1990	120 (see section 5.1.2)	2	sediment particle size, benthos	NIOO-CEMO
Phyto-plankton	1990	Vlissingen, Schaar v. Oudendoel	winter: monthly summer: fort-nightly	Phytoplankton species and biomass	RWS
Waterbirds	1979	Borssele-Hansweert, Verdr. land van Saefthinge, Hansweert-Belgische grens, Vlissingen-Rammekens, Paal-Perkpolder, Rammekens- Borssele, Terneuzen- Perkpolder, Terneuzen- Breskens, Hooge Platen	12	Number per area	Delta Project Management BV - Culemborg
Coastal breeding birds	1979	Hooge Platen, Margarethapolder, Verdr. Land van Saeftinge, Eendragtspolder, Terneuzen, PaulinaSchor, Molenpolder, Nummer Een, Hoek, Hoofdplaat, Kl. Huissenspolder, Baalhoek, Braakmanhaven, DOW Nieuw, Neuzenpolder II, Plaskreek, Kloosterzande, Ser Arendspolder, Zeedorp	1	Number per area, colonies	Delta Project Management BV - Culemborg
High-tide bird counts	1989	(from boat)	12	Numbers	RWS RIKZ/ZDE
Seals in the Delta	1975	intertidal mudflats	1975-1996: monthly since 1996: fort-nightly	Number of seals	RWS RIKZ/ZDE
Fish diseases (flounder / dab)	1983	Middelgat Brouwers-plaat, Molenplaat	1	fish diseases, moisture content, fat, heavy metals, PCBs, HCB	Rijkswaterstaat Noordzee/ IMARES IJmuiden
Shellfish water-quality	1956	Hooge Platen, Hoedekens-kerke	1	Thermo tolerant colibacteries	IMARES Yerseke
Active biol. mussel monitoring (ABM)		Vlissingen, Hansweert	2	%GV, fat, PCBs, HCB, Organotin, TIB	RWS RIKZ/ZDE
Passive biological mussel monitoring (PBM)	1983	Hoedekens-kerke	1	body comp. of mussels from various length classes: moisture, fat, ash, heavy metals, PCBs, PAKs, HCB,OCBs Organotin	IMARES IJmuiden (RWS RIKZ/ZDE)
periwinkle-intersex monitoring		Vlissingen	1	density, intersexindex, organotin	IMARES Yerseke
Vegetation mapping	(1974) 1994	seagrass: Rammekens saltmarshes: various areas	two-yearly	aerial photos of seagrass areas and salt marshes	AGI

5.1.5 Short-term projects or datasets

Over the years, institutes such as the Netherlands Institute for Ecology – Centre of Estuarine and Marine Ecology (NIOO-CEME), the University of Gent (RUGent) and the Instituut voor Natuur en Bos Onderzoek (INBO) have collected much data on macrobenthos of the Westerschelde. Some of these data provide coupled benthos and sediment data, which makes them potentially useful for validation of the ZES.1. Some of the data were collected by order of the RWS, and thus is freely available, while other data can be purchased from the responsible institute. Most of the data are incorporated in the 'Benthic Information System' (BIS), the NIOO-CEME database. A chronological overview of these data sets is given in Table 6. A previous overview was given by Craeymeersch (1999).

5.2 Data requirements

5.2.1 Benthos data

The ZES has been validated in 2003 with benthos data from BIOMON (Wijsman, 2003), and in 2006 with data from intertidal flats ('Molenplaat' and 'Platen WS', Table 6) by Wijnhoven et al (2006). BIOMON data were also used in the report on 'statistische validatie ecotopenkaarten Westerschelde' in 2006 (Baggelaar, 2006). For the report on the robustness of parameters for habitat assessment tools (Wijnhoven et al., 2007), the extended set of benthos data as described by Ysebaert et al. (2002) was used. The latter data set includes over 3000 benthos samples from the period 1978-1997, including those from the projects BIOMON (approx. 1500 samples) and MOVE (approx. 1000 samples), but also some from smaller datasets such as ECOFLAT (in total approx. 500 samples). For some half of the benthos samples in this extended data set, sediment data are available.

The dataset as described by Ysebaert (2002) is an extended dataset that has been used in various other studies and projects. Therefore, it is advised to use this dataset also for the current validation of the ZES.1. Though the BIOMON and MOVE benthos data are freely available at RWS, and in theory only the remaining datasets would have to be purchased from the NIOO, it may be still useful to purchase the full set (including the BIOMON and MOVE data), as NIOO has removed the errors from the dataset. Though the data set is extended, it does not contain data from 1998 or later years. Therefore, it could be considered to include also some more recent datasets such as 'Walsoorden' in the validation of the ZES.1, or to ask NIOO to extend their dataset with more recent samples.

Yet another option would be to use the full dataset as is used by Wijnhoven et al. (2007), which is in standard database format and includes both the coupled benthos and abiotic parameters. This dataset is complete, up to date, and ready to use, so it would save a lot of work and time in the upcoming validation that would otherwise be necessary for the incorporation of data into a data-managing tool, and coupling these data with abiotic parameters.

5.2.2 Additional biological parameters

In addition to the benthos data discussed above, some other biological taxa could be indicative of ecotopes, and it might thus be useful to include them as dependent variables in the validation (see for instance Wijsman & Kesteloo (2007)). Potential candidates are cockles, demersal fish, phytoplankton and microphytobenthos. Cockle densities are monitored in the Cockle surveys (section 5.1.3) and demersal fish in the DFS (section 5.1.4). Phytoplankton is measured in the MWTL biological monitoring network (section 5.1.1), while microphytobenthos is measured in the MOVE-program (section 5.1.6), and chlorophyll concentration in the MWTL chemical monitoring network (section 4.1.1). Though plenty of data are available, actually obtaining them and incorporating them in a data management tool will depend on whether additional parameters are going to be included in the validation of the ZES.1.

Alternatively, some additional parameters could be included as *independent* variables in the ZES.1. A potential candidate is food availability, with biotic parameters such as phytoplankton concentration, chlorophyll concentration, or the amount of benthic chlorophyll, or with abiotic parameters such as suspended matter, turbidity, or light extinction. Phytoplankton and microphytobenthos are measured in the MWTL biological monitoring network (section 5.1.1), while suspended matter and turbidity are measured in the MWTL chemical monitoring network (section 4.1.1). Also various data sets resulting from short-term projects provide relevant data (section 5.1.6). Again, their relevance depends on whether additional parameters are going to be included in the validation of the ZES.1 or not.

Table 6 Overview of short term benthos projects in the Westerschelde. An 'X' in the second column indicates that also sediment samples were taken. An '(X)' indicates that only a sediment *description* is available.

Project	S.	Period	Area	# samples	Freq.	carried out by	in database
Raaien		1963, 1965, 1973, 1974	Transects in central and eastern part	5-15	1-3	NIOO-CEME	BIS
Raaien SMB		1978-1988	Transects		2	RUGent-SMB	BIS
Meiobenthos van de Westerschelde		1979-?	?	?	2	RUGent MARBIOL	
WAARDE	X	1987-1991, 2002, 2007	Eastern part	1987-1991:9 2002,2007:30	1-2	NIOO-CEME	BIS
MER containerhaven Galgeschor		1987-1988	Galgeschor Groot Buitenschor	3	1	RUGent-LED/IN	INBRU
SAWES1	(X)	1987-1988	Whole area	1987:28 1988:14	1	RUGent-LED	BIS, DONAR
SAWES2	(X)	1988	Western part	82	1	RUGent-LED	BIS, DONAR
Oost West		1989-1990	Valkenisse	50+	4	RUGent-LED	BIS
Gent-Vlissingen		1990	Gent-Vlissingen	30	1	NIOO-CEME	BIS
Gr. Buitenschor		1990-1991	Gr. buitenschor		--	NIOO-CEME	BIS
Monitoring Groot Buitenschor		1990-1998	Groot Buitenschor	1990: 21 '91-'98:24	1	RUGent-LED / INBO	BEDMAN INBRU
Microphyto-benthos of the Schelde estuary		1991-1992	Westerschelde and the Yzer estuary	75	12	RUGent/ Phycology	
M00050	X	1984	Mouth	13	1	RUGent-SMB	
Effektstudie baggerspecie Waarde	(X)	1987-1991	Mudflats of the Waarde	9	in total 8	RUGent-LED	BEDMAN INBRU
Impuls-programma Zee wetenschappen	X	1993-1994	Paulinapolder Valkenisse, Baalhoek, Groot Buitenschoor	5	12	INBO	
MOVE benthos survey	X	1994-2006	14 transects	40	2	NIOO-CEME	BIS, DONAR
MOVE benthos survey	X	1994-2006	Plot 4	20	2	NIOO-CEME, RWS	BIS, DONAR
Ecoflat		1995-1997	Molenplaat	1995:92 others:2 or 5	2-4	NIOO-CEME, RWS	BIS

MolenplaatI		1995	Molenplaat	84-92	2	NIOO-CEME	BIS
Platen WS		1996	Mudflats	92	1	NIOO-CEME	BIS
Cont.haven Sloe	X	2001	Kalloot	20	4	NIOO-CEME	BIS
MolenplaatII		2003	Molenplaat	1	1		BIS
Himom		2003	Kapellebank	3	3	NIOO-CEME	BIS
MarBef		2004	Rithem	90	1	NIOO-CEME	BIS
SRON	X	2004	Mudflats	25	1	NIOO-CEME	BIS
BIOCOMBE		2004	Western part	20	2	NIOO-CEME	BIS
Walsoorden	X	2004-2007	Central/eastern	100	2	NIOO-CEME	BIS
INRAM		2007-2008	Vlissingen	1		RUGent/ MARBIOL	

6 Data incorporation into data managing tool

One of the objectives of the current project was to bring the data together in a database and/or data managing tool, which would improve the data accessibility and its manageability and would thus facilitate the validation of the ZES. Initially, it was proposed to use UCIT as a data-managing tool. However, during the project it became clear that UCIT may not be the most efficient and effective choice. Instead of continuing as planned, it was decided to carefully consider the alternative options again. Besides UCIT, these options are Arc-GIS and ACCESS. Pros and cons of these three alternatives are discussed below.

The 'Universal Coastal Intelligence Toolkit' (UCIT, pronounced as *Use it!*), is a free information system developed by WL | Delft Hydraulics aimed at facilitating the use of data and (expert) knowledge in coastal problems (<http://UCIT.wldelft.nl>). It does so by providing flexible access to and integration of various types of measurement data (transect, grid, point and line data), analysis routines, and models. Heart of the system is a database and a Matlab toolbox with a great number of analysis routines. A primary benefit of the UCIT approach is an increased efficiency in dealing with the traditional data problems such as data format, structure and availability: the incorporated data sets are centrally available in a standard format. A secondary benefit is the availability of routines to perform a range of basic or advanced calculations/transformations directly to the data. Moreover, the flexible Matlab-environment enables a customization of all existing calculations or the addition of new calculations, including multivariate statistics. A third benefit is the direct coupling of data to Delft3D models.

Clearly, UCIT has many advantages, but the tool is still under development, and is as yet not very user-friendly. Furthermore, though UCIT already incorporates various data sets, only few of these deal with the Westerschelde, and no ecological data is incorporated in the database yet. Data incorporation would thus take relatively much time. Moreover, the benthos data that is purchased from NIOO-CEME may only be used for specific purposes and projects, and would have to be removed from UCIT after ending the LTV O&M project.

An alternative data management tool is the renowned software package Arc-GIS. Arc-GIS provides a toolbox with many routines specialized in spatial analyses such as interpolation. Also, linking Arc-GIS data with Delft3D models is possible, as two plug-ins exist for data preprocessing (enabling the use of Arc-GIS data in Delft3D models) and postprocessing (enabling the visualization of Delft3D results in Arc-GIS) (pers. comm. G. Boot). As a last advantage, the required bathymetric, water level, velocity, and salinity maps are already available in Arc-GIS format. Therefore, only the benthos data would still need to be incorporated, but these data may be provided directly in Arc-GIS format by NIOO-CEME.

Disadvantages of Arc-GIS are that the software package is expensive, and that data in Arc-GIS format cannot be imported in other software programs. Also, for more advanced analyses such as multivariate statistics, the data would have to be extracted and put into a standard database format. Another disadvantage of Arc-GIS over UCIT is that Arc-GIS lacks a central database functionality.

A third data-management option would be to use a standard database program such as ACCESS. Though ACCESS is a Microsoft program and is thus not freely available, it is not expensive and it is installed on almost any PC. Another advantage of using ACCESS would be that the data has a standard spreadsheet format, which can be imported in many other programs including specialized statistical programs. Furthermore, ACCESS enables a well-structured data organization. As a last advantage, all RWS data in DONAR (benthos and abiotic) have a standard database format, as well as all NIOO-CEME data in BIS, so that reformatting would not be necessary at all.

The main disadvantage of using ACCESS is that it does not provide a central database functionality. Furthermore, ACCESS allows for some simple data queries, but does not provide spatial or statistical analyses. Neither does it provide a direct link with Delft3D models.

It was decided not yet to incorporate all data in a data management tool, as first some decisions will have to be made. First it should be decided which benthos dataset will be purchased from NIOO: the full dataset, only the parts that are not yet available at RWS, or the full set including the coupled abiotic parameters. Obviously, this choice will also affect the choice for one of the management tools. Secondly, it has to be decided which party is going to carry out the validation of the ZES.1. In case it is going to be done by NIOO, purchasing benthos data will not be necessary, and neither will the incorporation of data in a data management tool. Clearly, these decisions will depend on the corresponding business-offer(s), and on future plans within LTV O&M.

As a temporal solution, the data that were used for making the ecotope-maps (and the ecotope maps themselves) were collected and stored on a project disc, to enable central accessibility. These data were obtained from Directie Zeeland (Imre Schep), and include grid maps (in Arc-GIS format) on:

- Depth/elevation (1996, 2001, and 2004) (section 2.2.1),
- Geomorphology (1996, 2001, and 2004) (section 2.2.1),
- Exposure time (1996, 2001, and 2004) (section 3.2.1),
- Average high and low water levels at neap and spring tide (1996, 2001, and 2004) (section 3.2.1),
- Maximum current velocity (1996, 2001, and 2004) (section 3.2.2),
- Salinity (1992) (section 3.2.3),
- Ecotopes (1996, 2001, 2004)

Together, these maps constitute most of the available abiotic data that are relevant for the validation of the ZES.1. These abiotic data, as well as the benthos data from BIOMON and MOVE, are also directly available from DONAR in database format. Once the necessary decisions have been made, reformatting and incorporation of these data in one of the other data management tools will be relatively straightforward.

7 Conclusions

First, it is concluded that more accurate data on maximum current velocities are needed. Unfortunately, such data are not available and measuring the velocities would require major efforts. Instead, the focus should lie on improving the underlying hydrodynamic models, but this lies beyond the scope of the subproject 'HVI Validatietechnieken'.

Secondly, due to small scale sediment variability, sediment composition should not be derived from a geomorphological map, but should be measured in the field at the exact locations of the benthos samples. Additional data sets containing such coupled sediment-benthos samples are available at NIOO-CEME. It is advised to use the extended benthos data as described by Ysebaert et al 2002. This dataset includes data from BIOMON, MOVE, and some smaller datasets such as ECOFLAT. Though the BIOMON and MOVE data on benthos are freely available at RWS, and in theory thus only the remaining datasets would have to be purchased from the NIOO, it should still be given serious consideration to purchase the full set (including the BIOMON and MOVE data), as NIOO has cleaned up the data considerably. A further option would be to purchase the full set including the coupled abiotic parameters as is used by Wijnhoven et al. (2007). In addition, it could be considered to include also some more recent datasets (from 1998 or later) such as 'Walsoorden' in the validation of the ZES.1.

Besides the abiotic parameters of the ZES.1 and the benthos data as described in section 5.2.1, additional parameters such as cockle density, demersal fish density, or food availability could also be used for validation. The parameters corresponding to food availability (such as phytoplankton, microphytobenthos, chlorophyll, suspended matter or turbidity) could serve both as dependent or independent variables. Relevant data are (mostly freely) available, but whether these data should be included in this project and in the data management tool depends on the intended scope of the validation and the choice to include additional independent parameters in the ZES or not.

Furthermore, a change was made with regard to the data management tool. Though initially it was proposed to use UCIT, during the project it became clear that this may not be the most efficient and effective choice. As yet, UCIT is not very user-friendly, and incorporating data in its database would require a lot of time. Also, the use of the benthos data purchased from the NIOO are restricted to use in one project only, and should be removed from UCIT after the validation has ended. Instead of continuing as planned, it was decided to carefully consider the alternative options. Considered alternatives are Arc-GIS and ACCESS, which both have their advantages and disadvantages. Though neither of these programs provide a true database functionality such as is available in UCIT, this problem could be solved by making the data centrally available on a project disc.

Finally, it became clear that before a choice for one of the data management tools can be made, first some other decisions have to be made. First it should be decided exactly which benthos dataset(s) will be purchased from NIOO and which party is going to carry out the validation of the ZES.1. If it is to be done by NIOO, purchasing benthos data will no longer

be necessary, and neither the incorporation of data in a data management tool. Clearly, these decisions will depend on the corresponding business-offer(s), and on future plans within LTV O&M.

As a temporary solution, the data that were used for making the ecotope-maps were collected and stored on a project disc, to enable central accessibility. Together, these maps constitute most of the available abiotic data that are relevant for the validation of the ZES.1. These abiotic data, as well as the benthos data from BIOMON and MOVE, are also directly available from DONAR in database format. NIOO may provide its data equally well in either format. Once the necessary decisions have been made, reformatting and incorporation of these data in one of the other data management tools will thus be relatively straightforward.

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Consulted people and websites

NIOO:	Wil Sijm, Sander Wijnhoven, Peter Herman, Herman Hummel
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VLIZ:	http://www.VLIZ.be
Scheldemonitor:	http://www.Scheldemonitor.nl
HMCZ:	http://www.HMCZ.nl
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MOVE :	Gertjan Liek, Harlette Holzhauser
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