GPS Survey NAM Waddenzee

Date: October 26, 2006
Author: ir. Jean-Paul Henry, 06-GPS
Version: 1.0

Date: April 1, 2009
Author: ir. Frank Dentz, 06-GPS
Checked: ir. Jean-Paul Henry, 06-GPS
Version: 1.13

06-GPS B.V.
Kubus 11
NL 3364 DG Sliedrecht
Tel.: 0184 – 44 89 00
Fax: 0184 – 44 89 09

e-mail: **info@06-gps.nl**
internet: **www.06-gps.nl**

Contents

1 Introduction

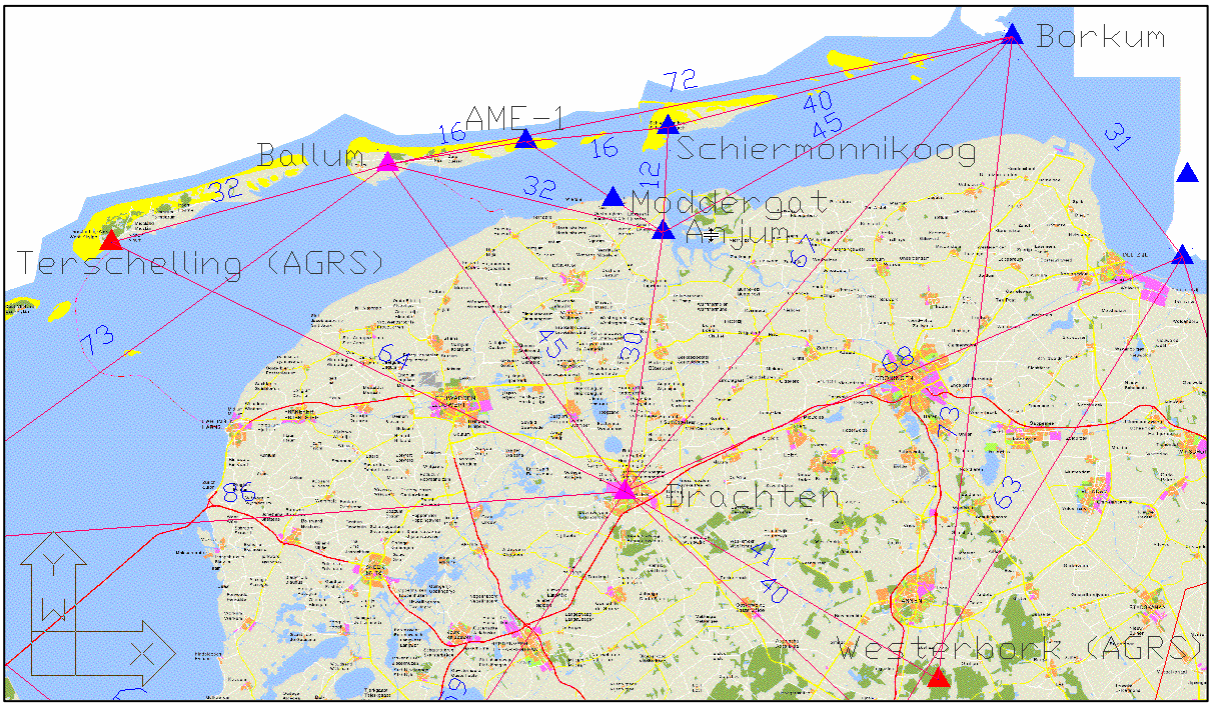
06-GPS has been assigned by SHELL / NAM to assist with a GPS survey and its processing for determining exact elevations of underground benchmarks in and around the Waddenzee. These surveys are expected to deliver elevations / heights with mm-accuracies. This report describes in short the activities as performed by 06-GPS concerning the preparations and actual GPS surveys. The main part however will describe the methods of how to process the GPS data to get the highest accuracy possible.

2 Preparation

For the positioning of the underground benchmarks in and around the Waddenzee it was necessary to use the technique of GPS post processing. This is a method of processing gathered GPS observations from both GPS reference stations (exactly known in position) as well as GPS observations from unknown points together to obtain relative but highly accurate positions for the unknown points. The use of fixed GPS receivers and antennas on well known points does not only make the results fit in the local coordinate system, but also creates conditions for determining and eliminating all the error sources that influence the quality of GPS positioning.

As a base three reference stations of the 06-GPS network for the Netherlands were used:
Ballum (Ameland), Drachten en Borkum (Germany). For better coverage and redundancy some extra stations in the direct neighbourhood of the Waddenzee area were build.
These stations are Schiermonnikoog, East Ameland (NAM plant AME-1) and Anjum (also a NAM location). The last two stations also have a permanent monitor function since they are located inside the area where subsidence due to gas extraction takes place. At the end of the year 2006 one more extra permanent monitor station has been build very near to the Moddergat NAM plant south of the Waddenzee. For an optimal fit within the Dutch geometrical infrastructure also two first order so called AGRS stations (Terschelling and Westerbork) are used in the computations.

This picture gives an impression of the situation and size (km-distances)of the GPS-infrastructure:



For all permanent stations as for the mobile GPS masts the same equipment is chosen. On all locations except for the AGRS-stations and Borkum a combination of a Topcon GB-1000 and a Topcon CR-3 choke ring antenna is used. All antennas are also individually calibrated so that their receiving characteristics are exactly known. Especially for an accurate determination of elevations/height it is necessary to have exact knowledge of the phase centre variations of the antennas. A simple comparison between individual antenna models shows that differences of 1 to 2 mm's exist between individual antennas.

Photos of the reference antennas placed in May, 2006 on respectively Schiermonnikoog and AME-1:

Photo of the reference antenna placed in December, 2006 nearby Moddergat:

All GPS reference antennas are also surveyed relatively to several nearby height benchmarks by means of levelling, to be able to detect (unsuspected) local deformation of the antennas.

3 Post-processing technique

For the GPS-processing “raw” observations per stations are collected with an interval of 15 seconds. The permanent stations have gathered data since May, 2006, while all mobile stations only collect observations for a typical 5 days per point.
Storing observations of the permanent stations is done in two different ways to minimise the risk of loosing data. Except for the governmental AGRS-stations all reference stations are connected to the 06-GPS control centre in Sliedrecht 24 hours per day either using KPN Managed VPN or a Shell VPN-connection to the stations of Anjum and East Ameland. Data is stored in the general used RINEX format (Receiver INdependent EXchange format). Next to the central RINEX storage all data is also stored on the internal Flash Memory card of the Topcon GPS receivers in a so called TPS-format (Topcon Positioning Systems). This TPS data serves as a back up in case of communication interruptions between Sliedrecht and one of the reference stations. Before the final processing all data has to be converted to the RINEX format. In these RINEX files phase- code- and dopppler observations are stored for both GPS frequencies L1 and L2 as well as Signal to Noise Ratios.

For the final post-processing NAM has chosen to use the GNSMART software of the Geo++ GmbH company from Hannover, Germany. GNSMART stands for “GNSS State Monitoring and Representation Technique”. In the year 2005 positive tests were realised with this software package at the Anjum site where deliberate lowering of the GPS-antenna could be detected at the mm-level within a few days of observation time.

The Geo++ software is able to deliver a highly accurate result for the combination of fixed, dynamic (Anjum, AME-1 and Moddergat) and unknown Waddenzee stations in one single processing with optimal use of antenna calibration models and modelling of all error sources involved with GPS surveying. Next to that it is able to deliver cross correlations between all individual stations making it a surveying tool comparable to optic levelling.

GNSMART
(This text has been copied from Geo++ documents).
Geo++® has developed the system GNPOM (Geodetic Navstar - Permanent Object Monitoring) to overcome the general restrictions using real time GNSS techniques. GNPOM is based on the multi-station real-time software GNNET, which is able to process the carrier phase observations of multiple receivers simultaneously. The result is not a set of single baselines, but a homogeneous set of coordinates with a realistic variance-covariance estimation for all stations.
For the processing the Software Package Geo++ GNSMART is used. GNSS-SMART stands for **S**tate **M**onitoring **A**nd **R**epresentation **T**echnique describing the essential concept, while GNSMART is the actual Geo++ software implementation of this technique. The GNSS errors must be precisely modelled and monitored to resolve phase ambiguities as a **primary task**. For any time and location within the covered network area sophisticated services must provide information on the GNSS errors based on the state monitoring. The methods for this **secondary task** are generally termed “representation technique”. This secondary task meets the requirements for the Waddenzee stations in and around the Waddenzee. In GNPOM the primary and secondary task can be done in one process, because all stations (reference and object station) are available at the central computer where GNSMART is running. As part of Geo++ GNSMART the program module GNNET enables a high precision GNSS multi-station processing. Normally GNNET processes the carrier phase measurements from single or dual frequency GPS and (optionally) GLONASS receivers in real time. Generally, the observations are provided by other program modules, for example reference station modules GNRT or GNREF. Thus, measurements from directly or indirectly accessible GNSS receivers or derived observations, e.g. RTCM correction, data can be processed. Depending on the individual application, GNNET can determine coordinates and/or system parameters such as atmospheric errors

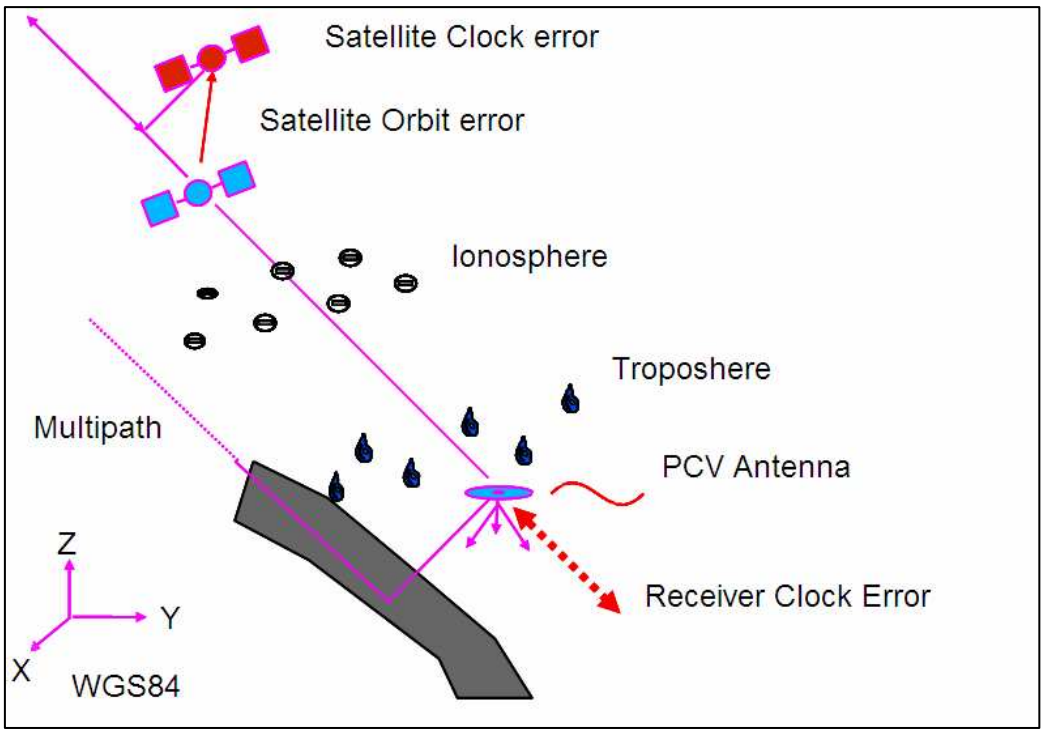
or orbit errors. The data set is based on RINEX observation. Therefore GNNET is run in post processing mode.

Consideration of GNSS errors

The modelling approach of GNSS is an important aspect. A complete state space model (SSM) with millimeter-accuracy is implemented for the rigorous and simultaneous adjustment of GNSS observables, which is essential for the **primary task**. The state space modeling follows the idea to model the actual error sources instead of handling the effects of the errors. The error effects belong to the observation space, while the error sources are associated with the state space. All error sources build up the state space model (SSM).To determine the (error) state of a GNSS system, GNSMART estimates the following state parameters:

- satellite clock synchronization error
- satellite signal delays (group delays)
- satellite orbit error (kinematic orbits)
- ionospheric signal propagation changes
- tropospheric signal delays
- receiver multipath (optional)
- carrier phase ambiguities
- receiver coordinates (optional)
- receiver clock synchronization error
- receiver signal delays (group delays)

The next picture is a simplified illustration of the main error sources and their influence on the distance measurements from receiver to satellite:



The state space modelling of GNSMART applies beforehand corrections to the GNSS observations.

The SSM model is prepared for the following corrections:

- satellite-receiver phase wind-up effect (satellite attitude)
- (absolute) satellite antenna PCV correction
- site displacement effect (solid earth tide, pole tide, ocean loading, atmospheric loading, local displacement)
- relativistic corrections
- higher order ionospheric correction
- (absolute) receiver antenna PCV correction

The extension of the network defines the significance of the corrections and consequently the quality of the state space modeling. In smaller networks, like the present six station network, some corrections can be neglected. Therefore GNSMART currently does not correct for loading effects and higher order ionosphere. The adjustment model is a Kalman filter for real time applications. The Kalman filter is proofed to be well suited for state estimation and monitoring tasks. The actual adjustment is a simultaneous adjustment of all L1 and L2 observations. Advantages of simultaneous L1/L2 adjustment are:

- rigorous modelling of correlations between linear combinations
- rigorous modelling of common parameters like L1-L2 delays for satellite and receiver
- improvement of noise level for derived state parameters

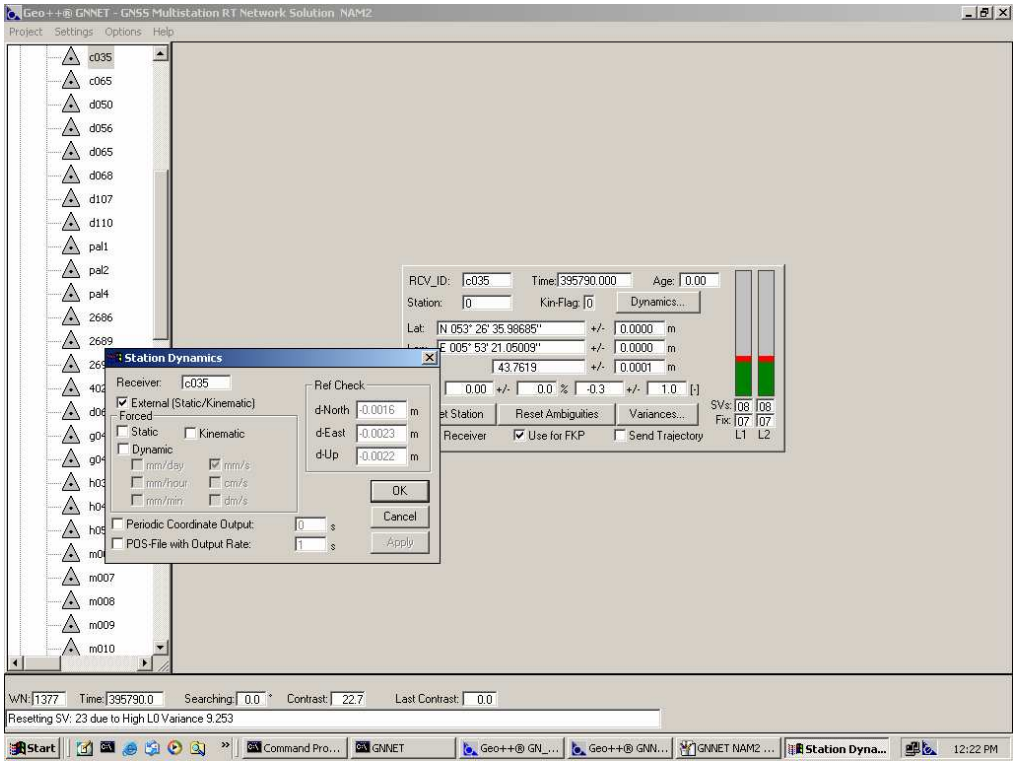
The separation and modelling of individual GNSS error components is straight forward using un-differenced or also termed non-differenced observations. The use of non-differenced observations is a key issue in ambiguity resolution, optimized modelling and processing in GNSMART. The advantages of non-differenced modelling and ambiguities are:

- network operates in absolute mode
- no mathematical correlation between observations
- robustness against failures of single reference stations
- optimal reliability

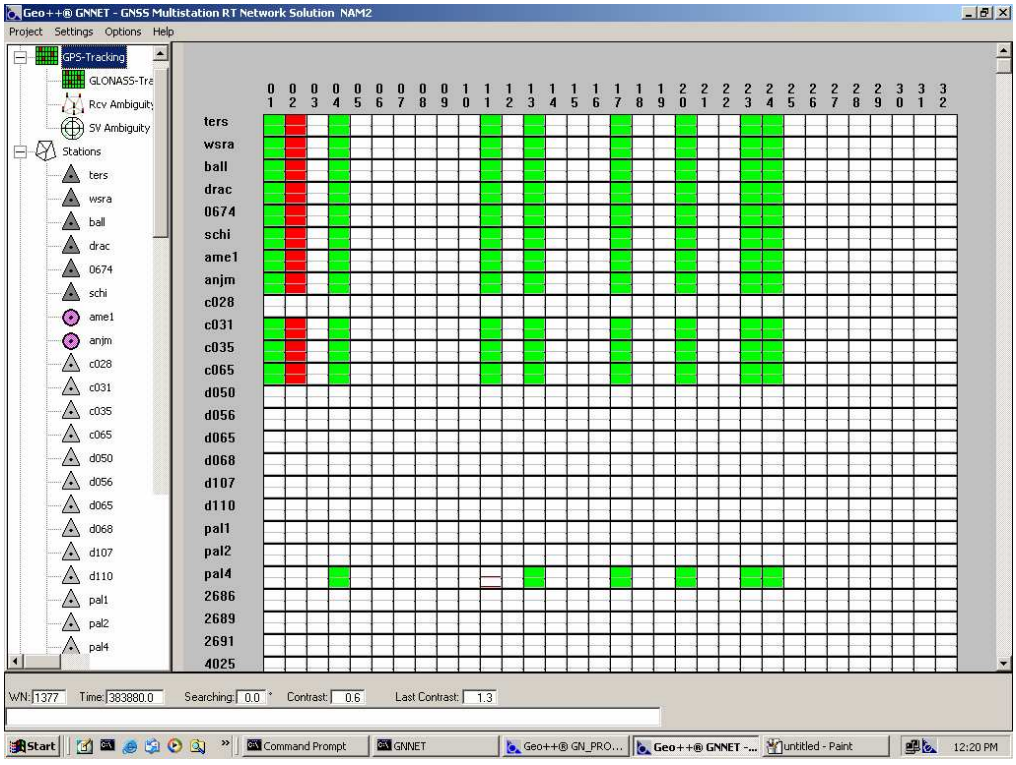
The use of differenced observations (i.e. double difference observable) and accordingly the use of baselines/triangles between reference stations is a limitation and a loss of information compared to the non-differenced approach. Information on the GNSS errors can be best obtained from the rigorous adjustment of multiple reference stations with sufficient redundancy and network size.

<u>Consideration of station dependent errors</u>
Multipath (MP) is the most limiting factor for very precise positioning applications with GNSS. Several MP mitigation techniques are known and implemented in many receiver types. However, these techniques normally only attack the code MP effects. MP errors in carrier phase measurements are much more complicated to be mitigated through signal tracking techniques. All GPS receivers from Topcon use the AMR (Advanced Multipath Mitigation) technique for both code and phase observations. Also all antennas have been chosen to be choke ring antennas which are much less receptive for multipath than normal, light rover antennas.
Geodetic and precise GPS measurements make the exact knowledge of the reception characteristics of the used antennas and therefore a calibration necessary. Intensive use of such characteristic have been made in the development of the absolute antenna calibration method. All used antennas in this project are individually calibrated.

Station parameters for point c035:



GPS Tracking status for several reference and unknown stations:



Further aspects of GNSMART processing:

- one rigorous solution of all stations, fixed, dynamic or unknown
- all correlations known in 1 run
- uses Ultra rapid Precise orbits
- all RINEX data needs to be converted to internal Geo++ format (*.zdb files) using the reference station module GNREF
- Very heavy computations
- Processing has to wait for end of survey campaign

Processing steps

The following steps have been taken for the processing:

General

- checking completeness of Ballum, Drachten and Borkum data
- repairing gaps Ballum and Drachten with locally stored data
- downloading tps-data from Schiermonnikoog, East Ameland, Anjum and Moddergat
- converting tps data to RINEX
- downloading AGRS data
- conversion AGRS data to RINEX with inverse Hatanaka compression
- conversion of tps data from Waddenzee points to RINEX format

GNSMART

- gathering of Precise Ephemerides from internet (IGS sites)
- converting of broadcast navigation files into one overall file per day
- conversion of all RINEX file into .zdb files using the accurate position from VRS processing, antenna information and antenna heights
- running of GNNET with options of station dynamics, numbers of stations to process, etc. (see previous page for some screen dumps of GNNET)
- conversion of ETRS89 XYZ results into Latitude, Longitude and Height.
- Sorting of LLH data per station.
- Graphical analysis

Of course the GPS results give a height of each ARP (Antenna Reference Point); in our case always the bottom of the antenna. Additional measurements have taken place for the antenna heights: the vertical distance between unknown point and ARP. Every mast used has a different length and throughout the project these distances have been monitored, carefully.
Only after relating the ARP heights to the actual survey points the data can be imported in the deformation analysing software and databases of the NAM. These offsets were measured and reported separately by Fugro Inpark.

4 Results

In order to obtain the best results it was first necessary to have good reference station coordinates that are not only good in absolute position, but also very homogenous: discrepancies should be as small as possible.

After having gathered a complete month (july 2006) of data all reference stations were evaluated with the GNSMART solution. Also the data of the AGRS stations Terschelling and Westerbork was entered and only these two stations and station Borkum were kept fixed. This dataset is used for all GNSMART processing. An overview of the coordinate can be found in Appendix I.
On July 12th 2007 station Borkum was moved a few meters and the equipment was modernized (station 0687 in stead of 0674). A month of data was used to determine the new coordinates of Borkum using a new individual antenna calibration file and the data of all other stations to guarantee homogenous coordinates again.

GNSMART results Waddenzee points 2006 - 2008
In Appendix II all the Waddenzee points as well as underground benchmarks on land and the Lauwersmeer and Grijpskerk points are shown including their observation times.

The NAP Elevation of the wad points can be obtained by subtracting the levelling offsets from the NAP heights of the antenna reference points (ARP). These offsets were measured and reported separately by Fugro Inpark.

GNSMART results Monitor Stations on land 2006 - 2008
In Appendix III plots are shown for the GNSMART results for the 3 dynamic stations AME1, Anjum and Moddergat. From GPS days 145 2006 to day 003 2009 the elevations are shown and one can see the linear trend over 2007 and 2008. The position filter used is a mm/hour filter. Although the results show some movement a subsidence is clearly visible. The trend (straight line) is determined by using a linear least squares approximation. The standard deviation of this least squares approximation is about 0.6mm.
The following table contains the annual subsidence rates over 2007 and 2008 for the three monitor stations:

Monitor Station	Subsidence rates 2007 (mm/year)	Subsidence rates 2008 (mm/year)
Ameland 1 (AME1)	7.9	6.9
Anjum (ANJM)	4.6	2.6
Moddergat (MODD)	1.5	0.6

APPENDIX I: reference station parameters

Reference Coordinate overview for all permanent stations together with information about the antenna type and number:

GNSMART

Station	owner	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ser. no. ant.	ant. Type	
0674	SAPOS	53	33	49.10129	6	44	50.79499	54.2100	245130.275	620586.321	14.026	0.053	220180416	TRM29659.00	SNOW
0687	SAPOS	53	33	49.15550	6	44	50.78800	54.4070	245130.114	620587.995	14.223	0.054	200110	LEIAT504GG	LEIS
ame1	NAM	*53*	*27*	*51.94252*	*5*	*55*	*16.80639*	*48.0146*	*190474.978*	*608822.469*	*7.421*	0.148	2170510	TPSCR3_GGD	CONE
anjm	NAM	*53*	*22*	*15.04173*	*6*	*9*	*8.59165*	*45.2834*	*205931.145*	*598546.039*	*4.657*	0.000	2170642	TPSCR3_GGD	CONE
modd	NAM	*53*	*24*	*19.27160*	*6*	*4*	*2.98546*	*47.4273*	*200244.559*	*602329.794*	*6.815*	0.147	2170639	TPSCR3_GGD	CONE
ball	06-GPS	53	26	29.58829	5	41	15.67011	54.5499	174967.385	606186.357	13.721	0.101	2170556	TPSCR3_GGD	CONE
drac	06-GPS	53	6	31.75441	6	4	58.04678	56.3542	201580.590	569339.057	15.040	0.147	2170593	TPSCR3_GGD	CONE
schi	NAM	53	28	38.43917	6	9	44.16452	50.8109	206461.096	610405.714	10.355	0.148	2170643	TPSCR3_GGD	CONE

Station	owner	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ser. no. ant.	ant. Type
ters	AGRS	53	21	45.84903	5	13	9.78826	56.1008	143827.236	597385.497	14.689	0.000	220193243	TRM29659.00
wsra	AGRS	52	54	52.58929	6	36	16.20650	82.2751	236880.508	548192.306	40.725	0.389	273	AOAD/M_T

APPENDIX II: GNSMART results Waddenzee points 2006 - 2008 plus overview maps

GNSMART processing Waddenzee, NES, Lauwersmeer and Grijpskerk 2006

Operator: 06-GPS

Date: 10-8-2007

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
0674	SAPOS	fixed			53	33	49.10129	6	44	50.79499	54.2100	0.053	54.2630	245130.275	620586.321	14.026	0.053	14.079	220180416	TRM29659.00	SNOW
ball	06-GPS	fixed			53	26	29.58829	5	41	15.67011	54.5499	0.101	54.6509	174967.385	606186.357	13.721	0.101	13.822	2170556	TPSCR3_GGD	CONE
drac	06-GPS	fixed			53	6	31.75441	6	4	58.04678	56.3542	0.147	56.5012	201580.590	569339.057	15.040	0.147	15.187	2170593	TPSCR3_GGD	CONE
schi	NAM	fixed			53	28	38.43917	6	9	44.16452	50.8109	0.148	50.9589	206461.096	610405.714	10.355	0.148	10.503	2170643	TPSCR3_GGD	CONE

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type
ters	AGRS	fixed			53	21	45.84903	5	13	9.78826	56.1008	0.000	56.1008	143827.236	597385.497	14.689	0.000	14.689	220193243	TRM29659.00
wsra	AGRS	fixed			52	54	52.58929	6	36	16.20650	82.2751	0.389	82.6641	236880.508	548192.306	40.725	0.389	41.114	273	AOAD/M_T

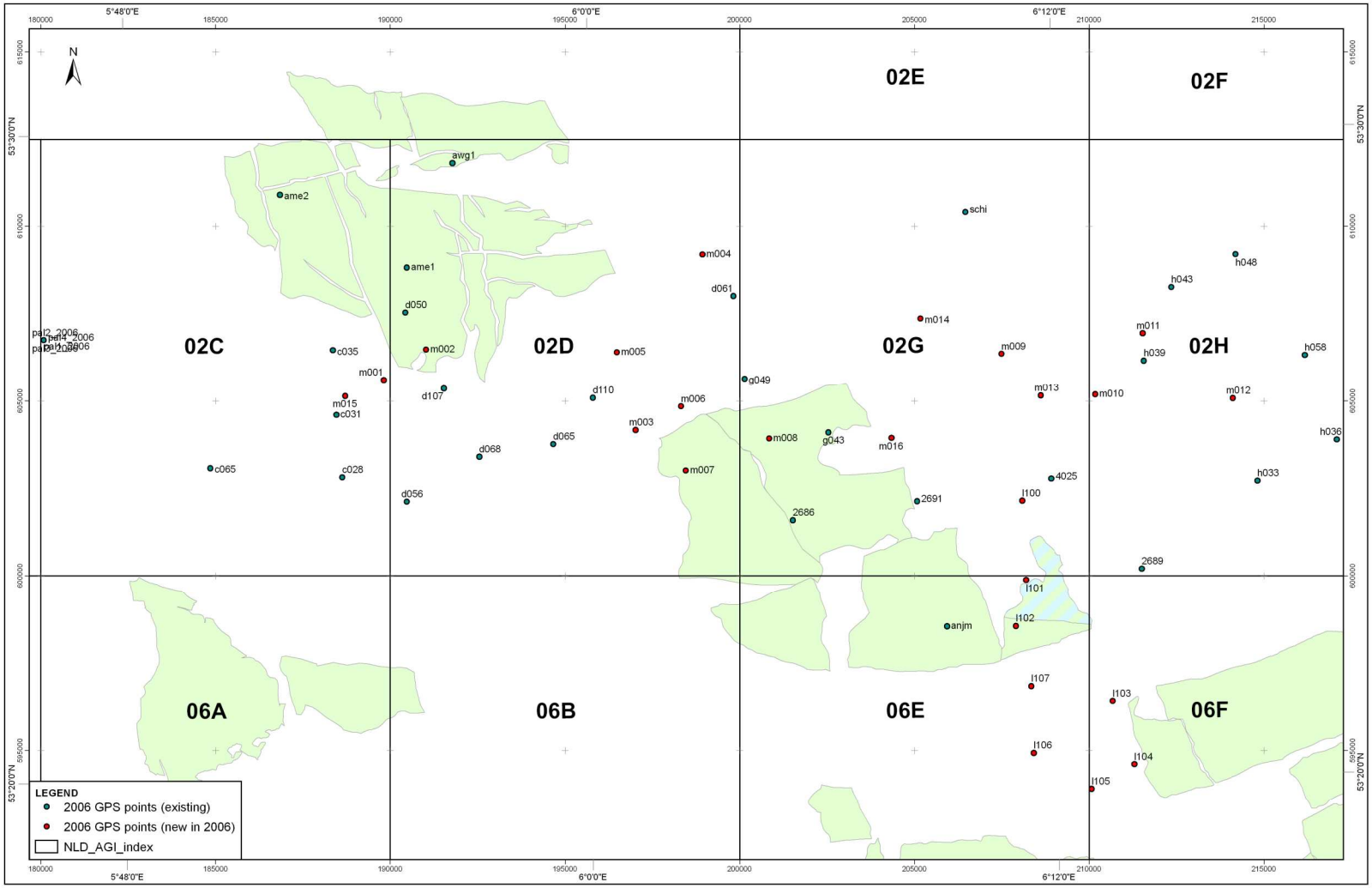
Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
ame1	NAM	231	j	19-8-2006	53	27	51.94252	5	55	16.80639	48.0131	0.148	48.1611	190474.978	608822.469	7.419	0.148	7.567	2170510	TPSCR3_GGD	CONE
anjm	NAM	231	j	19-8-2006	53	22	15.04173	6	9	8.59165	45.2831	0.000	45.2831	205931.145	598546.039	4.657	0.000	4.657	2170642	TPSCR3_GGD	CONE

Station Waddenzee		GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
2686	OA2686	205	h	24-7-2006	53	23	55.03241	6	5	11.58759	45.8130	0.000	45.8130	201519.194	601592.605	5.198	0.000	5.198	2170628	TPSCR3_GGD	CONE
2689	OA2689	186	k	5-7-2006	53	23	6.63993	6	14	11.21185	43.9562	0.000	43.9562	211507.364	600203.909	3.396	0.000	3.396	2170639	TPSCR3_GGD	CONE
2691	OA2691	198	k	17-7-2006	53	24	11.28179	6	8	24.27264	46.2653	0.000	46.2653	205074.132	602130.891	5.684	0.000	5.684	2170628	TPSCR3_GGD	CONE
4025	OA4025	210	r	29-7-2006	53	24	30.91220	6	11	52.49942	48.7620	0.000	48.7620	208914.240	602779.561	8.218	0.000	8.218	2170628	TPSCR3_GGD	CONE

c028	2C0028	162	n	11-6-2006	53	24	38.02227	5	53	34.26421	43.6227	0.000	43.6227		188625.315	602813.658	2.904	0.000	2.904	2170639	TPSCR3_GGD	CONE
c031	2C0031	155	g	4-6-2006	53	25	35.75089	5	53	25.67546	43.6470	0.000	43.6470		188454.180	604597.236	2.958	0.000	2.958	2170639	TPSCR3_GGD	CONE
c035	2C0035	157	i	6-6-2006	53	26	35.98683	5	53	21.05011	43.7617	0.000	43.7617		188355.777	606458.856	3.103	0.000	3.103	2170628	TPSCR3_GGD	CONE
c065	2C0065	153	d	2-6-2006	53	24	47.22433	5	50	10.25247	44.2272	0.000	44.2272		184854.984	603073.135	3.469	0.000	3.469	2170626	TPSCR3_GGD	CONE
d050	2D0050	164	n	13-6-2006	53	27	10.40297	5	55	14.01566	44.1785	0.000	44.1785		190433.019	607537.862	3.563	0.000	3.563	2170628	TPSCR3_GGD	CONE
d056	2D0056	174	l	23-6-2006	53	24	15.08393	5	55	14.02781	43.6905	0.000	43.6905		190473.428	602117.836	2.984	0.000	2.984	2170626	TPSCR3_GGD	CONE
d061	2D0061	178	n	27-6-2006	53	27	22.96277	6	3	42.72470	45.4528	0.000	45.4528		199816.981	608005.084	4.921	0.000	4.921	2170640	TPSCR3_GGD	CONE
d065	2D0065	168	f	17-6-2006	53	25	7.17590	5	59	1.71138	43.5803	0.000	43.5803		194666.505	603761.321	2.948	0.000	2.948	2170626	TPSCR3_GGD	CONE
d068	2D0068	166	p	15-6-2006	53	24	56.05825	5	57	6.60893	43.8702	0.000	43.8702		192543.417	603400.441	3.211	0.000	3.211	2170640	TPSCR3_GGD	CONE
d107	2D0107	160	k	9-6-2006	53	25	59.63059	5	56	12.74178	43.4600	0.000	43.4600		191533.473	605358.074	2.822	0.000	2.822	2170640	TPSCR3_GGD	CONE
d110	2D0110	170	f	19-6-2006	53	25	49.83129	6	0	3.69777	44.1699	0.000	44.1699		195800.046	605089.656	3.568	0.000	3.568	2170628	TPSCR3_GGD	CONE
g043	2G0043	181	f	30-6-2006	53	25	15.80987	6	6	8.04372	44.1013	0.000	44.1013		202537.498	604100.077	3.531	0.000	3.531	2170626	TPSCR3_GGD	CONE
g049	2G0049	186	g	5-7-2006	53	26	6.37338	6	3	58.89715	43.6931	0.000	43.6931		200137.765	605640.121	3.130	0.000	3.13	2170639	TPSCR3_GGD	CONE
h033	2H0033	219	k	7-8-2006	53	24	26.73922	6	17	11.87499	43.6014	0.000	43.6014		214815.481	602720.678	3.101	0.000	3.101	2170639	TPSCR3_GGD	CONE
h036	2H0036	228	s	16-8-2006	53	25	3.80587	6	19	15.26486	43.8694	0.000	43.8694		217079.936	603895.609	3.402	0.000	3.402	2170639	TPSCR3_GGD	CONE
h039	2H0039	190	j	9-7-2006	53	26	19.44854	6	14	18.02732	44.5079	0.000	44.5079		211562.765	606165.962	4.030	0.000	4.03	2170640	TPSCR3_GGD	CONE
h043	2H0043	184	f	3-7-2006	53	27	27.04844	6	15	1.99925	43.7375	0.000	43.7375		212349.349	608265.475	3.295	0.000	3.295	2170640	TPSCR3_GGD	CONE
h048	2H0048	231	j	19-8-2006	53	27	56.62090	6	16	42.47593	43.7053	0.000	43.7053		214191.923	609202.327	3.290	0.000	3.29	2170626	TPSCR3_GGD	CONE
h058	2H0058	188	i	7-7-2006	53	26	22.75407	6	18	27.49826	44.0874	0.000	44.0874		216166.511	606324.875	3.647	0.000	3.647	2170626	TPSCR3_GGD	CONE
m001		222	n	10-8-2006	53	26	7.99561	5	54	39.83071	43.5908	0.000	43.5908		189816.224	605603.869	2.936	0.000	2.936	2170640	TPSCR3_GGD	CONE
m002		221	n	9-8-2006	53	26	35.83770	5	55	45.69337	43.5927	0.000	43.5927		191025.656	606473.635	2.967	0.000	2.967	2170626	TPSCR3_GGD	CONE
m003		215	e	3-8-2006	53	25	19.63159	6	1	9.33138	44.3200	0.000	44.3200		197020.070	604166.538	3.713	0.000	3.713	2170626	TPSCR3_GGD	CONE
m004		178	l	27-6-2006	53	28	1.57049	6	2	55.13899	44.8069	0.000	44.8069		198927.941	609190.495	4.287	0.000	4.287	2170628	TPSCR3_GGD	CONE
m005		208	l	27-7-2006	53	26	32.01564	6	0	41.41410	44.5727	0.000	44.5727		196485.092	606399.792	3.996	0.000	3.996	2170640	TPSCR3_GGD	CONE
m006		214	g	2-8-2006	53	25	41.05154	6	2	20.20155	43.8185	0.000	43.8185		198322.819	604840.424	3.231	0.000	3.231	2170640	TPSCR3_GGD	CONE
m007		206	m	25-7-2006	53	24	41.68937	6	2	26.58380	44.0207	0.000	44.0207		198457.340	603006.317	3.406	0.000	3.406	2170626	TPSCR3_GGD	CONE
m008		202	i	21-7-2006	53	25	10.47012	6	4	36.11249	44.0807	0.000	44.0807		200841.374	603918.416	3.497	0.000	3.497	2170640	TPSCR3_GGD	CONE

m009		198	e	17-7-2006	53	26	27.04000	6	10	37.80202	44.2611	0.000	44.2611		207494.959	606354.267	3.756	0.000	3.756	2170639	TPSCR3_GGD	CONE
m010		192	m	11-7-2006	53	25	48.45509	6	13	2.08206	43.9265	0.000	43.9265		210171.926	605191.422	3.425	0.000	3.425	2170639	TPSCR3_GGD	CONE
m011		210	e	29-7-2006	53	26	44.81334	6	14	16.74814	44.5394	0.000	44.5394		211529.869	606949.829	4.072	0.000	4.072	2170639	TPSCR3_GGD	CONE
m012		200	g	19-7-2006	53	25	43.37993	6	16	35.19250	44.1981	0.000	44.1981		214108.539	605081.553	3.725	0.000	3.725	2170626	TPSCR3_GGD	CONE
m013		194	o	13-7-2006	53	25	47.87474	6	11	37.70086	43.3221	0.000	43.3221		208614.186	605155.755	2.809	0.000	2.809	2170626	TPSCR3_GGD	CONE
m014		196	d	15-7-2006	53	27	0.56298	6	8	32.72209	44.6332	0.000	44.6332		205175.280	607365.822	4.125	0.000	4.125	2170640	TPSCR3_GGD	CONE
m015		204	l	23-7-2006	53	25	53.26568	5	53	40.02823	43.6752	0.000	43.6752		188715.391	605140.572	2.999	0.000	2.999	2170639	TPSCR3_GGD	CONE
m016		229	f	17-8-2006	53	25	9.86559	6	7	45.54013	44.2172	0.000	44.2172		204339.870	603934.554	3.656	0.000	3.656	2170640	TPSCR3_GGD	CONE
pal1_2006	Nes	159	l	8-6-2006	53	26	46.90931	5	45	53.11527	49.6692	0.000	49.6692		180085.922	606746.014	8.917	0.000	8.917	2170626	TPSCR3_GGD	CONE
pal2_2006	Nes	173	h	22-6-2006	53	26	46.91124	5	45	53.11421	49.6660	0.000	49.6660		180085.902	606746.074	8.914	0.000	8.914	2170639	TPSCR3_GGD	CONE
pal3_2006	Nes	192	g	11-7-2006	53	26	46.90882	5	45	53.11531	49.6661	0.000	49.6661		180085.923	606745.999	8.914	0.000	8.914	2170628	TPSCR3_GGD	CONE
pal4_2006	Nes	152	l	1-6-2006	53	26	46.91007	5	45	53.11576	49.6648	0.000	49.6648		180085.931	606746.038	8.913	0.000	8.913	2170640	TPSCR3_GGD	CONE
l100		254	f	11-9-2006	53	24	10.77766	6	11	6.95316	44.4329	0.000	44.4329		208079.796	602147.705	3.874	0.000	3.874	2170640	TPSCR3_GGD	CONE
l101		254	i	11-9-2006	53	22	57.32078	6	11	11.96404	44.4919	0.000	44.4919		208197.615	599877.861	3.902	0.000	3.902	2170626	TPSCR3_GGD	CONE
l102		263	f	20-9-2006	53	22	14.52646	6	10	55.55928	44.4746	0.000	44.4746		207909.015	598551.549	3.863	0.000	3.863	2170626	TPSCR3_GGD	CONE
l103		247	l	4-9-2006	53	21	4.17227	6	13	23.97293	44.4293	0.000	44.4293		210678.272	596407.728	3.808	0.000	3.808	2170626	TPSCR3_GGD	CONE
l104		263	i	20-9-2006	53	20	5.63512	6	13	56.17303	45.4458	0.000	45.4458		211295.131	594605.091	4.802	0.000	4.802	2170628	TPSCR3_GGD	CONE
l105		257	g	14-9-2006	53	19	43.31404	6	12	49.85257	45.5905	0.000	45.5905		210075.858	593900.812	4.925	0.000	4.925	2170628	TPSCR3_GGD	CONE
l106		254	g	11-9-2006	53	20	17.27984	6	11	20.66661	44.2632	0.000	44.2632		208413.614	594932.146	3.601	0.000	3.601	2170639	TPSCR3_GGD	CONE
l107		247	g	4-9-2006	53	21	18.8153	6	11	18.12325	44.3863	0.000	44.3863		208345.374	596833.920	3.753	0.000	3.753	2170639	TPSCR3_GGD	CONE
gr01	Gr'kerk	271	x	28-9-2006	53	16	51.15124	6	18	25.53842	46.2214	0.000	46.2214		216356.274	588654.144	5.511	0.000	5.511	2170626	TPSCR3_GGD	CONE
gr02	Gr'kerk	271	x	28-9-2006	53	16	51.41382	6	18	25.53854	46.0138	0.000	46.0138		216356.173	588662.261	5.303	0.000	5.303	2170639	TPSCR3_GGD	CONE
gr03	Gr'kerk	270	q	27-9-2006	53	16	51.67243	6	18	25.53688	46.2093	0.000	46.2093		216356.040	588670.255	5.499	0.000	5.499	2170628	TPSCR3_GGD	CONE
gr04	Gr'kerk	271	x	28-9-2006	53	16	51.92875	6	18	25.54089	45.9871	0.000	45.9871		216356.013	588678.180	5.277	0.000	5.277	2170640	TPSCR3_GGD	CONE
ame2	NAM	319	x	15-11-2006	53	28	59.89339	5	52	0.69925	69.7759	0.000	69.7759		186842.964	610897.745	29.176	0.000	29.176	2170639	TPSCR3_GGD	CONE
awg1	NAM	320	x	16-11-2006	53	29	28.82919	5	56	28.72303	79.3532	0.000	79.3532		191778.669	611827.868	38.820	0.000	38.820	2170626	TPSCR3_GGD	CONE

Overview Map 2006



GNSMART processing Waddenzee, NES 2007

Operator: 06-GPS

Date: 10-8-2007

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
0674	SAPOS	fixed before 3-6-2007			53	33	49.10129	6	44	50.79499	54.2100	0.053	54.2630	245130.275	620586.321	14.026	0.053	14.079	220180416	TRM29659.00	SNOW
0687	SAPOS	fixed after 5-6-2007			53	33	49.15550	6	44	50.78800	54.4070	0.054	54.4610	245130.114	620587.995	14.223	0.054	14.277	200110	LEIAT504GG	
ball	06-GPS	fixed			53	26	29.58829	5	41	15.67011	54.5499	0.101	54.6509	174967.385	606186.357	13.721	0.101	13.822	2170556	TPSCR3_GGD	CONE
drac	06-GPS	fixed			53	6	31.75441	6	4	58.04678	56.3542	0.147	56.5012	201580.590	569339.057	15.040	0.147	15.187	2170593	TPSCR3_GGD	CONE
schi	NAM	fixed			53	28	38.43917	6	9	44.16452	50.8109	0.148	50.9589	206461.096	610405.714	10.355	0.148	10.503	2170643	TPSCR3_GGD	CONE

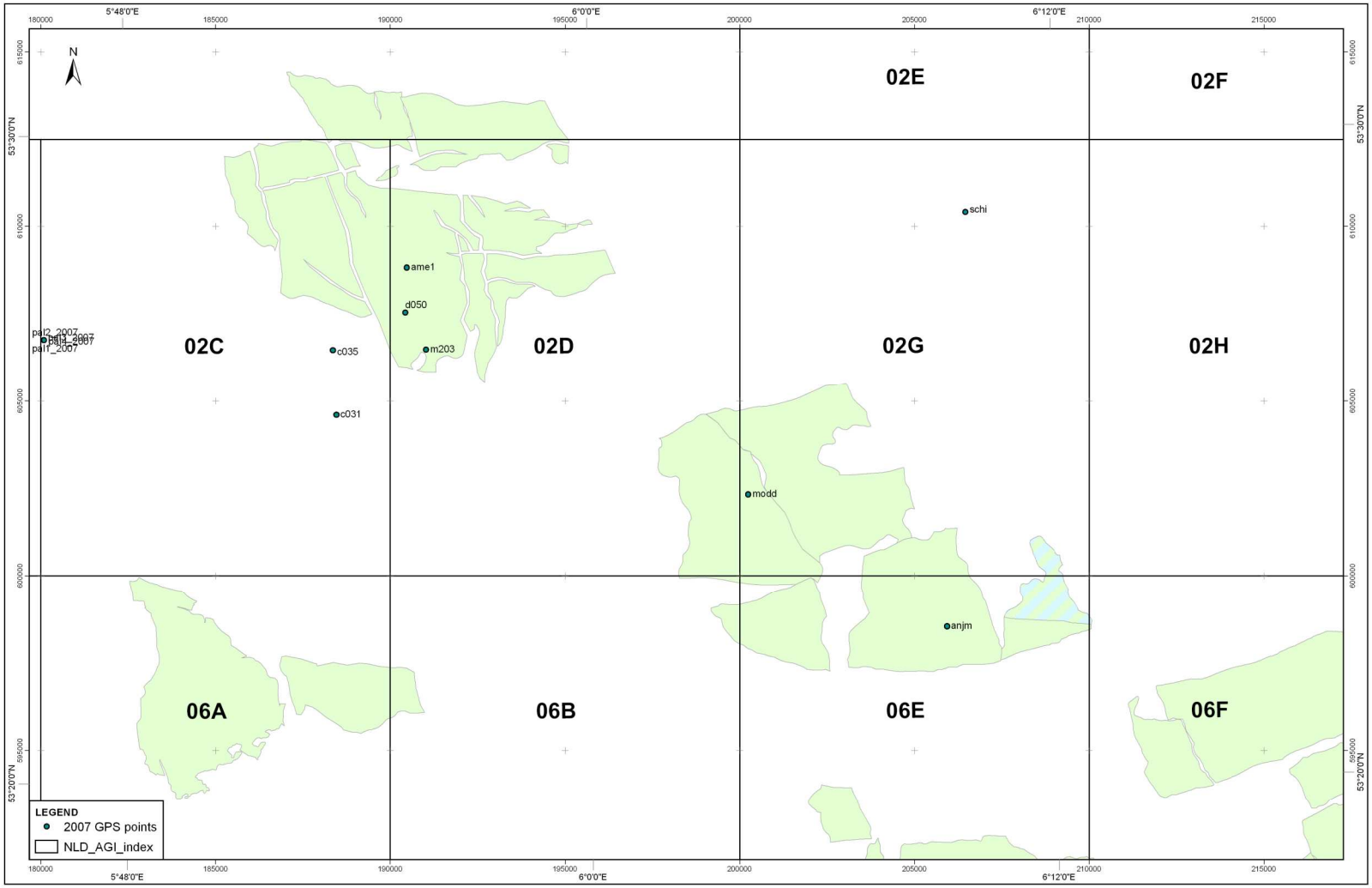
Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type
ters	AGRS	fixed			53	21	45.84903	5	13	9.78826	56.1008	0.000	56.1008	143827.236	597385.497	14.689	0.000	14.689	220193243	TRM29659.00
wsra	AGRS	fixed			52	54	52.58929	6	36	16.20650	82.2751	0.389	82.6641	236880.508	548192.306	40.725	0.389	41.114	273	AOAD/M_T

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
ame1	NAM	188	x	7-7-2007	53	27	51.94252	5	55	16.80639	48.0064	0.148	48.1544	190474.978	608822.469	7.412	0.148	7.560	2170510	TPSCR3_GGD	CONE
anjm	NAM	188	x	7-7-2007	53	22	15.04173	6	9	8.59165	45.2793	0.000	45.2793	205931.145	598546.039	4.653	0.000	4.653	2170642	TPSCR3_GGD	CONE
modd	NAM	188	x	7-7-2007	53	24	19.27159	6	4	2.98541	47.4195	0.147	47.5665	200244.559	602329.794	6.807	0.147	6.954	2170639	TPSCR3_GGD	CONE

Station Waddenzee		GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
c031	2C0031	183	o	2-7-2007	53	25	35.74948	5	53	25.67714	43.6628	0.000	43.6628	188454.211	604597.192	2.974	0.000	2.974	2170640	TPSCR3_GGD	CONE
c035	2C0035	170	n	19-6-2007	53	26	35.98647	5	53	21.05131	43.7109	0.000	43.7109	188355.799	606458.845	3.053	0.000	3.053	2170626	TPSCR3_GGD	CONE
d050	2D0050	170	h	19-6-2007	53	27	10.40307	5	55	14.01874	44.1726	0.000	44.1726	190433.076	607537.865	3.557	0.000	3.557	2170628	TPSCR3_GGD	CONE
m203/m002		171	t	20-6-2007	53	26	35.83732	5	55	45.69470	43.5771	0.000	43.5771	191025.680	606473.623	2.951	0.000	2.951	2170770	TPSCR3_GGD	CONE

pal1_2007	Nes	187	f	6-7-2007	53	26	46.91508	5	45	53.01786	49.7114	0.000	49.7114		180084.123	606746.183	8.959	0.000	8.959	2170626	TPSCR3_GGD	CONE
pal2_2007	Nes	187	f	6-7-2007	53	26	46.93934	5	45	53.19455	49.6920	0.000	49.6920		180087.380	606746.950	8.940	0.000	8.940	2170770	TPSCR3_GGD	CONE
pal3_2007	Nes	187	h	6-7-2007	53	26	46.96491	5	45	53.38297	49.6907	0.000	49.6907		180090.854	606747.759	8.939	0.000	8.939	2170628	TPSCR3_GGD	CONE
pal4_2007	Nes	187	h	6-7-2007	53	26	46.98782	5	45	53.57363	49.6402	0.000	49.6402		180094.369	606748.486	8.888	0.000	8.888	2170640	TPSCR3_GGD	CONE

Overview Map 2007



GNSMART processing Waddenzee 2008

Operator: 06-GPS

Date: 11-9-2008

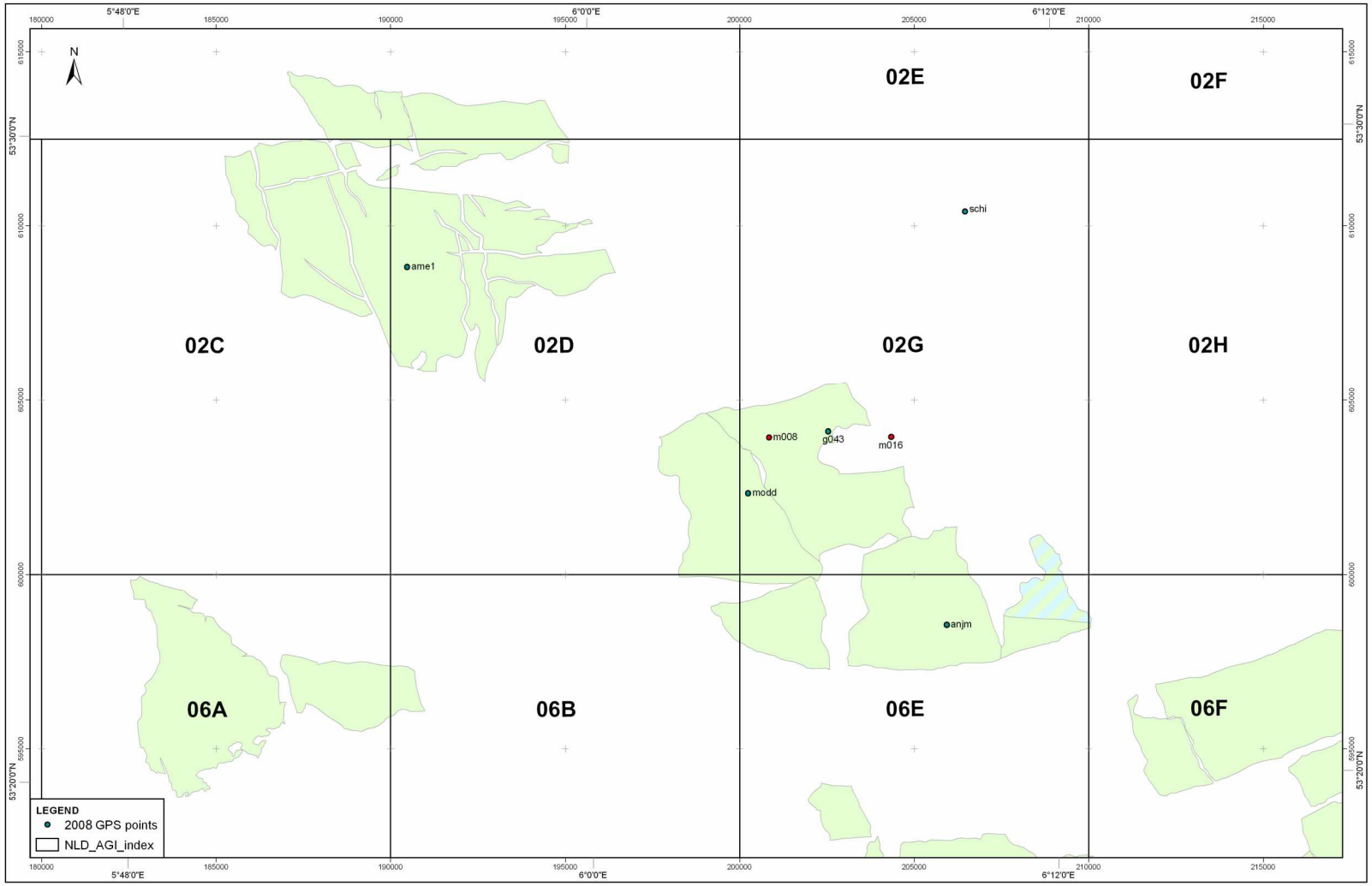
Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
0674	SAPOS	fixed before 3-6-2007			53	33	49.10129	6	44	50.79499	54.2100	0.053	54.2630	245130.275	620586.321	14.026	0.053	14.079	220180416	TRM29659.00	SNOW
0687	SAPOS	fixed after 5-6-2007			53	33	49.15550	6	44	50.78800	54.4070	0.054	54.4610	245130.114	620587.995	14.223	0.054	14.277	200110	LEIAT504GG	
ball	06-GPS	fixed			53	26	29.58829	5	41	15.67011	54.5499	0.101	54.6509	174967.385	606186.357	13.721	0.101	13.822	2170556	TPSCR3_GGD	CONE
drac	06-GPS	fixed			53	6	31.75441	6	4	58.04678	56.3542	0.147	56.5012	201580.590	569339.057	15.040	0.147	15.187	2170593	TPSCR3_GGD	CONE
schi	NAM	fixed			53	28	38.43917	6	9	44.16452	50.8109	0.148	50.9589	206461.096	610405.714	10.355	0.148	10.503	2170643	TPSCR3_GGD	CONE

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type
ters	AGRS	fixed			53	21	45.84903	5	13	9.78826	56.1008	0.000	56.1008	143827.236	597385.497	14.689	0.000	14.689	220193243	TRM29659.00
wsra	AGRS	fixed			52	54	52.58929	6	36	16.20650	82.2751	0.389	82.6641	236880.508	548192.306	40.725	0.389	41.114	273	AOAD/M_T

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
ame1	NAM	218	x	5-8-2008	53	27	51.94266	5	55	16.80625	47.9990	0.148	48.1470	190474.976	608822.475	7.405	0.148	7.553	2170510	TPSCR3_GGD	CONE
anjm	NAM	218	x	5-8-2008	53	22	15.04176	6	9	8.59151	45.2771	0.000	45.2771	205931.142	598546.041	4.651	0.000	4.651	2170642	TPSCR3_GGD	CONE
modd	NAM	218	x	5-8-2008	53	24	19.27163	6	4	2.98541	47.4164	0.147	47.5634	200244.558	602329.794	6.803	0.147	6.950	2170639	TPSCR3_GGD	CONE

Station Waddenzee		GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)	X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
g043	2G0043	218	c	5-8-2008	53	25	15.81038	6	6	8.04443	44.1014	0.000	44.1014	202537.510	604100.093	3.531	0.000	3.531	2170770	TPSCR3_GGD	CONE
m008		217	c	4-8-2008	53	25	10.46991	6	4	36.11263	44.0716	0.000	44.0716	200841.376	603918.409	3.488	0.000	3.488	2170640	TPSCR3_GGD	CONE
m016		219	d	6-8-2008	53	25	9.86411	6	7	45.54069	44.2163	0.000	44.2163	204339.881	603934.508	3.655	0.000	3.655	2170765	TPSCR3_GGD	CONE

Overview Map 2008



Cut and paste projection information here	Original page size A3 1:100,000 0 1 2 3 4 5 Kilometres	Nederlandse Aardolie Maatschappij B.V. Project: Project name Drawn by: Creator	WADDENZEE **GPS campaign 2008**	**Document Security Level** Author: Author's name Date issued: Date Mxd: 0000000 **Fig: No.**

GNSMART processing Waddenzee 2008

Operator: 06-GPS

Date: 02-12-2008

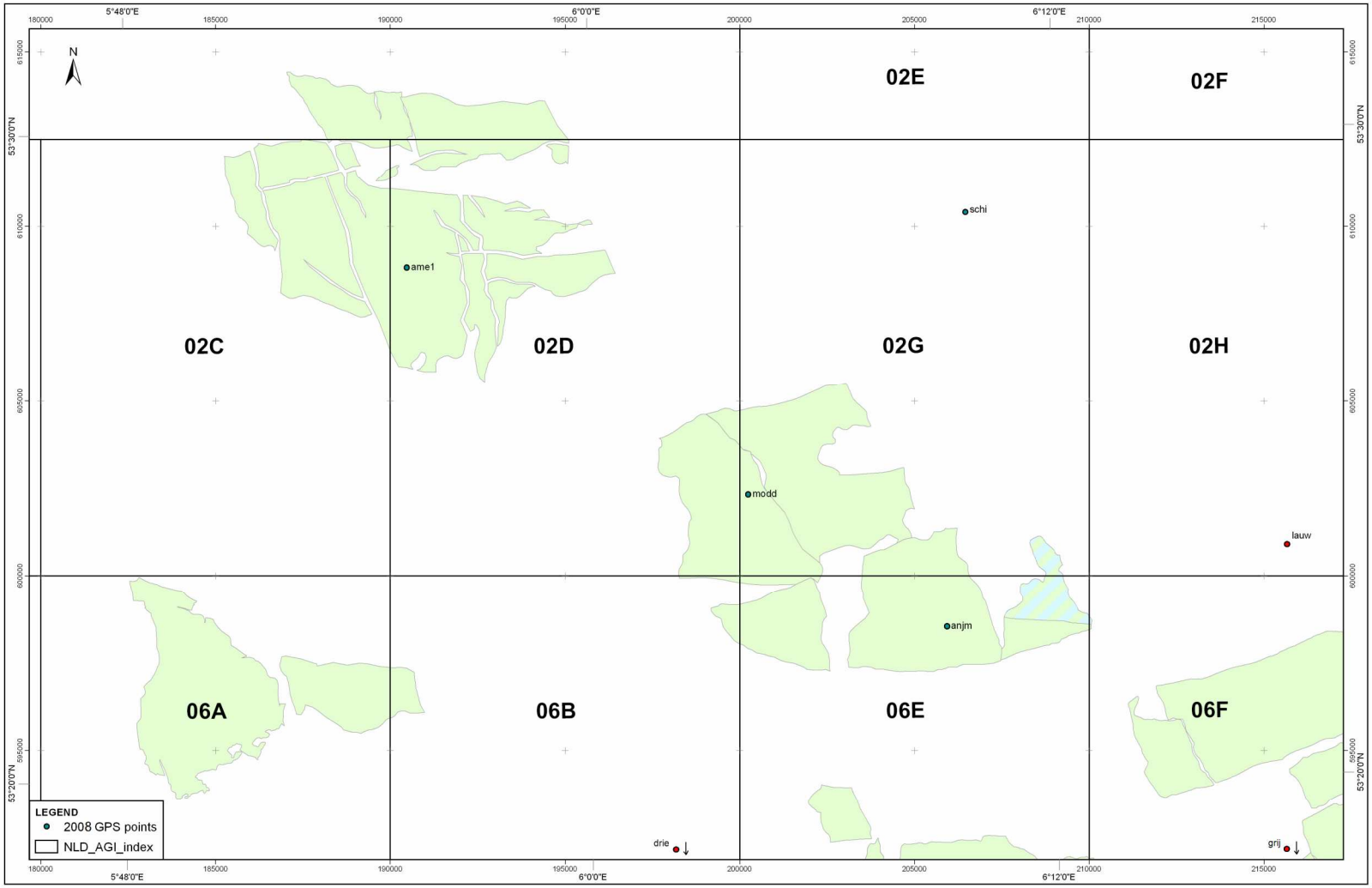
Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)		X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
0674	SAPOS	fixed before 3-6-2007			53	33	49.10129	6	44	50.79499	54.2100	0.053	54.2630		245130.275	620586.321	14.026	0.053	14.079	220180416	TRM29659.00	SNOW
0687	SAPOS	fixed after 5-6-2007			53	33	49.15550	6	44	50.78800	54.4070	0.054	54.4610		245130.114	620587.995	14.223	0.054	14.277	200110	LEIAT504GG	
ball	06-GPS	fixed			53	26	29.58829	5	41	15.67011	54.5499	0.101	54.6509		174967.385	606186.357	13.721	0.101	13.822	2170556	TPSCR3_GGD	CONE
drac	06-GPS	fixed			53	6	31.75441	6	4	58.04678	56.3542	0.147	56.5012		201580.590	569339.057	15.040	0.147	15.187	2170593	TPSCR3_GGD	CONE
schi	NAM	fixed			53	28	38.43917	6	9	44.16452	50.8109	0.148	50.9589		206461.096	610405.714	10.355	0.148	10.503	2170643	TPSCR3_GGD	CONE

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)		X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type
ters	AGRS	fixed			53	21	45.84903	5	13	9.78826	56.1008	0.000	56.1008		143827.236	597385.497	14.689	0.000	14.689	220193243	TRM29659.00
wsra	AGRS	fixed			52	54	52.58929	6	36	16.20650	82.2751	0.389	82.6641		236880.508	548192.306	40.725	0.389	41.114	273	AOAD/M_T

Station	owner	GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)		X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
ame1	NAM	296	a	22-10-2008	53	27	51.94265	5	55	16.80624	47.9967	0.148	48.1447		190474.974	608822.475	7.403	0.148	7.551	2170510	TPSCR3_GGD	CONE
anjm	NAM	296	a	22-10-2008	53	22	15.04171	6	9	8.59142	45.2744	0.000	45.2744		205931.140	598546.038	4.648	0.000	4.648	2170642	TPSCR3_GGD	CONE
modd	NAM	296	a	22-10-2008	53	24	19.27156	6	4	2.98537	47.4163	0.147	47.5633		200244.558	602329.794	6.803	0.147	6.950	2170639	TPSCR3_GGD	CONE

Station Waddenzee		GPS day	hr	Date	N [ø,',"]		ETRS89 (m)	E [ø,',"]		ETRS89 (m)	ell. h [m]	ant. h. (m)	ARP (m)		X-RD (m)	Y-RD (m)	Z-NAP (m)	ant. h. (m)	ARP (m)	ser. no. ant.	ant. Type	
drie		295	i	21-10-2008	53	17	57.28894	6	2	25.10593	46.1992	0.000	46.1992		198543.487	590504.282	5.356	0.000	5.356	2170770	TPSCR3_GGD	CONE
grij		296	i	22-10-2008	53	16	50.77753	6	18	21.34556	46.1065	0.000	46.1065		216278.741	588641.599	5.395	0.000	5.395	2170628	TPSCR3_GGD	CONE
lauw		297	f	23-10-2008	53	23	31.95207	6	18	23.06881	51.3340	0.000	51.3340		216152.278	601043.614	10.821	0.000	10.821	2170626	TPSCR3_GGD	CONE

Overview Map 2008 (Grij(pskerk) and Drie(sum) are out of map range).



Original page size A3
1:100,000
0 1 2 3 4 5
Kilometres

Cut and paste projection information here

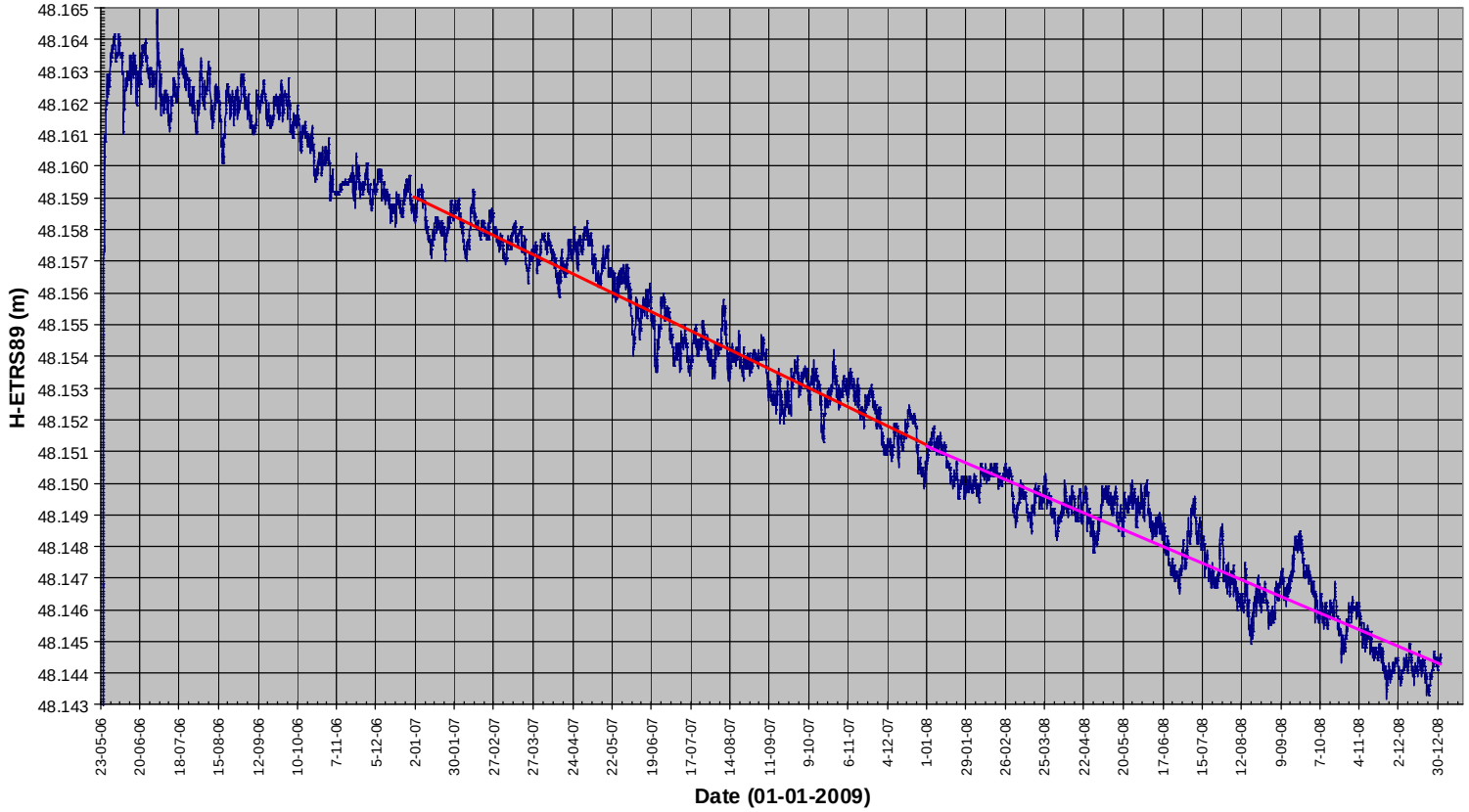
Nederlandse Aardolie Maatschappij B.V.
Project: Project name
Drawn by: Creator

WADDENZEE
GPS campaign 2008

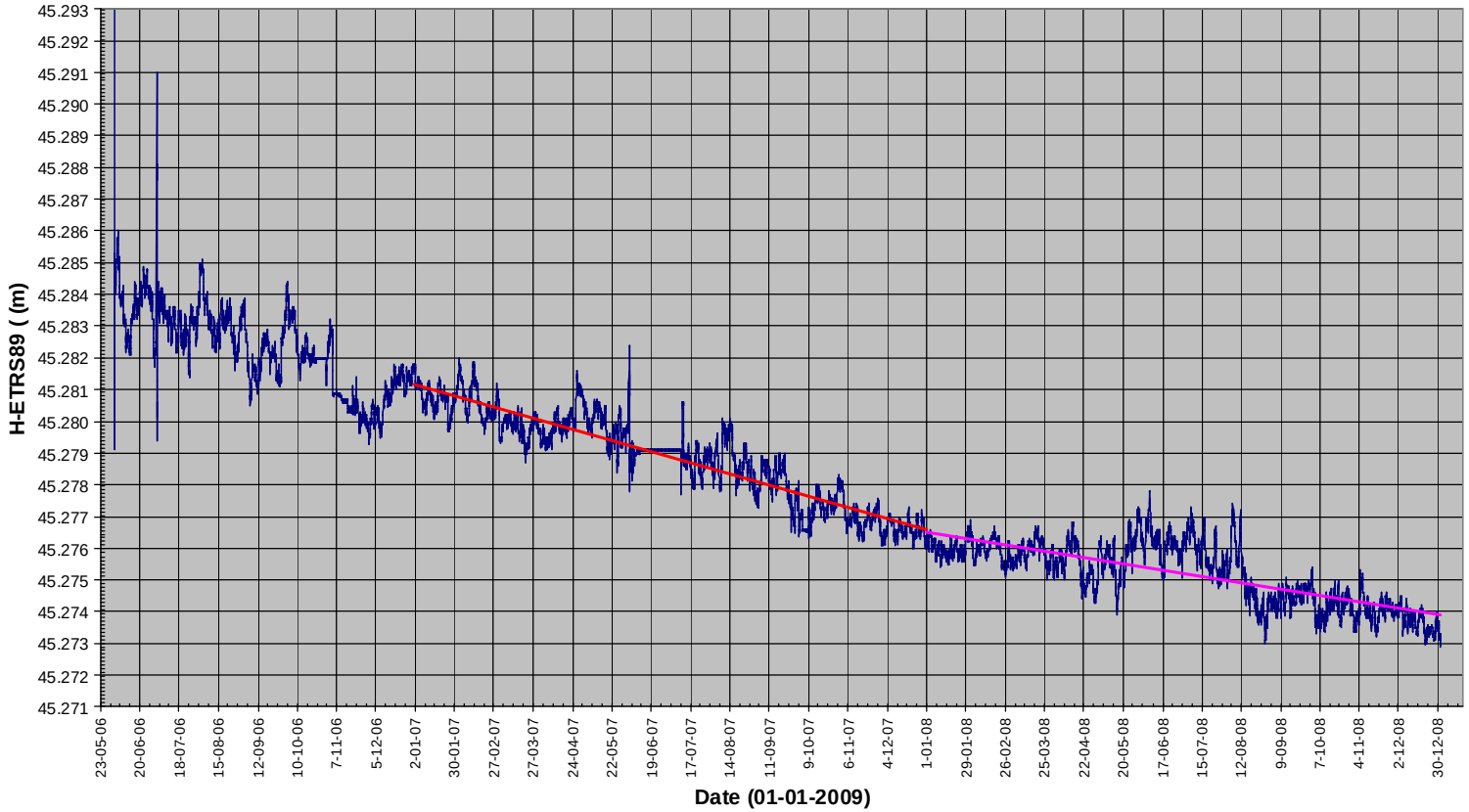
Document Security Level
Author: Author's name
Date issued: Date
Mxd: 0000000 Fig: No.

APPENDIX III: GNSMART results Monitor Stations on land 2006 - 2008

GEO++ GNSMART H-ETRS89 AME1 + trend 2007 and 2008 (least squares method)



GEO++ GNSMART H-ETRS89 ANJM + trend 2007 and 2008 (least squares method)



GEO++ GNSMART H-ETRS89 MODD + trend 2007 and 2008 (least squares method)